Rose Hill
#9135

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FEASIBILITY STUDY
FINAL REPORT

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TEXT

Rose Hill Regional Landfill Superfund Site
South Kingstown, Rhode Island

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GLOSSARY OF ACRONYMS AND ABBREVIATIONS

ACL	Alternate Concentration Limit
AHPA	Archaeological and Historical Preservation Act
ARARs	Applicable or Relevant and Appropriate Requirements
ARCS	Alternative Remedial Contracting Strategy
AWQC	Ambient Water Quality Criteria
BACT	Best Available Control Technology
BOD	Biological Oxygen Demand
BTEX	Benzene, Toluene, Ethylbenzene, and Xylenes
BTU	British Thermal Unit
cm/sec	centimeters per second
CAA	Clean Air Act
CERCLA	Comprehensive Environmental Response, Compensation, and Liability Act (aka Superfund)
CFR	Code of Federal Regulations
COCs	Chemicals of Concern
COD	Chemical Oxygen Demand
CWA	Clean Water Act
DCA	Dichloroethane
DCE	Dichloroethene (Dichloroethylene)
DEHP	Bis(2-ethylhexyl)phthalate

GLOSSARY OF ACRONYMS AND ABBREVIATIONS (Continued)

DOT	Department of Transportation
DRE	Destruction Removal Efficiency
DWHA	Drinking Water Health Advisories
EG	Emission Guidelines
EPA	Environmental Protection Agency (United States)
ft^2	square feet
ft^3	cubic feet
FEMA	Federal Emergency Management Agency
FR	Federal Register
FS	Feasibility Study
FWCA	Fish and Wildlife Coordination Act
FWS	Fish and Wildlife Service
GAC	Granular Activated Carbon
gpm	gallons per minute
hp	horse power
HCl	Hydrochloric acid
HDPE	High Density Polyethylene (a plastic)
HELP	Hydrologic Evaluation of Landfill Performance
HMTA	Hazardous Materials Transportation Act
HSWA	Hazardous and Solid Waste Amendments

GLOSSARY OF ACRONYMS AND ABBREVIATIONS (Continued)

ID	Inside Diameter
IDW	Investigation Derived Waste
IRIS	Integrated Risk Information System
ISQC	Interim Sediment Quality Criteria
kg	kilograms
lb	pound
L	Liter
LDRs	Land Disposal Restrictions
LEL	Lower Explosive Limit
LFG	Landfill Gas
LLDPE	Linear Low Density Polyethylene
LOEL	Lowest Observed Effect Level
m^3	cubic meter
mg	milligram
mg/L	milligram per liter: a mass to liquid ratio that in freshwater is equal to parts per million (ppm)
mil	millimeter
Mg	Megagrams
MCL	Maximum Contaminant Limit (may be preceded by "F" for final, "P" for proposed, or "S" for secondary)
MCLG	Maximum Contaminant Limit Goal
MSL	Mean Sea Level

GLOSSARY OF ACRONYMS AND ABBREVIATIONS (Continued)

NAA	Non-Attainment Area (Air Quality)
NAAQS	National Ambient Air Quality Standards
NASA	National Aeronautic & Space Administration
NCP	The National Oil and Hazardous Substances Pollution Contingency Plan
NESHAPS	National Emission Standards for Hazardous Air Pollutants
NFPA	National Fire Protection Association
NHPA	National Historic Preservation Act
NMOC	Non-Methane Organic Compound
NOS	Not Otherwise Specified
NPDES	National Pollutant Discharge Elimination System
NPL	National Priorities List
NSPS	New Source Performance Standard
NSR	New Source Review
O&M	Operation and Maintenance
OSHA	Occupational Safety and Health Act
OSWER	Office of Solid Waste Emergency Response
ppb	parts per billion
ppm	parts per million
psi	pounds per square inch
PAHs	Polynuclear Aromatic Hydrocarbons
PCBs	Polychlorinated Biphenyls

GLOSSARY OF ACRONYMS AND ABBREVIATIONS (Continued)

PMCL	Proposed Maximum Contaminant Level
PPE	personal protective equipment
POTW	Publicly Owned Treatment Works
PRG	Preliminary Remediation Goal
PRP	Potentially Responsible Party
PSD	Point Source Discharge (water); also Prevention of Significant Deterioration (air)
PVC	Polyvinyl Chloride (a plastic)
RAC	Response Action Contract
RAO	Remedial Action Objective
RCRA	Resource Conservation and Recovery Act
RfD	Reference Dose
RI	Remedial Investigation
RIDEM	Rhode Island Department of Environmental Management
RIGL	Rhode Island General Laws
RIPDES	Rhode Island Pollutant Discharge Elimination System
RO	Reverse Osmosis
ROD	Record of Decision
RPM	Remedial Project Manager
SARA	Superfund Amendments and Reauthorization Act
SDWA	Safe Drinking Water Act
SEAT	Superfund Environmental Assessment Team

GLOSSARY OF ACRONYMS AND ABBREVIATIONS (Continued)

SIP	State Implementation Plan
SITE	Superfund Innovative Technology Evaluation
SVOC	Semivolatile Organic Compound
SWMFR	Solid Waste Management Facility Rules
TBC	To Be Considered
TCE	Trichloroethene (aka Trichloroethylene)
TCLP	Toxicity Characteristic Leaching Procedure
TLV	Threshold Limiting Values
TOC	Total Organic Carbon
tpd	tons per day
tph	tons per hour
tpy	tons per year
TSDF	Treatment, Storage and/or Disposal Facility
TSS	Total Suspended Solids
μg/kg	microgram per kilogram
$\mu g/m^3$	microgram per cubic meter
μg/L	microgram per liter; a mass to liquid ratio that in freshwater is equal to parts per billion (ppb)
USGS	United States Geological Survey
UST	Underground Storage Tank
U.S.C.	United States Code

GLOSSARY OF ACRONYMS AND ABBREVIATIONS (Continued)

UV	Ultraviolet
VOC	Volatile Organic Compound
WWS	Wakefield Water Supply
yd^3	Cubic Yard
yd^2	Square Yard

EXECUTIVE SUMMARY

A feasibility study was conducted by Metcalf & Eddy (M&E) for the Rose Hill Regional Landfill Superfund Site (the "Site") located in South Kingstown, Rhode Island. The goal of the feasibility study was to provide the U.S. EPA Region I with an evaluation of remedial alternatives appropriate for the Site and to serve as technical support for the writing of a Record of Decision (ROD). To accomplish this goal, the feasibility study was conducted to: establish public health and ecological remedial action objectives; identify and screen potential treatment and containment technologies; and develop and evaluate in detail several remedial alternatives that provide varying degrees of protection and control. The primary objective of the FS is to develop and evaluate appropriate remedial action options for controlling the sources of contamination as an initial response action, and once this is accomplished propose a subsequent and final set of options in response to the Site's impact to local groundwater.

The Site is located in an abandoned sand and gravel quarry and consists of three separate, inactive waste disposal areas (landfills): the Solid Waste Area; the Bulky Waste Area; and the Sewage Sludge Area. Two primary surface water bodies flow through the Site: the Saugatucket River and Mitchell Brook. The study focused on the nature and extent of contamination identified in the Final Remedial Investigation Report (M&E, 1994). In most media sampled, the chemicals detected most frequently were volatile organics. Chlorinated and aromatic compounds and ketones were detected in the highest concentrations. Metals were also frequently detected in high concentrations.

The first step in the feasibility study is the development of remediation criteria. In this phase, remedial action objectives are developed to address baseline ecological and human health risks posed by exposure to several site chemicals. The primary chemicals posing human health and ecological risks were identified as vinyl chloride, 1,2-dichloroethene, acrylamide, and metals. The primary exposure pathway for human receptors was identified as inhalation of ambient air containing vinyl chloride,1,1-dichloroethene, 1,1,2,2-tetrachlorethane, and benzene originating

in landfill gas. Several chemicals of concern were also identified in groundwater; however, these will be evaluated as part of a potential future response action. Aluminum, iron, and manganese were identified as being of concern relative to ecological receptors in surface water. General response actions were then defined to meet the remedial action objectives. Applicable or relevant and appropriate federal, state, and local public health and environmental requirements (ARARs) pertinent to the implementation of remedial alternatives were also identified.

During the second step of the feasibility study, potential treatment and containment technologies were identified and screened. During this stage, remedial technologies encompassing institutional controls, management of migration, source control, collection, in-situ treatment, on-site treatment, and off-site treatment, were identified and screened for feasibility of application to Site conditions.

Eight alternatives were developed and evaluated in this feasibility study, based on the remedial technologies retained for further consideration. They include the no action alternative, a limited action alternative, and six remedial action alternatives that rely on engineering controls to provide protection. The eight alternatives are described as follows:

- Alternative #1: No action
- Alternative #2: Limited action
- Alternative #3a: Horizontal Containment (capping) of the Solid and Bulky Waste Disposal Areas combined with Gas Collection and Thermal Treatment
- Alternative #3b: Horizontal Containment (capping) of the Solid and Bulky Waste Disposal Areas combined with Gas Collection and Treatment by Photocatalytic Oxidation
- Alternative #4a: Horizontal Containment (capping) of Solid and Bulky Waste Disposal Areas, Leachate Collection and On-Site Treatment, combined with Gas Collection and Treatment
- Alternative #4b: Horizontal Containment (capping) of Solid Waste Disposal Area, Landfill Mining of Bulky Waste Area, Leachate Collection and On-Site Treatment, combined with Gas Collection and Treatment

- Alternative #5a: Horizontal Containment (capping) of Solid and Bulky Waste Disposal Areas, Leachate and Groundwater Collection and On-Site Treatment, combined with Gas Collection and Treatment

- Alternative #5b: Horizontal Containment (capping) of Solid Waste Disposal Area, Landfill Mining of Bulky Waste Area, Leachate and Groundwater Collection and On-Site Treatment, combined with Gas Collection and Treatment

Alternative #1 is developed, as required by the NCP, to provide a baseline from which to measure all other alternatives. Alternative #1 includes environmental monitoring and five-year reviews only. Alternative #2, also required by the NCP, provides an alternative that relies on institutional controls to provide protection. This limited action alternative provides human health protection by restricting access to contaminated media through land use/deed restrictions and fences. It also includes environmental monitoring, a contingency mechanism for implementing residential landfill gas controls, public education programs and other community relations activities, and five-year reviews.

The last six alternatives (Alternatives #3a through #5b) use engineering controls to provide increasing degrees of control and protection. Essentially, Alternatives #3a and #3b provide the minimum engineering controls necessary to meet most remedial objectives. These engineering controls include horizontal containment (capping) of the Solid and Bulky Waste Disposal Areas, installing active gas collection within and along the western perimeter of the Solid Waste Area with landfill gas treatment by enclosed flare in Alternative #3a and by photocatalytic oxidation in Alternative #3b, and providing passive venting of landfill gas at the Bulky Waste Area. Alternative #4a adds leachate collection and on-site treatment to the engineering controls established for Alternative #3a. Alternative #4b replaces capping the Bulky Waste Area with landfill mining and adds leachate collection and treatment to Alternative #3a. Alternative #5a adds a groundwater depression system and expanded on-site treatment system for the Solid Waste Area to Alternative #4a and Alternative #5b adds a groundwater depression system and expanded on-site treatment system to Alternative # 4b. Water collected from these additional controls would

on-site treatment system to Alternative # 4b. Water collected from these additional controls would be treated using a treatment train consisting of precipitation, media filtration, and UV/chemical oxidation. Each of these six alternatives would also include the components of appropriate access restrictions, public education programs and other community relation activities, environmental monitoring, and five-year reviews.

These alternatives are evaluated in detail based on overall protection of human health and the environment, compliance with ARARs, long-term effectiveness, implementability, reduction of toxicity-mobility-volume, short-term effectiveness, and cost. In order for an alternative to be considered for the ROD, it must, at a minimum, achieve the first two criteria: overall protection of human health and the environment and compliance with ARARs. (ARARs waivers may be obtained in very limited circumstances.)

Alternatives #1 and #2 fail to meet the threshold criteria for ROD consideration. The no action alternative, Alternative #1, includes no actions to protect human health or the environment and would not meet minimum landfill requirements. While Alternative #2 may achieve some degree of protection of human health, ecological protection would not be attained, and, again minimum landfill requirements would not be met.

Within the limits of the remedial action objectives, (groundwater source control only) Alternatives #4a through #5b meet the threshold criteria by providing overall protection of human health and the environment and by their ability to attain air and surface water ARARs. Alternatives #3a and #3b would provide overall protection of human health, but may not be totally protective of the environment since some leachate may still reach surface water bodies. Alternative #3a would attain air-quality ARARs.

Long-term effectiveness and permanence would be provided by Alternatives #3a through #5b by controlling landfill gas contamination at the Site. Alternatives #4a through #5b provide an increased long-term protection, over that provided by Alternatives #3a and #3b, by preventing

subsequent groundwater and surface water impacts at the Site. The engineering controls proposed under Alternatives #3a through #5b are commonly applied, readily available, and technologically proven. There would not be any expected technical, administrative, or availability problems with implementation of these six alternatives.

Alternatives #3a through #5b would result in short-term risks to human health and the environment, as a result of invasive work at the waste disposal areas. Actions could be conducted to mitigate for these risks.

Natural attenuation of groundwater and surface water may exceed the Feasibility Study 30 year remedial default period. For ambient air and soil gas, natural attenuation is estimated to occur within the range of 5 to 15 years.

Total costs (capital plus net present worth annual operations and maintenance) for remedial alternatives range from $3.6 million to a high of $22.8 million, within the EPA-prescribed +50/-30% degree of certainty range. Total costs for all alternatives are listed below:

- Alternative #1: Total cost of $3.6 million.
- Alternative #2: Total cost of $3.9 million.
- Alternative #3a: Total cost of $13.4 million.
- Alternative #3b: Total cost of $13.2 million.
- Alternative #4a: Total cost of 16.1 million.
- Alternative #4b: Total cost of 16.9 million.
- Alternative #5a: Total cost of $20.2 million.
- Alternative #5b: Total cost of $22.8 million.

SECTION 1.0
INTRODUCTION

This document is a comprehensive and interpretive feasibility study report prepared as part of the remedial investigation/feasibility study (RI/FS) conducted at the Rose Hill Regional Landfill Superfund Site in South Kingstown, Rhode Island, for Region I of the U.S. Environmental Protection Agency (EPA). This work was conducted by Metcalf & Eddy (M&E) under EPA's Alternative Remedial Contracting Strategy (ARCS) and Response Action Contract (RAC) programs.

1.1 PURPOSE OF REPORT

The feasibility study (FS) was undertaken utilizing the remedy selection process with a goal of selecting remedies that are protective of human health and the environment, that maintain protection over time, and that minimize untreated waste (40 CFR 300.430 (a)(I)). The primary objective of the FS is to develop and evaluate appropriate remedial action options for controlling the sources of contamination as an initial response action, and once this is accomplished propose a subsequent and final set of options in response to the site's impact to local groundwater. The EPA is the lead agency and decision-maker for the Rose Hill Regional Landfill site.

The Site contains three separate and inactive disposal areas (landfills) as shown in Figure 1-1: a Solid Waste Area, Bulky Waste Area, and Sewage Sludge Area. The Sewage Sludge Area is regulated by the State of Rhode Island, is in compliance with state regulations governing Sewage Sludge, and is within EPA's acceptable risk range with the exception of groundwater. Thus, no further source control action will be required under CERCLA.

In addition, natural resource damages have not been fully determined at this time and have not been included in the FS. However, the mitigation of ecological impacts have been considered in the development of the alternatives.

1.2 BACKGROUND INFORMATION

This section briefly describes the Rose Hill Regional Landfill site, its history, the nature and extent of contamination, the fate and transport of contaminants, and the baseline risk assessment. Information presented in this section has been summarized from the Final Remedial Investigation (RI) Report (M&E, 1994).

The area of study evaluated during the RI included not only the Superfund site itself, but also encompassed surrounding areas that may or may not be affected by the Rose Hill Regional Landfill site, such as the residences west of Rose Hill Road and east of the Saugatucket River. The entire study area evaluated during the RI was referred to as the "site study area" in the Final RI Report (M&E, 1994). This same designation is again used for the purposes of the FS; however, the term "Site" is used when only the Superfund site portion of the site study area is referenced.

1.2.1 Site Description and History

The Rose Hill Regional Landfill site is located within the town of South Kingstown, Rhode Island, in the village of Peace Dale (Figure 1-1). It lies about 5 miles inland from Narragansett Bay and 2 miles north of Wakefield, Rhode Island. The Site is bordered by Rose Hill Road to the west, the Saugatucket River to the east, and residential private property to the north and south.

The Site includes an abandoned sand and gravel quarry that encompasses approximately 70 acres. As shown in Figure 1-1, the Site contains three separate and inactive disposal areas (landfills): a Solid Waste Area, a Bulky Waste Area, and a Sewage Sludge Area. An active transfer station, south of the disposal areas, is also located on the Site (Figure 1-2).

Two primary surface water bodies flow through the Site: Saugatucket River and Mitchell Brook. An unnamed brook west of the Site flows into the Saugatucket River and an unnamed tributary in the northern portion of the Site flows into Mitchell Brook (Figure 1-2). The Saugatucket River is

classified as a Class B water body that is suitable for fishing and swimming and a potential public drinking water source. As a tributary to the Saugatucket River, Mitchell Brook is also classified as a Class B water body. An open excavated area approximately 400 feet north of the disposal areas is currently used for target and skeet shooting. Approximately 200 feet west of the disposal areas, and across Rose Hill Road, is an active sand and gravel operation.

Groundwater is used within a 3-mile radius of the Site for the following purposes:

- Private residential supplies (no alternate supply available)
- Municipal public water supply (no alternate supply available)

Residents in South Kingstown obtain water from both public and private wells. Private wells within a 3-mile radius of the Site consist of overburden or bedrock wells. Three supply wells for the University of Rhode Island are located 2.7 miles northwest of the Site. Two municipal supply wells for the Kingstown District are located 2.9 miles northwest of the Site. The university and the district utilize each other's systems as back-up because alternate systems are not available.

In 1985, the town provided a municipal water line extension to residences located on Rose Hill Road and to those in the northern portion of the Site. Hookups to the water line were voluntary, and at least one residence refused the service. By 1989, water service was provided to Broad Rock Road. Generally, residences along Rose Hill Road west and south of the Solid Waste Area use municipal water. Residences on Saugatucket Road and Broad Rock Road did not connect to municipal water and continue to use private wells.

Prior to 1941, the Site was used for agriculture. Sand and gravel excavation operations were conducted at the Site from at least 1948 through 1963 (U.S. EPA, 1991f). The Site began operation as a landfill in 1967 in the area previously used for sand and gravel excavation. The landfill was operated by the town of South Kingstown under state permit from RIDEM that was renewable

annually. For approximately 16 years, it received domestic and industrial wastes from residents and industries in South Kingstown and Narragansett. In October 1983, the landfill reached its state-permitted maximum capacity and active landfilling operations were ceased. For the past 50 years, the landfill owner has conducted organized small game hunts involving birds and dogs at the Site. Most recently target ranges were set up north and south of, as well as within the Sewage Sludge Area.

1.2.1.1 Facility Operations and Waste Disposal Practices. Table 1-1 provides a chronology of activities affecting the landfill operations.

The three disposal areas (the Solid Waste, Bulky Waste, and Sewage Sludge Areas), which began operations in 1967, 1978, and 1977, respectively, were closed in 1983. During that year, a transfer station for municipal refuse was located south of the Bulky Waste Area. The transfer station is currently active. At the station, refuse is unloaded from collection trucks and transferred to vehicles for transportation to the Johnston landfill in Johnston, Rhode Island. Figure 1-1 shows the three disposal areas and the transfer station at the Site.

Waste handling procedures for the Rose Hill Regional Landfill were set by state regulations and town ordinance. The waste handling practices conducted at the landfill consisted of the disposal of municipal refuse and industrial refuse including the disposal of industrial wastes. The exact quantity and location(s) of hazardous substances disposed of at the Site throughout the landfill's operation are unknown.

In 1967, when activity at the landfill officially commenced, a court order prohibited the disposal of combustibles at Rose Hill Regional Landfill. In 1978, the order was amended to allow the disposal of combustibles in the Bulky Waste Area. In 1979, the state of Rhode Island ordered cities and towns to establish facilities for the collection of waste oil. It was reported that a waste oil collection facility at the Rose Hill Regional Landfill was established during this time (M&E, 1994).

A known waste handling problem concerns the disposal of liquid waste from the Peacedale Processing Company, specifically a urethane adhesive. A letter dated January 8, 1970, transmitted from an engineer of the State Division of Solid Waste Management to the South Kingstown director of public works, put into writing an agreement on the disposal method for liquid waste from the Peacedale Processing Company. The two authorities came to an understanding that the drummed waste would be disposed of daily by dumping it onto other wastes that had been deposited each day, to take advantage of the absorptive characteristics of this urethane adhesive material.

A year later, on March 16, 1971, correspondence sent from the same state office notified the South Kingstown town manager that liquid waste from Peacedale Processing was being improperly disposed of in the Solid Waste Area. The communication reiterated that the liquid waste should be spread over the surface of the landfill to allow it to be absorbed by the fill, if acceptance of such waste were to continue.

In 1979, a resident observed and reported to the RIDEM the dumping of a number of barrels, with the lids intact, on the solid waste landfill slope within a few feet of Rose Hill Road. The truck transporting these drums on this occasion was reported to be labeled "Peacedale Processing." The resident further reported at least one barrel was labeled "slop glue." The drums were buried intact with the exception of one. It was further observed that the barrel's contents were at least in part liquid.

On December 6, 1979, the State Division of Solid Waste Management wrote to Kenyon Piece Dyeworks (a subsidiary of Peacedale Processing) to confirm an analysis of the waste adhesive procured from the Peacedale plant on November 19, 1979. The analysis revealed that the sample contained trichloroethene (TCE) at 29,000 parts per billion (ppb), toluene at 400 ppb, and tetrachloroethylene at 4 ppb. An analysis of the waste itself revealed that it contained TCE in the amount of 0.35%. Based upon the analyses, the waste adhesive produced at the plant was deemed not hazardous as defined by Rhode Island regulations and could be disposed of at any licensed solid waste management facility. The state added that the waste adhesive was to be in a solid form when

taken to the landfill and exposed to the air at least a week prior to its disposal. At the same time, Kenyon Piece Dyeworks had notified the state that the company had suspended shipment of the above-mentioned waste adhesive to the landfill pending further investigation of its environmental reactivity.

Peacedale Processing notified EPA, Region I, in 1981 that the company had disposed of laminating adhesive at Rose Hill Regional Landfill from 1971 to 1979. Although other volatile organics, inorganics, and phthalate compounds have been detected at the Site, as yet little is known about the disposal practices associated with these contaminants.

1.2.1.2 Landfill Disposal Areas. The Solid Waste Area operated from 1967 until 1982. The exact depth of deposited solid waste materials is unknown but was reportedly to bedrock in some places. Refuse was also reportedly deposited in areas above, below, and at the water table. Based on aerial photographs of the disposal area, the sand and gravel pit was filled in with refuse material starting in the southern portion and progressing north (U.S. EPA, 1987a and 1991f). By 1988, waste materials were present throughout the pit, and all remnants of the original sand and gravel pit were gone. At this time, waste disposal was also evident again in the southern and central portions of the area. Prior to 1977, the thickness of solid waste deposited throughout the landfill is unknown. However, from 1977 to 1982, between 10 and 14 feet of solid waste were deposited. Upon closure, the solid waste area was reported to have been covered with 0.5 to 2 feet of sandy soil and subsoil. Recent information indicates that only a portion of this area may have been properly covered. Natural vegetation is observed throughout most of the area.

The Sewage Sludge Area is located in the northeast section of the Site, between Mitchell Brook and the Saugatucket River. This area operated from 1977 to 1983. Its predominant use was to receive sludge from the South Kingstown wastewater treatment plant. The sludge was deposited in trenches. Aerial photographs taken in 1981 show that the northern section of a large north-to-south-orientated trench, running the entire length of this area, as well as two smaller trenches in the northern section, already contained sludge material (U.S. EPA, 1987a). Three unfilled trenches were also visible at

that time. The depth of each excavation and the number of trenches are unknown. Problems with the high moisture content of the sludge prompted the town of South Kingstown to initiate the hauling of the sludge to the Johnston landfill. Vegetative cover in this area is less prevalent than in the Solid Waste Area.

The Bulky Waste Area (used for disposal of large appliances, etc.) is an 11-acre area located east of the Solid Waste Area and southwest of the Sewage Sludge Area (Figure 1-1). This area is approximately 200 feet east of Mitchell Brook and 250 feet west of the Saugatucket River. Disposal of bulky waste began in this area in 1978. Solid waste was also reportedly disposed of in the period between closure of the Solid Waste Area and construction of the transfer station (May 1982 through October 1983). Vegetation, primarily grasses overlying natural fill materials, provide cover for this area.

1.2.1.3 Property Ownership. Edward L. Frisella, Sr., and Pearl F. Frisella are owners of record for the property within which the Site is located, although Edward Frisella, Sr. is deceased. The gravel quarry area, located adjacent to the landfill, is owned by the estate of Edward L. Frisella, Sr. In 1967, the town of South Kingstown entered into a lease with Mr. Frisella for the operation of a solid waste landfill. After the establishment of the Rose Hill Regional Landfill, in February 1973, the town of Narragansett entered into an agreement with the town of South Kingstown for joint use and operation of the landfill. In 1977, Edward L. Frisella, Sr., and the town of South Kingstown reached an agreement upon the continued use of the property as a landfill site. This amendment to the lease provided additional land for expansion of the landfill facility (i.e., the Sewage Sludge and Bulky Waste Areas). In 1982, the town of South Kingstown purchased 15.03 acres from Mr. Frisella for the location of the town's transfer station.

1.2.2 Previous Investigations

Several studies have been conducted at the Rose Hill Regional Landfill site which have generated reports and maps. The studies are documented in the following reports:

- *Investigation of Groundwater at Landfill, Rose Hill Road, South Kingstown, RI* (Kelly, 1975)
- *Phase I, Preliminary Design and Hydrogeological Investigations* (C.E. Maguire, 1977a)
- *Phase II Site Evaluation and Operation Plan for Municipal Sanitary Landfill, Rose Hill Road* (C.E. Maguire, 1977b)
- *Preliminary Assessment for Rose Hill Landfill, South Kingstown, RI* (U.S. EPA, 1982)
- *Assessment of Groundwater Contamination from a Municipal Landfill and Evaluation of Remedial Measures* (Bricknell, 1982)
- *Engineering and Hydrogeological Assessment of the Rose Hill Landfill* (York Wastewater Consultants, 1984)
- *Site Inspection Report, Rose Hill Regional Landfill, South Kingstown, RI* (NUS, 1984)
- *Hazardous Ranking System Report, Rose Hill Landfill, South Kingstown, RI* (NUS, 1987)
- *Site Analysis for Rose Hill Landfill, South Kingstown, RI* (U.S. EPA, 1987a)
- *Site Analysis for Rose Hill Landfill, South Kingstown, RI* (U.S. EPA, 1991f)
- *Ortho Photographic Composite Delineating Physical Features as They Relate to the Topography of the Site and Topographic Map* (EPIC, 1989)
- *Expanded Site Investigation, Rose Hill Landfill, South Kingstown, RI* (NUS, 1989)
- *Preliminary Health Assessment for Rose Hill Regional Landfill, South Kingstown, RI* (ATSDR, 1990)
- *Remedial Investigation Final Report, Rose Hill Regional Landfill Superfund Site, South Kingstown, Rhode Island* (Metcalf & Eddy, 1994)

Historical sampling data, prior to the RI, for groundwater, landfill leachate, surface water, and sediments within the vicinity of the Site has indicated the presence of contaminants periodically and

has also indicated potential seasonal variability. The contamination identified is summarized below from the preliminary health assessment (ATSDR, 1990):

- Historical contaminant concentrations in groundwater collected from on-site wells were variable
- Surface water quality data from Mitchell Brook collected in 1982 revealed the presence of 1,1,1-trichloroethane (2 ppb), methylene chloride (1 ppb), 1,2-dichloroethene (11 ppb), 1,1-dichloroethane (1 ppb), and toluene (2 ppb)
- Samples collected from the unnamed brook had measurable quantities of polynuclear aromatic hydrocarbons (PAHs)
- Off-site residential wells have also intermittently revealed the presence of contaminants reportedly attributable to the site. These contaminants included *trans*-1,2-dichloroethene, trichloroethene, di-n-butyl phthalate, and diethyl phthalate
- Volatile organic contaminants were detected in surface water samples collected from the Saugatucket River and Mitchell Brook between November 1987 and March 1988; these data, however, were suspect due to contamination detected in quality control samples

1.3 ENVIRONMENTAL SETTING

The data collected during the RI were used to characterize the geology, hydrogeology, and ecology. The site characteristics described in Section 3.0 of the RI Report (M&E, 1994) are summarized below.

1.3.1 Geology and Hydrogeology

Several geologic features that impact the movement of groundwater across the Site were identified. The behavior of groundwater in the bedrock was found to be influenced by bedrock topography, with recharge and discharge occurring at bedrock high and low areas, respectively. The predominant flow of groundwater in bedrock is to the southeast along regional fractures. Weathered and fractured

bedrock south and west of the Solid Waste Area appears to facilitate interconnection of the overburden and bedrock flow systems.

The three major constituents of the overburden are ablation till, glacial lacustrine deposits, and glacial outwash sediments. The till and glacial outwash permit unconfined groundwater flow in a south-southeast direction. Although the groundwater flow is predominantly to the south-southeast, mounding of groundwater in the northwest corner of the Solid Waste Area may facilitate radial flow to the north, east, and west. Lacustrine deposits, encountered in the south-southeastern portion of the Site, act as a confining layer between the till and outwash. A combination of the rise in the surface elevation of the bedrock and the presence of thick lacustrine deposits along the Saugatucket River plays a significant role in the increased horizontal gradient and strong upward gradients observed south of the Bulky Waste Area.

Due to the composition and condition of existing cover materials, infiltration of precipitation through these materials is expected to be high. Groundwater interactions with the Saugatucket River and Mitchell Brook most likely play an important role in the transport of contaminants. The Saugatucket River was observed to gain water from the shallow and deep overburden and the bedrock flow systems along the western side of the river. Mitchell Brook was observed to lose water to groundwater in its upper reaches and gain groundwater in its lower reaches.

1.3.2 Ecological Resources

Significant ecological habitats within the Site include the Saugatucket River and Mitchell Brook, their associated tributaries and forested wetlands, and the adjacent forested and old field upland habitats. Rare plant species known to occur within the Site include a species of state interest, tickseed sunflower *(Bidens coronata)*, and a species of state concern, bloodroot *(Sanguinaria canadensis)*. A probable sighting of an avian species of state concern, red-bellied woodpecker *(Melanerpes carolinus)*, also occurred within the Site. Two avian species of state interest, glossy ibis *(Plegadis falcinellus)* and great egret *(Casmerodius albus)*, were also observed within the Site.

However, the state designation applies only to breeding sites for these two species, and suitable breeding habitat does not exist within the Site, except possibly along the Saugatucket River.

As indicated by a single, reconnaissance-level survey, the Site is utilized by a variety of terrestrial species. Avian species observed on the Site were generally typical of those expected based upon geographical location, habitat present, and surrounding land uses. The extensive running of dogs and hunting on the Site have influenced the use of the Site by mammalian species. Reptiles and amphibians utilizing the Site are likely to be confined largely to terrestrial species, as Mitchell Brook does not appear to support large numbers of these organisms or other prey species, such as fish. However, the Saugatucket River likely supports a more diverse assemblage of wildlife and aquatic species.

The macroinvertebrate species composition in the sediments of the Saugatucket River appears to be affected by the disposal areas. The species composition (in terms of the relative abundance of dominant organisms) adjacent to the disposal areas appears to be different from the species composition in upstream and downstream locations. The area adjacent to the Bulky Waste Area has the most contaminated sediments and pollution-tolerant taxa did occur in relatively high numbers in the sediments compared to the taxa in sediments in upstream and downstream locations.

Organisms in the water column of the Saugatucket River also appear to be more directly influenced by the disposal areas and leachate seeps. Total densities of organisms in the water column downstream of the disposal areas and leachate seeps are significantly lower than at upstream locations. The occurrence of pollution-sensitive invertebrate taxa in the water column also decreased from upstream to downstream locations. There also appears to be a scarcity of fish in this section of the river, where resident and migratory fish would be expected to occur.

The benthic macroinvertebrate community in Mitchell Brook does not appear to be as diverse as that of the Saugatucket River. In general, the macroinvertebrates in Mitchell Brook sediments and surface waters showed a pattern of decreasing densities from upstream to downstream locations.

Species density and diversity were especially low adjacent to the disposal areas. Additionally, the occurrence of pollution-sensitive species decreased from upstream to downstream locations. In the brook, as in the Saugatucket River, few fish were observed.

1.4 SUMMARY OF REMEDIAL INVESTIGATION

The nature and extent of contamination, contaminant fate and transport, and the public health and ecological risk assessment are summarized in the following subsections.

1.4.1 Nature and Extent of Contamination

In surface soil, the presence of organic compounds and elevated metal concentrations detected were largely related to location. Volatile organics were the most prevalent of organic compounds detected, and chlorinated and aromatic compounds and ketones were detected most frequently and in the highest concentrations. Refuse and landfill gas were the primary sources of volatile organics in surface soil. Elevated iron concentrations were found in samples near leachate seeps, and elevated lead was found throughout the Site.

Soil borings were drilled within the disposal areas to collect subsurface soils. The chemicals detected included typical industrial and municipal wastes: ketones, toluene, PAHs, phthalates, phenols, pesticides, and dichlorobenzenes. These compounds were similar to the types of compounds detected in surface soils and landfill gas. Although several metals were detected, only copper in the Sewage Sludge Area was significantly elevated compared to background soils. Buried waste provides an active source for the release of contaminants to subsurface soils.

As indicated by surface and subsurface soil data, the disposal areas provide a potential source of organic compounds and metals in leachate, since the same types of organic compounds were found at lower concentrations in leachate. Concentrations of several metals were found to be significantly elevated in leachate compared to background groundwater.

Numerous organic compounds were detected in shallow and deep overburden and bedrock groundwater. The types of compounds detected included volatile organic compounds (VOCs), water soluble organics, semivolatile organic compounds (SVOCs), pesticides, and PCBs. Of these compounds, VOCs (primarily chlorinated and aromatic compounds) were most frequently and consistently detected. In the three disposal areas, the most elevated concentrations of VOCs were measured in the Solid Waste Area, and the lowest concentrations were found in the Sewage Sludge Area. Volatile organic contamination extended north and northeast of the Solid Waste Area as a result of localized mounding. Although low concentrations of VOCs were detected in residential wells east of the Saugatucket River, this contamination does not appear to be related to the Site. The predominant metals detected in groundwater were aluminum, iron, basic cations (calcium, magnesium, potassium, and sodium), barium, and manganese. The metals and concentrations detected in shallow and deep overburden were similar; however, the number and concentrations of metals detected were significantly lower in bedrock. Although variations were observed in the concentrations and number of chemicals detected, seasonal trends were not evident based on the data collected.

A few organic compounds were infrequently detected in low concentrations in the three surface water bodies: Mitchell Brook, the Saugatucket River, and the unnamed brook. Volatile organic compounds, primarily carbon disulfide and chlorinated and aromatic VOCs, were the major contaminants found. A few SVOCs and pesticides and a water-soluble organic, acrylamide, were also detected. Several surface water locations that were adjacent to leachate seeps and downgradient of the Solid Waste Area exhibited high metal concentrations.

In sediment as in surface water, VOCs were occasionally detected in low concentrations in Mitchell Brook, the Saugatucket River, and the unnamed brook. In contrast, the less mobile, more adsorptive organic compounds (phthalates, PAHs, and pesticides) were detected more often and in higher concentrations than VOCs. Metals were elevated in sediments relative to surface water; however, the trend of locations with elevated metals was the same for both media.

In the disposal areas, landfill gas was characterized by elevated methane, carbon dioxide, and VOCs. Hydrogen sulfide was also detected. In the Bulky Waste Area, the VOCs were primarily comprised of *cis*- and *trans*-1,2-dichloroethene (DCE), TCE, and BTEX compounds. In the Solid Waste Area, numerous VOCs were found in landfill gas, although vinyl chloride, *cis*-1,2-DCE and toluene were the major components. These compounds were also the major VOCs in landfill gas north and west of the Solid Waste Area. West of Rose Hill Road, VOCs were detected on three residential properties. Landfill gas contamination in the Sewage Sludge Area was generally low relative to the other disposal areas.

1.4.2 Contaminant Fate and Transport

Predominant transport processes for contaminants identified at the Site are leachate runoff, landfill gas migration, groundwater flow through overburden and bedrock, and surface water and sediment movement. Landfill gas migration and leachate are the primary contaminant transport mechanisms in the unsaturated zone. Venting of landfill gas was evident where soil/fill cover material was thin or absent; however, movement of gas into surface soil may decrease volatilization to the atmosphere. In areas of high landfill gas contamination, groundwater quality was affected.

Highest contaminant concentrations were found in wells adjacent to the disposal areas and decreased with distance from these areas. The predominant groundwater flow direction is south-southeast in the overburden and southeast in the bedrock, although mounding effects in the northwest of the Solid Waste Area facilitate radial migration of contaminants towards the west, north, and northeast. Mitchell Brook intercepts contamination in the shallow and deep overburden, while the Saugatucket River is a receptor for shallow and deep overburden and bedrock contamination. Glacial lacustrine deposits restrict the vertical movement of contaminants from deep to shallow overburden in the southern portion of the Site. Bedrock fractures provide pathways for contaminant transport in groundwater from overburden to bedrock.

Transport of contaminants via leachate has impacted surface soil, surface water, and sediment quality near the disposal areas. However, downgradient in the Saugatucket River, surface water and sediment contamination decreased. Likewise, in Mitchell Brook, contamination increased south of the Solid Waste Area but decreased after the confluence with the Saugatucket River. This trend indicates dilution of contaminated surface water by uncontaminated surface water and/or sediment retention of contamination.

1.4.3 Public Health and Ecological Risk Assessment

A baseline risk assessment was conducted to evaluate the potential adverse health effects to human populations (M&E, 1994). In addition, a Supplemental Human Health Risk Assessment was conducted (M&E, 1998). Chemicals of potential concern (COPCs) were selected from each media. Table 1-2 presents chemicals detected during the RI and those selected as COPCs. Five media (groundwater, surface soil, leachate, surface water, and air) were evaluated quantitatively under various exposure scenarios. Possible human exposure to the COPCs was characterized through exposure pathways for current and future use. Exposure to surface soil, surface water and leachate is not expected to exceed risk allowable by EPA. Exposure to air (ambient/indoor air) may result in increased carcinogenic and noncarcinogenic risks. Risk from exposure to site groundwater by ingestion exceeds EPA target levels for both noncarcinogenic and carcinogenic risk. The chemicals responsible for the majority of the risk include 1,2-DCE, vinyl chloride, acrylamide, antimony, arsenic, cadmium and manganese. With regard to manganese, the RI indicated high background levels of manganese in groundwater. Site-derived contaminants which may be impacting groundwater will be evaluated as part of a potential future response action.

A baseline ecological risk assessment was conducted to evaluate potential risks to ecological receptors from exposure to contaminants in surface water, leachate, sediment, surface soil, and landfill gas. Potential exposure pathways evaluated were dermal contact, inhalation, ingestion of contaminated media, and ingestion of contaminated food. COPCs identified for aquatic receptors included iron (chemical and physical risk), aluminum and manganese in surface water, iron,

aluminum, manganese and lead in leachate, and iron and aluminum in surface sediments (see Table 1-2). Benthic invertebrates and fish were identified as organisms which may be exposed to these inorganic contaminants. Results of sediment toxicity testing indicated that the chemicals of potential concern in sediments are not toxic to benthic organisms or fish. COPCs in surface water do, however, pose a risk to aquatic receptors based on a comparison of ecological effect levels and observed concentrations, and the toxicity of the leachate. Although toxicological information for manganese in surface water was limited, the fact that concentrations were more than an order of magnitude higher than background levels suggested that manganese may pose a risk to aquatic receptors.

COPCs identified for terrestrial receptors included lead, copper, and manganese present in surface soils. Amphibians, reptiles, birds, and mammals were identified as potential receptors for surface soil contaminants. With the exception of small areas with high concentrations of methane in landfill gas, plants growing in areas with surface soil contamination did not appear to be stressed. Likewise, significant adverse effects are not expected to birds or mammals, based on comparisons of ecological effect levels to the concentrations of metals in site soils. Certain aquatic reptiles and amphibians, however, may be adversely impacted by contact with contaminated surface water, as described for fish. High levels of contaminants in soils and leachate in the vicinity of leachate seeps may also pose some risk to ecological receptors, since maximum concentrations exceed effect levels. Due to the limited extent of these leachate seeps, however, these risks are not likely to be significant. Adverse effects to state-listed species are not expected to occur.

1.5 REPORT ORGANIZATION

This document is organized according to EPA guidance for feasibility studies (U.S. EPA, 1988c and 1991a) and the National Contingency Plan. It presents the results of the FS within the following discussions:

- **Section 2.0, Development of Remediation Criteria and Screening of Technologies** identifies remedial action objective development, general response actions, and state and federal applicable or relevant and appropriate requirements. This section also presents and screens various technologies for addressing site contamination.

- **Section 3.0, Development of Remedial Alternatives** develops approaches for remediating the source of contamination and reduction of migration.

- **Section 4.0, Detailed Evaluation of Alternatives** describes and evaluates in detail the remedial alternatives developed in Section 3.0.

- **Section 5.0, Comparative Analysis** summarizes the detailed evaluations of each alternative side-by-side with the other alternatives.

- **Section 6.0, References** contains references cited in the report.

SECTION 2.0

DEVELOPMENT OF REMEDIATION CRITERIA AND SCREENING OF TECHNOLOGIES

This section identifies site-specific cleanup objectives based on the nature and extent of contamination, the resources that are currently and potentially threatened, the potential for human and ecological exposures, and the current and projected future uses of the Rose Hill Regional Landfill site. The nature and extent of contamination at the Site was detailed in Section 4.0 of the RI report (M&E, 1994), and the human health and ecological risks were assessed and discussed in Sections 6.0 and 7.0 of the same report. In addition, a Supplemental Human Health Risk Assessment (HHRA) was performed to re-estimate risks based on updated toxicity and regulatory criteria (M&E, 1998). Overall remedial action objectives (RAOs), preliminary remediation goals (PRGs), and general response actions for the Site are described below. Also provided are the approximate remediation areas requiring general response actions, the potentially applicable or relevant and appropriate requirements (ARARs), and guidance to be considered during remediation of the Site.

2.1 REMEDIAL ACTION OBJECTIVES AND PRELIMINARY REMEDIATION GOALS

Remedial action objectives are developed to address ecological and human health risks posed by exposure to site contaminants. The RAOs are also developed to address potential safety risks. Surface soils, leachate, groundwater, surface water, and air were quantitatively evaluated in the RI human health risk assessment (M&E, 1994) and the Supplemental Human Health Risk Assessment (M&E, 1998). Among these, groundwater, soil gas, ambient and indoor air, and surface soil were determined to be of concern with regard to human health. Subsequent revisions to the mangenese toxicity value resulted in the determination that surface soil is no longer of concern with regard to human health (M&E, 1998). Surface soil, surface water, leachate, surface sediment, and soil gas were evaluated for potential ecological effects in the RI report (M&E, 1994). Among these, surface water was determined to be of concern with regard to ecological receptors. Safety risk is potentially posed by soil gas.

The human health risk assessment identified the chemicals listed in Table 2-1A as contributing to excessive potential risks under baseline conditions. Table 2-1A also includes chemicals that contribute to potential ecological risks. Chemicals marked with the letter "H" were identified as contributing to excess human health risks. Chemicals marked by the letter "E" were identified as the ecological chemicals of potential concern (COPCs) in the ecological risk assessment. Tables 2-1B and 2-1C illustrate the basis for selection of the media and disposal areas in need of remedial action. Tables 2-1D through 2-1BU present results from the Supplemental HHRA (M&E, 1998).

The human health subsection is organized as follows:

- Chemicals and media of potential human health concern
- RAOs
- Development of groundwater PRGs
- Development of ambient air PRGs
- Uncertainties in human health risk assessment and PRGs

The ecological subsection is organized as follows:

- Chemicals and media of potential ecological concern
- Summary of existing ecological conditions
- Exposure assessment and risk characterization
- RAOs
- Development of ecological PRGs
- Uncertainties in ecological risk assessment and PRGs
- Ecological endpoints

The safety subsection addresses one COPC for safety, identifies the RAOs, and develops PRGs for two different locations.

2.1.1 Development of Human Health RAOs and PRGs

Remedial action objectives for protecting human health are presented in this section, followed by PRGs associated with public health protection. These human health RAOs and PRGs are based on the RI report (M&E, 1994) including Section 6.0, "Human Health Risk Assessment," along with updated toxicity and regulatory data present in the Supplemental HHRA (M&E, 1998). The human health risk assessment evaluated current and potential exposures to contaminated media at the Site, based on current and projected future land use. Current use includes moderate recreational use of the Site, light recreational use of the Saugatucket River area and areas north and south of the Site, and residential use of land immediately to the west of the Site. Future use may include residential use of more of the surrounding area. The future use scenario includes the unlikely possibility that site groundwater will be used as a drinking water source. Exposure pathway assumptions and parameters used in the RI report (M&E, 1994) and Supplemental HHRA (M&E, 1998) have been maintained for the calculation of PRGs.

Remedial action objectives are therefore limited to media, geographic areas, and chemicals for which estimated risk exceeds EPA target risk ranges. Several media were screened out in the human health risk assessment as being unlikely to directly pose significant risks; these were subsurface soil, disposal area contents, stream sediments, and fish. Estimated risks from surface water and leachate did not exceed a hazard index of one or a cancer risk of 10^{-6} to 10^{-4}. Estimated risks for surface soil using updated toxicity values for manganese also did not exceed a hazard index of one or a cancer risk of 10^{-6} to 10^{-4}. Media for which risks may exceed EPA target risk ranges are groundwater, ambient air and indoor air.

2.1.1.1 Chemicals and Media of Potential Human Health Concern. EPA guidelines for baseline risks at a Superfund site are generally that noncarcinogenic risk should not exceed a total hazard index of one, and that carcinogenic risks should not exceed a target risk range of 10^{-6} to 10^{-4}. The human health risk assessment identified certain media and areas of the Site that may pose risks in excess of EPA risk guidelines. These include site groundwater in the vicinity of each of the three

disposal areas, ambient air in the Solid Waste Area, and ambient and/or indoor air in residential areas. Remedial action objectives are based on the potential health risks associated with site groundwater, ambient air and indoor air.

2.1.1.2 Human Health Remedial Action Objectives. Human health RAOs are summarized in Table 2-2. The human health RAOs for the Site include specific objectives to reduce risks identified in the baseline risk assessment as above EPA guidelines. Also, in order to avoid risks caused by future contaminant migration, RAOs to reduce contaminant mobility are included. Remedial action objectives relevant to protection of human health at the Site are as follows:

- Groundwater - To prevent ingestion of groundwater contamination in excess of chemical-specific drinking water ARARs or, in the absence of ARARs, in excess of the EPA target risk range of 10^{-6} to 10^{-4} for carcinogenic compounds and with a total hazard index greater than one among noncarcinogenic compounds with similar toxicity endpoints

- Air - Prevent migration of landfill gas COPCs from the Solid Waste Area to ambient or indoor air at levels exceeding ARARs or, in the absence of ARARs, in excess of the EPA target risk range of 10^{-6} to 10^{-4} for carcinogenic compounds and with a total hazard index greater than one among noncarcinogenic compounds with similar toxicity endpoints

2.1.1.3 Human Health Preliminary Remediation Goals. Where there are established ARARs for chemical-specific concentrations (i.e., groundwater Maximum Contaminant Levels [MCLs]), these are selected as PRGs. According to EPA guidance for Development of Risk-based Preliminary Remediation Goals (U.S. EPA, 1991d), it is appropriate to develop PRGs for site media with cumulative cancer risks greater than $1x10^{-4}$ or hazard indices greater than one, except for media with clearly defined ARARs. Within these media, PRGs are appropriate for each chemical with cumulative cancer risks above $1x10^{-6}$ or with a hazard index above one. A few groundwater contaminants without MCLs and some carcinogens and noncarcinogens in soil gas are eligible for risk-based PRGs based on this guidance. In each of the site media of human health concern, risk-based PRGs are recalculated using current toxicity data. Risk-based PRGs are calculated for all

analytes for which risks estimated in the Supplemental HHRA contribute substantially to total risks above RAOs.

Groundwater. Table 2-3 shows the proposed risk-based and/or standards-based PRGs corresponding to the groundwater remedial objectives. The target individual selected to represent exposure to groundwater was a future resident who may ingest groundwater 350 days a year for 30 years. The chemicals for which cleanup is indicated are those chemicals of potential concern (identified in the Supplemental HHRA; M&E, 1998) for which a cleanup level is below the maximum concentration detected in a particular area of the Site.

The groundwater PRGs shown in Table 2-3 are based on use of the aquifer as a potential drinking water source. Final MCLs developed under the Safe Drinking Water Act are used to establish PRGs for groundwater. If no MCLs are available, the goals are based on the more stringent of a 1×10^{-6} excess cancer risk or a hazard quotient of one. Since multiple contaminants are present, the combined excess cancer risk should be in the range of 10^{-6} to 10^{-4}, and the combined hazard index should be less than 10. The methodology used in determining the groundwater risk-based goals is presented below.

Preliminary remediation goals are developed for groundwater to protect a potential future resident who might use groundwater as a drinking water source. The equation shown below was used to derive risk-based PRGs for groundwater:

where:

$$C\ (\mu g/L) = \frac{TR \times BW \times AT \times 365\ \text{days/year} \times 1000\ \mu g/mg}{EF \times ED \times TOX \times IR^{w}}$$

C	=	Chemical concentration in water
TR	=	Target risk: target excess lifetime cancer risk (for carcinogenic effects) = 10^{-6}; and target hazard index (for noncarcinogenic effects) = 1
BW	=	Adult body weight = 70 (kg)

AT = Averaging time for carcinogens = 70 (years) and noncarcinogens = 30 (years)
EF = Exposure frequency = 350 (days/year)
ED = Exposure duration = 30 (years)
TOX = Toxicity value, which is chemical-specific for both carcinogens and noncarcinogens. Carcinogens are measured as oral slope factor $(mg/kg\text{-}day)^{-1}$ and noncarcinogens are measured as 1/reference dose (RfD) (mg/kg-day).
IR^W = Daily water ingestion rate = 2 (L/day)

Ambient Air. Table 2-4 shows proposed PRGs based on human health risk for ambient air for a site visitor on and in the vicinity of the Solid Waste Area as well as PRGs for indoor and/or ambient air in residential areas. Preliminary remediation goals are developed for ambient air to protect a nearby resident or visitor to the Solid Waste Area, or other persons who may inhale indoor and outdoor air at or adjacent to the site 350 days a per year for 30 years. The PRGs were based on attainment of an incremental cancer risk of 10^{-6} for each compound exceeding that level. The equation shown below is used to derive risk-based PRGs for waste area air:

$$C(\mu g/m^3) = \frac{TR \times AT \times 365 \text{ days/year} \times 24 \text{ hours/day}}{EF \times ED \times HR \times TOX^a}$$

where:

TR, AT, and ED are as defined above for groundwater, and

C = Chemical concentration in air

EF = Exposure frequency = 150 (days/year)

HR = Daily exposure duration = 4 (hours/day)

TOX^a = Toxicity value for inhalation, which is chemical-specific for both carcinogens and noncarcinogens. The toxicity value for both carcinogens and noncarcinogens are in units of $(\mu g/m^3)^{-1}$.

The equation shown below is used to derive risk-based PRGs for residential area ambient air:

$$C(\mu g/m^3) = \frac{TR \times AT \times 365 \text{ days/year}}{EF \times ED \times TOX^a}$$

where:

C, TR, AT, ED, and TOX^a are as defined above for waste area ambient air, and

EF = Exposure frequency = 350 (days/year)

2.1.1.4 Uncertainties in the Development of Human Health Preliminary Remediation Goals. Limitations and uncertainty of predicting human health risks were discussed in Section 6.0 of the RI report (M&E, 1994) and in the Supplemental HHRA (M&E, 1998). Much of the uncertainty in the health risk assessment also applies to the human health PRGs, since the PRG development is based on chemicals, media, and areas of concern identified in the RI. Also, the PRGs were developed using the same exposure assumptions and toxicity information. As a result, the following significant sources of uncertainty apply to the derivation of the PRGs:

- Identification of chemicals, media, and areas of concern
- Fate and transport assumptions
- Dose-response relationships for individual chemicals
- Toxicity interaction between chemicals
- Exposure scenario development
- Target population characteristics

A large number of soil and groundwater samples in the site study area were analyzed for numerous chemicals. The chemicals identified as of potential concern in groundwater and ambient/indoor air are likely to be representative of the toxicity in these media. Dose-response uncertainty is common to all hazardous waste risk assessments. There are many uncertainties regarding the amount of time people spend visiting the Site and about how much contact there will be in the future.

2.1.2 Development of Ecological Remedial Action Objectives and Preliminary Remediation Goals

Remedial action objectives and PRGs were developed based on actual or potential risks to ecological resources posed by exposure to site contaminants. Critical to the development of these objectives and goals was information collected on the ecological resources present on the Site during the biological field sampling program of the ecological assessment (M&E, 1994). Also of importance was the results of sediment and leachate toxicity testing which are summarized in the baseline ecological risk assessment (M&E, 1994). The methodology and principal results of the ecological assessment and the ecological risk assessment are summarized in this section to provide the background necessary to understand the rationale behind the development of the ecological RAOs and PRGs.

The ecological portion of the risk assessment for the site study area had four major objectives:

- Define the ecological condition of the site study area by identifying significant ecological resources that occur in the site study area and assessing their relative health
- Evaluate potential adverse effects to ecological resources from exposure to site contaminants by quantifying baseline risks to ecological receptors
- Develop RAOs and PRGs for ecological resources
- Develop ecological endpoints for the preservation or restoration of important on-site ecological values as part of the remediation program

The first objective was addressed through the development and implementation of a biological field sampling program, the results of which are presented in Section 3.4 "Ecological Assessment" of the RI report (M&E, 1994) and summarized in Section 2.1.2.2. Figure 2-1 presents wetland resource areas identified during the RI report preparation. The second objective was addressed in Section 7.0 of the RI report (M&E, 1994) "Baseline Ecological Risk Assessment". Information from the baseline ecological risk assessment is summarized in Section 2.1.2.3. Information contained in these

two assessments was then used to address the last two objectives in this FS. Remedial action objectives are outlined in Section 2.1.2.4, PRGs in Section 2.1.2.5, and ecological endpoints in Section 2.1.2.7.

2.1.2.1 Chemicals and Media of Potential Ecological Concern. Based on the observed contaminant levels in the various on-site media and likely exposure pathways for species observed or expected to occur, the following were considered of concern to ecological resources:

- Surface water in the Saugatucket River and Mitchell Brook, as well as in downgradient surface waters fed by these water bodies
- Leachate from landfill seeps
- Surface sediment in the Saugatucket River and Mitchell Brook in locations adjacent to the disposal areas
- Surface soil, notably in the three disposal areas
- Soil gas, notably in the Solid Waste Area

Groundwater (except where it surfaces as a leachate seep) and subsurface soils were not considered media of concern to ecological receptors since these organisms have little, if any, direct exposure to these media. Ambient air was evaluated concurrently with soil gas.

Screening of contaminants and selection of ecological COPCs considered a number of variables including observed contaminant concentrations in the media of concern, frequency of detection, mobility and persistence, toxicity (based on published effect levels), background levels, and existing guidelines, standards, or criteria. Based upon this analysis, the ecological COPCs were identified as:

- aluminum, iron, and manganese in surface water
- aluminum, iron, lead, and manganese in leachate

- aluminum and iron in surface sediment
- copper, lead, and manganese in surface soils

No compounds were considered of potential ecological concern in soil gas (or in ambient air from outgassing of soil gas). Although two small areas of dead trees along Rose Hill Road were associated with high methane levels in soil gas, these impacts were considered too limited to justify including methane as a COPC to ecological receptors (see Section 2.1.2.3.).

2.1.2.2 Summary of Existing Ecological Conditions. The nature and extent of site contamination and the fate and transport mechanisms of the ecological COPCs suggested that the primary ecological resource at risk was the aquatic system (Mitchell Brook and the Saugatucket River). Thus, quantitative studies of the on-site benthic community in these water bodies were conducted at locations adjacent to and downstream of the Site and at upstream "reference" locations. Since the wetland and upland habitats were expected to be less contaminated, qualitative studies of vegetation and wildlife were considered sufficient to define exposure pathways. Studies of wetland and terrestrial habitats consisted of wetland delineation, wetland functional assessment, vegetation (habitat) mapping, and wildlife surveys.

Significant ecological habitats within the site study area include the Saugatucket River and Mitchell Brook, their associated tributaries and forested wetlands, and the adjacent forested and old field upland habitats. Rare plant species known to occur within the site study area include a species of state interest, tickseed sunflower (*Bidens coronata*), and a species of state concern, bloodroot (*Sanguinaria canadensis*). A probable sighting of an avian species of state concern, red-bellied woodpecker (*Melanerpes carolinus*), also occurred within the site study area. Two avian species of state interest, glossy ibis (*Plegadis falcinellus*) and great egret (*Casmerodius albus*), were also observed within the site study area. However, the state designation applies only to breeding sites for these two species, and suitable breeding habitat does not exist within the site study area, except possibly along the Saugatucket River.

As indicated by a single, reconnaissance-level survey, the site study area is utilized by a variety of terrestrial species. Avian species observed on the Site were generally typical of those expected based upon geographical location, habitat present, and surrounding land uses. The extensive running of dogs and hunting on the Site have influenced the use of the site study area by mammalian species. Reptiles and amphibians utilizing the site study area are likely to be confined largely to terrestrial species, as Mitchell Brook does not appear to support large numbers of these organisms or other prey species, such as fish. However, the Saugatucket River likely supports a more diverse assemblage of wildlife and aquatic species. No overt effects of site contamination on terrestrial wildlife were apparent, although the study was not designed to document most potential chronic effects.

The macroinvertebrate species composition in the sediments of the Saugatucket River appear to be affected by the disposal areas. The species composition (in terms of the relative abundance of dominant organisms) adjacent to the disposal areas appears to be different from the species composition in upstream and downstream locations. The area adjacent to the Bulky Waste Area has the most contaminated sediments and pollution-tolerant taxa did occur in relatively high numbers in the sediments compared to the taxa in sediments in upstream and downstream locations.

Organisms in the water column of the Saugatucket River also appear to be influenced by the disposal areas and leachate seeps. Total densities of organisms in the water column downstream of the disposal areas and leachate seeps are significantly lower than at upstream locations. The occurrence of pollution-sensitive invertebrate taxa in the water column also decreased from upstream to downstream locations. There also appears to be a scarcity of fish in this section of the river, where resident and migratory fish would be expected to occur.

The benthic macroinvertebrate community in Mitchell Brook does not appear to be as diverse as that of the Saugatucket River. In general, the macroinvertebrates in Mitchell Brook sediments and surface waters showed a pattern of decreasing densities from upstream to downstream locations. Species density and diversity were especially low adjacent to the disposal areas. Additionally, the

occurrence of pollution-sensitive species decreased from upstream to downstream locations. In the brook, as in the Saugatucket River, few fish were observed.

2.1.2.3 Exposure Assessment and Risk Characterization. A baseline ecological risk assessment was conducted to evaluate potential risks to ecological receptors from exposure to contaminants in surface water, leachate, sediment, surface soil, and soil gas. Potential exposure pathways evaluated were dermal contact, inhalation, ingestion of contaminated media, and ingestion of contaminated food. Inhalation and food chain exposures were not considered significant, but may contribute to total exposure.

Risks were evaluated through the development of media-specific ecological effect levels, which are defined as the concentration of a particular contaminant in a particular medium below which no adverse effects to ecological receptors are likely to occur. Ecological effect levels for aquatic areas were based on established numerical criteria (EPA and RIDEM ambient water quality criteria [AWQC]). Information obtained from the literature was used to develop effect levels for upland and wetland habitats. These effect levels were used to assess baseline ecological risks by comparing them to existing contaminant levels in on-site media. In addition, aquatic invertebrate surveys, and toxicity testing with on-site sediments and leachate, served to more fully define baseline risks to aquatic receptors.

Aquatic Receptors. Benthic organisms and fish were identified as potential receptors in aquatic habitats. The *in-situ* benthic community exhibited some apparent effects from site contamination, particularly with respect to community structure, although the results of statistical analyses showed that there was no significant linear correlation between species densities and sediment contamination. Sediment toxicity tests were conducted on two aquatic invertebrates, *Hyalella azteca* and *Ceriodaphnia dubia*, and on the fathead minnow, *Pimephales promelas*. Based on the statistical results of these tests, it was concluded that there was no significant difference between the reference and study area samples in sediment toxicity. This indicates that the sediments within the site study area do not exhibit acute or chronic toxicity to representative, sensitive species.

Risk from the ecological COPCs in surface water and leachate were evaluated by comparing contaminant concentrations to known ecological effect levels. For iron and aluminum, the ecological effect levels were based on ambient water quality criteria for protecting aquatic life. The chronic AWQC is 1,000 μg/L for iron, and 87 μg/L for aluminum. Iron was measured at up to 65 times the criteria in surface water while aluminum was measured at up to 13 times its criteria value. Concentrations of these chemicals in surface waters throughout the Site frequently exceeded criteria levels, especially in areas downstream of leachate seeps. Thus, there is a risk to aquatic organisms in the surface waters from exposure to these ecological COPCs. Concentrations of iron and aluminum in leachate also exceeded AWQCs (by up to four orders of magnitude for aluminum).

There is no EPA AWQC for manganese. However, the average concentration of manganese in surface water at the Site was substantially greater than the average background concentration and the manganese criterion (80 µg/L; Suter and Mabrey, 1994) derived via the Great Lake System Tier II Method (EPA, 1993d). Due to these exceedances, manganese is identified as having the potential to pose a significant risk to ecological receptor populations.

The risk to aquatic organisms was confirmed by results from macroinvertebrate surveys and leachate toxicity testing. Total macroinvertebrate densities and densities of dominant species in the water column decrease with increasing iron concentration in the Saugatucket River. Toxicity tests were performed using composite leachate samples from the Site and the test organisms *C. dubia* and *P. promelas*. Test results indicate that the leachate was acutely toxic to *C. dubia* and also caused reproductive effects. Some chronic toxicity also occurred in the fathead minnow (*P. promelas*).

Terrestrial Receptors. Amphibians, reptiles, birds, and mammals were identified as potential receptors in upland and wetland habitats. Based upon on-site observations, plants were not considered at risk, since the on-site floral communities did not exhibit any signs of stress that could be attributed to the contamination at the Site, with the exception of several small groups of trees which appeared to have been killed by elevated methane levels in soil gas.

Ecological effect levels can be used to assess baseline risks to ecological receptors by comparing them to existing contaminant levels in the on-site media. For wetland and upland habitats, ecological effect levels were determined from the literature. The ecological COPCs in surface soils (copper, lead, and manganese) rarely exceeded their effect levels, so baseline risks to terrestrial organisms were not considered significant over most of the site study area. Areas of soil associated with leachate seeps, and the leachate itself, may pose some risks to biota since effect levels were exceeded. Due to the small areas affected, however, this risk is not considered significant. Food chain effects are not of concern, although indirect effects from reduced prey abundance in aquatic areas may be occurring. Small areas of dead trees associated with high methane levels in soil gas are also not considered significant, due to the extremely limited areas over which these effects have been observed. Certain aquatic or semiaquatic reptiles and amphibians, however, may be adversely impacted by contact with contaminated surface water or leachate, as described above for aquatic receptors.

2.1.2.4 Ecological Remedial Action Objectives. Ecological RAOs are summarized in Table 2-5. Based upon the results of the ecological assessment and the ecological risk assessment, the ecological RAOs for the Site are established to reduce contaminant migration via leachate to the surface waters and sediments of Mitchell Brook and the Saugatucket River.

2.1.2.5 Ecological Preliminary Remediation Goals. The ecological effect levels utilized in the baseline risk assessment and summarized above can be used to develop PRGs for the protection of ecological resources. Since the ecological effect levels for surface water (the only media within which significant adverse effects were identified) were based on criteria values designed to protect aquatic receptors (AWQC), these levels were also deemed appropriate for use as PRGs. Therefore, the PRG for iron was set at 1,000 μg/L, the chronic AWQC. This concentration is greater than the maximum iron concentration detected in background samples (250 μg/L). The aluminum PRG was set at a concentration greater than the chronic AWQC (87 μg/L) because the background aluminum concentration (140 μg/L) was greater than the AWQC. No EPA AWQC was available for manganese. Therefore, the PRG for manganese was set at the background concentration (45 μg/L).

The ecological PRGs are defined in Table 2-6.

- PRGs for surface water would be attainment of AWQC for iron (1,000 μg/L) as well as attainment of background levels for manganese (45 μg/L) and aluminum (140 μg/L).

2.1.2.6 Uncertainties in the Development of Ecological Preliminary Remediation Goals. There are many sources of uncertainty associated with an ecological risk assessment. Each component of an ecological risk assessment (i.e., receptor selection, toxicity assessment, and exposure assessment) has some uncertainty associated with it. The principal uncertainty associated with this analysis involves the determination of ecological effect levels. For many chemicals, especially for the terrestrial assessment, toxicity data were limited and criteria values were often unavailable. To compensate for this, the most conservative values were generally used to represent a reasonable worst-case scenario.

A second uncertainty involves using chemical-specific effect levels for individual compounds to assess toxicity. This approach fails to account for multiple exposure pathways, exposures to multiple chemicals, and potential additive or synergistic effects. This uncertainty is most evident for the terrestrial portion of the ecological risk assessment; the aquatic portion included toxicity testing with on-site media, which accounts for these factors.

Specific uncertainty relative to PRGs for iron, aluminum and manganese involve criterion derivation and degree of data collection. The EPA chronic AWQC for iron (1 mg/L; EPA, 1976) is based primarily on field observations (e.g., comparison of spatial presence of a species or community with iron concentrations in a watercourse). The toxicity of iron is heavily influenced by site-specific parameters such as alkalinity, pH, hardness, temperature, and the presence of ligands, which change the valence state and solubility. The effects of iron on aquatic receptors can be physical (e.g., egg-smothering iron floc) or chemical. The level of risk with each of these types of effects would be dependent on the form of iron, the amount, and the exposed receptor community. For manganese and

aluminum, determination of background levels at upstream locations was based on a limited number of samples and may not truly represent background levels.

2.1.2.7 Ecological Endpoints. In addition to the PRGs outlined above, an objective of remediation is to maintain, wherever possible, the functions and ecological values of the existing wetland and upland habitats. The following is a general discussion of the existing ecological values of the site study area worth protecting during remediation or enhancing/restoring following remediation. The goals (termed ecological endpoints) for the preservation or restoration of important ecological values are also outlined.

Terrestrial Habitats. One goal of remediation on upland areas should be the protection, from disturbance associated with remedial activities, of areas with relatively mature trees, as these resources are impossible to replace in a reasonable time frame. Thus, the desired ecological endpoint on upland areas would be the preservation of mature forested areas, and the restoration or enhancement of disturbed shrubby and herbaceous areas.

Vegetated Wetland Habitats. Special emphasis should be given to the preservation of forested wetlands along the Saugatucket River and Mitchell Brook, since the live and dead trees in these areas are important habitat resources that are difficult, if not impossible, to replace. Preservation applies to both direct impacts (through tree clearing) and indirect impacts (from groundwater drawdown or other hydrological alterations).

Aquatic Habitats. The goal of remediation activities in aquatic areas would be the restoration of a healthy and functioning benthic community in Mitchell Brook and the Saugatucket River.

2.1.3 Development of Safety Remedial Action Objectives and Preliminary Remediation Goals

The RAO for safety identified for the Site is to avoid the occurrence of potentially explosive levels of soil gas within structures. Structures on the Site and off the Site should be protected. Among

flammable or potentially explosive gases in soil gas, methane is predominant. Avoiding explosive levels of methane within structures is expected to achieve the RAO. In order to provide a margin of safety, the PRG for facility structures is a methane concentration less than 25% of the lower explosive limit (LEL). As a wider margin of safety is desirable for off-site structures, the same PRG of 25% of the LEL is also set to apply to the property boundary. These PRGs are consistent with Section 12-030-15.08, Gas Control, of the Code of Rhode Island Rules, pursuant to Chapters 23-18.9 and 23-63 of the Rhode Island General Laws.

2.2 GENERAL RESPONSE ACTIONS

General response actions are developed to satisfy the RAOs for the Site. The range of applicable general response actions for each medium's RAOs are identified in Table 2-7.

2.3 PERFORMANCE OF INSTITUTIONAL SCREENING (ARARs)

During the FS process, an analysis is made of legal and policy requirements that could affect the implementation of remedial alternatives. These institutional issues consist mainly of the compliance of each proposed remedial alternative with applicable or relevant and appropriate federal, state, and local public health and environmental requirements (ARARs). Determination of ARARs is site-specific and depends on the chemical contaminants, site/location characteristics, and remedial actions being investigated for site cleanup. Consideration of ARARs is undertaken to fulfill the requirements of the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) as amended, the National Contingency Plan (NCP), and other requirements of laws that must be addressed by the EPA or parties undertaking the remedial action. In Section 4.0, "Detailed Evaluation of Alternatives", each alternative is evaluated with respect to its compliance with the ARARs identified below.

CERCLA, as amended by the Superfund Amendments and Reauthorization Act (SARA, October 1986), governs the liability, cleanup, financial responsibility, and response for hazardous substances

released into the environment. CERCLA requires that all remedial actions be consistent with the NCP. The NCP, published as 40 CFR Part 300, specifies procedures, techniques, materials, equipment, and methods to be employed in identifying, removing, or remedying releases of hazardous substances. In particular, the NCP specifies procedures for determining the appropriate type and extent of remedial action at a site in order to effectively mitigate and minimize damage to, and provide adequate protection of, public health, welfare, and the environment.

The national goal of remedy selection is to protect human health and the environment, to maintain that protection over time, and to minimize untreated waste (40 CFR Part 300.430 of the NCP (55 FR 8846)). In accordance with Section 121(d) of CERCLA, site remediation must comply with all applicable or relevant and appropriate laws, regulations, and standards promulgated by the federal government, except where waived. State requirements must also be attained, under Section 121(d)(2)(c), if they are legally enforceable and consistently enforced statewide, and if the state ARAR is more stringent than the federal ARAR and has been presented to the EPA in a timely manner. Waiver conditions that may be used, if protection of human health and the environment is to be ensured, include the following:

- The remedial action selected is only part of a total remedial action that will attain such level or standard of control when completed
- Compliance with such requirements is technically impracticable from an engineering perspective
- Compliance with such requirement at that facility will result in greater risk to human health and the environment than alternative options
- The remedial action selected will attain, through use of another method or approach, a standard of performance that is equivalent to that required under the otherwise applicable standard, requirement, criteria, or limitation
- In the case of a remedial action to be undertaken solely under Section 104, selection of a remedial action that attains such level or standard of control will not provide a balance between the need for protection of public health and welfare and the environment at the facility under consideration, and the availability of money from

the fund to respond to other sites, taking into consideration the relative immediacy of such threats

- With respect to a state standard, requirement, criteria, or limitation, the state has not consistently applied (or demonstrated the intention to consistently apply) the standard, requirement, criteria, or limitation in similar circumstances at other remedial action sites within the state

The NCP defines "applicable" and "relevant and appropriate" requirements. Applicable requirements consist of those cleanup standards, standards of control, and other substantive environmental protection requirements, criteria, or limitations promulgated under law that specifically address a hazardous substance, pollutant, contaminant, remedial action, location, or other circumstance at a CERCLA site. Relevant and appropriate requirements are those cleanup standards, standards of control, and other substantive environmental protection requirements, criteria, or limitations promulgated under federal or state environmental or facility siting laws that, while not "applicable" to a hazardous substance, pollutant, contaminant, remedial action, location, or other circumstance at a CERCLA site, address problems or situations sufficiently similar to those encountered at the CERCLA site that their use is well suited to the particular site. In addition, other environmental and public health guidelines, although not ARARs, may be considered to help determine what is protective or to determine CERCLA remedies. These guidelines are termed "to be considered" or "TBC".

CERCLA Section 121(e), codified at 40 CFR Part 300.400(e), exempts any response action conducted entirely at the site from having to obtain a federal, state, or local permit, where the action is carried out in compliance with Section 121. Remedial actions conducted on Superfund sites need comply only with the substantive aspects of ARARs and not with the corresponding administrative requirements.

Identification of potential ARARs to be considered for the Site and adjacent wetland areas are organized into three categories, following EPA's *CERCLA Compliance with Other Laws Manual* (Interim Final -- EPA/540/G-89/006, Part II -- EPA/540/G-89/009 guidance (EPA, 1988b and 1989):

- Chemical-specific
- Location-specific
- Action-specific

The following subsections summarize ARARs for the Site. Each possible ARAR is reviewed to evaluate its potential applicability or relevancy and appropriateness according to the procedures identified in CERCLA Compliance with Other Laws Manual (OSWER Directive 9234.1-01) and *Guidance for Conducting Remedial Investigations and Feasibility Studies Under CERCLA* (OSWER Directive 9355.3-01). Refer to Section 4.0 for tabulations of ARARs from the following subsections which are specific to each alternative (action-specific).

2.3.1 Chemical-Specific ARARs

Chemical-specific ARARs provide criteria for evaluating concentrations of specific hazardous contaminants. They are developed based upon the protection of human health and the environment. Federal and state laws which may be potential chemical-specific ARARs or TBCs are summarized in Table 2-8 and include:

- Federal Safe Drinking Water Act, National Primary Drinking Water MCLs and MCLGs
- Resource Conservation and Recovery Act (RCRA) Maximum Concentration Limits
- Federal Clean Water Act, AWQC
- Federal Clean Air Act, National Ambient Air Quality Standards (NAAQS)
- Rhode Island Rules and Regulations for Groundwater Quality
- Rhode Island Water Quality Standards
- Rhode Island Air Pollution Control Regulations
- Rhode Island Solid Waste Management Facility Rules and Regulations

- Federal Criteria and Advisories To Be Considered

A discussion of the applicability or relevancy and appropriateness of each of the potential ARARs or criteria to be considered listed above is provided in this section.

No single set of federal or state criteria dictate acceptable concentrations in drinking water or surface water for all of the contaminants detected within the site study area. Chemical-specific ARARs and TBCs for groundwater are listed in Table 2-9, for surface water in Table 2-10, and for air in Table 2-11.

2.3.1.1 Safe Drinking Water Act. The Safe Drinking Water Act (SDWA) of 1974, most recently amended in 1996, was established to protect public drinking water supplies. The major elements of the drinking water program include:

- Drinking water standards, contaminant occurrence and selection treatment techniques
- Microbial disinfection by-product standards
- Source water protection
- Arsenic, lead and copper
- Operator certification
- Consumer confidence reports
- Radionuclide standards

Section 1424(e) of the SDWA authorizes EPA to determine that an aquifer is the "sole or principal" source of drinking water for an area.

Section 1412 of the SDWA requires the EPA to publish MCLGs and promulgate national drinking water regulations. Under Section 1401, EPA must develop enforceable MCLs and "criteria and

procedures to assure a supply of drinking water which dependably complies" with such MCLs. Under Section 1412(b)(7)(A), the use of a best available treatment technique instead of attainment of an MCL is allowed if it is not technically or economically feasible to ascertain the level of a contaminant in drinking water. Primary Drinking Water Regulations are set forth under 40 CFR Part 141 while 40 CFR Part 142 supplies National Primary Drinking Water Implementation Regulations and 40 CFR Part 143 provides National Secondary Drinking Water Regulations. 40 CFR Part 141 Subparts B and F specify MCLs and MCLGs, respectively.

MCLs are enforceable chemical-specific drinking water standards, developed under the SDWA. MCLs are based on the use of best technology, treatment techniques, and other factors, including cost. MCLGs are based entirely on health considerations and do not take cost or feasibility into account. MCLGs are set at levels which will result in no known or anticipated health effects, keeping a margin of safety. Section 121 of CERCLA states that remedial actions shall attain MCLs where they are relevant and appropriate.

The disposal area boundaries are defined as Rhode Island Class GB areas not suitable for public or private drinking water use. Hence, MCLs and MCLGs are not relevant and appropriate requirements for this site. Areas outside of the disposal boundaries are defined as class GA, or suitable for drinking water use. Therefore, MCLs and MCLGs are relevant and appropriate to offsite groundwater, and are thus used in developing the PRGs.

2.3.1.2 Resource Conservation and Recovery Act Maximum Concentration Limits. 40 CFR §264.94 establishes three categories of federal groundwater protection standards which are considered by Superfund as potentially ARAR: RCRA MCLs, Alternate Concentration Limits (ACLs), and background concentrations. RCRA MCLs have been adopted for 14 toxic compounds, primarily metals and pesticides, as a part of RCRA groundwater protection standards (40 CFR §264.94).

These standards apply to RCRA regulated units that received RCRA hazardous waste after July 26, 1982. If a comparison of indicator concentrations from background and downgradient wells shows a statistically significant increase, a groundwater protection standard is established for all hazardous constituents. The baseline protection standard is the background level of the constituent, one of the 14 RCRA MCLs, or an ACL. ACLs are applied for and granted on a site-by-site basis and must ensure that there will not be a substantial present or potential hazard to human health and the environment.

Since the Rose Hill Regional Landfill did not receive RCRA hazardous wastes, or similar wastes, after July 26, 1982, these requirements are not considered to be applicable. The Rose Hill Regional Landfill Site did, prior to 1980, however, receive waste that under current rules would be considered a hazardous waste. For this reason, RCRA Subtitle C requirements are considered relevant and appropriate for the Rose Hill Regional Landfill Site.

2.3.1.3 Federal Water Pollution Control Act, as Amended by the Clean Water Act, Ambient Water Quality Criteria. The Federal Water Pollution Control Act as amended by the Clean Water Act (referred to as the Clean Water Act or CWA) seeks to "restore and maintain the chemical, physical, and biological integrity of the Nation's waters" (40 CFR 101(a)).

The CWA, as amended, sets forth ambient water quality criteria for the protection of freshwater aquatic life and human health (authorized under CWA Section 304(a)(1) and regulated under 40 CFR 120). Water quality standards are based on the designated use(s) for the water, and the criteria necessary to protect the designated use(s). Federal AWQC developed under Section 304(a) of the CWA are unenforceable guidance criteria based on the latest scientific information to evaluate the effect a toxic pollutant concentration has on a particular aquatic species and/or human health. There are both proposed and final AWQC. With regards to human exposure, there are two categories to consider: ingestion of both contaminated drinking water and contaminated fish, and ingestion of contaminated fish alone. Although AWQC are nonenforceable, and thus cannot be applicable, Section 121 of CERCLA states that remedial actions shall attain AWQC where they are

relevant and appropriate. In determining if AWQC are relevant and appropriate, the primary factors to consider are the designated or potential uses of the water, the media affected, the purposes for which the potential requirement are intended and the latest information available.

The AWQC may be relevant and appropriate for Mitchell Brook, the unnamed brook, and the Saugatucket River when protection of aquatic life is a concern or human exposure from consumption of fish a concern. In the RI report (M&E, 1994), several surface water location exhibited high metal concentrations which coincided with areas adjacent to leachate seeps. Additionally, a few organic compounds were detected infrequently in low concentrations in Mitchell Brook, the unnamed brook, and the Saugatucket River. As identified in the ecological assessment of the RI, aquatic organisms appear to be directly and negatively impacted in surface water locations downstream of the disposal areas and leachate seeps. For this reason, AWQC for the protection of aquatic life are considered ARAR for the Site.

2.3.1.4 Clean Air Act and Rhode Island Air Pollution Control Regulations. The federal Clean Air Act directs EPA to establish national primary and secondary ambient air quality standards. National primary ambient air quality standards define levels of air quality that EPA judges necessary to protect the public health with an adequate margin of safety. National secondary ambient air quality standards define levels of air quality that EPA judges necessary to protect the public welfare from any known or anticipated adverse effects of a pollutant.

Of the six air contaminants for which standards have been established for specific sources, only particulate matter may be of concern at this site. The level of the national primary and secondary 24-hour ambient air quality standards for particulate matter is 150 micrograms per cubic meter ($\mu g/m^3$), 24-hour average concentration. The standards are attained when the expected number of days per calendar year with a 24-hour average concentration above 150 $\mu g/m^3$, as determined in accordance with appendix K to this part, is equal to or less than one. The level of the national primary and secondary annual standards for particulate matter is 50 micrograms per cubic meter ($\mu g/m^3$), annual arithmetic mean. The standards are attained when the expected annual arithmetic

mean concentration, as determined in accordance with appendix K to this part, is less than or equal to 50 $\mu g/m^3$.

Air Pollution Control Regulations No. 7, Emission of Air Contaminants Detrimental to person or property, prohibits emissions of any contaminants which may be injurious to human, plant or animal life, or cause damage to property or which unreasonably interferes with the enjoyment of life and property. This rule requires source approval if air quality modeling shows human health or environmental risks. The evaluation of human health risks was discussed in Section 2.1.

Air Pollution Control Regulation No. 22, regarding air toxics, specifies the acceptable air quality impacts for stationary sources emitting any of the 40 listed toxic air contaminants. Air quality modeling is used to determine allowable emissions. Of the listed contaminants, soil gas at the Rose Hill Regional Landfill site has been shown to contain benzene, methylene chloride, toluene, trichloroethylene, xylenes, carbon tetrachloride, and tetrachloroethylene.

Regulations Designating Areas for Air Quality Planning at 40 CFR 81.31 designates the entire state of Rhode Island to be within the "Metropolitan Providence Interstate Air Quality Control Region." The air quality designation at the Site for each National Ambient Air Quality Standards (NAAQS) is as follows:

Total Suspended Particulates: better than national standards
Sulfur Dioxide: better than national standards
Carbon Monoxide: unclassifiable/attainment
Nitrogen Dioxide: Cannot be classified or better than national standards
Ozone: Nonattainment

The classification of nonattainment for ozone is "serious". 40 CFR 172, Subpart D, Plan Requirements for Nonattainment Areas, defines a major source in a serious ozone nonattainment

areas as "any stationary source or group of sources located within a contiguous area and under common control that emits, or has the potential to emit, at least 50 tons per year of VOCs."

2.3.1.5 Rhode Island Rules and Regulations for Groundwater Quality. These rules, published as Regulation DEM-GW-01-92 and most recently amended June 25, 1998, classify groundwater resources of Rhode Island and set numerical groundwater quality standards for those classifications. The rules also include procedures for determining compliance with Rhode Island groundwater quality rules as well as procedures for corrective actions. The state of Rhode Island has classified the area under and surrounding the three disposal areas on the Site as GB - not suitable for public or private drinking water use. To comply with Rhode Island groundwater regulations, Class GB groundwaters shall not: threaten public health or the environment, cause a violation of surrounding groundwater quality standards; adversely impact groundwater and surface water at boundary of facility; or violate or have the potential to cause a violation of Rhode Island surface water quality standards.

2.3.1.6 Rhode Island Water Quality Standards. Under the CWA, every state is required to: classify waters within its boundaries according to its intended use; establish antidegradation requirements; and develop water quality standards. The Rhode Island Water Quality Standards, amended August 26, 1997 and designated under Rhode Island General Laws (RIGL) Title 46, Chapter 12, apply to discharges to surface water. The Saugatucket River is designated as a Class B water body, suitable for fishing and swimming, and public water source with appropriate treatment. Mitchell Brook, a tributary of the Saugatucket River, is also a Class B water body. The law sets general criteria for aquatic habitat, aesthetics, radioactive substances, nutrients, and mixing zones for all surface waters of the state. In addition, class-specific criteria are set for dissolved oxygen, temperature, nutrients, pH, sludge deposits or solid refuse, settleable solids, oil, grease, scum, turbidity, *E. Coli* bacteria, color, and tastes and odor. Rhode Island AWQC set in Appendix G of these rules do not apply to indirect discharges, such as the leachate seeps, and are not considered chemical-specific ARARs for the Site. These rules will be re-evaluated during examination of action-specific ARARs.

2.3.1.7 Rhode Island Solid Waste Management Facility Rules and Regulations. Rhode Island Solid Waste Management Facility Rules (SWMFR), authorized under Rhode Island General Laws (RIGL) Chapters 23-18.9 23-63, and 42-35, govern solid waste management. The rules include a description of gas controls and closure requirements with regard to solid waste facilities, and institute a prohibition on methane gas concentrations of greater than 25% of the LEL at the facility property boundary or in facility structures. These rules are applicable to methane levels at the Site.

2.3.1.8 Federal Criteria and Advisories To Be Considered. In addition to the ARARs listed above, there are other important issues and advisories which will require attention prior to and during remedial activities. These criteria and advisories to be considered include:

- **Reference Dose Concentrations** are available for many air and water contaminants on the Integrated Risk Information System (IRIS) on-line database. Where contaminant concentrations do not exceed air or water reference concentrations, adverse health effects other than cancer are unlikely to occur. These values are useful as health based goals to be considered.

- **Slope Factors and Unit Risks.** Carcinogenic slope factors and unit risks are developed by the EPA CAG from health effects studies using epidemiologic data or from animal testing. Slope factors and unit risks for various carcinogens provide a measure of the strength of a carcinogen; many are available from IRIS. Unit risks may be used to develop target concentrations to correspond to a selected acceptable risk.

- **Federal Groundwater Protection Strategy of 1984.** EPA developed the Groundwater Protection Strategy in 1984 with the goal of organizing and coordinating the various programs that protect groundwater. The groundwater protection strategy lists several policy statements that emphasize the protection of groundwater resources. The strategy is not a promulgated requirement and, therefore, cannot be a potential ARAR; it does, however, list several policy statements to be considered when developing a protective remedy. To help achieve consistency among programs, groundwater classification guidelines were developed to distinguish between different groundwaters meriting different levels of protection. Class I groundwaters are "special groundwaters" that are highly vulnerable and are either irreplaceable or ecologically vital. Class II groundwaters are current and potential sources of drinking water and waters having other beneficial uses. Class II groundwaters are estimated to comprise 84 to 94% of the nation's groundwater.

Class III groundwaters are those that cannot be used for drinking water due to high salinity or widespread naturally occurring contamination.

- **Threshold Limiting Values (TLVs).** TLVs refer to airborne concentrations of substances and represent conditions under which it is believed that nearly all workers may be repeatedly exposed to day after day without adverse health effects.

2.3.2 Location-Specific ARARs

Location-specific ARARs must be considered when developing the FS as these types of ARARs may affect or restrict remediation and site activities. Generally, location-specific requirements serve to protect individual site characteristics, resources, and specific environmental features on a site. The following federal and state laws which pertain to the protection of resources and are potential ARARs or criteria TBC for the Site are described below and summarized in Table 2-12:

- Clean Water Act (33 U.S.C. §1251 to 1387), Section 404 and Guidelines for Specification of Disposal Sites of Dredged or Fill Material (33 U.S.C. §1344), Section 10 of the Rivers and Harbors Act of 1899 (33 U.S.C. §403)
- Executive Order No. 11990, Wetlands Protection
- Statement of Procedures on Floodplain Management and Wetlands Protection (40 CFR 6, Appendix A)
- Federal Fish & Wildlife Coordination Act (16 U.S.C. §661-666c)
- Federal Resource Conservation and Recovery Act, location requirements (40 CFR 264.18)
- Federal Archaeological and Historical Preservation Act of 1974, National Historical Preservation Act of 1966 (16 U.S.C. §470), Archaeologic and Historical Protection
- Rhode Island Rules and Regulations Governing the Freshwater Wetlands Act
- Rhode Island Endangered Species Act
- Executive Order 11988, Floodplain Protection
- State Historic Cemetaries Act

As there are no wilderness areas, wild or scenic rivers, or coastal areas in the vicinity of Site, the requirements associated with the Wilderness Act, the Wild and Scenic River Act, Coastal Zone Management Act, Marine Mammal Protection Act, and the Marine Protection, Research and Sanctuaries Act were not considered. As no federal endangered or threatened species or critical habitat have been identified, the requirements of the federal Endangered Species Act are also not considered as ARARs; should any federal endangered or threatened species, or critical habitat, be identified in the vicinity of the Site, this act would become applicable. Also, if any bald eagles or golden eagles are sighted nesting in the vicinity of the Site, the Bald and Golden Eagle Protection Act would become applicable.

2.3.2.1 Clean Water Act, Rivers and Harbors Act of 1899 (33 U.S.C. §403) and Guidelines for Specification of Disposal Sites of Dredged or Fill Material (33 U.S.C. §1344). Section 10 of the Rivers and Harbors Act of 1899 requires a permit for construction of structures on or affecting navigable waters of the U.S. For the permit to be issued, the action must not obstruct or alter navigable waters, present a significant adverse effect on the aquatic environment, or result in violations of water quality criteria. Rivers and Harbors Act requirements are addressed by Clean Water Act regulations. Section 404 of the CWA prohibits discharge of dredged or fill materials into navigable waters of the U.S., including wetlands, without a permit. Under CERCLA, as amended by SARA, remedial activities on a federal Superfund site must comply with the substantive requirements of federal and state laws, regulations, and standards, although actual permits do not need to be obtained or filed. For wetlands, these would include the provisions of the CWA (Section 404). Section 404 prescribes avoidable impacts on aquatic environments and prohibits significant adverse impacts to the aquatic environment. Wetland replication (on a no-net-loss basis) or restoration would be required as mitigation under these regulations if impacts are unavoidable.

If there is a practicable alternative to the discharge which would have a less adverse impact on the aquatic ecosystem it should be implemented, so long as the alternative does not have other significant adverse environmental consequences. Appropriate and practicable steps must be taken

which will minimize the potential adverse impacts of the discharge of the dredged materials on the aquatic ecosystem, pursuant to 40 CFR §230.10(a). These guidelines, contained at 40 CFR Part 230 and developed under CWA Sections 404(b)(1) and 501(a), delineate procedures to evaluate the potential impacts of fill material on aquatic ecosystems. These procedures are followed to the extent that a remedial alternative has a potential to adversely affect a river, pond, or wetland on the Site, and are applicable for the Site.

2.3.2.2 Statement of Procedures on Floodplain Management and Wetland Protection. EPA policy for carrying out the provisions of Executive Orders 11988 (Floodplain Management) and 11990 (Protection of Wetlands) are set forth in 40 CFR Part 6, Appendix A. These policies are discussed below.

- **Floodplain Management.** Executive Order 11988 directs federal agencies to avoid long- and short-term adverse impacts associated with occupancy and modification of flood plains. Agencies responsible for providing federal assistance for construction and improvements and for conducting programs affecting land use must take actions to accomplish the following:

  - Reduce risk of flood loss
  - Minimize the impacts of floods on human safety, health and welfare
  - Restore and preserve the natural and beneficial values served by flood plains

  Most of the requirements associated with the order are set forth in the Floodplain Management Guideline, published February 10, 1978, by the Water Resource Council to aid federal agencies in complying with the order. These guidelines include alternative evaluation, impact assessment and mitigation, and public involvement that are already incorporated into the FS process. The only additional substantive requirement contained within these guidelines is that certain projects or portions may be designated as a critical action, which is any activity for which even a slight chance of flooding would be too great. In the case of critical actions, the area requiring consideration is expanded from the 100-year to the 500-year floodplain. EPA indicated in the CERCLA/SARA Environmental Review Manual (January 1988) that all CERCLA/SARA actions are to be considered critical actions and, therefore, the 500-year floodplain is considered potentially applicable.

The 100-year flood zone designated by the Federal Emergency Management Agency, as applied to the site map, is shown on Figure 2-2.

Floodplain management guidelines are considered applicable for those portions of the Site that are in the 100-year floodplain.

- **Protection of Wetlands.** Executive Order 11990 directs federal agencies to take actions to minimize the destruction, loss, or degradation of wetlands. To preserve and enhance the natural and beneficial values of remediation, potential wetlands in the area must be evaluated. Wetland protection requirements include assessing the impacts of any Proposed actions on the wetlands, evaluating alternatives and their potential effects on the wetlands, and identifying mitigative measures to minimize potential harm to the wetlands. These requirements are included within the FS process and therefore do not result in any additional requirements.

  Wetlands are defined as "areas that are inundated or saturated by surface or groundwater at a frequency and duration sufficient to support, and under normal circumstances do support, a prevalence of vegetation typically adapted for life in saturated soil conditions. Wetlands generally include swamps, marshes, bogs, and similar areas." (33 CFR §323.2(c)). As portions of the Site contain wetlands, protection of wetlands requirements are applicable.

2.3.2.3 Fish and Wildlife Coordination Act (16 U.S.C. §661 et seq.). The Fish and Wildlife Coordination Act (FWCA) requires that agencies be consulted and their recommendations be given "full consideration" taken to protect fish and wildlife that may be impacted by diversion, channeling, or other activities that modify a river or stream (16 U.S.C. §662). Specifically, the FWCA, along with the Conservation Act and other advisories, requires federal agencies issuing a permit to modify any off-site body of water to consult with federal and state wildlife agencies to ensure that resources are appropriately protected and that measures are developed to prevent, mitigate, or compensate for losses to fish and wildlife. Consultation and coordination with a number of state and federal agencies would be necessary for those alternatives which may impact area water bodies to prevent, mitigate, or compensate for project-related losses of fish or wildlife. In Rhode Island those agencies may include the Fish and Wildlife Service (FWS), and RIDEM, particularly the Division of Fish and Wildlife and the Office of Water Resources.

Throughout the identification, screening, and evaluation of alternatives, the impacts on fish, wildlife, and their habitat are evaluated and mitigation measures that would be employed are discussed. The FWS has been involved, through the Superfund Environmental Assessment Team (SEAT), throughout the entire RI/FS process at the Site.

2.3.2.4 Rhode Island Endangered Species Act. The endangered species act requires actions to be taken that will conserve identified local endangered or threatened species of fish, wildlife, and plants and their critical habitat. Actions must be taken to ensure that the continued existence of endangered or threatened species is not jeopardized, or critical habitat adversely modified or destroyed. Rare plant species known to occur within the Site include a species of state interest, tickseed sunflower, and a species of state concern, bloodroot. A probable sighting of an avian species of state concern, red-bellied woodpecker, also occurred within the Site. The requirements of these rules are considered applicable.

2.3.2.5 Federal Archaeological and Historical Preservation Act (16 U.S.C. §469-469c-1); Federal Historic Sites Building and Antiquities Act (16 U.S.C. §461 to 467); National Historic Preservation Act of 1966, Pub. I., No. 89-665, 80 State. 915 (codified as amended in scattered sections of U.S.C.). Several statutes govern the preservation of historic, scientific and archaeological sites. EPA policy in complying with such statues is presented in the National Environmental Policy Act, Subpart C.

Under the Archaeological and Historical Preservation Act (AHPA) of 1974, the Department of the Interior is authorized to undertake data recovery and preservation if an EPA activity may cause irreparable losses or destruction of scientific, prehistoric, or archaeological data. The AHPA also established procedures for preservation of historic and archaeological data that might be destroyed through alteration of terrain as a result of a federal construction project or a federally licensed activity or program (16 U.S.C. §469).

Under the Historic Sites Act of 1935, certain areas are designated as national natural landmarks by the Secretary of the Interior.

Under the National Historical Preservation Act (NHPA) of 1966 and Executive Order 11593, 30 CFR 800, EPA must consider the impact of actions on property that is listed or eligible for listing on the National Register of Historic Places. The NHPA also requires that for any alteration of terrain that may cause irreparable harm, loss, or destruction of significant artifacts or prehistorical, historical, or archaeological data, the project proponent is required to recover and preserve the artifacts and/or data.

2.3.2.6 Resource Conservation and Recovery Act, Location Standards. RCRA details several limitations on where on-site hazardous waste treatment, storage, or disposal may occur (40 CFR §264.18). Specifically, RCRA prohibits the placement of new treatment, storage, or disposal facilities within 61 meters of a Holocene fault (40 CFR 264.18(a)) or the placement of hazardous wastes in salt domes, salt bed formations, and underground mines or caves (264.18(c)). Because no such faults have been identified within 61 meters of the Rose Hill Landfill Site and because none of the formations are present in this area, these requirements are not considered to be potential ARAR for the Rose Hill Site.

In addition, RCRA requires that any facility located within a 100-year floodplain be designed, constructed, operated, and maintained to avoid washout (40 CFR 264.18(b)). Portions of the Rose Hill Landfill Site are in the 100-year floodplain. As the site is not a RCRA-regulated unit, the floodplain requirement is not applicable. However, because of the potential for release of RCRA-toxic hazardous substances due to flooding, the floodplain requirements are considered to be relevant and appropriate to the Solid Waste Area.

The floodplain requirements are potentially applicable to the design, construction, operation and maintenance of any new RCRA treatment, storage, or disposal facility that may be constructed or operated within 100 feet of the 100-year floodplain. Any facility built on-site to treat, store, or

dispose of material determined to be a RCRA-regulated waste would need to comply with substantive RCRA location standards.

2.3.2.7 Rhode Island Rules and Regulations Governing the Enforcement of the Freshwater Wetlands Act (12-100-003). These rules and regulations, most recently amended April 23, 1998, are intended to "preserve, protect, and/or restore the purity and integrity of all freshwater wetlands of the State of Rhode Island so that the freshwater wetlands shall be available for all beneficial uses and thus protect the health, welfare, and general well being of the general populace and the environment." Wetland functions and values requiring protection include, but are not limited to, the following:

1) Protection of life and/or property from flooding or flood flows by retaining, storing, metering, or slowing flood waters from storm events;

2) Providing and maintaining surface and/or groundwater supplies by acting as a recharge or discharge area;

3) Providing and maintaining valuable wildlife habitats;

4) Providing and maintaining high value recreation areas; and

5) Protecting and maintaining water quality.

These rules apply to any remedial action that would impact surface water bodies of the site. Surface water bodies include streams, ponds, wetlands and wetland buffer zones.

2.3.2.8 Rhode Island Act Relating to Historic Cemetaries. This act describes provisions for altering land within 25 feet of historical human cemetaries. Any action that has the potential for

impacting within 25 feet of a cemetery must undergo approval and scrutiny by the town offices, the Rhode Island Historical Preservation Commission and the Rhode Island Cemetaries Commission.

The Rose Hill Regional Landfill site has a historical cemetery near the Solid Waste Area which may be affected during remedial action implementation. Refer to Figure 2-2 for the location of this cemetery (Lot 35).

2.3.3 Action-Specific ARARs

Action-specific ARARs focus on remedial activities occurring within the Site under investigation. These requirements pertain to technology- or activity-based requirements or limitations, including storage, transportation, and disposal methods of hazardous substances as well as construction of facilities or treatment processes which might be implemented at the Site. Federal and state laws which need to be considered when planning and implementing remedial actions at the Site will continue to be developed throughout the Record of Decision (ROD) process. The following potential action-specific ARARs and TBCs, along with previously noted chemical and location-specific ARARs and TBCs, are revisited during the detailed evaluation of alternatives (Section 4.0).

- Federal RCRA, as amended (42 U.S.C. §6901 *et seq*)
- Federal Clean Air Act (42 U.S.C. §7401 *et seq.*)
- Rhode Island Air Pollution Control Regulations
- Rhode Island Rules and Regulations for Hazardous Waste Management
- Federal Clean Water Act as implemented by Rhode Island Water Quality Regulations and Rhode Island Regulations for the Rhode Island Pollution Discharge Elimination System (RIPDES)
- Rhode Island Underground Storage Facilities Rules
- Rhode Island Rules and Regulations for the Underground Injection Program

- Rhode Island Guidelines for the Management of Investigation-Derived Wastes IDWs)

2.3.3.1 Clean Water Act National Pollutant Discharge Elimination System as implemented by Rhode Island Regulations for the Rhode Island Pollution Discharge Elimination System, Rhode Island Water Quality Regulations (12-190-001). The Federal Water Pollution Control Act as amended by the Clean Water Act (referred to as the Clean Water or CWA) seeks to "restore and maintain the chemical, physical, and biological integrity of the Nation's waters" (40 CFR 101(a)), and authorizes EPA to control the discharge of pollutants into navigable waters. Important components of the CWA are briefly described below.

Industrial dischargers of wastewaters are subject to provisions of federal, state, and/or municipal regulations, under requirements imposed by the Clean Water Act. The CWA controls discharges of effluent from point and non-point sources into the waters of the U.S. There are five types of point source discharges regulated by the CWA: direct discharges, regulated under NPDES; indirect discharges/discharges to a local POTW; sources that have the potential to spill oil or hazardous substances, controlled by SPCC Plans; discharges of dredged or fill material; and sewage from vessels. Many of these requirements are implemented by state regulations. For this site, the following action-specific rules are discussed:

National Pollutant Discharge Elimination System (NPDES). The CWA established the National Pollutant Discharge Elimination System (NPDES) permit program as authorized under CWA (regulated at 40 CFR Part 122). Discharges of wastewater to surface water bodies must comply with NPDES requirements. Designated toxic pollutants are listed in 40 CFR 401.14, "General Provisions for Effluent Guidelines and Standards." Under the CWA Section 402, states may become authorized to administer the federal NPDES program and Rhode Island has such authorization. Toxic pollutants are subject to effluent limitations arising from the application of the best available technology economically achievable for the application class or point source category. Direct discharges triggering NPDES requirements are:

- Point-source discharge of treated wastewater directly into, or in very close proximity to, a surface water body either on or off a site

- Site-specific water runoff channeled directly to a surface water body via a ditch, culvert, storm sewer, or other means

- Unchanneled, non-point source surface water runoff from a site into surface water

NPDES requirements are applicable to remedial alternatives which generate an effluent requiring discharge to any surface water body, including Mitchell Brook and the Saugatucket River. A permit is not required for on-site discharge.

Water Quality Standards. A water quality standard defines the water quality goals of a water body, or portion thereof, by designating the use or uses to be made of the water and by setting criteria necessary to protect the uses. Water quality standards are intended to protect public health or welfare, enhance the quality of water. Water quality standards, whenever attainable, provide water quality for the protection and propagation of fish, shellfish and wildlife and for recreation in and on the water and take into consideration their use and value of public water supplies, propagation of fish, shellfish, and wildlife, recreation in and on the water and agricultural, industrial, and other purposes including navigation. Such standards serve the dual purposes of establishing the water quality goals for a specific water body and serve as the regulatory basis for the establishment of water-quality-based-treatment controls and strategies beyond the technology-based levels of treatment required by Clean Water Act.

These rules are applicable to any action that discharges water to a site surface water body. The Saugatucket River watershed is designated as Class B.

2.3.3.2 RCRA Subtitle C/HSWA and Rhode Island Rules and Regulations for Hazardous Waste Management. RCRA regulations (40 CFR Parts 260 through 280), set forth under Subtitle C of the Solid Waste Disposal Act, pertain to the overall management of hazardous wastes. RCRA sets forth criteria for identifying hazardous substances and lists those under its jurisdiction. It also specifies technical standards and administrative requirements that must be met by hazardous waste generators, transporters, and owners and operators of hazardous waste treatment, storage, disposal and recycling facilities. The Hazardous and Solid Waste Amendments (HSWA) of 1984 extended EPA's authority to remedy problems with any environmental media resulting from past waste management activities at RCRA facilities.

The federal role in RCRA is to establish the overall regulatory direction, by providing minimum standards for protecting human health and the environment, and to provide technical assistance to the states. Subtitle C of RCRA pertains to overall management of hazardous wastes from generation through ultimate disposal. States are authorized by the EPA on a state-by-state basis to administer Subtitle C. Rhode Island's base RCRA program was authorized by EPA in January 1986. In March 1990, the requirements of non-HSWA Clusters I and II were authorized. Non-HSWA Cluster III was authorized in May 1992, but the state does not have authorization for mixed waste, corrective action, or the Toxicity Characteristic rule. Those programs are administered by EPA's Region I office in Boston, MA. In December 1992, the state was authorized for requirements from non-HSWA Clusters III and IV. The statutory authority for the state program is Title 23 of the General Laws of Rhode Island, Chapter 19.1.

An important step in determining ARARs or TBC criteria is determining the RCRA status of a disposal area (Subtitle C, Interim Subtitle C, or Subtitle D). In general, RCRA Subtitle C is applicable if the waste disposed is a listed or characteristic waste under RCRA and was disposed of after November 19, 1980 or the response action constitutes treatment, storage, or disposal, as defined by RCRA (EPA, 1991b).

Analysis of the waste adhesive disposed in the Solid Waste Area revealed trichloroethylene at 29 parts per million (ppm), toluene at 0.4 ppm, and tetrachloroethylene at 0.004 ppm (RIDEM, 1979). Based upon the analysis and regulations in effect at that time, the waste was deemed to be non-hazardous. Thus, RCRA Subtitle C (hazardous waste) rules are not applicable. Since 1979, the regulatory criteria for determination of whether a waste is hazardous or not has changed. Current regulations specify that concentrations of TCE in waste above 0.5 ppm Maximum Concentration of Contaminants for the Toxicity Characteristic, established in 40 CFR §261.24, characterize the waste as hazardous (55 FR 11862, March 29, 1990, as amended at 55 FR 22684, June 1, 1990; 55 FR 26987, June 29, 1990). Toluene, TCE, and tetrachloroethylene are also listed in the 40 CFR Part 261, Appendix VIII list of hazardous constituents for which wastes are listed as hazardous waste. Laminating adhesive is known to have been disposed of in the Solid Waste Area between 1971 and 1979 (Peacedale Processing, 1981). Waste was deposited in the Solid Waste Area until closure in 1981, though it can not be confirmed that hazardous waste was disposed of in the landfill after November 19, 1980. Based on this assessment, RCRA Subtitle C (hazardous waste) rules are not applicable but are deemed to be relevant and appropriate to the Solid Waste Area.

Disposal of bulky wastes, such as appliances, began in the Bulky Waste Area in 1978. Although solid waste was also reportedly disposed of in this area during 1982 and 1983, disposal of laminating adhesive reportedly ceased at the Site in 1979. It is, therefore, felt that laminating adhesives were not disposed of in this area. RCRA Subtitle C is not applicable or relevant and appropriate to the Bulky Waste Area.

Section 300.415(b) of the NCP states that when off-site action is taken in connection with a removal action, the facility used for the off-site management must be in compliance with Subtitle C of RCRA. Procedures for implementing these provisions are established in EPA's "Procedures for Planning and Implementing CERCLA Offsite Response Actions" (May 6, 1985), in SARA Section 121 (CERCLA Section 121(a)-(d)), and supported by EPA RI/FS Guidance documents. Specific limitations state that:

- All hazardous substances transported off of the Site must be taken to a hazardous waste management facility holding either an applicable RCRA permit or an applicable interim status permit;

- The off-site storage, treatment, and disposal of hazardous substances must be cost-effective in comparison with other protective response actions; and

- A RCRA compliance inspection must be performed at any hazardous waste management facility before it can receive hazardous substances from a CERCLA-funded response. The inspection must demonstrate that the facility has no significant violations.

RCRA generator requirements of 40 CFR Part 262 are applicable if, during the course of implementing remedial actions, any RCRA-designated hazardous waste is distributed off of the Site. When the hazardous waste is distributed or moved, the operator is then considered a generator of hazardous waste.

RCRA transportation requirements of 40 CFR Part 263 are applicable to all remedial actions that include the transport of RCRA-designated hazardous waste off of the Site.

The following discussions present additional RCRA requirements that may potentially be ARARs for certain remedial actions.

Toxicity Characteristic (40 CFR Part 261.24). Criteria for identifying hazardous substances includes measures of toxicity, as defined by toxicity characteristic. Table 1 of 40 CFR §261.24 lists 40 contaminants and corresponding regulatory levels based on health-based concentration limits and on a dilution/attenuation factor based on a subsurface fate and transport model. Wastes identified as hazardous under the toxicity characteristic are also hazardous substances under Section 101(14) of CERCLA, as amended. Subtitle C of RCRA will apply to subsurface materials withdrawn from the Site if the material is a characteristic waste and the site activity constitutes treatment, storage, or disposal as defined by RCRA. Once the characteristic is removed, waste is no longer a characteristic RCRA waste.

Hazardous Waste Storage Tanks (40 CFR 264, Subpart J). Specifications and standards for all tank systems, including ancillary equipment and piping, are provided. Wastes meeting the definition of hazardous must meet these tank rules. Secondary containment must be provided for all new tanks. The tank system must be capable of detecting and collecting releases and accumulated liquids, and must be designed, installed, and operated to prevent releases to the environment. Aboveground tank systems must be inspected each operating day for leaks. Underground components must also comply with underground storage tank rules. Rhode Island Rules and Regulations for Hazardous Waste Management reference the federal requirements.

Underground Storage Tanks and Rhode Island Underground Storage Facilities Rules. Owners and operators of underground storage tanks (USTs) containing petroleum or hazardous materials must install leak detection report leaks from their tanks and piping, and must undertake corrective action to address such releases. Rhode Island's amended regulations became effective July 21, 1992. Effective March 5, 1993, the EPA granted final approval to Rhode Island's UST program (12-190-017). All new USTs must provide for secondary containment of the tank and associated piping and must be constructed in accordance with specific codes.

2.3.3.3 Federal Clean Air Act and Rhode Island Air Pollution Control Regulations. The Clean Air Act, enacted in 1970 and amended in 1977, is the federal statute mandating the prevention and control of air pollution from both stationary and mobile sources. The Clean Air Act (CAA) requires EPA to establish three types of national standards: NAAQS; New Source Performance Standards; and National Emission Standards for Hazardous Air Pollutants. The purpose of the CAA program, which is usually administered by the state, is to obtain and maintain acceptable levels of ambient air quality. Remedial alternatives which may have an adverse impact on air quality (for example, fugitive dust emissions generated during excavation activities or emissions generated from active soil venting) are subject to restrictions under this act.

The CAA mandates that states develop State Implementation Plans (SIPs) which regulate emissions from stationary and mobile sources to ensure attainment and maintenance of the NAAQS. The

NAAQS establish the allowable ambient concentrations for six priority pollutants (40 CFR Part 50): total suspended particulates; sulfur dioxide; nitrogen oxide; carbon monoxide; ozone; and lead. The NAAQS apply to pollutant concentrations in ambient air, and are not applicable to individual emission sources. SIP regulations are contained in 40 CFR Parts 51 and 52. The State of Rhode Island implements the air pollution regulations: Air Pollution Control Regulation No. 5: Fugitive Dust; Air Pollution Control Regulation No. 7: Emission of Air Contaminants Detrimental to Person or Property; Air Pollution Control Regulation No. 9: Approval to Construct, Install, Modify, or Operate; Air Pollution Control Regulation No. 16: Operation of Air Pollution Control Systems; Air Pollution Control Regulation No. 17: Odors; and Air Pollution Control Regulation No. 22: Air Toxics. The requirements of the state regulations, which are incorporated into the SIP, are designed to achieve the NAAQS standards overall by imposing emission standards and requirements on sources. Air Pollution Control Regulation No. 9, Rules for Approval to Construct, Install, or Modify constitutes Rhode Island's air source permit requirements. These rules define and regulate major and minor sources. Both major and minor sources require source approval and may require a study of health risks. Minor stationary sources are required to apply Best Available Control Technology (BACT) if there is a net increase in any pollutant it would have the potential to emit. An existing landfill closed without the use of air pollution control technologies (i.e. an enclosed flare) for LFG control is not considered a minor source since there is not an increase in pollutant emissions beyond what was emitted prior to closure. Addition of an air pollution control technology automatically requires approval as a minor source, but does not require BACT to be used if there is no net increase in any regulated pollutant (i.e. methane). Major sources of volatile organic compounds (VOCs) are required to apply Lowest Achievable Emission Rate (LAER) and obtain offsets.

There are regulations under the CAA which govern airborne emissions from new and existing sources. These regulations require new stationary sources and modifications to existing sources to undergo the New Source Review (NSR) permitting process before they can operate. The purpose of the NSR is to ensure that sources meet the applicable air quality standards for the area in which they are located. The applicable air quality standards are determined, in part, by the NAAQS set by the EPA. Two aspects of the NAAQS affect the stringency of the NSR permitting process. First,

it sets overall regional ambient air loadings from the criteria pollutants. Using these levels, most areas of the country are classified as in "attainment" or "nonattainment" for each criteria pollutant. Nonattainment areas are further categorized by their degree of nonattainment: marginal, moderate, serious, severe, and extreme. The greater the degree of nonattainment, the more stringent the regulations are in bringing that area to attainment and the lower the acceptable emission levels of that particular pollutants will be.

Second, the NAAQS also set emission levels for individual sources. These levels are expressed in terms of loadings (i.e. tons emitted per year), and are dependent upon location (attainment or nonattainment areas) and the type of source (new or existing and its quantity of emissions). New sources or modifications to existing sources that exceed these NAAQS emission levels are classified as "major" sources while those that do not are classified as "minor" sources.

Sources in attainment areas are required to undergo Prevention of Significant Deterioration (PSD) permitting, while sources in nonattainment areas are required to undergo Nonattainment Area (NAA) permitting. The basic difference between these NSR permitting processes is that the requirements are more stringent for sources in nonattainment areas than in attainment areas. Prevention of significant deterioration (PSD) requires BACT in attainment areas. Rhode Island's permit program is administered by RIDEM. The permit program regulates emissions released to the air from new and modified stationary sources. Two types of permits are issued by the NSR section: (1) permits to construct, and (2) permits to operate. Permits to construct are required prior to the commencement of construction, installation, or modification for those sources which have the potential to emit greater than or equal to 15 tons/year of any air pollutant. Permits to operate are required prior to the commencement of operations for those sources which have the potential to emit greater than or equal to 5 tons/year of any air pollutant. The regulation states that a permit application must be submitted to RIDEM and that they will review the application and determine if a permit is required. However, the requirement for permits may be unnecessary in accordance with CERCLA Section 121(e), 40 CFR Part 300.400(e). This section exempts response actions from obtaining such permits when the substantive requirements of the ARARs have been met.

There are statutory provisions concerning the construction and modification of stationary sources in areas where air quality is better than that required by NAAQS. These provisions are intended to prevent significant air quality degradation in these areas. The PSD regulations establish strict preconstruction guidelines and monitoring requirements. For construction or modification of sources in NAAs, where one or more NAAQS are not met, there are similar strict regulations for preconstruction review, emission control systems and monitoring. Facilities must comply with PSD regulations if they are located in an area of designated attainment for at least one criteria pollutant (i.e., sulfur dioxide, particulate matter, carbon monoxide, ozone, nitrogen oxide, lead) and they fulfill one of these conditions:

- A stationary source specifically listed in 40 CFR Part 52.21(a) which emits, or has the potential to emit, 100 tons/year or more of any pollutant subject to regulation under the CAA
- A stationary source which emits, or has the potential to emit, 250 tons/year or more of any pollutant subject to regulation under the CAA.

The NAAQS regulations apply to major sources constructed in areas of non-attainment for one or more criteria air pollutants that emit, or have the potential to emit, 100 tons/year of a pollutant subject to regulation under the CAA.

Federal New Source Performance Standards (NSPS) were developed for over 50 specific industrial categories to provide a ceiling for emissions from new sources. They are based on application of the best available technology to reduce emissions. These standards, which include requirements for notification, record keeping, performance tests, maintenance, and monitoring, are contained in 40 CFR Part 60.

National Emission Standards for Hazardous Air Pollutants (NESHAPs) were established to control air pollutants for which no ambient air quality standards are applicable and which may result in an increase in mortality or serious irreversible illness. Standards in 40 CFR Part 61 define emission

limits, monitoring requirements, restrictions on material use, worker practice standards, and reporting requirements for hazardous air pollutants.

On March 12, 1996, the EPA issued new regulations titled "Standards of Performance for Stationary Sources and Guidelines for Control of Existing Sources: Municipal Solid Waste Landfills" (Federal Register, 1996). The regulations provide NSPS for new landfills and Emission Guidelines (EG) for existing landfills. The Rose Hill Regional Landfill is an existing landfill and therefore subject to the EG. The EG require the collection and control of landfill gas at existing landfills which meet all of the following criteria:

Age: Landfills which accepted waste at any time since November 8, 1987, or have additional design capacity available for future waste.

Capacity: Landfills with a design capacity greater than 2.5 million megagrams (Mg) or 2.5 million m^3. Landfill design capacities may be calculated in either Mg or m^3 for comparison with the exemption limits.

Emission rate: Landfills which exceed an annual non-methane organic compound (NMOC) emission rate of 50 Mg/day. The NMOC emission rate can be calculated using an EPA model known as a Tier 1 analysis, or by EPA-defined physical testing and analysis procedures known as Tier 2 or Tier 3 analyses.

Landfills that meet these criteria are required to install: (1) a "well-designed and well-operated" landfill gas collection system, and (2) a control device capable of reducing NMOC in the collected landfill gas by 98 weight percent. The Rose Hill Regional Landfill ceased active landfill operations in 1983, and closed with less than 0.9 million m^3 of solid waste. Therefore, the Rose Hill Regional Landfill does not meet the above criteria for applicability. However, this regulation incorporates good engineering practices for operations of LFG control systems. For this reason, this regulation is considered relevant and appropriate at the Site.

Ambient air monitoring methods, detailing reference and equivalent methods approved by EPA for monitoring ambient air pollutants, are contained in 40 CFR Part 53.

2.3.3.4 Rhode Island Rules and Regulations for the Underground Injection Program (12-190-015). The purpose of the regulations is to preserve the quality of the groundwater of Rhode Island and protect it from contamination by discharge from injection wells and other subsurface waste disposal. These regulations define requirements for construction, maintenance and operation of injection wells. They also establish prohibitions for groundwater injection. These rules are applicable to any site activity that involves injection of waste materials or treated groundwater.

2.3.3.5 Rhode Island Guidelines For The Management Of Investigation-Derived Wastes. This RIDEM Policy Memo, dated April 18, 1995 and numbered 95-01, specifies procedures to be used to classify and handle drummed cuttings, disposable clothing and other refuse, purge waters, decontamination water, and other investigation-derived wastes. Under this policy, wastes generated at the site would be regulated by Rhode Island Rules and Regulations for Solid Waste Management Facilities, Rhode Island Rules and Regulations for Hazardous Waste Management, and by Rhode Island Policy *Guidelines on the Management of Investigation-Derived Waste*. This policy requires sampling and analysis for each expected soil contaminant. Soil action levels are defined as background concentrations. Soils demonstrated to be below the action levels may be disposed of on the Site. Soils found to contain contaminants at concentrations above action levels may be treated and disposed of on the Site or must be contained, shipped off the Site and managed in a pre-approved, environmentally sound manner.

2.4 MEDIA POTENTIALLY REQUIRING REMEDIATION

To develop alternatives, it is first necessary to determine areas or volumes of media to which general response actions might be applied. To ensure that alternatives can be assembled to reduce exposure(s) to protective levels, volume(s) or area(s) should be reviewed with respect to the RAOs. Media potentially requiring remediation include groundwater, surface water and sediments, air and soil gas. Estimated areas and volumes of these media are listed in Table 2-13 and/or defined in the following subsections.

2.4.1 Groundwater

Figure 2-2 shows the approximate areal extent of groundwater PRG exceedances. As stated in Section 1.0, groundwater remediation will be reviewed under another operable unit. However, source control is included in this FS and the following sections describe disposal area volumes. Properties affected by groundwater PRG exceedances are also described.

2.4.1.1 Solid Waste Area. The surficial extent of the Solid Waste Area is approximately 22.9 acres. Figure 2-2 shows the limit of waste placement. The volume of waste in the solid waste landfill is estimated at 703,000 yd^3, which amounts to 878,750 yd^3 when daily and final cover are included. The surface area of the Solid Waste Area was estimated using current topographic maps (M&E, 1994) and limits of fill as established in a solid waste disposal planning document prepared for the town of South Kingstown in 1977 and entitled Phase II Site Evaluation and Operational Plan for Municipal Sanitary Landfill - Rose Hill Road (C.E. Maguire, 1977b). This document will be referred to as the "Plan" throughout this section. The volume of waste in the Solid Waste Area was estimated from information obtained in the Plan, even though most of the design information presented was for proposed rather than actual conditions. The similarity of final grading elevations proposed in the Plan with the current site topography suggests that projected volumes provide a good approximation of actual waste loading.

The basis of the Plan was a field investigation performed in 1976 and 1977. Prior to 1976, there was no record keeping of the volume of refuse disposed of at the landfill. Field work undertaken by C.E. McGuire to prepare the Plan included advancement of five borings within the fill limits to establish the depth to bottom of fill. Several cross sections were prepared based on these borings. Using this information, M&E estimated fill contours for the waste in place prior to 1976. This waste volume was estimated to be 379,000 yd^3, assuming a waste-to-cover ratio of 4:1 (Robinson, 1986; Bagchi, 1990). Cover includes soil placed over waste daily for litter, odor, and vector control as well as soil placed for final closure.

The Plan estimated the filling rate based on two car-count surveys and projected the rate of increase based on population growth. Using this method, the report estimated the annual refuse disposal rate in 1977 to be 20,400 tons. This estimate excluded bulky waste since bulky wastes were to be diverted to the Bulky Waste Area, which was due to begin operation in 1978; the annual disposal rate of bulky waste in 1977 was approximately 3,600 tons. Together, refuse and bulky waste disposal in 1977 was estimated at 24,000 tons, an annual disposal rate that was assumed to be representative of waste loadings in 1976 and 1977. The 24,000-ton mass is equal to 60,000 yd^3 assuming an in-place unit density of 800 pounds per cubic yard (lbs/yd^3) (Robinson, 1986). Based on this information it is estimated that 120,000 yd^3 of waste was deposited into the Solid Waste Area from 1976 to 1977.

The 20,400 tons/year loading rate projected in the Plan from 1978 to 1982 was assumed to be accurate since the landfill reached capacity in the projected year (1982) and final contours compared closely with final grading plans. Assuming an in-place unit density of 800 lbs/yd^3, the annual volume of waste disposed of in the Solid Waste Area from 1978 to 1982 was 51,000 yd^3 for a total of 204,000 yd^3 over the 4-year period.

Approximately 13,365 yd^3 of solid waste (total fill and cover volume 16,700 yd^3) are located beneath the water table in the northwestern corner of the Solid Waste Area. This estimate is based on fill depths and groundwater observations made at several borings during the field investigation conducted for the Plan. The affected surface area (in the Plan) is estimated at 2.5 acres.

2.4.1.2 Bulky Waste Area. The area of waste placement in the Bulky Waste Area is approximately 7.4 acres, as shown in Figure 2-2. The volume of waste in the Bulky Waste Area is estimated to be 104,320 yd^3, which amounts to 130,400 yd^3 when fill and cover material are included. This estimate is based on information obtained from maps of existing topography (M&E, 1994) and excavation plans (C.E. Maguire, 1977b). The surface area of the Bulky Waste Area was determined using current topographic maps (M&E, 1994) and limits of fill projected in the Plan.

The Plan estimated that 3,000 tons/year of nonrecyclable bulky waste would be generated by the contributing municipalities. Assuming an in-place density of 800 lbs/yd^3, which was the density assumed in the Plan, an estimated 37,500 yd^3 of bulky waste was disposed of in the bulky waste landfill over the five-year filling period. Historical records show that the Bulky Waste Area also received municipal waste from May 1982 to October 1983. Assuming an annual disposal rate of 20,400 tons (C.E. Maguire, 1977b) and an in-place density of 800 lbs/yd^3, approximately 76,500 yd^3 of municipal solid waste was disposed of in the Bulky Waste Area. Based on these projected loading rates, approximately 114,000 yd^3 of waste is estimated to have been disposed of in the Bulky Waste Area. This number compares reasonably well to the 104,320 yd^3 volume estimated from topographic plans.

Based on available information, it is unclear if waste was placed beneath the water table in the Bulky Waste Area.

2.4.1.3 Sewage Sludge Area. The surface area of the Sewage Sludge Area is approximately 8.9 acres, as shown in Figure 2-2. The approximated surface area is based on filling limits estimated in the remedial investigation (M&E, 1994). The volume of waste disposed of in the Sewage Sludge Area cannot be adequately estimated. One exploratory boring conducted during the remedial investigation in the center of the waste area (BH-01) showed the sludge depth to be 6 feet.

Based on available information, it is unclear if waste was placed beneath the water table in the Sewage Sludge Area.

2.4.1.4 Locations Contaminated by Waste Areas. Property lots in the vicinity of the Site are presented in Figure 2-2. Table 2-13 lists the plat and lot numbers impacted by groundwater exceeding PRGs. Manganese exceeded its PRG in some residential wells. However, it was agreed to by EPA and RIDEM (M&E, 1996a) that manganese exceedances are unrelated to site contamination and therefore have not been included in Figure 2-2.

2.4.2 Surface Water and Sediments

Surface water and sediments in Mitchell Brook and the Saugatucket River have been impacted by:

- groundwater passing through waste and recharging the streams
- leachate breakouts which runoff into the streams
- leachate entering groundwater which recharges the streams

Groundwater passing through waste has been discussed in Section 2.4.1. Locations of leachate breakouts were identified based upon site reconnaissance and aerial photography and are shown on Figure 2-2. Leachate volumes generated by precipitation infiltration are estimated below.

Current rates of precipitation infiltration into waste and discharge to groundwater were estimated using the Hydrologic Evaluation of Landfill Performance (HELP) model. The HELP model is a two-dimensional hydrologic model of water movement across, into, through, and out of landfills. Climate data from the Providence, Rhode Island area plus site-specific soil data collected during the RI were input into the model. Infiltration rates of water passing through the solid waste, bulky waste, and Sewage Sludge Areas were 15.3, 17.6 and 17.7 inches/year, respectively. This results in average leachate generation rates of 18.1, 6.7 and 5.4 gpm for the three respective waste areas. HELP model results are presented in Appendix C.

2.4.3 Ambient Air

Ambient air impacts from the Solid Waste Area may be reduced through landfill gas control. Landfill gas generation rates for the Solid Waste Area are discussed below.

The rate of gas production in 1997 from the waste disposed of in the Solid Waste Area is estimated at 3.1 X 10^7 ft^3/year (60 ft^3/min). The rate was estimated assuming the annualized fill estimates

presented in Section 2.4.1 averaging 17,400 tons/year (43,400 yd^3/year) and using the Scholl Canyon predictive model (Emcon Associates, 1982).

The generation of landfill gas from refuse is dependent on the composition of the material; age of the refuse; moisture content; pH of the landfill environment; and the availability of nutrients relative to the stoichiometric requirements for microbial respiration. Of these factors, the first three have been found to have the most pronounced effect on the generation rate. In calculating the current gas production rate in the Solid Waste Area, the approximate refuse composition and age were considered; moisture content was also taken into consideration by using a decay rate constant representative of the high moisture climate of southern Rhode Island. The Scholl Canyon model is a single-stage first-order kinetic model that postulates peak landfill gas production at the time of waste placement (or after a brief lag period) followed by an exponential decline as the organic fraction of the landfill refuse decreases. The equation and assumptions used in the model can be referenced in (M&E, 1993a).

The estimated amount of landfill gas generated by the Solid Waste Area may increase if any remedial alternatives require placement of additional waste on the landfill.

2.4.4 Soil Gas

Soil gas impacts from the both the Solid Waste and Bulky Waste Areas may be reduced through landfill gas control. Landfill gas generation rates for the Solid Waste Area are presented in Section 2.4.3 and generation rates for the Bulky Waste Area are discussed below.

The rate of gas production in 1997 from the refuse disposed of in the Bulky Waste Area is estimated to be 4.3×10^6 ft^3/year (8 ft^3/minute). The rate was estimated assuming the annualized fill estimates presented in Section 2.4.1 and using the Scholl Canyon predictive model as described above.

The generation of gases from the bulky waste disposed of in the Bulky Waste Area is expected to be minimal. Because bulky waste is predominantly composed of inorganic materials that are nonbiodegradable, appreciable production of gases from microbial respiration does not occur. Inorganic gases can be produced from moisture coming into contact with the waste material (i.e., hydrogen sulfide from gypsum board); however, overall production of inorganic gases is expected to be minimal in the Bulky Waste Area in comparison with gases produced in the Solid Waste Area.

2.5 IDENTIFICATION AND SCREENING OF TECHNOLOGY TYPES AND PROCESS OPTIONS

A preliminary list of potential remedial technologies has been developed for each of the general response actions listed in Section 2.2. These remedial technologies and associated process options are presented and screened in this subsection. Several factors were used to determine feasibility and, in turn, to screen out those technologies that clearly should not be considered for use at the Site. The factors used in this screening process were based on the current EPA guidance for conducting RI/FSs under CERCLA and included, but were not limited to, the following:

- Effectiveness in handling the estimated areas or volumes of media and in meeting the PRGs
- Potential impacts to human health and the environment during construction and implementation
- Proven effectiveness and reliability with respect to the contaminants and conditions at the Site
- Implementability in terms of both the technical and administrative feasibility
- Relative costs as far as technologies or process options that accomplish the same result

The tables provided in this section are organized by groundwater/leachate remediation technologies and landfill gas remediation technologies. Table 2-14 presents technology and process option

screening for groundwater and leachate and Table 2-15 presents technology and process option screening for landfill gas. Each table presents a brief technology description and the justification for the elimination or further consideration of each technology.

SECTION 3.0
DEVELOPMENT OF REMEDIAL ALTERNATIVES

Remedial technologies not screened from further consideration in Section 2.5 are used as the basis for developing potential site-specific remedial alternatives in this section. Section 3.0 is presented in two subsections. Section 3.1 describes key technical criteria for some of the major technologies and process options. Section 3.2 combines the feasible technologies and process options into comprehensive site remedial alternatives that address the remedial action objectives (RAOs) detailed in Section 2.0.

3.1 TECHNICAL DISCUSSION OF MAJOR REMEDIAL ACTION TECHNOLOGIES AND PROCESS OPTIONS

This section describes key technical criteria for some of the major feasible remedial action technologies and process options in more detail than provided in the limited discussion in Section 2.0. Major remedial technologies and process options detailed in this section are divided into those addressing the media of groundwater (through control of disposal areas) and surface water/sediment (through control of leachate) and those addressing the media of ambient air and soil gas (through control of landfill gas).

Technologies and process options for groundwater and surface water/sediment that require description of key technical criteria include: institutional controls such as access restrictions, and monitoring, source control technologies such as horizontal containment (e.g. caps), a source removal technology for the Bulky Waste Area (landfill mining), groundwater and leachate collection, on-site treatment (physical, chemical), and discharge of treated water.

Technologies and process options for ambient air and soil gas that require description of key technical criteria include the following landfill gas control measures: institutional controls such as access restrictions, monitoring and residential landfill gas (LFG) control contingency, management

of migration barrier technologies such as passive horizontal barriers (e.g. caps), management of migration collection technologies such as active perimeter collection and passive and active internal collection systems, a source removal technology for the Bulky Waste Area (landfill mining), LFG treatment with thermal processes (enclosed flare), and LFG treatment with a physical/chemical process (photocatalytic oxidation).

3.1.1 Institutional Controls: Groundwater and Surface Water/Sediment

Potential remedial actions taken to prevent ingestion of groundwater exceeding preliminary remediation goals (PRGs) include institutional controls such as restrictions on groundwater usage. Monitoring of groundwater and surface water/sediment is a required component to verify the success of the selected alternative.

3.1.1.1 Access Restrictions. Access restrictions would restrict or limit use of the groundwater associated with current or future property lots in the vicinity of the Site and affected residential areas. Access restrictions may consist of physical barriers or restrictive covenants which limit access or land use on affected portions of the Site and affected residential areas. Physical barriers usually consist of fences, gates and signs designed to prohibit site entry.

Restrictive covenants may take the form of property deed restrictions, modifications to local zoning regulations or other changes in local ordinances. These restrictions would minimize the potential for contact with contaminated groundwater. They may also prevent interference with natural groundwater attenuation, which could occur through surface and subsurface development and groundwater use. Furthermore, the intent of these restrictions is to protect the public from exposure to site-related hazards and to protect the integrity of remediation processes or structures.

As shown previously in Figure 2-1 and Table 2-13, groundwater concentrations exceeded PRGs for all of the site disposal areas (Solid Waste, Bulky Waste, and Sewage Sludge) as well as some off-site property lots. Access restrictions in the form of restrictive covenants (e.g. deed restrictions) would

be applied to all affected on-site and off-site property lots to meet the human health RAO for preventing ingestion of site groundwater contaminants in concentrations exceeding the EPA target risk range. As discussed previously in Section 1.0, the type, nature and implementation of deed restrictions may be affected by the proposed site groundwater reclassification.

Since there is not a human health risk from the surface water/sediment pathway, no specific access restrictions are required to prevent contact with site surface water (Mitchell Brook or the Saugatucket River) or sediments. Although there is a risk from the surface water/sediment pathway to ecological receptors, access restrictions (e.g. fencing) are not appropriate to reduce this ecological risk.

3.1.1.2 Monitoring. This section outlines the conceptual scope of groundwater and surface water monitoring. Implementation of a groundwater monitoring program must accomplish three objectives:

- Monitor the migration of the plume
- Monitor success of the remedy
- Monitor water quality in the residential wells

A preliminary rationale for groundwater and surface water monitoring is presented in this section, with additional detail to be provided in Section 4.0.

The groundwater monitoring program is based upon federal and state requirements for waste management facilities. The potentially applicable federal requirements include regulations governing hazardous waste disposal facilities. Federal regulations for hazardous waste facilities, as defined under RCRA Subtitle C, come under 40 CFR 261 through 270. State requirements for groundwater monitoring of hazardous waste disposal facilities are written in the Rhode Island Hazardous Waste Rules and Regulations and are the same as federal requirements under RCRA.

Monitoring the migration of the plume is necessary to track the plume as its size and contaminant levels change over time. Changing site conditions such as future development, future groundwater well use increases or decreases, and migration from any future off-site sources may affect the size, contaminant levels, and migration pathway of the plume.

The list of parameters selected to monitor groundwater quality at the Site includes parameters required under RCRA Subtitle C regulations, CERCLA guidance and all COPCs identified in the RI report (M&E, 1994). Further discussion of specific analyses and monitoring frequency is presented in Section 4.0.

Surface and groundwater monitoring locations were established as required under state and federal regulations. Upgradient and downgradient surface water monitoring locations were established in both Mitchell Brook and the Saugatucket River. Upgradient and downgradient groundwater monitoring locations were selected in the shallow overburden, deep overburden, and bedrock aquifers at locations that will detect the migration of groundwater contamination.

Additional monitoring may also include elements of Monitored Natural Attenuation to aid in determining the effective performance of the remedy chosen. Site characterization information requires an understanding of source mass, groundwater flow, rates of biological and non-biological transformation and an understanding of how all of these factors are likely to vary with time. Guidance on the use of Monitored Natural Attenuation at Superfund sites has been recently developed by the U.S. EPA Office of Solid Waste and Emergency Response (U.S. EPA, 1997). This, along with other recent studies, will be used to define site-specific monitoring necessary to assess and characterize remedy performance and contaminant attenuation. Further discussion regarding additional performance monitoring is presented in Section 4.0.

EPA will review this monitoring program every five years following initial implementation of the chosen remedy as required under 40 CFR 300. At that time, a review of the number, frequency, and

analyses of samples needed to accomplish each objective will be performed. The program may be adjusted to reflect observed patterns, consistencies, or changes in the groundwater quality.

3.1.2 Source Control: Groundwater and Surface Water/Sediment - Horizontal Containment

This section describes the remedial technology, horizontal containment, which would be used for contaminant source control. Capping addresses RAOs by 1) reducing the leaching of contaminants from buried waste or contaminated soils by minimizing water infiltration, and 2) restricting or controlling migration of landfill gas (U.S. EPA, 1991a). Capping will also prevent receptors from coming in direct contact with waste by providing a physical barrier between the waste and potential receptors. The cap would be supplemented by the installation of an 8-foot-high chain-link fence around the Solid Waste and Bulky Waste Areas to protect the caps (complying with RCRA regulations), as well as the posting of signs to indicate appropriate hazards.

Prior to cap installation, grading of the disposal area is required to meet RAOs and comply with ARARs. Regulations governing grading on disposal facilities are designed to ensure positive drainage from the waste area, prevent surface water run-on from upgradient areas, prevent erosion of cover material, prevent downstream flooding or sedimentation of receiving water bodies, and ensure the slope stability of the landfill. Minimum and maximum slope requirements are often stipulated to accomplish these objectives. EPA guidance for hazardous waste landfills (RCRA Subtitle C) specifies a minimum slope of 3 to 5% for the barrier layer and a maximum slope of 33% (U.S. EPA, 1991c). Rhode Island Hazardous Waste Regulations have performance specifications that pertain to grading but do not stipulate specific slope requirements. Applicable regulations also require that measures be taken to prevent run-on, prevent sedimentation, and provide flood control for a 24-hour, 100-year storm event.

Proper grading and erosion control measures will prevent the migration of sediment-borne contamination to receiving water bodies. Drainage controls will minimize surface water run-on and promote runoff, which will minimize infiltration into the waste and leachate generation.

Horizontal containment details specific to each waste area are presented below.

3.1.2.1 Horizontal Containment: Solid Waste Area. Appendix B contains figures presenting existing topography and drainage used as a basis for grading and capping. The limits of waste placement in the Solid Waste Area include approximately 23 acres (C.E. McGuire, 1977b). The area has been filled to a height of 10 to 15 feet above the level of Rose Hill Road. Surface water drains from the northern and central portions of the landfill through a drainage channel running southeasterly along the perimeter of the landfill and eventually discharges to Mitchell Brook (M&E, 1994).

Six settlement platforms were constructed on the Solid Waste Area during the RI. Settlement over a 14-month period ranged from 0.1 to 0.25 feet with an average of 0.17 feet (M&E, 1994). This results in an average annual settlement rate of approximately 2 inches/year. It is unlikely that this rate will increase in the future if site conditions are not significantly altered by remedial actions. Landfills typically experience a total settlement of 10 to 30% of their original thickness and most of this settlement occurs in the first two years. After this period settlement continues at a declining rate (Sowers, 1968; Dodt *et al.*, 1989).

Large scale regrading is not proposed in the Solid Waste Area. The existing topography meets the federal and state standards with the exception of grades below 5% on some areas at the top of the landfill. As ponding has been observed within the limits of waste placement in the southeast corner of the Solid Waste Area (see field verified wetland delineation on Figure 2-1 and Appendix B), filling or construction of drainage trenches may be necessary in this area to prevent surface water accumulation. The wetland area is small (approximately 4,500 ft^2), isolated, and of limited ecological value. Continuation of the slow and evenly distributed subsidence observed should not lead to drainage problems in the future. However, remedial actions that would lower the water table by pumping or infiltration reduction (capping) may increase the settlement rate.

Construction measures are proposed to reduce the erosion observed along the eastern face of the landfill and the drainage channel. Slope distances of 200 feet at grades of 12% occur along this face. Drainage channels will be constructed running northerly along the top of the eastern slope to intercept runoff from the top of the landfill. Where the existing drainage swale running easterly along the northern face of the landfill is affected by grading or capping, the channel would be re-installed in its current location. Both drainage channels will discharge to detention basins on the eastern face of the landfill which in turn discharge to Mitchell Brook. These stormwater detention basins are sized approximately to accommodate post-remediation surface water runoff from a 24-hour storm at a 25-year recurrence interval, as required by state rules (RIDEM, 1989). Appendix B presents approximate basin sizing calculations.

The Solid Waste Area is currently covered with a silty sand material (USC classification SM) with a laboratory tested permeability of 6×10^{-5} cm/sec. The thickness of the existing cover ranges from 0 to 1.5 feet (M&E, 1994).

Figure 3-1 illustrates the proposed cap design utilized for cost purposes. Substitutions may be made to component materials based on availability during the design/construction phase. However, state and federal standards must be met at all times. The proposed protective cap consists of the following components: vegetation/topsoil, cover layer, drainage layer, 60 mil. linear low density polyethylene (LLDPE) geomembrane, low permeability soil layer, and a protective layer above the existing silty sand cover. The design is based on the assumption of active landfill gas collection for this area. The area will be stripped of the existing grass, graded and compacted to prepare a suitable base for the new cap. Installation of the capping system in the Solid Waste Area will require approximately 18,500 yd^3 of top soil, 74,000 yd^3 of granular fill, 37,000 yd^3 of silt/sand, 111,000 yd^2 of drainage composite, and 1.0 million ft^2 of geomembrane. The capped area will be revegetated following cap installation. Design considerations should include the possible reduction in the area requiring capping through cut and fill methods. Cost reductions achieved through this process must be weighed against costs incurred to reduce unacceptable nuisance odors which may be created during the implementation of this action.

3.1.2.2 Horizontal Containment: Bulky Waste Area. Appendix B contains figures presenting existing topography and drainage used as a basis for grading and capping. The limits of waste placement in the Bulky Waste Area include an area of approximately 7.4 acres. The area appears to have been filled 5 to 10 feet above original grade. Flow from the eastern portion of the landfill flows down the eastern slope toward the Saugatucket River. Flow from the western portion of the landfill flows westerly into Mitchell Brook (M&E, 1994). Drainage swales were observed on the eastern face of the landfill parallel to the slope (M&E, 1994).

Three settlement platforms were constructed on the Bulky Waste Area during the RI. Settlement over a 14-month period ranged from 0.09 to 0.13 feet yielding an average annual settlement rate of approximately 1 inch/year.

Minor filling may be necessary on top of the Bulky Waste Area to bring the slope to a minimum of 5%. Continuation of slow and evenly distributed subsidence such as that has been observed should not lead to ponding in the future. However, remedial actions that would lower the water table in the area by pumping or reducing infiltration would cause higher settlement rates.

The current drainage system conducts surface water runoff through reinforced swales down the western face of the landfill which discharge to the Saugatucket River. Since grading would impact this channel, the drainage system will be reconstructed. A small stormwater detention basin will be added to the area to accommodate post-remediation surface water runoff from a 24-hour storm at a 25-year recurrence interval. Appendix B presents approximate basin sizing calculations.

The Bulky Waste Area is currently covered with a silty sand material (USC classification SM) with a laboratory tested permeability of 9×10^{-5} cm/sec. The thickness of the existing cover ranges from 2 to 4 feet (M&E, 1994).

Figure 3-2 illustrates the proposed cap design utilized for cost purposes. Substitutions may be made to component materials based on availability during the design/construction phase. However, state

and federal standards must be met at all times. The proposed protective cap consists of the following components: vegetation/topsoil, cover layer, drainage layer, 60 mil. LLDPE geomembrane, low permeability soil layer, and a (passive) gas vent layer above the existing silty sand cover. The design is based on the assumption of passive landfill gas venting for this area. Installation of the capping system in the existing Bulky Waste Area will require approximately 6,000 yd^3 of topsoil, 18,000 yd^3 of granular fill, 12,000 yd^3 of silt/sand, 72,000 yd^2 of drainage composite, and 320,000 ft^2 of geomembrane. However, if landfill mining is performed but does not fully remove the source, a cap will still be required on the remaining waste. In this case, the materials will be reduced from the numbers shown above. The capped area will be revegetated following cap installation.

3.1.3 Source Control: Groundwater and Surface Water/Sediment - Landfill Mining

This section describes the source control technology of landfill mining, which is proposed as an alternative to capping for the Bulky Waste Area. Because the Bulky Waste Area is likely to contain a significant percentage of recyclable or reusable material (e.g., ferrous goods and uncontaminated soil), and because there is a relatively low probability of encountering hazardous waste in this area, landfill mining may be feasible as a source reduction or source elimination measure. Mined waste that could not be recycled or reused would be consolidated and disposed at the Solid Waste Area, unless it were deemed hazardous, in which case it would be disposed offsite. If complete removal of waste from the Bulky Waste Area is not feasible, partial mining could be employed to reduce the size of the cap that would be needed to manage migration of contaminants from the waste that would remain in place.

3.1.3.1 Excavation & Consolidation (Landfill Mining). Landfill mining, also known as landfill reclamation or landfill remodeling, is a landfill management technology that employs conventional surface mining techniques to excavate and sort buried waste material. This process can reduce the size of or eliminate old landfills, extend the life of operating facilities, and recover recyclables (Nelson, 1994). The application of this technology at the Site is to mine the Bulky Waste Area to remove and recycle soils and scrap metal, and re-dispose of non-recyclable wastes at the Solid Waste

Area. The ultimate objective is to defray the projected costs associated with capping and on-going monitoring of the Bulky Waste Area by removing the waste, thereby eliminating or significantly reducing the need for a cap and long-term monitoring.

There are a number of objectives that can be met by landfill mining, including: reclamation of land for reuse, extension of the life of an active landfill by creating additional space, deferral of landfill closure and monitoring costs, reduction of closure costs by reducing the size of the landfill, recovery of daily cover soil for reuse, recovery of waste that can be burned as fuel, and recovery of recyclable materials (e.g. steel, aluminum, and plastic) (Cobb and Ruckstuhl, 1988; Dickinson, 1995). Objectives that are applicable to the Bulky Waste Area are reclamation of land for reuse, reduction or elimination of capping costs, removal of a source contributing to leachate migrating to area surface waters, potential recovery of soil, and potential recovery of recyclable materials.

The equipment used for landfill mining is site-specific but in general it consists of backhoes or excavators, dump trucks, and various screening equipment. An example of a processing system used at the Collier County, Florida Landfill is presented in Figure 3-3. Initially the waste is sorted through a large grizzly screen with 6-inch spacing to screen out the larger waste materials. The waste is further classified using a trommel screen. Further screening is used as necessary to attain a higher level of size segregation. Magnetic drums may be used to help separate recyclable metals (i.e. ferrous metals).

3.1.3.2 Landfill Mining Pilot Study. A pilot study would need to be conducted to fully evaluate the applicability of landfill mining for the Bulky Waste Area. It is important to collect data on the types and quantities of wastes present; the locations and concentrations of various wastes; the condition of the waste; the depth of waste and depth to groundwater; and the likelihood of encountering hazardous waste. The evaluation of these factors for the Bulky Waste Area that is presented here is preliminary and should be revised after a pilot study is performed.

Types and Quantities of Wastes. The types and quantities of wastes disposed in this area may be amenable to landfill mining if recyclable items such as white goods are a significant component of the waste. A preliminary estimate of the quantity of recyclable metal waste in the Bulky Waste Area is 37,500 yd^3, which is 33% of the estimated total waste volume of 114,000 yd^3 (M&E, 1996a). It is further estimated that 40% of the 114,000 yd^3 is non-contaminated soil that can be used for backfilling the Bulky Waste Area. The remaining 27% of the total waste volume is assumed to consist of non-recyclable waste that will need to be re-disposed at the Solid Waste Area. If the amount of recyclable metal waste is found to be less than assumed and the amount of non-recyclable waste is larger, costs of capping the Solid Waste Area may increase significantly. It is assumed that the volume of hazardous waste encountered will be minimal. If any hazardous waste is encountered, it will be properly disposed of at an off-site facility.

Locations, Concentrations, Condition, and Depth of Wastes. The composition and condition of the waste is not fully known. Also, previous investigative activities in the vicinity of the Bulky Waste Area have resulted in inconclusive evidence with regard to whether or not landfilled materials are in contact with groundwater. Test pit excavations and/or soil borings would be conducted during the pilot study to determine the type, location, and condition of the waste, verify the depth of the bottom of the waste in relation to the water table, and determine the need for dewatering. The scope of the subsurface investigation program should be extensive enough to characterize the waste/groundwater relationship in detail as only a portion of the area may need to be dewatered.

Once the bottom of the waste horizon has been delineated, a contour map would be generated and compared with existing water table conditions. If dewatering is deemed necessary, a groundwater flow model could be used to optimize the locations and extraction rates of dewatering wells.

Management of Dewatering Water. Groundwater extracted during any dewatering would be treated if necessary and reinjected. Possible locations for reinjection include: 1) between the downgradient edge of the Bulky Waste Area and the Saugatucket River, and 2) upgradient of the Bulky Waste Area. Assuming that dewatering is necessary to conduct the landfill mining operation,

RIDEM rules under the Underground Injection Control Program would apply. Assuming that dewatering operations last more than one month, it would be necessary to provide RIDEM with plans, specifications, sample analyses and other information that show that the injection will be designed, constructed and operated so as to prevent pollution or endangerment of groundwater quality in Rhode Island.

3.1.4 Collection: Groundwater and Surface Water/Sediment

This section describes key technical criteria for the feasible remedial action technologies and process options related to collection of contaminated groundwater and leachate impacting the Site's surface water/sediments. Major remedial technologies and process options detailed in this section are divided into those addressing the media of groundwater (through control of disposal areas) and surface water/sediment (through control of leachate).

Technologies and process options for collection that require description of key technical criteria include: extraction wells and subsurface drains. Included in each of these sections are results of groundwater modeling simulations for recommended remedial technologies and process options, including horizontal barriers.

3.1.4.1 Subsurface Drains. This section describes measures that may be taken to reduce breakout of contaminated water along the slopes of the landfills, in addition to capping. Leachate breakout from landfill slopes is thought to have two sources: lateral migration of infiltration of precipitation due to temporary mounding in the disposal areas, and groundwater discharge. The locations of these leachate breakouts, based upon aerial photographs and site reconnaissance, are shown in Figure 2-1. Breakouts have been observed along the side slopes of the Solid Waste Area, especially in the southeastern portion, and southeast of the Bulky Waste Area.

The distinction between leachate and groundwater is difficult to make in an unlined landfill. Breakout in the Solid Waste Area is believed to be due primarily to mounding of water perched

above a confining layer of waste. Breakout in the Bulky Waste Area is believed to be due to groundwater discharge. This hypothesis is based on the elevations of the breakout locations relative to observed water table elevations.

Capping of the Solid Waste and Bulky Waste Areas will significantly reduce leachate breakout by reducing infiltration and by covering breakout locations. However, leachate breakout will continue in areas outside the capping limits and areas for which the principal source is groundwater discharge. This is particularly true of the breakout locations observed southeast of the Bulky Waste Area.

Landfill mining of the Bulky Waste Area will not reduce infiltration, but it will reduce the contaminant loading in the leachate breakout by removing a major source of contamination. Contaminant concentrations in the leachate would be expected to attenuate naturally once the major source is removed. However, leachate collection and treatment will be required initially during landfill mining of the Bulky Waste Area due to disturbance of the contaminant source.

A shallow drain would be constructed downgradient of the Bulky Waste Area to intercept leachate and shallow groundwater and mitigate migration of contaminated water from the Bulky Waste Area. To minimize the extraction of clean groundwater, the system would be designed to intercept only the upper layer of the aquifer, which contributes to surface water contamination (via leachate). The drain would consist of perforated pipe placed at the base of a trench dug 1 to 2 feet below the seasonal low groundwater elevation and backfilled with crushed stone. The pipe would slope to discharge to a sump, which in turn would pump to the groundwater/leachate treatment plant. The drain would be approximately 500 feet long and constructed 10 feet below grade.

The groundwater extraction rate necessary to intercept the top foot of groundwater in the area was estimated to be 5 gpm based upon model simulations of area infiltration and groundwater flow (discussed below and in Appendix C). This system would capture shallow groundwater at the eastern edge of the landfill.

The infiltration model used in the FS was EPA's Hydrologic Evaluation of Landfill Performance (HELP) computer program. The HELP program is a quasi-two-dimensional hydrologic model for conducting water balance analysis of landfills, cover systems and other solid waste contaminant facilities (U.S. EPA, 1994a). The proposed caps on the Solid Waste and Bulky Waste Areas were shown to reduce the rate of infiltration 100%. HELP model results were used as input for the groundwater flow model (Appendix C).

The groundwater flow model used for this FS was the United States Geological Survey's (USGS's) three-dimensional flow model, MODFLOW (McDonald and Harbaugh, 1988). The model is a finite differential formulation which computes vertical and horizontal flow between grid cells and layers made up of horizontal and vertical subdivisions of the Site. The model incorporates site-wide variations in hydraulic conductivity and saturated thickness and takes into account areal recharge and surface water flow.

A preliminary calibration of the model was performed by comparing modeled groundwater elevations generated using existing conditions with observed groundwater elevations measured in monitoring wells. The model results corresponded reasonably well to observed groundwater elevations and the model was deemed sufficient to perform the required simulations. Further calibration of the model was not performed. It should be noted that improved model results in the areas of interest would be achieved with further water level data in the waste areas. However, the results provide an estimate of what will occur due to implementation of a remedial action.

The model was used to evaluate the potential effects of capping the Solid Waste Area and the Bulky Waste Area with either composite or single barrier caps. The caps were simulated by reducing the rate of areal recharge in the portions of the model grid representing the two landfills. The reductions in recharge were determined using the HELP model. The model results suggested that groundwater levels would be lowered a maximum of 0.5 to 1.0 foot in the Solid Waste Area and 0.25 to 0.5 feet in the Bulky Waste Area with the use of single barrier caps. The modeling suggested that use of composite caps would not significantly lower groundwater levels more than single barrier caps in

the first few years following implementation. This is due to initial soil moisture which will recharge the groundwater and reduce in volume as its source (precipitation infiltration) is limited due to capping.

The model also used drains to simulate the performance of collection trenches which would provide leachate/groundwater outbreak control. Drains were placed just southwest of the Bulky Waste Area and the model simulated the effect of groundwater extraction via the drains, which were set at elevations approximately 1 foot below the existing water table. Extraction rates of approximately 5 gpm were determined to be the minimum necessary to generate a localized groundwater depression over the area of observed breakout in the Bulky Waste Area. This extraction rate should be refined through additional modeling during design. Additional model assumptions are provided in Appendix C.

Final determination of groundwater and leachate collection will be made during design following additional analysis. This analysis would determine which process option (subsurface drains or extraction wells) is more appropriate. For the purposes of estimating costs in this FS, the process option of subsurface drains has been utilized. Collected leachate will be treated using the technologies discussed later in Section 3.1.6.

3.1.4.2 Extraction Wells. This section describes key technical criteria for minimizing the impact of the Solid Waste Area on groundwater (and by extension, surface water/sediment). Similar to the subsurface drain system described in Section 3.1.4.1, extraction wells would be used in conjunction with horizontal containment described in Section 3.1.2 to reduce the impact of the Solid Waste Area on groundwater. Extraction wells reduce the groundwater flow through the waste by depressing the water table where groundwater is in contact with the waste.

There are two potential sources of waste impacts to groundwater: infiltration percolating through the waste which generates leachate, and groundwater flow through waste immersed below the water table. Leachate generation rates determined through HELP model hydrologic simulations are

provided in Section 3.1.4.1 as well as Appendix C. In addition, refuse is thought to be in contact with groundwater in the Solid Waste Area. Cross-sections generated from soil borings conducted during a pre-design investigation in 1987 showed refuse up to 5 feet below the water table in the northern portions of the Solid Waste Area (C.E. McGuire, 1977b). Based upon current information, the bottom of refuse appears to be above the water table in the Bulky Waste and Sewage Sludge Areas. Geological cross-sections generated from soil borings conducted during the RI show refuse approximately 10 feet above the water table in the Bulky Waste Area and 15 feet above the water table in the Sewage Sludge Area (M&E, 1994).

Capping the disposal areas will lower the water table beneath these areas by reducing the infiltration recharge rate. To evaluate whether capping alone would reduce the water table below the lower limit of the refuse in the Solid Waste Area, a hydrologic simulation using MODFLOW (Section 3.1.4.1 and Appendix C) was conducted.

The effect of capping was simulated by reducing recharge over the disposal areas to match HELP model simulations. Regional groundwater effects were minimal from landfill capping as a result of the strong interconnection between flow systems and the regional control of surface water on groundwater flow. The decrease in the upper overburden aquifer groundwater level was sufficient to lower it below the refuse, however, the water elevations were only slightly below the waste (within 1 to 2 feet). For the purposes of this modeling effort, the refuse in the Bulky Waste and Sewage Sludge Areas is assumed to be above the water table prior to capping.

The installation of a collection system upgradient of the Solid Waste Area was investigated to provide additional separation between the waste and the water table. A MODFLOW simulation shows that groundwater levels could be reduced up to an additional 5 feet within the Solid Waste Area using an extraction well/drain system approximately 4 feet below the water table, placed along the northern edge of the Solid Waste Area with groundwater extracted at a rate of 44 gpm.

3.1.6 Treatment: On-Site (Groundwater and Leachate)

On-site treatment involves treatment of groundwater and leachate in an on-site facility using precipitation, media filtration, and ultraviolet (UV)/chemical oxidation. The technical rationale and assumptions for on-site treatment of groundwater are detailed in Table 3-1. UV/chemical oxidation was selected over activated carbon adsorption for on-site treatment of organic COPCs. While both technologies are effective in treating most organic COPCs, UV/chemical oxidation is a better process option since it can remove vinyl chloride, which is difficult to remove through activated carbon adsorption. In addition, UV/chemical oxidation is a permanent destruction technology as opposed to carbon adsorption which only separates COPCs. Furthermore, UV/chemical oxidation generates fewer process residuals requiring disposal than activated carbon adsorption.

A typical process diagram of on-site treatment is shown in Figure 3-4. The major remedial technologies are further described below.

3.1.6.1 Media Filtration. Media filtration involves removing solids from a liquid, either as a pretreatment or as a polishing unit, by straining through a porous media, such as sand or anthracite coal. As large particles are removed from the liquid initially, smaller particles penetrate the media bed and are removed within the bed. Other mechanisms, including sedimentation within the media bed and chemical adsorption, are also involved in the media filtration process (Goldman and Bowen, 1992).

Granular media filters are most efficient when utilizing the entire bed depth instead of just the surface. The ideal bed is graded so that the influent stream flows through the largest media size first and progresses to the smallest size. The filters must be backwashed periodically with clean water to remove collected solids, which must then be disposed of off-site. This backwashing tends to distribute the media with the smallest sizes on top. Two methods have been used to approach the ideal bed: upflow filtration; or multi-media filtration using two or more materials with different densities.

Media filtration is typically used after gravity separation processes for additional removal of suspended solids prior to other treatment processes, as well as for polishing treated wastes to reduce suspended solids and associated contaminants to low levels (M&E, 1985). This technology is suggested as a pretreatment process at the Site to remove solids, such as oxidized iron and silt, which may cause fouling in subsequent treatment processes.

3.1.6.2 Precipitation. Precipitation is a process where dissolved contaminants are transformed into insoluble solids through the addition of pH-adjusting chemicals. These solids may then be separated from the liquid through either sedimentation or filtration. This technology would be used to remove the high concentration metals, such as iron, manganese, and aluminum, at the Site and is expected to remove other lower concentration metals during the process.

> "Usually, metals are precipitated from solution as their hydroxides, sulfides, or carbonates. Hydroxide precipitation with lime or caustic is most common. Because the optimum pH for precipitation as the hydroxide is different for each metal ion, treatment of mixed metal aqueous wastes require compromise. Generally, hydroxide precipitation is carried out at a pH between 9.5 and 12.
>
> Metal sulfides are generally much less soluble than hydroxides, thus better removal efficiencies are achievable. Sulfide can also be used to precipitate metals in the presence of complexing agents and over a broader pH range than possible for hydroxide precipitation." (M&E, 1985)

After the precipitation step, flocculent may be added to aid in the colloid/liquid separation step. The sludge is then typically dewatered and disposed of at a hazardous waste treatment, storage, and disposal facility (TSDF). If sulfide is used in the precipitation step, there is a risk of hydrogen sulfide generation from excess sulfide in the aqueous effluent with a low pH aqueous stream.

3.1.6.3 Ultraviolet/Chemical Oxidation. UV/chemical oxidation is a process applicable for the treatment of aqueous streams which contain less than 1% oxidizable compounds. It may be used to pretreat waste streams, to break down refractory organics (i.e., those resistant to biological oxidation), or for use as a polishing step after other treatment processes to oxidize untreated

organics. UV/chemical oxidation is an applicable treatment technology for contaminated groundwater containing a wide variety of organic compounds such as halogenated organics, phenols, pesticides, and PCBs (Sundstrom *et al.*, 1989; Ku and Ho, 1990; Topudurti *et al.*, 1993; and U.S. EPA, 1993a).

The key principle of UV/chemical oxidation is the generation of hydroxyl radicals through UV photolysis of oxidizing agents such as hydrogen peroxide and ozone (Topudurti *et al.*, 1993). Hydroxyl radicals are powerful oxidizing agents for destroying the organic COPCs. UV light is first used to create hydroxyl radicals from the hydrogen peroxide (H_2O_2) and ozone (O_3). Then the hydroxyl radicals, in combination with UV light, start to break bonds in oxidizing the organic COPCs. Formation of the radicals is shown as follows:

HYDROGEN PEROXIDE		ULTRAVIOLET LIGHT		HYDROXYL RADICAL			
H_2O_2	+	$h\nu$	→	$2OH\bullet$			
OZONE		ULTRAVIOLET LIGHT		WATER		HYDROGEN PEROXIDE	OXYGEN
O_3	+	$h\nu$	+	H_2O	→	H_2O_2 +	O_2
		THEN SIMILARLY:					
		H_2O_2	+	$h\nu$	→	$2OH\bullet$	

The chemical oxidants most widely used are ozone and hydrogen peroxide, either alone or in combination. Ozone is produced by passing air through an extremely large electrical potential. Electrical charges arc across the electrodes and through the air, thereby converting a small fraction of the oxygen present into ozone. This air containing the ozone gas is placed in contact and thoroughly mixed with the contaminated groundwater. The UV portion of this process option consists of a reactor which contains ultraviolet lamps. Hydrogen peroxide is added to the groundwater as it enters the reactor. The ultraviolet lamps, ozone and hydrogen peroxide produce hydroxyl radicals. The highly reactive hydroxyl radicals, along with ozone and hydrogen peroxide, oxidize the organics.

The UV/chemical oxidation process is carried out in a reaction vessel separated into chambers by baffles. Each chamber contains mercury vapor lamps encased in quartz as the UV source. Water flow is perpendicular to the lamps. Each chamber may also have a sparger for ozone enriched air dispersion along the length of the chamber. Hydrogen peroxide is added to the water influent line. Ozone is produced by drying ambient air and passing it through an ozone generator. The size of the reaction chamber and the water flow rate can be adjusted to achieve the desired retention time.

If a combination of hydrogen peroxide and ozone is to be used, the hydrogen peroxide-to-ozone ratio must be determined in a treatability test. A weight ratio between 2:1 and 3:1 of ozone-to-hydrogen peroxide has been shown to be the most efficient (U.S. EPA, 1990a; Glaze and Kang, 1988). Above a 3:1 ratio, excess ozone is emitted thus making ozone generation inefficient and thereby lowering the quality of emissions. Below 2:1 scavenging of oxidizers by impurities reduces the reactor effectiveness and efficiency. Off-gas treatment consisting of a catalytic ozone decomposer is expected to control fugitive organics emission.

Removal of VOCs using a UV/chemical oxidation process had been demonstrated effective as part of the Superfund Innovative Technologies Evaluation (SITE) program (U.S. EPA, 1990a). Eight sites and their results are included in the Applications Analysis Report. The report focused on the Lorentz Barrel & Drum site in San Jose, California during February and March of 1989. The indicator VOCs for this site were TCE, 1,1,1-trichloroethane (1,1,1-TCA) and 1,1-dichloroethane (1,1-DCA). Groundwater well results at the San Jose site indicated 1,1-DCA present at 180 μg/L. A 150 gallon UV/chemical oxidation reactor was used during the pilot test demonstration. Thirteen test runs were performed over a 2-week period; nine to determine the optimum conditions and four to verify those conditions. All effluent levels were below 5 μg/L.

Some constituents present in the Rose Hill Regional Landfill site groundwater may reduce the effectiveness of the UV/chemical oxidation process. These include iron and manganese (Nyer and Bitter, 1991). A pretreatment system may be required to remove these interfering compounds prior to entering the UV/chemical oxidation system. Based on the low concentrations detected, BOD

should not interfere with the UV/chemical oxidation process. Design concentrations are presented in Appendix D.

Equipment vendors offer conflicting opinions as to the necessity of groundwater pretreatment to remove iron. One vendor, Calgon/Peroxidation/Solarchem (formerly Solarchem Environmental Systems), claims to have a unit which can destroy chlorinated volatile contaminants with influent iron concentration as high as 10 ppm (M&E, 1992b). The Solarchem system is a self cleaning UV oxidation unit which prevents the buildup of ferric hydroxide precipitates that could adversely affect the efficiency of UV destruction by scraping the UV transmission lamps clean during operation. Although this treatment unit is apparently unaffected by iron precipitates, the problem of iron fouling is then simply shifted to the next process technology downstream. For example, discharge of water containing iron floc to a groundwater recharge well system may have negative impacts on operations & maintenance (O&M) requirements and equipment life. Iron precipitate could build-up and seal the system, thereby requiring replacement or, in a lesser case, cause much higher O&M costs for cleaning. Since both of these potential items may be cost prohibitive, M&E's approach in the FS is to assume removal of inorganics (such as iron and manganese) that may interfere with treatment of the COPCs even though remediation of iron and manganese is not required by the criteria detailed in Section 2.0. Also, removal of inorganics may be required to comply with Rhode Island Underground Injection Control Regulations (see below).

3.1.6.4 Discharge of Treated Water. Two discharge process options were retained for further consideration in Section 2.0: discharge to groundwater recharge wells, and discharge to surface water. Discharge to the South Kingstown publicly owned treatment works (POTW) was eliminated from further consideration due to the lack of a nearby sewer line and permit conditions of the facility which restrict influent to domestic sources. The ultimate selection of a discharge option would be made during remedial design. The remainder of this section discusses considerations relevant to this determination.

Discharge to groundwater must comply with the substantive provisions of Rhode Island Rules and Regulations for Groundwater Quality and state Underground Injection Control Regulations. These regulations are designed to maintain high quality groundwater sources and prevent the further degradation of lower quality sources. To implement these objectives the state has developed a groundwater classification system and a set of groundwater quality standards which are shown in Table 3-2. Site groundwater directly beneath the limits of waste disposal is currently classified as GB and Site groundwater outside the limits of waste placement is anticipated to be reclassified as GB. It must be demonstrated during design that the injection of treated groundwater would not lower the quality below GB or result in the groundwater being further degraded. It is likely that this could be demonstrated because the treatment system can be designed such that the treated effluent levels will meet the groundwater quality standards. It is also necessary that the operation of the injection system be incorporated into the design of any groundwater collection system. The volumes of water collected by the leachate and groundwater collection systems modeled in this FS did not include the effects of groundwater injection.

If discharge to surface water were to be utilized, it would most likely be to the Saugatucket River due to its size and proximity. This discharge must comply with the provisions of state Water Quality Regulations for Water Pollution Control. These regulations, similar to those for groundwater, are designed to preserve a level of water quality consistent with its use as indicated by a Water Use Classification for the water body. The Saugatucket River has been classified as a Class B water body which designates its use as a public water supply with appropriate treatment and as a fish and wildlife habitat and for agriculture, bathing and other primary contact recreational activities. To discharge to the Saugatucket River it must be demonstrated that the ambient concentration of a pollutant in the water body would not exceed the Ambient Water Quality Guidelines shown in Table 3-2, plus any other applicable standards under Rhode Island Water Pollution Control Regulations. The proposed treated effluent concentrations of the water treatment plant would be below these guidelines for all compounds in the site discharge.

Both surface water and groundwater discharge options are implementable. The selection will be made during design based upon relative human health protectiveness, ecological protectiveness, and cost. It has been assumed for costing of alternatives that the treatment plant will discharge to groundwater.

3.1.7 Institutional Controls: Landfill Gas

The technical rationale for each of the institutional controls is described below. Feasible institutional controls include access restrictions, monitoring and contingency for installation of residential LFG control methods.

3.1.7.1 Access Restrictions. This control consists of fencing and security measures to restrict human access. These measures would include a chain-link fence (8 feet high), gates and signs designed to prohibit site entry. This control is necessary to mitigate human health risk from LFG emissions to visitors on the Solid Waste Area.

3.1.7.2 Monitoring. Monitoring will be necessary to identify and track migration of landfill gas and its associated contaminants from the Solid Waste and Bulky Waste Areas. Monitoring is not anticipated to be required around the Sewage Sludge Area. Monitoring will be required in three areas: 1) perimeter zone outside refuse areas, 2) within the disposal areas, and 3) ambient air monitoring.

Preliminary rationale for landfill gas monitoring is described in this section. The detailed monitoring requirements are described by alternative in Section 4.0.

Perimeter Landfill Gas Monitoring. Monitoring wells would be used to monitor off-site landfill gas concentrations for alternatives that have perimeter extraction systems. Measurement of these concentrations provides an indication of lateral migration of landfill gas. The monitoring wells would be placed between the perimeter extraction system and the residential/off-site receptors. This

would result in a line of monitoring wells further from the landfill that parallel the line of perimeter extraction wells. If vapor testing of the gas monitoring wells revealed high concentrations of methane or VOCs relative to ambient air, then the perimeter extraction system would be adjusted or modified accordingly to minimize lateral landfill gas migration.

Landfill gas testing locations used during the RI would be converted to permanent points for long-term monitoring. Conversion to permanent points would involve drilling to greater depths within the refuse and installation of secure housings at ground surface.

Zone-of-Refuse Monitoring. The zone-of-refuse is the location within the Solid Waste and Bulky Waste Area boundaries and below any present or future caps. In short, a zone-of-refuse is the location where wastes were disposed. Since a zone-of-refuse is a source area for landfill gas, monitoring is needed to characterize changes that may affect adjacent subsurface landfill gas concentrations as well as ambient air.

Ambient Air Monitoring. Ambient air monitoring is required to characterize impacts of migrating landfill gases on ambient air quality. Key locations for testing include upgradient (i.e., upwind) locations, within Solid Waste and Bulky Waste Areas (for alternatives where the area is capped) and at site boundaries.

Gas Monitoring Wells. Since gas migration can occur at depths from the ground surface to the confining layer, the gas monitoring well should be constructed to screen the entire depth of the potential migration zone. Data from discrete depth intervals will permit an evaluation of the depth of migrating gases. For this reason, these wells will be constructed with multilevel sampling ports.

A schematic of a typical gas monitoring well is shown in Figure 3-5. Gas monitoring wells are typically constructed of slotted polyvinyl chloride (PVC) pipe, measuring 0.5 to 1 inch in diameter; the borehole into which the pipe(s) are placed is typically 4 inches in diameter. As shown in the

schematic, the landfill gas characteristics (i.e. concentration, pressure) can be monitored at discrete depth intervals by providing low permeability seals to separate the intervals.

3.1.7.3 Residential Landfill Gas Control Contingency. This measure involves a contingency to install LFG controls at individual residences or commercial properties affected by subsurface landfill gas migration. The contingency would be based on detection of landfill gas concentrations that exceed ARARs or other criteria defined in Section 2.0. The chain of events leading to implementation of the residential LFG contingency is illustrated in Figure 3-6.

Installation of gas controls involves addition of methane/hydrocarbon sensors and alarms, basement ventilation systems and instrumentation, and controls that tie the sensors and ventilation together in a complete system. A typical system is depicted in Figure 3-7. The technical rationale and assumptions for the residential LFG control contingency are detailed in Table 3-3.

The trigger mechanism for instituting the LFG controls would be two-fold: 1) detection of methane/COPCs in soil gas locations adjacent to, or on, the residential property in question and 2) detection of methane/COPCs within the indoor air of the residence. Based on instrument detection limits, appropriate trigger levels would be 1,000 ppm methane for the soil gas location and 10 ppm methane for the indoor air. Calculations showing the correlation of methane concentrations with vinyl chloride are presented in Appendix F. Based on these calculations, methane trigger levels of 10 and 1,000 ppm methane would result in vinyl chloride concentrations of 1.51 $\mu g/m^3$ and 5.36 $\mu g/m^3$, respectively.

3.1.8 Management of Migration: Landfill Gas Collection

Landfill gas migration controls address RAOs by reducing the migration of COPCs from the disposal areas to the ambient air. Landfill gas migration may be controlled by capping and/or collection systems. The capping remedial measure was discussed in detail in Section 3.1.2. This section discusses gas extraction and collection systems in detail.

There are two principal mechanisms that cause gas generated within a landfill to migrate into the surrounding environment: 1) pressure convection and 2) diffusion. Pressure convection is the cyclical build-up and release of landfill gases to adjacent areas after a build-up of positive pressures. Positive pressures build up within landfills due to microbial degradation that generates by-product gases which have a larger volume than the refuse from which they originated. Diffusion is a different mechanism altogether. With diffusion, landfill gas migrates into adjacent areas due to concentration differences. Thus, high concentrations of landfill gas components, such as vinyl chloride, diffuse into adjacent areas with lower (or zero) concentrations. Detailed discussion of these mechanisms is provided in Section 3.1.8.1. Effective control and collection of landfill gas at the Site would require negation of both migration mechanisms: pressure convection and diffusion.

The feasible remedial technologies for migration control and collection of landfill gas, active perimeter systems and/or active internal collection systems, would be utilized to control these migration mechanisms. Active perimeter systems are placed outside (i.e. along the perimeter) of the zone of landfilled refuse. These systems control and collect landfill gas migrating laterally into adjacent subsurface soils. Active perimeter systems were found to be the most feasible systems based on M&E's prior evaluation of landfill gas migration barrier systems (M&E, 1993a). Two process options are feasible for perimeter systems: 1) vertical extraction wells, and/or 2) horizontal extraction laterals.

Active internal well systems are placed within the zone of landfilled refuse. These systems are required to collect gas from the center of the landfill so that uncontrolled, fugitive emissions through the cap do not result. In addition, internal collection systems would reduce the migration burden exerted on a perimeter system. Fugitive emissions from uncollected landfill gas at the Site are a source of significant human health risk due to the presence of contaminants in the gas (M&E, 1994; M&E, 1998).

Landfill gas migration control and collection at the Site has three components:

- An active internal collection system in the Solid Waste Area
- A perimeter collection system along Rose Hill Road
- A passive venting system in the Bulky Waste Area (for alternatives in which this area is capped)

These components are discussed in Sections 3.1.8.2, 3.1.8.3, and 3.1.8.4, respectively. Section 3.1.8.1 describes landfill gas migration mechanisms.

3.1.8.1 Landfill Gas Migration Mechanisms. Gases migrating from a landfill will follow the path of least resistance. Landfill gases tend to move upward towards ambient air. However, if the vertical or upward path is blocked (e.g. due to a cap or frozen soil conditions in winter) then landfill gases will migrate laterally. Areas of concern near landfill environments, which may be impacted by lateral migration, include building foundations, utility conduits, porous soil zones and any other underground voids that can act as pathways of least resistance.

There are two principal mechanisms that cause gas generated within a landfill to migrate into the surrounding environment. These mechanisms are: 1) pressure convection and 2) diffusion. Landfill gas migration due to these two fundamental mechanisms is widely documented in the scientific literature (Moore *et al.*, 1979; Moore *et al.*, 1982; Metcalfe and Farquhar, 1986; Bogner *et al.*, 1988; Massman, 1989; Farquhar, 1989). Figure 3-8 illustrates the two mechanisms of pressure convection and diffusion. This is shown for illustration purposes, is not to scale, and describes methane.

Pressure convection is defined as gas flow from an area of high pressure to an area of lower pressure. Gas within a landfill is at greater pressure than atmospheric and will equalize by pushing outward through the cap and landfill sides towards an area of lower pressure. Methane and other gas compounds such as vinyl chloride will be carried along with the outward pressure flow into areas adjacent to the landfill. Landfill gas pressures originate from biological decomposition of wastes. There is a net increase in volume when organic solids in refuse are converted to gaseous products.

A net increase in volume within a fixed landfill cell causes the total gas pressure to become greater than atmospheric.

Diffusion is defined as gas movement from an area of high concentration to an area of lower concentration. Movement by diffusion will occur even in a medium that is quiescent, such as an undisturbed air pocket. For example, a cologne bottle opened in one corner of a room will eventually be detected by an observer in the opposite corner even though the air is still. The chemicals that make up the cologne have diffused from an area of high concentration (the bottle) to an area of low concentration (the room). Similarly, methane and other gas compounds such as vinyl chloride will diffuse from an area of high concentration (the landfill) through the cap and sides and into areas of lower concentration (ambient air above the cap, perimeter landfill gas).

The total methane or vinyl chloride concentration at any given point will be the sum of contributions from diffusion and pressure convection. The total concentration of compounds such as methane or vinyl chloride can be measured easily, but the degree of contribution from each mechanism is not easily determined. Both mechanisms, therefore, must be addressed in solving a landfill gas migration problem. Figure 3-9 illustrates the additive nature of these two mechanisms by presenting a total concentration profile for methane.

The flow of migrating gas will change seasonally, peaking in the winter months when gases are prohibited from escaping through the landfill surface due to frost or saturated surface soils. The flow levels out in the summer months when gases can escape through the landfill surface, limited only by the permeability of the silty soil cover material.

3.1.8.2 Perimeter Collection. Successful methods for controlling gas movement across the perimeter of a landfill involve interrupting the two mechanisms of migration: pressure convection and diffusion. Figure 3-10 details use of an active perimeter system to mitigate landfill gas migration. A perimeter system entails the installation of vertical gas extraction wells and/or

horizontal extraction laterals between the landfill boundaries and off-site receptors such as residential or commercial properties.

A perimeter system mitigates landfill gas migration away from the zone-of-refuse by applying a subsurface negative pressure zone. Pressure convection is mitigated by removal of excess landfill gas through the extraction wells. The diffusion component is counteracted by a reverse pressure gradient created by the well. The "reverse" pressure gradient is the clean soil vapors or air rushing towards the well from the residential side of the system. The net effect of the reverse pressure gradient is to overwhelm the diffusion component thereby minimizing the extent of gas migration beyond the well system (Moore *et al.*, 1982).

Migrating landfill gases enter the negative pressure zone and are extracted through the wells into a pipe manifold. The pipe manifold carries the extracted gases to the blower system and then to a treatment and discharge system. The effectiveness of an active perimeter system is evaluated by observing landfill gas concentrations and vacuum pressures beyond the perimeter system.

A more detailed evaluation of active perimeter systems was previously conducted during M&E's evaluation of proposed landfill gas migration barrier systems (M&E, 1993a). The key parameters and technical rationale from this evaluation are summarized in Table 3-4. Descriptions of each of the components of the active perimeter system are presented below.

Extraction Well System. In the design of an extraction well system, the two elements which vary most widely from site-to-site are the depth and lateral spacing of the wells. The depth of the wells is typically established as the depth to the uppermost confining layer; either a low-permeability layer that the gas will not permeate or the water table, as landfill gas is virtually immiscible in water. The lateral spacing of the wells is primarily dependent on the local geology, since the frequency of placement is determined by estimating the radius around the well to which an applied vacuum will penetrate (i.e. radius of influence). Placement is selected to establish a continuous zone of negative pressure along the route of migration. A radius of influence of 40 feet was assumed for the perimeter

well system, which is consistent with the spacing recommendation with respect to landfill gas venting applications when site-specific vacuum test data is unavailable (Johnson *et al.*, 1990). It should be noted that this radius of influence is significantly less than that assumed for the internal collection system as the perimeter system cannot rely on positive pressure from the landfill to encourage migration to the well.

A schematic of a typical extraction well is shown in Figure 3-11. Extraction wells are typically constructed of slotted PVC pipe, measuring 4 to 12 inches in diameter; the borehole into which the well is placed typically ranges from 8 to 24 inches in diameter. To permit unrestricted flow of landfill gas from the borehole to the extraction well, the annular space is back-filled with large-diameter granular material. The location of the slotted pipe with respect to the ground surface is an important element in the design, because placement of the slotted pipe too close to the surface of the ground will induce flow of atmospheric air to the well and short-circuiting of subsurface gas flow to the well.

Each well is constructed with a valve to permit the applied vacuum from the system blower to be regulated. This will allow for flow rate adjustment for each well. The required flow from each well is dependent on the well depth and the geology in the proximity of the radius of influence of the well, and the loss of pressure head from the system at each well location. The wells are connected to the collection system manifold with a solid high density polyethylene (HDPE) pipe. The HDPE pipe is more flexible than PVC and allows for differential settlement in the wells. Wellheads are typically accessed through a manhole hatch cover which can be secured. Wells are also designed with sampling ports which permit both pressure and concentration measurements to be taken. Pressure gauges may also be installed to facilitate monitoring of pressure at each wellhead.

The depth to which each well is constructed is dependent on the depth to the confining layer. In the conceptual design (M&E, 1993a), this depth was estimated as the average depth to groundwater. In a detailed design, the depth of each well would be established based on an estimate of depth to seasonal low water table at the location of the well. In this FS, an average depth of 22 feet was

assumed to accommodate potential seasonal fluctuations, affects of other technologies (e.g. horizontal barriers) and applied vacuum pressures at the well.

Collection System. The pipe manifold, or collection system, is typically constructed of HDPE piping and ranges in diameter from 4 to 24 inches depending on the flow rate, which varies throughout the system. HDPE is most widely used because it is flexible, which is beneficial for constructing a lateral system. It is also more chemical resistant than other plastics such as PVC for handling gas condensate. Typically, the manifold system would include different lengths of piping of varying diameters. The piping diameter for each reach would be selected to maintain adequate velocities.

Condensate Generation and Disposal. Condensate is generated by two mechanisms: 1) temperature reduction from landfill to ambient temperatures; and 2) compression from blowers in the extraction system. Since significant gas compression is not expected in the systems proposed for the Site, only condensate production via temperature reduction was addressed in the conceptual design (M&E, 1993a). Temperature reduction from landfill to ambient temperatures is primarily a function of the geographic location of the landfill.

The condensate generation rate used in the cost estimate for the conceptual design (M&E, 1993a) was based on actual quantities observed at a landfill in the New England area as communicated by the operator. This generation rate was 125 gallons/million ft^3 of extracted gas. It should be noted that this actual value was somewhat conservative for use in the conceptual design because the rate is based on gas extracted from an internal collection system that will likely have a higher temperature than the perimeter system. The 125 gallon/million ft^3 of extracted gas generation rate represents approximately one-half the theoretical rate of 300 gallons/million ft^3 of landfill gas extracted. The theoretical rate is calculated assuming that the landfill gas is at full saturation and 100°F and an inlet temperature of 50°F in the collection system (Maxwell, 1989).

Actual condensate generation rates are often significantly lower than the theoretical (RICL, 1993). The shortfall of actual versus theoretical condensate production is probably due to unsaturated air and landfill gas at the inlet, condensation in wells and pipelines dripping back to the landfill; and incomplete cooling of vapor in the system.

Condensate will be collected and transported in the perimeter collection piping system to a pump station. When a sufficient volume of condensate is formed, the station will pump the liquid to an aboveground storage tank where it will be held for either treatment or disposal.

Condensate will flow smoothly by gravity in collection lines where the gas and condensate are flowing in the same direction. For instances where the condensate and gas are flowing in opposite directions, the two streams will be channeled into two separate pipelines. Based on M&E's experience (M&E, 1989; M&E, 1990b), this is necessary to prevent build-up of condensate that can eventually plug the pipeline and prevent landfill gas collection.

Condensate drain piping will connect the perimeter collection system to the pump station. Drip and loop traps will be required in this piping to separate the vacuum pressure in the gas collection piping from the atmospheric pressure in the pump station.

A significant factor determining the ease and expense of condensate disposal is its classification under RCRA. Section 124 of the CERCLA states that condensate from methane recovery operations is not a hazardous waste unless it exhibits characteristics of a hazardous waste under RCRA. Condensate from the gas abatement system may be classified as toxic or corrosive under RCRA. Toxicity characteristics must be evaluated in comparison to Maximum Concentrations of Contaminants for the Toxicity Characteristic specified in 40 CFR 261.24, which set an upper limit for TCE and vinyl chloride concentrations. Corrosive wastes have a pH less than or equal to 2. No data is available on condensate quality at the Site and only a limited amount of published data is available from other sites. These data show significant variability and high biological and chemical oxygen demands (BOD and COD, respectively) and total organic carbon (TOC) levels. Aqueous

phase exceedances have been measured in other landfill condensates for benzene, 2-butanone, tetrachloroethane, and carbon tetrachloride (Vogt, 1989). Some collection systems generate both aqueous and liquid hydrocarbon condensate phases. The hydrocarbon phase is much more likely to be hazardous. However, the potential for liquid hydrocarbon phase condensate is considered low due to the lack of significant gas compression in the proposed systems (Maxwell, 1989).

The condensate disposal and transportation cost estimate assumes the condensate will be classified as a hazardous waste under RCRA (SCS Engineers, 1987), have no free hydrocarbon phase, have a relatively low TOC concentration and have low total suspended solids (TSS). The cost estimate also assumes the waste will be transported and disposed by licensed transporters and treatment facilities. However, depending on the alternative selected, other options may be reviewed such as treatment in any leachate or groundwater treatment system. If a flare is being utilized for LFG treatment, another option is to inject the condensate into the flare. This would alter the heat balance and may require more auxiliary fuel, but should be reviewed during the design phase.

3.1.8.3 Internal Collection. An internal collection system is required for collection of landfill gas to avoid uncontrolled and fugitive releases to the surrounding environment (ambient air, adjacent subsurface soils, etc.). Active internal collection systems were found to be the only feasible remedial technology since discharges from passive vents would pose unacceptable human health risk (M&E, 1993a).

A key aspect in conceptually sizing internal extraction well systems is to estimate the quantity and rate of landfill gas generation. A detailed description of M&E's estimates on gas production from the Solid Waste Area is given below. Once the rate of landfill gas has been estimated, then sizing of an active collection system such as internal extraction wells can be conducted. Technical rationale and assumptions are detailed in Table 3-5. Descriptions of this technical rationale are also provided below.

Gas Generation Rate. The generation of landfill gas from refuse is dependent on the composition of the material, age of the refuse, moisture content, pH of the landfill environment, and the availability of nutrients relative to the stoichiometric requirements for microbial respiration. Of these factors, the first three have been found to have the most pronounced affect on the generation rate (Zimmermann *et al.*, 1983). In calculating the current gas production rate at the Site, the approximate refuse composition and the age of the refuse were considered. While moisture content is also a significant factor, the only predictable differential in moisture content across the landfill is the fraction of refuse seasonally submerged in the water table. This fraction of refuse was found to be small relative to the total volume of refuse and was not factored into the estimation of total landfill gas generation (M&E, 1993a).

A first-order kinetic model (e.g. originally known as the "Scholl Canyon" model) was used in estimating the current gas generation rate for the Solid Waste Area (M&E, 1993a). The Scholl Canyon model assumes that the refuse reaches peak gas production shortly (2 years) after placement in the landfill. The reduction in gas production potential is assumed to decrease exponentially with time based on a decay constant. The annual production rate is predicted by the following equation:

$$Q_{@time,t} = kL_o e^{-k(t-lag)}$$

Where:

L_o = potential gas generation capacity, V/T;
k = decay constant, 1/T;
t = time since refuse placement, T;
lag = time since refuse placement to peak production, T.

The decay constant, k is dependent on the environmental conditions within the landfill, primarily the moisture content, availability of nutrients, pH and temperature. The value of the decay constant varies widely from 0.004 to 0.2 yr^{-1} and recent values of k have been correlated with studies on landfill settlement (Wall and Zeiss, 1995). The higher decay constants correlate to favorable environmental conditions, i.e. moisture contents between 60 and 80%, stoichiometric balance of nutrients, pH of 4.5 to 6.5, and high ambient temperatures. For New England, where the humid

climate enhances biodegradation, values near the higher end of the range are predictable. For the purposes of this FS, the EPA default value of 0.05 yr^{-1} was utilized (FR, 1996).

The estimation of refuse biodegradability; volume and age; and application of the model using these estimations is described in detail below. The fraction of the refuse which is biodegradable is directly proportional to gas generation. The fraction of biodegradable mass per total unit mass can be estimated assuming a waste composition (i.e. percentages of biodegradable food, garden and paper wastes versus virtually non-biodegradable plastic, textile and wood wastes) and representative empirical formula for each fraction (i.e. carbon, hydrogen, oxygen, nitrogen, and sulfur). Theoretical computations, however, are seldom observed in the field due to non-optimal microbial conditions (i.e., pH, moisture and nutrients) and the presence of inhibiting concentrations of compounds toxic to methanogenic bacteria. In addition, most records kept at landfills do not permit an estimation of the average waste composition. Refuse biodegradability has also been estimated using bioassay; results have varied several orders of magnitude. Because the methods of estimating refuse biodegradability produce wide ranging results, averages have been developed for potential gas generation capacity of domestic refuse. Theoretical values of the gas generation capacity have been investigated by many parties and range widely from 1,600 to 12,000 ft^3 LFG/ton of refuse (Barlaz *et al.*, 1989; Marticorena *et al.*, 1993; Kinman *et al.*, 1987; Marique *et al.*, 1989; Tasbaran, 1982; Findikakis *et al.*, 1988; EMCON, 1980). These values assume a typical value of 25% moisture content for in-place refuse.

The most accurate theoretical gas generation models require a detailed breakdown of municipal waste constituents by weight percentage (e.g. yard wastes, newspaper, food wastes, inerts, etc.). Gas generation coefficients are then applied to each category of waste and summed to obtain the total landfill gas generation rate. Due to the lack of definitive records on the solid waste constituents and the wide range of theoretical estimates discussed above, the EPA default value for the potential gas generation capacity of 3,204 ft^3 LFG/ton of refuse (U.S. EPA, 1997) was used for this FS.

An estimate of volume of waste disposed with time is needed to estimate the current gas generation rate. Prior to 1976, there was no record keeping of the volume of refuse disposed at the Solid Waste Area. In 1976, a plan was prepared for bringing the Solid Waste Area landfill to final closure in 1982. This plan estimated that the annual refuse disposal rate beginning in 1978 would be approximately 20,400 tons (C.E. McGuire, 1977b). This annual filling rate was assumed to be representative of 1976 and 1977, however, the bulky waste fraction of the waste was also included for these years because the Bulky Waste Area at the Site was not yet operating. The 1976 plan also included cross-sections of the then current filling status as extrapolated from several exploratory borings. M&E used this information to establish the approximate volume of waste disposed prior to 1976. The approximate 1970 fill boundary as predicted by aerial photography was then superimposed to further delineate the volume of refuse disposal with time. In summary, the estimated annual refuse disposal rate in tons for the time spans are listed below (M&E, 1993a) for the Solid Waste Area:

1967-1970: 18,667
1971-1975: 10,889
1976-1977: 24,000
1978-1982: 20,400

Active Extraction Well Collection Systems. Key aspects of internal collection systems involve estimating the "radius of influence," screened depths of the extraction wells and the operating vacuum at the well head. Well depth is usually a function of the depth of the specific landfill. Typical depths range from 30 to 200 feet (Zimmermann *et al.*, 1983). A typical rule of thumb is to vertically extend extraction wells down to two-thirds of the total landfill depth.

Horizontal spacing of the extraction wells along the landfill surface depends on the "radius" and "cylinder" of influence concept adopted from water well theory (Zimmermann *et al.*, 1983). It is advantageous to maximize the operating vacuum at the wellhead in order to maximize the radius of influence of the extraction well and minimize the number of wells necessary. However, the maximum vacuum is limited by the need to limit air infiltration.

Operation of each LFG extraction well, and the entire wellfield as a whole, requires constant balancing of the LFG production rate with the rate of LFG extraction. Three typical parameters for balancing LFG extraction versus production include: 1) gas temperature, 2) static wellhead vacuum and 3) gas composition. These are detailed further below (SWANA, 1997):

Gas Temperature. LFG temperature is an indicator of the state of anaerobic conditions at the well. Bacteria may be classified according to temperature as psychrophilic, mesophilic, and thermophilic. These ranges may be thought of on a simplistic and relative basis as cool, warm and hot environments, respectively in terms of the landfill environment and LFG temperatures. The anaerobic methane producing bacteria are slightly exothermic (i.e., they produce heat). The anaerobic bacteria thrive in all three ranges. Temperatures of LFG at the wellhead typically range from 16 to 60 deg. C. (60 to 140 degrees F.). Because of the short residence time, the temperature of the flowing gas measured at the wellhead will usually be very close to that of the waste mass temperature.

Excessive localized overpull (drawing in air) encourages aerobic activity in the well's vicinity and will tend to increase the operating temperature of the well. When LFG temperature is elevated above about 60°C. (140°F.), it could be an indication that aerobic conditions may be present and that the LFG flow should be reduced. This can be confirmed by evaluating the composition of the LFG. Typical wellhead temperature conditions are as follows:

- <60°F Reduce (or stop) flow; LFG extraction rate higher than LFG production rate from well; danger of air intrusion
- 60-140°F Acceptable operation range
- >140°F Reduce (or stop) flow; may be indicator of aerobic activity or landfill fire; well casing PVC temperature limit is typically 165°F (SWANA, 1997)

Static Wellhead Vacuum. Wellhead vacuum is a parameter that is often necessary to accurately calculate and determine flow. This technique relies on the relationship of well pressure/vacuum to flow for a given well. This relationship will be different for each well and will change with time. The technician may adjust the flow from each well judgementally based directly upon the vacuum reading.

- -5" W.C. Reduce (or stop) flow; LFG extraction rate higher than LFG production rate from well; danger of air intrusion
- -5" to +5" W.C. Acceptable operation range

- +5" W.C. or greater — Increase flow; LFG production rate from well greater than LFG extraction rate; danger of fugitive emissions to ambient air

Gas Composition. This technique uses gas composition as a basis for judgement about well adjustment. LFG composition parameters (methane, nitrogen (balance gas), oxygen, and carbon dioxide) are measured at wellheads using portable field instruments and sometimes analytical laboratory equipment. Methane, oxygen and nitrogen are the key parameters. It is usually necessary to measure carbon dioxide in order to determine nitrogen (balance gas). It is recommended that all gas composition parameters be checked whenever possible as this provides a check on the validity of all.

- Oxygen (O_2 at or near 0.0% by volume — Acceptable operation range
- O_2>0.5% by volume — Reduce (or stop) flow; LFG extraction rate higher than LFG production rate from well; danger of air intrusion

By generally staying within the operational ranges above, successful operation of the LFG extraction well system can be achieved.

Approximately 36 wells would be necessary to cover the Solid Waste Area. This number of wells is based on an overall 200-foot well spacing for the Solid Waste Area (22 wells) plus additional wells within the center of the area spaced at 150 feet (14 wells). The most recent standard in the landfill gas industry is for extraction well spacing at intervals of 100 to 200 feet (F.C. Rice & Co., 1997). This well spacing is closer than past literature values which tended to be in the vicinity of 250 feet (U.S. EPA, 1991g; Bagchi, 1990). The closer spacing was selected based on the fact that the depth of waste in the Solid Waste Area is shallower than typical landfills. It may be possible during the remedial design phase to develop measures that would limit air infiltration and therefore make possible a larger radius of influence.

A typical internal extraction well is shown in Figure 3-12. Design of these well systems typically must include integration with other technologies such as landfill caps, surface runoff controls and any other surface structures or features.

Collection piping and condensate generation will be similar to that previously discussed for perimeter collection systems. Collection piping may be placed above the existing cover or below depending on final design considerations. Condensate generation will typically be larger (on a per volume of gas basis) and may have higher concentrations of contaminants than perimeter systems. Direct, internal landfill gas usually is at a higher temperature and thus can hold (and later lose) more moisture than perimeter gas. Furthermore, internal landfill gas is in more intimate contact with the waste fill than perimeter gas. This may result in higher concentrations of contaminants.

3.1.8.4 Passive Venting in the Bulky Waste Area. Active collection and treatment of landfill gas generated in the Bulky Waste Area was determined to be unnecessary due to the lack of human-health risk from these landfill gas emissions (M&E, 1993a; M&E, 1998). More recent calculations of the Bulky Waste Area landfill gas emissions are presented in Appendix E. If the Bulky Waste Area undergoes landfill mining as part of the selected remedy, landfill gas generation would no longer be a concern because the waste would have been removed from this area. Hence, neither active collection nor passive venting would be necessary. However, if the selected remedy includes capping of the Bulky Waste Area, a passive venting system is proposed as part of the landfill cap design to provide a conduit for any landfill gases generated. Regulatory clarifications with regard to passive venting of landfill gas are presented in Appendix E. The passive venting system would consist of approximately 10 vertical rise pipes spread over the Bulky Waste Area and connected to a 1-foot-thick gas vent layer placed below the geomembrane.

3.1.9 Landfill Gas Treatment: Enclosed Flare

Landfill gas treatment is commonly performed thermally using an enclosed flare. A general schematic for an enclosed landfill gas flare is shown in Figure 3-13. The enclosed flare consists of a burner assembly surrounded by a tall refractory cylinder or stack. The stack is open at the top to allow discharge of the gaseous combustion products to ambient air. Stack openings at the base contain louver controls to allow air flow into the burner. The stack also contains temperature indicators as well as sampling ports to collect stack gas samples. Additional mechanical

appurtenances and support equipment include a pilot gas propane tank to ignite the pilot light, blowers to convey the flare feed gas, control valves, flame arresters, a condensate knock-out drum, an underground condensate storage tank, and concrete equipment pad with security fence.

Key technical aspects of enclosed flares include: temperature, time and turbulence. These factors dictate the destruction efficiencies that can be achieved (Tessitore *et al.*, 1990). Specifically these aspects are: 1) flue gas temperature or combustion temperature, 2) residence time within flare, and 3) turbulence or mixing within flare (to promote destruction efficiency). Other important aspects of enclosed flares are the stack dimensions (height and diameter) as well as exit gas exit velocity. These factors all are necessary inputs for an air dispersion model that assists in calculating risk to human health and other receptors (M&E, 1993a). Flare sizing rationale is presented in Table 3-6.

The collection and treatment system triggers Rhode Island air quality control regulations. Since the Rose Hill Regional Landfill site is a Superfund site, an air permit from the RIDEM Department of Air Quality would not be required. However, all permitting and operating requirements must still be followed.

Three streams enter a standard enclosed flare: 1) the feed gas to be burned, 2) excess air to supply sufficient oxygen for combustion, and 3) "quench" air to cool down the flare since combustion gives off heat which may damage the refractory wall. Due to the estimated high volume of the perimeter gas stream (Appendix E), an alternative flare design which utilizes this stream as combustion air is appropriate. The flare feed gas would then consist of flow from the internal collection system and possibly auxiliary fuel such as propane or natural gas. Auxiliary fuel may need to be added to the mixture to ensure that the feed gas has adequate heat or BTU-content to support stable flare combustion.

Fuel Requirements. Two types of fuel purchases will be necessary to operate the flare system; auxiliary fuel and pilot gas. Auxiliary fuel may be required to maintain a minimum BTU content for stable combustion. In order to ensure complete and continuous combustion, flare vendors

recommend a minimum fuel requirement equivalent to methane concentrations ranging from 15 to 35% by volume (John Zink Company, 1993). Based on initial LFG generation estimates, operation of the flare would initially require a small amount of auxiliary fuel to sustain proper combustion temperatures. However, the LFG generation rate reduces over time, thereby increasing the auxiliary fuel requirements. One method of operation for reducing or removing this need is to operate the flare on a timer so that LFG volumes can build up prior to collection. This method may not be appropriate due to the need for management of migration through operation of the perimeter collection system. Appendix E provides estimated auxiliary fuel requirements for the assumed LFG collection rates and assumed 24-hour operation. The standard auxiliary fuel for landfills is propane, however, extending a natural gas line to the site may also be appropriate. For the purposes of this FS, propane will be assumed as the auxiliary fuel based on higher heating value and initial order-of-magnitude cost comparison.

Pilot fuel (propane) will also be necessary for start-up and to provide backup if the main fuel source (i.e. feed gas) is interrupted. Pilot fuel maintains stable flare combustion and thus operating temperatures with the corresponding contaminant destruction removal efficiencies necessary to meet ARARs and risk criteria.

3.1.10 Landfill Gas Treatment: Photocatalytic Oxidation

Photocatalytic oxidation is an innovative treatment technology that removes and destroys organic contaminants in gaseous or aqueous streams using a fixed bed catalyst activated by ultraviolet (UV) light. Several variations of the photocatalytic oxidation technology for treatment of contaminated air streams have been demonstrated as part of EPA's SITE Program (U.S. EPA, 1994b). In response to comments from RIDEM on the Draft Final FS report (M&E, 1996c), in which RIDEM recommended that innovative technologies be considered as an alternative to flaring for treatment of landfill gas, this technology was evaluated in a technical memorandum (Appendix A) and has been retained for detailed evaluation. It was retained primarily because it does not require use of

auxiliary fuel, and hence may offer a cost advantage over thermal treatment via an enclosed flare. A summary of the information developed for the technical memorandum is presented below.

3.1.10.1 General Process Description. In general terms, the contaminated gas stream is fed into a reactor containing a solid catalyst material that is illuminated by UV light (Figure 3-14). Organic contaminants in the gas may adsorb to the solid material and may also absorb UV light; such absorption may cause the contaminant to decompose or become more susceptible to oxidation. The primary purpose of the UV light, however, is to activate the catalyst by exciting electrons on the catalyst surface, freeing them to react with adsorbed organic contaminants. Free electrons, or free radicals such as the hydroxyl radical (•OH) or the chlorine free radical (•Cl), are formed. These radicals initiate a series of chain oxidation reactions that ultimately result in the complete destruction of an organic contaminant into carbon dioxide, hydrogen chloride, and chlorine gas (Nimlos *et al.*, 1995). The hydrogen chloride and chlorine gas can be removed, if necessary, by a caustic scrubber before the treated gas is exhausted to the atmosphere. Research has shown that organic products of incomplete oxidation are also formed, but these products can themselves be oxidized given sufficient residence time in the reactor (Nimlos *et al.*, 1995). In a variation of the technology developed by Process Technologies, Inc. (Figure 3-15), it is claimed that the formation of harmful intermediate oxidation products, hydrogen chloride, and chlorine gas is inhibited by the solid material in the reactor (U.S. EPA, 1994).

3.1.10.2 Technology Applications. The primary application of the technology with respect to site remediation is for treatment of off-gases from air strippers and soil vapor extraction systems to remove VOCs. The technology is being developed and marketed as an alternative to activated carbon adsorption and catalytic or thermal oxidation for destruction of VOCs in these contaminated air streams. Advantages of the technology over carbon adsorption, catalytic oxidation, and thermal oxidation that are cited by the technology developers include: the ability to destroy VOCs at ambient temperature, eliminating the need for auxiliary fuel; no production of undesirable nitrogen oxides (as occurs during high temperature oxidation); and minimal generation of secondary wastes requiring regeneration or disposal (as occurs for carbon treatment systems). Other applications of

the technology include treatment of various industrial emissions sources, such as paint spray booths (BTEX compounds), bakeries and breweries (ethanol), the polystyrene industry (pentane), and contact lens manufacturing (hexane) (Nimlos *et al.*, 1995; Kittrell *et al.*, 1996 and b; Matrix Photocatalytic, Inc., 1997).

Three developers of photocatalytic oxidation technologies were contacted for general information on their processes as well as to discuss the specific application of their technologies for treatment of landfill gas. None of the technologies are currently developed for destruction of methane, but they have been demonstrated for destruction of other VOCs of potential concern at the Site. One developer (KSE, Inc.) is currently constructing a prototype unit for NASA that is intended for the oxidation of methane. However, given the early stage of development of the prototype, it is not possible to evaluate the effectiveness, implementability, and cost of this technology for methane destruction. Hence, photocatalytic oxidation will be evaluated with respect to its ability to destroy VOCs of potential concern, in particular vinyl chloride.

The technical rationale and assumptions on which the evaluation of this technology will be based are presented in Table 3-7. Similar to the enclosed flare technology, the photocatalytic oxidation technology also triggers Rhode Island air quality control regulations. The estimated emission rate of methane from a photocatalytic oxidation unit at the Site would be approximately 80 lb/hour, assuming no destruction of methane occurs in the unit (Appendix E). Emission rates greater than 10 lb/hour trigger the need for a permit from the RIDEM Department of Air Quality (Air Pollution Control Rule 12-031-009). Although a permit is not needed on a Superfund site, the substantive requirements of the permitting process would need to be met. This technology would be best utilized if the landfill is found to be generating a lower amount of methane compared to estimated values.

3.1.10.3 Residuals. The oxidation of the halogenated organic compounds present in the landfill gas, such as vinyl chloride, will result in the production of hydrogen chloride (HCl) and chlorine gas (Cl_2). According to KSE, Inc., for their system a gas stream containing 150 ppmv of vinyl chloride

would typically yield 70 ppmv of chlorine gas and 10 ppmv of hydrogen chloride. The exhaust from the photocatalytic reactor may be treated by scrubbing with caustic to remove these gases, if removal is necessary to meet Rhode Island air quality control regulations or to protect downstream equipment from corrosion. An emission rate for HCl of greater than 1.14 lb/hour would trigger the need to comply with the substantive requirements of the RIDEM Department of Air Quality permitting process, and the RIDEM Department of Air Quality could require that HCl be removed by scrubbing (Air Pollution Control Rule 12-031-009). However, material balance calculations (Appendix E) indicate that the HCl emission rate for a photocatalytic oxidation unit at the Site would not exceed 1.14 lb/hour. The estimated maximum HCl emission rate is 0.32 lb/hour. Hence, it is assumed that a scrubber will not be needed if the photocatalytic oxidation alternative is implemented.

3.2 COMPILATION OF REMEDIATION COMPONENTS INTO REMEDIAL ALTERNATIVES

The National Contingency Plan (NCP) requires that a range of alternatives be developed and evaluated such that an appropriate remedy can be selected. A range of options must be developed that extend from an alternative that remediates the Site to the maximum extent feasible to other alternatives that vary in the degree of treatment, including one or more alternative(s) that involve little or no treatment but do involve engineering or institutional controls to reduce risk (40 CFR 300.430(e)). The NCP further provides for the option of performing an alternative screening step "...when needed to select a reasonable number of alternatives for detailed analysis" (40 CFR 300.430(e)(1)). Since municipal landfill sites lend themselves to remediation by similar approaches (U.S. EPA, 1991a), a limited number of alternatives are developed in this section; an alternative screening step is considered unnecessary and is not performed.

In this section, the remediation components described in the previous section are combined into remedial alternatives that meet the NCP and guidance requirements, and that address the RAOs developed in Section 2.0. The five alternatives developed are summarized in Table 3-8.

3.2.1 Alternative #1: No Action

The no action alternative is provided as a baseline for comparison with other alternatives, as required by the NCP. Under this alternative, no actions are taken to prevent ingestion of COPCs or to limit migration of contaminated groundwater, leachate, or landfill gas. The alternative includes environmental monitoring, five-year reviews, and ongoing community relations activities to assess and monitor risks to human health and the environment and to communicate the results of these findings. These alternative components are discussed in greater detail in Section 4.0.

Because wastes would remain on the Site under this alternative, CERCLA §121(c) requires that the Site be subject to periodic monitoring as well as a re-evaluation every five years. The focus of the five-year review would be dependent upon the goals set in the Record of Decision (ROD).

3.2.2 Alternative #2: Limited Action

This alternative is intended as a limited action approach which would mitigate, to some degree, human health risk by preventing and controlling exposure to site COPCs through institutional controls. This alternative would include the following components: groundwater access restrictions, landfill gas access restrictions, a residential LFG control contingency, environmental monitoring, five-year reviews, and on-going community relations activities.

Groundwater access restrictions would be utilized to meet the human health RAO for preventing ingestion of groundwater contaminated by site COPCs. Landfill gas access restrictions at the Solid Waste Area mitigate ambient air human health risks to a limited extent by preventing humans from walking or driving on the disposal area. The residential LFG control contingency would be utilized to achieve the RAO for mitigating safety risks of fire/explosion at off-site properties from migrating landfill gas. To a limited extent, the residential LFG control contingency also prevents inhalation of site COPCs in ambient air that migrate to residences via soil gas.

The rationale for the environmental monitoring program, five-year reviews, and community relations activities would be the same as that defined for Alternative #1.

The RAOs related to ecological risks to surface water and sediments are not achieved with the limited action approach since containment or removal of disposal areas (Solid Waste and Bulky Waste) is not part of this alternative. The human health risk RAOs for ambient air are unlikely to be met since emissions from the Solid Waste Area are not controlled or mitigated.

3.2.3a Alternative #3a: Horizontal Containment of Solid Waste and Bulky Waste Areas, Gas Collection and Thermal Treatment

This alternative mitigates human health risks by combining the limited action components of Alternative #2 with containment of the Solid Waste and Bulky Waste Areas and collection of landfill gas. This alternative would include the following components: groundwater access restrictions, horizontal containment for both the Solid Waste and Bulky Waste Areas, active perimeter and internal LFG collection for the Solid Waste Area followed by thermal treatment, passive LFG collection for the Bulky Waste Area, environmental monitoring, five-year reviews, and on-going community relations activities.

As with Alternative #2, groundwater access restrictions would be utilized to meet the human health RAO for preventing ingestion of groundwater contaminated by site COPCs. Achievement of these groundwater RAOs is improved by the addition of horizontal containment at both the Solid Waste and Bulky Waste Areas.

Horizontal containment mitigates the ecological risks to Mitchell Brook from the Solid Waste Area by reducing infiltration and eliminating leachate breakouts. Therefore, this alternative achieves the ecological RAO for Mitchell Brook. Similarly, ecological risks to the Saugatucket River are substantially reduced through horizontal containment of the Bulky Waste Area.

Human health RAOs for ambient air are achieved in this alternative by a combination of active internal and active perimeter LFG collection in the Solid Waste Area followed by thermal treatment.

The active perimeter LFG collection system (Solid Waste Area), passive internal LFG collection system (Bulky Waste Area), and appropriate environmental monitoring all combine to achieve the safety risk RAOs for soil gas.

This alternative does not fully achieve the ecological risk RAO for the Saugatucket River since leachate is not collected or treated.

3.2.3b Alternative #3b: Horizontal Containment of Solid Waste and Bulky Waste Areas, Gas Collection and Treatment by Photocatalytic Oxidation

This alternative is identical to Alternative #3a, except that the gas collected by the active perimeter and internal LFG systems at the Solid Waste Area is treated by photocatalytic oxidation instead of a flare. RAOs for ambient air can be met by photocatalytic oxidation as well as by thermal treatment, because the technology is effective in destroying chlorinated VOCs. Detailed evaluation of this alternative along with Alternative #3a is being conducted because, although both meet RAOs equally, the alternatives will vary with respect to implementability, cost, and compliance with ARARs.

3.2.4a Alternative #4a: Horizontal Containment of Solid Waste and Bulky Waste Areas, Leachate Collection and On-Site Treatment, Gas Collection and Treatment

This alternative provides additional mitigation of ecological risks when compared with Alternatives #3a and 3b by collection and treatment of leachate from the Bulky Waste Area. For the purposes of detailed evaluation thermal treatment has been included as the gas treatment technology, although photocatalytic oxidation could be substituted depending on the results of the comparative analysis between Alternatives #3a and #3b. Mitigation of human health risks remains the same as Alternatives #3a and 3b. Components of this alternative would include all of those identified for

Alternatives #3a and 3b plus the following: Bulky Waste Area leachate collection, on-site treatment, and discharge.

All human health and ecological risk RAOs are met with this alternative by addressing all the site media of concern: groundwater, surface water/sediments, ambient air, and soil gas.

3.2.4b Alternative #4b: Horizontal Containment of Solid Waste Area, Landfill Mining of Bulky Waste Area, Leachate Collection and On-Site Treatment, Gas Collection and Thermal Treatment

This alternative differs from Alternative #4a in that the Bulky Waste Area is remediated by landfill mining, rather than containment. This alternative provides additional mitigation of ecological risks when compared with Alternatives #3a and 3b because it removes the major source contributing to the generation of contaminated leachate from the Bulky Waste Area. Ecological risks due to leachate entering the Saugatucket River must still be mitigated similar to Alternative #4a using leachate collection and treatment, but these processes will not be required for the entire remedial action time period due to source removal. This alternative offers the benefit over Alternative #4a of potentially being able to restore the Bulky Waste Area to natural conditions.

Mitigation of human health risks remains the same as Alternatives #3a, 3b, and 4a. Components of this alternative would include those identified for Alternatives #3a and 3b, except for horizontal containment of the Bulky Waste Area which is replaced by landfill mining.

3.2.5a Alternative #5a: Horizontal Containment of Solid Waste and Bulky Waste Areas, Groundwater and Leachate Collection and On-Site Treatment, Gas Collection and Thermal Treatment

This alternative further mitigates both human health and ecological risk by depressing and collecting groundwater from the Solid Waste Area thereby minimizing the impacts of COPCs from this area. Alternative #5a would include the same components identified in Alternative #4a with the exception that leachate collection, treatment, and discharge would also include groundwater from the Solid

Waste Area. The gas treatment technology is thermal treatment for the purposes of detailed evaluation.

3.2.5b Alternative #5b: Horizontal Containment of Solid Waste Area, Landfill Mining of Bulky Waste Area, Groundwater and Leachate Collection and On-Site Treatment, Gas Collection and Thermal Treatment

This alternative includes the same components as Alternative #5a, with the exception that containment for the Bulky Waste Area is replaced by landfill mining. This alternative provides the same mitigation of human health risks as Alternative #5a. The substitution of landfill mining for containment still requires leachate collection at the Bulky Waste Area for mitigation of ecological impacts to the Saugatucket River. However, this alternative offers the ecological benefit of potential restoration of the Bulky Waste Area to natural conditions.

SECTION 4.0
DETAILED EVALUATION OF REMEDIAL ALTERNATIVES

This section presents the results of the detailed evaluation of remedial action alternatives. This detailed evaluation has been performed to support the selection of a remedy for the Rose Hill Regional Landfill site, pursuant to 40 CFR §300.430(e), and provides the basis for regulatory agency and public review of remedial alternatives. The eight site remedial alternatives formed in Section 3.2 are evaluated in this section.

This detailed evaluation of remedial alternatives for the Site was prepared in accordance with the requirements of the NCP (40 CFR §300.430(e)(9)), using the following criteria:

- Overall protection of human health and the environment
- Compliance with applicable or relevant and appropriate requirements (ARARs)
- Long-term effectiveness and permanence
- Reduction of toxicity, mobility or volume through treatment
- Short-term effectiveness
- Implementability
- Cost
- State acceptance
- Community acceptance

These criteria are defined in detail in Table 4-1. Each of the following sections is comprised of a detailed description of an alternative, emphasizing the application of the technologies, plus the alternative's detailed evaluation based on the above criteria. The nine evaluation criteria defined in Table 4-1 encompass statutory requirements and technical, cost, and institutional considerations.

The first two criteria are called the threshold criteria and relate directly to statutory findings that must ultimately be made in the Record of Decision (ROD); any alternative ultimately selected must meet these criteria. The next five criteria, grouped as the balancing criteria, represent the primary criteria upon which the detailed analysis is based. The final criteria, state and community acceptance, are modifying criteria and are not evaluated in this document at this time; the modifying criteria assessments will be addressed in the ROD once the Proposed Plan is completed and comments on this FS and the Proposed Plan have been received.

The detailed evaluation of each alternative includes an introductory section which identifies and discusses the specific components of that alternative prior to the evaluation of the alternative versus the nine criteria.

4.1 EVALUATION OF ALTERNATIVE #1: NO ACTION

This section describes the components of Alternative #1 followed by detailed evaluation of those components versus the nine FS criteria.

4.1.1 Definition of Alternative #1

Alternative #1, the no action alternative, though generally not considered acceptable, is analyzed with all of the remedial alternatives for comparative purposes, as required by the NCP. Alternative #1 entails leaving the Site as it currently exists with no remedial work to be performed within or outside of the limits of the site boundaries. At present, the Site has undergone minimal remedial efforts. As shown by the RI, migration of site COPCs continues to occur with subsequent human health and ecological exposures.

The major components of this alternative include:

- Environmental Monitoring. Environmental monitoring includes monitoring of groundwater, surface water/sediment, ambient air, and soil gas. Monitoring locations, frequencies and analytes for groundwater and surface water/sediment are listed in Table 4-2. Ambient air and soil gas monitoring locations, frequencies and analytes are listed in Table 4-3.

  The detailed rationale for environmental monitoring locations, frequencies and analytes is discussed in Section 4.1.1.1.

- Five-Year Review. Because this alternative would result in contaminants remaining on the Site, CERCLA §121© and §300.430(f)(4)(ii) of the NCP require that the Site be reviewed every five years. Quarterly monitoring results collected over the previous five years would be compiled and evaluated for contaminant migration trends, as well as compared to ARARs. An assessment of human health and ecological risks would also be conducted, to bring the baseline up-to-date. This alternative would then be re-evaluated using the new data, and a determination made as to whether or not additional remedial actions were necessary.

- Community Relations Activities. As the remedy for the Proposed Plan is devised and implemented, on-going community relations activities will be conducted to provide appropriate information, receive comment on that information and to adjust the remedy at key milestones.

Figure 4-1 illustrates the site layout for Alternative #1. The components of the alternative, and how they interact with each media of concern, are presented on Figure 4-2.

4.1.1.1 Environmental Monitoring. In accordance with RCRA groundwater monitoring requirements, 40 CFR 264.95-264.100, long-term monitoring of site groundwater is necessary to measure the progress of the remedy and to ensure that the selected remedial alternative is protective of human health and the environment. Additional performance monitoring may be required for evaluating natural attenuation of the contaminants. Furthermore, surface water/sediment, ambient air, and soil gas would also be monitored on a periodic basis.

Groundwater. The groundwater locations that would be sampled as part of the long-term monitoring program are presented in Table 4-2 and are shown in Figure 4-1. To establish a baseline of current COPC concentrations and determine seasonal variations, all of the new and existing

monitoring wells (36 locations) sampled during the RI plus seven residential wells would be sampled quarterly for the first year (43 locations total). Comparison of current COPC concentrations with results found during the RI would identify changes in groundwater chemistry and monitor migration of COPCs from the Site. Monitoring of all of the new and existing monitoring wells should provide sufficient coverage of the Site in terms of background, source area, and downgradient conditions in each of the site groundwater flow zones (shallow overburden, deep overburden, and bedrock). The residential wells selected correspond to properties that are not currently connected to the Wakefield Water Supply line.

Following the first year, the number of site monitoring wells and the frequency of sampling may be reduced based on the findings from the first year's data. For purposes of estimating costs in this FS, it is assumed that starting the second year of the remedy, the sampling program would be conducted on a semi-annual basis at one-half of the site monitoring wells and residential wells presented in Table 4-2 (21 locations total).

Parameters selected for groundwater monitoring consist of volatile organic compounds (VOCs) including acrylamide, semivolatile organic compounds (SVOCs), and total metals. It is assumed that samples will be collected using EPA Region I low-flow groundwater sample collection methods. The parameters selected include the site COPCs.

Monitoring used to evaluate natural attenuation of COPCs at the site may include parameters such as dissolved oxygen, nitrate, nitrite, dissolved ferrous iron, sulfate, pH, redox potential and dissolved hydrogen. Selection of the site-specific parameters to be used should be performed during the design phase of the project.

Surface Water/Sediment Monitoring. The surface water/sediment monitoring program would be similar to the groundwater monitoring program. All of the surface water/sediment locations sampled during the RI (Table 4-2 and Figure 4-1) would be monitored quarterly for the first year (18 locations total). Following the first year, the number of surface water/sediment locations and the frequency

of sampling may be reduced based on the findings from the first year's data. For the purposes of estimating costs in this FS, it is assumed that starting the second year of the remedy, the sampling program would be conducted on a semi-annual basis at one-half of the surface water/sediment locations presented in Table 4-2 (9 locations total).

Parameters selected for surface water/sediment monitoring consist of VOCs including acrylamide, SVOCs, and total metals. The parameters selected include the site COPCs.

Ambient Air Monitoring. Ambient air monitoring is required to characterize impacts of migrating landfill gases on ambient air quality. The ambient air monitoring program is presented in Table 4-3. To establish a baseline of current COPC concentrations and evaluate seasonal variations, if any, six locations would be sampled quarterly for the first year. These results would be compared with ambient air results from the LFG removal action (U.S. EPA, 1993c). The six locations would include: three stations in the Solid Waste Area, two stations in the Bulky Waste Area, and one background station at an upwind location on the day of sampling. It should be noted that monitoring of indoor air in residential basements would not occur under any alternative in this FS since this is being conducted as part of the LFG removal action.

Following the first year, the number of ambient air monitoring locations and the frequency of sampling may be reduced based on the findings from the first years' data. For purposes of estimating costs in this FS, it is assumed that starting the second year of the remedy, the sampling program would be conducted on a semi-annual basis at only four locations.

The analytes proposed to be tested for would include: volatile organic compounds (TO-14 organics), sulfur, and odor causing compounds such as mercaptans and hydrogen sulfide (H_2S) and methane (CH_4). This list of analytes would include all potential COPCs for landfill gas as well as major compounds that could create odors. Methane is included to provide data to correlate methane concentrations, which can be easily measured using field instruments, with concentrations of COPCs which generally require analytical measurement.

Soil Gas Monitoring. Measurements of soil gas concentrations are needed to provide an indication of lateral migration of landfill gas into adjacent vadose zone soils from the Solid Waste and Bulky Waste Areas. Existing permanent soil gas points from the RI would be converted to permanent points for long-term monitoring and used to measure these soil gas concentrations. Conversion to permanent points would involve drilling to greater depths and installation of more secure housings at the ground surface.

The locations for perimeter soil gas monitoring would include three sides of the Solid Waste Area: 1) the northern edge of the area, 2) the western boundary with Rose Hill Road, and 3) the southern boundary with the transfer station access road. These boundaries would be covered by permanent soil gas monitoring points. A representative number of these points would be selected to characterize landfill gas migration in these directions. At a minimum, one soil gas point should be monitored for every 200 feet of perimeter distance, resulting in a minimum of 32 points for monitoring. In addition, two permanent locations would be selected within the Solid Waste Area along with one location within the Bulky Waste Area for comparison of source area results to perimeter results. This would result in a total of 35 locations for soil gas monitoring. The frequency of soil gas monitoring would be quarterly during the first year of the remedy to evaluate seasonal variance of landfill gas migration.

Following the first year, the number of soil gas monitoring locations and the frequency of sampling may be reduced based on the findings from the first years' data. For purposes of estimating costs in this FS, it is assumed that starting the second year of the remedy, the sampling program would be conducted on a semi-annual basis at 18 locations.

The analytes proposed to be tested for would include: methane, carbon dioxide (CO_2), oxygen (O_2), and vinyl chloride as an indicator compound for volatile COPCs. Analytical methods would only be used to verify field results during the first sampling round. Field instruments and test kits would be used to conduct analyses and select which samples would be sent for laboratory analysis. Field instruments such as the Model 1939 GasTechtor™, manufactured by GasTech, can monitor methane

(total explosive gas measured as methane) and oxygen. Field test kits such as Draeger™ adsorbent indicator tubes, manufactured by Drägerwerk Aktiengesellschaft of Germany, can test for carbon dioxide and selected volatile organic COPCs in relatively high concentrations.

Soil gas points would be modified or constructed with air-tight seals to minimize escape of volatile constituents (such as vinyl chloride) during testing. This may take the form of sample taps with appropriate valves and tubing that can directly connect to the sampling instruments.

4.1.2 Nine Criteria Evaluation of Alternative #1

The analysis of Alternative #1 with respect to the nine criteria is presented in a narrative form in the following paragraphs. The assessment focuses on how, and to what extent, the factors within each of the criteria are addressed. Evaluations of the criteria focus on the two primary means for migration of COPCs into site media; e.g. leachate from the disposal areas impacting groundwater and surface water/sediment and landfill gas affecting ambient air and soil gas.

4.1.2.1 Overall Protection of Human Health and the Environment from Alternative #1. Alternative #1 would not provide any protection of human health from risks identified in the baseline human health risk assessment (M&E, 1994; M&E, 1998). Current baseline risks to human health from inhalation of COPCs from landfill soil gas at the Solid Waste Area and at nearby residences are in excess of the EPA target cancer risk range of 10^{-4} to 10^{-6}. Future baseline risks to human health from ingestion of COPCs in groundwater at the Site are in excess of the EPA target cancer risk range under an assumption of residential use of the Site. However, future consumption of groundwater at the Site is not considered likely as a result of the groundwater classifications at the Site. As discussed in Section 2.4.1.4, however, this risk is not considered to be associated with the Site. Because there would be no removal or containment of contamination with this alternative, risks to potential receptors at the Site and in the vicinity of the Site would continue. There would be no additional short-term human health risks associated with this alternative. Specific long-term and short-term human health risks are discussed in Sections 4.1.2.3 and 4.1.2.5, respectively.

This alternative would not be protective of ecological resources as there would be no reduction in long- or short-term risks relative to existing (baseline) conditions. The documented adverse impacts to the benthic community in Mitchell Brook and the Saugatucket River would persist, as would possible adverse impacts to other wetland and aquatic species. There would be no reduction in contaminant migration via leachate and groundwater from the Site to these two water bodies. Other than the continued presence of contaminants in on-site media, there would be no direct impacts to wetlands and other wildlife habitats under the no action alternative, since no disturbance of these habitats would occur.

Alternative #1 fails to meet the RAOs for the Site and does not reduce risks to human health and the environment below baseline levels.

4.1.2.2 Compliance With ARARs from Alternative #1. Action-specific ARARs under this alternative are presented in Table 4-4. Any remedial actions taken under this alternative must comply with the ARARs listed in this table. Environmental monitoring will be used as an indicator of compliance with the site-specific chemical and location-specific ARARs described in Section 2.3. As this is a no action alternative, ARARs are not expected to be fully met.

4.1.2.3 Long-term Effectiveness and Permanence from Alternative #1. This alternative is evaluated below in terms of the risk remaining at the Site after RAOs are addressed. This portion of the evaluation focuses on the extent and effectiveness of the controls required to manage the risk posed by treatment residuals and/or untreated contamination.

Magnitude of Residual Risks. The no action alternative implements no controls to reduce the release of leachate to groundwater or landfill gas to air. It also includes no controls to prevent human contact with groundwater. Residual risks would include those risks identified in Section 2.0 as there would be no reduction of health risks with this alternative. Media associated with baseline health risks include groundwater, indoor air, and ambient air.

Carcinogenic human health risk to a visitor from inhalation of landfill gas components at the Solid Waste Area is estimated at 4.4×10^{-4}, based on maximum concentrations in landfill gas (see Table 2-1BO) (M&E, 1998). Carcinogenic risk to a resident from inhalation of landfill gas components in ambient air at nearby residential locations is estimated as 8.1×10^{-5} (see Table 2-1BM), based on modeling from maximum landfill gas concentrations (M&E, 1998). Carcinogenic risk from indoor inhalation of landfill gas components at a future residence is estimated as 1.9×10^{-3} (see Table 2-1BM) based on the maximum concentration of vinyl chloride measured in an off-site residential basement (M&E, 1998). Two residences, numbers 278 and 349 Rose Hill Road, currently have methane sensors with an alarm and ventilation system installed in their basements. Carcinogenic risk from indoor inhalation of landfill gas components at these residences is estimated to be 4.9×10^{-4} (see Table 2-1BK). This risk estimate is based on the estimated maximum concentration of vinyl chloride that could accumulate in a basement without detection of methane by the methane sensors and subsequent ventilation of the basement. This risk estimate could be exceeded at homes lacking an alarm and ventilation system.

Carcinogenic and non-carcinogenic risks to a potential future resident at the Site from ingestion of groundwater is estimated as 2.8×10^{-2} and 51, respectively, based on maximum concentrations of COPCs in Solid Waste Area groundwater (M&E, 1998). However, future consumption of groundwater at the Site is not considered likely as a result of groundwater reclassification as discussed in Section 1.0.

A hazard index of 17 is estimated for an off-site receptor at a nearby residence from ingestion of manganese in residential well water, exceeding the EPA target non-cancer risk limit of 1. As discussed in Section 2.4.1.4, this risk is not considered to be associated with the Site. Landfill refuse is believed to be in contact with groundwater at the Site, creating a continuous source of groundwater contamination. Residual risks with this alternative include human health risks from groundwater ingestion if the plume of groundwater contamination migrates to off-site residential well locations.

Residual risks would also include those risks identified in the baseline ecological risk assessment. The medium associated with significant baseline ecological risks includes the surface waters of Mitchell Brook and the Saugatucket River (due to contamination from on-site leachate discharges). The no action alternative would not result in a quantifiable long-term reduction in risk to ecological receptors since leachate would continue to be generated and enter Mitchell Brook and the Saugatucket River. Ecological exposures would continue over the long term and contaminant migration would continue to Mitchell Brook and the Saugatucket River. Documented adverse impacts to the aquatic community in these surface water bodies would persist.

Adequacy of Controls. Measures are described below that detail controls to be placed on untreated waste, waste-contaminated media, and treatment residuals from implementation of Alternative #1. Under this alternative, no measures would be conducted for untreated waste at the Site beyond remediation by natural attenuation. There would, therefore, be no treatment residuals generated in this alternative.

Groundwater/Leachate. There are no measures which would eliminate the source in this alternative. Monitoring of groundwater and surface water, however, would be part of the alternative and would monitor progress of any natural attenuation that occurs.

Landfill Gas. No measures are implemented in this alternative that remediate, capture, or treat landfill gas. Monitoring of ambient air and soil gas, however, would be part of the alternative and would monitor progress of any natural attenuation that occurs.

Reliability of Controls. Evaluations are described below that detail the effectiveness, reliability, and permanence control measures that are provided to protect human health and the environment from untreated waste and waste-contaminated media.

Groundwater/Leachate. In this alternative, there are no measures which would assist in protection against untreated waste or waste-contaminated media at the Site. However, monitoring of groundwater and surface water would provide an accurate measure of plume migration and/or any natural attenuation that may be occurring, thus providing a basis for modification of the remedy, if required.

Landfill Gas. Similar to groundwater/leachate, monitoring of air and landfill gas would provide a basis for implementation of additional controls, if required.

Need for Five-Year Review. Because wastes would remain on the Site under this alternative, CERCLA §121(c) and the NCP at §300.430(f)(4)(ii) require that a five-year review be conducted every five years until it is demonstrated that there is no longer a threat to human health or the environment from the Site. For the purpose of this FS and costing, it is assumed that a "Level I" review, the lowest level, would be conducted.

4.1.2.4 Reduction of Toxicity, Mobility or Volume through Treatment from Alternative #1. This criteria evaluates how the alternative mitigates the effects of site COPCs by describing the following: treatment technologies and process options utilized, quantity of site COPCs/contaminated media affected, degree of expected reductions in mobility of site COPCs into the environment, degree to which the treatment is irreversible, and the residuals remaining after treatment.

Treatment/Recycling Processes Utilized. The treatment, recycling and other mitigation processes of the remedy and any materials treated are listed below for this alternative:

Groundwater/Leachate. No treatment processes utilized.

Landfill Gas. No treatment processes utilized.

Amount of Hazardous Materials Treated or Recycled. The quantities or volumes of materials containing COPCs that are destroyed, recycled or treated are detailed below. These quantities may also include other hazardous materials that are involved in the remedy.

Groundwater/Leachate. None.

Landfill Gas. None.

Degree of Expected Reductions in Toxicity or Mobility. The expected degree of reductions in toxicity or mobility of the COPCs in site media are detailed below.

Groundwater/Leachate. None, except for natural attenuation.

Landfill Gas. None, except for natural attenuation.

Degree to Which Treatment Is Irreversible. The degree to which treatment, recycling or other appropriate remedial components of the selected remedy are irreversible is evaluated below.

Groundwater/Leachate. There are no remedial components in this alternative which may be evaluated for irreversibility.

Landfill Gas. There are no remedial components in this alternative which may be evaluated for irreversibility.

Type and Quantity of Residuals Remaining After Treatment. The quantity and composition of residuals generated by treatment processes in this alternative are described below. These residuals may require further disposal and handling.

Groundwater/Leachate. This alternative would not involve any treatment of groundwater/leachate and, therefore, would not generate any residuals.

Landfill Gas. This alternative would not involve any treatment of landfill gas and, therefore, would not generate any residuals.

4.1.2.5 Short-term Effectiveness of Alternative #1. This alternative is evaluated for effectiveness in protecting the community and local workers, site remediation workers, and the environment during the construction and implementation of the remedy.

Community Protection. Since this alternative involves no construction measures, there would not be an additional risk to the community from exposure to contaminants.

Worker Protection. Since this alternative involves no construction measures, there would not be an additional risk to workers from exposure to contaminants.

Environmental Protection. The no action alternative does not result in a quantifiable short-term increase or reduction in risk to ecological receptors. Ecological exposures would continue over the short term at baseline levels and contaminant migration would continue to Mitchell Brook and the Saugatucket River. Documented adverse impacts to the aquatic community in these surface water bodies would persist. Short-term habitat impacts due to remedial activities would not occur.

Time Until Remedial Action Objectives are Achieved. Estimates for the time to achieve RAOs are discussed below by site media of concern.

Groundwater. The time required to meet the RAOs will be the time until all site COPCs are removed from the disposal areas by natural attenuation. This time cannot be accurately estimated but would likely be at least as long as the default duration for remedial actions (30 years).

Surface Water/Sediments. The time required to meet the RAOs for this media will be the same as the groundwater media.

Ambient Air. The time required to meet the RAO for this media will be the time until LFG generation is significantly reduced or ceases (e.g. natural attenuation). Typically this is on the order of 20 to 30 years after placement of the waste. Since the last refuse was placed within the Solid Waste Area in 1982, natural attenuation will not occur for another 5 to 15 years.

Soil Gas. The time required to meet the RAO for this media will be the same as the ambient air media.

4.1.2.6 Implementability of Alternative #1. The implementability of this alternative is discussed as a measure of the technical and administrative feasibility of this approach as well as the availability of key services and materials required for this remedy.

Technical Feasibility. The relative ease of implementing the remedy is summarized below. Key items include: ability to be constructed and operated, reliability in meeting RAOs, ease of undertaking additional remedial actions and ability to monitor effectiveness of the remedy.

Groundwater/Leachate. There are no construction activities for Alternative #1, only on-going environmental monitoring as part of long-term operations. The necessary groundwater monitoring wells are already in place for the environmental monitoring program.

As this is the no action alternative, the RAOs will not be met.

Future actions could be implemented to increase this alternative's remedial effectiveness, if necessary.

The environmental monitoring approach would measure the effectiveness of groundwater natural attenuation.

Landfill Gas. As with groundwater/leachate, there are no construction activities for Alternative #1, only on-going environmental monitoring as part of long-term operations. Conversion of selected temporary soil gas points to permanent points will be required to conduct the soil gas portion of the environmental monitoring.

As this is the no action alternative, the RAOs will not be met.

Future actions could be implemented to increase this alternative's remedial effectiveness, if necessary.

The environmental monitoring approach will only indirectly measure the effectiveness of natural attenuation of the Solid Waste and Bulky Waste Areas for LFG production. Only methane and site COPC concentrations will be recorded; total LFG production cannot be effectively measured.

Administrative Feasibility. The relative effort and time required to obtain the necessary regulatory approvals and permits for the remedy is evaluated below.

Groundwater/Leachate. No regulatory approvals or permits are anticipated to be required to implement the remedy in Alternative #1. However, coordination with state and local authorities may be necessary to effectively implement the environmental monitoring program.

Landfill Gas. As with groundwater/leachate, no regulatory approvals or permits are anticipated to be required, but coordination with state and local authorities may be necessary to effectively implement the LFG portion of the environmental monitoring program.

Availability of Services and Materials. The availability of key services and materials needed to implement the alternative are discussed below and include: capacity and location of treatment storage and disposal facilities (TSDFs), availability of necessary equipment and specialists, timing and scheduling, and availability to obtain competitive cost bids.

Groundwater/Leachate. The only major effort required for Alternative #1 is monitoring of the groundwater and surface water/sediment which will not require a TSDF, specialized services, nor extensive scheduling. Many consultants and firms are available to conduct the environmental monitoring, five-year reviews and community relations activities in a cost-effective manner.

Landfill Gas. As with groundwater/leachate, environmental monitoring of the ambient air and soil gas is the only major effort. Therefore, availability of services and materials is the same as discussed for groundwater/leachate.

4.1.2.7 Cost of Alternative #1. Capital costs associated with this alternative are limited to construction of permanent soil gas monitoring probes required for the environmental monitoring. Total capital costs are $0.11 million. Annual operations and maintenance (O&M) costs are limited to monitoring of the remedy. The present value of all O&M costs is $3.46 million. This estimate assumes an inflation rate of 3.0%, a discount rate of 7.0% and a contingency of 20%. The duration of groundwater, surface water/sediment monitoring activities is assumed to be 30 years, in accordance with RI/FS guidance (EPA, 1988c). The duration of ambient air and soil gas monitoring is estimated to be 15 years since LFG generation is expected to cease by that time. Total costs are therefore $3.57 million. These costs are summarized in detail in Appendix G.

4.1.2.8 State and Community Acceptance of Alternative #1. Comments from the State of Rhode Island, the town of South Kingstown, and citizens of the community regarding this alternative will be addressed after the public comment period.

4.2 EVALUATION OF ALTERNATIVE #2: LIMITED ACTION

This section describes the components of Alternative #2 followed by detailed evaluation of those components versus the nine FS criteria.

4.2.1 Definition of Alternative #2

Alternative #2, the limited action alternative, involves no active treatment for mitigating site risks. Alternative #2 provides limited actions for protection of human health by preventing and controlling exposure to COPCs through institutional controls.

The major components of this alternative include:

- Groundwater Access Restrictions. Where appropriate, restrictive covenants would be placed on properties to restrict use of groundwater as a potable water source. Detailed discussion of this component is provided in Section 4.2.1.1.

- Landfill Gas Access Restrictions. Access restrictions in the form of fencing and appropriate security measures are included in this alternative to mitigate human health risk due to ambient air within the Solid Waste Area. Ambient air for this area is subject to high levels of fugitive LFG emissions which contain site COPCs. These measures have been described in Section 3.1.7.1.

- Residential Landfill Gas Control Contingency. Dependent upon results of the environmental monitoring program, impacted off-site residential or commercial properties may qualify for installation of LFG controls. Impacted receptors are those parties whose soil gas or indoor air concentrations exceed Section 2.0 criteria. This component includes the installation of LFG alarms, controls and venting systems at individual residences or commercial properties. A detailed description of this component is provided in Section 4.2.1.2.

- Environmental Monitoring. Environmental monitoring includes monitoring of groundwater, surface water/sediment, ambient air, and soil gas. Monitoring locations, frequencies and analytes are the same as described previously for Alternative #1.

- Five-Year Review. As described previously in Alternative #1, since this alternative would result in contaminants remaining on the Site, CERCLA §121(c) and §300.430(f)(4)(ii) of the NCP require that the site remedy be reviewed every five years.

- Community Relations Activities. In the same manner as Alternative #1, on-going community relations activities will be conducted to provide appropriate information, receive comment on that information and to adjust the remedy of the Proposed Plan at key milestones.

Figure 4-1 illustrates the site layout for Alternative #2. The components of the alternative, and how they interact with each media of concern, are presented on Figure 4-3.

4.2.1.1 Groundwater Access Restrictions. Access restrictions would restrict or limit use of the groundwater associated with current or future property lots for the site study area and affected residential areas. Restrictive covenants may take the form of property deed restrictions, modifications to local zoning regulations or other changes in local ordinances. These have been described in detail in Section 3.1.1.1.

4.2.1.2 Residential Landfill Gas Control Contingency. Dependent upon results of the environmental monitoring program, impacted off-site residential or commercial properties may qualify for installation of LFG controls. This component includes the installation of LFG alarms, controls and venting systems at individual residences or commercial properties. A detailed description of this component has been discussed previously in Section 3.1.7.3.

EPA's Environmental Services Division has already installed methane sensors in two residential locations adjacent to the Site (in April 1993). These locations are 278 and 349 Rose Hill Road (U.S. EPA, 1993b). Based on Section 2.0 criteria (and shown in the calculations in Appendix F), these two residences plus two additional residences (220 and 235 Rose Hill Road) would qualify for

the LFG control contingency. This FS includes installation of LFG control systems at all four residential locations.

4.2.2 Nine Criteria Evaluation of Alternative #2

The analysis of Alternative #2 with respect to the nine criteria is presented in a narrative form in the following paragraphs. The assessment focuses on how, and to what extent, the various factors within each of the criteria are addressed. Uncertainties associated with the alternative are included when changes in assumptions or unknown conditions could affect the analysis.

4.2.2.1 Overall Protection of Human Health and the Environment from Alternative #2. Alternative #2 would provide some overall protection of human health by reducing risks identified in the baseline risk assessment, which are discussed in Section 4.1 for Alternative #1. An increase in the overall protection of human health from implementation of Alternative #2 would result from the reduction or prevention of exposures to COPCs in soil gas and groundwater using institutional controls. Specific long-term and short-term human health risks are discussed in Sections 4.2.2.3 and 4.2.2.5, respectively. Site COPC concentrations in ambient air are expected to be the highest above the Solid Waste Area. Current risks from inhalation of COPCs in ambient air from landfill gas at the Solid Waste Area would be reduced as a result of access restrictions (fencing) to this disposal area. Due to the installation of fences, the frequency with which the public would be present on the Solid Waste Area would be significantly reduced. Therefore, inhalation exposures at the Solid Waste Area would be significantly reduced. However, potential risks at nearby residences, where exposures to ambient air would be of longer duration, would still be expected to slightly exceed EPA target cancer risk limits as a result of the lateral migration of site COPCs in landfill gas. Risks to residents from site COPCs migrating to indoor air through soil gas would be reduced as the result of the residential LFG controls, including basement methane sensors and ventilation systems. However, risks to residents with these systems may still exceed EPA target cancer risk limits.

The potential for future risks from ingestion of COPCs in groundwater at the Site would also be reduced, as a result of restrictions on the future use of groundwater at the Site as a drinking water source.

Additional short-term risks to workers would result from the installation of fences at the Solid Waste Area. These risks would be mitigated by the use of appropriate personal protection equipment (PPE) as needed.

Limited action, primarily fencing the Site, would have little or no effect on the ecological resources utilizing the Site. The fence would not be a barrier to avian species and most mammals could slip under or dig under the fence.

The overall protectiveness of ecological resources is similar to Alternative #1. Some minor, short-term disturbances to small areas of wetland buffer zone and upland habitats would occur during fence installation. These impacts would be reduced or mitigated by instituting proper construction and erosion control methods and minimizing tree clearing activities. Any wetlands and/or watercourse impacts would be mitigated in accordance with appropriate RIDEM guidance and policies.

4.2.2.2 Compliance With ARARs from Alternative #2. Action-specific ARARs under this alternative are presented in Table 4-5. Any remedial actions taken under this alternative must comply with the ARARs listed in this table. Environmental monitoring will be used as an indicator of compliance with the site-specific chemical and location-specific ARARs described in Section 2.3. As this is a limited action alternative, ARARs are not expected to be fully met without further action.

4.2.2.3 Long-term Effectiveness and Permanence from Alternative #2. This alternative is evaluated below in terms of the risk remaining at the Site after RAOs are addressed. This portion of the evaluation focuses on the extent and effectiveness of the controls required to manage the risk posed by treatment residuals and/or untreated contamination.

Magnitude of Residual Risks. Similar to Alternative #1, this alternative does not implement any controls to reduce the release of leachate to surface water and groundwater, or reduce the release of landfill gas to ambient air. It also does not actively remove or contain contamination at the Site. Under this alternative, the magnitude of residual risks would depend on the enforcement and reliability of institutional controls to prevent human exposures to COPCs in ambient air and groundwater.

Under this alternative, human health risks to a visitor from ambient air inhalation exposures to COPCs in ambient air at the Solid Waste Area, currently estimated as 8.1×10^{-4} (M&E, 1998), would be considerably reduced by the installation of 8-foot-high fencing around the Solid Waste Area. Risks at the Solid Waste Area, where ambient air COPC concentrations are expected to be the highest, would be reduced because a visitor's frequency of exposure would be much lower as a result of the fencing.

Residual human health risks to a resident from off-site inhalation exposure to COPCs in ambient air would not be reduced under Alternative #2, as there would be no containment of uncontrolled soil gas emissions at the Site. Risks from this exposure pathway would be equal to risks presented for Alternative #1: carcinogenic risk to a resident from inhalation of landfill gas components in ambient air at a nearby residence is estimated as 1.5×10^{-4} (M&E, 1998), based on dispersion modeling from the maximum on-site vinyl chloride concentration in landfill gas.

Risks to a resident from off-site inhalation exposures to COPCs in indoor air would be reduced following the installation of a residential LFG control system, which includes methane sensors, an alarm, and a basement ventilation system. Installation of this system would be triggered by long-term monitoring of soil gas and basement indoor air; however, monitoring equipment does not have the capacity to detect vinyl chloride at its PRG. Carcinogenic risks with this system installed are estimated to be below 2×10^{-4}, which is near the upper limit of the EPA target cancer risk range. This risk estimate is based on the estimated maximum concentration of vinyl chloride that is expected to accumulate in a basement without detection of methane by the methane sensors and subsequent

ventilation of the basement (see Appendix F). Two residences, numbers 278 and 349 Rose Hill Road, currently have methane sensors with an alarm and ventilation system installed in their basements.

Potential future residual human health risks to a resident from ingestion of COPCs in groundwater at the Site would be significantly reduced by the implementation of groundwater access restrictions at the Site. Residual risks from this exposure pathway would be eliminated if long-term enforcement of the groundwater access restrictions is maintained.

Contaminated groundwater would not be contained with this alternative. Therefore, the reduction of any residual risks to off-site receptors from groundwater ingestion exposures would be dependent on implementation of groundwater access restrictions. Residual risks from this exposure pathway would be eliminated if long-term enforcement of the groundwater access restrictions is maintained.

The long-term effectiveness and permanence with regards to ecological receptors is the same as Alternative #1.

Adequacy of Controls. Measures are described below that detail controls to be placed on untreated waste, waste-contaminated media and treatment residuals from implementation of Alternative #2. Under this alternative, no measures would be conducted for untreated waste at the Site beyond that of natural attenuation.

> Groundwater/Leachate. There are no measures which eliminate the source in this alternative. Groundwater access restrictions provide protection of human health. These measures would adequately protect against human exposures by ingestion of contaminated groundwater, provided they are implemented reliably. Monitoring of groundwater is also part of the alternative and would monitor progress of plume migration.
>
> Landfill Gas. No measures are implemented in this alternative that remediate, capture, or treat landfill gas from the Solid Waste Area. However, this alternative includes the residential LFG control contingency to mitigate LFG hazards in soil gas. Installation of the access restrictions (fence) at the Solid Waste Area would provide a moderate degree of

adequacy in protecting on-site human receptors from inhalation hazards. Monitoring of ambient air and soil gas would be part of the alternative and would confirm the adequacy of controls in this alternative.

Reliability of Controls. Evaluations are described below that detail the effectiveness, reliability, and permanence control measures that are provided to protect human health and the environment from untreated waste, waste-contaminated media, and treatment residues.

Groundwater/Leachate. This alternative would not include any treatment or source control measures. Groundwater use restrictions could reliably prevent ingestion exposures provided they are enforced. Monitoring of groundwater and surface water would provide an accurate measure of the success of this remedy and provide a basis for modification of the remedy, if required.

Landfill Gas. The access restrictions (fence) provide controls for protecting against human inhalation exposures. Similar to groundwater/leachate, monitoring of air and landfill gas would provide an accurate measure of the success of this remedy and provide a basis for modification of the remedy, if required.

Need for Five-Year Review. Because wastes would remain on the Site under this alternative, CERCLA §121(c) and the NCP at §300.430(f)(4)(ii) require that a five-year review be conducted every five years, until it is demonstrated that there is no longer a threat to human health or the environment from the Site. For the purpose of this FS and costing, it is assumed that a "Level I" review, the lowest level, would be conducted.

4.2.2.4 Reduction of Toxicity, Mobility or Volume through Treatment from Alternative #2. This criteria evaluates how the alternative mitigates the effects of site COPCs by describing the following: treatment technologies and process options utilized, quantity of site COPCs/contaminated media affected, degree of expected reductions in mobility of site COPCs into the environment, degree to which the treatment is irreversible, and the residuals remaining after treatment.

Treatment/Recycling Processes Utilized. The treatment, recycling and other mitigation processes of the remedy and any materials treated are listed below for this alternative:

Groundwater/Leachate No treatment processes utilized.

Landfill Gas. LFG alarms, controls and venting systems (as part of the residential LFG contingency) - soil gas

Amount of Hazardous Materials Treated or Recycled. The quantities or volumes of materials containing COPCs that are destroyed, recycled or treated are detailed below. These quantities may also include other hazardous materials that are involved in the remedy.

Groundwater/Leachate. None.

Landfill Gas. If residential LFG alarms, controls and venting systems are installed, then a small fraction of LFG migrating through vadose zone soils will be redirected to ambient air. No elimination of site COPCs will occur.

Degree of Expected Reductions in Toxicity or Mobility. The expected degree of reductions in toxicity or mobility of the COPCs in site media are detailed below.

Groundwater/Leachate. There is no degree of reductions in toxicity or mobility of the COPCs in site media, beyond natural attenuation. This alternative only eliminates a pathway from contaminated media to receptors.

Landfill Gas. There is no degree of reductions in toxicity or mobility of the COPCs in site media, beyond natural attenuation. This alternative only eliminates a pathway from contaminated media to receptors.

Degree to Which Treatment Is Irreversible. The degree to which treatment, recycling or other appropriate remedial components of the selected remedy are irreversible is evaluated below.

Groundwater/Leachate. There are no components in this alternative which may be evaluated for irreversibility.

Landfill Gas. Removal of components related to the residential LFG alarms, controls and venting systems would also result in conditions identical to the no-action alternative.

Type and Quantity of Residuals Remaining After Treatment. The quantity and composition of residuals generated by treatment processes in this alternative are described below. These residuals may require further disposal and handling.

Groundwater/Leachate. This alternative would not involve any treatment of groundwater/leachate and, therefore, would not generate any residuals.

Landfill Gas. Migrating LFG is only re-directed to ambient air and not combusted, therefore no residuals result.

4.2.2.5 Short-term Effectiveness of Alternative #2. This alternative is evaluated for effectiveness in protecting the community and local workers, site remediation workers, and the environment during the construction and implementation of the remedy.

Community Protection. The construction measures proposed under this alternative include implementation of the following: access restrictions (fencing), and the residential LFG control contingency. The implementation of these measures would not likely result in additional short-term risk to the community from exposure to contaminants.

Worker Protection. Exposure to COPCs in air during installation of fencing would result in a nominal health risk to workers. Use of PPE should be employed to reduce exposures if applicable OSHA standards are exceeded during these activities.

Environmental Protection. Some minor, short-term disturbances to small areas of wetland (primarily to areas within the wetland buffer zone) and upland habitats would occur during fence installation. These impacts would be reduced or mitigated by instituting proper construction and

erosion control methods and minimizing tree clearing activities. Any wetlands and watercourse impacts would be mitigated in accordance with appropriate RIDEM guidance and policies.

Time Until Remedial Action Objectives are Achieved. Estimates for the time to achieve RAOs are discussed below by site media of concern.

Groundwater. By use of groundwater access restrictions, the time required to meet the RAO will be the time required to implement these controls. This is expected to occur within 1 year of selection of the FS remedy.

Surface Water/Sediments. The time required to meet the RAOs will be the time until all site COPCs are removed from the disposal areas by natural attenuation. This time cannot be accurately estimated but would likely be at least as long as the default duration for remedial actions (30 years).

Ambient Air. This RAO will be partly met for those locations that receive the residential LFG control contingency and access restrictions (fencing) on the Solid Waste Area. In general, however, the time required to meet the RAO for this media will be the time until LFG generation is significantly reduced or ceases (e.g. natural attenuation). This time is the same as Alternative #1.

Soil Gas. By use of the residential LFG control contingency, the time required to meet the RAO will be the time required to implement, and achieve an operational and functional status of the contingency. This is expected to occur within 1 year of selection of the FS remedy.

4.2.2.6 Implementability of Alternative #2. The implementability of this alternative is discussed as a measure of the technical and administrative feasibility of this approach as well as the availability of key services and materials required for this remedy.

Technical Feasibility. The relative ease of implementing the remedy is summarized below. Key items include: ability to be constructed and operated, reliability in meeting RAOs, ease of undertaking additional remedial actions and ability to monitor effectiveness of the remedy.

Groundwater/Leachate. Similar to Alternative #1, there are no construction activities for this alternative. Implementation of environmental monitoring would be the same as Alternative #1.

The reliability to meet RAOs through use of groundwater access restrictions is dependent on effective negotiations of agreements to implement these followed by vigilant observance on a long-term basis.

Similar to Alternative #1, future actions could be implemented to increase this alternative's remedial effectiveness, if necessary.

Similar to Alternative #1, the environmental monitoring approach would measure the effectiveness of groundwater natural attenuation.

Landfill Gas. The only implementation issue for this alternative beyond Alternative #1 would be construction and operation of the residential LFG control contingency. This contingency would require routine maintenance and periodic troubleshooting.

The reliability to meet soil gas RAOs at locations receiving the residential LFG control contingency is relatively high. However, this alternative cannot reliably meet the ambient air RAOs. The reliability of access restrictions (fencing) to meet ambient air RAOs is limited.

Future actions could be implemented to increase this alternative's remedial effectiveness, if necessary.

Similar to Alternative #1, the environmental monitoring approach will only indirectly measure the effectiveness of natural attenuation of the Solid Waste and Bulky Waste Areas for LFG production. However, monitoring would measure the effectiveness of the residential LFG control contingency.

Administrative Feasibility. The relative effort and time required to obtain the necessary regulatory approvals and permits for the remedy is evaluated below.

Groundwater/Leachate. Similar to Alternative #1, coordination with state and local authorities may be necessary to effectively implement the environmental monitoring program.

Significant long-term coordination between federal, state, and local authorities would be required under this alternative. Implementation of access restrictions in the form of property deed restrictions, modifications to local zoning, or other changes in local ordinances would require significant legal services and coordination with the town of South Kingstown and with the property owners.

Landfill Gas. As with groundwater/leachate, coordination with state and local authorities may be necessary to effectively implement the LFG portion of the environmental monitoring program, access restrictions (fencing) and the residential LFG control contingency.

Availability of Services and Materials. The availability of key services and materials needed to implement the alternative are discussed below and include: capacity and location of TSDFs, availability of necessary equipment and specialists, timing and scheduling, and availability to obtain competitive cost bids.

Groundwater/Leachate. Availability of services and materials for environmental monitoring, five-year reviews and community relations support is the same as Alternative #1.

Landfill Gas. Availability of services and materials for environmental monitoring is the same as Alternative #1. Services and materials for installation of access restrictions (fencing) are readily available. Contractors familiar with landfill gas applications would be required to properly install and provide O&M support for the residential LFG control systems.

4.2.2.7 Cost of Alternative #2. Cost assumptions regarding escalation, discount rate, contingency and duration, unless otherwise specified, are the same as Alternative #1.

Capital costs associated with this alternative are expected to be $0.36 million. Operations and maintenance costs (expressed in net present worth dollars) are estimated at $3.48 million. Total costs are therefore $3.84 million. These costs are summarized in detail in Appendix G.

4.2.2.8 State and Community Acceptance of Alternative #2. Comments from the State of Rhode Island, the town of South Kingstown, and citizens of the community regarding this alternative will be addressed after the public comment period.

4.3a EVALUATION OF ALTERNATIVE #3a: HORIZONTAL CONTAINMENT OF SOLID WASTE AND BULKY WASTE AREAS, GAS COLLECTION AND THERMAL TREATMENT

This section describes the components of Alternative #3a followed by detailed evaluation of those components versus the nine FS criteria.

4.3a.1 Definition of Alternative #3a

Alternative #3a provides increased mitigation of human health risks through control of landfill gas when compared with Alternative #2 and provides improved mitigation of ecological risks through horizontal containment of the Solid Waste and Bulky Waste Areas. The containment of the Solid Waste Area also further mitigates human health risks by reducing migration of site COPCs into groundwater.

The major components of this alternative include:

- Groundwater Access Restrictions. Where appropriate, restrictive covenants would be placed on properties affected by site COPCs to limit use of groundwater as a potable water source. The scope for this component is the same as discussed previously under Alternative #2.

- Horizontal Containment - Solid Waste Area. Existing horizontal containment of the Solid Waste Area consists of an approximate 1-foot-thick layer of silty-sand material (Appendix C). To provide more effective horizontal containment, a protective cap would be added to the Solid Waste Area. A detailed description of horizontal containment for the Solid Waste Area has been provided previously in Section 3.1.2.1. In addition, five piezometers would be installed within the capped portion to monitor water levels and determine effectiveness of the containment.

- Horizontal Containment - Bulky Waste Area. Existing horizontal containment of the Bulky Waste Area consists of an approximate 3-foot-thick layer of silty-sand material (Appendix C). To provide a more effective horizontal containment, a protective cap would be added to the Bulky Waste Area. A detailed description of horizontal containment for the Bulky Waste Area has been provided previously in Section 3.1.2.2.

- Active Perimeter LFG Collection - Solid Waste Area. A perimeter LFG collection system would be implemented to prevent migration of landfill gas from the Solid Waste Area into adjacent, off-site vadose zone soils. This perimeter system would consist of a series of vapor extraction wells installed adjacent to the Solid Waste Area in a line parallel to Rose Hill Road. Refer to Section 3.1.8.2 for a description of this component in greater detail.

- Active Internal LFG Collection - Solid Waste Area. An internal LFG collection system would be implemented to prevent migration of landfill gas from the Solid Waste Area into ambient air. This internal system would consist of a series of vapor extraction wells installed within the confines of the Solid Waste Area in an evenly-spaced grid pattern. Further descriptive details of this component are provided in Section 3.1.8.3.

- Thermal LFG Treatment (Enclosed Flare) - Solid Waste Area. Landfill gas collected by the internal and perimeter Solid Waste Area collection systems would be burned in an enclosed flare for destruction of site COPCs prior to ambient air discharge. Detailed discussion of this component is presented below.

- Passive Internal LFG Collection - Bulky Waste Area. A passive internal LFG collection system would be implemented to prevent migration of landfill gas from the Bulky Waste Area into adjacent vadose zone soils. This internal system would consist of a series of LFG vents installed within the confines of the Bulky Waste Area in a spatially-distributed pattern. Further descriptive details of this component are provided in Section 3.1.8.4.

- Environmental Monitoring. Environmental monitoring includes monitoring of groundwater, surface water/sediment, ambient air and soil gas. Monitoring locations, frequencies and analytes are the same as described previously for Alternative #1.

- Five-Year Review. As described previously in Alternative #1, since this alternative would result in contaminants remaining on the Site, CERCLA §121(c) and §300.430(f)(4)(ii) of the NCP require that the site remedy be reviewed every five years.

- Community Relations Activities. In the same manner as Alternative #1, on-going community relations activities will be conducted to provide appropriate information, receive comment on that information and to adjust the remedy of the Proposed Plan at key milestones.

Figure 4-4 illustrates the site layout for Alternative #3a. The components of the alternative, and how they interact with each media of concern, are presented on Figure 4-5.

4.3a.1.1 Thermal LFG Treatment (Enclosed Flare). General discussions were presented in Section 3.1.9 regarding treatment of internal and perimeter landfill gases in an enclosed flare. This section provides many of the technical details for this portion of the remedy.

Sizing of the flare and necessary appurtenances was conducted through vendor communication. These communications are detailed in Appendix E. Key input values for sizing the flare include: 1) feed gas flowrate and composition, 2) flare residence time, 3) flare operating temperature, and 4) combustion air requirements. The flare residence time is the time that COPCs within the flare are exposed to the combustion temperature. The residence time is defined as the time needed for gas to flow through the zone between the burner and the stack sampling port. A residence time of approximately 1 second with an operating temperature of 1,500°F is commonly utilized as good engineering practice for complete combustion. A higher temperature allows for a shorter residence time.

Flow rates and compositions for the perimeter and internal LFG collection system were calculated in Appendix E. A summary of the results is presented below.

<u>Perimeter Gas Stream</u>

812 ft^3/minute of gas with composition of:

77% nitrogen (% by volume)
21% oxygen
1% methane
1% carbon dioxide

<u>Internal LFG Stream</u>

41 ft^3/minute of LFG with composition of:

50% methane (% by volume)
50% carbon dioxide

Combustion air is typically ambient air that is drawn into the flare to mix with the feed gas. Combustion air provides oxygen which is necessary for the combustion reaction to occur. Combustion air equal to approximately 125% of the theoretical minimum flowrate is typically used based on industry rule-of-thumb (John Zink Company, 1993). The additional 25% of combustion

air is needed to make up for imperfect mixing conditions between air and the fuel at the flare burner. Based on the gas stream compositions shown above, a flare design was selected which utilizes the perimeter gas stream as combustion air, yet still combusts the contaminants in that stream. This design uses the undiluted internal gas stream as the fuel, thereby allowing the fuel heating value to remain high.

Although the internal gas stream initially has a heating value high enough to support flare combustion with minor auxiliary fuel, this heating value will go down over time due to reduced LFG production. An increased auxiliary fuel rate will then be required to supplement the internal gas stream. An approximate propane flowrate of 6 ft^3/minute will be necessary as the assumed end of operation is approached. Future addition of refractory to reduce the flare internal diameter may be utilized to reduce the auxiliary fuel requirements as the LFG flow rate is reduced. This should be reviewed further during design.

Key sizing parameters necessary for ambient air dispersion modeling of an enclosed flare include: 1) flare dimensions, 2) the stack velocity, and 3) the exit or flue gas composition. Based on the communications presented in Appendix E, the recommended flare would be 30 feet high with an inner diameter of 3.1 feet.

The flowrate of the flue gas is determined by combining the inlet flows of three streams: the combustion air (perimeter gas), the fuel (internal LFG), and quench air. Quench air is necessary to prevent the flare temperature from rising above the proper operating range since methane combustion gives off heat. The quench air acts as the medium to carry this excess heat up through the stack and away from the flare. Based on the flare dimensions, combustion air and fuel flows presented above, the recommended quench air flow rate is 560 ft^3/minute for flare operation at 1500°F. After temperature expansion of the inlet streams, the exit gas stack velocity is approximately 11.9 ft/second.

Destruction removal efficiencies (DREs) for the FS are assumed to be the same as previously specified in the design report (M&E, 1993a) since the residence time and operating temperature of the flare are similar. Minimum expected DREs were 95% for all volatile organic compounds of potential concern (including vinyl chloride) with the exception of benzene which was 82%. For many COPCs, DREs were significantly higher than 95% but the estimates discussed above were used to provide a conservative basis.

Principal combustion products from the enclosed flare include water vapor and carbon dioxide. These are the products of hydrocarbon (i.e. methane) combustion in air. Secondary combustion products are also generated during this process. These secondary products include trace amounts of the following: undestroyed or partially destroyed COPCs (as defined by the DREs), undestroyed or partially destroyed odor causing compounds such as methyl mercaptan (CH_3SH) and hydrogen sulfide, hydrogen chloride (HCl), sulfur oxides (SO_X), and nitrogen oxides (NO_X). The sulfur-containing compounds such as methyl mercaptan and hydrogen sulfide are present in the landfill gas and will oxidize during combustion to form sulfur oxides (SO_X). These sulfur-containing compounds are not COPCs but are a nuisance from the standpoint of odors. Nitrogen oxides are formed from nitrogen in air during high temperature combustion.

4.3a.2 Nine Criteria Evaluation of Alternative #3a

The analysis of Alternative #3a with respect to the nine criteria is presented in a narrative form in the following paragraphs. The assessment focuses on how, and to what extent, the various factors within each of the criteria are addressed. Uncertainties associated with the alternative are included when changes in assumptions or unknown conditions could affect the analysis.

4.3a.2.1 Overall Protection of Human Health and the Environment from Alternative #3a. Alternative #3a would provide a significant increase in the overall protection of human health using both the institutional controls presented in Alternative #2 to prevent exposures from occurring and engineering controls to further reduce exposures and reduce and contain contamination at the Site.

This alternative would provide a significant increase in the overall protection of human health, specifically from inhalation exposures, by capping two of the disposal areas and actively collecting and treating landfill gas within and along the perimeter of the Solid Waste Area. Access restrictions (fencing) for the Solid Waste Area presented for Alternative #2 would be included in this alternative to further reduce the potential for inhalation exposures on the Site. Risks to off-site receptors from inhalation exposures to COPCs in ambient air would be reduced with a cap by minimizing uncontrolled landfill gas emissions at the Solid Waste Area. This risk would be expected to be reduced to within the EPA target cancer risk range. The addition of an active perimeter LFG collection system would be expected to reduce risks to nearby residents from indoor inhalation exposures to within the EPA target risk range.

Exposures to groundwater contaminants would be limited through implementation of groundwater access restrictions.

Protection of human health by reductions in risk, discussed above, would result from the containment and reduction of COPCs at the Site and from implementation of institutional controls. Site related health risks are unlikely to exceed the EPA target risk range with this alternative.

Additional short-term risks to the community and workers at the Site may result from inhalation exposures associated with the construction activities for this alternative. These activities include installation of horizontal containment (e.g. caps) on the Solid Waste and Bulky Waste Areas and intrusive work at the Solid Waste Area. Intrusive work includes installation of active internal LFG and active perimeter LFG collection systems as well as the thermal LFG treatment system (enclosed flare). These additional short-term risks to the community and workers would be mitigated using dust control measures and air monitoring to detect soil gas emissions and off-site migration of COPCs. Because worker exposures at the Site are expected to be the highest, short-term risks to workers would be further mitigated by using PPE, as appropriate. Specific long-term and short-term human health risks are discussed in Sections 4.3a.2.3 and 4.3a.2.5, respectively.

Horizontal containment or capping of the Solid Waste and Bulky Waste Areas would reduce ecological exposures to site-related contaminants in wetland and aquatic habitats since leachate generation and discharge to Mitchell Brook and the Saugatucket River would be substantially reduced. However, since some leachate would still reach surface water bodies, ecological RAOs and PRGs may not be met. Thus, this alternative may not be completely protective of the environment.

Capping the Solid Waste and Bulky Waste Areas and constructing the surface water detention basins, LFG collection systems and treatment plant would result in some temporary and/or minor impacts to ecological habitats. Installation of the cap on the Solid Waste Area would result in the loss of a small emergent wetland area (<0.15 acres) which is dominated by common reed (*Phragmites communis*). Although this wetland has minimal existing value due to its small size, isolation, lack of standing water during most of the year, and low quality habitat, a functional analysis (prior to construction activities) and mitigation may be required.

The presence of the cap and detention basins may also affect the hydrology of the Mitchell Brook wetlands, due to prevention of water infiltration on the Solid Waste Area and the interception of surface water flows from the Solid Waste Area into detention basins. Fence installation and construction of the LFG gas treatment plant would encroach into the buffer zone of the vegetated wetlands bordering Mitchell Brook and the Saugatucket River. Clearing of herbaceous vegetation covering the two disposal areas, and trees and shrubs along the fringes of the disposal areas, would be necessary during cap installation and fence construction. These areas would be revegetated upon completion of construction activities. Similar to Alternative #2, any wetlands and watercourse impacts would be mitigated in accordance with appropriate RIDEM guidance and policies.

4.3a.2.2 Compliance With ARARs from Alternative #3a. Action-specific ARARs under this alternative are presented in Table 4-6. Any remedial actions taken under this alternative must comply with the ARARs listed in this table. Environmental monitoring will be used as an indicator of compliance with the site-specific chemical and location-specific ARARs described in Section 2.3.

Further actions may be required to comply with ARARs if they are not met through this source control remedy.

4.3a.2.3 Long-term Effectiveness and Permanence from Alternative #3a. This alternative is evaluated below in terms of the risk remaining at the Site after RAOs are addressed. This portion of the evaluation focuses on the extent and effectiveness of the controls required to manage the risk posed by treatment residuals and/or untreated contamination.

Magnitude of Residual Risks. Alternative #3a would combine technologies to contain and reduce site COPCs in ambient air, soil gas and groundwater at the Site. Institutional controls are implemented to minimize human exposures to COPCs in soil gas and groundwater both on and off the Site. This capping and gas collection alternative would leave refuse in place, but would reduce migration of contamination. Containment and removal efficiencies of the cap and of the active LFG collection and treatment systems would be expected to significantly reduce risks from inhalation exposures.

Residual human health risks at the Site would include inhalation exposures to soil gas components in ambient air that would escape the collection and treatment system. For the purposes of this FS risk evaluation, gas capture rates are assumed to be 100% and the treatment efficiency of the enclosed flare is assumed to be 95%.

Landfill gas collection and treatment would be expected to reduce human health risk to a visitor from inhalation exposures to COPCs in ambient air at the Solid Waste Area to within the EPA target risk range. Risks to a resident from off-site ambient inhalation exposure to COPCs would be expected to be reduced by capping the disposal areas and collecting and treating LFG at the Solid Waste Area. Residual risks would be from exposure to COPCs in ambient air which would not be contained by the cap and gas collection system. Carcinogenic risk from inhalation of site COPCs in ambient air at a nearby residence is estimated to be within EPA's target risk range. Therefore, implementation of Alternative #3a would be expected to reduce risks from indoor inhalation exposures at nearby

residences to within the EPA target risk range. The perimeter system is expected to capture a significant proportion of soil gas migrating laterally off the Site which was not captured by the active internal collection system. Therefore, a majority of soil gas migrating toward the nearby residences would be collected, thus reducing risks to within EPA target risk range.

New risks could be anticipated from the implementation of this remedial alternative. Long-term generation of combustion products would be expected in the enclosed flare. The combustion of collected LFG using an enclosed flare would result in the emission of undestroyed COPCs, and combustion products such as sulfur oxides, carbon dioxide, carbon monoxide, and acid gases, including hydrogen chloride (U.S. EPA, 1992). These emissions could result in low-level inhalation exposures at nearby residences. However, these emissions would be reduced by optimal combustion conditions. In addition, it is expected that risks from combustion by-product emissions would be evaluated using data from Demonstration of Compliance stack sampling from the combustion reaction.

Based on the discussion in Section 3.1.8.2, pump stations and aboveground storage tanks would be used for storage of condensate waste from the LFG collection systems. Risks to the community may result from leaks in these storage units and subsequent soil and/or groundwater contamination. Risks to the community may also result from transport and disposal of condensate waste. These risks would be very small, and would be mitigated by adhering to proper design requirements and OSHA/DOT requirements for the transport of hazardous waste.

Potential risks would be anticipated for site workers involved with O&M activities at the Site. Inhalation exposures potentially may result from leaks and/or maintenance to the LFG collection and treatment systems; however, a negative pressure would exist within the collection systems, and only potential leaks between the blower and the flare are expected. Condensate would accumulate in the aboveground storage tank for transport off of the Site; however, risks associated with contact with these materials would be mitigated with appropriate PPE. There would be a potential explosion hazard to workers monitoring or maintaining the system from methane in LFG, as well as from the

use of propane as an auxiliary source of fuel for the combustion reaction. To minimize any risks, the levels of methane in LFG would be monitored frequently to mitigate any risk from explosion and necessary safety requirements would be followed to reduce any risk from an auxiliary source of fuel at the Site.

Residual human health risks to a resident from ingestion of COPCs in groundwater at the Site would be reduced by groundwater access restrictions at the Site presented for Alternative #2 and over the long-term by horizontal containment of the disposal areas. Sources of groundwater contamination include leachate from the infiltration of precipitation, and direct contact of the water table with refuse. Capping the disposal areas would reduce groundwater contamination by minimizing infiltration of precipitation and may help to reduce contact between the water table and refuse by lowering the water table.

Groundwater contamination would not be contained with this alternative. However, residual human health risks to off-site receptors from ingestion of contaminated groundwater resulting from any future plume migration would be reduced using long-term monitoring of water supply wells. Residual risks from off-site exposures to groundwater contamination are therefore similar to Alternative #2.

Long-term risks to ecological receptors in wetland and aquatic habitats would be substantially reduced by this capping alternative, provided that the integrity of the cap is not compromised and it is effective in reducing leachate. RAOs may not be completely met over the long term in aquatic areas since some leachate from the Bulky Waste Area would still reach the Saugatucket River. The residual risk represented by this leachate is difficult to quantify but, based on the leachate generation modeling presented in Section 4.3a.2.4, is likely to be relatively small. New, long-term risks from the generation of combustion products in the enclosed flare are not likely. Any risks from combustion by-product emissions would be evaluated using data from Demonstration of Compliance stack sampling once remedial actions begin.

Adequacy of Controls. Measures are described below that detail controls to be placed on untreated waste, waste-contaminated media, and treatment residuals from implementation of Alternative #3a.

Groundwater/Leachate. The performance of institutional controls is the same as Alternative #2. Horizontal containment (capping) would adequately reduce or eliminate the infiltration of precipitation into waste, thereby reducing the generation of leachate. The caps would require long-term maintenance to ensure that their integrity is not compromised. This maintenance includes periodic mowing, inspections, and maintenance of surface water drainage channels. Additional fill may be required as landfill subsidence occurs. The caps would also lower the water table to a limited degree, reducing contact between in-place refuse and groundwater. This action reduces the volume of groundwater that becomes contaminated as well as the quantity of leachate produced. The caps, however, may not adequately cover or eliminate all leachate outbreaks. Further analysis of the cap adequacy has been provided in Sections 3.1.2, 4.3a.1, and 4.3a.2.4. Monitoring of groundwater would confirm progress of the remedy.

Landfill Gas. Landfill gas not captured by the active internal collection system would be captured by the active perimeter collection system. The perimeter system and caps provide an adequate secondary containment of landfill gas and substantially reduce fugitive emissions to ambient air.

The hazard from untreated site COPCs exiting the enclosed flare would be very low due to the high destruction removal efficiencies that can be expected (M&E, 1993a). Destruction removal efficiencies would be expected to be a minimum of 95% for all VOCs. Greater hazards are posed by condensate from the landfill gas as well as combustion by-products such as hydrochloric acid, acid gases and odor-causing sulfur oxides. Analysis of expected DREs and combustion by-products was described previously in Section 4.3a.1.1.

Reliability of Controls. Evaluations are described below that detail the effectiveness, reliability, and permanence control measures will provide to protect human health and the environment from exposures to untreated waste, waste-contaminated media, and treatment residues.

Groundwater/Leachate. The reliability of institutional controls would be identical to Alternative #2. There is a high degree of confidence associated with caps in relation to their ability to reduce infiltration of precipitation and control the escape of landfill gas. Furthermore, capping is an indirect method of providing protection from exposure to untreated groundwater. By lowering the water table, the caps reduce contact between the waste materials and groundwater. The caps, however, would not be expected to cover all leachate outbreaks that could still be potential exposure locations.

The 2-foot-cover layer that is part of the horizontal containments should be sufficient to prevent cap penetration by most species of burrowing mammals. Based on the habitat provided by the herbaceous vegetation to be planted atop the caps, species likely to burrow in these areas include moles, voles, and woodchucks (*Marmota monax*). Moles and voles rarely burrow deeper than 1.5 feet (Degraaf and Rudis, 1987; Yates and Pederson, 1982) and thus should not affect the integrity of the cap. Woodchucks can burrow as deep as 5 feet (Lee and Funderburg, 1982) but most tunnels are considerably shallower. Since woodchucks prefer to dig in easily-excavated soils, it is unlikely that they would dig through the drainage composite and geomembrane (present at a depth of 2 feet) unless these layers are cracked or otherwise damaged. Thus, it is unlikely that waste materials would be exposed due to the activities of burrowing animals, although burrows which penetrate the geomembrane could allow landfill gas to escape and rain water to percolate in. During landfill inspections, signs of burrows would be noted and appropriate action taken (e.g., trapping of animals and filling in of burrows), if it is determined that the cap layers are being breached by these animals.

Control of woody plant growth on top of the cap would be necessary to prevent tree roots from penetrating the cap and, thereby, compromising its integrity. This plant control would be accomplished by periodic mowing.

Monitoring of groundwater and surface water would provide an accurate measure of the success of this remedy and provide a basis for modification of the remedy, if required.

Landfill Gas. The presence of the active perimeter LFG collection system and caps provide a significant degree of protection from hazards posed by uncollected landfill gas not collected by the active internal LFG collection system.

Reliability of the landfill gas collection and treatment system will be dependent on close attention of the operator(s), and engineering support staff on a daily, weekly or monthly basis as appropriate. Typical operations functions would include: delivery of propane or other auxiliary fuel, removal and disposal of condensate, analytical sampling, process monitoring, and preparation of operations reports.

Typical maintenance and troubleshooting activities would involve the following: well and pipeline inspections, condensate tank inspection, blower inspections/overhauls, flare burner adjustments, instrumentation calibration, and any equipment repair. Due to the long duration of operations, equipment replacement will also be required during planned intervals. Key items associated with some of the equipment should be stocked. These items may include components of the flare burner or flare louvers, instrumentation replacement parts and other process sensors.

Troubleshooting specialists and maintenance staff should be "on call" via auto-dial modems when operators are not present, such as nights, holidays, etc. The landfill gas collection and flare system should be designed to default to a "shut-down" mode if equipment failures

occurred. Thus, staff would be called in order to re-start the system. Since, the landfill gas is generated with or without collection, the duration of these shutdowns should be limited. While a shut-down of hours and days may be acceptable, shutdowns of weeks or months would likely not be.

While not a COPC, methane is a safety hazard due to the potential for uncontrolled fire and explosion. Design of all necessary system features (i.e. flame arresters, explosion-proof wiring/instrumentation) into the collection and flare system will be required to prevent such safety hazards.

Similar to groundwater/leachate, monitoring of air and landfill gas would provide an accurate measure of the success of this remedy and provide a basis for operational changes such as modification of well vacuum rate, or installation of additional wells, if required.

Need for Five-Year Review. Because wastes would remain on the Site under this alternative, CERCLA §121(c) and the NCP at §300.430(f)(4)(ii) require that a five-year review be conducted every five years. This five-year review would continue until it is demonstrated that there is no longer a threat to human health or the environment from the Site. For the purpose of this FS and costing, it is assumed that a "Level I" review, the lowest level, would be conducted.

4.3a.2.4 Reduction of Toxicity, Mobility or Volume through Treatment from Alternative #3a. This criteria evaluates how the alternative mitigates the effects of site COPCs by describing the following: treatment technologies and process options utilized, quantity of site COPCs/contaminated media affected, degree of expected reductions in mobility of site COPCs into the environment, degree to which the treatment is irreversible, and the residuals remaining after treatment.

Treatment/Recycling Processes Utilized. The treatment, recycling and other mitigation processes of the remedy and any materials treated are listed below for this alternative:

<u>Groundwater/Leachate</u>

- Horizontal Containment - Solid Waste Area
- Horizontal Containment - Bulky Waste Area

Landfill Gas

- Active perimeter LFG collection - Solid Waste Area
- Active internal LFG collection - Solid Waste Area
- Thermal LFG Treatment (enclosed flare) - Solid Waste Area
- Passive internal LFG collection - Bulky Waste Area

Amount of Hazardous Materials Treated or Recycled. The quantities or volumes of materials containing COPCs that are destroyed, recycled or treated are detailed below. These quantities may also include other hazardous materials that are involved in the remedy.

Groundwater/Leachate. Horizontal containment will reduce infiltration, and therefore leachate generation, over time as follows (refer to specific quantities in Appendix C):

Solid Waste Area	100% reduction from Alt.#1
Bulky Waste Area	100% reduction from Alt.#1

Landfill Gas. The combination of the active internal LFG collection system, perimeter LFG collection system and horizontal containment will capture essentially 100% of the LFG production from the Solid Waste Area (refer to Section 4.3a.1.1). The enclosed flare DRE of site COPCs in this captured LFG would be expected to be a minimum of 95%, but is typically greater than 98%.

The passive internal LFG collection system in the Bulky Waste Area will redirect migrating LFG from vadose zone soils to ambient air. No elimination of site COPCs will occur.

Degree of Expected Reductions in Toxicity or Mobility. The expected degree of reductions in toxicity or mobility of the COPCs in site media are detailed below.

Groundwater/Leachate. There is no degree of reduction in toxicity of the site COPCs, beyond natural attenuation. Horizontal containment reduces the mobility of site COPCs from the disposal areas by limiting leachate generation.

Landfill Gas. For the Solid Waste Area, this alternative reduces both the toxicity of site COPCs as well as their mobility into soil gas and ambient air. The degree of LFG mobility reduction is directly related to the overall LFG capture efficiency. The LFG capture efficiency is expected to be very high (near 100%) since this remedy includes both active

internal and perimeter systems as well as horizontal containment. The degree of toxicity reduction is directly related to the enclosed flare DREs which are described above.

For the Bulky Waste Area, this alternative reduces the mobility of LFG migration into vadose zone soil gas. There is no degree of reductions in toxicity or mobility of the COPCs in site media, beyond natural attenuation.

Degree to Which Treatment Is Irreversible. The degree to which treatment, recycling or other appropriate remedial components of the selected remedy are irreversible is evaluated below.

Groundwater/Leachate. Removal of horizontal containment at the disposal areas would result in conditions marginally improved over the no-action alternative due to regrading.

Landfill Gas. Combustion of collected LFG in the enclosed flare is an irreversible elimination of site COPCs. Removal of components related to the LFG collection and thermal treatment systems, however, would still allow the Site to revert back to no action conditions less the site COPCs destroyed previously.

Type and Quantity of Residuals Remaining After Treatment. The quantity and composition of residuals generated by treatment processes in this alternative are described below. These residuals may require further disposal and handling.

Groundwater/Leachate. This alternative would not involve any treatment of groundwater/leachate and, therefore, would not generate any residuals.

Landfill Gas. Residuals from collection and treatment of LFG at the Solid Waste Area would include the following:

- combustion by-products such as nitrogen oxides, sulfur oxides, carbon monoxide, small quantities of undestroyed site COPCs and hydrogen chloride (from destroyed chlorinated VOCs). Additional by-products may include dioxins as well.
- landfill gas condensate which may require disposal as a hazardous liquid.

Further detail on quantities is described in detail in Section 3.1.8.2 and Appendix E.

4.3a.2.5 Short-term Effectiveness of Alternative #3a. This alternative is evaluated for effectiveness in protecting the community and local workers, site remediation workers, and the environment during the construction of the remedy.

Community Protection. Prior to cap installation, it would be necessary to grade the surfaces of the Solid Waste and Bulky Waste Areas and remove any vegetation. This may result in fugitive dust emissions causing inhalation of airborne soil particles and ingestion of dust depositions at nearby residences. With regard to COPCs in LFG (i.e., vinyl chloride and 1,1-DCA), risks from these contaminants in dust are expected to be low because they do not adsorb strongly to soil particles. Appropriate dust control measures will be utilized during grading activities. Other short-term inhalation exposures may result from invasive activities such as installation of the LFG collection systems (i.e., internal and perimeter) at the Solid Waste Area. This may result in short-term increases in LFG emissions. These risks would not be expected to be critical because, for the chemicals of greatest concern in soil gas, short-term exposures are of lesser concern than chronic exposures. Any short-term exposures could be minimized by enacting proper engineering controls and scheduling of invasive operations. These risks can be monitored by conducting air sampling on a weekly basis during construction and/or by conducting continuous air monitoring for methane with air monitoring field instruments.

Worker Protection. Sources of short-term risks to workers would be similar to those outlined for the community during construction and implementation of the remedial system. However, concentrations of COPCs in air would be higher at the Site, where workers are, than at nearby residences. Workers may be exposed to COPCs by the inhalation pathway during installation of horizontal containment, during installation of the LFG collection systems, and during grading activities. It is possible that air concentrations of soil gas contaminants may exceed acceptable levels during invasive activities. These short-term risks would be mitigated using proper engineering controls and dust controls. In addition, risks to workers can be mitigated by using PPE where invasive work would be conducted.

Environmental Protection. Although best management practices will be utilized, there may be short-term risks to ecological receptors due to the mobilization of contaminants during capping operations (primarily from fugitive dust emissions). In addition, some mortality of upland organisms (e.g., small mammals) would occur during capping operations. Other species would be displaced during remedial activities. Depending upon the timing of activities, impacts to species breeding on the affected portions of the Site may occur and could include destruction of nests and young. Beginning remedial activities during the winter or early spring period may discourage some species, such as migratory birds, from breeding on the Site when they arrive in the spring, thereby minimizing direct mortality to nests or young. Use of proper erosion and sedimentation control practices would prevent adverse impacts to adjacent wetland areas during cap and facility construction; these controls are especially important during work within the wetland buffer zone.

Direct impacts to habitats include the filling of a small, isolated emergent wetland on the southern portion of the Solid Waste Area, removal of approximately 30 acres of habitat atop the existing disposal areas (grasses and shrubs) and clearing of small areas of wooded habitats along the fringes of the disposal areas. These disturbed areas would be revegetated following remediation, as described below.

Upland Areas. A minimum of 6 inches of loam topsoil would be placed on disturbed upland areas, including the top of the two landfill caps, if suitable soils are not present. These areas would then be graded, mulched, fertilized, and planted with a herbaceous seed mixture. Since existing forested areas on the Site are largely avoided during remedial activities, no woody plantings are proposed.

Controlling the growth of woody plant species on top of the caps would be necessary and would be accomplished by periodic mowing. The timing and frequency of mowing would be scheduled to interfere as little as possible with wildlife use of the area, especially during Spring bird migration and nesting.

Wetland Areas. The loss of a small emergent wetland on the southern portion of the Solid Waste Area would likely be mitigated through wetland restoration or creation on the Site.

Some indirect impacts to the Mitchell Brook and Saugatucket River wetlands may also occur during remedial activities due to the prevention of infiltration to groundwater and the

interception of surface water flow on the Solid Waste and Bulky Waste Areas. During the design phase, hydrologic investigations would be conducted and proper steps taken to ensure that the presence of the two landfill caps and the detention basins would not adversely affect the hydrology of Mitchell Brook, the Saugatucket River or bordering wetlands. Similar to Alternative #2, any wetlands and watercourse impacts would be mitigated in accordance with appropriate RIDEM guidance and policies.

Time Until Remedial Action Objectives are Achieved. Estimates for the time to achieve RAOs are discussed below by site media of concern.

Groundwater. As with Alternative #2, the time required to meet the RAO is assumed to be within 1 year of selection of the FS remedy for groundwater access restrictions. An additional year is required for the horizontal containment to be completed.

Surface Water/Sediments. This RAO will be partially met upon completion of the horizontal containment as described for groundwater. This time frame is expected to be within 2 years of selection of the FS remedy. Refer to Alternative #2 for the discussion on time required for natural attenuation.

Ambient Air. By use of the active internal LFG collection system, thermal LFG treatment (enclosed flare) and horizontal containment, the time required to meet the RAOs will be the time required to implement, and achieve an operational and functional status of these technologies and process options. This is expected to occur within 1 to 2 years of selection of the FS remedy.

Soil Gas. By use of the passive venting system and active perimeter LFG collection system combined with thermal LFG treatment (enclosed flare), the time required to meet the RAOs will be the time required to implement, and achieve an operational and functional status of these technologies and process options. This is expected to occur within 1 to 2 years of selection of the FS remedy.

4.3a.2.6 Implementability of Alternative #3a. The implementability of this alternative is discussed as a measure of the technical and administrative feasibility of this approach as well as the availability of key services and materials required for this remedy.

Technical Feasibility. The relative ease of implementing the remedy is summarized below. Key items include: ability to be constructed and operated, reliability in meeting RAOs, ease of undertaking additional remedial actions and ability to monitor effectiveness of the remedy.

Groundwater/Leachate. For Alternative #3a, the technical feasibility associated with access restrictions would be similar to that described for Alternative #2. Implementation of environmental monitoring would be the same as Alternative #1. The caps described under this alternative have been constructed on other sites, are proven, and commonly applied. Construction of new caps on the Solid Waste and Bulky Waste Areas would require stripping of existing grass as well as grading and compaction to prepare suitable bases for the caps. Movement of large volumes of capping materials to the Site would be required for this alternative and may require access road improvements. Local traffic problems may occur in the area during the time of construction, due to the number of trucks required for transport of cover materials. Also, five piezometers would be installed to monitor water levels under the Solid Waste Area cap, resulting in a need for coordination between drilling and capping contractors.

The reliability to meet RAOs for the groundwater access restrictions is the same as Alternative #2. Installation of horizontal containment will provide a permanent and effective way to meet RAOs for groundwater. To ensure operational reliability, cap maintenance and inspections would be required.

Similar to Alternative #2, future actions could be implemented to increase this alternative's remedial effectiveness, if necessary. Extraction wells or trenches may be added beyond the boundaries of the caps to remove groundwater/leachate. Any attempt to add these within the capped area may affect the integrity of the caps.

The monitoring approach would be similar to that described for Alternative #2 with the exception of five additional water level piezometers within the Solid Waste Area. These piezometers would assist with monitoring the source control measures used in this alternative.

Landfill Gas. Implementation of access restrictions (fencing) would be the same as Alternative #2. Individual components of the landfill gas collection and treatment remedy would not present difficulties during construction. Some aspects, however, may be encountered that may increase the complexity of the construction and may require greater evaluation or engineering. These aspects include:

- integration of the active internal LFG collection system with the horizontal containment
- space restrictions for the active perimeter LFG collection system

- minimizing landfill gas emissions during subsurface work
- difficulties associated with worker health and safety equipment

Alternative #3a is expected to reliably meet ambient air and soil gas RAOs. The operational reliability of the enclosed flare would be dependent on keeping the burner lit since DREs would be zero if combustion does not occur. Flame controls and a separate pilot flame would be provided to ensure that the burner stays lit. The pilot light would have its own supply of propane gas and would not be dependent on the landfill gas supply.

Future actions could be implemented to increase this alternative's remedial effectiveness, if necessary. For example, additional perimeter wells or internal collection wells could be added if gas capture is inadequate. Some remedial actions, however, could not be accommodated. Removal or excavation of landfill contents after cap installation is not practical. In addition, capped areas could not be used for other purposes such as ballfields, parks or future construction that could compromise the cap integrity.

The environmental monitoring program would measure the effectiveness of the landfill gas remedy at the Site.

Administrative Feasibility. The relative effort and time required to obtain the necessary regulatory approvals and permits for the remedy is evaluated below.

Groundwater/Leachate. Regulatory approvals or permits anticipated to be required to implement the remedy in Alternative #2 will also apply to this alternative. State permits are anticipated to be required prior to any cap construction. Coordination with state and local authorities may be necessary to effectively implement groundwater/leachate monitoring and cap maintenance.

Landfill Gas. As with groundwater/leachate, coordination with state and local authorities may be necessary to effectively implement the LFG portion of the environmental monitoring program.

Under Superfund, permits are not required for remediation activities. Compliance with substantive requirements is, however, required. Thus, while an air permit would not be required for operation of the enclosed flare, flare design must meet state standards and RIDEM must be consulted during the design. Coordination with state and local authorities may be necessary to effectively implement flare operation and cap maintenance. The pump stations and aboveground storage tank for handling gas condensate would need to be designed and installed in compliance with RCRA tank rules. Local ordinances would need to be followed (such as building permits, well drilling or UST registration, etc.) during construction of the collection system flare, and support facilities.

Availability of Services and Materials. The availability of key services and materials needed to implement the alternative are discussed below and include: capacity and location of treatment, storage, and/or disposal facilities (TSDFs), availability of necessary equipment and specialists, timing and scheduling, and ability to obtain competitive cost bids.

Groundwater/Leachate. Availability of services and materials for the access restrictions, environmental monitoring, five-year reviews and community relations support is the same as Alternative #2.

The only major effort required which is different from Alternative #2 would be horizontal containment of the disposal areas. The large volumes of materials necessary for the cap constructions should be obtained from as near the Site as possible.

Landfill Gas. Availability of services and materials for access restrictions (fencing) and environmental monitoring is the same as Alternative #2.

Construction of the gas collection system and fabrication of the enclosed flare would be the most difficult aspects of implementation regarding landfill gas. Construction contractors familiar with methane safety practices as well as knowledgeable about controlling fugitive vapors/COPCs would be required. Fabrication of the flare would take a significant lead time and may be limited to specific, specialty contractors.

LFG condensate may require disposal at a TSDF. There are currently no TSDFs in Rhode Island which handle this waste stream. However, there are many companies in nearby states which would be able to dispose of the condensate.

4.3a.2.7 Cost of Alternative #3a. Cost assumptions regarding escalation, discount rate, contingency and duration, unless otherwise specified, are the same as Alternative #2. The duration of O&M activities related to landfill gas collection and treatment is limited to 15 years since landfill gas generation is expected to cease by this point in time.

Capital costs associated with this alternative are expected to be $6.42 million. Operations and maintenance costs (expressed in net present worth dollars) are estimated at $7.01 million. Total costs are therefore $13.43 million. These costs are summarized in detail in Appendix G.

4.3a.2.8 State and Community Acceptance of Alternative #3a. Comments from the State of Rhode Island, the town of South Kingstown, and citizens of the community regarding this alternative will be addressed after the public comment period.

4.3b EVALUATION OF ALTERNATIVE #3b: HORIZONTAL CONTAINMENT OF SOLID WASTE AND BULKY WASTE AREAS, GAS COLLECTION AND TREATMENT BY PHOTOCATALYTIC OXIDATION

This section describes the components of Alternative #3b followed by detailed evaluation of those components versus the nine FS criteria.

4.3b.1 Definition of Alternative #3b

Alternative #3b is the same as Alternative #3a, with the exception that collected landfill gas is treated using an innovative technology, photocatalytic oxidation, instead of an enclosed flare. Photocatalytic oxidation is capable of destroying COPCs in the landfill gas with an effectiveness similar to that of an enclosed flare. Hence, this alternative is similar to Alternative #3a in that it provides increased mitigation of human health risks through control of landfill gas when compared with Alternative #2. It also provides improved mitigation of ecological risks through horizontal containment of the Solid Waste and Bulky Waste Areas. The containment of the Solid Waste Area also further mitigates human health risks by reducing migration of site COPCs into groundwater.

The major components of this alternative include:

- Groundwater Access Restrictions. Where appropriate, restrictive covenants would be placed on properties affected by site COPCs to limit use of groundwater as a potable water source. The scope for this component is the same as discussed previously under Alternative #2.

- Horizontal Containment - Solid Waste Area. Existing horizontal containment of the Solid Waste Area consists of an approximate 1-foot-thick layer of silty-sand material (Appendix C). To provide more effective horizontal containment, a protective cap would be added to the Solid Waste Area. A detailed description of horizontal

containment for the Solid Waste Area has been provided previously in Section 3.1.2.1. In addition, five piezometers would be installed within the capped portion to monitor water levels and determine effectiveness of the containment.

- Horizontal Containment - Bulky Waste Area. Existing horizontal containment of the Bulky Waste Area consists of an approximate 3-foot-thick layer of silty-sand material (Appendix C). To provide a more effective horizontal containment, a protective cap would be added to the Bulky Waste Area. A detailed description of horizontal containment for the Bulky Waste Area has been provided previously in Section 3.1.2.2.

- Active Perimeter LFG Collection - Solid Waste Area. A perimeter LFG collection system would be implemented to prevent migration of landfill gas from the Solid Waste Area into adjacent, off-site vadose zone soils. This perimeter system would consist of a series of vapor extraction wells installed adjacent to the Solid Waste Area in a line parallel to Rose Hill Road. Refer to Section 3.1.8.2 for a description of this component in greater detail.

- Active Internal LFG Collection - Solid Waste Area. An internal LFG collection system would be implemented to prevent migration of landfill gas from the Solid Waste Area into ambient air. This internal system would consist of a series of vapor extraction wells installed within the confines of the Solid Waste Area in an evenly-spaced grid pattern. Further descriptive details of this component are provided in Section 3.1.8.3.

- LFG Treatment (Photocatalytic Oxidation) - Solid Waste Area. Landfill gas collected by the internal and perimeter Solid Waste Area collection systems would be combined and treated by a photocatalytic oxidation system for destruction of site COPCs prior to ambient air discharge. Detailed discussion of this component is presented below.

- Passive Internal LFG Collection - Bulky Waste Area. A passive internal LFG collection system would be implemented to prevent migration of landfill gas from the Bulky Waste Area into adjacent vadose zone soils. This internal system would consist of a series of LFG vents installed within the confines of the Bulky Waste Area in a spatially-distributed pattern. Further descriptive details of this component are provided in Section 3.1.8.4.

- Environmental Monitoring. Environmental monitoring includes monitoring of groundwater, surface water/sediment, ambient air and soil gas. Monitoring locations, frequencies and analytes are the same as described previously for Alternative #1.

- Five-Year Review. As described previously in Alternative #1, since this alternative would result in contaminants remaining on the Site, CERCLA §121(c) and §300.430(f)(4)(ii) of the NCP require that the site remedy be reviewed every five years.

- Community Relations Activities. In the same manner as Alternative #1, on-going community relations activities will be conducted to provide appropriate information, receive comment on that information and to adjust the remedy of the Proposed Plan at key milestones.

Figure 4-4 illustrates the site layout for Alternative #3b. The components of the alternative, and how they interact with each media of concern, are presented on Figure 4-5.

4.3b.1.1 LFG Treatment by Photocatalytic Oxidation. A general description of the photocatalytic oxidation technology for treatment of chlorinated VOCs in gaseous waste streams was presented in Section 3.1.10. This section presents the basis used to estimate the size and cost of a photocatalytic oxidation system for treating the combined perimeter gas/internal landfill gas stream from the Solid Waste Area, and describes several vendor-specific variations of the technology.

Influent Gas Stream Characterization. Estimated flow rates and compositions for the perimeter LFG and interior LFG collection systems are presented in Appendix E. These flows were then combined to provide the resulting photocatalytic oxidation system influent gas stream. These streams are as follows:

Perimeter Gas Stream

812 ft^3/minute of gas with composition of:

77% nitrogen (% by volume)
21% oxygen
1% methane
1% carbon dioxide
VOC concentrations assumed to be negligible in comparison to concentrations in internal LFG

Internal LFG Stream

41 ft^3/minute of LFG with composition of:

50% methane (% by volume)
50% carbon dioxide
1,200 ppmv vinyl chloride
See Appendix E for concentrations of other COPCs

Combined perimeter and internal LFG gas stream (feed to photocatalytic oxidation system)

853 ft^3/minute of gas with composition of:

3.5% methane (% by volume)
3.5% carbon dioxide
73.5% nitrogen
19.5% oxygen
83 ppmv vinyl chloride
See Appendix E for concentrations of other COPCs

Unlike an enclosed flare or other thermal treatment system, photocatalytic oxidation systems should not require the use of auxiliary fuel at any time during the remediation because the oxidation reactions that destroy the COPCs are catalytic, ambient temperature reactions rather than combustion reactions. Energy input to the photocatalytic system would be in the form of electricity to power the UV lamps, rather than an auxiliary fuel such as natural gas or propane.

Specific Technology Descriptions and Material Balances. Process flow schematics for two variations of this technology are presented in Figures 3-16 and 3-17. Two systems, the Matrix Photocatalytic system and the KSE AIR-II system, are described by their developers as "photocatalytic oxidation" systems and are similar in concept. The system developed by Process Technologies, Inc. (PTI) is called a "photolytic" system as opposed to a "photocatalytic" system, and is sufficiently different from the other two systems that a separate description is warranted. Material balances for each system are presented in Appendix A.

Photocatalytic Systems. The Matrix Photocatalytic system and the KSE AIR-II system are illustrated jointly in Figure 3-16. A system for collection of both perimeter and internal landfill gas is installed, and the combined gas streams are collected and drawn into the

photocatalytic system by a blower (or blowers). The perimeter gas and internal landfill gas would pass through a knock-out drum to remove entrained water droplets before entering the photocatalytic reactor. The primary difference between the two systems is the catalyst material used. The Matrix Photocatalytic system uses titanium dioxide (TiO_2) as the catalyst. For certain applications, the Matrix Photocatalytic system also adds a small amount of ozone gas to the gas stream to be treated. The purpose of the ozone is to create more free radicals within the reactor, thereby enhancing contaminant destruction.

The KSE AIR-II system uses a proprietary catalyst that adsorbs the VOCs of potential concern where they are then oxidized by the combined action of the UV light and the catalyst. The developer claims that this catalyst has a higher activity, stability, and selectivity than the competing TiO_2 catalyst, resulting in lower capital and operating costs.

Photolytic System. The photolytic system of PTI, Inc. is illustrated schematically in Figure 3-17. The PTI system differs from the photocatalytic systems in two respects: (1) the influent gas stream is concentrated to reduce the flow rate and increase contaminant concentrations before treatment and (2) the solid material within the photolytic units is technically not a catalyst, in that the material (a proprietary cementitious liner material) is a consumable that has to be replaced. However, catalysts also require replacement at intervals due to deactivation over time, and the difference between "photocatalytic" and "photolytic" is not considered to be a significant difference, when compared to the differences between these systems vs. an enclosed flare or other thermal treatment technology.

The adsorber/concentrator, supplied by PTI as part of their overall system, works by adsorbing organic contaminants on an adsorbent material (i.e. carbon), and then desorbing them using a much smaller gas flow rate. After treatment in the adsorber/concentrator, the bulk of the landfill gas (approximately 90% of the influent flow) is exhausted to the atmosphere, or routed to a process for destruction of methane if such destruction is deemed necessary. The concentrated gas stream containing desorbed organic contaminants

(approximately 10% of the total influent flow) is routed to a condenser. The condenser removes some of the concentrated organic contaminants as a liquid. This liquid would need to be disposed of offsite. The volume of this liquid was assumed negligible for costing purposes. The combination of the adsorber/concentrator and the condenser is not mandatory, but it generally results in a lower lifecycle cost than photolytically treating the dilute gas stream directly, because it reduces the number/size of photolytic units needed and increases their efficiency. After treatment in the photolytic units to destroy the organic contaminants that are not condensed, the gas is recycled to the adsorber/concentrator.

Key sizing parameters necessary for ambient air dispersion modeling of a non-combustion treatment system include: 1) stack dimensions, 2) the stack velocity, and 3) the exit or flue gas composition. Since the system operates at ambient temperature, the flue gas flow rate is the same as what entered the system (851 ft^3/minute). Unlike the enclosed flare, the stack dimensions are not based on a residence time. Stack dimensions are based on good engineering practice and air dispersion required to meet site PRGs.

Destruction removal efficiencies ranging from 95% to 98% are attainable for the VOCs of potential concern (including vinyl chloride). Higher DREs are attainable if necessary to attain PRGs at the site boundary. The DREs to be specified would be determined during design of the remedy, and would depend on the results of on-site pilot testing of the photocatalytic oxidation technology and air dispersion modeling of emissions from the system.

Preliminary air dispersion modeling was performed to determine approximate stack dimensions required for a photocatalytic system to meet site PRGs. Assumptions and modeling are presented in Appendix F. For a vinyl chloride DRE of 98%, a 1-foot diameter stack with a height of 30 feet would meet PRGs at the site boundary. Dispersion may be improved through use of an additional blower or by altering stack dimensions to increase stack velocity.

Principal oxidation products from the photocatalytic oxidation system include water vapor, carbon dioxide, hydrogen chloride gas (HCl), and chlorine gas (Cl_2). Secondary oxidation products that may also be generated in trace amounts include: undestroyed or partially destroyed COPCs (as defined by the DREs), undestroyed or partially destroyed odor causing compounds such as methyl mercaptan (CH_3SH) and hydrogen sulfide, and sulfur oxides (SO_x). The sulfur-containing compounds such as methyl mercaptan and hydrogen sulfide are present in the landfill gas and may oxidize to form sulfur oxides (SO_X). These sulfur-containing compounds are not COPCs but are a nuisance from the standpoint of odors. Whether such compounds are present and would oxidize to sulfur oxides would need to be determined during an on-site pilot test of photocatalytic oxidation.

4.3b.2 Nine Criteria Evaluation of Alternative #3b

The analysis of Alternative #3b with respect to the nine criteria is presented in a narrative form in the following paragraphs. The assessment focuses on how, and to what extent, the various factors within each of the criteria are addressed. Uncertainties associated with the alternative are included when changes in assumptions or unknown conditions could affect the analysis.

4.3b.2.1 Overall Protection of Human Health and the Environment from Alternative #3b. Like Alternative #3a, Alternative #3b would provide a significant increase in the overall protection of human health. The alternative uses both the institutional controls presented in Alternative #2 to prevent exposures from occurring, and engineering controls to further reduce exposures and reduce and contain contamination at the Site. This alternative would provide a significant increase in the overall protection of human health, specifically from inhalation exposures, by capping the disposal areas and actively collecting and treating landfill gas within and along the perimeter of the Solid Waste Area. Access restrictions (fencing) for the Solid Waste Area presented for Alternative #2 would be included in this alternative to further reduce the potential for inhalation exposures on the Site. Risks to off-site receptors from inhalation exposures to COPCs in ambient air would be reduced with a cap by minimizing uncontrolled landfill gas emissions at the Solid Waste Area. This risk would be expected to be reduced to within the EPA target cancer risk range. The addition of

an active perimeter LFG collection system would be expected to reduce risks to nearby residents from indoor inhalation exposures to within the EPA target risk range.

Exposures to groundwater contaminants would be limited through implementation of groundwater access restrictions.

Protection of human health by reductions in risk, discussed above, would result from the containment and reduction of COPCs at the Site and from implementation of institutional controls. Site related health risks are unlikely to exceed the EPA target risk range with this alternative.

Additional short-term risks to the community and workers at the Site may result from inhalation exposures associated with the construction activities for this alternative. These activities include installation of horizontal containment (e.g. caps) on the Solid Waste and Bulky Waste Areas and intrusive work at the Solid Waste Area. Intrusive work includes pilot testing of the photocatalytic oxidation technology, installation of active internal LFG and active perimeter LFG collection systems, and installation of a full-scale photocatalytic oxidation system. These additional short-term risks to the community and workers would be mitigated using dust control measures and air monitoring to detect soil gas emissions and off-site migration of COPCs. Because worker exposures at the Site are expected to be the highest, short-term risks to workers would be further mitigated by using PPE, as appropriate. Specific long-term and short-term human health risks are discussed in Sections 4.3b.2.3 and 4.3b.2.5, respectively.

The overall protection of ecological receptors for Alternative #3b would be the same as Alternative #3a.

4.3b.2.2 Compliance With ARARs from Alternative #3b. Action-specific ARARs under this alternative are presented in Table 4-7. Any remedial actions taken under this alternative must comply with the ARARs listed in this table. Environmental monitoring will be used as an indicator of compliance with the site-specific chemical and location-specific ARARs described in Section 2.3.

Further actions may be required to comply with ARARs if they are not met through this source control remedy.

4.3b.2.3 Long-term Effectiveness and Permanence from Alternative #3b. This alternative is evaluated below in terms of the risk remaining at the Site after RAOs are addressed. This portion of the evaluation focuses on the extent and effectiveness of the controls required to manage the risk posed by treatment residuals and/or untreated contamination.

Magnitude of Residual Risks. Alternative #3b would combine technologies to contain and reduce site COPCs in ambient air, soil gas and groundwater at the Site. Institutional controls are implemented to minimize human exposures to COPCs in soil gas and groundwater both on and off the Site. Residual risks are the same as Alternative #3a, except as discussed below.

The photocatalytic oxidation system for LFG treatment destroys site COPCs but does not destroy methane. Known human health risks from methane exposure are evident only at relatively high concentrations (1% or greater) and are limited to asphyxiation and the potential for injury due to fire or explosion. However, the presence of methane in the atmosphere is believed to be a contributor to global warming. Dispersion of methane from the stack of the photocatalytic oxidation system will result in ambient air concentrations below the lower explosive limit of 5% and below levels which could cause asphyxiation. The quantity of methane emitted from the Site is not reduced by this alternative.

Residual human health risks at the Site would include inhalation exposures to soil gas components in ambient air that would escape the collection and treatment system. For the purposes of this FS risk evaluation, gas capture rates are assumed to be 100% and the treatment efficiency of the photocatalytic oxidation system is assumed to be 98%. This treatment efficiency is higher than the more conservative value of 95% used for the flare in Alternative #3a. Due to ambient temperature operation, dispersion of site COPCs from a photocatalytic oxidation discharge stack would tend to be less than that from a flare.

New risks could be anticipated from the implementation of this remedial alternative. By-products of the photocatalytic oxidation of chlorinated VOCs include chlorine gas and hydrogen chloride gas. These compounds will be emitted from the stack of the photocatalytic oxidation system. In addition, undestroyed COPCs will be emitted in trace amounts, since destruction and removal efficiencies for VOCs in the photocatalytic oxidation system are not 100%. These emissions could result in low-level inhalation exposures at nearby residences. Emissions of chlorine and hydrogen chloride can be controlled by using a caustic scrubber following the photocatalytic oxidation system if it is determined that emission levels of these compounds pose an unacceptable risk. Emission levels of these compounds and other potential by-products can be quantified during pilot testing of the photocatalytic oxidation technology.

Long-term risks to ecological receptors would be similar to those described for Alternative #3a. New, long-term risks from the emission of methane and by-products of photocatalytic oxidation are unlikely. However, any risks from by-product emissions would be evaluated using data from pilot testing of the photocatalytic oxidation system. If deemed necessary during the design, emission controls (i.e., a caustic scrubber following the photocatalytic oxidation system, and/or a unit to destroy methane) would be included as part of the remedial design.

Adequacy of Controls. Measures are described below that detail controls to be placed on untreated waste, waste-contaminated media, and treatment residuals from implementation of Alternative #3b.

Groundwater/Leachate. Adequacy of controls for groundwater/leachate under Alternative #3b would be similar to Alternative #3a.

Landfill Gas. Landfill gas not captured by the active internal collection system would be captured by the active perimeter collection system. The perimeter system and caps provide a significant secondary containment of landfill gas and significantly reduce fugitive emissions to ambient air.

The hazard from untreated site COPCs exiting the photocatalytic oxidation system would be very low due to the high destruction removal efficiencies that can be expected. Destruction removal efficiencies would be expected to be a minimum of 95% for all VOCs. Greater hazards are posed by condensate from the landfill gas, methane, and oxidation by-products

such as hydrogen chloride and chlorine. Analysis of expected DREs and production of hydrogen chloride and chlorine was described previously in Section 4.3b.1.1.

Reliability of Controls. Evaluations are described below that detail the effectiveness, reliability, and permanence control measures will provide to protect human health and the environment from exposures to untreated waste, waste-contaminated media, and treatment residues.

Groundwater/Leachate. Reliability of controls for groundwater/leachate would be similar to Alternative #3a.

Landfill Gas. The presence of the active perimeter LFG collection system and caps provide a significant degree of protection from hazards posed by uncollected landfill gas not collected by the active internal LFG collection system.

Because photocatalytic oxidation is an innovative technology, its reliability over years of operation has not been determined. The technology has not yet been tested on landfill gas. An on-site pilot test is necessary to evaluate factors related to reliability such as catalyst life and the potential for equipment corrosion.

Reliability of the landfill gas collection and treatment system will be dependent on close attention of the operator(s), and engineering support staff on a daily, weekly or monthly basis as appropriate. Typical operations functions would include: replacement of burnt-out UV lamps and spent catalyst in the photocatalytic oxidation system, removal and disposal of condensate, analytical sampling, process monitoring, and preparation of operations reports.

Typical maintenance and troubleshooting activities would involve the following: well and pipeline inspections, condensate tank inspection, blower inspections/overhauls, instrumentation calibration, and any equipment repair. Due to the long duration of operations, equipment replacement will also be required during planned intervals. Key items associated with some of the equipment should be stocked. These items may include UV lamps, instrumentation replacement parts and other process sensors.

Troubleshooting specialists and maintenance staff should be "on call" via auto-dial modems when operators are not present, such as nights, holidays, etc. The landfill gas collection and photocatalytic oxidation system should be designed to default to a "shut-down" mode if equipment failures occurred. Thus, staff would be called in order to re-start the system. Since, the landfill gas is generated with or without collection, the duration of these shutdowns should be limited. While a shut-down of hours and days may be acceptable, shutdowns of weeks or months would likely not be.

While not a COPC, methane is a safety hazard due to the potential for uncontrolled fire and explosion. Design of all necessary system features (i.e. flame arresters, explosion-proof wiring/instrumentation) into the collection and photocatalytic oxidation system will be required to prevent such safety hazards.

Similar to groundwater/leachate, monitoring of air and landfill gas would provide an accurate measure of the success of this remedy and provide a basis for operational changes such as modification of well vacuum rate, installation of additional wells, and adjustments to the photocatalytic oxidation system. Such adjustments may include shutdown of some fraction of the UV lamps as concentrations of COPCs in the landfill gas decline.

Need for Five-Year Review. Because wastes would remain on the Site under this alternative, CERCLA §121(c) and the NCP at §300.430(f)(4)(ii) require that a five-year review be conducted every five years. This five-year review would continue until it is demonstrated that there is no longer a threat to human health or the environment from the Site. For the purpose of this FS and costing, it is assumed that a "Level I" review, the lowest level, would be conducted.

4.3b.2.4 Reduction of Toxicity, Mobility or Volume through Treatment from Alternative #3b. This criterion evaluates how the alternative mitigates the effects of site COPCs by describing the following: treatment technologies and process options utilized, quantity of site COPCs/contaminated media affected, degree of expected reductions in mobility of site COPCs into the environment, degree to which the treatment is irreversible, and the residuals remaining after treatment.

Treatment/Recycling Processes Utilized. The treatment, recycling and other mitigation processes of the remedy and any materials treated are listed below for this alternative:

<u>Groundwater/Leachate</u>

- Horizontal Containment - Solid Waste Area
- Horizontal Containment - Bulky Waste Area

<u>Landfill Gas</u>

- Active perimeter LFG collection - Solid Waste Area
- Active internal LFG collection - Solid Waste Area

- LFG Treatment (photocatalytic oxidation) - Solid Waste Area
- Passive internal LFG collection - Bulky Waste Area

Amount of Hazardous Materials Treated or Recycled. The quantities or volumes of materials containing COPCs that are destroyed, recycled or treated are detailed below. These quantities may also include other hazardous materials that are involved in the remedy.

Groundwater/Leachate. The amount of materials treated or recycled for horizontal containment of the Bulky Waste and Solid Waste Areas is the same as described previously for Alternative #3a.

Landfill Gas. The combination of the active internal LFG collection system, perimeter LFG collection system and horizontal containment will capture essentially 100% of the LFG production from the Solid Waste Area (refer to Section 4.3a.1.1). DREs for the photocatalytic oxidation system are expected to be a minimum of 95% for site COPCs, but the systems can be designed to destroy site COPCs with an efficiency of 99% or greater. To attain higher DREs, the residence time of the system is increased by adding more individual photocatalytic oxidation modules, or by using larger modules. No destruction of methane will occur in the photocatalytic oxidation system. Hence, the quantity of methane emitted from the Site will not be reduced by this alternative. Methane is not classified as a hazardous material, but it is considered to be a contributor to global warming.

The passive internal LFG collection system in the Bulky Waste Area will redirect migrating LFG from vadose zone soils to ambient air. No elimination of site COPCs will occur.

Degree of Expected Reductions in Toxicity or Mobility. The expected degree of reductions in toxicity or mobility of the COPCs in site media are detailed below.

Groundwater/Leachate. The expected reduction in toxicity or mobility for horizontal containment of the Bulky and Solid Waste Areas is the same as described previously for Alternative #3a.

Landfill Gas. For the Solid Waste Area, this alternative reduces both the toxicity of site COPCs as well as their mobility into soil gas and ambient air. The degree of LFG mobility reduction is directly related to the overall LFG capture efficiency. The LFG capture efficiency is expected to be very high (near 100%) since this remedy includes both active internal and perimeter systems as well as horizontal containment. The degree of toxicity

reduction is directly related to the destruction efficiency of the photocatalytic oxidation system which is described above.

For the Bulky Waste Area, this alternative reduces the mobility of LFG migration into vadose zone soil gas. There is no degree of reductions in toxicity or mobility of the COPCs in site media, beyond natural attenuation.

Degree to Which Treatment Is Irreversible. The degree to which treatment, recycling or other appropriate remedial components of the selected remedy are irreversible is evaluated below.

Groundwater/Leachate. The degree of reversibility for horizontal containment of the Bulky Waste and Solid Waste Areas is the same as described previously for Alternative #3a.

Landfill Gas. Treatment of collected LFG in the photocatalytic oxidation system is an irreversible elimination of site COPCs. Removal of components related to the LFG collection and thermal treatment systems, however, would still allow the Site to revert back to no action conditions less the site COPCs destroyed previously.

Type and Quantity of Residuals Remaining After Treatment. The quantity and composition of residuals generated by treatment processes in this alternative are described below. These residuals may require further disposal and handling.

Groundwater/Leachate. This alternative would not involve any treatment of groundwater/leachate and, therefore, would not generate any residuals.

Landfill Gas. Residuals from collection and treatment of LFG at the Solid Waste Area would include the following:

- untreated methane that exits the stack of the photocatalytic oxidation system. The estimated emission rate for the first year of operation is 75 lb/hour.
- oxidation by-products such as hydrogen chloride and chlorine (from destroyed chlorinated VOCs), small quantities of undestroyed site COPCs, and possibly sulfur oxides from oxidation of sulfur compounds in the LFG. On-site pilot testing is needed to better estimate residuals, since the photocatalytic oxidation technology has not been previously demonstrated on LFG. If it is determined that the system needs

to include a scrubber to remove hydrogen chloride and chlorine from the stack gas, residuals will also include blowdown water from the scrubber.

- landfill gas condensate which may require disposal as a hazardous liquid.

Further detail on quantities is included in Section 3.1.8.2 and Appendix E.

4.3b.2.5 Short-term Effectiveness of Alternative #3b. This alternative is evaluated for effectiveness in protecting the community and local workers, site remediation workers, and the environment during the construction of the remedy.

Community Protection. Short-term risks to the community would include those identified for Alternative #3a, and would be mitigated using similar measures.

Worker Protection. Short-term risks to workers would include those identified for Alternative #3a, and would be mitigated using similar measures.

Environmental Protection. Short-term risks to the environment would include those identified for Alternative #3a, and would be mitigated using similar measures.

Time Until Remedial Action Objectives are Achieved. Estimates for the time to achieve RAOs are discussed below by site media of concern.

Groundwater. The time required to meet the RAOs for this media is the same as Alternative #3a.

Surface Water/Sediments. The time required to meet the RAOs for this media is the same as Alternative #3a.

Ambient Air. By use of the active internal LFG collection system, LFG treatment (photocatalytic oxidation) and horizontal containment, the time required to meet the RAOs will be the time required to implement, and achieve an operational and functional status of these technologies and process options. This is expected to occur within 1 to 2 years of selection of the FS remedy.

Soil Gas. By use of the passive venting system and active perimeter LFG collection system combined with LFG treatment by photocatalytic oxidation, the time required to meet the RAOs will be the time required to implement, and achieve an operational and functional status of these technologies and process options. This is expected to occur within 1 to 2 years of selection of the FS remedy.

4.3b.2.6 Implementability of Alternative #3b. The implementability of this alternative is discussed as a measure of the technical and administrative feasibility of this approach as well as the availability of key services and materials required for this remedy.

Technical Feasibility. The relative ease of implementing the remedy is summarized below. Key items include: ability to be constructed and operated, reliability in meeting RAOs, ease of undertaking additional remedial actions and ability to monitor effectiveness of the remedy.

Groundwater/Leachate. The technical feasibility for groundwater/leachate would be the same as for Alternative #3a.

Landfill Gas. Implementation of access restrictions (fencing) would be the same as Alternative #2. Individual components of the landfill gas collection and treatment remedy would not present difficulties during construction. Some aspects, however, may be encountered that may increase the complexity of the construction and may require greater evaluation or engineering. These aspects include:

- integration of the active internal LFG collection system with the horizontal containment
- space restrictions for the active perimeter LFG collection system
- minimizing landfill gas emissions during subsurface work
- difficulties associated with worker health and safety equipment

An on-site pilot demonstration of the photocatalytic oxidation technology would be needed prior to design and construction of a full-scale system. A number of suppliers are available that can provide pilot testing services and that have previously developed units that can destroy vinyl chloride and other Site COPCs. Since the suppliers do not have previous experience with treating landfill gas, however, there may be implementation problems that are not readily apparent now that may be revealed during demonstration testing. The photocatalytic oxidation system itself may need to be explosion proof.

Alternative #3b is expected to reliably meet ambient air and soil gas RAOs. The operational reliability of the photocatalytic oxidation technology in the long term (over several years) is not known, since the technology is relatively new. Operational problems that may occur after extended operation include catalyst deactivation and UV lamp burn out. The instrumentation and control system should be designed to notify operators and shut down the system if one or more lamps burn out. The system would be manually restarted by an operator once the lamps had been replaced. Catalyst deactivation will be more difficult to detect. Routine monitoring of the gas exiting the photocatalytic oxidation system will be required to determine if design DREs for Site COPCs are being attained.

Future actions could be implemented to increase this alternative's remedial effectiveness, if necessary. For example, additional perimeter wells or internal collection wells could be added if gas capture is inadequate. Some remedial actions, however, could not be accommodated. Removal or excavation of landfill contents after cap installation is not practical. In addition, capped areas could not be used for other purposes such as ballfields, parks or future construction that could compromise the cap integrity.

The environmental monitoring program would measure the effectiveness of the landfill gas remedy at the Site.

Administrative Feasibility. The relative effort and time required to obtain the necessary regulatory approvals and permits for the remedy is evaluated below.

Groundwater/Leachate. The administrative feasibility for groundwater/leachate would be the same as for Alternative #3a.

Landfill Gas. Coordination with state and local authorities may be necessary to effectively implement the LFG portion of the environmental monitoring program.

Under Superfund, permits are not required for remediation activities. Compliance with substantive requirements is, however, required. Thus, while an air permit would not be required for operation of the photocatalytic oxidation system, the design must meet state standards and RIDEM must be consulted during the design.

Coordination with state and local authorities may be necessary to effectively implement cap maintenance and operation of the photocatalytic oxidation system. The pump stations and aboveground storage tank for handling gas condensate would need to be designed and installed in compliance with RCRA tank rules. Local ordinances would need to be followed (such as building permits, well drilling or UST registration, etc.) during construction of the collection system, treatment system, and support facilities.

Availability of Services and Materials. The availability of key services and materials needed to implement the alternative are discussed below and include: capacity and location of TSDFs, availability of necessary equipment and specialists, timing and scheduling, and ability to obtain competitive cost bids.

Groundwater/Leachate. The availability of services and materials for this alternative is the same as Alternative #3a.

Landfill Gas. Availability of services and materials for access restrictions (fencing) and environmental monitoring is the same as Alternative #2. Availability of TSDFs for LFG condensate is the same as Alternative #3a.

Construction of the gas collection system and design, testing and installation of the photocatalytic oxidation system would be the most difficult aspects of implementation regarding landfill gas. Construction contractors familiar with methane safety practices as well as knowledgeable about controlling fugitive vapors/COPCs would be required.

Other implementation difficulties relate to the innovative nature of the photocatalytic oxidation technology. There are only a few vendors who supply photocatalytic oxidation systems, and each vendor's system is somewhat different and contains components that the vendor may consider to be proprietary. Pilot testing would be needed to demonstrate the technology, and success during testing of one vendor's system would not necessarily guarantee that another vendor's system would be equally effective. One approach would be to allow several vendors to pilot their respective systems, and the results of the testing would be used to specify acceptable suppliers for the full-scale photocatalytic oxidation system. An alternative approach is to specify the system by performance criteria only, require a performance guarantee, and allow bidders on the remedial design to select the system supplier.

4.3b.2.7 Cost of Alternative #3b. Cost assumptions regarding escalation, discount rate, contingency and duration, unless otherwise specified, are the same as Alternative #3a.

Capital costs associated with this alternative are expected to be $6.56 million. Operations and maintenance costs (expressed in net present worth dollars) are estimated at $6.63 million. Total costs are therefore $13.19 million. These costs are summarized in detail in Appendix G.

4.3b.2.8 State and Community Acceptance of Alternative #3b. Comments from the State of Rhode Island, the town of South Kingstown, and citizens of the community regarding this alternative will be addressed after the public comment period.

4.4a EVALUATION OF ALTERNATIVE #4a: HORIZONTAL CONTAINMENT OF SOLID WASTE AND BULKY WASTE AREAS, LEACHATE COLLECTION AND ON-SITE TREATMENT, GAS COLLECTION AND THERMAL TREATMENT

This section describes the components of Alternative #4a followed by detailed evaluation of those components versus the nine FS criteria.

4.4a.1 Definition of Alternative #4a

Alternative #4a provides the same level of human health risk mitigation as Alternative #3a through control of landfill gas and migration of site COPCs into groundwater. Mitigation of ecological risk is improved through control of leachate at the Bulky Waste Area when compared with Alternatives #3a and #3b.

The major components of this alternative include:

- Groundwater Access Restrictions. Where appropriate, restrictive covenants would be placed on properties affected by site COPCs to limit use of groundwater as a potable water source. The scope of this component is the same as discussed previously under Alternative #2.

- Horizontal Containment - Solid Waste Area. The implementation of the protective cap for the Solid Waste Area would be the same as Alternatives #3a and #3b.

- Horizontal Containment - Bulky Waste Area. The implementation of the protective cap for the Bulky Waste Area would be the same as Alternatives #3a and #3b.

- Active Perimeter LFG Collection - Solid Waste Area. The implementation of the active perimeter LFG collection system would be the same as described previously for Alternatives #3a and #3b.

- Active Internal LFG Collection - Solid Waste Area. The implementation of the active internal LFG collection system would be the same as described previously for Alternatives #3a and #3b.

- Thermal LFG Treatment (Enclosed Flare) - Solid Waste Area. This alternative would implement the LFG treatment enclosed flare system in the same manner as Alternative #3a.

- Passive Internal LFG Collection - Bulky Waste Area. This alternative would implement the passive internal LFG collection system for the Bulky Waste Area in the same manner as Alternatives #3a and #3b..

- Leachate Collection (Wells/Drains) - Bulky Waste Area. A leachate collection system would be installed southeast of the Bulky Waste Area to intercept leachate migrating toward the Saugatucket River. Details of the collection system design and expected flowrates have been provided in Section 3.1.4.

- On-site Leachate Treatment. Treatment of extracted water would be accomplished utilizing a treatment train consisting of precipitation, media filtration and UV/chemical oxidation. This system is described in greater detail below.

- Discharge of Treated Water. Treated water would be discharged to either groundwater or surface water, as discussed previously in Section 3.1.6.4.

- Environmental Monitoring. Environmental monitoring includes monitoring of groundwater, surface water/sediment, ambient air and soil gas. Monitoring locations, frequencies and analytes are the same as described previously for Alternative #1.

- Five-Year Review. As described previously in Alternative #1, since this alternative would result in contaminants remaining on the Site, CERCLA §121(c) and §300.430(f)(4)(ii) of the NCP require that the site remedy be reviewed every five years.

- Community Relations Activities. In the same manner as Alternative #1, on-going community relations activities will be conducted to provide appropriate information, receive comment on that information and to adjust the remedy of the Proposed Plan at key milestones.

Figure 4-6 illustrates the site layout for Alternative #4a. The components of the alternative, and how they interact with each media of concern, are presented on Figure 4-7.

4.4a.1.1 On-Site Leachate Treatment. In this alternative, a treatment train consisting of precipitation, media filtration and UV/chemical oxidation would be used to remove site COPCs to within ARAR limits prior to discharge. General descriptions of the various process options have been previously discussed in Section 3.1.6.

The expected flowrate of leachate to be processed in this treatment train is approximately 5 gpm (Appendix C). Some equipment (such as pumps) would not be commonly available for continuous operation at this flowrate. Therefore, a larger plant operated on a part-time basis (e.g. batch mode) may be more appropriate. For example, a 20 gpm plant, with adequate equalization storage capacity, could treat the required daily flow (7,200 gallons @5 gpm) in approximately a 6-hour shift each day. The specific mode of operation (continuous or batch) and the resulting plant sizing should be addressed as part of the remedial design activities. For the purposes of this FS, estimation of on-site treatment plant costs in this alternative have been based on 40% of the 50 gpm treatment plant size detailed in Alternatives #5a and #5b (Appendix D). This size plant has a flowrate approximately equal to 20 gpm.

Precipitation. Precipitation would be used to remove high concentrations of inorganic compounds from collected water, which could cause fouling in other treatment train components. These inorganics include iron, manganese, and aluminum. This process option includes the following: 5,000 gallon holding/equalization tank, PVC-lined pH adjustment/coagulant addition tank, neutralization tank, flocculation tank, solids separation tank, sludge thickener, and a filter press. Further equipment sizing specifics, such as vendor quotations, are presented in Appendix D. It is assumed that media filtration would not be needed prior to precipitation, as any suspended solids which do not settle during equalization would assist in the flocculation process. Fugitive emissions of VOCs would be treated by a catalytic ozone/VOC destruction unit included as part of the UV/chemical oxidation process option.

Media Filtration. After precipitation, a sand filter would be used to further remove any suspended matter remaining in the water. A continuous backwash, upflow sand filter would be expected to

remove particles sizes greater than 11 μm resulting in total suspended solids concentrations less than 10 mg/L. Further equipment sizing specifics, such as vendor quotations, are presented in Appendix D.

UV/Chemical Oxidation. This alternative would utilize UV/chemical oxidation to destroy organic COPCs. A general description of the system used in this FS includes the following: an ozone generator, an ozone generator air preparation system (compressor, dryer, filter), a peroxide feed system, an oxidation reactor (includes UV lamps), a catalytic ozone/VOC destruction unit to treat any vapors, and a control unit. Other vendor-supplied systems may substitute alternate oxidants and off-gas control technologies in place of the ozone-based system described here. Further equipment sizing specifics, such as vendor quotations, are presented in Appendix D.

Based on discussion with leading UV/chemical oxidation suppliers (Appendix D), treatment efficiencies for organic site COPCs should be adequate to meet ARAR limits for discharge of treated water.

4.4a.2 Nine Criteria Evaluation of Alternative #4a

The analysis of Alternative #4a with respect to the nine criteria is presented in a narrative form in the following paragraphs. The assessment focuses on how, and to what extent, the various factors within each of the criteria are addressed. Uncertainties associated with the alternative are included when changes in assumptions or unknown conditions could affect the analysis.

4.4a.2.1 Overall Protection of Human Health and the Environment from Alternative #4a. To further increase the overall protection of human health and the environment, Alternative #4a would combine institutional controls to prevent exposures with engineering controls, to reduce concentrations of COPCs in soil gas and ambient air, to reduce leachate generation and to collect and treat leachate. Specific long-term and short-term human health and environmental risks are

discussed in Sections 4.4a.2.3 and 4.4a.2.5, respectively; the discussion below provides a general overview.

The overall protection of human health from inhalation exposures on and off the Site would be similar to that described for Alternatives #3a and #3b. Installation of a leachate collection and treatment system for the Bulky Waste Area would reduce subsequent groundwater impacts in this area. This will reduce contaminant migration observed as breakout of contaminated leachate along this area. The system is not designed to intercept the entire saturated thickness of the overburden and contamination may migrate below the intercept trenches. Although these controls would further reduce groundwater contamination, institutional controls presented in Alternative #2, including groundwater access restrictions and residential well monitoring, would be included in this alternative. Therefore, future risks from residential ingestion of groundwater on and off the Site would not be expected.

Short-term risks to the community and workers at the Site from construction and implementation of Alternative #4a would be similar to those identified for Alternatives #3a and #3b and would be mitigated in the same way. Any additional short-term risks to workers from installation of the leachate collection and treatment system would be mitigated with PPE.

This alternative would be protective of the environment. Capping the Solid Waste and Bulky Waste Areas and installing a leachate collection system would eliminate leachate migration into Site surface waters, thus controlling the source of continuing ecological risk. Leachate generation and discharge to Mitchell Brook and the Saugatucket River would be prevented and/or controlled. Assuming that the integrity of the caps remain intact and the leachate collection and treatment system function properly, it is expected that ecological RAOs and PRGs would be met. Impacts to ecological receptors and habitat associated with remedial activities are similar to those described for Alternatives #3a and #3b. Hydrology impacts due to water reinjection must be reviewed further during the remedial design phase of the project.

4.4a.2.2 Compliance With ARARs from Alternative #4a. Action-specific ARARs under this alternative are presented in Table 4-8. Any remedial actions taken under this alternative must comply with the ARARs listed in this table. Environmental monitoring will be used as an indicator of compliance with the site-specific chemical and location-specific ARARs described in Section 2.3. Further actions may be required to comply with ARARs if they are not met through this source control/leachate treatment remedy.

4.4a.2.3 Long-term Effectiveness and Permanence from Alternative #4a. This alternative is evaluated below in terms of the risk remaining at the Site after RAOs are addressed. This portion of the evaluation focuses on the extent and effectiveness of the controls required to manage the risk posed by treatment residuals and/or untreated contamination.

Magnitude of Residual Risks. With this alternative, capping, gas collection and leachate controls would leave solid wastes in place but would reduce migration of contamination. Capping, and gas collection and treatment would reduce uncontrolled emissions of landfill gas and leachate generation, as presented for Alternative #3a. Migration of COPCs to groundwater and surface water would be further reduced by the leachate collection system at the Bulky Waste Area.

The residual human health risks from inhalation exposures both on and off the Site under Alternative #4a would be similar to those described for Alternative #3a.

Residual human health risks from future ingestion of contaminated groundwater at the Site would be reduced further over the long-term. Reduction of leachate (due to capping) in the Solid Waste Area and collection and treatment of leachate in the Bulky Waste Area would reduce future groundwater impacts.

Residential well monitoring would be included under this alternative. Therefore, future risks to nearby residents from ingestion of contaminated groundwater as a result of plume migration would not be expected.

Residual risks to the community and workers at the Site from remediation activities would include residual risks identified for Alternative #3a. In addition, there would be residual risks to the community and workers at the Site from the treatment of collected leachate which would be achieved by media filtration and UV/chemical oxidation. The UV/chemical oxidation process could lead to inhalation exposures to ozone and products of incomplete oxidation of groundwater VOCs. These risks would be mitigated by 1) proper sizing of the reaction chamber for optimal residence time, 2) containment of off-gases in a secondary chamber to allow for longer reaction time, and 3) a catalytic ozone decomposer. Off-site risks could also occur from the off-site transport and disposal of solid and liquid wastes from the media filtration and precipitation systems. These potential risks would be mitigated by using the required safety procedures for the transport and disposal of hazardous wastes.

Residual risks to workers on the Site could also result from monitoring and maintenance of the leachate collection and treatment system. Risks from dermal exposure to leachate and waste streams from the media filtration treatment would be mitigated by using the appropriate PPE. Monitoring or maintenance to the UV oxidation system could result in inhalation exposures to products of incomplete oxidation of VOCs and ozone gas, as described above. Potential exposures to these by-products would be higher for a worker at the Site than for community residents, but will be mitigated as described above. Any risks to workers would also be mitigated by using the appropriate PPE.

Risks to aquatic ecological receptors would be abated by this capping and leachate collection/treatment alternative. RAOs would be met over the long term in aquatic areas since leachate is controlled.

Adequacy of Controls. Measures are described below that detail controls to be placed on untreated waste, waste-contaminated media, and treatment residuals from implementation of Alternative #4a.

Groundwater/Leachate. The institutional controls and capping are the same as Alternatives #3a and #3b and perform the same function. Additional technologies in this alternative include leachate collection (wells/drains) and on-site treatment.

These additions create soil residues during construction. Soils demonstrated to be below the action levels may be disposed of on the Site. Soils found to contain contaminants at concentrations above action levels may be treated and disposed of on the Site or must be contained, shipped off of the Site and managed in a pre-approved, environmentally sound manner.

Treatment technologies in on-site treatment are precipitation, which generates a hydroxide sludge precipitate, media filtration, which generates a backwash waste stream and UV/chemical oxidation, which generates vapors and cleaning residues.

The hydroxide sludge would be thickened and sent through a filter press to dewater as much as possible before off-site disposal of the filter cake. The media filtration backwash waste stream would be returned to the precipitation system along with the cleaning residues from the UV/chemical oxidation system. Vapors containing VOCs/ozone which may be created in the UV/chemical oxidation reactor would be treated in a catalytic ozone/VOC destruction unit.

Monitoring of groundwater and surface water would be included in the alternative and would adequately measure progress of the remedy.

Landfill Gas. Adequacy of controls for landfill gas under Alternative #4a would be similar to Alternative #3a.

Reliability of Controls. Evaluations are described below that detail the effectiveness, reliability, and permanence control measures would provide to protect human health and the environment from exposures to untreated waste, waste-contaminated media, and treatment residues.

Groundwater/Leachate. The performance of institutional controls and capping would be similar to Alternatives #3a and #3b. The leachate collection system would reduce the leachate outbreaks near the Saugatucket River. The treatment system would be housed in a building, which would protect the public from contacting untreated water and treatment system areas. Depending upon the discharge option chosen, treated effluent could affect groundwater quality or water quality in the Saugatucket River.

Monitoring of groundwater and surface water/sediment would provide an accurate measure of the success of this remedy and provide a basis for modification of the remedy, if required.

Landfill Gas. Reliability of controls for landfill gas would be similar to Alternative #3a.

Need for Five-Year Review. Because wastes would remain on site for this alternative, CERCLA §121(c) and the NCP at §300.430(f)(4)(ii) require that a five-year review be conducted every five years until it is demonstrated that there is no longer a threat to human health or the environment from the Site. For the purpose of this FS and costing, it is assumed that a "Level I" review, the lowest level, would be conducted.

4.4a.2.4 Reduction of Toxicity, Mobility or Volume through Treatment from Alternative #4a. This criterion evaluates how the alternative mitigates the effects of site COPCs by describing the following: treatment technologies and process options utilized, quantity of site COPCs/contaminated media affected, degree of expected reductions in mobility of site COPCs into the environment, degree to which the treatment is irreversible, and the residuals remaining after treatment.

Treatment/Recycling Processes Utilized. The treatment, recycling and other mitigation processes of the remedy and any materials treated are listed below for this alternative:

Groundwater/Leachate

- Horizontal Containment - Solid Waste Area
- Horizontal Containment - Bulky Waste Area
- Leachate collection (wells/drains) - Bulky Waste Area
- On-Site leachate treatment (precipitation, media filtration and UV/chemical oxidation)
- Discharge of treated water

Landfill Gas.

- Active perimeter LFG collection - Solid Waste Area
- Active internal LFG collection - Solid Waste Area
- Thermal LFG Treatment (enclosed flare) - Solid Waste Area
- Passive internal LFG collection - Bulky Waste Area

Amount of Hazardous Materials Treated or Recycled. The quantities or volumes of materials containing COPCs that are destroyed, recycled or treated are detailed below. These quantities may also include other hazardous materials that are involved in the remedy.

Groundwater/Leachate. The amount of materials treated or recycled for horizontal containment of the Bulky Waste and Solid Waste Areas is the same as described previously for Alternatives #3a and #3b.

The leachate collection system for the Bulky Waste Area will capture approximately 5 gpm of leachate which will then be treated and discharged to either groundwater or surface water.

Landfill Gas. The amount of materials treated or recycled relating to LFG impacts to ambient air and soil gas are the same as described for Alternative #3a.

Degree of Expected Reductions in Toxicity or Mobility. The expected degree of reductions in toxicity or mobility of the COPCs in site media are detailed below.

Groundwater/Leachate. The expected reduction in toxicity or mobility for horizontal containment of the Bulky and Solid Waste Areas is the same as described previously for Alternatives #3a and #3b.

The leachate collection system for the Bulky Waste Area will further limit mobility of site COPCs towards the Saugatucket River. The reduction of toxicity of the captured leachate will be proportional to the treatment efficiencies as follows (refer to Section 3.1.6 and Appendix D):

Type of Site COPC:	Removal Efficiency
metals	85%
organics	90%

Landfill Gas. The expected degree in toxicity or mobility of LFG site COPCs are the same as described for Alternative #3a.

Degree to Which Treatment Is Irreversible. The degree to which treatment, recycling or other appropriate remedial components of the selected remedy are irreversible is evaluated below.

Groundwater/Leachate. The degree of reversibility for horizontal containment of the Bulky and Solid Waste Areas is the same as described previously for Alternatives #3a and #3b.

The on-site leachate treatment system would be an irreversible destruction process for site COPCs. Removal of the treatment system would result in conditions the same as Alternative #3a and #3b less the quantity of contaminants removed during past operation.

Landfill Gas. The degree to which treatment of landfill gas is irreversible is the same as described for Alternative #3a.

Type and Quantity of Residuals Remaining After Treatment. The quantity and composition of residuals generated by treatment processes in this alternative are described below. These residuals may require further disposal and handling.

Groundwater/Leachate. Process residuals from the on-site leachate treatment plant are detailed in Section 3.1.6 and Appendix D and would include:

- Soil residuals from drilling/construction of extraction wells, trenches, and recharge wells.
- Sludge filter cake from the precipitation process option containing metal hydroxide sludges such as $Al(OH)_3$, $Fe(OH)_3$, and $Mn(OH)_2$. The quantity of sludge generated is expected to be approximately 2 ft^3/day.
- Remaining volatile organic COPCs not destroyed in the UV/chemical oxidation system off-gas.

Landfill Gas. The type and quantity of residuals remaining after treatment of LFG are the same as described previously for Alternative #3a.

4.4a.2.5 Short-term Effectiveness of Alternative #4a. This alternative is evaluated for effectiveness in protecting the community and local workers, site remediation workers, and the environment during the construction of the remedy.

Community Protection. Short-term risks to the community would include those identified for Alternatives #3a and #3b, and would be mitigated using similar measures. Installation of the leachate collection system would involve limited invasive work at the Bulky Waste Areas. Additional short-term risks to the community would not be anticipated from this invasive work.

Worker Protection. Short-term risks to workers would include those identified for Alternatives #3a and #3b, and would be mitigated using similar measures. In addition, installation of the leachate collection system could result in dermal exposures from direct contact with surface soil contamination and with COPCs in leachate. These risks would be mitigated using appropriate PPE.

Environmental Protection. Impacts to habitat are similar to those presented under Alternatives #3a and #3b. However, the areal extent of impacts to upland and wetland resources would be larger.

Time Until Remedial Action Objectives are Achieved. Estimates for the time to achieve RAOs are discussed below by site media of concern.

Groundwater. The time required to meet the RAOs for this media is the same as Alternatives #3a and #3b.

Surface Water/Sediments. By addition of the leachate collection system and on-site treatment (precipitation, media filtration and UV/chemical oxidation), the time required to meet the RAOs will be the time required to implement and achieve an operational and functional status of these technologies and process options. This is expected to be within 1-2 years of selection of the FS remedy.

Ambient Air. The time required to meet the RAOs for this media is the same as Alternative #3a.

Soil Gas. The time required to meet the RAOs for this media is the same as Alternatives #3a and #3b.

4.4a.2.6 Implementability of Alternative #4a. The implementability of this alternative is discussed as a measure of the technical and administrative feasibility of this approach as well as the availability of key services and materials required for this remedy.

Technical Feasibility. The relative ease of implementing the remedy is summarized below. Key items include: ability to be constructed and operated, reliability in meeting RAOs, ease of undertaking additional remedial actions and ability to monitor effectiveness of the remedy.

Groundwater/Leachate. For Alternative #4a, the technical feasibility associated with access restrictions and horizontal containment would be similar to that described for Alternatives #3a and #3b. Implementation of environmental monitoring would be the same as Alternative #1. This alternative only adds construction of extraction wells/drains for the leachate collection system, on-site leachate and discharge of treated water. The location and construction of these items must be coordinated with the implementation of the horizontal containment to ensure cap integrity is maintained. Construction of the leachate treatment system would require building construction, connection of skid mounted systems, utility hookup, and piping from extraction locations to the treatment location.

The reliability to meet RAOs for groundwater access restrictions and horizontal containment is the same as Alternatives #3a and #3b. Addition of leachate collection and treatment when combined with horizontal containment improves the reliability in meeting surface water/sediment RAOs.

Similar to Alternatives #3a and #3b, future actions could be implemented to increase this alternative's remedial effectiveness, but should maintain the integrity of the horizontal containment.

The monitoring approach would be similar to that described for Alternatives #3a and #3b.

Landfill Gas. The technical feasibility for landfill gas would be the same as for Alternative #3a.

Administrative Feasibility. The relative effort and time required to obtain the necessary regulatory approvals and permits for the remedy is evaluated below.

Groundwater/Leachate. Regulatory approvals or permits anticipated to be required to implement the remedy in Alternative #3a will also apply to this alternative. State approval is anticipated to be required prior to any treated water discharge and construction of the treatment system. A significant amount of effort will be required to determine which discharge option is more appropriate for the Site: groundwater or surface water. Surface water discharge will require a completed and approved application for a Rhode Island Pollution Discharge Elimination System Permit. Groundwater discharge, however, is dependent upon the anticipated groundwater reclassification.

Landfill Gas. The administrative feasibility for landfill gas would be the same as for Alternative #3a.

Availability of Services and Materials. The availability of key services and materials needed to implement the alternative are discussed below and include: capacity and location of TSDFs, availability of necessary equipment and specialists, timing and scheduling, and ability to obtain competitive cost bids.

Groundwater/Leachate. Availability of services and materials for horizontal containment, access restrictions, environmental monitoring, five-year reviews and community relations support is the same as Alternatives #3a and #3b.

The only major effort required which is different from Alternatives #3a and #3b would be leachate collection, on-site treatment and discharge of treated water. A TSDF would likely be needed for filter cake sludge disposal from the precipitation process option. Consulting specialists, equipment and services are commonly available to conduct such activities in a timely and cost-effective manner.

Landfill Gas. The availability of services and materials for this alternative is the same as Alternative #3a.

4.4a.2.7 Cost of Alternative #4a. Cost assumptions regarding escalation, discount rate, contingency and duration, unless otherwise specified, are the same as Alternative #3a. Capital costs associated with this alternative are expected to be $7.24 million. Operation and maintenance costs (expressed in net present worth dollars) are estimated at $8.83 million. Total costs are therefore $16.07 million. These costs are summarized in detail in Appendix G.

4.4a.2.8 State and Community Acceptance of Alternative #4a. Comments from the State of Rhode Island, the town of South Kingstown, and citizens of the community regarding this alternative will be addressed after the public comment period.

4.4b EVALUATION OF ALTERNATIVE #4b: HORIZONTAL CONTAINMENT OF SOLID WASTE AREA, LANDFILL MINING OF BULKY WASTE AREA, LEACHATE COLLECTION AND ON-SITE TREATMENT, GAS COLLECTION AND THERMAL TREATMENT

This section describes the components of Alternative #4b followed by detailed evaluation of those components versus the nine FS criteria.

4.4b.1 Definition of Alternative #4b

Alternative #4b provides a similar level of human health risk mitigation as Alternative #4a through control of landfill gas and migration of site COPCs into groundwater. Alternative #4b differs from #4a in how the Bulky Waste Area is remediated. Instead of capping, Alternative #4b uses the technology of landfill mining to restore the Bulky Waste Area. Non-recyclable wastes from the Bulky Waste Area are re-disposed at the Solid Waste Area. Leachate control is still implemented for the Bulky Waste Area. However, length of operation is assumed to be reduced due to source removal.

The major components of this alternative include:

- Groundwater Access Restrictions. Where appropriate, restrictive covenants would be placed on properties affected by site COPCs to limit use of groundwater as a potable water source. The scope of this component is the same as discussed previously under Alternative #2.

- Horizontal Containment - Solid Waste Area. The implementation of the protective cap for the Solid Waste Area would be the same as Alternatives #3a and #3b.

- Landfill Mining - Bulky Waste Area. The Bulky Waste Area would be excavated to remove all wastes. The wastes would be segregated into three major categories: recyclable wastes (ferrous goods and possibly plastics), reusable soil, and non-recyclable wastes. The reusable soil would be backfilled at the Bulky Waste Area, the non-recyclable wastes would be disposed at the Solid Waste Area, and the recyclable wastes would be brought to an off-site recycling facility. Preliminary

discussion of this technology was presented in Section 3.1.3. Further details are presented below.

- Active Perimeter LFG Collection - Solid Waste Area. The implementation of the active perimeter LFG collection system would be the same as described previously for Alternatives #3a and #3b.

- Active Internal LFG Collection - Solid Waste Area. The implementation of the active internal LFG collection system would be the same as described previously for Alternatives #3a and #3b.

- Thermal LFG Treatment (Enclosed Flare) - Solid Waste Area. This alternative would implement the LFG treatment enclosed flare system in the same manner as Alternative #3a.

- Leachate Collection (Wells/Drains) - Bulky Waste Area. The implementation of a leachate collection system would be the same as described previously for Alternative #4a. However, the length of operation would be reduced to the time of landfill mining.

- On-site Leachate Treatment. The implementation of a leachate treatment system would be the same as described previously for Alternative #4a.

- Discharge of Treated Water. Treated water would be discharged to either groundwater or surface water, as discussed previously in Section 3.1.6.4.

- Environmental Monitoring. Environmental monitoring includes monitoring of groundwater, surface water/sediment, ambient air and soil gas. Monitoring locations, frequencies and analytes are the same as described previously for Alternative #1 except for additional monitoring at three new dewatering wells (see Table 4-2).

- Five-Year Review. As described previously in Alternative #1, since this alternative would result in contaminants remaining on the Site, CERCLA §121(c) and §300.430(f)(4)(ii) of the NCP require that the site remedy be reviewed every five years.

- Community Relations Activities. In the same manner as Alternative #1, on-going community relations activities will be conducted to provide appropriate information, receive comment on that information and to adjust the remedy of the Proposed Plan at key milestones.

Figure 4-6 illustrates the site layout for Alternative #4b. The components of the alternative, and how they interact with each media of concern, are presented on Figure 4-8.

4.4b.1.1 Landfill Mining of the Bulky Waste Area. Under this alternative, landfill mining is used to extract waste from the Bulky Waste Area and recycle soil and other recyclable materials. Non-recyclable, non-hazardous waste would be disposed of at the Solid Waste Area before it is capped. If hazardous wastes are encountered, they would be containerized in drums for off-site treatment/disposal at a RCRA Treatment, Storage, and Disposal Facility (TSDF). The Bulky Waste Area would be backfilled with recycled soil (supplemented as necessary with clean fill) and graded once all the waste had been removed and recycled or re-disposed.

A pilot study would need to be conducted to fully evaluate the applicability of landfill mining for the Bulky Waste Area. As discussed in Section 3.1.3, it is important to collect data on the types and quantities of wastes present; the locations and concentrations of various wastes; the condition of the waste; the depth of waste and depth to groundwater; and the likelihood of encountering hazardous waste. The evaluation of these factors that is presented in this report for the Bulky Waste Area is preliminary and should be revised after a pilot study is performed.

A preliminary estimate of the quantity of recyclable metal waste in the Bulky Waste Area is presented in Section 3.1.3.2. The town of South Kingstown is currently using Metals Recycling in Johnston, Rhode Island to recycle scrap metal (South Kingstown transfer station staff, 1997). Metals Recycling was contacted for pricing information. If the scrap material is sufficiently free of dirt, if chlorofluorocarbons or capacitors have already been removed, and if the material is delivered to Metals Recycling, the scrap value is $40.00 per ton. If Metals Recycling must pick up the dirt-free materials and remove chlorofluorocarbons and capacitors, the scrap value is negated by transportation and handling charges (Metals Recycling, 1997).

It is assumed that 30,900 yd^3 of waste will be non-recyclable and that this waste will be re-disposed at the Solid Waste Area, which is to be covered with a protective cap. Cost allowances must be

made for employee training, personal protective equipment, continuous monitoring equipment, and decontamination facilities and supplies in the event that hazardous waste is encountered. It is assumed that the volume of hazardous waste encountered will be minimal. If any hazardous waste is encountered, it must be properly disposed of at an off-site RCRA TSDF.

The assumptions regarding waste types and volumes strongly influence the feasibility of landfill mining as a remedial alternative for the Bulky Waste Area. Depending on the pilot study results, it may be feasible to excavate the entire Bulky Waste Area as described above, or it may be advantageous to consider mining only a portion of the landfill. If it is found that a significant quantity of hazardous waste is present, and/or if a large percentage of the waste is non-recyclable, capping the Bulky Waste Area could potentially be more cost-effective than mining the waste and re-disposing of it at the Solid Waste Area or offsite.

Groundwater extracted during any dewatering would be treated if necessary and reinjected. Based on the anticipated groundwater reclassification, the aquifer underlying the Rose Hill area is considered classification GB. If the groundwater is shown to be free of contamination, treatment would not be necessary. In the case of the Bulky Waste Area, it appears that groundwater has substantial levels of metals, with beryllium and lead above regulatory objectives. State review will be required to determine the extent of treatment required, if any, prior to reinjection in nearby wells.

For this alternative, it is assumed that some dewatering and treatment before discharge will be needed. Assumptions made for costing purposes include: three dewatering wells, two to three injection wells, treatment in a 5 gpm metals precipitation system, and system operation for no more than one year.

Because non-recyclable mined waste will be re-disposed of at the Solid Waste Area under this alternative, it is necessary to coordinate landfill mining activities with installation of the cap and LFG collection system at the Solid Waste Area. One possible sequence is to complete landfill mining and waste placement activities before initiating any remedial activities at the Solid Waste

Area. While this sequence is the least difficult logistically, it results in an increase in the overall time to complete the remedial action because remediation of the Bulky Waste and Solid Waste Areas would not take place concurrently. A further disadvantage is that landfill gas and leachate from the Solid Waste Area would remain uncontrolled for approximately one year while landfill mining is conducted. An alternate sequence would be to install a gas collection and treatment system at the Solid Waste Area concurrently with landfill mining of the Bulky Waste Area. As non-recyclable waste is placed at the Solid Waste Area, the gas collection well risers and manifolds would need to be extended so that the gas collection system would remain above the level of the waste. Alternatively, the wells could be installed but not piped together, and "mini-flares" could be installed at each well to treat the gas as an interim measure. The mini-flares would remain in place until mining and waste placement are completed, at which time it would be possible to cap the Solid Waste Area and install a permanent gas collection and treatment system above the cap.

Any interim collection and treatment system will not be as efficient as a permanent system, primarily because the cap will not be in place during its operation. However, an interim system would provide some reduction in emissions of COPCs during the period when wastes are being placed at the Solid Waste Area.

Cost assumptions for landfill mining are further detailed in Appendix A.

4.4b.2 Nine Criteria Evaluation of Alternative #4b

The analysis of Alternative #4b with respect to the nine criteria is presented in a narrative form in the following paragraphs. The assessment focuses on how, and to what extent, the various factors within each of the criteria are addressed. Uncertainties associated with the alternative are included when changes in assumptions or unknown conditions could affect the analysis.

4.4b.2.1 Overall Protection of Human Health and the Environment from Alternative #4b. Specific long-term and short-term human health and environmental risks are discussed in Sections 4.4b.2.3 and 4.4b.2.5, respectively; the discussion below provides a general overview.

The overall long-term protection of human health from inhalation exposures on and off the Site would be similar to that described for Alternative #4a. Removal of waste from the Bulky Waste Area, and backfilling it with clean fill, would be expected to eventually reduce subsequent groundwater impacts in this area. However, the sources of groundwater contamination in this area may not be completely removed by landfill mining. Initially, groundwater impacts may increase due to disturbance of the area. Institutional controls presented in Alternative #2, including groundwater access restrictions and residential well monitoring, would be included in this alternative. Therefore, future risks from residential ingestion of groundwater on and off the Site would not be expected.

Short-term risks to the community and workers at the Site from construction and implementation of Alternative #4b would include those identified for Alternative #4a. Additional short-term risks from landfill mining include the potential for exposure of workers and nearby residents to dust and gases emitted during mining activities and placement of waste at the Solid Waste Area, the potential for ecological impacts to the Saugatucket River and adjacent wetlands as a result of excavation. Because it will be necessary to delay installation of the cap and active LFG collection system at the Solid Waste Area until landfill mining is completed, the duration of short-term risks is longer for this alternative than for Alternative #4a.

The overall protection of the environment would be the similar to Alternative #4a. Proper engineering controls would be utilized to ensure that this invasive action would not result in long-term ecological damage (e.g., sedimentation of wetlands or surface waters).

4.4b.2.2 Compliance With ARARs from Alternative #4b. Action-specific ARARs under this alternative are presented in Table 4-9. Any remedial actions taken under this alternative must comply with the ARARs listed in this table. Environmental monitoring will be used as an indicator

of compliance with the site-specific chemical and location-specific ARARs described in Section 2.3. Further actions may be required to comply with ARARs if they are not met through this source control/leachate treatment remedy.

4.4b.2.3 Long-term Effectiveness and Permanence from Alternative #4b. This alternative is evaluated below in terms of the risk remaining at the Site after RAOs are addressed. This portion of the evaluation focuses on the extent and effectiveness of the controls required to manage the risk posed by treatment residuals and/or untreated contamination.

Magnitude of Residual Risks. With this alternative, capping and gas collection would leave solid wastes in place at the Solid Waste Area but would reduce migration of contamination. Capping, and gas collection and treatment would reduce uncontrolled emissions of landfill gas and leachate generation from the Solid Waste Area, as presented for Alternative #4a. Wastes would be removed from the Bulky Waste Area, thereby reducing the potential for contaminated leachate to be generated and migrate to the Saugatucket River. However, source removal may not be complete and a residual risk of contaminant migration will remain until natural attenuation of sources outside the limits of the Bulky Waste Area occurs.

The residual human health risks from inhalation exposures both on and off the Site under Alternative #4b would be similar to those described for Alternative #4a.

Residual human health risks from future ingestion of contaminated groundwater at the Site would be further reduced over the long-term. Control of leachate in the Solid Waste Area and removal of a source of groundwater contamination at the Bulky Waste Area would reduce future groundwater impacts.

Residential well monitoring would be included under this alternative. Therefore, future risks to nearby residents from ingestion of contaminated groundwater as a result of plume migration would not be expected.

Long-term risks to ecological receptors in Alternative #4b would be the same as Alternative #4a.

Adequacy of Controls. Measures are described below that detail controls to be placed on untreated waste, waste-contaminated media, and treatment residuals from implementation of Alternative #4b.

Groundwater/Leachate. The institutional controls, capping and leachate collection/treatment are the same as Alternative #4a and perform the same function. The cap for the Solid Waste Area may require additional maintenance under this alternative, however, due to the increased potential for differential settlement caused by placement of mined waste from the Bulky Waste Area in this area.

Source removal through landfill mining would eliminate the generation of leachate in the Bulky Waste Area, assuming complete source removal can be attained. However, operation of the leachate collection system would be required for a period of time to capture remaining contamination. If waste needs to be left in place, additional controls (i.e., a cap and long-term leachate collection) would be necessary.

Residuals created by this alternative that are not created by Alternative #4a include the wastes removed from the Bulky Waste Area during landfill mining. That portion of the mined waste that cannot be reused or recycled will be re-disposed at the Solid Waste Area (if not hazardous) or disposed off-site at a RCRA TSDF.

Monitoring of groundwater and surface water would be included in the alternative and would adequately measure progress of the remedy.

Landfill Gas. Adequacy of controls for landfill gas under Alternative #4b would be similar to Alternative #4a.

Reliability of Controls. Evaluations are described below that detail the effectiveness, reliability, and permanence control measures would provide to protect human health and the environment from exposures to untreated waste, waste-contaminated media, and treatment residues.

Groundwater/Leachate. The performance of institutional controls, capping and leachate collection/treatment would be similar to Alternative #4a.

Landfill mining and restoration of the Bulky Waste Area will reliably control contamination in this area, provided source removal is complete. If waste needs to be left in place at the Bulky Waste Area, additional controls such as a cap and long-term leachate collection will be necessary. The reliability of these additional controls is similar to Alternative #4a.

Monitoring of groundwater and surface water/sediment would provide an accurate measure of the success of this remedy and provide a basis for modification of the remedy, if required.

Landfill Gas. Reliability of controls for landfill gas would be similar to Alternative #4a.

Need for Five-Year Review. Because wastes would remain on site for this alternative, CERCLA §121(c) and the NCP at §300.430(f)(4)(ii) require that a five-year review be conducted every five years until it is demonstrated that there is no longer a threat to human health or the environment from the Site. For the purpose of this FS and costing, it is assumed that a "Level I" review, the lowest level, would be conducted.

4.4b.2.4 Reduction of Toxicity, Mobility or Volume through Treatment from Alternative #4b. This criterion evaluates how the alternative mitigates the effects of site COPCs by describing the following: treatment technologies and process options utilized, quantity of site COPCs/contaminated media affected, degree of expected reductions in mobility of site COPCs into the environment, degree to which the treatment is irreversible, and the residuals remaining after treatment.

Treatment/Recycling Processes Utilized. The treatment, recycling and other mitigation processes of the remedy and any materials treated are listed below for this alternative:

Groundwater/Leachate

- Horizontal Containment - Solid Waste Area
- Landfill Mining - Bulky Waste Area
- Leachate collection (wells/drains) - Bulky Waste Area
- On-Site leachate treatment (precipitation, media filtration and UV/chemical oxidation)
- Discharge of treated water

Landfill Gas

- Active perimeter LFG collection - Solid Waste Area
- Active internal LFG collection - Solid Waste Area
- Thermal LFG Treatment (enclosed flare) - Solid Waste Area

Amount of Hazardous Materials Treated or Recycled. The quantities or volumes of materials containing COPCs that are destroyed, recycled or treated are detailed below. These quantities may also include other hazardous materials that are involved in the remedy.

Groundwater/Leachate. The amount of materials treated or recycled for horizontal containment of the Solid Waste Area is the same as described previously for Alternative #4a.

Landfill mining of the Bulky Waste Area is estimated to result in recycling of approximately 37,500 yd^3 of metal waste, and reuse of approximately 45,600 yd^3 of soil as backfill. The remaining 30,900 yd^3 of mined waste is assumed to be contaminated or otherwise non-recyclable, and would be re-disposed at the Solid Waste Area.

Landfill Gas. The amount of materials treated or recycled relating to LFG impacts to ambient air and soil gas are the same as described for Alternative #4a.

Degree of Expected Reductions in Toxicity or Mobility. The expected degree of reductions in toxicity or mobility of the COPCs in site media are detailed below.

Groundwater/Leachate. The expected reduction in toxicity or mobility for horizontal containment of the Solid Waste Area is the same as described previously for Alternative #4a.

Landfill mining of the Bulky Waste Area will limit mobility of some site COPCs towards the Saugatucket River by removing waste from the area and relocating it under the cap at the Solid Waste Area. In the short term, however, mobility may be increased due to the disturbance caused by mining activities. The leachate collection system will further limit mobility of site COPCs towards the Saugatucket River. The reduction of toxicity of the captured leachate is the same as described in Alternative #4a.

Landfill Gas. The expected degree of reduction in toxicity or mobility of LFG site COPCs are the same as described for Alternative #4a.

Degree to Which Treatment Is Irreversible. The degree to which treatment, recycling or other appropriate remedial components of the selected remedy are irreversible is evaluated below.

Groundwater/Leachate. The degree of reversibility for horizontal containment of the Solid Waste Area and leachate collection/treatment at the Bulky Waste Area is the same as described previously for Alternative #4a.

Landfill mining would be an irreversible removal process which, if discontinued at any point would result in altered site conditions and increased mobility of site COPCs.

Landfill Gas. The degree to which treatment of landfill gas is irreversible is the same as described for Alternative #4a.

Type and Quantity of Residuals Remaining After Treatment. The quantity and composition of residuals generated by treatment processes in this alternative are described below. These residuals may require further disposal and handling.

Groundwater/Leachate. Residuals from leachate collection/treatment would be the same as described in Alternative #4a.

Residuals from landfill mining of the Bulky Waste Area include recyclable metal wastes (37,500 yd^3), reusable soil (45,600 yd^3), and non-recyclable wastes (30,900 yd^3). It will be necessary to locate an off-site recycling facility to accept the recyclable metals wastes. Reusable soil will be backfilled at the Bulky Waste Area during restoration of that area. Non-recyclable wastes will be re-disposed on site at the Solid Waste Area.

Landfill Gas. The type and quantity of residuals remaining after treatment of LFG are the same as described previously for Alternative #3a.

4.4b.2.5 Short-term Effectiveness of Alternative #4b. This alternative is evaluated for effectiveness in protecting the community and local workers, site remediation workers, and the environment during the construction of the remedy.

Community Protection. Short-term risks to the community would include those identified for Alternative #4a, and would be mitigated using similar measures. Additional short-term risks will exist during landfill mining of the Bulky Waste Area and placement of non-recyclable mined wastes at the Solid Waste Area. Placement of additional waste at the Solid Waste Area may expose nearby residents to additional odors, noise and blowing trash. Nearby residents may also be exposed to dust

and site COPCs released during mining activities. It will be necessary to leave the Solid Waste Area uncapped until pilot tests for landfill mining of the Bulky Waste Area and the actual mining are completed (estimated to take approximately one year). The LFG collection system will not be as efficient during the time the Solid Waste Area is uncapped. Hence, this delay may result in additional exposures to untreated LFG.

Worker Protection. Short-term risks to workers would include those identified for Alternative #4a, and would be mitigated using similar measures. In addition, landfill mining of the Bulky Waste Area could result in inhalation exposures from dust and gases emitted during excavation and processing of waste, as well as dermal exposures from direct contact with surface soil contamination and with COPCs in leachate. Vermin may also be attracted to the uncovered waste once mining begins.

If it is determined that there are no hazardous substances in the soil and groundwater at the Bulky Waste Area that could result in employee exposure, then work would proceed as a conventional construction operation. However, if at any time during the mining process an accumulation of hazardous substances in the soil or groundwater is identified that results in the reasonable possibility for employee exposure to safety or health hazards, then all the requirements of 29 CFR 1910.120 Hazardous Waste Operations and Emergency Response would need to be met. At a minimum this would require: generation of a site-specific health and safety plan, initial training for general site workers, management training for supervisory personnel, training of several individuals in First Aid/CPR, higher levels of personal protective equipment, continuous use of exposure monitoring equipment, decontamination facilities and supplies, and emergency response equipment.

Environmental Protection. Impacts to habitat and proposed mitigation activities are similar to those presented under Alternative #4a, plus additional impacts related to the landfill mining component of the alternative. Emergent wetlands, forested wetlands, and two lotic waterbodies are located within 100 meters of the eastern and western boundaries of the Bulky Waste Area. The main ecological concern associated with landfill mining is the potential impact of surface runoff and dust

from landfill operations. If erosion/dust suppression controls are not implemented, substantial sedimentation would take place in wetland resources. Sedimentation would decrease water depth and could change both the temperature regime and the character of the substrate. Runoff or dust reaching the Saugatucket River and Mitchell Brook would increase sediment loads and suspended solids levels. Runoff and dust are potential problems regardless of whether the materials are contaminated. The risk to receptor communities would only be compounded if hazardous materials were released to aquatic resources via dust, runoff, or through groundwater discharge to surface water. Noise may also be factor that would temporarily discourage wildlife from nesting near the landfill.

It is anticipated that landfill mining will cause some short-term ecological impacts due to dust and runoff. However, best management practices will limit media migration from the Bulky Waste Area to a level which will not result in long-term ecological damage.

Time Until Remedial Action Objectives are Achieved. Estimates for the time to achieve RAOs are discussed below by site media of concern.

Groundwater. The time required to meet the RAOs for this media is the same as Alternative #4a.

Surface Water/Sediments. Through use of landfill mining and leachate collection with on-site treatment (precipitation, media filtration and UV/chemical oxidation), the time required to meet the RAOs will be the time required to implement and achieve an operational and functional status of these technologies and process options. This time frame is expected to be within 2 years of selection of the FS remedy.

Ambient Air. The time required to meet the RAOs for this media is the same as Alternative #4a.

Soil Gas. Through use of landfill mining and the active perimeter LFG collection system combined with thermal LFG treatment (enclosed flare), the time required to meet the RAOs will be the time required to implement, and achieve an operational and functional status of these technologies and process options. This is expected to occur within 2 years of selection of the FS remedy.

4.4b.2.6 Implementability of Alternative #4b. The implementability of this alternative is discussed as a measure of the technical and administrative feasibility of this approach as well as the availability of key services and materials required for this remedy.

Technical Feasibility. The relative ease of implementing the remedy is summarized below. Key items include: ability to be constructed and operated, reliability in meeting RAOs, ease of undertaking additional remedial actions and ability to monitor effectiveness of the remedy.

Groundwater/Leachate. For Alternative #4b, the technical feasibility associated with access restrictions and horizontal containment would be similar to that described for Alternative #4a. Implementation of environmental monitoring would be the same as Alternative #1.

The landfill mining component of Alternative #4b may be technically difficult to implement, depending on the contents of the Bulky Waste Area, the location of the waste with respect to the water table, and potential markets for recyclable metal waste. A pilot study will be needed to evaluate potential implementation difficulties. If hazardous waste is found to be present and/or if a significant percentage of the waste is below the water table, mining will be technically difficult and there will be a corresponding increase in costs. Similarly, if the market for recyclable waste is limited, it may be necessary to re-dispose a large amount of waste at the Solid Waste Area, which will increase the complexity of efforts to install the gas collection system and cap for that area.

The reliability to meet RAOs for the groundwater access restrictions and horizontal containment is the same as Alternative #4a. Reliability in attaining RAOs for surface water/sediment in the Saugatucket River is slightly improved from Alternative #4a, because Alternative #4b involves source removal (landfill mining) which should reduce the amount of leachate at the Bulky Waste Area required to be collected and treated.

Similar to Alternative #4a, future actions could be implemented to increase this alternative's remedial effectiveness, but should maintain the integrity of the horizontal containment.

The monitoring approach would be similar to that described for Alternative #4a.

Landfill Gas. The technical feasibility for landfill gas would be the same as for Alternative #4a.

Administrative Feasibility. The relative effort and time required to obtain the necessary regulatory approvals and permits for the remedy is evaluated below.

Groundwater/Leachate. Regulatory approvals or permits anticipated to be required to implement the remedy in Alternative #4a will also apply to this alternative. For any dewatering activities required for landfill mining, RIDEM would determine the acceptability of reinjection and the need for treatment according to the Rhode Island Underground Injection Control Program rules.

Landfill Gas. The administrative feasibility for landfill gas would be the same as for Alternative #4a.

Availability of Services and Materials. The availability of key services and materials needed to implement the alternative are discussed below and include: capacity and location of TSDFs, availability of necessary equipment and specialists, timing and scheduling, and ability to obtain competitive cost bids.

Groundwater/Leachate. Availability of services and materials for horizontal containment, access restrictions, environmental monitoring, five-year reviews and community relations support is the same as Alternative #4a.

The major component of this alternative that differs from Alternative #4a is landfill mining of the Bulky Waste Area. A contractor experienced in landfill mining, and with employees trained according to OSHA 1910.120, would need to be retained. A RCRA TSDF would be needed to dispose of any hazardous wastes that are encountered during mining. An out-of-state transporter/RCRA TSDF would likely be required for any hazardous waste disposal as the number of Rhode Island facilities are limited and handle specific wastes. A recycling facility that will accept recyclable metal wastes from the Site will also need to be located. There are multiple facilities in Rhode Island which will accept these metals. However, some may not be able to accept the metal unless it is sufficiently clean of dirt/debris and any chlorofluorocarbons or capacitors are removed.

Landfill Gas. The availability of services and materials for this alternative is the same as Alternative #4a.

4.4b.2.7 Cost of Alternative #4b. Cost assumptions regarding escalation, discount rate, contingency and duration, unless otherwise specified, are the same as Alternative #4a. Leachate

collection and treatment is anticipated to be utilized for approximately one year, based on the assumed duration of landfill mining.

Capital costs associated with this alternative are expected to be $9.82 million. Operation and maintenance costs (expressed in net present worth dollars) are estimated at $7.10 million. Total costs are therefore $16.92 million. These costs are summarized in detail in Appendices A and G.

4.4b.2.8 State and Community Acceptance of Alternative #4b. Comments from the State of Rhode Island, the town of South Kingstown, and citizens of the community regarding this alternative will be addressed after the public comment period.

4.5a EVALUATION OF ALTERNATIVE #5a: HORIZONTAL CONTAINMENT OF SOLID WASTE AND BULKY WASTE AREAS, GROUNDWATER AND LEACHATE COLLECTION AND ON-SITE TREATMENT, GAS COLLECTION AND THERMAL TREATMENT

This section describes the components of Alternative #5a followed by detailed evaluation of those components versus the nine FS criteria.

4.5a.1 Definition of Alternative #5a

Alternative #5a provides the same level of human health risk mitigation as Alternative #4a through control of landfill gas. It also provides improved mitigation of human health risk by additional engineering controls preventing migration of site COPCs into groundwater. Mitigation of ecological risk is the same as Alternative #4a.

The major components of this alternative include:

- Groundwater Access Restrictions. Where appropriate, restrictive covenants would be placed on properties affected by site COPCs to limit use of groundwater as a

potable water source. The scope of this component is the same as discussed previously under Alternative #2.

- Horizontal Containment - Solid Waste Area. The implementation of the protective cap for the Solid Waste Area would be the same as Alternatives #3a and #3b.

- Horizontal Containment - Bulky Waste Area. The implementation of the protective cap for the Bulky Waste Area would be the same as Alternatives #3a and #3b.

- Active Perimeter LFG Collection - Solid Waste Area. The implementation of the active perimeter LFG collection system would be the same as described previously for Alternatives #3a and #3b.

- Active Internal LFG Collection - Solid Waste Area. The implementation of the active internal LFG collection system would be the same as described previously for Alternatives #3a and #3b.

- Thermal LFG Treatment (Enclosed Flare) - Solid Waste Area. This alternative would implement the LFG treatment enclosed flare system in the same manner as Alternative #3a.

- Passive Internal LFG Collection - Bulky Waste Area. This alternative would implement the passive internal LFG collection system for the Bulky Waste Area in the same manner as Alternatives #3a and #3b.

- Leachate Collection (Wells/Drains) - Bulky Waste Area. A leachate collection system would be installed southeast of the Bulky Waste Area to intercept leachate migrating toward the Saugatucket River. The scope of this component is the same as presented for Alternative #4a.

- Groundwater Collection System (Wells/Drains) - Solid Waste Area. A groundwater depression system would be installed on the northern end of the Solid Waste Area to intercept groundwater prior to contact with refuse in the landfill. Details of the groundwater collection system and expected flowrates have been provided in Section 3.1.4.

- On-site Groundwater and Leachate Treatment. Treatment of extracted water would be accomplished using the same process options as for leachate treatment in Alternative #4a. These process options include precipitation, media filtration and UV/chemical oxidation. However, due to the increased water volume from the Solid Waste Area groundwater, the treatment system would be larger. Details of this system are described further below.

- Discharge of Treated Water. Similar to Alternative #4a, treated water would be discharged to either groundwater or surface water, as discussed previously in Section 3.1.6.4.

- Environmental Monitoring. Environmental monitoring includes monitoring of groundwater, surface water/sediment, ambient air and soil gas. Monitoring locations, frequencies and analytes are the same as described previously for Alternative #1.

- Five-Year Review. As described previously in Alternative #1, since this alternative would result in contaminants remaining on the Site, CERCLA §121(c) and §300.430(f)(4)(ii) of the NCP require that the site remedy be reviewed every five years.

- Community Relations Activities. In the same manner as Alternative #1, on-going community relations activities will be conducted to provide appropriate information, receive comment on that information and to adjust the remedy of the Proposed Plan at key milestones.

Figure 4-9 illustrates the site layout for Alternative #5a. The components of the alternative, and how they interact with each media of concern, are presented on Figure 4-10.

4.5a.1.1 On-Site Groundwater and Leachate Treatment. Similar to Alternative #4a, a treatment train consisting of precipitation, media filtration and UV/chemical oxidation would be used to remove site COPCs to within ARAR limits prior to discharge. However, due to the increased water volume from the Solid Waste Area groundwater, the system would be larger.

The expected combined flowrate of leachate and groundwater to be processed in this treatment train is 50 gpm (Appendix C). Based on this flow rate, continuous operation will be used to process the collected water.

Precipitation. As in Alternative #4a, precipitation would be used to remove high concentrations of inorganic compounds from collected water. To handle the increased water volume, equipment sizes for this process option would be increased to the following: 12,000 gallon holding/equalization tank, PVC-lined pH adjustment/coagulant addition tank, neutralization tank, flocculation tank, solids

separation tank, 3,500 gallon sludge thickener, and a filter press with 5 ft^3/100 psi capacity. Further equipment sizing specifics, such as vendor quotations, are presented in Appendix D.

Media Filtration. Similar to Alternative #4a, a sand filter would be used to further remove any suspended matter remaining in the water after precipitation. A larger size, continuous backwash, upflow sand filter would be utilized for this process option to handle the additional groundwater flows. Further equipment sizing specifics, such as vendor quotations, are presented in Appendix D.

UV/Chemical Oxidation. As with Alternative #4a, UV/chemical oxidation would be used to destroy organic COPCs. A general description of the system includes the following: an ozone generator, an ozone generator air preparation system (compressor, dryer, filter), a peroxide feed system, an oxidation reactor (includes UV lamps), a catalytic ozone/VOC destruction unit to treat any vapors, and a control unit. Further equipment sizing specifics, such as vendor quotations, are presented in Appendix D.

4.5a.2 Nine Criteria Evaluation of Alternative #5a

The analysis of Alternative #5a with respect to the nine criteria is presented in a narrative form in the following paragraphs. The assessment focuses on how, and to what extent, the various factors within each of the criteria are addressed. Uncertainties associated with the alternative are included when changes in assumptions or unknown conditions could affect the analysis.

4.5a.2.1 Overall Protection of Human Health and the Environment from Alternative #5a. Alternative #5a provides the maximum degree of overall protection of human health for this FS using both institutional controls to prevent exposures and engineering controls to reduce and contain concentrations of COPCs at the Site. This alternative maximizes groundwater source control, thereby minimizing the effort required for any future groundwater remediation, if necessary. By doing so, reduction in human health risks from groundwater ingestion is also maximized.

Overall protection of human health from inhalation exposures to Site COPCs in ambient air and soil gas would be the same as Alternatives #3a and #4a. Specific long-term and short-term human health risks are discussed in Sections 4.5a.2.3 and 4.5a.2.5, respectively.

Groundwater access restrictions, presented in Alternative #2 and included in this alternative, would prevent potential future exposures from residential ingestion of groundwater at the Site.

Additional short-term risks to workers from implementation of the groundwater collection/depression and treatment systems would be similar to those identified for leachate in Alternative #4a; however, these risks could be higher because the implementation of this alternative would be expected to take longer and entail more extensive intrusive work at the Site. Risks to workers would be mitigated by using appropriate PPE. There may be additional short-term risks to the community from inhalation exposures because of the additional intrusive work at the Site with this alternative. However, any potential short-term risks would be evaluated using air monitoring during construction activities.

With one exception, the overall protection of ecological habitat and proposed mitigation activities are the same as those presented for Alternative #4a. The exception is that more substantial impacts to the hydrogeology of Mitchell Brook and the Saugatucket River may be realized due to drawdown associated with the operation of the groundwater collection/depression system at the Solid Waste Area. However, reinjection or surface water discharge will be utilized to mitigate drawdown in Mitchell Brook and associated wetlands.

4.5a.2.2 Compliance With ARARs from Alternative #5a. Action-specific ARARs under this alternative are presented in Table 4-10. Any remedial actions taken under this alternative must comply with the ARARs listed in this table. Environmental monitoring will be used as an indicator of compliance with the site-specific chemical and location-specific ARARs described in Section 2.3. Further actions may be required to comply with ARARs if they are not met through this source control/leachate and groundwater treatment remedy.

4.5a.2.3 Long-term Effectiveness and Permanence from Alternative #5a. This alternative is evaluated below in terms of the risk remaining at the Site after RAOs are addressed. This portion of the evaluation focuses on the extent and effectiveness of the controls required to manage the risk posed by treatment residuals and/or untreated contamination.

Magnitude of Residual Risks. Under Alternative #5a, the residual human health risks from inhalation exposures to site COPCs in LFG both on and off the Site would be the same as those for Alternatives #3a and #4a. Risk estimates for these exposure pathways are qualitatively expected to be within EPA's target risk range.

Residual risks from fugitive landfill gas emissions would be the same as for Alternatives #3a and #4a.

Groundwater access restrictions, included under Alternative #2, would prevent potential future exposures from ingestion of groundwater contaminated with site COPCs. Implementation of Alternative #5a could provide the largest reduction of risk to nearby residents from exposure to contaminated groundwater.

Risks to the community and workers at the Site from soil gas collection and treatment activities would be the same as those risks identified for Alternatives #3a and #4a. The mitigation measures presented for Alternatives #3a and #4a would also be the same for this alternative. Sources of residual risks from groundwater/leachate collection and treatment activities would be similar to those identified for Alternative #4a. Treatment technologies for groundwater/leachate in Alternative #5a are the same as Alternative #4a, but would include a larger flowrate of collected water due to the addition of the groundwater collection/depression system. Mitigation measures presented for Alternative #4a would also be the same for this alternative.

Long-term risks to ecological receptors would be similar to those described for Alternative #4a. However, the extent of required watercourse mitigation may be greater.

Adequacy of Controls. Measures are described below that detail controls to be placed on untreated waste, waste-contaminated media, and treatment residuals from implementation of Alternative #5a.

Groundwater/Leachate. The adequacy of controls for groundwater/leachate would be the same as Alternative #5a.

Landfill Gas. Adequacy of controls for landfill gas would be the same as in Alternative #4b.

Reliability of Controls. Evaluations are described below that detail the effectiveness, reliability, and permanence that control measures would provide to protect human health and the environment from untreated waste, waste-contaminated media, and treatment residues.

Groundwater/Leachate. The reliability of controls for groundwater/leachate would be the similar to Alternative #4b. However, the effectiveness of lowering the water table to a level below the landfill source cannot be determined at this time.

Landfill Gas. Reliability of controls for landfill gas would be the same as in Alternative #4b.

Need for Five-Year Review. Because wastes would remain on the Site under this alternative, CERCLA §121(c) and the NCP at §300.430(f)(4)(ii) require that a five-year review be conducted every five years until it is demonstrated that there is no longer a threat to human health or the environment from the Site. For the purpose of this FS and costing, it is assumed that a "Level I" review, the lowest level, would be conducted.

4.5a.2.4 Reduction of Toxicity, Mobility or Volume through Treatment from Alternative #5a. This criteria evaluates how the alternative mitigates the effects of site COPCs by describing the following: treatment technologies and process options utilized, quantity of site COPCs/contaminated media affected, degree of expected reductions in mobility of site COPCs into the environment, degree to which the treatment is irreversible, and the residuals remaining after treatment.

Treatment/Recycling Processes Utilized. The treatment, recycling and other mitigation processes of the remedy and any materials treated are listed below for this alternative:

Groundwater/Leachate

- Horizontal Containment - Solid Waste Area
- Horizontal Containment - Bulky Waste Area
- Leachate collection (wells/drains) - Bulky Waste Area
- Groundwater collection (wells/drains) - Solid Waste Area
- On-Site groundwater and leachate treatment (precipitation, media filtration and UV/chemical oxidation)
- Discharge of treated water

Landfill Gas.

- Active perimeter LFG collection - Solid Waste Area
- Active internal LFG collection - Solid Waste Area
- Thermal LFG Treatment (enclosed flare) - Solid Waste Area
- Passive internal LFG collection - Bulky Waste Area

Amount of Hazardous Materials Treated or Recycled. The quantities or volumes of materials containing COPCs that are destroyed, recycled or treated are detailed below. These quantities may also include other hazardous materials that are involved in the remedy.

Groundwater/Leachate. The amount of materials treated or recycled for horizontal containment of the Bulky Waste and Solid Waste Areas is the same as described previously for Alternative #3a and #3b.

As with Alternative #4a, the leachate collection system for the Bulky Waste Area will capture approximately 5 gpm. The groundwater collection system for the Solid Waste Area will capture approximately 45 gpm. Both streams will be combined (50 gpm total), treated on the Site and discharged to either groundwater or surface water.

Landfill Gas. The amount of materials treated or recycled relating to LFG impacts to ambient air and soil gas are the same as described for Alternative #3a.

Degree of Expected Reductions in Toxicity or Mobility. The expected degree of reductions in toxicity or mobility of the COPCs in site media are detailed below.

Groundwater/Leachate. The expected reduction in toxicity or mobility for horizontal containment of the Bulky and Solid Waste Areas is the same as described previously for Alternatives #3a and #3b.

The leachate collection system for the Bulky Waste Area will limit mobility and reduce toxicity of site COPCs the same as Alternative #4a.

The groundwater collection system for the Solid Waste Area will further limit downgradient mobility of site COPCs. Since the on-site treatment system is the same, the reduction of toxicity of the captured groundwater, when combined with the collected leachate, will be the same as Alternative #4a.

Landfill Gas. The expected degree in toxicity or mobility of LFG site COPCs are the same as described for Alternative #3a.

Degree to Which Treatment Is Irreversible. The degree to which treatment, recycling or other appropriate remedial components of the selected remedy are irreversible is evaluated below.

Groundwater/Leachate. The degree of reversibility for horizontal containment of the Bulky and Solid Waste Areas is the same as described previously for Alternatives #3a and #3b.

The on-site leachate and groundwater treatment system would be an irreversible destruction process for site COPCs. Removal of the treatment system would result in conditions the same as Alternatives #3a and #3b less the quantity of contaminants removed during past operation.

Landfill Gas. The degree to which treatment of landfill gas is irreversible is the same as described for Alternative #3a.

Type and Quantity of Residuals Remaining After Treatment. The quantity and composition of residuals generated by treatment processes in this alternative are described below. These residuals may require further disposal and handling.

Groundwater/Leachate. The types of process residuals from the on-site groundwater and leachate treatment plant are the same as Alternative #4a. Since the total flowrate is higher, larger quantities of residuals are expected and include:

- Larger quantities of soil residuals from drilling/construction of extraction wells, trenches, and recharge wells (when compared with Alternative #4a).

- Sludge filter cake from the precipitation process option containing metal hydroxide sludges such as $Al(OH)_3$, $Fe(OH)_3$, and $Mn(OH)_2$. The quantity of sludge generated is expected to be approximately 9 ft^3/day.

- Remaining volatile organic COPCs not destroyed in the UV/chemical oxidation system off-gas.

Landfill Gas. The type and quantity of residuals remaining after treatment of LFG are the same as described previously for Alternative #3a.

4.5a.2.5 Short-term Effectiveness of Alternative #5a. This alternative is evaluated for effectiveness in protecting the community and local workers, site remediation workers, and the environment during the construction and implementation of the remedy.

Community Protection. Short-term risks to the community would be the same as those identified for Alternative #4a and would be mitigated using similar measures. Additional short-term risks to the community from the installation of the groundwater collection/depression system may result from inhalation exposures. Construction measures for the installation of this system are expected to take more time as a result of additional intrusive work at the Site. Any potential risks would be evaluated using air monitoring.

Worker Protection. Short-term risks to workers would be the same as those identified for Alternative #4a and would be mitigated using similar measures. Additional short-term risks to workers may result from inhalation exposures or dermal exposures from contact with groundwater at the Site during the installation of the groundwater collection/depression system. This alternative entails the highest degree of intrusive work at the Site and construction activities would take longer and occur over more area at the Site. Potential short-term risks would be the highest for a worker at the Site. Any potential risks to workers would be mitigated using appropriate PPE. Risks to workers from long-term mitigation exposures are discussed in Section 4.5a.2.3.

Environmental Protection. Short-term risks and impacts to the environment would be the same as those identified for Alternative #4a.

Time Until Remedial Action Objectives are Achieved. Estimates for the time to achieve RAOs are discussed below by site media of concern.

Groundwater. The time required to meet the RAOs for this media is the same as Alternatives #3a and #3b. RAOs will be exceeded by addition of the groundwater collection system to the leachate collection and on-site treatment (precipitation, media filtration and UV/chemical oxidation) of Alternative #4a. The time required to achieve the RAOs in this manner will be the time required to implement and achieve an operational and functional status of the above technologies and process options. This is also expected to be within 1-2 years of selection of the FS remedy.

Surface Water/Sediments. The time required to meet the RAOs for this media is the same as Alternative #4a.

Ambient Air. The time required to meet the RAOs for this media is the same as Alternative #3a.

Soil Gas. The time required to meet the RAOs for this media is the same as Alternative #3a.

4.5a.2.6 Implementability of Alternative #5a. The implementability of this alternative is discussed as a measure of the technical and administrative feasibility of this approach as well as the availability of key services and materials required for this remedy.

Technical Feasibility. The relative ease of implementing the remedy is summarized below. Key items include: ability to be constructed and operated, reliability in meeting RAOs, ease of undertaking additional remedial actions and ability to monitor effectiveness of the remedy.

Groundwater/Leachate. For Alternative #5a, the technical feasibility associated with leachate collection, access restrictions and horizontal containment would be similar to that described for Alternative #4a. Implementation of environmental monitoring would be the same as Alternative #1. This alternative only adds construction of extraction wells/drains for the groundwater collection/depression system in the Solid Waste Area, a larger on-site treatment system and discharge of an increased volume of treated water. As with Alternative #4a, the location and construction of these items must be coordinated with the implementation of the horizontal containment to ensure cap integrity is maintained. The technical feasibility associated with the on-site groundwater/leachate treatment system would be the same as Alternative #4a.

The reliability to meet RAOs is increased over Alternative #4a with the addition of the groundwater depression system.

Similar to Alternative #4a, future actions could be implemented to increase this alternative's remedial effectiveness, but should maintain the integrity of the horizontal containment.

The monitoring approach would be similar to that described for Alternative #4a.

Landfill Gas. The technical feasibility for landfill gas would be the same as for Alternative #3a.

Administrative Feasibility. The relative effort and time required to obtain the necessary regulatory approvals and permits for the remedy is evaluated below.

Groundwater/Leachate. Regulatory approvals or permits that may be required to implement the remedy in Alternative #4a will also apply to this alternative. Similar to Alternative #4a, State approval is anticipated to be required prior to any treated water discharge and construction of the treatment system. State approval would be dependent on a larger volume of treated water than Alternative #4a and therefore may be more difficult to obtain.

Landfill Gas. The administrative feasibility for landfill gas would be the same as for Alternative #3a.

Availability of Services and Materials. The availability of key services and materials needed to implement the alternative are discussed below and include: capacity and location of TSDFs, availability of necessary equipment and specialists, timing and scheduling, and availability to obtain competitive cost bids.

Groundwater/Leachate. Availability of services and materials for this alternative is the same as Alternative #4a.

Landfill Gas. The availability of services and materials for this alternative is the same as Alternative #3a.

4.5a.2.7 Cost of Alternative #5a. Cost assumptions regarding escalation, discount rate, contingency and duration, unless otherwise specified, are the same as Alternative #4a. Capital costs

associated with this alternative are expected to be $8.43 million. Operation and maintenance costs (expressed in net present worth dollars) are estimated at $11.81 million. Total costs are therefore $20.24 million. These costs are summarized in detail in Appendix G.

4.5a.2.8 State and Community Acceptance of Alternative #5a. Comments from the State of Rhode Island, the town of South Kingstown, and citizens of the community regarding this alternative will be addressed after the public comment period.

4.5b EVALUATION OF ALTERNATIVE #5b: HORIZONTAL CONTAINMENT OF SOLID WASTE AREA, LANDFILL MINING OF BULKY WASTE AREA, GROUNDWATER AND LEACHATE COLLECTION AND ON-SITE TREATMENT, GAS COLLECTION AND THERMAL TREATMENT

This section describes the components of Alternative #5b followed by detailed evaluation of those components versus the nine FS criteria.

4.5b.1 Definition of Alternative #5b

Alternative #5b provides the same level of human health risk mitigation as Alternative #4b, except it also provides improved mitigation of human health risk by additional engineering controls preventing migration of site COPCs into groundwater, as in Alternative #5a. Mitigation of ecological risk is the same as Alternative #4b.

The major components of this alternative include:

- Groundwater Access Restrictions. Where appropriate, restrictive covenants would be placed on properties affected by site COPCs to limit use of groundwater as a potable water source. The scope of this component is the same as discussed previously under Alternative #2.

- Horizontal Containment - Solid Waste Area. The implementation of the protective cap for the Solid Waste Area would be the same as Alternatives #3a and #3b.

- Landfill Mining - Bulky Waste Area. The implementation of landfill mining would be the same as described previously for Alternative #4b.

- Active Perimeter LFG Collection - Solid Waste Area. The implementation of the active perimeter LFG collection system would be the same as described previously for Alternatives #3a and #3b.

- Active Internal LFG Collection - Solid Waste Area. The implementation of the active internal LFG collection system would be the same as described previously for Alternatives #3a and #3b.

- Thermal LFG Treatment (Enclosed Flare) - Solid Waste Area. This alternative would implement the LFG treatment enclosed flare system in the same manner as Alternative #3a.

- Passive Internal LFG Collection - Bulky Waste Area. This alternative would implement the passive internal LFG collection system for the Bulky Waste Area in the same manner as Alternatives #3a and #3b.

- Leachate Collection (Wells/Drains) - Bulky Waste Area. A leachate collection system would be installed southeast of the Bulky Waste Area to intercept leachate migrating toward the Saugatucket River. The scope of this component is the same as presented for Alternative #4a. However, the length of operation would be reduced to the time of landfill mining.

- Groundwater Collection System (Wells/Drains) - Solid Waste Area. A groundwater depression system would be installed on the northern end of the Solid Waste Area to intercept groundwater prior to contact with refuse in the landfill. The scope of this component is the same as presented for Alternative #5a.

- On-site Groundwater and Leachate Treatment. Implementation of extracted water treatment would be the same as described for Alternative #5a.

- Discharge of Treated Water. Similar to Alternative #4a, treated water would be discharged to either groundwater or surface water, as discussed previously in Section 3.1.6.4.

- Environmental Monitoring. Environmental monitoring includes monitoring of groundwater, surface water/sediment, ambient air and soil gas. Monitoring locations, frequencies and analytes are the same as described previously for Alternative #4b.

- Five-Year Review. As described previously in Alternative #1, since this alternative would result in contaminants remaining on the Site, CERCLA §121(c) and §300.430(f)(4)(ii) of the NCP require that the site remedy be reviewed every five years.

- Community Relations Activities. In the same manner as Alternative #1, on-going community relations activities will be conducted to provide appropriate information, receive comment on that information and to adjust the remedy of the Proposed Plan at key milestones.

Figure 4-9 illustrates the site layout for Alternative #5b. The components of the alternative, and how they interact with each media of concern, are presented on Figure 4-11.

4.5b.2 Nine Criteria Evaluation of Alternative #5b

The analysis of Alternative #5b with respect to the nine criteria is presented in a narrative form in the following paragraphs. The assessment focuses on how, and to what extent, the various factors within each of the criteria are addressed. Uncertainties associated with the alternative are included when changes in assumptions or unknown conditions could affect the analysis.

4.5b.2.1 Overall Protection of Human Health and the Environment from Alternative #5b. Alternative #5b provides the same degree of overall protection of human health as Alternative #5a, using both institutional controls to prevent exposures and engineering controls to reduce and contain concentrations of COPCs at the Site. This alternative maximizes groundwater source control, thereby minimizing the effort required for any future groundwater remediation, if necessary. By doing so, reduction in human health risks from groundwater ingestion is also maximized.

Overall protection of human health from inhalation exposures to Site COPCs in ambient air and soil gas would be the same as Alternative #4b. Specific long-term and short-term human health risks are discussed in Sections 4.5b.2.3 and 4.5b.2.5, respectively.

Groundwater access restrictions, presented in Alternative #2 and included in this alternative, would prevent potential future exposures from residential ingestion of groundwater at the Site.

Short-term risks to the community and workers from landfill mining and implementation of the groundwater collection/depression and treatment systems are the same as those identified in Alternatives #4b and #5a, respectively.

With one exception, the overall protection of ecological habitat and proposed mitigation activities are the same as those presented for Alternative #4b. The exception is that more substantial impacts to the hydrogeology of Mitchell Brook and the Saugatucket River may be realized due to drawdown associated with the operation of the groundwater collection/depression system at the Solid Waste Area. However, reinjection or surface water discharge will be utilized to mitigate drawdown in Mitchell Brook and associated wetlands.

4.5b.2.2 Compliance With ARARs from Alternative #5b. Action-specific ARARs under this alternative are presented in Table 4-11. Any remedial actions taken under this alternative must comply with the ARARs listed in this table. Environmental monitoring will be used as an indicator of compliance with the site-specific chemical and location-specific ARARs described in Section 2.3. Further actions may be required to comply with ARARs if they are not met through this source control/leachate and groundwater treatment remedy.

4.5b.2.3 Long-term Effectiveness and Permanence from Alternative #5b. This alternative is evaluated below in terms of the risk remaining at the Site after RAOs are addressed. This portion of the evaluation focuses on the extent and effectiveness of the controls required to manage the risk posed by treatment residuals and/or untreated contamination.

Magnitude of Residual Risks. Under Alternative #5b, the residual human health risks from inhalation exposures to site COPCs in LFG both on and off the Site would be the same as those for

Alternative #4b. Risk estimates for these exposure pathways are qualitatively expected to be within EPA's target risk range.

Residual risks from fugitive landfill gas emissions would be the same as for Alternative #4b.

Groundwater access restrictions, included under Alternative #2, would prevent potential future exposures from ingestion of groundwater contaminated with site COPCs.

Risks to the community and workers at the Site would be the same as those risks identified for Alternative #4b. Sources of residual risks from groundwater/leachate collection and treatment activities would be similar to those identified for Alternative #5a because treatment technologies for groundwater/leachate in Alternative #5b are the same as Alternative #5a. Mitigation measures presented for Alternatives #4b and #5a would be similar for this alternative.

Long-term risks to ecological receptors would be similar to those described for Alternative #4b. However, the extent of required watercourse mitigation may be greater.

Adequacy of Controls. Measures are described below that detail controls to be placed on untreated waste, waste-contaminated media, and treatment residuals from implementation of Alternative #5b.

> Groundwater/Leachate. The adequacy of controls for groundwater/leachate would be the same as Alternative #4b.
>
> Landfill Gas. Adequacy of controls for landfill gas would be the same as in Alternative #3a.

Reliability of Controls. Evaluations are described below that detail the effectiveness, reliability, and permanence that control measures would provide to protect human health and the environment from untreated waste, waste-contaminated media, and treatment residues.

Groundwater/Leachate. The reliability of controls for groundwater/leachate would be the similar to Alternative #4b. However, the effectiveness in lowering the water table to a level below the landfill source cannot be determined at this time.

Landfill Gas. Reliability of controls for landfill gas would be the same as in Alternative #3a.

Need for Five-Year Review. Because wastes would remain on the Site under this alternative, CERCLA §121(c) and the NCP at §300.430(f)(4)(ii) require that a five-year review be conducted every five years until it is demonstrated that there is no longer a threat to human health or the environment from the Site. For the purpose of this FS and costing, it is assumed that a "Level I" review, the lowest level, would be conducted.

4.5b.2.4 Reduction of Toxicity, Mobility or Volume through Treatment from Alternative #5b. This criteria evaluates how the alternative mitigates the effects of site COPCs by describing the following: treatment technologies and process options utilized, quantity of site COPCs/contaminated media affected, degree of expected reductions in mobility of site COPCs into the environment, degree to which the treatment is irreversible, and the residuals remaining after treatment.

Treatment/Recycling Processes Utilized. The treatment, recycling and other mitigation processes of the remedy and any materials treated are listed below for this alternative:

Groundwater/Leachate

- Horizontal Containment - Solid Waste Area
- Landfill Mining - Bulky Waste Area
- Leachate collection (wells/drains) - Bulky Waste Area
- Groundwater collection (wells/drains) - Solid Waste Area
- On-Site groundwater and leachate treatment (precipitation, media filtration and UV/chemical oxidation)
- Discharge of treated water

Landfill Gas.

- Active perimeter LFG collection - Solid Waste Area
- Active internal LFG collection - Solid Waste Area

- Thermal LFG Treatment (enclosed flare) - Solid Waste Area
- Passive internal LFG collection - Bulky Waste Area

Amount of Hazardous Materials Treated or Recycled. The quantities or volumes of materials containing COPCs that are destroyed, recycled or treated are detailed below. These quantities may also include other hazardous materials that are involved in the remedy.

Groundwater/Leachate. The amount of materials treated or recycled for horizontal containment of the Solid Waste Area is the same as described previously for Alternative #3a.

As with Alternative #5a, the leachate collection system for the Bulky Waste Area will capture approximately 5 gpm. The groundwater collection system for the Solid Waste Area will capture approximately 45 gpm. Both streams will be combined (50 gpm total), treated on the Site and discharged to either groundwater or surface water.

The amount of materials treated or recycled using landfill mining of the Bulky Waste Area is the same as described previously for Alternative #4b.

Landfill Gas. The amount of materials treated or recycled relating to LFG impacts to ambient air and soil gas are the same as described for Alternative #3a.

Degree of Expected Reductions in Toxicity or Mobility. The expected degree of reductions in toxicity or mobility of the COPCs in site media are detailed below.

Groundwater/Leachate. The expected reduction in toxicity or mobility for horizontal containment of the Solid Waste Area is the same as described previously for Alternatives #3a and #3b.

The leachate collection system for the Bulky Waste Area will limit mobility and reduce toxicity of site COPCs the same as Alternative #4b.

The groundwater collection system for the Solid Waste Area will further limit downgradient mobility of site COPCs the same as Alternative #5a. Since the on-site treatment system is the same, the reduction of toxicity of the captured groundwater, when combined with the collected leachate, will be the same as Alternative #4a.

The expected reduction in toxicity and mobility using landfill mining is the same as described in Alternative #4b.

Landfill Gas. The expected degree in toxicity or mobility of LFG site COPCs are the same as described for Alternative #3a.

Degree to Which Treatment Is Irreversible. The degree to which treatment, recycling or other appropriate remedial components of the selected remedy are irreversible is evaluated below.

Groundwater/Leachate. The degree of reversibility for horizontal containment of the Solid Waste Area is the same as described previously for Alternatives #3a and #3b.

The degree of reversibility for the on-site leachate and groundwater treatment system would be the same as for Alternative #5a.

The degree of reversibility for landfill mining would be the same as described for Alternative #4b.

Landfill Gas. The degree to which treatment of landfill gas is irreversible is the same as described for Alternative #3a.

Type and Quantity of Residuals Remaining After Treatment. The quantity and composition of residuals generated by treatment processes in this alternative are described below. These residuals may require further disposal and handling.

Groundwater/Leachate. The types and quantities of process residuals from the on-site groundwater and leachate treatment plant are the same as Alternative #5a.

Landfill Gas. The type and quantity of residuals remaining after treatment of LFG are the same as described previously for Alternative #3a.

4.5b.2.5 Short-term Effectiveness of Alternative #5b. This alternative is evaluated for effectiveness in protecting the community and local workers, site remediation workers, and the environment during the construction and implementation of the remedy.

Community Protection. Short-term risks to the community would be the same as those identified for Alternative #4b and would be mitigated using similar measures. As with Alternative #5a, short-term risks to the community from the installation of the groundwater collection/depression system

may result from inhalation exposures. Construction measures for the installation of this system are expected to take more time as a result of additional intrusive work at the Site. Any potential risks would be evaluated using air monitoring.

Worker Protection. Short-term risks to workers from installation of the LFG collection and treatment systems would be the same as those identified for Alternative #4b and would be mitigated using similar measures. Additional short-term risks to workers may result from the installation of the groundwater collection/depression system as identified for Alternative #5a. Mitigation measures identified for Alternative #5a are, as a result, appropriate for use with Alternative #5b as well. Risks to workers from long-term exposures and mitigation measures are discussed in Section 4.5b.2.3.

Environmental Protection. Short-term risks and impacts to the environment would be the same as those identified for Alternative #4b.

Time Until Remedial Action Objectives are Achieved. Estimates for the time to achieve RAOs are discussed below by site media of concern.

Groundwater. The time required to meet the RAOs for this media is the same as Alternatives #3a and #3b. RAOs will be achieved by addition of the groundwater collection system to the leachate collection and on-site treatment (precipitation, media filtration and UV/chemical oxidation) of Alternative #4b. The time required to achieve the RAOs in this manner will be the time required to implement and achieve an operational and functional status of the above technologies and process options. This is also expected to be within 2 years of selection of the FS remedy.

Surface Water/Sediments. The time required to meet the RAOs for this media is the same as Alternative #4b.

Ambient Air. The time required to meet the RAOs for this media is the same as Alternative #3a.

Soil Gas. The time required to meet the RAOs for this media is the same as Alternative #3a.

4.5b.2.6 Implementability of Alternative #5b. The implementability of this alternative is discussed as a measure of the technical and administrative feasibility of this approach as well as the availability of key services and materials required for this remedy.

Technical Feasibility. The relative ease of implementing the remedy is summarized below. Key items include: ability to be constructed and operated, reliability in meeting RAOs, ease of undertaking additional remedial actions and ability to monitor effectiveness of the remedy.

Groundwater/Leachate. For Alternative #5b, the technical feasibility associated with leachate collection, access restrictions and horizontal containment would be similar to that described for Alternative #4b. Implementation of environmental monitoring would be the same as Alternative #1. The implementation of the groundwater collection/depression system in the Solid Waste Area is the same as Alternative #5a.

The reliability to meet RAOs is increased over Alternative #4b with the addition of the groundwater depression system.

Similar to Alternative #4b, future actions could be implemented to increase this alternative's remedial effectiveness, but should maintain the integrity of the horizontal containment.

The monitoring approach would be similar to that described for Alternative #4b.

Landfill Gas. The technical feasibility for landfill gas would be the same as for Alternative #3a.

Administrative Feasibility. The relative effort and time required to obtain the necessary regulatory approvals and permits for the remedy is evaluated below.

Groundwater/Leachate. Regulatory approvals or permits that may be required to implement the remedy in Alternative #4b will also apply to this alternative. Similar to Alternative #4b, State approval is anticipated to be required prior to any treated water discharge and construction of the treatment system. State approval would be dependent on a larger volume of treated water than Alternative #4b and therefore may be more difficult to obtain.

Landfill Gas. The administrative feasibility for landfill gas would be the same as for Alternative #3a.

Availability of Services and Materials. The availability of key services and materials needed to implement the alternative are discussed below and include: capacity and location of TSDFs, availability of necessary equipment and specialists, timing and scheduling, and availability to obtain competitive cost bids.

Groundwater/Leachate. Availability of services and materials for this alternative is the same as Alternative #4b.

Landfill Gas. The availability of services and materials for this alternative is the same as Alternative #3a.

4.5b.2.7 Cost of Alternative #5b. Cost assumptions regarding escalation, discount rate, contingency and duration, unless otherwise specified, are the same as Alternative #4b. Capital costs associated with this alternative are expected to be $11.01 million. Operation and maintenance costs (expressed in net present worth dollars) are estimated at $11.81 million. Total costs are therefore $22.82 million. These costs are summarized in detail in Appendices A and G.

4.5b.2.8 State and Community Acceptance of Alternative #5b. Comments from the State of Rhode Island, the town of South Kingstown, and citizens of the community regarding this alternative will be addressed after the public comment period.

SECTION 5.0

COMPARATIVE ANALYSIS OF SITE REMEDIATION ALTERNATIVES

This section provides a detailed comparison for each of the five site remediation alternatives in terms of the nine evaluation criteria presented in Section 4.0. Comparisons are presented qualitatively, identifying substantive differences between alternatives. A summary of the comparison of alternatives, by criteria, is presented in Table 5-1.

5.1 OVERALL PROTECTION OF HUMAN HEALTH AND THE ENVIRONMENT

Overall protection of human health and the environment, within the limits of the remedial action objectives defined for this feasibility study, is a key threshold criteria that must be attained by an alternative to be eligible for selection in the ROD. This section describes the overall assessment of whether each alternative achieves adequate protection of human health and the environment.

Alternatives #1 and #2 do not meet this criteria, while Alternatives #4a, #4b, #5a and #5b would attain or exceed adequate protection of human health and the environment. Alternatives #3a and #3b would attain adequate protection of human health, but only approach adequate attainment for protection of the environment, since some portion of leachate would still reach surface water/sediment bodies.

5.1.1 Human Health Protection

Alternative #1 provides no protection against human health risks and, thus, does not meet this threshold criteria. The estimated cancer risk and hazard index would continue to exceed EPA's target cancer risk range of 10^{-6} to 10^{-4} and the target non-cancer risk limit of 1, for those exposure pathways identified in the baseline risk assessment (see Sections 2.0 and 4.0 for further definition). Alternative #1 also provides no protection from potential future risks, if off-site migration of contamination occurs.

Alternative #2 uses institutional controls (access restrictions) to provide some degree of overall protection of human health by significantly reducing the potential for on-site human exposures to occur. Overall risks to human health at the Site may be greater than for Alternative #1, but human health risks remain at unacceptable levels under this alternative if the proposed institutional controls are not effective. Risks from on-site exposures are expected to exceed EPA's target risk range. Engineering controls (residential LFG control contingency) are provided under this alternative to increase overall protection of human health at off-site locations in the event that site COPCs impact these locations in the future. Since contamination at the Site is not reduced or contained under this alternative, off-site exposures to COPCs in ambient air or indoor air at nearby residences would exceed the EPA target cancer risk range. This occurs even at locations with the residential LFG control contingency since these systems are appropriate only for reducing safety risks from methane in soil gas. There would also be limited short-term risks to workers from the installation of fencing under this alternative.

Human health risks from inhalation exposures are reduced to acceptable levels by engineering controls and access restrictions for Alternatives #3a through #5b. These alternatives also use engineering controls to increase the protection of human health from inhalation exposures to COPCs originating in landfill gas (cap installation, LFG collection, and treatment of LFG at the Solid Waste Area). Risks from inhalation exposures to COPCs in soil gas in ambient air and indoor air at nearby residences are expected to be reduced to within EPA's target risk range under these alternatives.

Installation of a cap in Alternatives #3a through #5b also provide some leachate control to help reduce subsequent groundwater impacts by minimizing infiltration of precipitation. Furthermore, alternatives #4a through #5b use a leachate collection and treatment system to provide additional leachate control. Alternatives #4b and #5b utilize landfill mining to remove a source of groundwater impacts (Bulky Waste Area) from the Site. Separation of the water table from refuse in the Solid Waste Area using a groundwater depression system would be expected to further reduce risks from this groundwater/leachate exposure pathway to acceptable levels for Alternatives #5a and #5b. However, Alternatives #2, #3a, #3b, #4a, and #5a do not provide source reduction of existing

groundwater contamination at the Site. Groundwater access restrictions included in these alternatives would prevent any exposures from potential future groundwater ingestion at the Site. For Alternatives #2 through #5b, potential future risks from groundwater ingestion at the Site would not exceed the EPA target cancer risk range as long as groundwater access restrictions are effective. Overall protection of human health from this groundwater ingestion exposure pathway for Alternatives #2 through #5b would depend on the long-term effectiveness of institutional controls, since these alternatives would not provide any source containment of the groundwater contamination. Alternatives #4b and #5b remove the Bulky Waste Area through landfill mining, but move some of it to another area of the Site. If groundwater contamination migrates off of the Site, potential future risks from residential ingestion of groundwater at nearby residences may exceed EPA's target risk range. However, risks to off-site residents from this exposure pathway are not expected for Alternatives #2 through #5b, because institutional controls are proposed for each of these alternatives. Overall protection of human health from this exposure pathway for Alternatives #2 through #5b would depend on long-term monitoring.

Although Alternative #1 would not result in any additional short-term risks to the community or workers, other alternatives would as a result of mitigation activities. Alternative #2 would result in limited additional short-term risks to workers as a result of the installation of fencing at the Solid Waste Area. For Alternatives #3a through #5b, installation of the LFG collection and treatment systems would result in increased short-term risks from the movement of soils and/or invasive work at the Solid Waste Area, as well as from the increased human presence at the Site for the duration of remediation work. Furthermore, Alternatives #4a through #5b would result in additional short-term risks relative to Alternative #3 from increased invasive work during installation of a groundwater/leachate collection and treatment systems. Alternatives #4b and #5b would result in additional short-term risks relative to Alternatives #4a and #5a, respectively, from increased invasive work during landfill mining activities. However, all additional short-term risks identified for Alternatives #2 through #5b, to either the community or workers at the Site, are expected to be sufficiently mitigated using engineering controls and/or PPE. Alternatives #3a through #5b result in limited residual long-term health risks to the community and/or workers relative to Alternatives

#1 and #2. On-site LFG collection and treatment in Alternatives #3a through #5a would result in long-term residual risks to on-site workers working around and with the LFG remediation equipment. Alternatives #4a through #5b would result in long-term residual risks to workers charged with maintaining the groundwater/leachate collection and treatment systems. A relatively small long-term residual risk to the community results from Alternatives #3a through #5a due to the off-site transport of site contaminants from the leachate/groundwater treatment process and the LFG condensate collection. These long-term risks to workers and the community are expected to be sufficiently mitigated by some combination of engineering controls, use of PPE, and proper hazardous materials handling and transport procedures.

5.1.2 Ecological Protection

The no action and limited action alternatives, Alternative #1 and #2, respectively, are not protective of the environment and, thus, do not meet this criteria. These alternatives provide no reduction in long- or short-term risks to ecological receptors relative to baseline levels since there would be no reduction in contaminant migration via leachate and groundwater. Therefore, the documented adverse impacts to the aquatic community (as were described in Section 2.0), especially to Mitchell Brook and the Saugatucket River, would persist under these two alternatives.

Under Alternatives #3a and #3b, capping of the two disposal areas would substantially decrease ecological exposures to site-related contaminants in wetland and aquatic habitats since leachate generation and subsequent discharge to Mitchell Brook and the Saugatucket River would be substantially reduced. However, these alternatives may not be totally protective of the environment since some leachate would still reach surface water bodies.

Alternatives #4a through #5b are protective of the environment, since capping of the disposal areas, landfill mining and installation of groundwater/leachate collection and treatment systems would essentially eliminate ecological exposures to site-related contaminants in wetland and aquatic

habitats. Leachate generation and subsequent discharge to Mitchell Brook and the Saugatucket River would be prevented and/or controlled.

The remedial alternatives differ in the magnitude of potential impacts to ecological habitats. Other than the continued presence of contaminants in on-site media, there would be no impacts to wetlands or other habitats under the no action alternative, since no disturbance of these habitats would occur. For the limited action alternative, some minor, short-term impacts to small areas of wetland and upland habitats would occur due to fence installation. For Alternatives #3a, #3b, #4a, and #5a, capping the disposal areas and constructing the various collection and treatment systems would result in some temporary and/or minor impacts to ecological habitat, the filling of one small emergent wetland (<0.15 acres) and impacts to forested wetlands (0 to 0.5 acres). These potential impacts can be mitigated and are lowest for Alternatives #3a and #3b and highest for Alternatives #4a through #5b (due to the number and extent of remedial actions to be conducted).

For Alternatives #3a through #5b, the caps and collection/treatment systems also have the potential to affect the hydrology of on-site wetlands, Saugatucket River and Mitchell Brook. These potential impacts are relatively low for Alternatives #3a and #3b compared to Alternatives #4a through #5b (due to the presence of both groundwater collection/depression and leachate collection systems).

5.2 COMPLIANCE WITH ARARS

Compliance with ARARs is the second of the two key criteria that must be attained by an alternative to be eligible for selection in the ROD. Compliance with ARARs is partially or substantially met by Alternatives #3a through #5b and is not attained by Alternatives #1 and #2.

The no action and limited action alternatives, Alternatives #1 and #2 respectively, fail to meet requirements for hazardous waste landfills. These two alternatives also fail to attain groundwater quality criteria and standards. Alternatives #3a through #5b meet either the intent or the letter of the Rhode Island and federal regulatory requirements for a landfill cap. Groundwater protection

standards are currently not attained under any alternative since there is no remediation of groundwater. Based on the use of source control and an anticipated groundwater reclassification, this non-attainment is expected to be temporary and will be reviewed further following monitoring, which is included as a part of each alternative.

Landfill gas emissions controls, proposed under Alternatives #3a through #5b, would be designed, installed, and operated to meet Rhode Island Air Pollution Control Regulations and the federal Clean Air Act. Emissions from the gas treatment systems would attain RIDEM Air Pollution Control Regulation No. 7, which prohibits the emission of air contaminants detrimental to person or property. These emissions would also be expected to be below the minimum reportable quantities and acceptable ambient levels set forth in RIDEM air toxics rules, No. 22, which prohibits the emission of air toxics without a permit. Under this regulation, air quality modeling may be required to determine allowable emissions.

Alternatives #3a through #5b also include a condensate aboveground storage tank and condensate pump stations which are regulated as ancillary equipment to tanks. This condensate is assumed to be hazardous by characteristic and would require off-site disposal at a RCRA-compliant TSDF. The tank and pump stations would need to be installed in compliance with state, federal, and local tank rules and underground components would also need to comply with appropriate UST rules.

For the no action and limited action alternatives, Alternatives #1 and #2, federal and state AWQC for the protection of aquatic life for the chemicals of potential ecological concern in surface water would not be met since leachate seeps are neither eliminated nor contained. For Alternatives #3a and #3b, AWQC may not be met in the Saugatucket River and Mitchell Brook since release of leachate to these water bodies is substantially reduced but is not eliminated. AWQC would be met under Alternatives #4a through #5b since leachate generation and discharge would be eliminated and/or controlled. Discharge of treated wastewater, proposed for Alternatives #4a through #5b, would require consultation and coordination with state authorities, including RIDEM and the Rhode Island Fish and Wildlife Division. Treated groundwater/leachate may be discharged to surface water

and/or groundwater. It is anticipated that a discharge scheme in compliance with Rhode Island Groundwater Quality Standards and Preventive Action Limits, Rhode Island Water Quality Criteria, Federal Clean Water Act AWQC, and other action-specific ARARs would be developed between state and federal authorities as part of the remedial design.

Wetland-related ARARs and TBCs would be met under the no action and limited action alternatives since these areas are not disturbed (although some minimal disturbance would occur to small areas within the wetland buffer zone under the limited action alternative) and no surface water discharges from treatment facilities would occur. For Alternatives #3a through #5b, wetlands-related ARARs would be met through on-site mitigation (replacement of a small emergent wetland area to be impacted during cap installation on the Solid Waste Area as well as replacement of other impacted forested wetlands) and through proper hydrological design (to mitigate potential hydrological impacts to surface water bodies and wetlands due to the caps and/or the collection and treatment systems).

Federal and state ARARs relating to threatened and endangered species would be met under all alternatives since none of the remedial alternatives directly affect any known threatened or endangered species nor do they adversely modify or destroy any critical habitat. In addition, the baseline ecological risk assessment did not identify any significant exposure pathways to site contaminants for any endangered species which could potentially occur on the Site.

For Alternatives #3a through #5b, actions must be taken during construction to protect (or mitigate unavoidable impacts to) wetlands, surface waterbodies, the floodplain, and the nearby cemetery.

5.3 LONG-TERM EFFECTIVENESS AND PERMANENCE

This section summarizes the evaluation for risks remaining at the Site after RAOs have been met, and risk from management of residuals.

5.3.1 Magnitude of Residual Risk: Human Health

Alternative #1 provides no long-term effectiveness and permanence and does not protect against the human health risks identified in the baseline human health risk assessment. Exposure pathways which exceed acceptable human health risk levels include inhalation exposures at the Site, inhalation exposures from indoor air and ambient air at off-site receptors and groundwater ingestion exposures at the Site.

Alternative #2 only provides minor long-term effectiveness and permanence since no source reduction or containment measures are implemented under this alternative. This alternative reduces residual human health risks by using institutional controls and residential contingencies to prevent exposures from occurring. Provided that institutional controls are effective over the long-term, residual human health risks from exposure to site COPCs in soil gas and groundwater at the Site would be reduced to or near acceptable risk levels. In addition, assuming that there is long-term monitoring, residual human health risks from off-site exposures to groundwater may be reduced to acceptable risk levels. However, residual human health risks from ambient air inhalation exposures of off-site receptors may continue to exceed acceptable risk levels.

Through engineering controls and treatment, Alternatives #3a through #5b provide an increase in long-term effectiveness and permanence, relative to Alternative #2, by controlling and reducing site COPCs in ambient air and soil gas. As a result, residual human health risks from inhalation exposures at off-site receptors would be reduced to acceptable risk levels.

Alternatives #3a through #5b provide some increase in long-term effectiveness and permanence with respect to residual human health risks from exposures to surface water and groundwater contamination. Institutional controls provide reductions in long-term residual human health risks from ingestion exposures to both on- and off-site groundwater. These risks are expected to be reduced to acceptable levels provided that institutional controls and monitoring continue over the long term.

Additional long-term residual risks would result from the engineering controls proposed for the various alternatives. The LFG collection and treatment system proposed for Alternatives #3 through #5 would result in additional long-term risks from the condensate waste stream and from combustion products at the enclosed flare. In addition, Alternatives #4a through #5b would have long-term residual risks from the treatment train for collected groundwater and leachate. Residual risks would result from waste streams requiring disposal and the release of off-gases. These potential risks associated with treatment technologies could be mitigated by using appropriate engineering controls where possible and by using proper operating and transport methods and procedures.

5.3.2 Magnitude of Residual Risk: Ecological

The no action and limited action alternatives, Alternatives #1 and #2, would not result in a quantifiable long-term reduction in risk to ecological receptors since leachate would continue to be generated and enter Mitchell Brook and the Saugatucket River. Documented adverse impacts (see Section 2.0) to the aquatic communities in these water bodies would continue from exposure to this leachate.

Long-term risks to ecological receptors in wetland and aquatic habitats would be substantially reduced under Alternatives #3a and #3b due to installation of horizontal containments on the Solid Waste and Bulky Waste Areas. Since some leachate would still reach on-site water bodies under these alternatives, there is a residual risk associated with them. The magnitude of residual ecological risks are proportional to the amount of residual leachate discharged following capping.

Long-term risks to ecological receptors in wetland and aquatic habitats would be virtually eliminated under Alternatives #4a through #5b.

5.3.3 Adequacy and Reliability of Controls

Alternative #1 would not provide adequate or reliable protection of human health or the environment as it involves no treatment or management controls for either groundwater/leachate or landfill gas, and relies on only natural attenuation for protection. Alternative #2 would not involve treatment controls for groundwater/leachate or landfill gas, but provides protection through access restrictions and the LFG control contingency. The reliability of these controls are dependent upon the frequency of routine monitoring. The adequacy and reliability of monitoring is, in turn, dependent upon the use of proper sampling and analytical procedures. Regardless, protection of human health due to off-site inhalation of ambient air is not fully adequate under Alternative #2.

Horizontal containment (capping) proposed under Alternatives #3a through #5b would adequately reduce or eliminate the infiltration of precipitation into waste, thereby reducing the generation of leachate. The caps would require long-term maintenance to ensure that their integrity is not compromised. The caps would also lower the water table to a limited degree, reducing contact between in-place refuse and groundwater. This action reduces the volume of groundwater that becomes contaminated as well as the quantity of leachate produced. The caps, however, may not adequately cover or eliminate all leachate outbreaks. There is a high degree of confidence associated with caps in relation to their ability to reduce infiltration of precipitation and control the escape of landfill gas. Furthermore, capping is an indirect method of providing protection from exposure to untreated groundwater. The caps, however, would not be expected to cover all leachate outbreaks that could still be potential exposure locations.

The leachate collection system proposed under Alternatives #4a through #5b would reduce the leachate outbreaks near the Saugatucket River. The groundwater depression system proposed under Alternatives #5a and #5b would lower the water table in the Solid Waste Area so that waste is no longer in direct contact with the groundwater. The systems used to treat the groundwater/leachate collected would be housed in a building which would protect the public from contacting untreated water and treatment system areas.

Source removal through landfill mining would eliminate the generation of leachate in the Bulky Waste Area, assuming complete source removal can be attained. However, operation of the leachate collection system would be required for a period of time to capture remaining contamination. If waste needs to be left in place, additional controls (i.e., a cap and long-term leachate collection) would be necessary.

The reliability and adequacy of the LFG collection and treatment systems proposed under Alternatives #3a through #5b is initially dependent on the collection system. Landfill gas not captured by the active internal collection system would be captured by the active perimeter collection system. The perimeter system and caps provide an adequate secondary containment of landfill gas and substantially reduce fugitive emissions to ambient air.

Treatment by enclosed flare is proposed for Alternatives #3a, and #4a through #5b. The hazard from untreated site COPCs exiting the enclosed flare would be very low due to the high destruction removal efficiencies that can be expected (95% minimum for all VOCs). Other hazards are posed by condensate from the landfill gas as well as combustion by-products such as hydrochloric acid, acid gases and odor-causing sulfur oxides. Reliability of the landfill gas collection and treatment system will be dependent on close attention of the operator(s), and engineering support staff.

Alternative #3b proposes LFG treatment by photocatalytic oxidation. Because photocatalytic oxidation is an innovative technology, its reliability over years of operation has not been determined. The technology has not yet been tested on landfill gas.

Each of the five alternatives would require periodic five-year reviews to examine the reliability and adequacy of the process options and technologies selected.

5.4 REDUCTION OF TOXICITY, MOBILITY, OR VOLUME THROUGH TREATMENT

5.4.1 Treatment/Recycling Processes Utilized

Alternatives #1 and #2 do not utilize any treatment processes beyond natural attenuation and therefore do not remediate source areas. In Alternative #2, utilization of the LFG control contingency would only result in negligible reduction of toxicity, mobility, and volume of the treated waste. Alternatives #3a, #4a, #4b, #5a and #5b treat captured landfill gases by combustion in an enclosed flare, reducing the toxicity and mobility of landfill gas migrating off the Site. Similar to Alternative #3a, Alternative #3b also treats COPCs in LFG, but does not destroy methane. Alternatives #4a through #5b additionally treat groundwater/leachate using precipitation, media filtration and UV/chemical oxidation.

5.4.2 Amount of Hazardous Materials Treated or Recycled

The total flow rate of leachate that would be treated under Alternatives #4a and #4b is approximately 5 gpm. The total flow rate of groundwater/leachate in Alternatives #5a and #5b which would be treated is approximately 50 gpm. The Bulky Waste Area leachate comprises 5 gpm of this flow, while the groundwater depression system north of the Solid Waste Area contributes 45 gpm, mostly groundwater migrating into the Site. During landfill mining in Alternatives #4b and #5b, the flow rate of leachate at the Bulky Waste Area may be increased due to ground disturbances.

Under Alternatives #3a, #4a, #4b, #5a and #5b, the majority of the LFG would be burned using an enclosed flare. Under Alternative #3b, the majority of the LFG would be treated using photocatalytic oxidation. Only limited quantities of landfill gas would be addressed under Alternative #2 through the residential LFG control contingency.

5.4.3 Degree of Expected Reductions in Toxicity, Mobility, or Volume

While none of the alternatives remove the source of LFG contamination, Alternatives #3a through #5b provide the greatest degree of reduction in COPC toxicity, mobility, and volume from landfill gas through appropriate controls. Alternatives #3a and b, #4a and #5b provide progressively more reduction in COPC toxicity, mobility and volume for groundwater/leachate. Alternatives #4b and #5b also provide more reduction in groundwater/leachate COPC toxicity than Alternatives #3a and #3b. They also reduce the volume of leachate due to source removal. However, short-term mobility may be increased due to ground disturbances.

5.4.4 Irreversibility

Alternatives #3a through #5b are irreversible with respect to implemented treatment technologies and process options which destroy site COPCs. To a small extent, Alternative #2 (through the LFG control contingency) also irreversibly removes or destroys site COPCs.

5.4.5 Type and Quantity of Residuals

For groundwater, Alternatives #1 and #2 would generate no treatment residuals. Alternative #3a would generate condensate from the landfill gas collection system as well as combustion by-products. Landfill gas condensate is expected to generate at a rate of 125 gal/10^6 ft^3 of extracted gas. Combustion gases would be expected to include trace nitrogen oxides, sulfur oxides, and small quantities of undestroyed COPCs. Alternative #3b would also generate condensate from the LFG collection system as well as residuals such as methane and possibly small quantities of hydrogen chloride. Alternatives #4a through #5b would generate landfill gas condensate and combustion by-products (at the same rates as predicted for Alternative #3a), drilling/construction soils from installation of the groundwater depression/leachate collection and treatment systems, and sludge filter cakes from the wastewater treatment plant. The sludge filter cakes would be expected to contain hydroxide sludges of aluminum, iron, and manganese. Alternatives #4b and #5b would

generate waste, soil and scrap metal residuals during landfill mining. There may also be minor hazardous waste encountered under these two alternatives.

Further reduction in toxicity and mobility of Site COPCs in groundwater would be achieved with Alternatives #4b, #5a, and #5b. Landfill mining (Alternatives #4b and #5b) would eliminate a waste source (Bulky Waste Area), while groundwater depression (Alternatives #5a and #5b) would separate the waste source from the water table.

5.5 SHORT-TERM EFFECTIVENESS

The effects of each remedial alternative during construction and implementation are compared to one another in the following paragraphs.

5.5.1 Protection of Community and Workers During Remedial Actions

Short-term risks include any additional risks to the community or workers at the Site from exposures as a result of construction measures and implementation of remediation activities. There would be no additional short-term risks from exposures under Alternative #1, as this alternative entails no action at the Site.

Alternative #2 has nominal increases of short-term risks due to installation of the residential LFG control contingency as well as fence installation.

Alternatives #3a through #5b would result in additional short-term risks to the community and workers from ingestion and inhalation exposures to soil particles in dust during preparation of disposal areas for capping and inhalation exposures to VOCs from invasive work at the Solid Waste Area. Air sampling and monitoring would be used to evaluate any potential risks from inhalation exposures and in addition, engineering controls would be used to reduce any potential inhalation risks from invasive activities. Dust control measures would be used to mitigate potential soil

ingestion or inhalation exposures. Concentrations of COPCs are expected to be the highest at the Site, therefore, workers at the Site would also use appropriate PPE to mitigate any potential risks from exposures.

Alternatives #4a through #5b may present short-term risks in addition to those described for Alternatives #3a and #3b, as a result of additional invasive work required for installation of leachate collection and treatment and the groundwater collection/depression and treatment systems. These short-term risks could be mitigated by a variety of measures. Air sampling and monitoring would be used to evaluate any potential risks to the community. As discussed above, engineering controls would also be used to minimize the degree of invasive work to mitigate potential risks from this exposure pathway. Workers would also wear appropriate PPE to mitigate any potential risks from increased exposures at the Site. Alternatives #4b and #5b also present short-term risks due to landfill mining. Similar to above, these risks could be mitigated by sampling/monitoring, engineering controls and PPE.

5.5.2 Environmental Impacts

For Alternative #1, short-term habitat impacts due to remediation activities would not occur. Minimal short-term habitat impacts would occur under Alternative #2. Short-term risks to ecological receptors are likely to increase slightly due to the mobilization of contaminants during horizontal containment operations for Alternatives #3a through #5b. These three alternatives would also temporarily displace some resident organisms, and some mortality of animals would occur during capping operations.

Direct, relatively short-term (1 year) habitat impacts would occur during remedial construction activities for Alternatives #3a through #5b and would affect approximately 30 acres of habitat, including one small emergent wetland and up to 0.5 acres of forested wetlands (Alternatives #4a through #5b). Most of the impacted areas occur on top of the disposal areas; the primary disturbance would occur during installation of the caps. These impacts are lowest for Alternative #3a and #3b

and highest for Alternatives #5a and #5b (due to the greater extent of remedial activities), although differences among these alternatives are not substantial. Additional disturbances include construction of roadways, groundwater depression/leachate collection systems, and installation of treatment facilities. Disturbed areas would be restored following remediation. The increase for potential erosion, run-off, and sedimentation related to invasive activities for Alternatives #4a through #5b would be mitigated with appropriate engineering controls.

5.5.3 Time Until Remedial Action Objectives are Achieved

For Alternative #1, the time for natural attenuation of contaminants from the disposal areas is unknown and may be larger than the 30 year default value for CERCLA remedies. The time required to meet RAOs, however, is considerably less for alternatives that employ active remedial measures for these disposal areas.

For groundwater, Alternatives #2 through #5b achieve RAOs within 1 to 2 years of implementation of remedial design and remedial action (e.g. construction) activities. These RAOs are achieved quickly since groundwater remediation is not required at this time, as only prevention of COPC ingestion from affected groundwater is required. Surface water/sediment RAOs are achieved in the same periods as groundwater for Alternatives #3a through #5b through control of leachate.

For Alternative #1, natural attenuation of LFG from the Solid Waste Area is estimated to be 5 to 15 years (e.g., 20 to 30 years after the last waste placement in 1982). Soil gas RAOs for Alternatives #2 through #5b will be achieved within 1 to 2 years of remedy implementation through the residential LFG control contingency and LFG collection/treatment systems. The time required to meet ambient air RAOs for Alternative #2 would be the same as Alternative #1. The time required to meet ambient air RAOs for Alternatives #3a through #5b would be within 1 to 2 years of remedy selection or the time required for remedial design and construction of the LFG control measures.

5.6 IMPLEMENTABILITY

This section summarizes the technical and administrative feasibility of implementing an alternative and the availability of various services and material required during it implementation. As Alternative #1 would not entail implementation of any actions, it's implementability is not an issue and is not discussed below.

5.6.1 Technical Feasibility

There are not significant differences between Alternatives #3a, #3b, #4a and #5a with regards to ability to construct and operate the associated technologies and process options. Alternatives #4b and #5b are similar to those above except for landfill mining. The technical feasibility of this technology option would be determined during pilot testing. Since Alternative #2 only includes residential contingencies, installation and operation will be simplified in comparison to the above alternatives. Details regarding the ability to construct and operate technologies and process options are discussed further below.

Gas extraction wells would be installed in the Solid Waste Area in Alternatives #3a through #5b. Installation of the wells would necessitate drilling into disposal areas. Obstructions may be encountered in the disposal areas, which may complicate the drilling operation. Installation of the perimeter LFG collection system would be complicated by the power lines and proximity of residences along Rose Hill Road. The perimeter system should be constructed outside the limit of waste. However, this may not be possible due to the lack of area between the western limit of refuse placement and Rose Hill Road.

Cap construction in Alternatives #3a through #5b would require stripping existing vegetation, installation and seaming of a geomembrane, backfill and compaction of the soil components of the cap, and revegetation. Installation of the geomembrane would be complicated by the numerous gas extraction wells. The top of each extraction well would penetrate the cap and the measures taken

to prevent leakage around these penetrations would slow and increase the cost of the cap installation. Cap construction at the Solid Waste Area for Alternatives #4b and #5b will also be complicated by the need to place non-recyclable landfill mined wastes at the Solid Waste Area before capping is conducted. Level B PPE may be necessary especially during invasive construction activities. This would slow the schedule and increase the cost of construction significantly.

Alternatives #4a through #5b would also involve the construction of groundwater/leachate collection systems and a treatment plant. Portions of the groundwater/leachate collection system may be in disposal areas, which would cause the same problems as mentioned above with respect to the landfill gas collection system. The groundwater/leachate treatment plant would involve building construction, connection of the different skid mounted processes, utility connection, and piping from the extraction systems.

Alternatives #4b and #5b would involve landfill mining of the Bulky Waste Area. If waste is found to be below the water table during pilot testing, dewatering would be necessary. Treatment of this water prior to discharge may be required. Any hazardous waste encountered may require PPE upgrades as well as appropriate handling and disposal.

Potential future remedial actions at the Site may involve on-site activities such as expanded groundwater/collection and treatment. Alternative #2 offers the least difficulty in conducting future remedial actions since most activities for this alternative occur off of the Site. The greatest difficulty in instituting future remedial actions would occur with Alternatives #4a through #5b since they incorporate the largest number of on-site remedial actions (capping, landfill gas collection/treatment, landfill mining, groundwater depression/leachate collection and treatment).

Monitoring would play the largest role in Alternative #2 since it is needed for two major functions: 1) as the decision mechanism for instituting the residential LFG control contingency and 2) as a means to confirm the success of the remedy. Environmental monitoring outlined in this FS is the same for most alternatives since contaminants in disposal areas are left in place for all but

Alternatives #4b and #5b. Monitoring for these two alternatives may be reduced over time in the Bulky Waste Area, but initially must be performed to determine the technology's effectiveness.

5.6.2 Administrative Feasibility

Institutional controls (access restrictions) are included in Alternatives #2 through #5b; therefore, administrative feasibility is the same with respect to this component. Effort required for administrative implementability will increase incrementally from Alternatives #3a through #5b. This is due to permitting required for landfill gas control and treatment, leachate control and treatment, landfill mining, and groundwater/leachate control and treatment. Further administrative feasibility details are described below.

Alternatives #2 through #5b would require significant long-term coordination between federal, state, and local authorities. Implementation of restrictive covenants in the form of property deed restrictions, modifications to local zoning, or other changes in local ordinances would require significant legal services and coordination with the town of South Kingstown and with the property owners. Reclassification of groundwater and/or surface water would require coordination with the town of South Kingstown and RIDEM.

Environmental monitoring programs proposed under all five alternatives would require coordination with the State of Rhode Island and the property owners of record. Long-term coordination would be required for analytical services and review and maintenance of data.

Under Superfund, permits are not required for remediation activities. Compliance with substantive requirements is, however, required. Thus, while an air permit would not be required for operation of the enclosed flare or photocatalytic oxidation unit in Alternatives #3a through #5b, designs must meet state standards and RIDEM must be consulted during the design phase. Coordination with state and local authorities may be necessary to effectively implement air monitoring, flare operation, and cap maintenance. The condensate storage tank and pump stations would need to be designed and

installed in compliance with state, federal and local tank rules and underground components would also need to comply with appropriate UST rules. Local ordinances would need to be followed (such as building permits, etc.) during construction of the collection system, treatment system, and support facilities.

For Alternatives #4a through #5b, state approval is anticipated to be required prior to any groundwater discharge and construction of the treatment system. Coordination with state and local authorities may be necessary to effectively implement cap maintenance, water treatment train operation, and filter cake disposal under these alternatives.

Landfill mining under Alternatives #4b and #5b will require further state approval for refuse transfers to the Solid Waste Area. The increased height of the Solid Waste Area will have to be approved as well as part of the remedial design phase.

5.6.3 Availability of Services and Materials

Contractors familiar with landfill gas applications would be required to install residential control systems in Alternative #2. Large volumes of capping materials (topsoil, earth, sand, vegetation, etc.) would be necessary under Alternatives #3a through #5b. Construction contractors familiar with methane safety as well as fugitive vapors/COPCs would be required for Alternatives #3a through #5b. Also for those alternatives, fabrication of the LFG treatment system would take significant lead time and may be limited to specific, specialty contractors. Contractors would be necessary for construction of the extraction system, discharge wells, water treatment train, building, and piping in Alternatives #4a through #5b. OSHA-trained contractors would be required for landfill mining under Alternatives #4b and #5b. In all alternatives, consulting specialists, equipment and services are readily available to perform monitoring.

Alternatives #3a through #5b will generate a waste stream (landfill gas condensate) that may require disposal at a RCRA-compliant TSDF. Alternatives #4a through #5b require disposal of wastewater

treatment plant filter cakes. Metals reclamation facilities would also be required under Alternatives #4b and #5b. There may also be a need for a RCRA-compliant TSDF if hazardous waste is encountered during the landfill mining process. Although there are no RCRA-compliant facilities in Rhode Island which would accept these RCRA wastes, availability of this service is not expected to present any difficulties.

5.7 COST

The total net present cost (capital plus operations and maintenance over the duration of the remedial action) for the five alternatives evaluated ranges from $3.57 million to $22.8 million. A cost summary is presented in Table 5-2. The cost differential between Alternatives #1 and #2 is relatively low ($0.3 million) as the major cost component for each would be annual expenditures associated with environmental monitoring. Both alternatives have a relatively low capital cost component. The costs of Alternative #3a ($13.4 million) and #3b ($13.2 million) are significantly more than the previous two alternatives. The additional costs are required principally for installation of the horizontal containments, active LFG internal and perimeter collection systems and landfill gas treatment. The difference in costs between Alternatives #3a and #3b is due to capital costs of the two LFG treatment systems. Landfill gas collection and treatment is conducted for a 15-year duration based on estimates of LFG production. The costs for Alternatives #4a and #5a are $16.1 million and $20.2 million, respectively. The additional cost expenditures over the cost of Alternative #3a are primarily for groundwater and leachate treatment. The groundwater depression system proposed for Alternatives #5a and #5b is more extensive than the leachate collection/treatment system proposed for Alternatives #4a and #4b and will be conducted for a 30-year duration. Leachate collection and treatment are based on a 30-year duration for Alternatives #4a and #5a. The costs for Alternatives #4b and #5b are $16.9 million and $22.8 million, respectively. The additional cost expenditures over Alternatives #4a and #5a, respectively, is due to landfill mining.

The costs presented above provide order-of-magnitude estimates which may be used to compare the relative expense of each alternative. A 20% contingency is utilized to account for any inaccuracy

of the costs. Based on the accuracies of the estimates, the cost differences between alternatives may not be significant. To provide a better analysis of these differences, cost sensitivities were provided as described below.

Key cost variables were tested to determine the cost sensitivity of each of the alternatives. The results of this sensitivity analysis are shown in Table 5-2. The variables tested include: discount rate (for net present worth estimation), total capital costs, total annual (e.g. O&M) costs, contingency, and O&M duration related to the landfill gas components of each alternative.

Variation of the discount rate was evaluated at 5 and 9%. These values are estimated to be reasonable lower and upper bounds, respectively, for long-term financial performance and reflect values above the rate of inflation.

Total capital and annual costs were varied from the base case by a +50% increase and -30% decrease. This range was selected based upon the minimum accuracy of the costs required per EPA's RI/FS guidance (U.S. EPA, 1988c).

Variation of the contingency costs were evaluated at 15 and 25%. These values are estimated to be reasonable lower and upper bounds, respectively, for the degree of cost unknowns associated with these remedial alternatives.

O&M duration of the landfill gas components of each of the alternatives was varied based on the range of times possible for natural attenuation of landfill gas from the Solid Waste Area. As described in Section 4.1.2.5, the Solid Waste Area is expected to generate landfill gas for a duration of 5 to 15 more years. Since 15 years was evaluated as the base case, lower durations were used in the cost sensitivity of 5 years (low value of range) and 10 years (midpoint of range).

In Table 5-2, "Overall" costs reflect the highest and lowest total cost of each alternative for any of the variables evaluated. Based on this, the potential sensitivity range of costs varies from a low case of $2.5 million (for Alternative #1) to a high value of $28.7 million (for Alternative #5b).

5.8 STATE AND COMMUNITY ACCEPTANCE

Acceptance of the remedy by the State of Rhode Island, the Town of South Kingstown, and the community residents are modifying criteria that affect the remedy selection. Comments from the State, Town and residents regarding the selection process will be addressed in the ROD after the public comment period. Therefore, at this time, there are no differences in the remedial alternatives with respect to these criteria.

SECTION 6.0

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FEASIBILITY STUDY
FINAL REPORT

VOLUME II of III
TABLES AND FIGURES

Rose Hill Regional Landfill Superfund Site
South Kingstown, Rhode Island

November 1998

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Section One

TABLE 1-1. CHRONOLOGY OF ACTIVITIES AT THE ROSE HILL REGIONAL LANDFILL

Year	Activity Affecting Landfill Operations
1967	Solid waste landfill begins operation in an abandoned gravel quarry off Rose Hill Road.
	Court order limits use of landfill by prohibiting disposal of combustibles.
1970	State Division of Solid Waste Management suggests to South Kingstown director of public works that liquid waste from Peacedale Processing be spread over the other waste if the town continued to accept Peacedale waste for disposal.
1971	State Division of Solid Waste Management notifies South Kingstown town manager that liquid waste from Peacedale Processing is improperly being disposed of; again, town is told to spread liquid waste on top of other waste if it continues to accept Peacedale waste.
1973	Town of Narragansett enters into an agreement with South Kingstown to engage in a regional landfill and disposal program concerning Rose Hill and West Kingston landfill facilities.
1975	Town of South Kingstown retains independent professional engineer to conduct groundwater study because the landfill facility has been found to be the source of objectionable groundwater in off-site private well. A new well is installed by town to this residence.
1976	South Kingstown Town Council votes to lease additional property (Lots OL16A and OL16 on Block 93A) for landfill facility from private resident.
1977	Town of South Kingstown retains engineering firm to conduct site analysis and develop operation plans for solid waste activities to comply with state regulations. Engineering report deems site suitable for bulky waste disposal and sludge landfill and recommends monitoring of water quality at four wells close to site.
	State Water Resource Board notifies State Division that site is not adequate as a landfill site; leachate formation and drainage noted as reasons for disapproval.
	Sewage sludge landfill begins operations.
	Town of South Kingstown recommends Rose Hill Regional Landfill as disposal site for refuse, bulky waste, and sewage sludge, if acceptable to state health authorities.
1978	Bulky waste disposal area opens.

TABLE 1-1 (Continued). CHRONOLOGY OF ACTIVITIES AT THE ROSE HILL REGIONAL LANDFILL

Year	Activity Affecting Landfill Operations
	Town of South Kingstown initiates monitoring of seven residential wells in landfill area for water quality parameters.
	Monitoring well installation begins at landfill. By 1982, eleven monitoring wells have been installed.
1979	State orders cities and towns to provide for collection of waste oil.
	RIDEM collects sample from drum at landfill; analysis shows presence of trichloroethylene. The glue waste is also known to contain dimethyl formamide and cellosolve solvent. State bans glue waste from Rose Hill Regional Landfill because industrial waste should not have been dumped at refuse facility.
1980	State Department of Waste Management official is quoted in newspaper, stating that Peacedale Processing glue wastes must be exposed to air and in solid form before disposal.
1981	Peacedale Processing notifies EPA Region I that laminating adhesive containing trichloroethylene was disposed of at the Rose Hill Regional Landfill from 1971 to 1979.
	Results of sampling document high copper and zinc concentrations in sludge; this is consistent with test results of December 1978 and October 1979. Origin of source is not resolved.
1982	Solid waste landfill closes; solid waste is disposed of in bulky waste area until transfer station is completed.
	Highest concentration of volatile organic compounds is reported; 1,2-dichloroethene is substance having highest concentration level.
	Town of South Kingstown redelivers a $\pm$6-acre parcel to private resident and votes to purchase 15.03-acre parcel from same resident.
1983	Town of South Kingstown declares zone change to accommodate transfer station.
	Court order prohibits disposal of combustibles at Rose Hill Regional Landfill.
	EPA conducts identification and preliminary assessment; potential hazards to human health through contaminated well and contaminated water supply, groundwater, and soil are identified.

TABLE 1-1 (Continued). CHRONOLOGY OF ACTIVITIES AT THE ROSE HILL REGIONAL LANDFILL

Year	Activity Affecting Landfill Operations
	Sampling in Saugatucket River below confluence with Mitchell Brook shows presence of substance susceptible to biological and chemical oxidation, qualitatively indicating contamination.
	Bulky waste disposal area and sewage sludge landfill close.
1984	Landfill rental payments from town of South Kingstown to Frisella cease as of June 30, 1984.
	Consultant site inspection shows volatile organic compounds at detectable levels in groundwater on site, in bedrock and overburden residential wells, and in soils in bulky waste disposal area. Sampling of surface water shows no contamination from volatile organic compounds.
	Later sampling is conducted by the town for iron, phosphate, total Kjeldahl nitrogen, and chemical oxygen demand (COD); COD shows levels indicative of contamination.
1985	Town of South Kingstown extends municipal water supply line to residents on Rose Hill Road.
	Sampling analysis indicates that volatile organic compounds continue to be released to underlying groundwater on site. Compounds are not detected in Saugatucket River, Mitchell Brook, or downgradient at groundwater and surface water locations.
	Consultant recommends that monitoring of water and soil continue even though low contamination releases do not appear to adversely affect water quality.
1986	Neither heavy metals nor volatile organic compounds are detected in RIDEM monitoring wells; high conductivity appears in some groundwater monitoring wells but not in others.
1987	Volatile organic compounds are detected in breathing zone at bulky waste and solid waste disposal areas; concentrations detected higher than background levels. Low resistivity survey indicates likely contamination of overburden.
	Rose Hill Regional Landfill is ranked for inclusion on the NPL (score 38.11).
	Consulting team observes leachate pools in solid waste landfill area.
	Consultants learn that portion of landfill area has been rezoned; action may allow development of property.

TABLE 1-1 (Continued). CHRONOLOGY OF ACTIVITIES AT THE ROSE HILL REGIONAL LANDFILL

Year	Activity Affecting Landfill Operations
	Rose Hill Regional Landfill is proposed on NPL update #7 on 6/24/88.
1989	Rose Hill Regional Landfill is placed on NPL 10/4/89.

TABLE 1-2. CONTAMINANTS DETECTED AT THE ROSE HILL REGIONAL LANDFILL SITE AND THOSE OF POTENTIAL CONCERN TO HUMAN HEALTH AND THE ENVIRONMENT IN VARIOUS MEDIA

CHEMICAL NAME	Groundwater	Residential Wells	Leachate	Surface Water	Sediment	Surface Soil	Landfill Gas	Residential Ambient Air ***
VOLATILE ORGANICS								
Acetone						H	H	
Benzene	H	H					H	H
Carbon Disulfide							H	
Chloroethane	H	H	H					
1,1-Dichloroethane	H						H	
1,1-Dichloroethene							H	
cis-1,2-Dichloroethene *	H		H				H	
trans-1,2-Dichloroethene							H	
Dichlorodifluoromethane							H	
Ethylbenzene							H	H
4-Methyl-2-pentanone							H	
Methylene chloride							H	H
1,1,2,2-Tetrachloroethane								H
Toluene							H	H
1,2,4-Trichlorobenzene							H	
1,1,1-Trichloroethane								H
Trichloroethene		H					H	
1,2,4-Trimethylbenzene							H	
1,3,5-Trimethylbenzene							H	
Vinyl chloride **	H					H	H	H
m,p-Xylene							H	H
o-Xylene								H
SEMIVOLATILE ORGANICS								
Acrylamide	H			H				
Benzo(a)anthracene						H		
Benzo(a)pyrene						H		
Benzo(b)fluoranthene						H		
Benzo(k)fluoranthene						H		
Bis(2-ethylhexyl)phthalate	H		H					
4-Chloro-3-methylphenol	H							
Chrysene						H		
2,4-Dimethylphenol								
N,N-Dimethylformamide	H	H		H				

TABLE 1-2. CONTAMINANTS DETECTED AT THE ROSE HILL REGIONAL LANDFILL SITE AND THOSE OF POTENTIAL CONCERN TO HUMAN HEALTH AND THE ENVIRONMENT IN VARIOUS MEDIA

CHEMICAL NAME	Groundwater	Residential Wells	Leachate	Surface Water	Sediment	Surface Soil	Landfill Gas	Residential Ambient Air ***
Indeno(1,2,3-c,d)pyrene						H		
2-Methylnaphthalene	H							
4-Methylphenol		H						
Pentachlorophenol	H							
PESTICIDES								
Dieldrin		H						
INORGANICS								
Aluminum	H	H	H,E	H,E	H,E	H		
Antimony	H			H				
Arsenic	H		H		H	H		
Barium	H	H	H	H	H	H		
Beryllium	H		H		H	H		
Cadmium	H							
Chromium ****	H		H		H	H		
Cobalt	H		H		H	H		
Copper	H	H	H		H	H,E		
Cyanide								
Iron			E	E	E			
Lead	H		H,E		H	H,E		
Manganese	H	H	H,E	H,E	H	H,E		
Mercury		H				H		
Nickel	H				H			
Selenium					H			
Thallium						H		
Vanadium	H		H		H	H		
Zinc	H	H			H			
Ammonia	H		H	H	H			
Sulfide	H	H		H	H			

H - Human Health Chemical of Potential Concern

E - Ecological/Environmental Chemical of Potential Concern

* Laboratory reported 1,2-dichloroethene (total) in all media except soil gas; this was conservatively assumed to be cis-1,2-dichloroethene.

** Vinyl chloride was the only chemical of concern used to evaluate potential future risk from indoor air exposure at nearby residences.

*** All chemicals detected in ambient air at nearby residences were include as chemicals of concern, except for those rejected during data validation.

**** Laboratory reported [total] chromium; this was conservatively assumed to be chromium VI.

Section Two

TABLE 2-1A. CHEMICALS OF POTENTIAL CONCERN WITH SUBSTANTIAL RISKS BY MEDIA AND DISPOSAL AREA [1]

Media	Disposal Area	Chemical of Concern [2]
Groundwater	Solid Waste Area (Table 2-1AK)	Vinyl chloride [H] 1,2-Dichloroethene [H] Acrylamide [H] Arsenic [H] Cadmium [H] Manganese [H]
	Bulky Waste Area (Table 2-1AM)	Antimony [H] Manganese [H]
	Sewage Sludge Area (Table 2-1AO)	Antimony [H] Cadmium [H] Manganese [H]
	Residential Wells (Table 2-1AQ)	Manganese [H]
Ambient/Indoor Air	Solid Waste Area (Tables 2-1BE and 2-1BO)	Vinyl chloride [H]
	Residential Area (Tables 2-1BK, 2-1BM, and 2-1BS)	Benzene [H] Vinyl chloride [H]
Surface Water	Solid Waste Area	Aluminum [E] Iron [E] Manganese [E]
	Bulky Waste Area	Aluminum [E] Iron [E] Manganese [E]

(1) The substantial associated risks are identified and discussed in the Supplemental HHRA (M&E, 1998).

(2) This list includes those chemicals which individually exceed a hazard index of one and/or a baseline cancer risk of 10^{-4}, so this list is not the same as the list of chemicals shown on the following tables of Preliminary Remediation Goals which were developed for compounds greater than a cancer risk of 10^{-6} and an HI of one. For groundwater, benzene, pentachlorophenol, bis(2-ethylhexyl)phthalate, chromium, lead, and beryllium are not major contributors to site risks, but exceed MCLs.

(E) Chemical contributes to ecological risks.

(H) Chemical contributes to current or future excess human health risks.

TABLE 2 - 1 B*. SUMMARY OF CANCER RISK ESTIMATES

Exposure Point	Target	Route	Average (a)	Maximum (a)	Table Reference
Analyses Originally Conducted in the Remedial Investigation (1994):					
Solid Waste Area Surface Soil	Adult	Ingestion	5.9E-7	1.3E-6	2-1D, 2-1E
		Dermal	5.7E-8	2.7E-7	2-1P, 2-1Q
		Total Adult	6.5E-7	1.6E-6	(b)
	Child	Ingestion	1.4E-6	3.0E-6	2-1J, 2-1K
		Dermal	6.6E-8	3.2E-7	2-1V, 2-1W
		Total Child	1.5E-6	3.3E-6	(b)
		Total Lifetime	*2.1E-6*	*4.9E-6*	(b,c)
Bulky Waste Area Surface Soil	Adult	Ingestion	3.7E-7	4.0E-7	2-1F, 2-1G
		Dermal	2.1E-9	2.1E-9	2-1R, 2-1S
		Total Adult	3.7E-7	4.0E-7	(b)
	Child	Ingestion	8.7E-7	9.4E-7	2-1L, 2-1M
		Dermal	2.5E-9	2.5E-9	2-1X, 2-1Y
		Total Child	8.7E-7	9.4E-7	(b)
		Total Lifetime	*1.2E-6*	*1.3E-6*	(b,c)
Sewage Sludge Area Surface Soil	Adult	Ingestion	2.4E-7	2.6E-7	2-1H, 2-1I
		Dermal	--	--	2-1T, 2-1U
		Total Adult	2.4E-7	2.6E-7	(b)
	Child	Ingestion	5.6E-7	6.1E-7	2-1N, 2-1O
		Dermal	--	--	2-1Z, 2-1AA
		Total Child	5.6E-7	6.1E-7	(b)
		Total Lifetime	*8.0E-7*	*8.7E-7*	(b,c)
Solid Waste Area Leachate	Adult	Dermal	4.9E-9	4.9E-9	2-1AB, 2-1AC
	Adolescent	Dermal	1.7E-8	1.7E-8	2-1AF, 2-1AG
Bulky Waste Area Leachate	Adult	Dermal	--	--	2-1AD, 2-1AE
	Adolescent	Dermal	--	--	2-1AH, 2-1AI
Solid Waste Area Groundwater	Adult	Ingestion	**9.3E-3**	**2.8E-2**	2-1AJ, 2-1AK
Bulky Waste Area Groundwater	Adult	Ingestion	1.5E-5	4.1E-5	2-1AL, 2-1AM
Sewage Sludge Area Groundwater	Adult	Ingestion	3.2E-5	9.7E-5	2-1AN, 2-1AO
Residential Wells Groundwater	Adult	Ingestion	7.0E-7	9.8E-7	2-1AP, 2-1AQ

TABLE 2 - 1 B* (continued). SUMMARY OF CANCER RISK ESTIMATES

Exposure Point	Target	Route	Average (a)	Maximum (a)	Table Reference
Analyses Originally Conducted in the Remedial Investigation (1994) (*continued*):					
Saugatucket River Water	Adult	Ingestion	--	--	2-1AR, 2-1AS
		Dermal	--	--	2-1AT, 2-1AU
	Adolescent	Ingestion	--	--	2-1AV, 2-1AW
		Dermal	--	--	2-1AX, 2-1AY
Mitchell Brook Water	Adult	Dermal	1.1E-7	2.3E-7	2-1AZ, 2-1BA
	Adolescent	Dermal	3.1E-8	6.5E-8	2-1BB, 2-1BC
Solid Waste Soil Gas	Visitor	Inhalation (d)	**2.0E-4**	**4.4E-4**	2-1BD, 2-1BE
Bulky Waste Soil Gas	Visitor	Inhalation (d)	1.9E-7	3.4E-7	2-1BF, 2-1BG
Sewage Sludge Soil Gas	Visitor	Inhalation (d)	2.6E-11	2.3E-10	2-1BH, 2-1BI
Residential Ambient/Indoor Air	Resident	Inhalation	**2.1E-4**	**4.9E-4**	2-1BJ, 2-1BK
Future Residential Indoor Air	Resident	Inhalation	**7.9E-4**	**1.9E-3**	2-1BL, 2-1BM
Analyses Originally Conducted in the Supplemental Human Health Risk Assessment (1998):					
Solid Waste Soil Gas	Visitor	Inhalation (d)	**1.6E-4**	**4.4E-4**	2-1BN, 2-1BO
	Passer-by	Inhalation (d)	5.3E-7	1.5E-6	2-1BT, 2-1BU
Residential Ambient/Indoor Air	Resident	Inhalation (d)	2.9E-5	8.1E-5	2-1BP, 2-1BQ
	Resident	Inhalation	**1.7E-4**	**4.5E-4**	2-1BR, 2-1BS

NOTES:
-- No carcinogens detected or no carcinogens significantly absorbed.
a. **Values greater than 1.0E-4 are in bold.**
b. Ingestion plus dermal risks
c. Adult plus child risks
d. Air concentrations modeled from soil gas data.

*** EDITED FINAL SUPPLEMENTAL HUMAN HEALTH RISK ASSESSMENT (1998) TABLE 7**

TABLE 2 - 1 C*. SUMMARY OF HAZARD INDEX ESTIMATES

Exposure Point	Target	Route	Average (a)	Maximum (a)	Table Reference
Analyses Originally Conducted in the Remedial Investigation (1994):					
Solid Waste Area Surface Soil	Adult	Ingestion	7.5E-3	1.7E-2	2-1D, 2-1E
		Dermal	2.1E-4	2.3E-3	2-1P, 2-1Q
		Total Adult	*7.7E-3*	*1.9E-2*	(b)
	Child	Ingestion	7.0E-2	1.6E-1	2-1J, 2-1K
		Dermal	9.6E-4	1.1E-2	2-1V, 2-1W
		Total Child	*7.1E-2*	*1.7E-1*	(b)
Bulky Waste Area Surface Soil	Adult	Ingestion	1.7E-2	5.8E-2	2-1F, 2-1G
		Dermal	7.0E-5	3.5E-4	2-1R, 2-1S
		Total Adult	*1.7E-2*	*5.8E-2*	(b)
	Child	Ingestion	1.5E-1	5.5E-1	2-1L, 2-1M
		Dermal	3.3E-4	1.6E-3	2-1X, 2-1Y
		Total Child	*1.5E-1*	*5.5E-1*	(b)
Sewage Sludge Area Surface Soil	Adult	Ingestion	5.7E-3	8.0E-3	2-1H, 2-1I
		Dermal	2.1E-7	3.4E-7	2-1T, 2-1U
		Total Adult	*5.7E-3*	*8.0E-3*	(b)
	Child	Ingestion	5.3E-2	7.4E-2	2-1N, 2-1O
		Dermal	9.6E-7	1.6E-6	2-1Z, 2-1AA
		Total Child	*5.3E-2*	*7.4E-2*	(b)
Solid Waste Area Leachate	Adult	Dermal	9.9E-4	9.9E-4	2-1AB, 2-1AC
	Adolescent	Dermal	8.2E-4	8.2E-4	2-1AF, 2-1AG
Bulky Waste Area Leachate	Adult	Dermal	3.1E-3	5.8E-3	2-1AD, 2-1AE
	Adolescent	Dermal	2.6E-3	4.8E-3	2-1AH, 2-1AI
Solid Waste Area Groundwater	Adult	Ingestion	**2.5E+1**	**5.1E+1**	2-1AJ, 2-1AK
Bulky Waste Area Groundwater	Adult	Ingestion	**3.4E+0**	**2.0E+1**	2-1AL, 2-1AM
Sewage Sludge Area Groundwater	Adult	Ingestion	**4.6E+0**	**1.5E+1**	2-1AN, 2-1AO
Residential Wells Groundwater	Adult	Ingestion	**1.1E+0**	**4.0E+0**	2-1AP, 2-1AQ

TABLE 2 - 1 C* (continued). SUMMARY OF HAZARD INDEX ESTIMATES

Exposure Point	Target	Route	Average (a)	Maximum (a)	Table Reference
Analyses Originally Conducted in the Remedial Investigation (1994) (*continued*):					
Saugatucket River Water	Adult	Ingestion	7.4E-4	3.0E-3	2-1AR, 2-1AS
		Dermal	2.7E-4	1.1E-3	2-1AT, 2-1AU
	Adolescent	Ingestion	8.9E-4	3.6E-3	2-1AV, 2-1AW
		Dermal	2.9E-4	1.1E-3	2-1AX, 2-1AY
Mitchell Brook Water	Adult	Dermal	3.6E-4	8.6E-4	2-1AZ, 2-1BA
	Adolescent	Dermal	4.4E-4	1.0E-3	2-1BB, 2-1BC
Solid Waste Soil Gas	Visitor	Inhalation (c)	1.2E-2	1.5E-2	2-1BD, 2-1BE
Bulky Waste Soil Gas	Visitor	Inhalation (c)	5.4E-4	8.9E-3	2-1BF, 2-1BG
Sewage Sludge Soil Gas	Visitor	Inhalation (c)	8.2E-5	7.9E-5	2-1BH, 2-1BI
Residential Ambient/Indoor Air	Resident	Inhalation	**3.8E+0**	**1.2E+1**	2-1BJ, 2-1BK
Future Residential Indoor Air	Resident	Inhalation	--	--	2-1BL, 2-1BM
Analyses Originally Conducted in the Supplemental Human Health Risk Assessment (1998):					
Solid Waste Soil Gas	Visitor	Inhalation (c)	8.1E-3	1.6E-2	2-1BN, 2-1BO
	Passer-by	Inhalation (c)	2.7E-5	5.3E-5	2-1BT, 2-1BU
Residential Ambient/Indoor Air	Resident	Inhalation (c)	1.5E-3	2.9E-3	2-1BP, 2-1BQ
	Resident	Inhalation	**3.8E+0**	**1.2E+1**	2-1BR, 2-1BS

NOTES:

a. **Values greater than 1.0E+0 are in bold.**

b. Ingestion plus dermal risks

c. Air concentrations modeled from soil gas data.

*** EDITED FINAL SUPPLEMENTAL HUMAN HEALTH RISK ASSESSMENT (1998) TABLE 8**

TABLE 2 - 1 D*
POTENTIAL RISK FROM INGESTION OF SURFACE SOILS WITHIN THE SOLID WASTE AREA BY SITE VISITORS
AVERAGE CONCENTRATIONS USED FOR AN ADULT EXPOSURE

ANALYTE	Average Concentration (mg/kg)	Relative Absorption Factor (RAF)	Exposure Dose Chronic (a) (mg/kg/day)	Oral Reference Dose (RfD) (mg/kg/day)	Hazard Quotient (b)	Exposure Dose Lifetime (a) (mg/kg/day)	Oral Slope Factor /(mg/kg/day)	Cancer Risk (c)
Acetone	14	1	8.2E-06	0.1	8.2E-05	2.8E-06	na	---
Vinyl Chloride	0.025	1	1.5E-08	na	---	5.0E-09	1.9	9.6E-09
Benzo(a)anthracene	0.078	1	4.6E-08	na	---	1.6E-08	0.73	1.1E-08
Benzo(a)pyrene	0.068	1	4.0E-08	na	---	1.4E-08	7.3	1.0E-07
Benzo(b)fluoranthene	0.076	1	4.5E-08	na	---	1.5E-08	0.73	1.1E-08
Benzo(k)fluoranthene	0.064	1	3.8E-08	na	---	1.3E-08	0.073	9.4E-10
Chrysene	0.095	1	5.6E-08	na	---	1.9E-08	0.0073	1.4E-10
Indeno(1,2,3-cd)pyrene	0.052	1	3.1E-08	na	---	1.0E-08	0.73	7.6E-09
Aluminum	8000	1	4.7E-03	na	---	1.6E-03	na	---
Arsenic	1.5	1	8.8E-07	0.0003	2.9E-03	3.0E-07	1.5	4.5E-07
Barium	16	1	9.4E-06	0.07	1.3E-04	3.2E-06	na	---
Beryllium	0.41	1	2.4E-07	0.002	1.2E-04	8.3E-08	na	---
Chromium (d)	7.5	1	4.4E-06	0.005	8.8E-04	1.5E-06	na	---
Cobalt	2.9	1	1.7E-06	na	---	5.8E-07	na	---
Copper	27	1	1.6E-05	na	---	5.4E-06	na	---
Lead	12	1	7.0E-06	na	---	2.4E-06	na	---
Manganese (e)	110	1	6.5E-05	0.07	9.2E-04	2.2E-05	na	---
Mercury	0.067	1	3.9E-08	0.0003	1.3E-04	1.3E-08	na	---
Thallium	0.15	1	8.8E-08	0.00008	1.1E-03	3.0E-08	na	---
Vanadium	14	1	8.2E-06	0.007	1.2E-03	2.8E-06	na	---
			Total Hazard Index =		7.5E-03	Total Risk =		5.9E-07

NOTES:
(a) Calculation for exposure dose :

INGESTION =	Conc.	x Ingestion	x	Exposure	x Exposure	x	R.A.F	/	Body	x	Averaging	x	Conversion
EXPOSURE		Rate		Frequency	Duration				Weight		Time		Factor
DOSE	Conc.	100		150	24		R.A.F		70		(f) 365	x	1E+06
		mg/day		days/yr	years				kg		years days/year		mg/kg

(b) Hazard quotient = chronic exposure dose / RfD
(c) Cancer risk = lifetime exposure dose x slope factor
(d) The reference dose for chromium VI was used.
(e) The reference dose for manganese is based on total allowable intake (10 mg/day) minus the background intake (5 mg/day).
The remaining intake (5 mg/day) was normalized for body weight (70 kg) to derive the RfD.
(f) Averaging times of 24 years for chronic doses and 70 years for lifetime doses were used.

na = toxicity value not available
nd = not detected
--- = not calculated due to absence of data

* EDITED FINAL SUPPLEMENTAL HUMAN HEALTH RISK ASSESSMENT (1998) TABLE B-1

TABLE 2 - 1 E*

POTENTIAL RISK FROM INGESTION OF SURFACE SOILS WITHIN THE SOLID WASTE AREA BY SITE VISITORS

MAXIMUM CONCENTRATIONS USED FOR AN ADULT EXPOSURE

ANALYTE	Maximum Concentration (mg/kg)	Relative Absorption Factor (RAF)	Exposure Dose Chronic (a) (mg/kg/day)	Oral Reference Dose (RfD) (mg/kg/day)	Hazard Quotient (b)	Exposure Dose Lifetime (a) (mg/kg/day)	Oral Slope Factor /(mg/kg/day)	Cancer Risk (c)
Acetone	160	1	9.4E-05	0.1	9.4E-04	3.2E-05	na	---
Vinyl Chloride	0.25	1	1.5E-07	na	---	5.0E-08	1.9	9.6E-08
Benzo(a)anthracene	0.078	1	4.6E-08	na	---	1.6E-08	0.73	1.1E-08
Benzo(a)pyrene	0.068	1	4.0E-08	na	---	1.4E-08	7.3	1.0E-07
Benzo(b)fluoranthene	0.076	1	4.5E-08	na	---	1.5E-08	0.73	1.1E-08
Benzo(k)fluoranthene	0.064	1	3.8E-08	na	---	1.3E-08	0.073	9.4E-10
Chrysene	0.095	1	5.6E-08	na	---	1.9E-08	0.0073	1.4E-10
Indeno(1,2,3-cd)pyrene	0.052	1	3.1E-08	na	---	1.0E-08	0.73	7.6E-09
Aluminum	14400	1	8.5E-03	na	---	2.9E-03	na	---
Arsenic	3.5	1	2.1E-06	0.0003	6.8E-03	7.0E-07	1.5	1.1E-06
Barium	20.5	1	1.2E-05	0.07	1.7E-04	4.1E-06	na	---
Beryllium	1.1	1	6.5E-07	0.002	3.2E-04	2.2E-07	na	---
Chromium (d)	13.9	1	8.2E-06	0.005	1.6E-03	2.8E-06	na	---
Cobalt	6.2	1	3.6E-06	na	---	1.2E-06	na	---
Copper	253	1	1.5E-04	na	---	5.1E-05	na	---
Lead	31.1	1	1.8E-05	na	---	6.3E-06	na	---
Manganese (e)	257	1	1.5E-04	0.07	2.2E-03	5.2E-05	na	---
Mercury	0.2	1	1.2E-07	0.0003	3.9E-04	4.0E-08	na	---
Thallium	0.36	1	2.1E-07	0.00008	2.6E-03	7.2E-08	na	---
Vanadium	27.2	1	1.6E-05	0.007	2.3E-03	5.5E-06	na	---
			Total Hazard Index =		1.7E-02	Total Risk =		1.3E-06

NOTES:

(a) Calculation for exposure dose :

INGESTION =	Conc.	x Ingestion	x	Exposure	x Exposure	x	R.A.F	/	Body	x	Averaging	x	Conversion
EXPOSURE		Rate		Frequency	Duration				Weight		Time		Factor
DOSE	Conc.	100		150	24		R.A.F		70		(f) 365	x	1E+06
		mg/day		days/yr	years				kg		years days/year		mg/kg

(b) Hazard quotient = chronic exposure dose / RfD

(c) Cancer risk = lifetime exposure dose x slope factor

(d) The reference dose for chromium VI was used.

(e) The reference dose for manganese is based on total allowable intake (10 mg/day) minus the background intake (5 mg/day).
The remaining intake (5 mg/day) was normalized for body weight (70 kg) to derive the RfD.

(f) Averaging times of 24 years for chronic doses and 70 years for lifetime doses were used.

na = toxicity value not available

nd = not detected

--- = not calculated due to absence of data

* EDITED FINAL SUPPLEMENTAL HUMAN HEALTH RISK ASSESSMENT (1998) TABLE B-2

TABLE 2 - 1 F*

POTENTIAL RISK FROM INGESTION OF SURFACE SOILS WITHIN THE BULKY WASTE AREA BY SITE VISITORS

AVERAGE CONCENTRATIONS USED FOR AN ADULT EXPOSURE

ANALYTE	Average Concentration (mg/kg)	Relative Absorption Factor (RAF)	Exposure Dose Chronic (a) (mg/kg/day)	Oral Reference Dose (RfD) (mg/kg/day)	Hazard Quotient (b)	Exposure Dose Lifetime (a) (mg/kg/day)	Oral Slope Factor /(mg/kg/day)	Cancer Risk (c)
Acetone	4.8	1	2.8E-06	0.1	2.8E-05	9.7E-07	na	---
Vinyl Chloride	nd	1	---	na	---	---	1.9	---
Benzo(a)anthracene	nd	1	---	na	---	---	0.73	---
Benzo(a)pyrene	nd	1	---	na	---	---	7.3	---
Benzo(b)fluoranthene	0.057	1	3.3E-08	na	---	1.1E-08	0.73	8.4E-09
Benzo(k)fluoranthene	nd	1	---	na	---	---	0.073	---
Chrysene	0.055	1	3.2E-08	na	---	1.1E-08	0.0073	8.1E-11
Indeno(1,2,3-cd)pyrene	nd	1	---	na	---	---	0.73	---
Aluminum	6400	1	3.8E-03	na	---	1.3E-03	na	---
Arsenic	1.2	1	7.0E-07	0.0003	2.3E-03	2.4E-07	1.5	3.6E-07
Barium	34	1	2.0E-05	0.07	2.9E-04	6.8E-06	na	---
Beryllium	0.57	1	3.3E-07	0.002	1.7E-04	1.1E-07	na	---
Chromium (d)	5.8	1	3.4E-06	0.005	6.8E-04	1.2E-06	na	---
Cobalt	6.0	1	3.5E-06	na	---	1.2E-06	na	---
Copper	3.3	1	1.9E-06	na	---	6.6E-07	na	---
Lead	29	1	1.7E-05	na	---	5.8E-06	na	---
Manganese (e)	1400	1	8.2E-04	0.07	1.2E-02	2.8E-04	na	---
Mercury	0.13	1	7.6E-08	0.0003	2.5E-04	2.6E-08	na	---
Thallium	nd	1	---	0.00008	---	---	na	---
Vanadium	12	1	7.0E-06	0.007	1.0E-03	2.4E-06	na	---
			Total Hazard Index =		1.7E-02	Total Risk =		3.7E-07

NOTES:

(a) Calculation for exposure dose :

INGESTION =	Conc.	x Ingestion	x	Exposure	x Exposure	x	R.A.F	/	Body	x	Averaging	x	Conversion
EXPOSURE		Rate		Frequency	Duration				Weight		Time		Factor
DOSE	Conc.	100		150	24		R.A.F		70		(f) 365	x	1E+06
		mg/day		days/yr	years				kg		years days/year		mg/kg

(b) Hazard quotient = chronic exposure dose / RfD

(c) Cancer risk = lifetime exposure dose x slope factor

(d) The reference dose for chromium VI was used.

(e) The reference dose for manganese is based on total allowable intake (10 mg/day) minus the background intake (5 mg/day). The remaining intake (5 mg/day) was normalized for body weight (70 kg) to derive the RfD.

(f) Averaging times of 24 years for chronic doses and 70 years for lifetime doses were used.

na = toxicity value not available

nd = not detected

--- = not calculated due to absence of data

*** EDITED FINAL SUPPLEMENTAL HUMAN HEALTH RISK ASSESSMENT (1998) TABLE B-3**

TABLE 2 - 1 G*
POTENTIAL RISK FROM INGESTION OF SURFACE SOILS WITHIN THE BULKY WASTE AREA BY SITE VISITORS
MAXIMUM CONCENTRATIONS USED FOR AN ADULT EXPOSURE

ANALYTE	Maximum Concentration (mg/kg)	Relative Absorption Factor (RAF)	Exposure Dose Chronic (a) (mg/kg/day)	Oral Reference Dose (RfD) (mg/kg/day)	Hazard Quotient (b)	Exposure Dose Lifetime (a) (mg/kg/day)	Oral Slope Factor /(mg/kg/day)	Cancer Risk (c)
Acetone	23.7	1	1.4E-05	0.1	1.4E-04	4.8E-06	na	---
Vinyl Chloride	nd	1	---	na	---	---	1.9	---
Benzo(a)anthracene	nd	1	---	na	---	---	0.73	---
Benzo(a)pyrene	nd	1	---	na	---	---	7.3	---
Benzo(b)fluoranthene	0.057	1	3.3E-08	na	---	1.1E-08	0.73	8.4E-09
Benzo(k)fluoranthene	nd	1	---	na	---	---	0.073	---
Chrysene	0.055	1	3.2E-08	na	---	1.1E-08	0.0073	8.1E-11
Indeno(1,2,3-cd)pyrene	nd	1	---	na	---	---	0.73	---
Aluminum	8940	1	5.2E-03	na	---	1.8E-03	na	---
Arsenic	1.3	1	7.6E-07	0.0003	2.5E-03	2.6E-07	1.5	3.9E-07
Barium	86.2	1	5.1E-05	0.07	7.2E-04	1.7E-05	na	---
Beryllium	0.88	1	5.2E-07	0.002	2.6E-04	1.8E-07	na	---
Chromium (d)	9.8	1	5.8E-06	0.005	1.2E-03	2.0E-06	na	---
Cobalt	12.8	1	7.5E-06	na	---	2.6E-06	na	---
Copper	5.6	1	3.3E-06	na	---	1.1E-06	na	---
Lead	124	1	7.3E-05	na	---	2.5E-05	na	---
Manganese (e)	6120	1	3.6E-03	0.07	5.1E-02	1.2E-03	na	---
Mercury	0.41	1	2.4E-07	0.0003	8.0E-04	8.3E-08	na	---
Thallium	nd	1	---	0.00008	---	---	na	---
Vanadium	18.1	1	1.1E-05	0.007	1.5E-03	3.6E-06	na	---
			Total Hazard Index =		5.8E-02	Total Risk =		4.0E-07

NOTES:
(a) Calculation for exposure dose :

INGESTION =	Conc.	x Ingestion Rate	x Exposure Frequency	x Exposure Duration	x R.A.F /	Body Weight	x Averaging Time	x Conversion Factor
EXPOSURE DOSE	Conc.	100 mg/day	150 days/yr	24 years	R.A.F	70 kg	(f) 365 years days/year	x 1E+06 mg/kg

(b) Hazard quotient = chronic exposure dose / RfD
(c) Cancer risk = lifetime exposure dose x slope factor
(d) The reference dose for chromium VI was used
(e) The reference dose for manganese is based on total allowable intake (10 mg/day) minus the background intake (5 mg/day).
The remaining intake (5 mg/day) was normalized for body weight (70 kg) to derive the RfD.
(f) Averaging times of 24 years for chronic doses and 70 years for lifetime doses were used.

na = toxicity value not available
nd = not detected
--- = not calculated due to absence of data

* EDITED FINAL SUPPLEMENTAL HUMAN HEALTH RISK ASSESSMENT (1998) TABLE B-4

TABLE 2 - 1 H*

POTENTIAL RISK FROM INGESTION OF SURFACE SOILS WITHIN THE SEWAGE SLUDGE AREA BY SITE VISITORS

AVERAGE CONCENTRATIONS USED FOR AN ADULT EXPOSURE

ANALYTE	Average Concentration (mg/kg)	Relative Absorption Factor (RAF)	Exposure Dose Chronic (a) (mg/kg/day)	Oral Reference Dose (RfD) (mg/kg/day)	Hazard Quotient (b)	Exposure Dose Lifetime (a) (mg/kg/day)	Oral Slope Factor /(mg/kg/day)	Cancer Risk (c)
Acetone	0.014	1	8.2E-09	0.1	8.2E-08	2.8E-09	na	---
Vinyl Chloride	nd	1	---	na	---	---	1.9	---
Benzo(a)anthracene	nd	1	---	na	---	---	0.73	---
Benzo(a)pyrene	nd	1	---	na	---	---	7.3	---
Benzo(b)fluoranthene	nd	1	---	na	---	---	0.73	---
Benzo(k)fluoranthene	nd	1	---	na	---	---	0.073	---
Chrysene	nd	1	---	na	---	---	0.0073	---
Indeno(1,2,3-cd)pyrene	nd	1	---	na	---	---	0.73	---
Aluminum	5500	1	3.2E-03	na	---	1.1E-03	na	---
Arsenic	0.79	1	4.6E-07	0.0003	1.5E-03	1.6E-07	1.5	2.4E-07
Barium	28	1	1.6E-05	0.07	2.3E-04	5.6E-06	na	---
Beryllium	0.35	1	2.1E-07	0.002	1.0E-04	7.0E-08	na	---
Chromium (d)	6.4	1	3.8E-06	0.005	7.5E-04	1.3E-06	na	---
Cobalt	2.9	1	1.7E-06	na	---	5.8E-07	na	---
Copper	37	1	2.2E-05	na	---	7.4E-06	na	---
Lead	6.3	1	3.7E-06	na	---	1.3E-06	na	---
Manganese (e)	110	1	6.5E-05	0.07	9.2E-04	2.2E-05	na	---
Mercury	0.13	1	7.6E-08	0.0003	2.5E-04	2.6E-08	na	---
Thallium	0.15	1	8.8E-08	0.00008	1.1E-03	3.0E-08	na	---
Vanadium	9.2	1	5.4E-06	0.007	7.7E-04	1.9E-06	na	---
			Total Hazard Index =		5.7E-03	Total Risk =		2.4E-07

NOTES:

(a) Calculation for exposure dose :

INGESTION =	Conc.	x Ingestion	x	Exposure	x Exposure	x	R.A.F	/	Body	x	Averaging		x	Conversion
EXPOSURE		Rate		Frequency	Duration				Weight		Time			Factor
DOSE	Conc.	100		150	24		R.A.F		70		(f)	365	x	1E+06
		mg/day		days/yr	years				kg		years	days/year		mg/kg

(b) Hazard quotient = chronic exposure dose / RfD

(c) Cancer risk = lifetime exposure dose x slope factor

(d) The reference dose for chromium VI was used.

(e) The reference dose for manganese is based on total allowable intake (10 mg/day) minus the background intake (5 mg/day). The remaining intake (5 mg/day) was normalized for body weight (70 kg) to derive the RfD.

(f) Averaging times of 24 years for chronic doses and 70 years for lifetime doses were used.

na = toxicity value not available

nd = not detected

--- = not calculated due to absence of data

*** EDITED FINAL SUPPLEMENTAL HUMAN HEALTH RISK ASSESSMENT (1998) TABLE B-5**

TABLE 2 - 11*
POTENTIAL RISK FROM INGESTION OF SURFACE SOILS WITHIN THE SEWAGE SLUDGE AREA BY SITE VISITORS
MAXIMUM CONCENTRATIONS USED FOR AN ADULT EXPOSURE

ANALYTE	Maximum Concentration (mg/kg)	Relative Absorption Factor (RAF)	Exposure Dose Chronic (a) (mg/kg/day)	Oral Reference Dose (RfD) (mg/kg/day)	Hazard Quotient (b)	Exposure Dose Lifetime (a) (mg/kg/day)	Oral Slope Factor /(mg/kg/day)	Cancer Risk (c)
Acetone	0.023	1	1.4E-08	0.1	1.4E-07	4.6E-09	na	---
Vinyl Chloride	nd	1	---	na	---	---	1.9	---
Benzo(a)anthracene	nd	1	---	na	---	---	0.73	---
Benzo(a)pyrene	nd	1	---	na	---	---	7.3	---
Benzo(b)fluoranthene	nd	1	---	na	---	---	0.73	---
Benzo(k)fluoranthene	nd	1	---	na	---	---	0.073	---
Chrysene	nd	1	---	na	---	---	0.0073	---
Indeno(1,2,3-cd)pyrene	nd	1	---	na	---	---	0.73	---
Aluminum	6740	1	4.0E-03	na	---	1.4E-03	na	---
Arsenic	0.86	1	5.0E-07	0.0003	1.7E-03	1.7E-07	1.5	2.6E-07
Barium	58.9	1	3.5E-05	0.07	4.9E-04	1.2E-05	na	---
Beryllium	0.4	1	2.3E-07	0.002	1.2E-04	8.1E-08	na	---
Chromium (d)	9.8	1	5.8E-06	0.005	1.2E-03	2.0E-06	na	---
Cobalt	3.6	1	2.1E-06	na	---	7.2E-07	na	---
Copper	99.3	1	5.8E-05	na	---	2.0E-05	na	---
Lead	11.8	1	6.9E-06	na	---	2.4E-06	na	---
Manganese (e)	135	1	7.9E-05	0.07	1.1E-03	2.7E-05	na	---
Mercury	0.28	1	1.6E-07	0.0003	5.5E-04	5.6E-08	na	---
Thallium	0.25	1	1.5E-07	0.00008	1.8E-03	5.0E-08	na	---
Vanadium	12.1	1	7.1E-06	0.007	1.0E-03	2.4E-06	na	---
			Total Hazard Index =		8.0E-03	Total Risk =		2.6E-07

NOTES:
(a) Calculation for exposure dose :

INGESTION =	Conc.	x Ingestion	x	Exposure	x Exposure	x	R.A.F	/	Body	x	Averaging	x	Conversion
EXPOSURE		Rate		Frequency	Duration				Weight		Time		Factor
DOSE	Conc.	100		150	24		R.A.F		70		(f) 365	x 1E+06	
		mg/day		days/yr	years				kg		years days/year	mg/kg	

(b) Hazard quotient = chronic exposure dose / RfD
(c) Cancer risk = lifetime exposure dose x slope factor
(d) The reference dose for chromium VI was used.
(e) The reference dose for manganese is based on total allowable intake (10 mg/day) minus the background intake (5 mg/day).
The remaining intake (5 mg/day) was normalized for body weight (70 kg) to derive the RfD.
(f) Averaging times of 24 years for chronic doses and 70 years for lifetime doses were used.

na = toxicity value not available
nd = not detected
--- = not calculated due to absence of data

* EDITED FINAL SUPPLEMENTAL HUMAN HEALTH RISK ASSESSMENT (1998) TABLE B-6

TABLE 2 - 1 J*

POTENTIAL RISK FROM INGESTION OF SURFACE SOILS WITHIN THE SOLID WASTE AREA BY SITE VISITORS

AVERAGE CONCENTRATIONS USED FOR A CHILD EXPOSURE

ANALYTE	Average Concentration (mg/kg)	Relative Absorption Factor (RAF)	Exposure Dose Chronic (a) (mg/kg/day)	Oral Reference Dose (RfD) (mg/kg/day)	Hazard Quotient (b)	Exposure Dose Lifetime (a) (mg/kg/day)	Oral Slope Factor /(mg/kg/day)	Cancer Risk (c)
Acetone	14	1	7.7E-05	0.1	7.7E-04	6.6E-06	na	---
Vinyl Chloride	0.025	1	1.4E-07	na	---	1.2E-08	1.9	2.2E-08
Benzo(a)anthracene	0.078	1	4.3E-07	na	---	3.7E-08	0.73	2.7E-08
Benzo(a)pyrene	0.068	1	3.7E-07	na	---	3.2E-08	7.3	2.3E-07
Benzo(b)fluoranthene	0.076	1	4.2E-07	na	---	3.6E-08	0.73	2.6E-08
Benzo(k)fluoranthene	0.064	1	3.5E-07	na	---	3.0E-08	0.073	2.2E-09
Chrysene	0.095	1	5.2E-07	na	---	4.5E-08	0.0073	3.3E-10
Indeno(1,2,3-cd)pyrene	0.052	1	2.8E-07	na	---	2.4E-08	0.73	1.8E-08
Aluminum	8000	1	4.4E-02	na	---	3.8E-03	na	---
Arsenic	1.5	1	8.2E-06	0.0003	2.7E-02	7.0E-07	1.5	1.1E-06
Barium	16	1	8.8E-05	0.07	1.3E-03	7.5E-06	na	---
Beryllium	0.41	1	2.2E-06	0.002	1.1E-03	1.9E-07	na	---
Chromium (d)	7.5	1	4.1E-05	0.005	8.2E-03	3.5E-06	na	---
Cobalt	2.9	1	1.6E-05	na	---	1.4E-06	na	---
Copper	27	1	1.5E-04	na	---	1.3E-05	na	---
Lead	12	1	6.6E-05	na	---	5.6E-06	na	---
Manganese (e)	110	1	6.0E-04	0.07	8.6E-03	5.2E-05	na	---
Mercury	0.067	1	3.7E-07	0.0003	1.2E-03	3.1E-08	na	---
Thallium	0.15	1	8.2E-07	0.00008	1.0E-02	7.0E-08	na	---
Vanadium	14	1	7.7E-05	0.007	1.1E-02	6.6E-06	na	---
			Total Hazard Index =		7.0E-02	Total Risk =		1.4E-06

NOTES:

(a) Calculation for exposure dose :

INGESTION =	Conc.	x Ingestion	x	Exposure	x Exposure	x	R.A.F	/	Body	x	Averaging	x	Conversion
EXPOSURE		Rate		Frequency	Duration				Weight		Time		Factor
DOSE	Conc.	200		150	6		R.A.F		15		(f)	365	x 1E+06
		mg/day		days/yr	years				kg		years	days/year	mg/kg

(b) Hazard quotient = chronic exposure dose / RfD

(c) Cancer risk = lifetime exposure dose x slope factor

(d) The reference dose for chromium VI was used.

(e) The reference dose for manganese is based on total allowable intake (10 mg/day) minus the background intake (5 mg/day)
The remaining intake (5 mg/day) was normalized for body weight (70 kg) to derive the RfD.

(f) Averaging times of 6 years for chronic doses and 70 years for lifetime doses were used.

na = toxicity value not available

nd = not detected

--- = not calculated due to absence of data

* EDITED FINAL SUPPLEMENTAL HUMAN HEALTH RISK ASSESSMENT (1998) TABLE B-7

TABLE 2 - 1 K*
POTENTIAL RISK FROM INGESTION OF SURFACE SOILS WITHIN THE SOLID WASTE AREA BY SITE VISITORS
MAXIMUM CONCENTRATIONS USED FOR A CHILD EXPOSURE

ANALYTE	Maximum Concentration (mg/kg)	Relative Absorption Factor (RAF)	Exposure Dose Chronic (a) (mg/kg/day)	Oral Reference Dose (RfD) (mg/kg/day)	Hazard Quotient (b)	Exposure Dose Lifetime (a) (mg/kg/day)	Oral Slope Factor /(mg/kg/day)	Cancer Risk (c)
Acetone	160	1	8.8E-04	0.1	8.8E-03	7.5E-05	na	---
Vinyl Chloride	0.25	1	1.4E-06	na	---	1.2E-07	1.9	2.2E-07
Benzo(a)anthracene	0.078	1	4.3E-07	na	---	3.7E-08	0.73	2.7E-08
Benzo(a)pyrene	0.068	1	3.7E-07	na	---	3.2E-08	7.3	2.3E-07
Benzo(b)fluoranthene	0.076	1	4.2E-07	na	---	3.6E-08	0.73	2.6E-08
Benzo(k)fluoranthene	0.064	1	3.5E-07	na	---	3.0E-08	0.073	2.2E-09
Chrysene	0.095	1	5.2E-07	na	---	4.5E-08	0.0073	3.3E-10
Indeno(1,2,3-cd)pyrene	0.052	1	2.8E-07	na	---	2.4E-08	0.73	1.8E-08
Aluminum	14400	1	7.9E-02	na	---	6.8E-03	na	---
Arsenic	3.5	1	1.9E-05	0.0003	6.4E-02	1.6E-06	1.5	2.5E-06
Barium	20.5	1	1.1E-04	0.07	1.6E-03	9.6E-06	na	---
Beryllium	1.1	1	6.0E-06	0.002	3.0E-03	5.2E-07	na	---
Chromium (d)	13.9	1	7.6E-05	0.005	1.5E-02	6.5E-06	na	---
Cobalt	6.2	1	3.4E-05	na	---	2.9E-06	na	---
Copper	253	1	1.4E-03	na	---	1.2E-04	na	---
Lead	31.1	1	1.7E-04	na	---	1.5E-05	na	---
Manganese (e)	257	1	1.4E-03	0.07	2.0E-02	1.2E-04	na	---
Mercury	0.2	1	1.1E-06	0.0003	3.7E-03	9.4E-08	na	---
Thallium	0.36	1	2.0E-06	0.00008	2.5E-02	1.7E-07	na	---
Vanadium	27.2	1	1.5E-04	0.007	2.1E-02	1.3E-05	na	---
			Total Hazard Index =		1.6E-01	Total Risk =		3.0E-06

NOTES:

(a) Calculation for exposure dose :

INGESTION =	Conc.	x Ingestion	x	Exposure	x Exposure	x	R.A.F	/	Body	x	Averaging	x	Conversion
EXPOSURE		Rate		Frequency	Duration				Weight		Time		Factor
DOSE	Conc.	200		150	6		R.A.F		15		(f)	365	x 1E+06
		mg/day		days/yr	years				kg		years	days/year	mg/kg

(b) Hazard quotient = chronic exposure dose / RfD

(c) Cancer risk = lifetime exposure dose x slope factor

(d) The reference dose for chromium VI was used.

(e) The reference dose for manganese is based on total allowable intake (10 mg/day) minus the background intake (5 mg/day).
The remaining intake (5 mg/day) was normalized for body weight (70 kg) to derive the RfD.

(f) Averaging times of 6 years for chronic doses and 70 years for lifetime doses were used.

na = toxicity value not available
nd = not detected
--- = not calculated due to absence of data

*** EDITED FINAL SUPPLEMENTAL HUMAN HEALTH RISK ASSESSMENT (1998) TABLE B-8**

TABLE 2 - 1 L*
POTENTIAL RISK FROM INGESTION OF SURFACE SOILS WITHIN THE BULKY WASTE AREA BY SITE VISITORS
AVERAGE CONCENTRATIONS USED FOR A CHILD EXPOSURE

ANALYTE	Average Concentration (mg/kg)	Relative Absorption Factor (RAF)	Exposure Dose Chronic (a) (mg/kg/day)	Oral Reference Dose (RfD) (mg/kg/day)	Hazard Quotient (b)	Exposure Dose Lifetime (a) (mg/kg/day)	Oral Slope Factor /(mg/kg/day)	Cancer Risk (c)
Acetone	4.8	1	2.6E-05	0.1	2.6E-04	2.3E-06	na	---
Vinyl Chloride	nd	1	---	na	---	---	1.9	---
Benzo(a)anthracene	nd	1	---	na	---	---	0.73	---
Benzo(a)pyrene	nd	1	---	na	---	---	7.3	---
Benzo(b)fluoranthene	0.057	1	3.1E-07	na	---	2.7E-08	0.73	2.0E-08
Benzo(k)fluoranthene	nd	1	---	na	---	---	0.073	---
Chrysene	0.055	1	3.0E-07	na	---	2.6E-08	0.0073	1.9E-10
Indeno(1,2,3-cd)pyrene	nd	1	---	na	---	---	0.73	---
Aluminum	6400	1	3.5E-02	na	---	3.0E-03	na	---
Arsenic	1.2	1	6.6E-06	0.0003	2.2E-02	5.6E-07	1.5	8.5E-07
Barium	34	1	1.9E-04	0.07	2.7E-03	1.6E-05	na	---
Beryllium	0.57	1	3.1E-06	0.002	1.6E-03	2.7E-07	na	---
Chromium (d)	5.8	1	3.2E-05	0.005	6.4E-03	2.7E-06	na	---
Cobalt	6	1	3.3E-05	na	---	2.8E-06	na	---
Copper	3.3	1	1.8E-05	na	---	1.5E-06	na	---
Lead	29	1	1.6E-04	na	---	1.4E-05	na	---
Manganese (e)	1400	1	7.7E-03	0.07	1.1E-01	6.6E-04	na	---
Mercury	0.13	1	7.1E-07	0.0003	2.4E-03	6.1E-08	na	---
Thallium	nd	1	---	0.00008	---	---	na	---
Vanadium	12	1	6.6E-05	0.007	9.4E-03	5.6E-06	na	---
			Total Hazard Index =		1.5E-01	Total Risk =		8.7E-07

NOTES:

(a) Calculation for exposure dose :

INGESTION = EXPOSURE DOSE	Conc.	x Ingestion Rate	x Exposure Frequency	x Exposure Duration	x R.A.F /	Body Weight	x Averaging Time	x Conversion Factor
	Conc.	200	150	6	R.A.F	15	(f)	365 x 1E+06
		mg/day	days/yr	years		kg	years	days/year mg/kg

(b) Hazard quotient = chronic exposure dose / RfD

(c) Cancer risk = lifetime exposure dose x slope factor

(d) The reference dose for chromium VI was used.

(e) The reference dose for manganese is based on total allowable intake (10 mg/day) minus the background intake (5 mg/day). The remaining intake (5 mg/day) was normalized for body weight (70 kg) to derive the RfD.

(f) Averaging times of 6 years for chronic doses and 70 years for lifetime doses were used.

na = toxicity value not available

nd = not detected

--- = not calculated due to absence of data

* EDITED FINAL SUPPLEMENTAL HUMAN HEALTH RISK ASSESSMENT (1998) TABLE B-9

TABLE 2 - 1 M*

POTENTIAL RISK FROM INGESTION OF SURFACE SOILS WITHIN THE BULKY WASTE AREA BY SITE VISITORS

MAXIMUM CONCENTRATIONS USED FOR A CHILD EXPOSURE

ANALYTE	Maximum Concentration (mg/kg)	Relative Absorption Factor (RAF)	Exposure Dose Chronic (a) (mg/kg/day)	Oral Reference Dose (RfD) (mg/kg/day)	Hazard Quotient (b)	Exposure Dose Lifetime (a) (mg/kg/day)	Oral Slope Factor /(mg/kg/day)	Cancer Risk (c)
Acetone	23.7	1	1.3E-04	0.1	1.3E-03	1.1E-05	na	---
Vinyl Chloride	nd	1	---	na	---	---	1.9	---
Benzo(a)anthracene	nd	1	---	na	---	---	0.73	---
Benzo(a)pyrene	nd	1	---	na	---	---	7.3	---
Benzo(b)fluoranthene	0.057	1	3.1E-07	na	---	2.7E-08	0.73	2.0E-08
Benzo(k)fluoranthene	nd	1	---	na	---	---	0.073	---
Chrysene	0.055	1	3.0E-07	na	---	2.6E-08	0.0073	1.9E-10
Indeno(1,2,3-cd)pyrene	nd	1	---	na	---	---	0.73	---
Aluminum	8940	1	4.9E-02	na	---	4.2E-03	na	---
Arsenic	1.3	1	7.1E-06	0.0003	2.4E-02	6.1E-07	1.5	9.2E-07
Barium	86.2	1	4.7E-04	0.07	6.7E-03	4.0E-05	na	---
Beryllium	0.88	1	4.8E-06	0.002	2.4E-03	4.1E-07	na	---
Chromium (d)	9.8	1	5.4E-05	0.005	1.1E-02	4.6E-06	na	---
Cobalt	12.8	1	7.0E-05	na	---	6.0E-06	na	---
Copper	5.6	1	3.1E-05	na	---	2.6E-06	na	---
Lead	124	1	6.8E-04	na	---	5.8E-05	na	---
Manganese (e)	6120	1	3.4E-02	0.07	4.8E-01	2.9E-03	na	---
Mercury	0.41	1	2.2E-06	0.0003	7.5E-03	1.9E-07	na	---
Thallium	nd	1	---	0.00008	---	---	na	---
Vanadium	18.1	1	9.9E-05	0.007	1.4E-02	8.5E-06	na	---
			Total Hazard Index =		5.5E-01	Total Risk =		9.4E-07

NOTES:

(a) Calculation for exposure dose :

INGESTION =	Conc.	x Ingestion	x	Exposure	x Exposure	x	R.A.F /	Body	x	Averaging	x	Conversion
EXPOSURE		Rate		Frequency	Duration			Weight		Time		Factor
DOSE	Conc.	200		150	6		R.A.F	15		(f)	365	x 1E+06
		mg/day		days/yr	years			kg		years	days/year	mg/kg

(b) Hazard quotient = chronic exposure dose / RfD

(c) Cancer risk = lifetime exposure dose x slope factor

(d) The reference dose for chromium VI was used.

(e) The reference dose for manganese is based on total allowable intake (10 mg/day) minus the background intake (5 mg/day).
The remaining intake (5 mg/day) was normalized for body weight (70 kg) to derive the RfD.

(f) Averaging times of 6 years for chronic doses and 70 years for lifetime doses were used.

na = toxicity value not available

nd = not detected

--- = not calculated due to absence of data

* EDITED FINAL SUPPLEMENTAL HUMAN HEALTH RISK ASSESSMENT (1998) TABLE B-10

TABLE 2 - 1 N*

POTENTIAL RISK FROM INGESTION OF SURFACE SOILS WITHIN THE SEWAGE SLUDGE AREA BY SITE VISITORS

AVERAGE CONCENTRATIONS USED FOR A CHILD EXPOSURE

ANALYTE	Average Concentration (mg/kg)	Relative Absorption Factor (RAF)	Exposure Dose Chronic (a) (mg/kg/day)	Oral Reference Dose (RfD) (mg/kg/day)	Hazard Quotient (b)	Exposure Dose Lifetime (a) (mg/kg/day)	Oral Slope Factor /(mg/kg/day)	Cancer Risk (c)
Acetone	0.014	1	7.7E-08	0.1	7.7E-07	6.6E-09	na	---
Vinyl Chloride	nd	1	---	na	---	---	1.9	---
Benzo(a)anthracene	nd	1	---	na	---	---	0.73	---
Benzo(a)pyrene	nd	1	---	na	---	---	7.3	---
Benzo(b)fluoranthene	nd	1	---	na	---	---	0.73	---
Benzo(k)fluoranthene	nd	1	---	na	---	---	0.073	---
Chrysene	nd	1	---	na	---	---	0.0073	---
Indeno(1,2,3-cd)pyrene	nd	1	---	na	---	---	0.73	---
Aluminum	5500	1	3.0E-02	na	---	2.6E-03	na	---
Arsenic	0.79	1	4.3E-06	0.0003	1.4E-02	3.7E-07	1.5	5.6E-07
Barium	28	1	1.5E-04	0.07	2.2E-03	1.3E-05	na	---
Beryllium	0.35	1	1.9E-06	0.002	9.6E-04	1.6E-07	na	---
Chromium (d)	6.4	1	3.5E-05	0.005	7.0E-03	3.0E-06	na	---
Cobalt	2.9	1	1.6E-05	na	---	1.4E-06	na	---
Copper	37	1	2.0E-04	na	---	1.7E-05	na	---
Lead	6.3	1	3.5E-05	na	---	3.0E-06	na	---
Manganese (e)	110	1	6.0E-04	0.07	8.6E-03	5.2E-05	na	---
Mercury	0.13	1	7.1E-07	0.0003	2.4E-03	6.1E-08	na	---
Thallium	0.15	1	8.2E-07	0.00008	1.0E-02	7.0E-08	na	---
Vanadium	9.2	1	5.0E-05	0.007	7.2E-03	4.3E-06	na	---
			Total Hazard Index =		5.3E-02	Total Risk =		5.6E-07

NOTES:

(a) Calculation for exposure dose :

INGESTION =	Conc.	x Ingestion	x	Exposure	x Exposure	x	R.A.F	/	Body	x	Averaging	x	Conversion
EXPOSURE		Rate		Frequency	Duration				Weight		Time		Factor
DOSE	Conc.	200		150	6		R.A.F		15		(f) 365	x	1E+06
		mg/day		days/yr	years				kg		years days/year		mg/kg

(b) Hazard quotient = chronic exposure dose / RfD

(c) Cancer risk = lifetime exposure dose x slope factor

(d) The reference dose for chromium VI was used.

(e) The reference dose for manganese is based on total allowable intake (10 mg/day) minus the background intake (5 mg/day).
The remaining intake (5 mg/day) was normalized for body weight (70 kg) to derive the RfD.

(f) Averaging times of 6 years for chronic doses and 70 years for lifetime doses were used.

na = toxicity value not available

nd = not detected

--- = not calculated due to absence of data

* EDITED FINAL SUPPLEMENTAL HUMAN HEALTH RISK ASSESSMENT (1998) TABLE B-11

TABLE 2 - 1 O*
POTENTIAL RISK FROM INGESTION OF SURFACE SOILS WITHIN THE SEWAGE SLUDGE AREA BY SITE VISITORS
MAXIMUM CONCENTRATIONS USED FOR A CHILD EXPOSURE

ANALYTE	Maximum Concentration (mg/kg)	Relative Absorption Factor (RAF)	Exposure Dose Chronic (a) (mg/kg/day)	Oral Reference Dose (RfD) (mg/kg/day)	Hazard Quotient (b)	Exposure Dose Lifetime (a) (mg/kg/day)	Oral Slope Factor /(mg/kg/day)	Cancer Risk (c)
Acetone	0.023	1	1.3E-07	0.1	1.3E-06	1.1E-08	na	---
Vinyl Chloride	nd	1	---	na	---	---	1.9	---
Benzo(a)anthracene	nd	1	---	na	---	---	0.73	---
Benzo(a)pyrene	nd	1	---	na	---	---	7.3	---
Benzo(b)fluoranthene	nd	1	---	na	---	---	0.73	---
Benzo(k)fluoranthene	nd	1	---	na	---	---	0.073	---
Chrysene	nd	1	---	na	---	---	0.0073	---
Indeno(1,2,3-cd)pyrene	nd	1	---	na	---	---	0.73	---
Aluminum	6740	1	3.7E-02	na	---	3.2E-03	na	---
Arsenic	0.86	1	4.7E-06	0.0003	1.6E-02	4.0E-07	1.5	6.1E-07
Barium	58.9	1	3.2E-04	0.07	4.6E-03	2.8E-05	na	---
Beryllium	0.4	1	2.2E-06	0.002	1.1E-03	1.9E-07	na	---
Chromium (d)	9.8	1	5.4E-05	0.005	1.1E-02	4.6E-06	na	---
Cobalt	3.6	1	2.0E-05	na	---	1.7E-06	na	---
Copper	99.3	1	5.4E-04	na	---	4.7E-05	na	---
Lead	11.8	1	6.5E-05	na	---	5.5E-06	na	---
Manganese (e)	135	1	7.4E-04	0.07	1.1E-02	6.3E-05	na	---
Mercury	0.28	1	1.5E-06	0.0003	5.1E-03	1.3E-07	na	---
Thallium	0.25	1	1.4E-06	0.00008	1.7E-02	1.2E-07	na	---
Vanadium	12.1	1	6.6E-05	0.007	9.5E-03	5.7E-06	na	---
			Total Hazard Index =		7.4E-02	Total Risk =		6.1E-07

NOTES:

(a) Calculation for exposure dose :

INGESTION =	Conc.	x Ingestion	x	Exposure	x Exposure	x	R.A.F	/	Body	x	Averaging	x	Conversion
EXPOSURE		Rate		Frequency	Duration				Weight		Time		Factor
DOSE	Conc.	200		150	6		R.A.F		15		(f)	365	x 1E+06
		mg/day		days/yr	years				kg		years	days/year	mg/kg

(b) Hazard quotient = chronic exposure dose / RfD

(c) Cancer risk = lifetime exposure dose x slope factor

(d) The reference dose for chromium VI was used.

(e) The reference dose for manganese is based on total allowable intake (10 mg/day) minus the background intake (5 mg/day). The remaining intake (5 mg/day) was normalized for body weight (70 kg) to derive the RfD.

(f) Averaging times of 6 years for chronic doses and 70 years for lifetime doses were used.

na = toxicity value not available

nd = not detected

--- = not calculated due to absence of data

*** EDITED FINAL SUPPLEMENTAL HUMAN HEALTH RISK ASSESSMENT (1998) TABLE B-12**

TABLE 2 - 1 P*

POTENTIAL RISK FROM DERMAL CONTACT OF SURFACE SOILS WITHIN THE SOLID WASTE AREA BY SITE VISITORS
AVERAGE CONCENTRATIONS USED FOR AN ADULT EXPOSURE

ANALYTE	Average Concentration (mg/kg)	Relative Absorption Factor (RAF)	Exposure Dose Chronic (a) (mg/kg/day)	Oral Reference Dose (RfD) (mg/kg/day)	Hazard Quotient (b)	Exposure Dose Lifetime (a) (mg/kg/day)	Oral Slope Factor /(mg/kg/day)	Cancer Risk (c)
Acetone	14	0.5	2.1E-05	0.1	2.1E-04	7.0E-06	na	---
Vinyl Chloride	0.025	0.5	3.7E-08	na	---	1.3E-08	1.9	2.4E-08
Benzo(a)anthracene	0.078	0.05	1.1E-08	na	---	3.9E-09	0.73	2.9E-09
Benzo(a)pyrene	0.068	0.05	1.0E-08	na	---	3.4E-09	7.3	2.5E-08
Benzo(b)fluoranthene	0.076	0.05	1.1E-08	na	---	3.8E-09	0.73	2.8E-09
Benzo(k)fluoranthene	0.064	0.05	9.4E-09	na	---	3.2E-09	0.073	2.4E-10
Chrysene	0.095	0.05	1.4E-08	na	---	4.8E-09	0.0073	3.5E-11
Indeno(1,2,3-cd)pyrene	0.052	0.05	7.6E-09	na	---	2.6E-09	0.73	1.9E-09
Aluminum	8000	(d)	---	na	---	---	na	---
Arsenic	1.5	(d)	---	0.0003	---	---	1.5	---
Barium	16	(d)	---	0.07	---	---	na	---
Beryllium	0.41	(d)	---	0.002	---	---	na	---
Chromium (e)	7.5	(d)	---	0.005	---	---	na	---
Cobalt	2.9	(d)	---	na	---	---	na	---
Copper	27	(d)	---	na	---	---	na	---
Lead	12	(d)	---	na	---	---	na	---
Manganese (f)	110	(d)	---	0.07	---	---	na	---
Mercury	0.067	(d)	---	0.0003	---	---	na	---
Thallium	0.15	(d)	---	0.00008	---	---	na	---
Vanadium	14	(d)	---	0.007	---	---	na	---
			Total Hazard Index =		2.1E-04	Total Risk =		5.7E-08

NOTES:

(a) Calculation for exposure dose :

DERMAL EXPOSURE DOSE	=	Conc. x	Soil Contact Rate	x	Exposure Frequency	x	Exposure Duration	x	R.A.F. /	Body Weight	x	Averaging Time	x	Conversion Factor
		Conc.	500		150		24		RAF	70		(g)	365	x 1E+06
			mg/day		days/yr		years			kg		years	days/year	mg/kg

(b) Hazard quotient = chronic exposure dose / RfD

(c) Cancer Risk = lifetime exposure dose x slope factor

(d) R.A.F. for metals is neglible; (USEPA, 1989, "Supplemental Risk Assessment Guidance ", EPA/901/5-89-001)

(e) The reference dose for chromium VI was used.

(f) The reference dose for manganese is based on total allowable intake (10 mg/day) minus the background intake (5 mg/day). The remaining intake (5mg/day) was normalized for body weight (70 kg) to derive the RfD.

(g) Averaging times of 24 years for chronic doses and 70 years for lifetime doses were used.

na = toxicity value not available

nd = chemical not detected

--- = not calculated due to an absence of data

* EDITED FINAL SUPPLEMENTAL HUMAN HEALTH RISK ASSESSMENT (1998) TABLE B-13

TABLE 2 - 1 Q*

POTENTIAL RISK FROM DERMAL CONTACT OF SURFACE SOILS WITHIN THE SOLID WASTE AREA BY SITE VISITORS
MAXIMUM CONCENTRATIONS USED FOR AN ADULT EXPOSURE

ANALYTE	Maximum Concentration (mg/kg)	Relative Absorption Factor (RAF)	Exposure Dose Chronic (a) (mg/kg/day)	Oral Reference Dose (RfD) (mg/kg/day)	Hazard Quotient (b)	Exposure Dose Lifetime (a) (mg/kg/day)	Oral Slope Factor /(mg/kg/day)	Cancer Risk (c)
Acetone	160	0.5	2.3E-04	0.1	2.3E-03	8.1E-05	na	---
Vinyl Chloride	0.25	0.5	3.7E-07	na	---	1.3E-07	1.9	2.4E-07
Benzo(a)anthracene	0.078	0.05	1.1E-08	na	---	3.9E-09	0.73	2.9E-09
Benzo(a)pyrene	0.068	0.05	1.0E-08	na	---	3.4E-09	7.3	2.5E-08
Benzo(b)fluoranthene	0.076	0.05	1.1E-08	na	---	3.8E-09	0.73	2.8E-09
Benzo(k)fluoranthene	0.064	0.05	9.4E-09	na	---	3.2E-09	0.073	2.4E-10
Chrysene	0 095	0.05	1.4E-08	na	---	4.8E-09	0.0073	3.5E-11
Indeno(1,2,3-cd)pyrene	0.052	0.05	7.6E-09	na	---	2.6E-09	0.73	1.9E-09
Aluminum	14400	(d)	---	na	---	---	na	---
Arsenic	3.5	(d)	---	0.0003	---	---	1.5	---
Barium	20.5	(d)	---	0.07	---	---	na	---
Beryllium	1.1	(d)	---	0.002	---	---	na	---
Chromium (e)	13.9	(d)	---	0.005	---	---	na	---
Cobalt	6.2	(d)	---	na	---	---	na	---
Copper	253	(d)	---	na	---	---	na	---
Lead	31.1	(d)	---	na	---	---	na	---
Manganese (f)	257	(d)	---	0.07	---	---	na	---
Mercury	0.2	(d)	---	0.0003	---	---	na	---
Thallium	0.36	(d)	---	0.00008	---	---	na	---
Vanadium	27.2	(d)	---	0.007	---	---	na	---
			Total Hazard Index =		2.3E-03	Total Risk =		2.7E-07

NOTES:

(a) Calculation for exposure dose :

DERMAL EXPOSURE DOSE	=	Conc. x	Soil Contact Rate	x	Exposure Frequency	x	Exposure Duration	x	R.A.F. /	Body Weight	x	Averaging Time	x	Conversion Factor
		Conc.	500		150		24		RAF	70		(g)	365	x 1E+06
			mg/day		days/yr		years			kg		years	days/year	mg/kg

(b) Hazard quotient = chronic exposure dose / RfD

(c) Cancer Risk = lifetime exposure dose x slope factor

(d) R.A.F. for metals is neglible; (USEPA, 1989, "Supplemental Risk Assessment Guidance ", EPA/901/5-89-001)

(e) The reference dose for chromium VI was used.

(f) The reference dose for manganese is based on total allowable intake (10 mg/day) minus the background intake (5 mg/day). The remaining intake (5mg/day) was nornalized for body weight (70 kg) to derive the RfD.

(g) Averaging times of 24 years for chronic doses and 70 years for lifetime doses were used.

na = toxicity value not available

nd = chemical not detected

--- = not calculated due to an absence of data

*** EDITED FINAL SUPPLEMENTAL HUMAN HEALTH RISK ASSESSMENT (1998) TABLE B-14**

TABLE 2 - 1 R*

POTENTIAL RISK FROM DERMAL CONTACT OF SURFACE SOILS WITHIN THE BULKY WASTE AREA BY SITE VISITORS
AVERAGE CONCENTRATIONS USED FOR AN ADULT EXPOSURE

ANALYTE	Average Concentration (mg/kg)	Relative Absorption Factor (RAF)	Exposure Dose Chronic (a) (mg/kg/day)	Oral Reference Dose (RfD) (mg/kg/day)	Hazard Quotient (b)	Exposure Dose Lifetime (a) (mg/kg/day)	Oral Slope Factor /(mg/kg/day)	Cancer Risk (c)
Acetone	4.8	0.5	7.0E-06	0.1	7.0E-05	2.4E-06	na	---
Vinyl Chloride	nd	0.5	---	na	---	---	1.9	---
Benzo(a)anthracene	nd	0.05	---	na	---	---	0.73	---
Benzo(a)pyrene	nd	0.05	---	na	---	---	7.3	---
Benzo(b)fluoranthene	0.057	0.05	8.4E-09	na	---	2.9E-09	0.73	2.1E-09
Benzo(k)fluoranthene	nd	0.05	---	na	---	---	0.073	---
Chrysene	0.055	0.05	8.1E-09	na	---	2.8E-09	0.0073	2.0E-11
Indeno(1,2,3-cd)pyrene	nd	0.05	---	na	---	---	0.73	---
Aluminum	6400	(d)	---	na	---	---	na	---
Arsenic	1.2	(d)	---	0.0003	---	---	1.5	---
Barium	34	(d)	---	0.07	---	---	na	---
Beryllium	0.57	(d)	---	0.002	---	---	na	---
Chromium (e)	5.8	(d)	---	0.005	---	---	na	---
Cobalt	6	(d)	---	na	---	---	na	---
Copper	3.3	(d)	---	na	---	---	na	---
Lead	29	(d)	---	na	---	---	na	---
Manganese (f)	1400	(d)	---	0.07	---	---	na	---
Mercury	0.13	(d)	---	0.0003	---	---	na	---
Thallium	nd	(d)	---	0.00008	---	---	na	---
Vanadium	12	(d)	---	0.007	---	---	na	---
			Total Hazard Index =		7.0E-05	Total Risk =		2.1E-09

NOTES:

(a) Calculation for exposure dose :

DERMAL EXPOSURE DOSE	=	Conc.	x	Soil Contact Rate	x	Exposure Frequency	x	Exposure Duration	x	R.A.F.	/	Body Weight	x
		Conc.		500 mg/day		150 days/yr		24 years		RAF		70 kg	

Averaging Time	x	Conversion Factor					
(g) years		365 days/year	x	1E+06 mg/kg			

(b) Hazard quotient = chronic exposure dose / RfD

(c) Cancer Risk = lifetime exposure dose x slope factor

(d) R.A.F. for metals is neglible; (USEPA, 1989, "Supplemental Risk Assessment Guidance ", EPA/901/5-89-001)

(e) The reference dose for chromium VI was used.

(f) The reference dose for manganese is based on total allowable intake (10 mg/day) minus the background intake (5 mg/day). The remaining intake (5mg/day) was normalized for body weight (70 kg) to derive the RfD.

(g) Averaging times of 24 years for chronic doses and 70 years for lifetime doses were used.

na = toxicity value not available

nd = chemical not detected

--- = not calculated due to an absence of data

*** EDITED FINAL SUPPLEMENTAL HUMAN HEALTH RISK ASSESSMENT (1998) TABLE B-15**

TABLE 2 - 1 S*

POTENTIAL RISK FROM DERMAL CONTACT OF SURFACE SOILS WITHIN THE BULKY WASTE AREA BY SITE VISITORS
MAXIMUM CONCENTRATIONS USED FOR AN ADULT EXPOSURE

ANALYTE	Maximum Concentration (mg/kg)	Relative Absorption Factor (RAF)	Exposure Dose Chronic (a) (mg/kg/day)	Oral Reference Dose (RfD) (mg/kg/day)	Hazard Quotient (b)	Exposure Dose Lifetime (a) (mg/kg/day)	Oral Slope Factor /(mg/kg/day)	Cancer Risk (c)
Acetone	23.7	0.5	3.5E-05	0.1	3.5E-04	1.2E-05	na	---
Vinyl Chloride	nd	0.5	---	na	---	---	1.9	---
Benzo(a)anthracene	nd	0.05	---	na	---	---	0.73	---
Benzo(a)pyrene	nd	0.05	---	na	---	---	7.3	---
Benzo(b)fluoranthene	0.057	0.05	8.4E-09	na	---	2.9E-09	0.73	2.1E-09
Benzo(k)fluoranthene	nd	0.05	---	na	---	---	0.073	---
Chrysene	0.055	0.05	8.1E-09	na	---	2.8E-09	0.0073	2.0E-11
Indeno(1,2,3-cd)pyrene	nd	0.05	---	na	---	---	0.73	---
Aluminum	8940	(d)	---	na	---	---	na	---
Arsenic	1.3	(d)	---	0.0003	---	---	1.5	---
Barium	86.2	(d)	---	0.07	---	---	na	---
Beryllium	0.88	(d)	---	0.002	---	---	na	---
Chromium (e)	9.8	(d)	---	0.005	---	---	na	---
Cobalt	12.8	(d)	---	na	---	---	na	---
Copper	5.6	(d)	---	na	---	---	na	---
Lead	124	(d)	---	na	---	---	na	---
Manganese (f)	6120	(d)	---	0.07	---	---	na	---
Mercury	0.41	(d)	---	0.0003	---	---	na	---
Thallium	nd	(d)	---	0.00008	---	---	na	---
Vanadium	18.1	(d)	---	0.007	---	---	na	---
			Total Hazard Index =		3.5E-04	Total Risk =		2.1E-09

NOTES:

(a) Calculation for exposure dose :

DERMAL EXPOSURE DOSE	=	Conc. x	Soil Contact Rate	x	Exposure Frequency	x	Exposure Duration	x	R.A.F. /	Body Weight	x	Averaging Time	x	Conversion Factor
		Conc.	500		150		24		RAF	70		(g)	365	x 1E+06
			mg/day		days/yr		years			kg		years	days/year	mg/kg

(b) Hazard quotient = chronic exposure dose / RfD

(c) Cancer Risk = lifetime exposure dose x slope factor

(d) R.A.F. for metals is neglible; (USEPA, 1989, "Supplemental Risk Assessment Guidance ", EPA/901/5-89-001)

(e) The reference dose for chromium VI was used.

(f) The reference dose for manganese is based on total allowable intake (10 mg/day) minus the background intake (5 mg/day). The remaining intake (5mg/day) was normalized for body weight (70 kg) to derive the RfD.

(g) Averaging times of 24 years for chronic doses and 70 years for lifetime doses were used.

na = toxicity value not available

nd = chemical not detected

--- = not calculated due to an absence of data

* EDITED FINAL SUPPLEMENTAL HUMAN HEALTH RISK ASSESSMENT (1998) TABLE B-16

TABLE 2 - 1 T*

POTENTIAL RISK FROM DERMAL CONTACT OF SURFACE SOILS WITHIN THE SEWAGE SLUDGE AREA BY SITE VISITORS
AVERAGE CONCENTRATIONS USED FOR AN ADULT EXPOSURE

ANALYTE	Average Concentration (mg/kg)	Relative Absorption Factor (RAF)	Exposure Dose Chronic (a) (mg/kg/day)	Oral Reference Dose (RfD) (mg/kg/day)	Hazard Quotient (b)	Exposure Dose Lifetime (a) (mg/kg/day)	Oral Slope Factor /(mg/kg/day)	Cancer Risk (c)
Acetone	0.014	0.5	2.1E-08	0.1	2.1E-07	7.0E-09	na	---
Vinyl Chloride	nd	0.5	---	na	---	---	1.9	---
Benzo(a)anthracene	nd	0.05	---	na	---	---	0.73	---
Benzo(a)pyrene	nd	0.05	---	na	---	---	7.3	---
Benzo(b)fluoranthene	nd	0.05	---	na	---	---	0.73	---
Benzo(k)fluoranthene	nd	0.05	---	na	---	---	0.073	---
Chrysene	nd	0.05	---	na	---	---	0.0073	---
Indeno(1,2,3-cd)pyrene	nd	0.05	---	na	---	---	0.73	---
Aluminum	5500	(d)	---	na	---	---	na	---
Arsenic	0.79	(d)	---	0.0003	---	---	1.5	---
Barium	28	(d)	---	0.07	---	---	na	---
Beryllium	0.35	(d)	---	0.002	---	---	na	---
Chromium (e)	6.4	(d)	---	0.005	---	---	na	---
Cobalt	2.9	(d)	---	na	---	---	na	---
Copper	37	(d)	---	na	---	---	na	---
Lead	6.3	(d)	---	na	---	---	na	---
Manganese (f)	110	(d)	---	0.07	---	---	na	---
Mercury	0.13	(d)	---	0.0003	---	---	na	---
Thallium	0.15	(d)	---	0.00008	---	---	na	---
Vanadium	9.2	(d)	---	0.007	---	---	na	---
			Total Hazard Index =		2.1E-07	Total Risk =		---

NOTES:

(a) Calculation for exposure dose :

DERMAL EXPOSURE DOSE	=	Conc. x	Soil Contact Rate	x	Exposure Frequency	x	Exposure Duration	x	R.A.F. /	Body Weight	x	Averaging Time	x	Conversion Factor
		Conc.	500		150		24		RAF	70		(g)		365 x 1E+06
			mg/day		days/yr		years			kg		years		days/year mg/kg

(b) Hazard quotient = chronic exposure dose / RfD

(c) Cancer Risk = lifetime exposure dose x slope factor

(d) R.A.F. for metals is neglible; (USEPA, 1989, "Supplemental Risk Assessment Guidance ", EPA/901/5-89-001)

(e) The reference dose for chromium VI was used.

(f) The reference dose for manganese is based on total allowable intake (10 mg/day) minus the background intake (5 mg/day).
The remaining intake (5mg/day) was normalized for body weight (70 kg) to derive the RfD.

(g) Averaging times of 24 years for chronic doses and 70 years for lifetime doses were used.

na = toxicity value not available

nd = chemical not detected

--- = not calculated due to an absence of data

* EDITED FINAL SUPPLEMENTAL HUMAN HEALTH RISK ASSESSMENT (1998) TABLE B-17

TABLE 2 - 1 U*

POTENTIAL RISK FROM DERMAL CONTACT OF SURFACE SOILS WITHIN THE SEWAGE SLUDGE AREA BY SITE VISITORS
MAXIMUM CONCENTRATIONS USED FOR AN ADULT EXPOSURE

ANALYTE	Maximum Concentration (mg/kg)	Relative Absorption Factor (RAF)	Exposure Dose Chronic (a) (mg/kg/day)	Oral Reference Dose (RfD) (mg/kg/day)	Hazard Quotient (b)	Exposure Dose Lifetime (a) (mg/kg/day)	Oral Slope Factor /(mg/kg/day)	Cancer Risk (c)
Acetone	0.023	0.5	3.4E-08	0.1	3.4E-07	1.2E-08	na	---
Vinyl Chloride	nd	0.5	---	na	---	---	1.9	---
Benzo(a)anthracene	nd	0.05	---	na	---	---	0.73	---
Benzo(a)pyrene	nd	0.05	---	na	---	---	7.3	---
Benzo(b)fluoranthene	nd	0.05	---	na	---	---	0.73	---
Benzo(k)fluoranthene	nd	0.05	---	na	---	---	0.073	---
Chrysene	nd	0.05	---	na	---	---	0.0073	---
Indeno(1,2,3-cd)pyrene	nd	0.05	---	na	---	---	0.73	---
Aluminum	6740	(d)	---	na	---	---	na	---
Arsenic	0.86	(d)	---	0.0003	---	---	1.5	---
Barium	58.9	(d)	---	0.07	---	---	na	---
Beryllium	0.4	(d)	---	0.002	---	---	na	---
Chromium (e)	9.8	(d)	---	0.005	---	---	na	---
Cobalt	3.6	(d)	---	na	---	---	na	---
Copper	99.3	(d)	---	na	---	---	na	---
Lead	11.8	(d)	---	na	---	---	na	---
Manganese (f)	135	(d)	---	0.07	---	---	na	---
Mercury	0.28	(d)	---	0.0003	---	---	na	---
Thallium	0.25	(d)	---	0.00008	---	---	na	---
Vanadium	12.1	(d)	---	0.007	---	---	na	---
			Total Hazard Index =		3.4E-07	Total Risk =		---

NOTES:

(a) Calculation for exposure dose :

DERMAL EXPOSURE DOSE	=	Conc. x	Soil Contact Rate	x	Exposure Frequency	x	Exposure Duration	x	R.A.F. /	Body Weight	x	Averaging Time	x	Conversion Factor
		Conc.	500		150		24		RAF	70		(g)	365 x	1E+06
			mg/day		days/yr		years			kg		years	days/year	mg/kg

(b) Hazard quotient = chronic exposure dose / RfD

(c) Cancer Risk = lifetime exposure dose x slope factor

(d) R.A.F. for metals is neglible; (USEPA, 1989, "Supplemental Risk Assessment Guidance ", EPA/901/5-89-001)

(e) The reference dose for chromium VI was used.

(f) The reference dose for manganese is based on total allowable intake (10 mg/day) minus the background intake (5 mg/day). The remaining intake (5mg/day) was normalized for body weight (70 kg) to derive the RfD.

(g) Averaging times of 24 years for chronic doses and 70 years for lifetime doses were used.

na = toxicity value not available

nd = chemical not detected

--- = not calculated due to an absence of data

*** EDITED FINAL SUPPLEMENTAL HUMAN HEALTH RISK ASSESSMENT (1998) TABLE B-18**

TABLE 2 - 1 V*

POTENTIAL RISK FROM DERMAL CONTACT OF SURFACE SOILS WITHIN THE SOLID WASTE AREA BY SITE VISITORS
AVERAGE CONCENTRATIONS USED FOR A CHILD EXPOSURE

ANALYTE	Average Concentration (mg/kg)	Relative Absorption Factor (RAF)	Exposure Dose Chronic (a) (mg/kg/day)	Oral Reference Dose (RfD) (mg/kg/day)	Hazard Quotient (b)	Exposure Dose Lifetime (a) (mg/kg/day)	Oral Slope Factor /(mg/kg/day)	Cancer Risk (c)
Acetone	14	0.5	9.6E-05	0.1	9.6E-04	8.2E-06	na	---
Vinyl Chloride	0.025	0.5	1.7E-07	na	---	1.5E-08	1.9	2.8E-08
Benzo(a)anthracene	0.078	0.05	5.3E-08	na	---	4.6E-09	0.73	3.3E-09
Benzo(a)pyrene	0.068	0.05	4.7E-08	na	---	4.0E-09	7.3	2.9E-08
Benzo(b)fluoranthene	0.076	0.05	5.2E-08	na	---	4.5E-09	0.73	3.3E-09
Benzo(k)fluoranthene	0.064	0.05	4.4E-08	na	---	3.8E-09	0.073	2.7E-10
Chrysene	0.095	0.05	6.5E-08	na	---	5.6E-09	0.0073	4.1E-11
Indeno(1,2,3-cd)pyrene	0.052	0.05	3.6E-08	na	---	3.1E-09	0.73	2.2E-09
Aluminum	8000	(d)	---	na	---	---	na	---
Arsenic	1.5	(d)	---	0.0003	---	---	1.5	---
Barium	16	(d)	---	0.07	---	---	na	---
Beryllium	0.41	(d)	---	0.002	---	---	na	---
Chromium (e)	7.5	(d)	---	0.005	---	---	na	---
Cobalt	2.9	(d)	---	na	---	---	na	---
Copper	27	(d)	---	na	---	---	na	---
Lead	12	(d)	---	na	---	---	na	---
Manganese (f)	110	(d)	---	0.07	---	---	na	---
Mercury	0.067	(d)	---	0.0003	---	---	na	---
Thallium	0.15	(d)	---	0.00008	---	---	na	---
Vanadium	14	(d)	---	0.007	---	---	na	---
			Total Hazard Index =		9.6E-04	Total Risk =		6.6E-08

NOTES:

(a) Calculation for exposure dose :

DERMAL EXPOSURE DOSE	=	Conc. x Conc.	Soil Contact Rate 500 mg/day	x	Exposure Frequency 150 days/yr	x	Exposure Duration 6 years	x	R.A.F. / RAF	Body Weight 15 kg	x	Averaging Time (g) years	x	Conversion Factor 365 days/year x 1E+06 mg/kg

(b) Hazard quotient = chronic exposere dose / RfD

(c) Cancer Risk = lifetime exposure dose x slope factor

(d) R.A.F. for metals is neglible; (USEPA,1989,"Supplemental Risk Assessment Guidance", EPA/901/5-89-001)

(e) The reference dose for chromium VI was used.

(f) The reference dose for manganese is based on total allowable intake (10 mg/day) minus the background intake (5 mg/day). The remaining intake (5mg/day) was normalized for body weight (70 kg) to derive the RfD.

(g) Averaging times of 6 years for chronic doses and 70 years for lifetime doses were used.

na = toxicity value not available

nd = chemical not detected

--- = not calculated due to an absence of data

*** EDITED FINAL SUPPLEMENTAL HUMAN HEALTH RISK ASSESSMENT (1998) TABLE B-19**

TABLE 2 - 1 W*

POTENTIAL RISK FROM DERMAL CONTACT OF SURFACE SOILS WITHIN THE SOLID WASTE AREA BY SITE VISITORS
MAXIMUM CONCENTRATIONS USED FOR A CHILD EXPOSURE

ANALYTE	Maximum Concentration (mg/kg)	Relative Absorption Factor (RAF)	Exposure Dose Chronic (a) (mg/kg/day)	Oral Reference Dose (RfD) (mg/kg/day)	Hazard Quotient (b)	Exposure Dose Lifetime (a) (mg/kg/day)	Oral Slope Factor /(mg/kg/day)	Cancer Risk (c)
Acetone	160	0.5	1.1E-03	0.1	1.1E-02	9.4E-05	na	---
Vinyl Chloride	0.25	0.5	1.7E-06	na	---	1.5E-07	1.9	2.8E-07
Benzo(a)anthracene	0.078	0.05	5.3E-08	na	---	4.6E-09	0.73	3.3E-09
Benzo(a)pyrene	0.068	0.05	4.7E-08	na	---	4.0E-09	7.3	2.9E-08
Benzo(b)fluoranthene	0.076	0.05	5.2E-08	na	---	4.5E-09	0.73	3.3E-09
Benzo(k)fluoranthene	0.064	0.05	4.4E-08	na	---	3.8E-09	0.073	2.7E-10
Chrysene	0.095	0.05	6.5E-08	na	---	5.6E-09	0.0073	4.1E-11
Indeno(1,2,3-cd)pyrene	0.052	0.05	3.6E-08	na	---	3.1E-09	0.73	2.2E-09
Aluminum	14400	(d)	---	na	---	---	na	---
Arsenic	3.5	(d)	---	0.0003	---	---	1.5	---
Barium	20.5	(d)	---	0.07	---	---	na	---
Beryllium	1.1	(d)	---	0.002	---	---	na	---
Chromium (e)	13.9	(d)	---	0.005	---	---	na	---
Cobalt	6.2	(d)	---	na	---	---	na	---
Copper	253	(d)	---	na	---	---	na	---
Lead	31.1	(d)	---	na	---	---	na	---
Manganese (f)	257	(d)	---	0.07	---	---	na	---
Mercury	0.2	(d)	---	0.0003	---	---	na	---
Thallium	0.36	(d)	---	0.00008	---	---	na	---
Vanadium	27.2	(d)	---	0.007	---	---	na	---
			Total Hazard Index =		1.1E-02	Total Risk =		3.2E-07

NOTES:

(a) Calculation for exposure dose :

DERMAL EXPOSURE DOSE	=	Conc. x	Soil Contact Rate	x	Exposure Frequency	x	Exposure Duration	x	R.A.F. /	Body Weight	x	Averaging Time	x	Conversion Factor
		Conc.	500		150		6		RAF	15		(g)	365	x 1E+06
			mg/day		days/yr		years			kg		years	days/year	mg/kg

(b) Hazard quotient = chronic exposere dose / RfD

(c) Cancer Risk = lifetime exposure dose x slope factor

(d) R.A.F. for metals is neglible; (USEPA,1989,"Supplemental Risk Assessment Guidance", EPA/901/5-89-001)

(e) The reference dose for chromium VI was used.

(f) The reference dose for manganese is based on total allowable intake (10 mg/day) minus the background intake (5 mg/day). The remaining intake (5mg/day) was normalized for body weight (70 kg) to derive the RfD.

(g) Averaging times of 6 years for chronic doses and 70 years for lifetime doses were used.

na = toxicity value not available

nd = chemical not detected

--- = not calculated due to an absence of data

* EDITED FINAL SUPPLEMENTAL HUMAN HEALTH RISK ASSESSMENT (1998) TABLE B-20

TABLE 2 - 1 X*

POTENTIAL RISK FROM DERMAL CONTACT OF SURFACE SOILS WITHIN THE BULKY WASTE AREA BY SITE VISITORS
AVERAGE CONCENTRATIONS USED FOR A CHILD EXPOSURE

ANALYTE	Average Concentration (mg/kg)	Relative Absorption Factor (RAF)	Exposure Dose Chronic (a) (mg/kg/day)	Oral Reference Dose (RfD) (mg/kg/day)	Hazard Quotient (b)	Exposure Dose Lifetime (a) (mg/kg/day)	Oral Slope Factor /(mg/kg/day)	Cancer Risk (c)
Acetone	4.8	0.5	3.3E-05	0.1	3.3E-04	2.8E-06	na	---
Vinyl Chloride	nd	0.5	---	na	---	---	1.9	---
Benzo(a)anthracene	nd	0.05	---	na	---	---	0.73	---
Benzo(a)pyrene	nd	0.05	---	na	---	---	7.3	---
Benzo(b)fluoranthene	0.057	0.05	3.9E-08	na	---	3.3E-09	0.73	2.4E-09
Benzo(k)fluoranthene	nd	0.05	---	na	---	---	0.073	---
Chrysene	0.055	0.05	3.8E-08	na	---	3.2E-09	0.0073	2.4E-11
Indeno(1,2,3-cd)pyrene	nd	0.05	---	na	---	---	0.73	---
Aluminum	6400	(d)	---	na	---	---	na	---
Arsenic	1.2	(d)	---	0.0003	---	---	1.5	---
Barium	34	(d)	---	0.07	---	---	na	---
Beryllium	0.57	(d)	---	0.002	---	---	na	---
Chromium (e)	5.8	(d)	---	0.005	---	---	na	---
Cobalt	6	(d)	---	na	---	---	na	---
Copper	3.3	(d)	---	na	---	---	na	---
Lead	29	(d)	---	na	---	---	na	---
Manganese (f)	1400	(d)	---	0.07	---	---	na	---
Mercury	0.13	(d)	---	0.0003	---	---	na	---
Thallium	nd	(d)	---	0.00008	---	---	na	---
Vanadium	12	(d)	---	0.007	---	---	na	---
			Total Hazard Index =		3.3E-04	Total Risk =		2.5E-09

NOTES:

(a) Calculation for exposure dose :

DERMAL EXPOSURE DOSE	=	Conc. x	Soil Contact Rate	x	Exposure Frequency	x	Exposure Duration	x	R.A.F. /	Body Weight	x	Averaging Time	x	Conversion Factor
		Conc.	500		150		6		RAF	15		(g)	365 x	1E+06
			mg/day		days/yr		years			kg		years	days/year	mg/kg

(b) Hazard quotient = chronic exposere dose / RfD

(c) Cancer Risk = lifetime exposure dose x slope factor

(d) R.A.F. for metals is neglible; (USEPA,1989,"Supplemental Risk Assessment Guidance", EPA/901/5-89-001)

(e) The reference dose for chromium VI was used.

(f) The reference dose for manganese is based on total allowable intake (10 mg/day) minus the background intake (5 mg/day). The remaining intake (5mg/day) was normalized for body weight (70 kg) to derive the RfD.

(g) Averaging times of 6 years for chronic doses and 70 years for lifetime doses were used.

na = toxicity value not available

nd = chemical not detected

--- = not calculated due to an absence of data

* EDITED FINAL SUPPLEMENTAL HUMAN HEALTH RISK ASSESSMENT (1998) TABLE B-21

TABLE 2 - 1 Y*

POTENTIAL RISK FROM DERMAL CONTACT OF SURFACE SOILS WITHIN THE BULKY WASTE AREA BY SITE VISITORS
MAXIMUM CONCENTRATIONS USED FOR A CHILD EXPOSURE

ANALYTE	Maximum Concentration (mg/kg)	Relative Absorption Factor (RAF)	Exposure Dose Chronic (a) (mg/kg/day)	Oral Reference Dose (RfD) (mg/kg/day)	Hazard Quotient (b)	Exposure Dose Lifetime (a) (mg/kg/day)	Oral Slope Factor /(mg/kg/day)	Cancer Risk (c)
Acetone	23.7	0.5	1.6E-04	0.1	1.6E-03	1.4E-05	na	---
Vinyl Chloride	nd	0.5	---	na	---	---	1.9	---
Benzo(a)anthracene	nd	0.05	---	na	---	---	0.73	---
Benzo(a)pyrene	nd	0.05	---	na	---	---	7.3	---
Benzo(b)fluoranthene	0.057	0.05	3.9E-08	na	---	3.3E-09	0.73	2.4E-09
Benzo(k)fluoranthene	nd	0.05	---	na	---	---	0.073	---
Chrysene	0 055	0.05	3 8E-08	na	---	3.2E-09	0.0073	2.4E-11
Indeno(1,2,3-cd)pyrene	nd	0.05	---	na	---	---	0.73	---
Aluminum	8940	(d)	---	na	---	---	na	---
Arsenic	1.3	(d)	---	0.0003	---	---	1.5	---
Barium	86.2	(d)	---	0.07	---	---	na	---
Beryllium	0.88	(d)	---	0.002	---	---	na	---
Chromium (e)	9.8	(d)	---	0.005	---	---	na	---
Cobalt	12.8	(d)	---	na	---	---	na	---
Copper	5.6	(d)	---	na	---	---	na	---
Lead	124	(d)	---	na	---	---	na	---
Manganese (f)	6120	(d)	---	0.07	---	---	na	---
Mercury	0.41	(d)	---	0.0003	---	---	na	---
Thallium	nd	(d)	---	0.00008	---	---	na	---
Vanadium	18.1	(d)	---	0.007	---	---	na	---
			Total Hazard Index =		1.6E-03	Total Risk =		2.5E-09

NOTES:

(a) Calculation for exposure dose :

DERMAL EXPOSURE DOSE	=	Conc. x	Soil Contact Rate	x	Exposure Frequency	x	Exposure Duration	x	R.A.F. /	Body Weight	x	Averaging Time	x	Conversion Factor
		Conc.	500		150		6		RAF	15		(g)	365 x	1E+06
			mg/day		days/yr		years			kg		years	days/year	mg/kg

(b) Hazard quotient = chronic exposere dose / RfD

(c) Cancer Risk = lifetime exposure dose x slope factor

(d) R.A.F. for metals is neglible; (USEPA,1989,"Supplemental Risk Assessment Guidance", EPA/901/5-89-001)

(e) The reference dose for chromium VI was used.

(f) The reference dose for manganese is based on total allowable intake (10 mg/day) minus the background intake (5 mg/day). The remaining intake (5mg/day) was normalized for body weight (70 kg) to derive the RfD.

(g) Averaging times of 6 years for chronic doses and 70 years for lifetime doses were used.

na = toxicity value not available

nd = chemical not detected

--- = not calculated due to an absence of data

* EDITED FINAL SUPPLEMENTAL HUMAN HEALTH RISK ASSESSMENT (1998) TABLE B-22

TABLE 2 - 1 Z*

POTENTIAL RISK FROM DERMAL CONTACT OF SURFACE SOILS WITHIN THE SEWAGE SLUDGE AREA BY SITE VISITORS
AVERAGE CONCENTRATIONS USED FOR A CHILD EXPOSURE

ANALYTE	Average Concentration (mg/kg)	Relative Absorption Factor (RAF)	Exposure Dose Chronic (a) (mg/kg/day)	Oral Reference Dose (RfD) (mg/kg/day)	Hazard Quotient (b)	Exposure Dose Lifetime (a) (mg/kg/day)	Oral Slope Factor /(mg/kg/day)	Cancer Risk (c)
Acetone	0.014	0.5	9.6E-08	0.1	9.6E-07	8.2E-09	na	---
Vinyl Chloride	nd	0.5	---	na	---	---	1.9	---
Benzo(a)anthracene	nd	0.05	---	na	---	---	0.73	---
Benzo(a)pyrene	nd	0.05	---	na	---	---	7.3	---
Benzo(b)fluoranthene	nd	0.05	---	na	---	---	0.73	---
Benzo(k)fluoranthene	nd	0.05	---	na	---	---	0.073	---
Chrysene	nd	0.05	---	na	---	---	0.0073	---
Indeno(1,2,3-cd)pyrene	nd	0.05	---	na	---	---	0.73	---
Aluminum	5500	(d)	---	na	---	---	na	---
Arsenic	0.79	(d)	---	0.0003	---	---	1.5	---
Barium	28	(d)	---	0.07	---	---	na	---
Beryllium	0.35	(d)	---	0.002	---	---	na	---
Chromium (e)	6.4	(d)	---	0.005	---	---	na	---
Cobalt	2.9	(d)	---	na	---	---	na	---
Copper	37	(d)	---	na	---	---	na	---
Lead	6.3	(d)	---	na	---	---	na	---
Manganese (f)	110	(d)	---	0.07	---	---	na	---
Mercury	0.13	(d)	---	0.0003	---	---	na	---
Thallium	0.15	(d)	---	0.00008	---	---	na	---
Vanadium	9.2	(d)	---	0.007	---	---	na	---
			Total Hazard Index =		9.6E-07	Total Risk =		---

NOTES:

(a) Calculation for exposure dose :

DERMAL EXPOSURE DOSE	=	Conc. x Conc.	Soil Contact Rate 500 mg/day	x	Exposure Frequency 150 days/yr	x	Exposure Duration 6 years	x	R.A.F. / RAF	Body Weight 15 kg	x	Averaging Time (g) years	x	Conversion Factor 365 days/year x 1E+06 mg/kg

(b) Hazard quotient = chronic exposere dose / RfD

(c) Cancer Risk = lifetime exposure dose x slope factor

(d) R.A.F. for metals is neglible; (USEPA,1989,"Supplemental Risk Assessment Guidance", EPA/901/5-89-001)

(e) The reference dose for chromium VI was used.

(f) The reference dose for manganese is based on total allowable intake (10 mg/day) minus the background intake (5 mg/day). The remaining intake (5mg/day) was normalized for body weight (70 kg) to derive the RfD.

(g) Averaging times of 6 years for chronic doses and 70 years for lifetime doses were used.

na = toxicity value not available

nd = chemical not detected

--- = not calculated due to an absence of data

*** EDITED FINAL SUPPLEMENTAL HUMAN HEALTH RISK ASSESSMENT (1998) TABLE B-23**

TABLE 2 - 1 AA*

POTENTIAL RISK FROM DERMAL CONTACT OF SURFACE SOILS WITHIN THE SEWAGE SLUDGE AREA BY SITE VISITORS
MAXIMUM CONCENTRATIONS USED FOR A CHILD EXPOSURE

ANALYTE	Maximum Concentration (mg/kg)	Relative Absorption Factor (RAF)	Exposure Dose Chronic (a) (mg/kg/day)	Oral Reference Dose (RfD) (mg/kg/day)	Hazard Quotient (b)	Exposure Dose Lifetime (a) (mg/kg/day)	Oral Slope Factor /(mg/kg/day)	Cancer Risk (c)
Acetone	0.023	0.5	1.6E-07	0.1	1.6E-06	1.4E-08	na	---
Vinyl Chloride	nd	0.5	---	na	---	---	1.9	---
Benzo(a)anthracene	nd	0.05	---	na	---	---	0.73	---
Benzo(a)pyrene	nd	0.05	---	na	---	---	7.3	---
Benzo(b)fluoranthene	nd	0.05	---	na	---	---	0.73	---
Benzo(k)fluoranthene	nd	0.05	---	na	---	---	0.073	---
Chrysene	nd	0.05	---	na	---	---	0.0073	---
Indeno(1,2,3-cd)pyrene	nd	0.05	---	na	---	---	0.73	---
Aluminum	6740	(d)	---	na	---	---	na	---
Arsenic	0.86	(d)	---	0.0003	---	---	1.5	---
Barium	58.9	(d)	---	0.07	---	---	na	---
Beryllium	0.4	(d)	---	0.002	---	---	na	---
Chromium (e)	9.8	(d)	---	0.005	---	---	na	---
Cobalt	3.6	(d)	---	na	---	---	na	---
Copper	99.3	(d)	---	na	---	---	na	---
Lead	11.8	(d)	---	na	---	---	na	---
Manganese (f)	135	(d)	---	0.07	---	---	na	---
Mercury	0.28	(d)	---	0.0003	---	---	na	---
Thallium	0.25	(d)	---	0.00008	---	---	na	---
Vanadium	12.1	(d)	---	0.007	---	---	na	---
			Total Hazard Index =		1.6E-06	Total Risk =		---

NOTES:

(a) Calculation for exposure dose :

DERMAL EXPOSURE DOSE	=	Conc. x Conc.	Soil Contact Rate 500 mg/day	x	Exposure Frequency 150 days/yr	x	Exposure Duration 6 years	x	R.A.F. / RAF	Body Weight 15 kg	x	Averaging Time (g) years	x	Conversion Factor 365 days/year x 1E+06 mg/kg

(b) Hazard quotient = chronic exposere dose / RfD

(c) Cancer Risk = lifetime exposure dose x slope factor

(d) R.A.F. for metals is neglible; (USEPA,1989,"Supplemental Risk Assessment Guidance", EPA/901/5-89-001)

(e) The reference dose for chromium VI was used.

(f) The reference dose for manganese is based on total allowable intake (10 mg/day) minus the background intake (5 mg/day). The remaining intake (5mg/day) was normalized for body weight (70 kg) to derive the RfD.

(g) Averaging times of 6 years for chronic doses and 70 years for lifetime doses were used.

na = toxicity value not available

nd = chemical not detected

--- = not calculated due to an absence of data

*** EDITED FINAL SUPPLEMENTAL HUMAN HEALTH RISK ASSESSMENT (1998) TABLE B-24**

TABLE 2 - 1 AB*

POTENTIAL RISK FROM DERMAL ABSORPTION OF LEACHATE WITHIN THE SOLID WASTE AREA FOR SITE VISITORS
AVERAGE CONCENTRATIONS USED FOR AN ADULT EXPOSURE (a)

ANALYTE	Average Concentration (ug/L)	Dermal Permeability Constant (b)	Exposure Dose Chronic (c) (mg/kg/day)	Oral Reference Dose (RfD) (mg/kg/day)	Hazard Quotient (d)		Exposure Dose Lifetime (c) (mg/kg/day)	Oral Slope Factor /(mg/kg/day)	Cancer Risk (e)
Chloroethane	nd	8.0E-03	---	na	---		---	na	---
1,2-Dichloroethene (f)	44	1.0E-02	3.9E-06	0.01	3.9E-04		3.89E-07	na	---
bis(2-Ethylhexyl)phthalate	nd	3.3E-02	---	0.02	---		---	0.014	---
Aluminum	60500	1.0E-03	5.3E-04	na	---		5.35E-05	na	---
Arsenic	3.7	1.0E-03	3.3E-08	0.0003	1.1E-04		3.27E-09	1.5	4.9E-09
Barium	328	1.0E-03	2.9E-06	0.07	4.1E-05		2.90E-07	na	---
Beryllium	11.2	1.0E-03	9.9E-08	0.002	5.0E-05		9.90E-09	na	---
Chromium (g)	23.9	1.0E-03	2.1E-07	0.005	4.2E-05		2.11E-08	na	---
Cobalt	nd	1.0E-03	---	na	---		---	na	---
Copper	37.8	1.0E-03	3.3E-07	na	---		3.34E-08	na	---
Lead	150	1.0E-03	1.3E-06	na	---		1.33E-07	na	---
Manganese (h)	814	1.0E-03	7.2E-06	0.024	3.0E-04		7.20E-07	na	---
Vanadium	49.8	1.0E-03	4.4E-07	0.007	6.3E-05		4.40E-08	na	---
Ammonia	nd	1.0E-03	---	na	---		---	na	---
			Total Hazard Index =		9.9E-04			Total Risk =	4.9E-09

NOTES:

(a) Tables 2-1AB and 2-1AC are the same because there is only one leachate sample at this location.

(b) Source: EPA, 1992, "Dermal Exposure Assessment: Principles and Applications", EPA/600/8-91/011B

(c) Calculation for exposure dose:

DERMAL =	Conc.	x Dermal x	Skin Surface	x Exposure	x Exposure	x Exposure	/ Body	x Averaging		Conversion
EXPOSURE		Perm. Const.	Area	Time	Frequency	Duration	Weight	Time	x	Factor
DOSE	Conc.	Kp (b)	1,800	1	104	7	58	(i) x 365	x	1E+06
		cm/hour	sq. cm	hr/day	days/yr	years	kg	years days/yr		cm^3-ug/mg-L

(d) Hazard quotient = chronic exposure dose / RfD

(e) Cancer risk = lifetime exposure dose x slope factor

(f) Dose-response data for cis-1,2-DCE and DPC for trans-1,2-DCE was used.

(g) Reference Dose for chromium VI used.

(h) The reference dose for manganese is based on total allowable intake (10 mg/day) minus the background intake (5 mg/day). The remaining intake (5 mg/day) was normalized for body weight (70 kg) and an additional uncertainty factor of 3 applied for water exposures.

(i) Averaging times of 7 years for chronic doses and 70 years for lifetime doses were used

nd = chemical not detected

na = toxicity value not available

--- = not calculated due to absence of data

*** EDITED FINAL SUPPLEMENTAL HUMAN HEALTH RISK ASSESSMENT (1998) TABLE B-25**

TABLE 2 - 1 AC*

POTENTIAL RISK FROM DERMAL ABSORPTION OF LEACHATE WITHIN THE SOLID WASTE AREA FOR SITE VISITORS
MAXIMUM CONCENTRATIONS USED FOR AN ADULT EXPOSURE (a)

ANALYTE	Maximum Concentration (ug/L)	Dermal Permeability Constant (b)	Exposure Dose Chronic (c) (mg/kg/day)	Oral Reference Dose (RfD) (mg/kg/day)	Hazard Quotient (d)	Exposure Dose Lifetime (c) (mg/kg/day)	Oral Slope Factor /(mg/kg/day)	Cancer Risk (e)
Chloroethane	nd	8.0E-03	---	na	---	---	na	---
1,2-Dichloroethene (f)	44	1.0E-02	3.9E-06	0.01	3.9E-04	3.89E-07	na	---
bis(2-Ethylhexyl)phthalate	nd	3.3E-02	---	0.02	---	---	0.014	---
Aluminum	60500	1.0E-03	5.3E-04	na	---	5.35E-05	na	---
Arsenic	3.7	1.0E-03	3.3E-08	0.0003	1.1E-04	3.27E-09	1.5	4.9E-09
Barium	328	1.0E-03	2.9E-06	0.07	4.1E-05	2.90E-07	na	---
Beryllium	11.2	1.0E-03	9.9E-08	0.002	5.0E-05	9.90E-09	na	---
Chromium (g)	23.9	1.0E-03	2.1E-07	0.005	4.2E-05	2.11E-08	na	---
Cobalt	nd	1.0E-03	---	na	---	---	na	---
Copper	37.8	1.0E-03	3.3E-07	na	---	3.34E-08	na	---
Lead	150	1.0E-03	1.3E-06	na	---	1.33E-07	na	---
Manganese (h)	814	1.0E-03	7.2E-06	0.024	3.0E-04	7.20E-07	na	---
Vanadium	49.8	1.0E-03	4.4E-07	0.007	6.3E-05	4.40E-08	na	---
Ammonia	nd	1.0E-03	---	na	---	---	na	---
			Total Hazard Index =		9.9E-04		Total Risk =	4.9E-09

NOTES:

(a) Tables 2-1AB and 2-1AC are the same because there is only one leachate sample at this location.

(b) Source: EPA, 1992, "Dermal Exposure Assessment: Principles and Applications", EPA/600/8-91/011B

(c) Calculation for exposure dose:

DERMAL EXPOSURE DOSE	=	Conc. Conc.	x Dermal Perm. Const. Kp (b) cm/hour	x Skin Surface Area 1,800 sq. cm	x Exposure Time 1 hr/day	x Exposure Frequency 104 days/yr	x Exposure Duration 30 years	/ Body Weight 70 kg	x Averaging Time (i) years	x 365 days/yr	x Conversion Factor 1E+06 cm^3-ug/mg-L

(d) Hazard quotient = chronic exposure dose / RfD

(e) Cancer risk = lifetime exposure dose x slope factor

(f) Dose-response data for cis-1,2-DCE and DPC for trans-1,2-DCE was used.

(g) Reference Dose for chromium VI used.

(h) The reference dose for manganese is based on total allowable intake (10 mg/day) minus the background intake (5 mg/day).
The remaining intake (5 mg/day) was normalized for body weight (70 kg) and an additional uncertainty factor of 3 applied for water exposures.

(i) Averaging times of 7 years for chronic doses and 70 years for lifetime doses were used

nd = chemical not detected
na = toxicity value not available
--- = not calculated due to absence of data

* EDITED FINAL SUPPLEMENTAL HUMAN HEALTH RISK ASSESSMENT (1998) TABLE B-26

TABLE 2 - 1 AD*

POTENTIAL RISK FROM DERMAL ABSORPTION OF LEACHATE WITHIN THE BULKY WASTE AREA FOR SITE VISITORS
AVERAGE CONCENTRATIONS USED FOR AN ADULT EXPOSURE

ANALYTE	Average Concentration (ug/L)	Dermal Permeability Constant (a)	Exposure Dose Chronic (b) (mg/kg/day)	Oral Reference Dose (RfD) (mg/kg/day)	Hazard Quotient (c)		Exposure Dose Lifetime (b) (mg/kg/day)	Oral Slope Factor /(mg/kg/day)	Cancer Risk (d)
Chloroethane	5.7	8.0E-03	---	na	---		---	na	---
1,2-Dichloroethene (e)	1	1.0E-02	8.8E-08	0.01	8.8E-06		8.84E-09	na	---
bis(2-Ethylhexyl)phthalate	50	3.3E-02	---	0.02	---		---	0.014	---
Aluminum	2100	1.0E-03	1.9E-05	na	---		1.86E-06	na	---
Arsenic	nd	1.0E-03	---	0.0003	---		---	1.5	---
Barium	510	1.0E-03	4.5E-06	0.07	6.4E-05		4.51E-07	na	---
Beryllium	2.2	1.0E-03	1.9E-08	0.002	9.7E-06		1.95E-09	na	---
Chromium (f)	2.4	1.0E-03	2.1E-08	0.005	4.2E-06		2.12E-09	na	---
Cobalt	63	1.0E-03	---	na	---		---	na	---
Copper	nd	1.0E-03	---	na	---		---	na	---
Lead	37	1.0E-03	3.3E-07	na	---		3.27E-08	na	---
Manganese (g)	8200	1.0E-03	7.3E-05	0.024	3.0E-03		7.25E-06	na	---
Vanadium	15	1.0E-03	1.3E-07	0.007	1.9E-05		1.33E-08	na	---
Ammonia	13000	1.0E-03	---	na	---		---	na	---
			Total Hazard Index =		3.1E-03			*Total Risk =*	---

NOTES:

(a) Source: EPA, 1992, "Dermal Exposure Assessment: Principles and Applications", EPA/600/8-91/011B

(b) Calculation for exposure dose:

DERMAL =	Conc.	x Dermal	x Skin Surface	x Exposure	x Exposure	x Exposure	/	Body	x Averaging		Conversion
EXPOSURE		Perm. Const.	Area	Time	Frequency	Duration		Weight	Time		x Factor
DOSE	Conc.	Kp	1,800	1	104	7		58	(h) x	365	x 1E+06
		cm/hour	sq. cm	hr/day	days/yr	years		kg	years	days/yr	cm^3-ug/mg-L

(c) Hazard quotient = chronic exposure dose / RfD

(d) Cancer risk = lifetime exposure dose x slope factor

(e) Dose-response data for cis-1,2-DCE and DPC for trans-1,2-DCE was used.

(f) Reference Dose for chromium VI used.

(g) The reference dose for manganese is based on total allowable intake (10 mg/day) minus the background intake (5 mg/day).
The remaining intake (5 mg/day) was normalized for body weight (70 kg) and an additional uncertainty factor of 3 applied for water exposures.

(h) Averaging times of 7 years for chronic doses and 70 years for lifetime doses were used

nd = chemical not detected

na = toxicity value not available

--- = not calculated due to absence of data

*** EDITED FINAL SUPPLEMENTAL HUMAN HEALTH RISK ASSESSMENT (1998) TABLE B-27**

TABLE 2 - 1 AE*

POTENTIAL RISK FROM DERMAL ABSORPTION OF LEACHATE WITHIN THE BULKY WASTE AREA FOR SITE VISITORS
MAXIMUM CONCENTRATIONS USED FOR AN ADULT EXPOSURE

ANALYTE	Maximum Concentration (ug/L)	Dermal Permeability Constant (a)	Exposure Dose Chronic (b) (mg/kg/day)	Oral Reference Dose (RfD) (mg/kg/day)	Hazard Quotient (c)		Exposure Dose Lifetime (b) (mg/kg/day)	Oral Slope Factor /(mg/kg/day)	Cancer Risk (d)
Chloroethane	8	8.0E-03	---	na	---		---	na	---
1,2-Dichloroethene (e)	1	1.0E-02	8.8E-08	0.01	8.8E-06		8.84E-09	na	---
bis(2-Ethylhexyl)phthalate	230	3.3E-02	---	0.02	---		---	0.014	---
Aluminum	9220	1.0E-03	8.2E-05	na	---		8.15E-06	na	---
Arsenic	nd	1.0E-03	---	0.0003	---		---	1.5	---
Barium	2120	1.0E-03	1.9E-05	0.07	2.7E-04		1.87E-06	na	---
Beryllium	8.7	1.0E-03	7.7E-08	0.002	3.8E-05		7.69E-09	na	---
Chromium (f)	5	1.0E-03	4.4E-08	0.005	8.8E-06		4.42E-09	na	---
Cobalt	295	1.0E-03	---	na	---		---	na	---
Copper	nd	1.0E-03	---	na	---		---	na	---
Lead	174	1.0E-03	1.5E-06	na	---		1.54E-07	na	---
Manganese (g)	14700	1.0E-03	1.3E-04	0.024	5.4E-03		1.30E-05	na	---
Vanadium	65.2	1.0E-03	5.8E-07	0.007	8.2E-05		5.77E-08	na	---
Ammonia	21800	1.0E-03	---	na	---		---	na	---
			Total Hazard Index =		5.8E-03		Total Risk =		---

NOTES:

(a) Source: EPA, 1992, "Dermal Exposure Assessment: Principles and Applications", EPA/600/8-91/011B

(b) Calculation for exposure dose:

DERMAL =	Conc.	x Dermal x	Skin Surface	x Exposure	x Exposure	x Exposure /	Body	x Averaging		Conversion
EXPOSURE		Perm. Const.	Area	Time	Frequency	Duration	Weight	Time	x	Factor
DOSE	Conc.	Kp	1,800	1	104	7	58	(h) x 365	x	1E+06
		cm/hour	sq. cm	hr/day	days/yr	years	kg	years days/yr		cm^3-ug/mg-L

(c) Hazard quotient = chronic exposure dose / RfD

(d) Cancer risk = lifetime exposure dose x slope factor

(e) Dose-response data for cis-1,2-DCE and DPC for trans-1,2-DCE was used.

(f) Reference Dose for chromium VI used.

(g) The reference dose for manganese is based on total allowable intake (10 mg/day) minus the background intake (5 mg/day).
The remaining intake (5 mg/day) was normalized for body weight (70 kg) and an additional uncertainty factor of 3 applied for water exposures.

(h) Averaging times of 7 years for chronic doses and 70 years for lifetime doses were used

nd = chemical not detected

na = toxicity value not available

--- = not calculated due to absence of data

*** EDITED FINAL SUPPLEMENTAL HUMAN HEALTH RISK ASSESSMENT (1998) TABLE B-28**

TABLE 2 - 1 AF*
POTENTIAL RISK FROM DERMAL ABSORPTION OF LEACHATE WITHIN THE SOLID WASTE AREA FOR SITE VISITORS
AVERAGE CONCENTRATIONS USED FOR AN ADOLESCENT EXPOSURE (a)

ANALYTE	Average Concentration (ug/L)	Dermal Permeability Constant (b)	Exposure Dose Chronic (c) (mg/kg/day)	Oral Reference Dose (RfD) (mg/kg/day)	Hazard Quotient (d)	Exposure Dose Lifetime (c) (mg/kg/day)	Oral Slope Factor /(mg/kg/day)	Cancer Risk (e)
Chloroethane	nd	8.0E-03	---	na	---	---	na	---
1,2-Dichloroethene (f)	44	1.0E-02	3.2E-06	0.01	3.2E-04	1.38E-06	na	---
bis(2-Ethylhexyl)phthalate	nd	3.3E-02	---	0.02	---	---	0.014	---
Aluminum	60500	1.0E-03	4.4E-04	na	---	1.90E-04	na	---
Arsenic	3.7	1.0E-03	2.7E-08	0.0003	9.0E-05	1.16E-08	1.5	1.7E-08
Barium	328	1.0E-03	2.4E-06	0.07	3.4E-05	1.03E-06	na	---
Beryllium	11.2	1.0E-03	8.2E-08	0.002	4.1E-05	3.52E-08	na	---
Chromium (g)	23.9	1.0E-03	1.8E-07	0.005	3.5E-05	7.50E-08	na	---
Cobalt	nd	1.0E-03	---	na	---	---	na	---
Copper	37.8	1.0E-03	2.8E-07	na	---	1.19E-07	na	---
Lead	150	1.0E-03	1.1E-06	na	---	4.71E-07	na	---
Manganese (h)	814	1.0E-03	6.0E-06	0.024	2.5E-04	2.56E-06	na	---
Vanadium	49.8	1.0E-03	3.6E-07	0.007	5.2E-05	1.56E-07	na	---
Ammonia	nd	1.0E-03	---	na	---	---	na	---
			Total Hazard Index =		8.2E-04		Total Risk =	1.7E-08

NOTES:
(a) Tables 2-1AF and 2-1AG are the same because there is only one leachate sample at this location.
(b) Source: EPA, 1992, "Dermal Exposure Assessment: Principles and Applications", EPA/600/8-91/011B
(c) Calculation for exposure dose:

DERMAL EXPOSURE DOSE	=	Conc. Conc.	x Dermal Perm. Const. Kp cm/hour	x Skin Surface Area 1,800 sq. cm	x Exposure Time 1 hr/day	x Exposure Frequency 104 days/yr	x Exposure Duration 30 years	/	Body Weight 70 kg	x Averaging Time (i) years	x 365 days/yr	x Conversion Factor 1E+06 cm^3-ug/mg-L

(d) Hazard quotient = chronic exposure dose / RfD
(e) Cancer risk = lifetime exposure dose x slope factor
(f) Dose-response data for cis-1,2-DCE and DPC for trans-1,2-DCE were used.
(g) Reference Dose for chromium VI used.
(h) The reference dose for manganese is based on total allowable intake (10 mg/day) minus the background intake (5 mg/day).
The remaining intake (5 mg/day) was normalized for body weight (70 kg) and an additional uncertainty factor of 3 applied for water exposures.
(i) Averaging times of 30 years for chronic doses and 70 years for lifetime doses were used

nd = chemical not detected
na = toxicity value not available
--- = not calculated due to absence of data

*** EDITED FINAL SUPPLEMENTAL HUMAN HEALTH RISK ASSESSMENT (1998) TABLE B-29**

TABLE 2 - 1 AG*

POTENTIAL RISK FROM DERMAL ABSORPTION OF LEACHATE WITHIN THE SOLID WASTE AREA FOR SITE VISITORS
MAXIMUM CONCENTRATIONS USED FOR AN ADOLESCENT EXPOSURE (a)

ANALYTE	Maximum Concentration (ug/L)	Dermal Permeability Constant (b)	Exposure Dose Chronic (c) (mg/kg/day)	Oral Reference Dose (RfD) (mg/kg/day)	Hazard Quotient (d)	Exposure Dose Lifetime (c) (mg/kg/day)	Oral Slope Factor /(mg/kg/day)	Cancer Risk (e)
Chloroethane	nd	8.0E-03	---	na	---	---	na	---
1,2-Dichloroethene (f)	44	1.0E-02	3.2E-06	0.01	3.2E-04	1.38E-06	na	---
bis(2-Ethylhexyl)phthalate	nd	3.3E-02	---	0.02	---	---	0.014	---
Aluminum	60500	1.0E-03	4.4E-04	na	---	1.90E-04	na	---
Arsenic	3.7	1.0E-03	2.7E-08	0.0003	9.0E-05	1.16E-08	1.5	1.7E-08
Barium	328	1.0E-03	2.4E-06	0.07	3.4E-05	1.03E-06	na	---
Beryllium	11.2	1.0E-03	8.2E-08	0.002	4.1E-05	3.52E-08	na	---
Chromium (g)	23.9	1.0E-03	1.8E-07	0.005	3.5E-05	7.50E-08	na	---
Cobalt	nd	1.0E-03	---	na	---	---	na	---
Copper	37.8	1.0E-03	2.8E-07	na	---	1.19E-07	na	---
Lead	150	1.0E-03	1.1E-06	na	---	4.71E-07	na	---
Manganese (h)	814	1.0E-03	6.0E-06	0.024	2.5E-04	2.56E-06	na	---
Vanadium	49.8	1.0E-03	3.6E-07	0.007	5.2E-05	1.56E-07	na	---
Ammonia	nd	1.0E-03	---	na	---	---	na	---
			Total Hazard Index =		8.2E-04		Total Risk =	1.7E-08

NOTES:

(a) Tables 2-1AF and 2-1AG are the same because there is only one leachate sample at this location.

(b) Source: EPA, 1992, "Dermal Exposure Assessment: Principles and Applications", EPA/600/8-91/011B

(c) Calculation for exposure dose:

DERMAL =	Conc.	x Dermal	x Skin Surface	x Exposure	x Exposure	x Exposure	/	Body	x Averaging			Conversion
EXPOSURE		Perm. Const.	Area	Time	Frequency	Duration		Weight	Time		x	Factor
DOSE	Conc.	Kp	1,800	1	104	30		70	(i)	x 365	x	1E+06
		cm/hour	sq. cm	hr/day	days/yr	years		kg	years	days/yr		cm^3-ug/mg-L

(d) Hazard quotient = chronic exposure dose / RfD

(e) Cancer risk = lifetime exposure dose x slope factor

(f) Dose-response data for cis-1,2-DCE and DPC for trans-1,2-DCE were used.

(g) Reference Dose for chromium VI used.

(h) The reference dose for manganese is based on total allowable intake (10 mg/day) minus the background intake (5 mg/day).
The remaining intake (5 mg/day) was normalized for body weight (70 kg) and an additional uncertainty factor of 3 applied for water exposures.

(i) Averaging times of 30 years for chronic doses and 70 years for lifetime doses were used

nd = chemical not detected

na = toxicity value not available

--- = not calculated due to absence of data

*** EDITED FINAL SUPPLEMENTAL HUMAN HEALTH RISK ASSESSMENT (1998) TABLE B-30**

TABLE 2 - 1 AH*

POTENTIAL RISK FROM DERMAL ABSORPTION OF LEACHATE WITHIN THE BULKY WASTE AREA FOR SITE VISITORS

AVERAGE CONCENTRATIONS USED FOR AN ADOLESCENT EXPOSURE

ANALYTE	Average Concentration (ug/L)	Dermal Permeability Constant (a)	Exposure Dose Chronic (b) (mg/kg/day)	Oral Reference Dose (RfD) (mg/kg/day)	Hazard Quotient (c)	Exposure Dose Lifetime (b) (mg/kg/day)	Oral Slope Factor /(mg/kg/day)	Cancer Risk (d)
Chloroethane	5.7	8.0E-03	---	na	---	---	na	---
1,2-Dichloroethene (e)	1	1.0E-02	7.3E-08	0.01	7.3E-06	3.14E-08	na	---
bis(2-Ethylhexyl)phthalate	50	3.3E-02	---	0.02	---	---	0.014	---
Aluminum	2100	1.0E-03	1.5E-05	na	---	6.59E-06	na	---
Arsenic	nd	1.0E-03	---	0.0003	---	---	1.5	---
Barium	510	1.0E-03	3.7E-06	0.07	5.3E-05	1.60E-06	na	---
Beryllium	2.2	1.0E-03	1.6E-08	0.002	8.1E-06	6.91E-09	na	---
Chromium (f)	2.4	1.0E-03	1.8E-08	0.005	3.5E-06	7.54E-09	na	---
Cobalt	63	1.0E-03	---	na	---	---	na	---
Copper	nd	1.0E-03	---	na	---	---	na	---
Lead	37	1.0E-03	2.7E-07	na	---	1.16E-07	na	---
Manganese (g)	8200	1.0E-03	6.0E-05	0.024	2.5E-03	2.57E-05	na	---
Vanadium	15	1.0E-03	1.1E-07	0.007	1.6E-05	4.71E-08	na	---
Ammonia	13000	1.0E-03	---	na	---	---	na	---
			Total Hazard Index =		2.6E-03	Total Risk =		---

NOTES:

(a) Source: EPA, 1992, "Dermal Exposure Assessment: Principles and Applications", EPA/600/8-91/011B

(b) Calculation for exposure dose:

DERMAL EXPOSURE DOSE =	Conc.	x Dermal Perm. Const.	x Skin Surface Area	x Exposure Time	x Exposure Frequency	x Exposure Duration	/ Body Weight	x Averaging Time		Conversion Factor
	Conc.	Kp	1,800	1	104	30	70	(h)	x 365	x 1E+06
		cm/hour	sq. cm	hr/day	days/yr	years	kg	years	days/yr	cm^3-ug/mg-L

(c) Hazard quotient = chronic exposure dose / RfD

(d) Cancer risk = lifetime exposure dose x slope factor

(e) Dose-response data for cis-1,2-DCE and DPC for trans-1,2-DCE were used.

(f) Reference Dose for chromium VI used.

(g) The reference dose for manganese is based on total allowable intake (10 mg/day) minus the background intake (5 mg/day). The remaining intake (5 mg/day) was normalized for body weight (70 kg) and an additional uncertainty factor of 3 applied for water exposures.

(h) Averaging times of 30 years for chronic doses and 70 years for lifetime doses were used

nd = chemical not detected

na = toxicity value not available

--- = not calculated due to absence of data

*** EDITED FINAL SUPPLEMENTAL HUMAN HEALTH RISK ASSESSMENT (1998) TABLE B-31**

TABLE 2 - 1 AI*

POTENTIAL RISK FROM DERMAL ABSORPTION OF LEACHATE WITHIN THE BULKY WASTE AREA FOR SITE VISITORS
MAXIMUM CONCENTRATIONS USED FOR AN ADOLESCENT EXPOSURE

ANALYTE	Maximum Concentration (ug/L)	Dermal Permeability Constant (a)	Exposure Dose Chronic (b) (mg/kg/day)	Oral Reference Dose (RfD) (mg/kg/day)	Hazard Quotient (c)	Exposure Dose Lifetime (b) (mg/kg/day)	Oral Slope Factor /(mg/kg/day)	Cancer Risk (d)
Chloroethane	8	8.0E-03	---	na	---	---	na	---
1,2-Dichloroethene (e)	1	1.0E-02	7.3E-08	0.01	7.3E-06	3.14E-08	na	---
bis(2-Ethylhexyl)phthalate	230	3.3E-02	---	0.02	---	---	0.014	---
Aluminum	9220	1.0E-03	6.8E-05	na	---	2.90E-05	na	---
Arsenic	nd	1.0E-03	---	0.0003	---	---	1.5	---
Barium	2120	1.0E-03	1.6E-05	0.07	2.2E-04	6.66E-06	na	---
Beryllium	8.7	1.0E-03	6.4E-08	0.002	3.2E-05	2.73E-08	na	---
Chromium (f)	5	1.0E-03	3.7E-08	0.005	7.3E-06	1.57E-08	na	---
Cobalt	295	1.0E-03	---	na	---	---	na	---
Copper	nd	1.0E-03	---	na	---	---	na	---
Lead	174	1.0E-03	1.3E-06	na	---	5.46E-07	na	---
Manganese (g)	14700	1.0E-03	1.1E-04	0.024	4.5E-03	4.62E-05	na	---
Vanadium	65.2	1.0E-03	4.8E-07	0.007	6.8E-05	2.05E-07	na	---
Ammonia	21800	1.0E-03	---	na	---	---	na	---
			Total Hazard Index =		4.8E-03	Total Risk =		---

NOTES:

(a) Source: EPA, 1992, "Dermal Exposure Assessment: Principles and Applications", EPA/600/8-91/011B

(b) Calculation for exposure dose:

DERMAL =	Conc.	x Dermal x	Skin Surface	x Exposure	x Exposure	x Exposure /	Body	x Averaging		Conversion
EXPOSURE		Perm. Const.	Area	Time	Frequency	Duration	Weight	Time		x Factor
DOSE	Conc.	Kp	1,800	1	104	30	70	(h)	x 365	x 1E+06
		cm/hour	sq. cm	hr/day	days/yr	years	kg	years	days/yr	cm^3-ug/mg-L

(c) Hazard quotient = chronic exposure dose / RfD

(d) Cancer risk = lifetime exposure dose x slope factor

(e) Dose-response data for cis-1,2-DCE and DPC for trans-1,2-DCE were used.

(f) Reference Dose for chromium VI used.

(g) The reference dose for manganese is based on total allowable intake (10 mg/day) minus the background intake (5 mg/day).
The remaining intake (5 mg/day) was normalized for body weight (70 kg) and an additional uncertainty factor of 3 applied for water exposures.

(h) Averaging times of 30 years for chronic doses and 70 years for lifetime doses were used

nd = chemical not detected

na = toxicity value not available

--- = not calculated due to absence of data

* EDITED FINAL SUPPLEMENTAL HUMAN HEALTH RISK ASSESSMENT (1998) TABLE B-32

TABLE 2 - 1 AJ*

POTENTIAL RISK FROM INGESTION OF SITE GROUNDWATER WITHIN THE SOLID WASTE AREA (AS DRINKING WATER)

AVERAGE CONCENTRATIONS USED FOR AN ADULT EXPOSURE (a)

Analyte	Average Concentration (ug/L)	Exposure Dose Chronic (b) (mg/kg/day)	Oral Reference Dose (RfD) (mg/kg/day)	Hazard Quotient (c)		Exposure Dose Lifetime (b) (mg/kg/day)	Oral Slope Factor /(mg/kg/day)	Cancer Risk (d)
Benzene	11	3.0E-04	na	---		1.3E-04	0.029	3.7E-06
1,1-Dichloroethane	14	3.8E-04	0.1	3.8E-03		1.6E-04	na	---
1,2-Dichloroethene (e)	34	9.3E-04	0.01	9.3E-02		4.0E-04	na	---
Vinyl Chloride	34	9.3E-04	na	---		4.0E-04	1.9	7.6E-04
Pentachlorophenol	3	8.2E-05	0.03	2.7E-03		3.5E-05	0.12	4.2E-06
bis(2-Ethylhexyl)phthalate	5.6	1.5E-04	0.02	7.7E-03		6.6E-05	0.014	9.2E-07
Acrylamide	160	4.4E-03	0.0002	2.2E+01		1.9E-03	4.5	8.5E-03
N,N-DMF	200	5.5E-03	0.1	5.5E-02		2.3E-03	na	---
Antimony	nd	---	0.0004	---		---	na	---
Arsenic	2.7	7.4E-05	0.0003	2.5E-01		3.2E-05	1.5	4.8E-05
Barium	170	4.7E-03	0.07	6.7E-02		2.0E-03	na	---
Beryllium	1.7	4.7E-05	0.002	2.3E-02		2.0E-05	na	---
Cadmium (f)	4.4	1.2E-04	0.0005	2.4E-01		5.2E-05	na	---
Chromium (e)	24	6.6E-04	0.005	1.3E-01		2.8E-04	na	---
Manganese (h)	1900	5.2E-02	0.024	2.2E+00		2.2E-02	na	---
Nickel	26	7.1E-04	0.02	3.6E-02		3.1E-04	na	---
Vanadium	21	5.8E-04	0.007	8.2E-02		2.5E-04	na	---
Zinc	680	1.9E-02	0.3	6.2E-02		8.0E-03	na	---
		Total Hazard Index =		2.5E+01		Total Risk =		9.3E-03
		Hazard Index (liver toxins)=		0.07				
		Hazard Index (nervous system toxins)=		24.09				
		Hazard Index (kidney toxins)=		0.24				
		Hazard Index (red blood cell effects) -		0.16				

NOTES:

(a) This table does not include groundwater chemicals of concern for which no reference dose or slope factor exists.
(chloroethane,2-methylnapthalene, 4-chloro-3-methylphenol, aluminum, cobalt, copper, lead, sulfide and ammonia)

(b) Calculation for exposure dose :

INGESTION EXPOSURE DOSE	= Conc. x	Ingestion Rate	x Exposure Frequency	x Exposure Duration	/ Body Weight	Averaging Time	x Conversion Factor
	Conc.	2	350	30	70	(g)	365 x 1E+03
		L/day	days/yr	years	kg	years	days/year ug/mg

(c) Hazard quotient = chronic exposure dose / RfD

(d) Cancer Risk = lifetime exposure dose x slope factor

(e) Dose-response data for cis-1,2-dichloroethene and chromium VI were used.

(f) Reference Dose for cadmium in water was used.

(g) Averaging times of 30 years for chronic doses and 70 years for lifetime doses were used.

(h) The reference dose for manganese is based on total allowable intake (10 mg/day) minus the background intake (5 mg/day).
The remaining intake (5 mg/day) was normalized for body weight (70 kg) and an additional uncertainty factor of 3 applied for water exposures.

nd = chemical not detected

na = toxicity value not available

--- = not calculated due to absence of data

*** EDITED FINAL SUPPLEMENTAL HUMAN HEALTH RISK ASSESSMENT (1998) TABLE B-33**

TABLE 2 - 1 AK*

POTENTIAL RISK FROM INGESTION OF SITE GROUNDWATER WITHIN THE SOLID WASTE AREA (AS DRINKING WATER)

MAXIMUM CONCENTRATIONS USED FOR AN ADULT EXPOSURE (a)

Analyte	Maximum Concentration (ug/L)	Exposure Dose Chronic (b) (mg/kg/day)	Oral Reference Dose (RfD) (mg/kg/day)	Hazard Quotient (c)		Exposure Dose Lifetime (b) (mg/kg/day)	Oral Slope Factor /(mg/kg/day)	Cancer Risk (d)
Benzene	31	8.5E-04	na	---		3.6E-04	0.029	1.1E-05
1,1-Dichloroethane	220	6.0E-03	0.1	---		2.6E-03	na	---
1,2-Dichloroethene (e)	730	2.0E-02	0.01	2.0E+00		8.6E-03	na	---
Vinyl Chloride	690	1.9E-02	na	---		8.1E-03	1.9	1.5E-02
Pentachlorophenol	3	8.2E-05	0.03	2.7E-03		3.5E-05	0.12	4.2E-06
bis(2-Ethylhexyl)phthalate	36	9.9E-04	0.02	4.9E-02		4.2E-04	0.014	5.9E-06
Acrylamide	229	6.3E-03	0.0002	3.1E+01		2.7E-03	4.5	1.2E-02
N,N-DMF	1440	3.9E-02	0.1	3.9E-01		1.7E-02	na	---
Antimony	nd	---	0.0004	---		---	na	---
Arsenic	9.7	2.7E-04	0.0003	8.9E-01		1.1E-04	1.5	1.7E-04
Barium	508	1.4E-02	0.07	2.0E-01		6.0E-03	na	---
Beryllium	13.7	3.8E-04	0.002	1.9E-01		1.6E-04	na	---
Cadmium (f)	40	1.1E-03	0.0005	2.2E+00		4.7E-04	na	---
Chromium (e)	154	4.2E-03	0.005	8.4E-01		1.8E-03	na	---
Manganese (h)	9790	2.7E-01	0.024	1.1E+01		1.1E-01	na	---
Nickel	125	3.4E-03	0.02	1.7E-01		1.5E-03	na	---
Vanadium	142	3.9E-03	0.007	5.6E-01		1.7E-03	na	---
Zinc	7360	2.0E-01	0.3	6.7E-01		8.6E-02	na	---
		Total Hazard Index =		5.1E+01		Total Risk =		2.8E-02
		Hazard Index (liver toxins)=		0.45				
		Hazard Index (nervous system toxins)=		42.55				
		Hazard Index (kidney toxins)=		2.19				
		Hazard Index (red blood cell effects)=		2.67				

NOTES:

(a) This table does not include groundwater chemicals of concern for which no reference dose or slope factor exists. (chloroethane,2-methylnapthalene, 4-chloro-3-methylphenol, aluminum, cobalt, copper, lead, sulfide and ammonia)

(b) Calculation for exposure dose :

INGESTION EXPOSURE DOSE	= Conc. x Conc.	Ingestion Rate 2 L/day	x Exposure Frequency 350 days/yr	x Exposure Duration 30 years	/ Body Weight 70 kg	Averaging Time (g) years	x	Conversion Factor 365 days/year	x 1E+03 ug/mg

(c) Hazard quotient = chronic exposure dose / RfD

(d) Cancer Risk = lifetime exposure dose x slope factor

(e) Dose-response data for cis-1,2-dichloroethene and chromium VI were used.

(f) Reference Dose for cadmium in water was used.

(g) Averaging times of 30 years for chronic doses and 70 years for lifetime doses were used.

(h) The reference dose for manganese is based on total allowable intake (10 mg/day) minus the background intake (5 mg/day). The remaining intake (5 mg/day) was normalized for body weight (70 kg) and an additional uncertainty factor of 3 applied for water exposures.

nd = chemical not detected

na = toxicity value not available

--- = not calculated due to absence of data

* EDITED FINAL SUPPLEMENTAL HUMAN HEALTH RISK ASSESSMENT (1998) TABLE B-34

TABLE 2-1 AL*
POTENTIAL RISK OF INGESTION OF SITE GROUNDWATER WITHIN THE BULKY WASTE AREA (AS DRINKING WATER)
AVERAGE CONCENTRATIONS USED FOR AN ADULT EXPOSURE (a)

Analyte	Average Concentration (ug/L)	Exposure Dose Chronic (b) (mg/kg/day)	Oral Reference Dose (RfD) (mg/kg/day)	Hazard Quotient (c)		Exposure Dose Lifetime (b) (mg/kg/day)	Oral Slope Factor /(mg/kg/day)	Cancer Risk (d)
Benzene	1	2.7E-05	na	---		1.2E-05	0.029	3.4E-07
1,1-Dichloroethane	5	1.4E-04	0.1	1.4E-03		5.9E-05	na	---
1,2-Dichloroethene (e)	5	1.4E-04	0.01	1.4E-02		5.9E-05	na	---
Vinyl Chloride	nd	---	na	---		---	1.9	---
Pentachlorophenol	nd	---	0.03	---		---	0.12	---
bis(2-Ethylhexyl)phthalate	nd	---	0.02	---		---	0.014	---
Acrylamide	nd	---	0.0002	---		---	4.5	---
N,N-DMF	33	9.0E-04	0.1	9.0E-03		3.9E-04	na	---
Antimony	19	5.2E-04	0.0004	1.3E+00		2.2E-04	na	---
Arsenic	0.84	2.3E-05	0.0003	7.7E-02		9.9E-06	1.5	1.5E-05
Barium	81	2.2E-03	0.07	---		9.5E-04	na	---
Beryllium	2	5.5E-05	0.002	2.7E-02		2.3E-05	na	---
Cadmium (f)	nd	---	0.0005	---		---	na	---
Chromium (e)	9.9	2.7E-04	0.005	5.4E-02		1.2E-04	na	---
Manganese (h)	1600	4.4E-02	0.024	1.8E+00		1.9E-02	na	---
Nickel	13	3.6E-04	0.02	1.8E-02		1.5E-04	na	---
Vanadium	15	4.1E-04	0.007	5.9E-02		1.8E-04	na	---
Zinc	61	1.7E-03	0.3	5.6E-03		7.2E-04	na	---
		Total Hazard Index =		3.4E+00		Total Risk =		1.5E-05
		Hazard Index (liver toxins)=		0.01				
		Hazard Index (nervous system toxins)=		1.83				
		Hazard Index (kidney toxins)=		0.00				
		Hazard Index (red blood cell effects)=		0.02				
		Hazard Index (longevity)=		1.30				

NOTES:
(a) This table does not include groundwater chemicals of concern for which no reference dose or slope factor exists.
(chloroethane,2-methylnapthalene, 4-chloro-3-methylphenol, aluminum, cobalt, copper, lead, sulfide and ammonia)
(b) Calculation for exposure dose :

INGESTION EXPOSURE DOSE	= Conc.	x	Ingestion Rate	x Exposure Frequency	x Exposure Duration	/	Body Weight	Averaging Time	x	Conversion Factor
	Conc.		2	350	30		70	(g)		365 x 1E+03
			L/day	days/yr	years		kg	years		days/year ug/mg

(c) Hazard quotient = chronic exposure dose / RfD
(d) Cancer Risk = lifetime exposure dose x slope factor
(e) Dose-response data for cis-1,2-dichloroethene and chromium VI were used.
(f) Reference Dose for cadmium in water was used.
(g) Averaging times of 30 years for chronic doses and 70 years for lifetime doses were used.
(h) The reference dose for manganese is based on total allowable intake (10 mg/day) minus the background intake (5 mg/day).
The remaining intake (5 mg/day) was normalized for body weight (70 kg) and an additional uncertainty factor of 3 applied for water exposures.

nd = chemical not detected
na = toxicity value not available
--- = not calculated due to absence of data

*** EDITED FINAL SUPPLEMENTAL HUMAN HEALTH RISK ASSESSMENT (1998) TABLE B-35**

TABLE 2 - 1 AM^

POTENTIAL RISK OF INGESTION OF SITE GROUNDWATER WITHIN THE BULKY WASTE AREA (AS DRINKING WATER)

MAXIMUM CONCENTRATIONS USED FOR AN ADULT EXPOSURE (a)

Analyte	Maximum Concentration (ug/L)	Exposure Dose Chronic (b) (mg/kg/day)	Oral Reference Dose (RfD) (mg/kg/day)	Hazard Quotient (c)		Exposure Dose Lifetime (b) (mg/kg/day)	Oral Slope Factor /(mg/kg/day)	Cancer Risk (d)
Benzene	1	2.7E-05	na	---		1.2E-05	0.029	3.4E-07
1,1-Dichloroethane	5	1.4E-04	0.1	1.4E-03		5.9E-05	na	---
1,2-Dichloroethene (e)	5	1.4E-04	0.01	1.4E-02		5.9E-05	na	---
Vinyl Chloride	nd	---	na	---		---	1.9	---
Pentachlorophenol	nd	---	0.03	---		---	0.12	---
bis(2-Ethylhexyl)phthalate	nd	---	0.02	---		---	0.014	---
Acrylamide	nd	---	0.0002	---		---	4.5	---
N,N-DMF	183	5.0E-03	0.1	5.0E-02		2.1E-03	na	---
Antimony	104.9	2.9E-03	0.0004	7.2E+00		1.2E-03	na	---
Arsenic	2.3	6.3E-05	0.0003	2.1E-01		2.7E-05	1.5	4.1E-05
Barium	430	1.2E-02	0.07	---		5.0E-03	na	---
Beryllium	10.5	2.9E-04	0.002	1.4E-01		1.2E-04	na	---
Cadmium (f)	nd	---	0.0005	---		---	na	---
Chromium (e)	66.6	1.8E-03	0.005	3.6E-01		7.8E-04	na	---
Manganese (h)	9995	2.7E-01	0.024	1.1E+01		1.2E-01	na	---
Nickel	71.3	2.0E-03	0.02	9.8E-02		8.4E-04	na	---
Vanadium	91	2.5E-03	0.007	3.6E-01		1.1E-03	na	---
Zinc	215	5.9E-03	0.3	2.0E-02		2.5E-03	na	---
		Total Hazard Index =		2.0E+01		Total Risk =		4.1E-05
		Hazard Index (liver toxins)=		0.05				
		Hazard Index (nervous system toxins)=		11.41				
		Hazard Index (kidney toxins)=		0.00				
		Hazard Index (red blood cell effects) =		0.03				
		Hazard Index (longevity)=		7.18				

NOTES:

(a) This table does not include groundwater chemicals of concern for which no reference dose or slope factor exists. (chloroethane,2-methylnapthalene, 4-chloro-3-methylphenol, aluminum, cobalt, copper, lead, sulfide and ammonia)

(b) Calculation for exposure dose :

INGESTION EXPOSURE DOSE	= Conc. x Conc.	Ingestion Rate 2 L/day	x Exposure Frequency 350 days/yr	x Exposure Duration 30 years	/ Body Weight 70 kg	Averaging Time (g) years	x	Conversion Factor 365 days/year	x 1E+03 ug/mg

(c) Hazard quotient = chronic exposure dose / RfD

(d) Cancer Risk = lifetime exposure dose x slope factor

(e) Dose-response data for cis-1,2-dichloroethene and chromium VI were used.

(f) Reference Dose for cadmium in water was used.

(g) Averaging times of 30 years for chronic doses and 70 years for lifetime doses were used.

(h) The reference dose for manganese is based on total allowable intake (10 mg/day) minus the background intake (5 mg/day). The remaining intake (5 mg/day) was normalized for body weight (70 kg) and an additional uncertainty factor of 3 applied for water exposures.

nd = chemical not detected

na = toxicity value not available

--- = not calculated due to absence of data

^ EDITED FINAL SUPPLEMENTAL HUMAN HEALTH RISK ASSESSMENT (1998) TABLE B-36

TABLE 2 - 1 AN*

POTENTIAL RISK FROM INGESTION OF SITE GROUNDWATER WITHIN THE SEWAGE SLUDGE AREA (AS DRINKING WATER)

AVERAGE CONCENTRATIONS USED FOR AN ADULT EXPOSURE (a)

Analyte	Average Concentration (ug/L)	Exposure Dose Chronic (b) (mg/kg/day)	Oral Reference Dose (RfD) (mg/kg/day)	Hazard Quotient (c)		Exposure Dose Lifetime (b) (mg/kg/day)	Oral Slope Factor /(mg/kg/day)	Cancer Risk (d)
Benzene	nd	---	na	---		---	0.029	---
1,1-Dichloroethane	nd	---	0.1	---		---	na	---
1,2-Dichloroethene (e)	nd	---	0.01	---		---	na	---
Vinyl Chloride	nd	---	na	---		---	1.9	---
Pentachlorophenol	nd	---	0.03	---		---	0.12	---
bis(2-Ethylhexyl)phthalate	nd	---	0.02	---		---	0.014	---
Acrylamide	nd	---	0.0002	---		---	4.5	---
N,N-DMF	nd	---	0.1	---		---	na	---
Antimony	17	4.7E-04	0.0004	1.2E+00		2.0E-04	na	---
Arsenic	1.8	4.9E-05	0.0003	1.6E-01		2.1E-05	1.5	3.2E-05
Barium	97	2.7E-03	0.07	---		1.1E-03	na	---
Beryllium	1.7	4.7E-05	0.002	2.3E-02		2.0E-05	na	---
Cadmium (f)	3.3	9.0E-05	0.0005	1.8E-01		3.9E-05	na	---
Chromium (e)	14	3.8E-04	0.005	7.7E-02		1.6E-04	na	---
Manganese (h)	2500	6.8E-02	0.024	2.9E+00		2.9E-02	na	---
Nickel	33	9.0E-04	0.02	4.5E-02		3.9E-04	na	---
Vanadium	22	6.0E-04	0.007	8.6E-02		2.6E-04	na	---
Zinc	140	3.8E-03	0.3	1.3E-02		1.6E-03	na	---
		Total Hazard Index =		4.6E+00		Total Risk =		3.2E-05
		Hazard Index (liver toxins)=		0.00				
		Hazard Index (nervous system toxins)=		2.85				
		Hazard Index (kidney toxins)=		0.18				
		Hazard Index (red blood cell effects)=		0.01				
		Hazard Index (longevity)=		1.16				

NOTES:

(a) This table does not include groundwater chemicals of concern for which no reference dose or slope factor exists. (chloroethane,2-methylnapthalene, 4-chloro-3-methylphenol, aluminum, cobalt, copper, lead, sulfide and ammonia)

(b) Calculation for exposure dose :

INGESTION EXPOSURE DOSE	= Conc. x	Ingestion Rate	x Exposure Frequency	x Exposure Duration	/	Body Weight	Averaging Time	x	Conversion Factor
	Conc.	2	350	30		70	(g)		365 x 1E+03
		L/day	days/yr	years		kg	years		days/year ug/mg

(c) Hazard quotient = chronic exposure dose / RfD

(d) Cancer Risk = lifetime exposure dose x slope factor

(e) Dose-response data for cis-1,2-dichloroethene and chromium VI were used.

(f) Reference Dose for cadmium in water was used.

(g) Averaging times of 30 years for chronic doses and 70 years for lifetime doses were used.

(h) The reference dose for manganese is based on total allowable intake (10 mg/day) minus the background intake (5 mg/day). The remaining intake (5 mg/day) was normalized for body weight (70 kg) and an additional uncertainty factor of 3 applied for water exposures.

nd = chemical not detected

na = toxicity value not available

--- = not calculated due to absence of data

* EDITED FINAL SUPPLEMENTAL HUMAN HEALTH RISK ASSESSMENT (1998) TABLE B-37

TABLE 2 - 1 AO*

POTENTIAL RISK FROM INGESTION OF SITE GROUNDWATER WITHIN THE SEWAGE SLUDGE AREA (AS DRINKING WATER)

MAXIMUM CONCENTRATIONS USED FOR AN ADULT EXPOSURE (a)

Analyte	Maximum Concentration (ug/L)	Exposure Dose Chronic (b) (mg/kg/day)	Oral Reference Dose (RfD) (mg/kg/day)	Hazard Quotient (c)		Exposure Dose Lifetime (b) (mg/kg/day)	Oral Slope Factor /(mg/kg/day)	Cancer Risk (d)
Benzene	nd	---	na	---		---	0.029	---
1,1-Dichloroethane	nd	---	0.1	---		---	na	---
1,2-Dichloroethene (e)	nd	---	0.01	---		---	na	---
Vinyl Chloride	nd	---	na	---		---	1.9	---
Pentachlorophenol	nd	---	0.03	---		---	0.12	---
bis(2-Ethylhexyl)phthalate	nd	---	0.02	---		---	0.014	---
Acrylamide	nd	---	0.0002	---		---	4.5	---
N,N-DMF	nd	---	0.1	---		---	na	---
Antimony	74.2	2.0E-03	0.0004	5.1E+00		8.7E-04	na	---
Arsenic	5.5	1.5E-04	0.0003	5.0E-01		6.5E-05	1.5	9.7E-05
Barium	284	7.8E-03	0.07	1.1E-01		3.3E-03	na	---
Beryllium	3.4	9.3E-05	0.002	4.7E-02		4.0E-05	na	---
Cadmium (f)	19.4	5.3E-04	0.0005	1.1E+00		2.3E-04	na	---
Chromium (e)	54.5	1.5E-03	0.005	3.0E-01		6.4E-04	na	---
Manganese (h)	6230	1.7E-01	0.024	7.1E+00		7.3E-02	na	---
Nickel	76.6	2.1E-03	0.02	1.0E-01		9.0E-04	na	---
Vanadium	101	2.8E-03	0.007	4.0E-01		1.2E-03	na	---
Zinc	362	9.9E-03	0.3	3.3E-02		4.3E-03	na	---
		Total Hazard Index =		1.5E+01		Total Risk =		9.7E-05
		Hazard Index (liver toxins)=		0.00				
		Hazard Index (nervous system toxins)=		7.11				
		Hazard Index (kidney toxins)=		1.06				
		Hazard Index (red blood cell effects)=		0.03				
		Hazard Index (longevity)=		5.08				

NOTES:

(a) This table does not include groundwater chemicals of concern for which no reference dose or slope factor exists.
(chloroethane,2-methylnapthalene, 4-chloro-3-methylphenol, aluminum, cobalt, copper, lead, sulfide and ammonia)

(b) Calculation for exposure dose :

INGESTION EXPOSURE DOSE	= Conc. x Conc.	Ingestion Rate 2 L/day	x Exposure Frequency 350 days/yr	x Exposure Duration 30 years	/ Body Weight 70 kg	Averaging Time (g) years	x	Conversion Factor 365 x 1E+03 days/year ug/mg

(c) Hazard quotient = chronic exposure dose / RfD

(d) Cancer Risk = lifetime exposure dose x slope factor

(e) Dose-response data for cis-1,2-dichloroethene and chromium VI were used

(f) Reference Dose for cadmium in water was used.

(g) Averaging times of 30 years for chronic doses and 70 years for lifetime doses were used.

(h) The reference dose for manganese is based on total allowable intake (10 mg/day) minus the background intake (5 mg/day).
The remaining intake (5 mg/day) was normalized for body weight (70 kg) and an additional uncertainty factor of 3 applied for water exposures.

nd = chemical not detected

na = toxicity value not available

--- = not calculated due to absence of data

*** EDITED FINAL SUPPLEMENTAL HUMAN HEALTH RISK ASSESSMENT (1998) TABLE B-38**

TABLE 2 - 1 AP*

POTENTIAL RISK FROM INGESTION OF GROUNDWATER FROM RESIDENTIAL WELLS

AVERAGE CONCENTRATIONS USED FOR AN ADULT EXPOSURE

Analyte	Average Concentration (ug/L)	Exposure Dose Chronic (a) (mg/kg/day)	Oral Reference Dose (RfD) (mg/kg/day)	Hazard Quotient (b)		Exposure Dose Lifetime (a) (mg/kg/day)	Oral Slope Factor /(mg/kg/day)	Cancer Risk (c)
Benzene	0.52	1.4E-05	na	---		6.1E-06	0.029	1.8E-07
Chloroethane	0.53	1.5E-05	na	---		6.2E-06	na	---
Trichloroethene	0.56	1.5E-05	na	---		6.6E-06	0.011	7.2E-08
4-Methylphenol	7.9	2.2E-04	0.005	4.3E-02		9.3E-05	na	---
N,N-DMF	14	3.8E-04	0.1	3.8E-03		1.6E-04	na	---
Dieldrin	0.0024	6.6E-08	0.00005	1.3E-03		2.8E-08	16	4.5E-07
Aluminum	90	2.5E-03	na	---		1.1E-03	na	---
Barium	8.3	2.3E-04	0.07	3.2E-03		9.7E-05	na	---
Copper	14	3.8E-04	na	---		1.6E-04	na	---
Manganese (d)	890	2.4E-02	0.024	1.0E+00		1.0E-02	na	---
Mercury	0.14	3.8E-06	0.0003	1.3E-02		1.6E-06	na	---
Zinc	24	6.6E-04	0.3	2.2E-03		2.8E-04	na	---
Sulfide	1600	4.4E-02	na	---		1.9E-02	na	---
		Total Hazard Index =		1.1E+00		Total Risk =		7.0E-07
		Hazard Index (liver toxins) =		0.01				
		Hazard Index (nervous system toxins) =		1.06				

NOTES:

(a) Calculation for exposure dose :

INGESTION EXPOSURE DOSE	= Conc. x Conc.	Ingestion Rate 2 L/day	x Exposure Frequency 350 days/yr	x Exposure Duration 30 years	/ Body Weight 70 kg	Averaging Time (e) years	x	Conversion Factor 365 x 1E+03 days/year ug/mg

(b) Hazard quotient = chronic exposure dose / RfD

(c) Cancer Risk = lifetime exposure dose x slope factor

(d) The reference dose for manganese is based on total allowable intake (10 mg/day) minus the background intake (5 mg/day). The remaining intake (5 mg/day) was normalized for body weight (70 kg) and an additional uncertainty factor of 3 applied for water exposures.

(e) Averaging times of 30 years for chronic doses and 70 years for lifetime doses were used.

nd = chemical not detected

na = toxicity value not available

--- = not calculated due to absence of data

* EDITED FINAL SUPPLEMENTAL HUMAN HEALTH RISK ASSESSMENT (1998) TABLE B-39

TABLE 2-1 AQ*
POTENTIAL RISK FROM INGESTION OF GROUNDWATER FROM RESIDENTIAL WELLS
MAXIMUM CONCENTRATIONS USED FOR AN ADULT EXPOSURE

Analyte	Maximum Concentration (ug/L)	Exposure Dose Chronic (a) (mg/kg/day)	Oral Reference Dose (RfD) (mg/kg/day)	Hazard Quotient (b)		Exposure Dose Lifetime (a) (mg/kg/day)	Oral Slope Factor /(mg/kg/day)	Cancer Risk (c)
Benzene	0.8	2.2E-05	na	---		9.4E-06	0.029	2.7E-07
Chloroethane	1	2.7E-05	na	---		1.2E-05	na	---
Trichloroethene	2	5.5E-05	na	---		2.3E-05	0.011	2.6E-07
4-Methylphenol	63	1.7E-03	0.005	3.5E-01		7.4E-04	na	---
N,N-DMF	14	3.8E-04	0.1	3.8E-03		1.6E-04	na	---
Dieldrin	0.0024	6.6E-08	0.00005	1.3E-03		2.8E-08	16	4.5E-07
Aluminum	552	1.5E-02	na	---		6.5E-03	na	---
Barium	44.3	1.2E-03	0.07	1.7E-02		5.2E-04	na	---
Copper	58.6	1.6E-03	na	---		6.9E-04	na	---
Manganese (d)	3100	8.5E-02	0.024	3.5E+00		3.6E-02	na	---
Mercury	0.46	1.3E-05	0.0003	4.2E-02		5.4E-06	na	---
Zinc	165	4.5E-03	0.3	1.5E-02		1.9E-03	na	---
Sulfide	3700	1.0E-01	na	---		4.3E-02	na	---
		Total Hazard Index =		4.0E+00		Total Risk =		9.8E-07
		Hazard Index (liver toxins) =		0.01				
		Hazard Index (nervous system toxins) =		3.88				

NOTES:
(a) Calculation for exposure dose :

INGESTION EXPOSURE DOSE	= Conc. x	Ingestion Rate	x Exposure Frequency	x Exposure Duration	/ Body Weight	Averaging Time	x	Conversion Factor
	Conc.	2	350	30	70	(e)	365	x 1E+03
		L/day	days/yr	years	kg	years	days/year	ug/mg

(b) Hazard quotient = chronic exposure dose / RfD
(c) Cancer Risk = lifetime exposure dose x slope factor
(d) The reference dose for manganese is based on total allowable intake (10 mg/day) minus the background intake (5 mg/day).
The remaining intake (5 mg/day) was normalized for body weight (70 kg) and an additional uncertainty factor of 3 applied for water exposures.
(e) Averaging times of 30 years for chronic doses and 70 years for lifetime doses were used.

nd = chemical not detected
na = toxicity value not available
--- = not calculated due to absence of data

*** EDITED FINAL SUPPLEMENTAL HUMAN HEALTH RISK ASSESSMENT (1998) TABLE B-40**

TABLE 2-1 AR*
POTENTIAL RISK FROM INGESTION OF SAUGATUCKET RIVER WATER BY SWIMMERS
AVERAGE CONCENTRATIONS USED FOR AN ADULT EXPOSURE

ANALYTE	Average Concentration (ug/L)	Exposure Dose Chronic (a) (mg/kg/day)	Oral Reference Dose (RfD) (mg/kg/day)	Hazard Quotient (b)		Exposure Dose Lifetime (a) (mg/kg/day)	Oral Slope Factor /(mg/kg/day)	Cancer Risk (c)
Aluminum	200	3.9E-06	na	---		1.7E-06	na	---
Antimony	11	2.2E-07	0.0004	5.4E-04		9.2E-08	na	---
Barium	15	2.9E-07	0.07	4.2E-06		1.3E-07	na	---
Manganese (d)	240	4.7E-06	0.024	2.0E-04		2.0E-06	na	---
Ammonia (f)	210	4.1E-06	na	---		1.8E-06	na	---
Sulfide	790	1.5E-05	na	---		6.6E-06	na	---
Acrylamide	nd	---	0.0002	---		---	4.5	---
N N dimethylformamide	nd	---	0.1	---		---	na	---
		Total Hazard Index=		7.4E-04		Total Risk =		---

NOTES:
(a) Calculation for exposure dose :

INGESTION EXPOSURE DOSE	=	Conc.	x	Ingestion Rate	x	Exposure Time	x	Exposure Frequency	x	Exposure Duration	/	Body Weight	x	Averaging Time	x	Conversion Factor
		Conc.		0.05		1		10		30		70		(e)	365 x 1E+03	
				L/hr		hr/day		days/yr		years		kg		years	days/year ug/mg	

(b) Hazard quotient = chronic exposere dose / RfD
(c) Cancer Risk = lifetime exposure dose x slope factor
(d) The reference dose for manganese is based on total allowable intake (10 mg/day) minus the background intake (5 mg/day). The remaining intake (5 mg/day) was normalized for body weight (70 kg) and an additional uncertainty factor of 3 applied for water exposures.
(e) Averaging times of 30 years for chronic doses and 70 years for lifetime doses were used.
(f) HEAST '97 provides a taste threshold of 34,000 ug/L. The concentration detected was well below this.

nd = chemical not detected
na = toxicity value not available
--- = not calculated due to absence of data

*** EDITED FINAL SUPPLEMENTAL HUMAN HEALTH RISK ASSESSMENT (1998) TABLE B-41**

TABLE 2 - 1 AS*
POTENTIAL RISK FROM INGESTION OF SAUGATUCKET RIVER WATER BY SWIMMERS
MAXIMUM CONCENTRATIONS USED FOR AN ADULT EXPOSURE

ANALYTE	Maximum Concentration (ug/L)	Exposure Dose Chronic (a) (mg/kg/day)	Oral Reference Dose (RfD) (mg/kg/day)	Hazard Quotient (b)		Exposure Dose Lifetime (a) (mg/kg/day)	Oral Slope Factor /(mg/kg/day)	Cancer Risk (c)
Aluminum	424	8.3E-06	na	---		3.6E-06	na	---
Antimony	25	4.9E-07	0.0004	1.2E-03		2.1E-07	na	---
Barium	279	5.5E-06	0.07	7.8E-05		2.3E-06	na	---
Manganese (d)	2030	4.0E-05	0.024	1.7E-03		1.7E-05	na	---
Ammonia (f)	670	1.3E-05	na	---		5.6E-06	na	---
Sulfide	1900	3.7E-05	na	---		1.6E-05	na	---
Acrylamide	nd	---	0.0002	---		---	4.5	---
N N dimethylformamide	nd	---	0.1	---		---	na	---
		Total Hazard Index=		3.0E-03		Total Risk =		---

NOTES:
(a) Calculation for exposure dose :

INGESTION EXPOSURE DOSE	=	Conc.	x	Ingestion Rate	x	Exposure Time	x	Exposure Frequency	x	Exposure Duration	/	Body Weight	x	Averaging Time	x	Conversion Factor
		Conc.		0.05		1		10		30		70		(e)	365 x 1E+03	
				L/hr		hr/day		days/yr		years		kg		years	days/year	ug/mg

(b) Hazard quotient = chronic exposere dose / RfD
(c) Cancer Risk = lifetime exposure dose x slope factor
(d) The reference dose for manganese is based on total allowable intake (10 mg/day) minus the background intake (5 mg/day). The remaining intake (5 mg/day) was normalized for body weight (70 kg) and an additional uncertainty factor of 3 applied for water exposures.
(e) Averaging times of 30 years for chronic doses and 70 years for lifetime doses were used.
(f) HEAST '97 provides a taste threshold of 34,000 ug/L. The concentration detected was well below this.

nd = chemical not detected
na = toxicity value not available
--- = not calculated due to absence of data

*** EDITED FINAL SUPPLEMENTAL HUMAN HEALTH RISK ASSESSMENT (1998) TABLE B-42**

TABLE 2 - 1 AT*
POTENTIAL RISK FROM DERMAL CONTACT WITH SAUGATUCKET RIVER WATER BY SWIMMERS
AVERAGE CONCENTRATIONS USED FOR AN ADULT EXPOSURE

ANALYTE	Average Concentration (ug/L)	Dermal Penneability Constant (a)	Exposure Dose Chronic (b) (mg/kg/day)	Oral Reference Dose (RfD) (mg/kg/day)	Hazard Quotient (c)	Exposure Dose Lifetime (b) (mg/kg/day)	Oral Slope Factor /(mg/kg/day)	Cancer Risk (d)
Aluminum	200	1.0E-03	1.4E-06	na	---	6.04E-07	na	---
Antimony	11	1.0E-03	7.7E-08	0.0004	1.9E-04	3.32E-08	na	---
Barium	15	1.0E-03	1.1E-07	0.07	1.5E-06	4.53E-08	na	---
Manganese (e)	240	1.0E-03	1.7E-06	0.024	7.0E-05	7.25E-07	na	---
Ammonia	210	1.0E-03	1.5E-06	na	---	6.34E-07	na	---
Sulfide	790	1.0E-03	5.6E-06	na	---	2.39E-06	na	---
Acrylamide	nd	2.4E-04	---	0.0002	---	---	4.5	---
N N dimethylformamide	nd	na	---	0.1	---	---	na	---
			Hazard Index =		2.7E-04	Total Risk =		---

NOTES:
(a) Source: EPA, 1992, "Dermal Exposure Assessment: Principles and Applications", EPA/600/8-91/011B
(b) calculation for exposure dose:

DERMAL =	Conc.	x Dermal x	Skin Surface	x Exposure	x Exposure	x Exposure	/	Body	x Averaging	x Conversion
EXPOSURE		Perm. Const.	Area	Time	Frequency	Duration		Weight	Time	Factor
DOSE	Conc.	Kp	18,000	1	10	30		70	(f)	365 X 1E+06
		cm/hour	sq. cm	hr/day	days/yr	years		kg	years	days/yr cu.cm-ug/L-mg

(c) Hazard quotient = chronic exposure dose / RfD
(d) cancer risk = lifetime exposure dose x slope factor
(e) The reference dose for manganese is based on total allowable intake (10 mg/day) minus the background intake (5 mg/day).
The remaining intake (5 mg/day) was normalized for body weight (70 kg) and an additional uncertainty factor of 3 applied for water exposures.
(f) Averaging times of 30 years for chronic doses and 70 years for lifetime doses were used

nd = chemical not detected
na = toxicity value not available

*** EDITED FINAL SUPPLEMENTAL HUMAN HEALTH RISK ASSESSMENT (1998) TABLE B-43**

TABLE 2 - 1 AU*
POTENTIAL RISK FROM DERMAL CONTACT WITH SAUGATUCKET RIVER WATER BY SWIMMERS
MAXIMUM CONCENTRATIONS USED FOR AN ADULT EXPOSURE

ANALYTE	Maximum Concentration (ug/L)	Dermal Permeability Constant (a)	Exposure Dose Chronic (b) (mg/kg/day)	Oral Reference Dose (RfD) (mg/kg/day)	Hazard Quotient (c)	Exposure Dose Lifetime (b) (mg/kg/day)	Oral Slope Factor /(mg/kg/day)	Cancer Risk (d)
Aluminum	424	1.0E-03	3.0E-06	na	---	1.28E-06	na	---
Antimony	25	1.0E-03	1.8E-07	0.0004	4.4E-04	7.55E-08	na	---
Barium	279	1.0E-03	2.0E-06	0.07	2.8E-05	8.42E-07	na	---
Manganese (e)	2030	1.0E-03	1.4E-05	0.024	6.0E-04	6.13E-06	na	---
Ammonia	670	1.0E-03	4.7E-06	na	---	2.02E-06	na	---
Sulfide	1900	1.0E-03	1.3E-05	na	---	5.74E-06	na	---
Acrylamide	nd	2.4E-04	---	0.0002	---	---	4.5	---
N N dimethylformamide	nd	na	---	0.1	---	---	na	---
			Hazard Index =		1.1E-03	Total Risk =		---

NOTES:
(a) Source: EPA, 1992, "Dermal Exposure Assessment: Principles and Applications", EPA/600/8-91/011B
(b) calculation for exposure dose:

DERMAL =	Conc.	x	Dermal	x	Skin Surface	x	Exposure	x	Exposure	x	Exposure	/	Body	x Averaging	x Conversion
EXPOSURE			Perm. Const.		Area		Time		Frequency		Duration		Weight	Time	Factor
DOSE	Conc.		Kp		18,000		1		10		30		70	(f)	365 X 1E+06
			cm/hour		sq. cm		hr/day		days/yr		years		kg	years	days/yr cu.cm-ug/L-mg

(c) Hazard quotient = chronic exposure dose / RfD
(d) cancer risk = lifetime exposure dose x slope factor
(e) The reference dose for manganese is based on total allowable intake (10 mg/day) minus the background intake (5 mg/day).
The remaining intake (5 mg/day) was normalized for body weight (70 kg) and an additional uncertainty factor of 3 applied for water exposures.
(f) Averaging times of 30 years for chronic doses and 70 years for lifetime doses were used

nd = chemical not detected
na = toxicity value not available
--- = not calculated due to the absence of data

*** EDITED FINAL SUPPLEMENTAL HUMAN HEALTH RISK ASSESSMENT (1998) TABLE B-44**

TABLE 2-1 AV*
POTENTIAL RISK FROM INGESTION OF SAUGATUCKET RIVER WATER BY SWIMMERS
AVERAGE CONCENTRATIONS USED FOR AN ADOLESCENT EXPOSURE

ANALYTE	Average Concentration (ug/L)	Exposure Dose Chronic (a) (mg/kg/day)	Oral Reference Dose (RfD) (mg/kg/day)	Hazard Quotient (b)		Exposure Dose Lifetime (a) (mg/kg/day)	Oral Slope Factor /(mg/kg/day)	Cancer Risk (c)
Aluminum	200	4.7E-06	na	---		4.7E-07	na	---
Antimony	11	2.6E-07	0.0004	6.5E-04		2.6E-08	na	---
Barium	15	3.5E-07	0.07	5.1E-06		3.5E-08	na	---
Manganese (d)	240	5.7E-06	0.024	2.4E-04		5.7E-07	na	---
Ammonia (f)	210	5.0E-06	na	---		5.0E-07	na	---
Sulfide	790	1.9E-05	na	---		1.9E-06	na	---
Acrylamide	nd	---	0.0002	---		---	4.5	---
N N dimethylformamide	nd	---	0.1	---		---	na	---
		Total Hazard Index=		8.9E-04		Total Risk =		---

NOTES:
(a) Calculation for exposure dose :

INGESTION = EXPOSURE DOSE	Conc. x Conc.	Ingestion Rate 0.05 L/hr	x Exposure Time 1 hr/day	x Exposure Frequency 10 days/yr	x Exposure Duration 7 years	/ Body Weight 58 kg	x Averaging Time (e) years	365	x Conversion Factor X 1E+03 days/year ug/mg

(b) Hazard quotient = chronic exposere dose / RfD
(c) Cancer Risk = lifetime exposure dose x slope factor
(d) The reference dose for manganese is based on total allowable intake (10 mg/day) minus the background intake (5 mg/d
The remaining intake (5 mg/day) was normalized for body weight (70 kg) and an additional uncertainty factor of 3 applied for water exposures.
(e) Averaging times of 7 years for chronic doses and 70 years for lifetime doses were used.
(f) HEAST '97 provides a taste threshold of 34,000 ug/L. The concentration detected was well below this.

nd = chemical not detected
na = toxicity value not available
--- = not calculated due to absence of data

* EDITED FINAL SUPPLEMENTAL HUMAN HEALTH RISK ASSESSMENT (1998) TABLE B-45

TABLE 2 - 1 AW*
POTENTIAL RISK FROM INGESTION OF SAUGATUCKET RIVER WATER BY SWIMMERS
MAXIMUM CONCENTRATIONS USED FOR AN ADOLESCENT EXPOSURE

ANALYTE	Maximum Concentration (ug/L)	Exposure Dose Chronic (a) (mg/kg/day)	Oral Reference Dose (RfD) (mg/kg/day)	Hazard Quotient (b)		Exposure Dose Lifetime (a) (mg/kg/day)	Oral Slope Factor /(mg/kg/day)	Cancer Risk (c)
Aluminum	424	1.0E-05	na	---		1.0E-06	na	---
Antimony	25	5.9E-07	0.0004	1.5E-03		5.9E-08	na	---
Barium	279	6.6E-06	0.07	9.4E-05		6.6E-07	na	---
Manganese (d)	2030	4.8E-05	0.024	2.0E-03		4.8E-06	na	---
Ammonia (f)	670	1.6E-05	na	---		1.6E-06	na	---
Sulfide	1900	4.5E-05	na	---		4.5E-06	na	---
Acrylamide	nd	---	0.0002	---		---	4.5	---
N N dimethylformamide	nd	---	0.1	---		---	na	---
		Total Hazard Index=		3.6E-03		Total Risk =		---

NOTES:
(a) Calculation for exposure dose :

INGESTION =	Conc. x	Ingestion	x Exposure	x Exposure	x Exposure	/ Body	x	Averaging		x Conversion
EXPOSURE		Rate	Time	Frequency	Duration	Weight		Time		Factor
DOSE	Conc.	0.05	1	10	7	58		(e)	365	X 1E+03
		L/hr	hr/day	days/yr	years	kg		years		days/year ug/mg

(b) Hazard quotient = chronic exposere dose / RfD
(c) Cancer Risk = lifetime exposure dose x slope factor
(d) The reference dose for manganese is based on total allowable intake (10 mg/day) minus the background intake (5 mg/d
The remaining intake (5 mg/day) was normalized for body weight (70 kg) and an additional uncertainty factor of 3 applied for water exposures.
(e) Averaging times of 7 years for chronic doses and 70 years for lifetime doses were used.
(f) HEAST '97 provides a taste threshold of 34,000 ug/L. The concentration detected was well below this.

nd = chemical not detected
na = toxicity value not available
--- = not calculated due to absence of data

*** EDITED FINAL SUPPLEMENTAL HUMAN HEALTH RISK ASSESSMENT (1998) TABLE B-46**

TABLE 2-1 AX*
POTENTIAL RISK FROM DERMAL CONTACT WITH SAUGATUCKET RIVER WATER BY SWIMMERS
AVERAGE CONCENTRATIONS USED FOR AN ADOLESCENT EXPOSURE

ANALYTE	Average Concentration (ug/L)	Dermal Permeability Constant (a)	Exposure Dose Chronic (b) (mg/kg/day)	Oral Reference Dose (RfD) (mg/kg/day)	Hazard Quotient (c)		Exposure Dose Lifetime (b) (mg/kg/day)	Oral Slope Factor /(mg/kg/day)	Cancer Risk (d)
Aluminum	200	1.0E-03	1.5E-06	na	---		1.51E-07	na	---
Antimony	11	1.0E-03	8.3E-08	0.0004	2.1E-04		8.31E-09	na	---
Barium	15	1.0E-03	1.1E-07	0.07	1.6E-06		1.13E-08	na	---
Manganese (e)	240	1.0E-03	1.8E-06	0.024	7.6E-05		1.81E-07	na	---
Ammonia	210	1.0E-03	1.6E-06	na	---		1.59E-07	na	---
Sulfide	790	1.0E-03	6.0E-06	na	---		5.97E-07	na	---
Acrylamide	nd	2.4E-04	---	0.0002	---		---	4.5	---
N N dimethylformamide	nd	na	---	0.1	---		---	na	---
			Hazard Index =		2.9E-04		Total Risk =		---

NOTES:
(a) Source: EPA, 1992, "Dermal Exposure Assessment: Principles and Applications", EPA/600/8-91/011B
(b) calculation for exposure dose:

DERMAL EXPOSURE DOSE	=	Conc.	x	Dermal Perm. Const.	x	Skin Surface Area	x	Exposure Time	x	Exposure Frequency	x	Exposure Duration	/	Body Weight	x	Averaging Time	x	Conversion Factor
		Conc.		Kp		16,000		1		10		7		58		(f)	365 X 1E+06	
				cm/hour		sq. cm		hr/day		days/yr		years		kg		years	days/yr cu.cm-ug/L-mg	

(c) Hazard quotient = chronic exposure dose / RfD
(d) cancer risk = lifetime exposure dose x slope factor
(e) The reference dose for manganese is based on total allowable intake (10 mg/day) minus the background intake (5 mg/day).
The remaining intake (5 mg/day) was normalized for body weight (70 kg) and an additional uncertainty factor of 3 applied for water exposures.
(f) Averaging times of 7 years for chronic doses and 70 years for lifetime doses were used

nd = chemical not detected
na = toxicity value not available

*** EDITED FINAL SUPPLEMENTAL HUMAN HEALTH RISK ASSESSMENT (1998) TABLE B-47**

TABLE 2 - 1 AY*
POTENTIAL RISK FROM DERMAL CONTACT WITH SAUGATUCKET RIVER WATER BY SWIMMERS
MAXIMUM CONCENTRATIONS USED FOR AN ADOLESCENT EXPOSURE

ANALYTE	Maximum Concentration (ug/L)	Dermal Permeability Constant (a)	Exposure Dose Chronic (b) (mg/kg/day)	Oral Reference Dose (RfD) (mg/kg/day)	Hazard Quotient (c)	Exposure Dose Lifetime (b) (mg/kg/day)	Oral Slope Factor /(mg/kg/day)	Cancer Risk (d)
Aluminum	424	1.0E-03	3.2E-06	na	---	3.20E-07	na	---
Antimony	25	1.0E-03	1.9E-07	0.0004	4.7E-04	1.89E-08	na	---
Barium	279	1.0E-03	2.1E-06	0.07	3.0E-05	2.11E-07	na	---
Manganese (e)	2030	1.0E-03	1.5E-05	0.024	6.4E-04	1.53E-06	na	---
Ammonia	670	1.0E-03	5.1E-06	na	---	5.06E-07	na	---
Sulfide	1900	1.0E-03	1.4E-05	na	---	1.44E-06	na	---
Acrylamide	nd	2.4E-04	---	0.0002	---	---	4.5	---
N N dimethylformamide	nd	na	---	0.1	---	---	na	---
			Hazard Index =		1.1E-03	Total Risk =		---

NOTES:
(a) Source: EPA, 1992, "Dermal Exposure Assessment: Principles and Applications", EPA/600/8-91/011B
(b) calculation for exposure dose:

DERMAL EXPOSURE DOSE =	Conc.	x Dermal Perm. Const.	x Skin Surface Area	x Exposure Time	x Exposure Frequency	x Exposure Duration	/ Body Weight	x Averaging Time	x Conversion Factor
	Conc.	Kp	16,000	1	10	7	58	(f)	365 X 1E+06
		cm/hour	sq. cm	hr/day	days/yr	years	kg	years	days/yr cu.cm-ug/L-mg

(c) Hazard quotient = chronic exposure dose / RfD
(d) cancer risk = lifetime exposure dose x slope factor
(e) The reference dose for manganese is based on total allowable intake (10 mg/day) minus the background intake (5 mg/day).
The remaining intake (5 mg/day) was normalized for body weight (70 kg) and an additional uncertainty factor of 3 applied for water exposures.
(f) Averaging times of 7 years for chronic doses and 70 years for lifetime doses were used

nd = chemical not detected
na = toxicity value not available
--- = not calculated due to the absence of data

*** EDITED FINAL SUPPLEMENTAL HUMAN HEALTH RISK ASSESSMENT (1998) TABLE B-48**

TABLE 2 - 1 AZ*
POTENTIAL RISK FROM DERMAL CONTACT WITH MITCHELL BROOK WATER
AVERAGE CONCENTRATIONS USED FOR AN ADULT EXPOSURE

ANALYTE	Average Concentration (ug/L)	Dermal Permeability Constant (a)	Exposure Dose Chronic (b) (mg/kg/day)	Oral Reference Dose (RfD) (mg/kg/day)	Hazard Quotient (c)	Exposure Dose Lifetime (b) (mg/kg/day)	Oral Slope Factor /(mg/kg/day)	Cancer Risk (d)
Aluminum	400	1.0E-03	7.3E-07	na	---	3.14E-07	na	---
Antimony	12	1.0E-03	2.2E-08	0.0004	5.5E-05	9.42E-09	na	---
Barium	17	1.0E-03	3.1E-08	0.07	4.4E-07	1.33E-08	na	---
Manganese (e)	280	1.0E-03	5.1E-07	0.024	2.1E-05	2.20E-07	na	---
Ammonia	670	1.0E-03	1.2E-06	na	---	5.26E-07	na	---
Sulfide	760	1.0E-03	1.4E-06	na	---	5.97E-07	na	---
Acrylamide	130	2.4E-04	5.7E-08	0.0002	2.9E-04	2.45E-08	4.5	1.1E-07
N N dimethylformamide	nd	na	---	0.1	---	---	na	---
			Hazard Index =		3.6E-04	Total Risk =		1.1E-07

NOTES:
(a) Source: EPA, 1992, "Dermal Exposure Assessment: Principles and Applications", EPA/600/8-91/011B
(b) calculation for exposure dose:

DERMAL =	Conc.	x	Dermal x	Skin Surface	x	Exposure	x	Exposure	x	Exposure	/	Body	x Averaging	x Conversion
EXPOSURE			Perm. Const.	Area		Time		Frequency		Duration		Weight	Time	Factor
DOSE	Conc.		Kp	1,800		1		26		30		70	(f)	365 X 1E+06
			cm/hour	sq. cm		hr/day		days/yr		years		kg	years	days/yr cu.cm-ug/L-mg

(c) Hazard quotient = chronic exposure dose / RfD
(d) cancer risk = lifetime exposure dose x slope factor
(e) The reference dose for manganese is based on total allowable intake (10 mg/day) minus the background intake (5 mg/day).
The remaining intake (5 mg/day) was normalized for body weight (70 kg) and an additional uncertainty factor of 3 applied for water exposures.
(f) Averaging times of 30 years for chronic doses and 70 years for lifetime doses were used

nd = chemical not detected
na = toxicity value not available
--- = not calculated due to the absence of data

*** EDITED FINAL SUPPLEMENTAL HUMAN HEALTH RISK ASSESSMENT (1998) TABLE B-49**

TABLE 2-1 BA*
POTENTIAL RISK FROM DERMAL CONTACT WITH MITCHELL BROOK WATER
MAXIMUM CONCENTRATIONS USED FOR AN ADULT EXPOSURE

ANALYTE	Maximum Concentration (ug/L)	Dermal Permeability Constant (a)	Exposure Dose Chronic (b) (mg/kg/day)	Oral Reference Dose (RfD) (mg/kg/day)	Hazard Quotient (c)	Exposure Dose Lifetime (b) (mg/kg/day)	Oral Slope Factor /(mg/kg/day)	Cancer Risk (d)
Aluminum	1140	1.0E-03	2.1E-06	na	---	8.95E-07	na	---
Antimony	28.8	1.0E-03	5.3E-08	0.0004	1.3E-04	2.26E-08	na	---
Barium	173	1.0E-03	3.2E-07	0.07	4.5E-06	1.36E-07	na	---
Manganese (e)	1610	1.0E-03	2.9E-06	0.024	1.2E-04	1.26E-06	na	---
Ammonia	3530	1.0E-03	6.5E-06	na	---	2.77E-06	na	---
Sulfide	1900	1.0E-03	3.5E-06	na	---	1.49E-06	na	---
Acrylamide	272	2.4E-04	1.2E-07	0.0002	6.0E-04	5.12E-08	4.5	2.3E-07
N N dimethylformamide	nd	na	---	0.1	---	---	na	---
			Hazard Index =		8.6E-04	Total Risk =		2.3E-07

NOTES:
(a) Source: EPA, 1992, "Dermal Exposure Assessment: Principles and Applications", EPA/600/8-91/011B
(b) calculation for exposure dose:

DERMAL EXPOSURE DOSE =	Conc.	x	Dermal Perm. Const.	x	Skin Surface Area	x	Exposure Time	x	Exposure Frequency	x	Exposure Duration	/
	Conc.		Kp		1,800		1		26		30	
			cm/hour		sq. cm		hr/day		days/yr		years	

Body Weight	x	Averaging Time	x	Conversion Factor			
70		(f)	365	X	1E+06		
kg		years	days/yr	cu.cm-ug/L-mg			

(c) Hazard quotient = chronic exposure dose / RfD
(d) cancer risk = lifetime exposure dose x slope factor
(e) The reference dose for manganese is based on total allowable intake (10 mg/day) minus the background intake (5 mg/day).
The remaining intake (5 mg/day) was normalized for body weight (70 kg) and an additional uncertainty factor of 3 applied for water exposures.
(f) Averaging times of 30 years for chronic doses and 70 years for lifetime doses were used

nd = chemical not detected
na = toxicity value not available
--- = not calculated due to the absence of data

*** EDITED FINAL SUPPLEMENTAL HUMAN HEALTH RISK ASSESSMENT (1998) TABLE B-50**

TABLE 2 - 1 BB*
POTENTIAL RISK FROM DERMAL CONTACT WITH MITCHELL BROOK WATER
AVERAGE CONCENTRATIONS USED FOR AN ADOLESCENT EXPOSURE

ANALYTE	Average Concentration (ug/L)	Dermal Permeability Constant (a)	Exposure Dose Chronic (b) (mg/kg/day)	Oral Reference Dose (RfD) (mg/kg/day)	Hazard Quotient (c)		Exposure Dose Lifetime (b) (mg/kg/day)	Oral Slope Factor /(mg/kg/day)	Cancer Risk (d)
Aluminum	400	1.0E-03	8.8E-07	na	---		8.84E-08	na	---
Antimony	12	1.0E-03	2.7E-08	0.0004	6.6E-05		2.65E-09	na	---
Barium	17	1.0E-03	3.8E-08	0.07	5.4E-07		3.76E-09	na	---
Manganese (e)	280	1.0E-03	6.2E-07	0.024	2.6E-05		6.19E-08	na	---
Ammonia	670	1.0E-03	1.5E-06	na	---		1.48E-07	na	---
Sulfide	760	1.0E-03	1.7E-06	na	---		1.68E-07	na	---
Acrylamide	130	2.4E-04	6.9E-08	0.0002	3.4E-04		6.90E-09	4.5	3.1E-08
N N dimethylformamide	nd	na	0.0E+00	0.1	---		---	na	---
			Hazard Index =		4.4E-04		Total Risk =		3.1E-08

NOTES:
(a) Source: EPA, 1992, "Dermal Exposure Assessment: Principles and Applications", EPA/600/8-91/011B
(b) calculation for exposure dose:

DERMAL =	Conc.	x Dermal x	Skin Surface	x Exposure	x Exposure	x Exposure	/	Body	x Averaging	x Conversion
EXPOSURE		Perm. Const.	Area	Time	Frequency	Duration		Weight	Time	Factor
DOSE	Conc.	Kp	1,800	1	26	7		58	(f)	365 X 1E+06
		cm/hour	sq. cm	hr/day	days/yr	years		kg	years	days/yr cu.cm-ug/L-mg

(c) Hazard quotient = chronic exposure dose / RfD
(d) cancer risk = lifetime exposure dose x slope factor
(e) The reference dose for manganese is based on total allowable intake (10 mg/day) minus the background intake (5 mg/day).
The remaining intake (5 mg/day) was normalized for body weight (70 kg) and an additional uncertainty factor of 3 applied for water exposures.
(f) Averaging times of 7 years for chronic doses and 70 years for lifetime doses were used

nd = chemical not detected
na = toxicity value not available
--- = not calculated due to the absence of data

*** EDITED FINAL SUPPLEMENTAL HUMAN HEALTH RISK ASSESSMENT (1998) TABLE B-51**

TABLE 2 - 1 BC*
POTENTIAL RISK FROM DERMAL CONTACT WITH MITCHELL BROOK WATER
MAXIMUM CONCENTRATIONS USED FOR AN ADOLESCENT EXPOSURE

ANALYTE	Maximum Concentration (ug/L)	Dermal Permeability Constant (a)	Exposure Dose Chronic (b) (mg/kg/day)	Oral Reference Dose (RfD) (mg/kg/day)	Hazard Quotient (c)		Exposure Dose Lifetime (b) (mg/kg/day)	Oral Slope Factor /(mg/kg/day)	Cancer Risk (d)
Aluminum	1140	1.0E-03	2.5E-06	na	---		2.52E-07	na	---
Antimony	28.8	1.0E-03	6.4E-08	0.0004	1.6E-04		6.37E-09	na	---
Barium	173	1.0E-03	3.8E-07	0.07	5 5E-06		3.82E-08	na	---
Manganese (e)	1610	1.0E-03	3.6E-06	0.024	1.5E-04		3.56E-07	na	---
Ammonia	3530	1.0E-03	7.8E-06	na	---		7.80E-07	na	---
Sulfide	1900	1.0E-03	4.2E-06	na	---		4.20E-07	na	---
Acrylamide	272	2.4E-04	1.4E-07	0.0002	7.2E-04		1.44E-08	4.5	6.5E-08
N N dimethylformamide	nd	na	---	0.1	---		---	na	---
			Hazard Index =		1.0E-03		Total Risk =		6.5E-08

NOTES:
(a) Source: EPA, 1992, "Dermal Exposure Assessment: Principles and Applications", EPA/600/8-91/011B
(b) calculation for exposure dose:

DERMAL =	Conc.	x Dermal	x Skin Surface	x Exposure	x Exposure	x Exposure	/	Body	x Averaging	x Conversion
EXPOSURE		Perm. Const.	Area	Time	Frequency	Duration		Weight	Time	Factor
DOSE	Conc.	Kp	1,800	1	26	7		58	(f)	365 X 1E+06
		cm/hour	sq. cm	hr/day	days/yr	years		kg	years	days/yr cu.cm-ug/L-mg

(c) Hazard quotient = chronic exposure dose / RfD
(d) - cancer risk = lifetime exposure dose x slope factor
(e) The reference dose for manganese is based on total allowable intake (10 mg/day) minus the background intake (5 mg/day).
The remaining intake (5 mg/day) was normalized for body weight (70 kg) and an additional uncertainty factor of 3 applied for water exposures.
(f) Averaging times of 7 years for chronic doses and 70 years for lifetime doses were used

nd = chemical not detected
na = toxicity value not available
--- = not calculated due to the absence of data

*** EDITED FINAL SUPPLEMENTAL HUMAN HEALTH RISK ASSESSMENT (1998) TABLE B-52**

TABLE 2 - 1 BD*
POTENTIAL RISK FROM INHALATION OF OUTDOOR AIR BY ADULTS IN THE SOLID WASTE AREA
AVERAGE CONCENTRATIONS USED BASED ON SOIL GAS CONTAMINATION COLLECTED BY SUMMA CANISTERS

ANALYTE	Avg. Soil Gas Conc. (mg/m^3)	Estimated Emission Rate (mg/sec)(a)	Modeled Air Concentration (mg/m^3)(b)	Annualized Avg. Conc. (mg/m^3)(c)	RfC (mg/m^3)	Inhalation Unit Risk /(ug/m^3)	Hazard Quotient (d)	Cancer Risk (e)
Acetone	0	0	0	0	na	na	na	---
Benzene	8.0	0.23	4.6E-04	3.1E-05	0.006	8.3E-06	5.2E-03	1.1E-07
Carbon Disulfide	0.87	0.02	5.0E-05	3.4E-06	0.7	nd	4.9E-06	---
1,1-Dichloroethane	61	1.72	3.5E-03	2.4E-04	0.5	nd	4.8E-04	---
1,1-Dichloroethene	17	0.48	9.7E-04	6.7E-05	na	5.0E-05	na	1.4E-06
cis-1,2-Dichloroethene	9800	276.36	5.6E-01	3.8E-02	na	na	na	---
trans-1,2-Dichloroethene	11	0.31	6.3E-04	4.3E-05	na	nd	na	---
Dichlorodifluoromethane	51	1.44	2.9E-03	2.0E-04	0.2	nd	1.0E-03	---
Ethylbenzene	25	0.71	1.4E-03	9.8E-05	1	na	9.8E-05	---
4-Methyl-2-pentanone	6.5	0.18	3.7E-04	2.5E-05	0.08	nd	3.2E-04	---
Methylene Chloride	26	0.73	1.5E-03	1.0E-04	3	4.7E-07	3.4E-05	2.1E-08
Toluene	100	2.82	5.7E-03	3.9E-04	0.4	na	9.8E-04	---
1,2,4-Trichlorobenzene	0	0	0	0	0.2	na	---	---
1,2,4-Trimethylbenzene	2	0.06	1.1E-04	7.8E-06	0.006	na	1.3E-03	---
1,3,5-Trimethylbenzene	4.3	0.12	2.5E-04	1.7E-05	0.006	na	2.8E-03	---
Trichloroethene	31	0.87	1.8E-03	1.2E-04	na	1.7E-06	na	8.8E-08
Vinyl Chloride	1400	39.48	8.0E-02	5.5E-03	na	8.4E-05	na	2.0E-04
m,p-Xylene	41	1.16	2.3E-03	1.6E-04	na	nd	na	---
					Total Hazard Index =		1.2E-02	
						Total Cancer Risk =		2.0E-04

NOTES:
(a) Soil gas concentration x gas generation rate (60 cfm, or 0.0282 m^3/sec, calculated in M&E FS, 1998)
(b) Emission rate x Disposal area length in prevailing wind direction (NW)/ Surface area x Breathing zone height x Windspeed.
[(Emission rate x 450 m) / (110950 m^2 x 2 m x 1 m/sec)]
(c) Annualized Air Concentration = Modeled Air Concentration (mg/m^3) x 4 hrs/24 hrs x 150 days / 365 days
(d) Hazard quotient = Annualized Air Concentration / RfC
(e) Cancer Risk = Annualized Air Concentration (mg/m^3) x 1000 ug/mg x Unit Risk /(ug/m^3) x 30 yrs / 70 yrs

na - not available
nd - not determined
-- - not calculated due to absence of data

*** EDITED FINAL SUPPLEMENTAL HUMAN HEALTH RISK ASSESSMENT (1998) TABLE B-53**

TABLE 2 - 1 BE*
POTENTIAL RISK FROM INHALATION OF OUTDOOR AIR BY ADULTS IN THE SOLID WASTE AREA
MAXIMUM CONCENTRATIONS USED BASED ON SOIL GAS CONTAMINATION COLLECTED BY SUMMA CANISTERS

ANALYTE	Max. Soil Gas Conc. (mg/m^3)	Estimated Emission Rate (mg/sec)(a)	Modeled Air Concentration (mg/m^3)(b)	Annualized Avg. Conc. (mg/m^3)(c)	RfC (mg/m^3)	Inhalation Unit Risk /(ug/m^3)	Hazard Quotient (d)	Cancer Risk (e)
Acetone	0	0	0	0	na	na	na	---
Benzene	8.0	0.23	4.6E-04	3.1E-05	0.006	8.3E-06	5.2E-03	1.1E-07
Carbon Disulfide	0.87	0.02	5.0E-05	3.4E-06	0.7	nd	4.9E-06	---
1,1-Dichloroethane	140	3.95	8.0E-03	5.5E-04	0.5	nd	1.1E-03	---
1,1-Dichloroethene	32	0.90	1.8E-03	1.3E-04	na	5.0E-05	na	2.7E-06
cis-1,2-Dichloroethene	23000	648.60	1.3E+00	9.0E-02	na	na	na	---
trans-1,2-Dichloroethene	27	0.76	1.5E-03	1.1E-04	na	nd	na	---
Dichlorodifluoromethane	100	2.82	5.7E-03	3.9E-04	0.2	nd	2.0E-03	---
Ethylbenzene	25	0.71	1.4E-03	9.8E-05	1	na	9.8E-05	---
4-Methyl-2-pentanone	6.5	0.18	3.7E-04	2.5E-05	0.08	nd	3.2E-04	---
Methylene Chloride	66	1.86	3.8E-03	2.6E-04	3	4.7E-07	8.6E-05	5.2E-08
Toluene	230	6.49	1.3E-02	9.0E-04	0.4	na	2.3E-03	---
1,2,4-Trichlorobenzene	0	0	0	0	0.2	na	---	---
1,2,4-Trimethylbenzene	2	0.06	1.1E-04	7.8E-06	0.006	na	1.3E-03	---
1,3,5-Trimethylbenzene	4.3	0.12	2.5E-04	1.7E-05	0.006	na	2.8E-03	---
Trichloroethene	31	0.87	1.8E-03	1.2E-04	na	1.7E-06	na	8.8E-08
Vinyl Chloride	3100	87.42	1.8E-01	1.2E-02	na	8.4E-05	na	4.4E-04
m,p-Xylene	41	1.16	2.3E-03	1.6E-04	na	nd	na	---
					Total Hazard Index =		1.5E-02	
						Total Cancer Risk =		4.4E-04

NOTES:
(a) Soil gas concentration x gas generation rate (60 cfm, or 0.0282 m^3/sec, calculated in M&E FS, 1998)
(b) Emission rate x Disposal area length in prevailing wind direction (NW)/ Surface area x Breathing zone height x Windspeed.
[(Emission rate x 450 m) / (110950 m^2 x 2 m x 1 m/sec)]
(c) Annualized Air Concentration = Modeled Air Concentration (mg/m^3) x 4 hrs/24 hrs x 150 days / 365 days
(d) Hazard quotient = Annualized Air Concentration / RfC
(e) Cancer Risk = Annualized Air Concentration (mg/m^3) x 1000 ug/mg x Unit Risk /(ug/m^3) x 30 yrs / 70 yrs

na - not available
nd - not determined
-- - not calculated due to absence of data

*** EDITED FINAL SUPPLEMENTAL HUMAN HEALTH RISK ASSESSMENT (1998) TABLE B-54**

TABLE 2 - 1 BF*
POTENTIAL RISK FROM INHALATION OF OUTDOOR AIR BY ADULTS IN THE BULKY WASTE AREA
AVERAGE CONCENTRATIONS USED BASED ON SOIL GAS CONTAMINATION COLLECTED BY SUMMA CANISTERS

ANALYTE	Avg. Soil Gas Conc. (mg/m^3)	Estimated Emission Rate (mg/sec)(a)	Modeled Air Concentration (mg/m^3)(b)	Annualized Avg. Conc. (mg/m^3)(c)	RfC (mg/m^3)	Inhalation Unit Risk /(ug/m^3)	Hazard Quotient (d)	Cancer Risk (e)
Acetone	1	0.004	9.6E-06	6.6E-07	na	na	na	---
Benzene	1.6	0.006	1.5E-05	1.1E-06	0.006	8.3E-06	1.8E-04	3.7E-09
Carbon Disulfide	0	0.000	0	0	0.7	nd	---	---
1,1-Dichloroethane	4.5	0.018	4.3E-05	3.0E-06	0.5	nd	5.9E-06	---
1,1-Dichloroethene	0.2	0.001	1.9E-06	1.3E-07	na	5.0E-05	na	2.8E-09
cis-1,2-Dichloroethene	11	0.043	1.1E-04	7.2E-06	na	na	na	---
trans-1,2-Dichloroethene	0.21	0.001	2.0E-06	1.4E-07	na	nd	na	---
Dichlorodifluoromethane	14	0.054	1.3E-04	9.2E-06	0.2	nd	4.6E-05	---
Ethylbenzene	8.8	0.034	8.4E-05	5.8E-06	1	na	5.8E-06	---
4-Methyl-2-pentanone	0	0.000	0	0	0.08	nd	---	---
Methylene Chloride	1.7	0.007	1.6E-05	1.1E-06	3	4.7E-07	3.7E-07	2.3E-10
Toluene	28	0.109	2.7E-04	1.8E-05	0.4	na	4.6E-05	---
1,2,4-Trichlorobenzene	0.27	0.001	2.6E-06	1.8E-07	0.2	na	8.9E-07	---
1,2,4-Trimethylbenzene	1.5	0.006	1.4E-05	9.9E-07	0.006	na	1.6E-04	---
1,3,5-Trimethylbenzene	0.9	0.004	8.6E-06	5.9E-07	0.006	na	9.9E-05	---
Trichloroethene	3.5	0.014	3.4E-05	2.3E-06	na	1.7E-06	na	1.7E-09
Vinyl Chloride	7.6	0.030	7.3E-05	5.0E-06	na	8.4E-05	na	1.8E-07
m,p-Xylene	14	0.054	0.0E+00	0.0E+00	na	nd	na	---
					Total Hazard Index =		5.4E-04	
						Total Cancer Risk =		1.9E-07

NOTES:
(a) Soil gas concentration x gas generation rate (8.2 cfm, or 0.00389 m^3/sec, calculated in M&E FS, 1998)
(b) Emission rate x Disposal area length in prevailing wind direction (NW)/ Surface area x Breathing zone height x Windspeed.
[(Emission rate x 190 m) / (38511 m^2 x 2 m x 1 m/sec)]
(c) Annualized Air Concentration = Modeled Air Concentration (mg/m^3) x 4 hrs/24 hrs x 150 days / 365 days
(d) Hazard quotient = Annualized Air Concentration / RfC
(e) Cancer Risk = Annualized Air Concentration (mg/m^3) x 1000 ug/mg x Unit Risk /(ug/m^3) x 30 yrs / 70 yrs

na - not available
nd - not determined
-- - not calculated due to absence of data

*** EDITED FINAL SUPPLEMENTAL HUMAN HEALTH RISK ASSESSMENT (1998) TABLE B-55**

TABLE 2 - 1 BG*
POTENTIAL RISK FROM INHALATION OF OUTDOOR AIR BY ADULTS IN THE BULKY WASTE AREA
MAXIMUM CONCENTRATIONS USED BASED ON SOIL GAS CONTAMINATION COLLECTED BY SUMMA CANISTERS

ANALYTE	Max. Soil Gas Conc. (mg/m^3)	Estimated Emission Rate (mg/sec)(a)	Modeled Air Concentration (mg/m^3)(b)	Annualized Avg. Conc. (mg/m^3)(c)	RfC (mg/m^3)	Inhalation Unit Risk /(ug/m^3)	Hazard Quotient (d)	Cancer Risk (e)
Acetone	1.3	0.005	1.2E-05	8.5E-07	na	na	na	---
Benzene	2.9	0.011	2.8E-05	1.9E-06	0.006	8.3E-06	3.2E-04	6.8E-09
Carbon Disulfide	0	0.000	0	0	0.7	nd	---	---
1,1-Dichloroethane	6.9	0.027	6.6E-05	4.5E-06	0.5	nd	9.1E-06	---
1,1-Dichloroethene	0.31	0.001	3.0E-06	2.0E-07	na	5.0E-05	na	4.4E-09
cis-1,2-Dichloroethene	17	0.066	1.6E-04	1.1E-05	na	na	na	---
trans-1,2-Dichloroethene	0.3	0.001	2.9E-06	2.0E-07	na	nd	na	---
Dichlorodifluoromethane	26	0.101	2.5E-04	1.7E-05	0.2	nd	8.5E-05	---
Ethylbenzene	12	0.047	1.2E-04	7.9E-06	1	na	7.9E-06	---
4-Methyl-2-pentanone	0	0.000	0	0	0.08	nd	---	---
Methylene Chloride	2.4	0.009	2.3E-05	1.6E-06	3	4.7E-07	5.3E-07	3.2E-10
Toluene	34	0.132	3.3E-04	2.2E-05	0.4	na	5.6E-05	---
1,2,4-Trichlorobenzene	0.27	0.001	2.6E-06	1.8E-07	0.2	na	8.9E-07	---
1,2,4-Trimethylbenzene	2.3	0.009	2.2E-05	1.5E-06	0.006	na	2.5E-04	---
1,3,5-Trimethylbenzene	1.5	0.006	1.4E-05	9.9E-07	0.006	na	1.6E-04	---
Trichloroethene	3.8	0.015	3.6E-05	2.5E-06	na	1.7E-06	na	1.8E-09
Vinyl Chloride	14	0.054	1.3E-04	9.2E-06	na	8.4E-05	na	3.3E-07
m,p-Xylene	24	0.093	2.3E-04	1.6E-05	na	nd	na	---
					Total Hazard Index =		8.9E-04	
						Total Cancer Risk =		3.4E-07

NOTES:
(a) Soil gas concentration x gas generation rate (8.2 cfm, or 0.00389 m^3/sec, calculated in M&E FS, 1998)
(b) Emission rate x Disposal area length in prevailing wind direction (NW)/ Surface area x Breathing zone height x Windspeed.
[(Emission rate x 190 m) / (38511 m^2 x 2 m x 1 m/sec)]
(c) Annualized Air Concentration = Modeled Air Concentration (mg/m^3) x 4 hrs/24 hrs x 150 days / 365 days
(d) Hazard quotient = Annualized Air Concentration / RfC
(e) Cancer Risk = Annualized Air Concentration (mg/m^3) x 1000 ug/mg x Unit Risk /(ug/m^3) x 30 yrs / 70 yrs

na - not available
nd - not determined
-- - not calculated due to absence of data

*** EDITED FINAL SUPPLEMENTAL HUMAN HEALTH RISK ASSESSMENT (1998) TABLE B-56**

TABLE 2 - 1 BH*
POTENTIAL RISK FROM INHALATION OF OUTDOOR AIR BY ADULTS IN THE SEWAGE SLUDGE AREA
AVERAGE CONCENTRATIONS USED BASED ON SOIL GAS CONTAMINATION COLLECTED BY SUMMA CANISTERS

ANALYTE	Avg. Soil Gas Conc. (mg/m^3)	Estimated Emission Rate (mg/sec)(a)	Modeled Air Concentration (mg/m^3)(b)	Annualized Avg. Conc. (mg/m^3)(c)	RfC (mg/m^3)	Inhalation Unit Risk /(ug/m^3)	Hazard Quotient (d)	Cancer Risk (e)
Acetone	0.081	0.04543	7.5E-05	5.2E-06	na	na	na	---
Benzene	0	0	0	0	0.006	8.3E-06	---	---
Carbon Disulfide	0	0	0	0	0.7	nd	---	---
1,1-Dichloroethane	0	0	0	0	0.5	nd	---	---
1,1-Dichloroethene	0	0	0	0	na	5.0E-05	na	---
cis-1,2-Dichloroethene	0	0	0	0	na	na	na	---
trans-1,2-Dichloroethene	0	0	0	0	na	nd	na	---
Dichlorodifluoromethane	0	0	0	0	0.2	nd	---	---
Ethylbenzene	0.01	0.00514	8.5E-06	5.8E-07	1	na	5.8E-07	---
4-Methyl-2-pentanone	0	0	0	0	0.08	nd	---	---
Methylene Chloride	0.002	0.00114	1.9E-06	1.3E-07	3	4.7E-07	4.3E-08	2.6E-11
Toluene	0	0	0	0	0.4	na	---	---
1,2,4-Trichlorobenzene	0	0	0	0	0.2	na	---	---
1,2,4-Trimethylbenzene	0.005	0.00269	4.5E-06	3.1E-07	0.006	na	5.1E-05	---
1,3,5-Trimethylbenzene	0.003	0.00161	2.7E-06	1.8E-07	0.006	na	3.1E-05	---
Trichloroethene	0	0	0	0	na	1.7E-06	na	---
Vinyl Chloride	0	0	0	0	na	8.4E-05	na	---
m,p-Xylene	0.02	0.01041	1.7E-05	1.2E-06	na	nd	na	---
					Total Hazard Index =		8.2E-05	
						Total Cancer Risk =		2.6E-11

NOTES:
(a) See Appendix E in M&E RI
(b) Emission rate x Disposal area length in prevailing wind direction (NW)/ Surface area x Breathing zone height x Windspeed.
[(Emission rate x 120 m) / (36118 m^2 x 2 m x 1 m/sec)]
(c) Annualized Air Concentration = Modeled Air Concentration (mg/m^3) x 4 hrs/24 hrs x 150 days / 365 days
(d) Hazard quotient = Annualized Air Concentration / RfC
(e) Cancer Risk = Annualized Air Concentration (mg/m^3) x 1000 ug/mg x Unit Risk /(ug/m^3) x 30 yrs / 70 yrs

na - not available
nd - not determined
-- - not calculated due to absence of data

*** EDITED FINAL SUPPLEMENTAL HUMAN HEALTH RISK ASSESSMENT (1998) TABLE B-57**

TABLE 2-1 BI*
POTENTIAL RISK FROM INHALATION OF OUTDOOR AIR BY ADULTS IN THE SEWAGE SLUDGE AREA
MAXIMUM CONCENTRATIONS USED BASED ON SOIL GAS CONTAMINATION COLLECTED BY SUMMA CANISTERS

ANALYTE	Max. Soil Gas Conc. (mg/m^3)	Estimated Emission Rate (mg/sec)(a)	Modeled Air Concentration (mg/m^3)(b)	Annualized Avg. Conc. (mg/m^3)(c)	RfC (mg/m^3)	Inhalation Unit Risk /(ug/m^3)	Hazard Quotient (d)	Cancer Risk (e)
Acetone	0.081	0.0453	7.5E-05	5.2E-06	na	na	na	---
Benzene	0	0	0	0	0.006	8.3E-06	---	---
Carbon Disulfide	0	0	0	0	0.7	nd	---	---
1,1-Dichloroethane	0	0	0	0	0.5	nd	---	---
1,1-Dichloroethene	0	0	0	0	na	5.0E-05	na	---
cis-1,2-Dichloroethene	0	0	0	0	na	na	na	---
trans-1,2-Dichloroethene	0	0	0	0	na	nd	na	---
Dichlorodifluoromethane	0	0	0	0	0.2	nd	---	---
Ethylbenzene	0.01	0.005	8.3E-06	5.7E-07	1	na	5.7E-07	---
4-Methyl-2-pentanone	0	0	0	0	0.08	nd	---	---
Methylene Chloride	0.002	0.01	1.7E-05	1.1E-06	3	4.7E-07	3.8E-07	2.3E-10
Toluene	0	0	0	0	0.4	na	---	---
1,2,4-Trichlorobenzene	0	0	0	0	0.2	na	---	---
1,2,4-Trimethylbenzene	0.005	0.0026	4.3E-06	3.0E-07	0.006	na	4.9E-05	---
1,3,5-Trimethylbenzene	0.003	0.0015	2.5E-06	1.7E-07	0.006	na	2.8E-05	---
Trichloroethene	0	0	0	0	na	1.7E-06	na	---
Vinyl Chloride	0	0	0	0	na	8.4E-05	na	---
m,p-Xylene	0.02	0.0103	1.7E-05	1.2E-06	na	nd	na	---
					Total Hazard Index =		7.9E-05	
						Total Cancer Risk =		2.3E-10

NOTES:
(a) See Appendix E in M&E RI
(b) Emission rate x Disposal area length in prevailing wind direction (NW)/ Surface area x Breathing zone height x Windspeed.
[(Emission rate x 120 m) / (36118 m^2 x 2 m x 1 m/sec)]
(c) Annualized Air Concentration = Modeled Air Concentration (mg/m^3) x 4 hrs/24 hrs x 150 days / 365 days
(d) Hazard quotient = Annualized Air Concentration / RfC
(e) Cancer Risk = Annualized Air Concentration (mg/m^3) x 1000 ug/mg x Unit Risk /(ug/m^3) x 30 yrs / 70 yrs

na - not available
nd - not determined
-- - not calculated due to absence of data

*** EDITED FINAL SUPPLEMENTAL HUMAN HEALTH RISK ASSESSMENT (1998) TABLE B-58**

TABLE 2 - 1 BJ*
POTENTIAL RISK FROM INHALATION OF AMBIENT AIR BY NEARBY RESIDENTS
AVERAGE CONCENTRATIONS USED FOR AN ADULT EXPOSURE

ANALYTE	Ambient Air Concentration (mg/m^3)	Annualized Avg. Conc. (mg/m^3)(a)	RfC (mg/m^3)	Inhalation Unit Risk /(ug/m^3)	Hazard Quotient (b)	Cancer Risk (c)
Benzene	2.4E-02	2.3E-02	0.006	8.3E-06	3.8E+00	8.2E-05
Ethylbenzene	2.0E-03	1.9E-03	1	na	1.9E-03	na
Methylene Chloride	1.0E-03	9.6E-04	3	4.7E-07	3.2E-04	1.9E-07
1,1,2,2-Tetrachloroethane	4.0E-03	3.8E-03	na	5.8E-05	na	9.5E-05
Toluene	1.0E-03	9.6E-04	0.4	na	2.4E-03	na
1,1,1-Trichloroethane	2.0E-03	1.9E-03	1	na	1.9E-03	na
Vinyl Chloride	1.0E-03	9.6E-04	na	8.4E-05	na	3.5E-05
m,p-Xylene	4.0E-03	3.8E-03	na	na	na	na
o-Xylene	5.0E-03	4.8E-03	na	na	na	na
			Total Hazard Index =		3.8E+00	
				Total Cancer Risk =		2.1E-04

NOTES:
(a) Annualized Air Concentration = Ambient Air Concentration (mg/m^3) x 350 days / 365 days
(b) Hazard quotient = Annualized Air Concentration / RfC
(c) Cancer Risk = Annualized Air Concentration (mg/m^3) x 1000 ug/mg x Unit Risk /(ug/m^3) x 30 yrs / 70 yrs

na - not available
nd - not determined

*** EDITED FINAL SUPPLEMENTAL HUMAN HEALTH RISK ASSESSMENT (1998) TABLE B-59**

TABLE 2 - 1 BK*
POTENTIAL RISK FROM INHALATION OF AMBIENT AIR BY NEARBY RESIDENTS
MAXIMUM CONCENTRATIONS USED FOR AN ADULT EXPOSURE

ANALYTE	Ambient Air Concentration (mg/m^3)	Annualized Avg. Conc. (mg/m^3)(a)	RfC (mg/m^3)	Inhalation Unit Risk /(ug/m^3)	Hazard Quotient (b)	Cancer Risk (c)
Benzene	7.5E-02	7.2E-02	0.006	8.3E-06	1.2E+01	2.6E-04
Ethylbenzene	2.0E-03	1.9E-03	1	na	1.9E-03	na
Methylene Chloride	1.0E-03	9.6E-04	3	4.7E-07	3.2E-04	1.9E-07
1,1,2,2-Tetrachloroethane	4.0E-03	3.8E-03	na	5.8E-05	na	9.5E-05
Toluene	2.0E-03	1.9E-03	0.4	na	4.8E-03	na
1,1,1-Trichloroethane	2.0E-03	1.9E-03	1	na	1.9E-03	na
Vinyl Chloride	4.0E-03	3.8E-03	na	8.4E-05	na	1.4E-04
m,p-Xylene	7.0E-03	6.7E-03	na	na	na	na
o-Xylene	7.0E-03	6.7E-03	na	na	na	na
			Total Hazard Index =		1.2E+01	
				Total Cancer Risk =		4.9E-04

NOTES:
(a) Annualized Air Concentration = Ambient Air Concentration (mg/m^3) x 350 days / 365 days
(b) Hazard quotient = Annualized Air Concentration / RfC
(c) Cancer Risk = Annualized Air Concentration (mg/m^3) x 1000 ug/mg x Unit Risk /(ug/m^3) x 30 yrs / 70 yrs

na - not available
nd - not determined

*** EDITED FINAL SUPPLEMENTAL HUMAN HEALTH RISK ASSESSMENT (1998) TABLE B-60**

TABLE 2 - 1 BL*
POTENTIAL FUTURE RISK FROM INHALATION OF INDOOR AIR BY NEARBY RESIDENTS
AVERAGE CONCENTRATION OF VINYL CHLORIDE USED FOR AN ADULT EXPOSURE

ANALYTE	Indoor Air Concentration (mg/m^3)	Annualized Avg. Conc. (mg/m^3)(a)	RfC (mg/m^3)	Inhalation Unit Risk /(ug/m^3)	Hazard Quotient (b)	Cancer Risk (c)
Vinyl Chloride	2.3E-02	2.2E-02	na	8.4E-05	na	7.9E-04
			Total Hazard Index =		na	
				Total Cancer Risk =		7.9E-04

NOTES:
(a) Annualized Air Concentration = Indoor Air Concentration (mg/m^3) x 350 days / 365 days
(b) Hazard quotient = Annualized Air Concentration / RfC
(c) Cancer Risk = Annualized Air Concentration (mg/m^3) x 1000 ug/mg x Unit Risk /(ug/m^3) x 30 yrs / 70 yrs

na - not available
nd - not determined

*** EDITED FINAL SUPPLEMENTAL HUMAN HEALTH RISK ASSESSMENT (1998) TABLE B-61**

TABLE 2 - 1 BM*
POTENTIAL FUTURE RISK FROM INHALATION OF INDOOR AIR BY NEARBY RESIDENTS
MAXIMUM CONCENTRATION OF VINYL CHLORIDE USED FOR AN ADULT EXPOSURE

ANALYTE	Indoor Air Concentration (mg/m^3)	Annualized Avg. Conc. (mg/m^3)(a)	RfC (mg/m^3)	Inhalation Unit Risk /(ug/m^3)	Hazard Quotient (b)	Cancer Risk (c)
Vinyl Chloride	5.6E-02	5.4E-02	na	8.4E-05	na	1.9E-03
			Total Hazard Index =		na	
				Total Cancer Risk =		1.9E-03

NOTES:
(a) Annualized Air Concentration = Indoor Air Concentration (mg/m^3) x 350 days / 365 days
(b) Hazard quotient = Annualized Air Concentration / RfC
(c) Cancer Risk = Annualized Air Concentration (mg/m^3) x 1000 ug/mg x Unit Risk /(ug/m^3) x 30 yrs / 70 yrs

na - not available
nd - not determined

*** EDITED FINAL SUPPLEMENTAL HUMAN HEALTH RISK ASSESSMENT (1998) TABLE B-62**

TABLE 2 - 1 BN*.
POTENTIAL CENTRAL TENDENCY RISKS FOR A CURRENT/FUTURE SITE VISITOR TO THE SOLID WASTE AREA, FROM INHALATION OF AMBIENT AIR, ESTIMATED FROM SUMMA CANISTER SAMPLES OF LANDFILL GAS AND BOX DISPERSION MODEL

ANALYTE	Avg. Landfill Gas Conc. (mg/m^3)(a)	Estimated Emission Rate (mg/sec)(b)	Modeled Air Concentration (mg/m^3)(c)	Annualized Avg. Conc. (mg/m^3)(d)	RfC (mg/m^3)	Inhalation Unit Risk /(ug/m^3)	Hazard Quotient (e)	Cancer Risk (f)
Acetone	nd	nd	nd	nd	na	na	nd	---
Benzene	4.2	0.12	2.4E-04	1.7E-05	0.006	8.3E-06	2.8E-03	5.9E-08
Carbon disulfide	0.87	0.02	5.0E-05	3.4E-06	0.7	na	4.9E-06	---
Dichlorodifluoromethane	44	1.24	2.5E-03	1.7E-04	0.2	nd	8.7E-04	nd
1,1-Dichloroethane	43	1.21	2.5E-03	1.7E-04	0.5	nd	3.4E-04	nd
1,1-Dichloroethene	14	0.39	8.1E-04	5.5E-05	na	5.0E-05	nd	1.2E-06
cis-1,2-Dichloroethene	7800	220	4.5E-01	3.1E-02	na	na	nd	---
trans-1,2-Dichloroethene	8.2	0.23	4.7E-04	3.2E-05	na	nd	nd	---
Ethylbenzene	25	0.71	1.4E-03	9.9E-05	1	na	9.9E-05	---
4-Methyl-2-pentanone	3.5	0.10	2.0E-04	1.4E-05	0.08	na	1.7E-04	---
Methylene chloride	19	0.54	1.1E-03	7.5E-05	3	4.7E-07	2.5E-05	1.5E-08
1,1,2,2-Tetrachloroethane	nd	nd	nd	nd	na	5.8E-05	nd	---
Toluene	83	2.34	4.8E-03	3.3E-04	0.4	na	8.2E-04	---
1,2,4-Trichlorobenzene	nd	nd	nd	nd	0.2	na	nd	---
1,1,1-Trichloroethane	4.0	0.11	2.3E-04	1.6E-05	1	na	1.6E-05	---
Trichloroethene	15	0.42	8.6E-04	5.9E-05	na	1.7E-06	nd	4.3E-08
1,2,4-Trimethylbenzene	2.5	0.07	1.4E-04	9.9E-06	0.006	na	1.6E-03	---
1,3,5-Trimethylbenzene	2.0	0.06	1.2E-04	7.9E-06	0.006	na	1.3E-03	---
Vinyl chloride	1100	31	6.3E-02	4.3E-03	na	8.4E-05	nd	1.6E-04
m,p-Xylene	41	1.16	2.4E-03	1.6E-04	na	na	nd	---
o-Xylene	11	0.31	6.3E-04	4.3E-05	na	na	nd	---
					Total Hazard Index =		8.1E-03	
						Total Cancer Risk =		1.6E-04

NOTES:

(a) Average concentration among three SUMMA canister locations, or substitute value, as specified in Table 5

(b) Soil gas concentration x gas generation rate (0.0282 m^3/sec, calculated in FS: M&E, 1998)

(c) Emission rate x Disposal area length in prevailing wind direction (NW)/ Surface area x Breathing zone height x Windspeed
[(Emission rate x 370 m) / (90,580 m^2 x 2 m x 1 m/sec)]

(d) Annualized Air Concentration = Modeled Air Concentration (mg/m^3) x 4 hrs/24 hrs x 150 days / 365 days

(e) Hazard quotient = Annualized Air Concentration (mg/m^3) / Chronic RfC (mg/m^3)

(f) Cancer Risk = Annualized Air Concentration (mg/m^3) x 1000 ug/mg x Unit Risk (m^3/ug) x 30 yrs / 70 yrs

na not available or not applicable

nd not detected or not determined

--- minimal risk from compounds that were not detected or that are not considered carcinogenic

*** EDITED FINAL SUPPLEMENTAL HUMAN HEALTH RISK ASSESSMENT (1998) TABLE B-63**

TABLE 2 - 1 BO*.
POTENTIAL RME RISKS FOR A CURRENT/FUTURE SITE VISITOR TO THE SOLID WASTE AREA, FROM INHALATION OF AMBIENT AIR, ESTIMATED FROM SUMMA CANISTER SAMPLES OF LANDFILL GAS AND BOX DISPERSION MODEL

ANALYTE	Max. Landfill Gas Conc. (mg/m^3)(a)	Estimated Emission Rate (mg/sec)(b)	Modeled Air Concentration (mg/m^3)(c)	Annualized Avg. Conc. (mg/m^3)(d)	RfC (mg/m^3)	Inhalation Unit Risk /(ug/m^3)	Hazard Quotient (e)	Cancer Risk (f)
Acetone	nd	nd	nd	nd	na	na	nd	---
Benzene	8.0	0.23	4.6E-04	3.2E-05	0.006	8.3E-06	5.3E-03	1.1E-07
Carbon disulfide	0.87	0.02	5.0E-05	3.4E-06	0.7	na	4.9E-06	---
Dichlorodifluoromethane	110	3.10	6.3E-03	4.3E-04	0.2	nd	2.2E-03	nd
1,1-Dichloroethane	140	3.95	8.1E-03	5.5E-04	0.5	nd	1.1E-03	nd
1,1-Dichloroethene	32	0.90	1.8E-03	1.3E-04	na	5.0E-05	nd	2.7E-06
cis-1,2-Dichloroethene	23000	649	1.3E+00	9.1E-02	na	na	nd	---
trans-1,2-Dichloroethene	27	0.76	1.6E-03	1.1E-04	na	nd	nd	---
Ethylbenzene	25	0.71	1.4E-03	9.9E-05	1	na	9.9E-05	---
4-Methyl-2-pentanone	6.6	0.19	3.8E-04	2.6E-05	0.08	na	3.3E-04	---
Methylene chloride	66	1.86	3.8E-03	2.6E-04	3	4.7E-07	8.7E-05	5.2E-08
1,1,2,2-Tetrachloroethane	nd	nd	nd	nd	na	5.8E-05	nd	---
Toluene	230	6.49	1.3E-02	9.1E-04	0.4	na	2.3E-03	---
1,2,4-Trichlorobenzene	nd	nd	nd	nd	0.2	na	nd	---
1,1,1-Trichloroethane	10	0.28	5.8E-04	3.9E-05	1	na	3.9E-05	---
Trichloroethene	31	0.87	1.8E-03	1.2E-04	na	1.7E-06	nd	8.9E-08
1,2,4-Trimethylbenzene	2.5	0.07	1.4E-04	9.9E-06	0.006	na	1.6E-03	---
1,3,5-Trimethylbenzene	4.3	0.12	2.5E-04	1.7E-05	0.006	na	2.8E-03	---
Vinyl chloride	3100	87	1.8E-01	1.2E-02	na	8.4E-05	nd	4.4E-04
m,p-Xylene	41	1.16	2.4E-03	1.6E-04	na	na	nd	---
o-Xylene	11	0.31	6.3E-04	4.3E-05	na	na	nd	---
					Total Hazard Index =		1.6E-02	
						Total Cancer Risk =		4.4E-04

NOTES:

(a) Maximum concentration among three SUMMA canister locations, or substitute value, as specified in Table 5

(b) Soil gas concentration x gas generation rate (0.0282 m^3/sec, calculated in FS: M&E, 1998)

(c) Emission rate x Disposal area length in prevailing wind direction (NW)/ Surface area x Breathing zone height x Windspeed
[(Emission rate x 370 m) / (90,580 m^2 x 2 m x 1 m/sec)]

(d) Annualized Air Concentration = Modeled Air Concentration (mg/m^3) x 4 hrs/24 hrs x 150 days / 365 days

(e) Hazard quotient = Annualized Air Concentration (mg/m^3) / Chronic RfC (mg/m^3)

(f) Cancer Risk = Annualized Air Concentration (mg/m^3) x 1000 ug/mg x Unit Risk (m^3/ug) x 30 yrs / 70 yrs

na not available or not applicable

nd not detected or not determined

--- minimal risk from compounds that were not detected or that are not considered carcinogenic

*** EDITED FINAL SUPPLEMENTAL HUMAN HEALTH RISK ASSESSMENT (1998) TABLE B-64**

TABLE 2 - 1 BP*.

POTENTIAL CENTRAL TENDENCY RISKS FOR A CURRENT/FUTURE RESIDENT, FROM INHALATION OF AMBIENT AND INDOOR AIR, ESTIMATED FROM SUMMA CANISTER SAMPLES OF SOLID WASTE AREA LANDFILL GAS AND ISCST3 DISPERSION MODEL

ANALYTE	Avg. Landfill Gas Conc. (mg/m^3)(a)	Estimated Emission Rate (mg/sec)(b)	Modeled Air Concentration (mg/m^3)(c)	Annualized Avg. Conc. (mg/m^3)(d)	RfC (mg/m^3)	Inhalation Unit Risk /(ug/m^3)	Hazard Quotient (e)	Cancer Risk (f)
Acetone	nd	nd	nd	nd	na	na	nd	---
Benzene	4.2	0.12	3.2E-06	3.0E-06	0.006	8.3E-06	5.0E-04	1.1E-08
Carbon disulfide	0.87	0.02	6.5E-07	6.3E-07	0.7	na	8.9E-07	---
Dichlorodifluoromethane	44	1.24	3.3E-05	3.2E-05	0.2	nd	1.6E-04	nd
1,1-Dichloroethane	43	1.21	3.2E-05	3.1E-05	0.5	nd	6.2E-05	nd
1,1-Dichloroethene	14	0.39	1.1E-05	1.0E-05	na	5.0E-05	nd	2.2E-07
cis-1,2-Dichloroethene	7800	220	5.9E-03	5.6E-03	na	na	nd	---
trans-1,2-Dichloroethene	8.2	0.23	6.2E-06	5.9E-06	na	nd	nd	---
Ethylbenzene	25	0.71	1.9E-05	1.8E-05	1	na	1.8E-05	---
4-Methyl-2-pentanone	3.5	0.10	2.6E-06	2.5E-06	0.08	na	3.1E-05	---
Methylene chloride	19	0.54	1.4E-05	1.4E-05	3	4.7E-07	4.6E-06	2.8E-09
1,1,2,2-Tetrachloroethane	nd	nd	nd	nd	na	5.8E-05	nd	---
Toluene	83	2.34	6.2E-05	6.0E-05	0.4	na	1.5E-04	---
1,2,4-Trichlorobenzene	nd	nd	nd	nd	0.2	na	nd	---
1,1,1-Trichloroethane	4	0.11	3.0E-06	2.9E-06	1	na	2.9E-06	---
Trichloroethene	15	0.42	1.1E-05	1.1E-05	na	1.7E-06	nd	7.9E-09
1,2,4-Trimethylbenzene	2.5	0.07	1.9E-06	1.8E-06	0.006	na	3.0E-04	---
1,3,5-Trimethylbenzene	2	0.06	1.5E-06	1.4E-06	0.006	na	2.4E-04	---
Vinyl chloride	1100	31	8.3E-04	7.9E-04	na	8.4E-05	nd	2.8E-05
m,p-Xylene	41	1.16	3.1E-05	2.9E-05	na	na	nd	---
o-Xylene	11	0.31	8.3E-06	7.9E-06	na	na	nd	---
					Total Hazard Index =		1.5E-03	
						Total Cancer Risk =		2.9E-05

NOTES:

(a) Average concentration among three SUMMA canister locations, or substitute value, as specified in Table 5

(b) Soil gas concentration x gas generation rate (0.0282 m^3/sec, calculated in FS: M&E, 1998)

(c) Emission rate x unit dispersion estimated using ISCST3 at highest residential receptor among 5 years of meteorological data (highest value, 2.66 x 10^{-5} sec/m^3)

(d) Annualized Air Concentration = Modeled Air Concentration (mg/m^3) x 24 hrs/24 hrs x 350 days / 365 days

(e) Hazard quotient = Annualized Air Concentration (mg/m^3) / Chronic RfC (mg/m^3)

(f) Cancer Risk = Annualized Air Concentration (mg/m^3) x Unit Risk (m^3/ug) x 1000 ug/mg x 30 yrs / 70 yrs

na not available or not applicable

nd not detected or not determined

--- minimal risk from compounds that were not detected or that are not considered carcinogenic

*** EDITED FINAL SUPPLEMENTAL HUMAN HEALTH RISK ASSESSMENT (1998) TABLE B-65**

TABLE 2 - 1 BQ*.
POTENTIAL RME RISKS FOR A CURRENT/FUTURE RESIDENT, FROM INHALATION OF AMBIENT AND INDOOR AIR, ESTIMATED FROM SUMMA CANISTER SAMPLES OF SOLID WASTE AREA LANDFILL GAS AND ISCST3 DISPERSION MODEL

ANALYTE	Max. Landfill Gas Conc. (mg/m^3)(a)	Estimated Emission Rate (mg/sec)(b)	Modeled Air Concentration (mg/m^3)(c)	Annualized Avg. Conc. (mg/m^3)(d)	RfC (mg/m^3)	Inhalation Unit Risk /(ug/m^3)	Hazard Quotient (e)	Cancer Risk (f)
Acetone	nd	nd	nd	nd	na	na	nd	---
Benzene	8.0	0.23	6.0E-06	5.8E-06	0.006	8.3E-06	9.6E-04	2.0E-08
Carbon disulfide	0.87	0.02	6.5E-07	6.3E-07	0.7	na	8.9E-07	---
Dichlorodifluoromethane	110	3.10	8.3E-05	7.9E-05	0.2	nd	4.0E-04	nd
1,1-Dichloroethane	140	3.95	1.1E-04	1.0E-04	0.5	nd	2.0E-04	nd
1,1-Dichloroethene	32	0.90	2.4E-05	2.3E-05	na	5.0E-05	nd	4.9E-07
cis-1,2-Dichloroethene	23000	649	1.7E-02	1.7E-02	na	na	nd	---
trans-1,2-Dichloroethene	27	0.76	2.0E-05	1.9E-05	na	nd	nd	---
Ethylbenzene	25	0.71	1.9E-05	1.8E-05	1	na	1.8E-05	---
4-Methyl-2-pentanone	6.6	0.19	5.0E-06	4.7E-06	0.08	na	5.9E-05	---
Methylene chloride	66	1.86	5.0E-05	4.7E-05	3	4.7E-07	1.6E-05	9.6E-09
1,1,2,2-Tetrachloroethane	nd	nd	nd	nd	na	5.8E-05	nd	---
Toluene	230	6.49	1.7E-04	1.7E-04	0.4	na	4.1E-04	---
1,2,4-Trichlorobenzene	nd	nd	nd	nd	0.2	na	nd	---
1,1,1-Trichloroethane	10	0.28	7.5E-06	7.2E-06	1	na	7.2E-06	---
Trichloroethene	31	0.87	2.3E-05	2.2E-05	na	1.7E-06	nd	1.6E-08
1,2,4-Trimethylbenzene	2.5	0.07	1.9E-06	1.8E-06	0.006	na	3.0E-04	---
1,3,5-Trimethylbenzene	4.3	0.12	3.2E-06	3.1E-06	0.006	na	5.2E-04	---
Vinyl chloride	3100	87	2.3E-03	2.2E-03	na	8.4E-05	nd	8.0E-05
m,p-Xylene	41	1.16	3.1E-05	2.9E-05	na	na	nd	---
o-Xylene	11	0.31	8.3E-06	7.9E-06	na	na	nd	---
					Total Hazard Index =		2.9E-03	
						Total Cancer Risk =		8.1E-05

NOTES:
(a) Maximum concentration among three SUMMA canister locations, or substitute value, as specified in Table 5
(b) Soil gas concentration x gas generation rate (0.0282 m^3/sec, calculated in FS: M&E, 1998)
(c) Emission rate x unit dispersion estimated using ISCST3 at highest residential receptor among 5 years of meteorological data (highest value, 2.66 x 10^-5 sec/m^3)
(d) Annualized Air Concentration = Modeled Air Concentration (mg/m^3) x 24 hrs/24 hrs x 350 days / 365 days
(e) Hazard quotient = Annualized Air Concentration (mg/m^3) / Chronic RfC (mg/m^3)
(f) Cancer Risk = Annualized Air Concentration (mg/m^3) x Unit Risk (m^3/ug) x 1000 ug/mg x 30 yrs / 70 yrs

na not available or not applicable
nd not detected or not determined
--- minimal risk from compounds that were not detected or that are not considered carcinogenic

*** EDITED FINAL SUPPLEMENTAL HUMAN HEALTH RISK ASSESSMENT (1998) TABLE B-66**

TABLE 2 - 1 BR*.

POTENTIAL CENTRAL TENDENCY RISKS FOR A CURRENT/FUTURE RESIDENT, FROM INHALATION OF AMBIENT AND INDOOR AIR, ESTIMATED FROM SUMMA CANISTER SAMPLES OF RESIDENTIAL AREA AMBIENT AIR

ANALYTE	Measured Air Concentration (mg/m^3)(a)	Annualized Avg. Conc. (mg/m^3)(b)	RfC (mg/m^3)	Inhalation Unit Risk /(ug/m^3)	Hazard Quotient (c)	Cancer Risk (d)
Benzene	0.024	2.3E-02	0.006	8.3E-06	3.8E+00	8.2E-05
Ethylbenzene	0.0017	1.6E-03	1	na	1.6E-03	---
Methylene chloride	0.0010	9.6E-04	3	4.7E-07	3.2E-04	1.9E-07
1,1,2,2-Tetrachloroethane	0.0021	2.0E-03	na	5.8E-05	nd	5.0E-05
Toluene	0.0011	1.1E-03	0.4	na	2.6E-03	---
1,1,1-Trichloroethane	0.0014	1.3E-03	1	na	1.3E-03	---
Vinyl chloride	0.0011	1.1E-03	na	8.4E-05	nd	3.8E-05
m,p-Xylene	0.0045	4.3E-03	na	na	nd	---
o-Xylene	0.0055	5.3E-03	na	na	nd	---
			Total Hazard Index =		3.8E+00	
				Total Cancer Risk =		1.7E-04

NOTES:

(a) Average concentration among valid outdoor SUMMA canister samples, as specified in Table 6

(b) Annualized Air Concentration = Modeled Air Concentration (mg/m^3) x 24 hrs/24 hrs x 350 days / 365 days

(c) Hazard quotient = Annualized Air Concentration (mg/m^3) / Chronic RfC (mg/m^3)

(d) Cancer Risk = Annualized Air Concentration (mg/m^3) x Unit Risk (m^3/ug) x 1000 ug/mg x 30 yrs / 70 yrs

na not available or not applicable

nd not detected or not determined

--- minimal risk from compounds that were not detected or that are not considered carcinogenic

*** EDITED FINAL SUPPLEMENTAL HUMAN HEALTH RISK ASSESSMENT (1998) TABLE B-67**

TABLE 2 - 1 BS*.
POTENTIAL RME RISKS FOR A CURRENT/FUTURE RESIDENT, FROM INHALATION OF AMBIENT AND INDOOR AIR, ESTIMATED FROM SUMMA CANISTER SAMPLES OF RESIDENTIAL AREA AMBIENT AIR

ANALYTE	Measured Air Concentration (mg/m^3)(a)	Annualized Avg. Conc. (mg/m^3)(b)	RfC (mg/m^3)	Inhalation Unit Risk /(ug/m^3)	Hazard Quotient (c)	Cancer Risk (d)
Benzene	0.075	7.2E-02	0.006	8.3E-06	1.2E+01	2.6E-04
Ethylbenzene	0.0017	1.6E-03	1	na	1.6E-03	---
Methylene chloride	0.0014	1.3E-03	3	4.7E-07	4.5E-04	2.7E-07
1,1,2,2-Tetrachloroethane	0.0021	2.0E-03	na	5.8E-05	nd	5.0E-05
Toluene	0.0015	1.4E-03	0.4	na	3.6E-03	---
1,1,1-Trichloroethane	0.0016	1.5E-03	1	na	1.5E-03	---
Vinyl chloride	0.0043	4.1E-03	na	8.4E-05	nd	1.5E-04
m,p-Xylene	0.0069	6.6E-03	na	na	nd	---
o-Xylene	0.0069	6.6E-03	na	na	nd	---
			Total Hazard Index =		1.2E+01	
				Total Cancer Risk =		4.5E-04

NOTES:

(a) Maximum concentration among valid outdoor SUMMA canister samples, as specified in Table 6

(b) Annualized Air Concentration = Modeled Air Concentration (mg/m^3) x 24 hrs/24 hrs x 350 days / 365 days

(c) Hazard quotient = Annualized Air Concentration (mg/m^3) / Chronic RfC (mg/m^3)

(d) Cancer Risk = Annualized Air Concentration (mg/m^3) x Unit Risk (m^3/ug) x 1000 ug/mg x 30 yrs / 70 yrs

na not available or not applicable

nd not detected or not determined

--- minimal risk from compounds that were not detected or that are not considered carcinogenic

*** EDITED FINAL SUPPLEMENTAL HUMAN HEALTH RISK ASSESSMENT (1998) TABLE B-68**

TABLE 2 - 1 BT*.
POTENTIAL CENTRAL TENDENCY RISKS FOR A CURRENT/FUTURE PASSER-BY, FROM INHALATION OF AMBIENT AIR, ESTIMATED FROM SUMMA CANISTER SAMPLES OF SOLID WASTE AREA LANDFILL GAS AND ISCST3 DISPERSION MODEL

ANALYTE	Avg. Landfill Gas Conc. (mg/m^3)(a)	Estimated Emission Rate (mg/sec)(b)	Modeled Air Concentration (mg/m^3)(c)	Annualized Avg. Conc. (mg/m^3)(d)	RfC (mg/m^3)	Inhalation Unit Risk /(ug/m^3)	Hazard Quotient (e)	Cancer Risk (f)
Acetone	nd	nd	nd	nd	na	na	nd	---
Benzene	4.2	0.12	6.5E-06	5.5E-08	0.006	8.3E-06	9.2E-06	2.0E-10
Carbon disulfide	0.87	0.02	1.3E-06	1.1E-08	0.7	na	1.6E-08	---
Dichlorodifluoromethane	44	1.24	6.8E-05	5.8E-07	0.2	nd	2.9E-06	nd
1,1-Dichloroethane	43	1.21	6.6E-05	5.7E-07	0.5	nd	1.1E-06	nd
1,1-Dichloroethene	14	0.39	2.2E-05	1.8E-07	na	5.0E-05	nd	3.9E-09
cis-1,2-Dichloroethene	7800	220	1.2E-02	1.0E-04	na	na	nd	---
trans-1,2-Dichloroethene	8.2	0.23	1.3E-05	1.1E-07	na	nd	nd	---
Ethylbenzene	25	0.71	3.8E-05	3.3E-07	1	na	3.3E-07	---
4-Methyl-2-pentanone	3.5	0.10	5.4E-06	4.6E-08	0.08	na	5.8E-07	---
Methylene chloride	19	0.54	2.9E-05	2.5E-07	3	4.7E-07	8.3E-08	5.0E-11
1,1,2,2-Tetrachloroethane	nd	nd	nd	nd	na	5.8E-05	nd	---
Toluene	83	2.34	1.3E-04	1.1E-06	0.4	na	2.7E-06	---
1,2,4-Trichlorobenzene	nd	nd	nd	nd	0.2	na	nd	---
1,1,1-Trichloroethane	4	0.11	6.1E-06	5.3E-08	1	na	5.3E-08	---
Trichloroethene	15	0.42	2.3E-05	2.0E-07	na	1.7E-06	nd	1.4E-10
1,2,4-Trimethylbenzene	2.5	0.07	3.8E-06	3.3E-08	0.006	na	5.5E-06	---
1,3,5-Trimethylbenzene	2	0.06	3.1E-06	2.6E-08	0.006	na	4.4E-06	---
Vinyl chloride	1100	31	1.7E-03	1.4E-05	na	8.4E-05	nd	5.2E-07
m,p-Xylene	41	1.16	6.3E-05	5.4E-07	na	na	nd	---
o-Xylene	11	0.31	1.7E-05	1.4E-07	na	na	nd	---
					Total Hazard Index =		2.7E-05	
						Total Cancer Risk =		5.3E-07

NOTES:

(a) Average concentration among three SUMMA canister locations, or substitute value, as specified in Table 5.
(b) Soil gas concentration x gas generation rate (0.0282 m^3/sec, calculated in FS: M&E, 1998)
(c) Emission rate x unit dispersion at transfer station, estimated using ISCST3 among 5 years of meteorological data (5.45 x 10^{-5} sec/m^3)
(d) Annualized Air Concentration = Modeled Air Concentration (mg/m^3) x 0.5 hrs/24 hrs x 150 days / 365 days
(e) Hazard quotient = Annualized Air Concentration (mg/m^3) / Chronic RfC (mg/m^3)
(f) Cancer Risk = Annualized Air Concentration (mg/m^3) x Unit Risk (m^3/ug) x 1000 ug/mg x 30 yrs / 70 yrs

na not available or not applicable
nd not detected or not determined
--- minimal risk from compounds that were not detected or that are not considered carcinogenic

*** EDITED FINAL SUPPLEMENTAL HUMAN HEALTH RISK ASSESSMENT (1998) TABLE B-69**

TABLE 2 - 1 BU*.
POTENTIAL RME RISKS FOR A CURRENT/FUTURE PASSER-BY, FROM INHALATION OF AMBIENT AIR, ESTIMATED FROM SUMMA CANISTER SAMPLES OF SOLID WASTE AREA LANDFILL GAS AND ISCST3 DISPERSION MODEL

ANALYTE	Avg. Landfill Gas Conc. (mg/m^3)(a)	Estimated Emission Rate (mg/sec)(b)	Modeled Air Concentration (mg/m^3)(c)	Annualized Avg. Conc. (mg/m^3)(d)	RfC (mg/m^3)	Inhalation Unit Risk /(ug/m^3)	Hazard Quotient (e)	Cancer Risk (f)
Acetone	nd	nd	nd	nd	na	na	nd	---
Benzene	8.0	0.23	1.2E-05	1.1E-07	0.006	8.3E-06	1.8E-05	3.7E-10
Carbon disulfide	0.87	0.02	1.3E-06	1.1E-08	0.7	na	1.6E-08	---
Dichlorodifluoromethane	110	3.10	1.7E-04	1.4E-06	0.2	nd	7.2E-06	nd
1,1-Dichloroethane	140	3.95	2.2E-04	1.8E-06	0.5	nd	3.7E-06	nd
1,1-Dichloroethene	32	0.90	4.9E-05	4.2E-07	na	5.0E-05	nd	9.0E-09
cis-1,2-Dichloroethene	23000	649	3.5E-02	3.0E-04	na	na	nd	---
trans-1,2-Dichloroethene	27	0.76	4.1E-05	3.6E-07	na	nd	nd	---
Ethylbenzene	25	0.71	3.8E-05	3.3E-07	1	na	3.3E-07	---
4-Methyl-2-pentanone	6.6	0.19	1.0E-05	8.7E-08	0.08	na	1.1E-06	---
Methylene chloride	66	1.86	1.0E-04	8.7E-07	3	4.7E-07	2.9E-07	1.7E-10
1,1,2,2-Tetrachloroethane	nd	nd	nd	nd	na	5.8E-05	nd	---
Toluene	230	6.49	3.5E-04	3.0E-06	0.4	na	7.6E-06	---
1,2,4-Trichlorobenzene	nd	nd	nd	nd	0.2	na	nd	---
1,1,1-Trichloroethane	10	0.28	1.5E-05	1.3E-07	1	na	1.3E-07	---
Trichloroethene	31	0.87	4.8E-05	4.1E-07	na	1.7E-06	nd	3.0E-10
1,2,4-Trimethylbenzene	2.5	0.07	3.8E-06	3.3E-08	0.006	na	5.5E-06	---
1,3,5-Trimethylbenzene	4.3	0.12	6.6E-06	5.7E-08	0.006	na	9.4E-06	---
Vinyl chloride	3100	87	4.8E-03	4.1E-05	na	8.4E-05	nd	1.5E-06
m,p-Xylene	41	1.16	6.3E-05	5.4E-07	na	na	nd	---
o-Xylene	11	0.31	1.7E-05	1.4E-07	na	na	nd	---
					Total Hazard Index =		5.3E-05	
						Total Cancer Risk =		1.5E-06

NOTES:

(a) Maximum concentration among three SUMMA canister locations, or substitute value, as specified in Table 5
(b) Soil gas concentration x gas generation rate (0.0282 m^3/sec, calculated in FS: M&E, 1998)
(c) Emission rate x unit dispersion at transfer station, estimated using ISCST3 among 5 years of meteorological data (5.45 x 10^-5 sec/m^3)
(d) Annualized Air Concentration = Modeled Air Concentration (mg/m^3) x 0.5 hrs/24 hrs x 150 days / 365 days
(e) Hazard quotient = Annualized Air Concentration (mg/m^3) / Chronic RfC (mg/m^3)
(f) Cancer Risk = Annualized Air Concentration (mg/m^3) x Unit Risk (m^3/ug) x 1000 ug/mg x 30 yrs / 70 yrs

na not available or not applicable
nd not detected or not determined
--- minimal risk from compounds that were not detected or that are not considered carcinogenic

*** EDITED FINAL SUPPLEMENTAL HUMAN HEALTH RISK ASSESSMENT (1998) TABLE B-70**

TABLE 2-2. HUMAN HEALTH REMEDIAL ACTION OBJECTIVES

Media	Remedial Action Objectives
Groundwater	<u>Solid Waste Area:</u> Prevent ingestion of benzene, vinyl chloride, pentachlorophenol, DEHP[1], arsenic and acrylamide at concentrations greater than ARARs or, if there is no ARAR, greater than the EPA target risk range of 10^{-6} to 10^{-4}. Prevent ingestion of cadmium, 1,2-dichloroethene, acrylamide and manganese at concentrations greater than ARARs or, if there is no ARAR, greater than a total Hazard Index of 1. Prevent ingestion of beryllium, chromium and lead at concentrations greater than ARARs. <u>Bulky Waste Area:</u> Prevent ingestion of antimony and manganese at concentrations greater than ARARs or, if there is no ARAR, greater than a total hazard index of 1. Prevent ingestion of beryllium and lead at concentrations greater than ARARs. <u>Sewage Sludge Area:</u> Prevent ingestion of antimony, cadmium, and manganese at concentrations greater than ARARs or, if there is no ARAR, greater than a total hazard index of 1. <u>Locations Contaminated by Waste Areas:</u> Prevent ingestion of benzene, vinyl chloride, pentachlorophenol, DEHP, arsenic and acrylamide at concentrations greater than ARARs or, if there is no ARAR, greater than the EPA target risk range of 10^{-6} to 10^{-4}. Prevent ingestion of antimony, cadmium, 1,2-dichloroethene, and manganese at concentrations greater than ARARs or, if there is no ARAR, greater than a total hazard index of 1. Prevent ingestion of beryllium, chromium and lead at concentrations greater than ARARs.

TABLE 2-2 (Continued). HUMAN HEALTH REMEDIAL ACTION OBJECTIVES

Media	Remedial Action Objectives
Ambient Air	Solid Waste Area: Prevent inhalation of site-related vinyl chloride and 1,1-dichloroethene in air at levels greater than the EPA target risk range of 10^{-6} to 10^{-4}. Residential Areas: Prevent inhalation of site-related benzene, 1,1,2,2-tetrachloroethane and vinyl chloride in air at levels greater than the EPA target risk range of 10^{-6} to 10^{-4}. Prevent inhalation of site-related benzene in air at levels greater than a hazard index of one.
Soil Gas	Off-Site Properties: Maintain soil gas concentrations below ARARs or, if there is no ARAR, below explosive levels at the site boundaries and beyond. On-Site Structures: Maintain air concentrations below ARARs or, if there is no ARAR, below explosive levels within any on-site structures.

(1) DEHP: Bis(2-ethylhexyl)phthalate

TABLE 2-3. HUMAN HEALTH PRELIMINARY REMEDIATION GOALS FOR GROUNDWATER

Analyte Exceeding Preliminary Remediation Goal (PRG)	PRG (μg/L)	Basis
SOLID WASTE AREA [a]		
Benzene	5	Final MCL
1,2-Dichloroethene	70	Final MCL [b]
Vinyl chloride	2	Final MCL
Pentachlorophenol	1	Final MCL
bis(2-Ethylhexyl)phthalate	6	Final MCL
Acrylamide	0.02	Human Health Risk-Based
Beryllium	4	Final MCL
Cadmium	5	Final MCL
Chromium	100	Final MCL
Lead [c]	15	SDWA Action Level
Manganese [d]	840	Human Health Risk-Based
BULKY WASTE AREA		
Antimony [e]	6	Final MCL
Beryllium	4	Final MCL
Lead [c]	15	SDWA Action Level
Manganese [d]	840	Human Health Risk-Based
SEWAGE SLUDGE AREA		
Antimony [e]	6	Final MCL
Cadmium	5	Final MCL
Manganese [d]	840	Human Health Risk-Based

Note: These PRGs are determined for baseline conditions, which include an assumption of direct consumption of groundwater.
MCL: Maximum Contaminant Level under the Federal Safe Drinking Water Act (SDWA, U.S. EPA, 1996MCL).

Footnotes:

[a] Arsenic, which is listed on Table 2-1A, is not an anlyte exceeding the PRG since it was detected at concentrations lower than the SDWA MCL.

[b] The MCL for cis-1,2-DCE, 70 μg/L is selected; the MCL for trans-1,2-DCE is higher, 100 μg/L.

[c] The average concentration at a background location (MW-01-01) was 36.7 μg/L.

[d] The average concentration at a background location (MW-01-01) was 2,041 μg/L.

[e] There was one detection of antimony at a background location (RES#9) during the RI.

TABLE 2-4. HUMAN HEALTH PRELIMINARY REMEDIATION GOALS FOR AMBIENT AIR

Analyte Exceeding Preliminary Remediation Goal (PRG)	PRG ($\mu g/m^3$)	Basis
SOLID WASTE AREA		
Vinyl chloride	0.2	Human Health Risk-Based
1,1-Dichloroethene	0.05	Human Health Risk-Based
RESIDENTIAL AREA		
Benzene	0.1	Rhode Island AAL [1]
1,1,2,2-Tetrachloroethane	0.04	Human Health Risk-Based
Vinyl chloride	0.03	Human Health Risk-Based

Notes:
[1] AAL - Acceptable Ambient Level as defined in Air Pollution Control Regulation No. 22

TABLE 2-5. ECOLOGICAL REMEDIAL ACTION OBJECTIVES

Media	Remedial Action Objectives
Surface Water & Sediments	Mitchell Brook: Reduce contaminant migration via leachate to surface waters and sediments of Mitchell Brook. Saugatucket River: Reduce contaminant migration via leachate to surface waters and sediments of Saugatucket River.

TABLE 2-6. ECOLOGICAL PRELIMINARY REMEDIATION GOALS FOR SURFACE WATER

Analyte Exceeding Preliminary Remediation Goal (PRG)	PRG (μg/l)	Basis
MITCHELL BROOK		
Aluminum	140	Background
Iron	1,000	AWQC
Manganese	45	Background
SAUGATUCKET RIVER		
Aluminum	140	Background
Iron	1,000	AWQC
Manganese	45	Background

TABLE 2-7. REMEDIAL ACTION OBJECTIVES AND GENERAL RESPONSE ACTIONS

Media	Remedial Action Objectives	Range of General Response Actions
Groundwater	Solid Waste Area: *Human Health Risk* Prevent ingestion of benzene, vinyl chloride, pentachlorophenol, DEHP[1], arsenic and acrylamide at concentrations greater than ARARs or, if there is no ARAR, greater than the EPA target risk range of 10^{-6} to 10^{-4}. Prevent ingestion of cadmium, 1,2-dichloroethene, acrylamide and manganese at concentrations greater than ARARs or, if there is no ARAR, greater than a total Hazard Index of 1. Prevent ingestion of beryllium, chromium and lead at concentrations greater than ARARs. *Ecological Risk* No RAOs required.	• No Action • Institutional Controls: Access Restrictions, Monitoring • Source Control: Containment • Collection • Treatment: On-Site • No Action
	Bulky Waste Area: *Human Health Risk* Prevent ingestion of antimony and manganese at concentrations greater than ARARs or, if there is no ARAR, greater than a total hazard index of 1. Prevent ingestion of beryllium and lead at concentrations greater than ARARs. *Ecological Risk* No RAOs required.	• No Action • Institutional Controls: Access Restrictions, Monitoring • Source Control: Containment • Source Control: Landfill Mining • No Action

TABLE 2-7 (Continued). REMEDIAL ACTION OBJECTIVES AND GENERAL RESPONSE ACTIONS

Media	Remedial Action Objectives	Range of General Response Actions
Groundwater (continued)	Sewage Sludge Area: *Human Health Risk* Prevent ingestion of antimony, cadmium, and manganese at concentrations greater than ARARs or, if there is no ARAR, greater than a total hazard index of 1.	• No Action • Institutional Controls: Access Restrictions, Monitoring
	Ecological Risk No RAOs required.	• No Action
	Locations Contaminated by Disposal Areas: *Human Health Risk* Prevent ingestion of benzene, vinyl chloride, pentachlorophenol, DEHP, arsenic and acrylamide at concentrations greater than ARARs or, if there is no ARAR, greater than the EPA target risk range of 10^{-6} to 10^{-4}. Prevent ingestion of antimony, cadmium, 1,2-dichloroethene, and manganese at concentrations greater than ARARs or, if there is no ARAR, greater than a total hazard index of 1. Prevent ingestion of beryllium, chromium and lead at concentrations greater than ARARs.	• No Action • Institutional Controls: Access Restrictions, Monitoring
	Ecological Risk No RAOs required.	• No Action

TABLE 2-7 (Continued). REMEDIAL ACTION OBJECTIVES AND GENERAL RESPONSE ACTIONS

Media	Remedial Action Objectives	Range of General Response Actions
Surface Water & Sediments	Mitchell Brook: *Human Health Risk* No RAOs required.	• No Action
	Ecological Risk Reduce site-related contamination migration to surface water and sediments.	• No Action • Institutional Controls: Monitoring • Source Control: Containment (Solid Waste Area & leachate breakouts)
	Saugatucket River: *Human Health Risk* No RAOs required.	• No Action
	Ecological Risk Reduce site-related contaminant migration to surface water/sediments from leachate.	• No Action • Institutional Controls: Monitoring • Source Control: Containment (Bulky Waste Area) • Source Control: Landfill Mining (Bulky Waste Area) • Collection (leachate breakouts) • Treatment: On-Site (leachate)

TABLE 2-7 (Continued). REMEDIAL ACTION OBJECTIVES AND GENERAL RESPONSE ACTIONS

Media	Remedial Action Objectives	Range of General Response Actions
Ambient Air	Solid Waste Area: *Human Health Risk* Prevent inhalation of site-related vinyl chloride and 1,1-dichloroethene in air at levels greater than the EPA target risk range of 10^{-6} to 10^{-4}.	• No Action • Institutional Controls: Monitoring, Access Restrictions • Management of Migration (Landfill Gas): - Passive Horizontal Barriers - Internal Collection: Active • Treatment (Landfill Gas)
	Ecological Risk No RAOs required.	• No Action
Ambient Air	Residential Areas: *Human Health Risk* Prevent inhalation of site-related benzene, 1,1,2,2-tetrachloroethane and vinyl chloride in air at levels greater than the EPA target risk range of 10^{-6} to 10^{-4}. Prevent inhalation of site-related benzene in air at levels greater than a hazard index of one.	• No Action • Institutional Controls: Monitoring, Residential LFG Control Contingency • Management of Migration (Landfill Gas): - Passive Horizontal Barriers - Perimeter Collection: Active • Treatment (Landfill Gas)
	Ecological Risk No RAOs required.	• No Action

TABLE 2-7 (Continued). REMEDIAL ACTION OBJECTIVES AND GENERAL RESPONSE ACTIONS

Media	Remedial Action Objectives	Range of General Response Actions
Soil Gas	Off-Site Properties: *Safety Risk* Maintain soil gas concentrations below ARARs or, if there is no ARAR, below explosive levels at the site boundaries and beyond.	• No Action • Institutional Controls: Monitoring, Residential LFG Control Contingency • Management of Migration (Landfill Gas - Solid Waste Area): - Passive Horizontal Barriers - Perimeter Collection: Active • Treatment (Landfill Gas - Solid Waste Area) • Management of Migration (Landfill Gas - Bulky Waste Area): - Internal Collection: Passive • Source Control (Landfill Gas - Bulky Waste Area): - Landfill Mining
Soil Gas	On-Site Structures: *Safety Risk* Maintain air concentrations below ARARs or, if there is no ARAR, below explosive levels within any on-site structures.	• No Action • Institutional Controls: Monitoring

(1) DEHP: Bis(2-ethylhexyl)phthalate

TABLE 2-8. CHEMICAL-SPECIFIC ARARS, CRITERIA, ADVISORIES, AND GUIDANCE

Media/Authority	Requirements	Status	Requirement Synopsis	Action to be taken to attain ARAR
Air				
Federal Regulatory Requirements	Clean Air Act, NAAQS (40 CFR 50.1 - 50.12)	Relevant and Appropriate	NAAQS define levels of primary and secondary levels for listed air contaminants.	Standards for particulate matter will be used when assessing excavation and emission controls for gas treatment.
State Regulatory Requirements	Air Pollution Control Regulation No. 7: Emissions Detrimental to Persons or Property	Applicable	Prohibits emissions of contaminants which may be injurious to human, plant or life or cause damage to property or which interferes with the enjoyment of life or property.	The system will be designed, constructed, and operated in accordance with these rules.
	Air Pollution Control Regulation No. 22: Air Toxics	Applicable	Identifies toxic air contaminants, lists acceptable ambient levels, and specifies minimum quantities that may be discharged to atmosphere without a permit.	Air quality modeling will be conducted in compliance with RI guidance. The system will be designed, constructed, and operated to prevent exceedences of acceptable ambient air levels.
	Solid Waste Management Facility Rules (12-030-015)	Applicable	Identifies requirements for gas controls and closure for solid waste landfills	Methane gas concentrations at the site will be controlled to less than 25% of the LEL.
Federal Criteria, Advisories and Guidance	Threshold Limiting Values (TLVs)	To be Considered	These standards were issued as consensus standards for controlling air quality in work place environments.	TLVs could be used for assessing site inhalation risks for site remediation workers.
Groundwater				
State Regulatory Requirements	Rules and Regulations for Groundwater Quality (12-100-006)	Applicable	Sets groundwater quality standards and classifies all groundwaters within the state. Specifies procedures for determination of compliance with RI groundwater quality rules, as well as procedures for corrective actions.	Class GB groundwaters shall not: threaten public health or the environment, cause a violation of surrounding groundwater quality standards; adversely impact groundwater and surface water at boundary of facility; or violate or have the potential to cause a violation of Rhode Island surface water quality standards.

TABLE 2-8. CHEMICAL-SPECIFIC ARARS, CRITERIA, ADVISORIES, AND GUIDANCE

Media/Authority	Requirements	Status	Requirement Synopsis	Action to be taken to attain ARAR
Federal Criteria, Advisories and Guidance	EPA Groundwater Protection Strategy	To be considered	The Groundwater Protection Strategy provides a common reference for preserving clean groundwater and protecting the public health against the effects of past contamination. Guidelines for consistency in groundwater protection programs focus on the highest beneficial use of a groundwater aquifer and defines three classes of groundwater.	Class II groundwaters, potentially sources of drinking water, are protected at levels consistent with current sources of drinking water. SDWA MCLs were used when PRG's were established.
	EPA Carcinogen Assessment Group Potency Factors	To be considered	Carcinogenic effects present the most up-to-date information on cancer risk potency derived from EPA's cancer assessment group.	Carcinogen potency factors are used to compute the individual incremental cancer risk resulting from exposure to certain compounds.
	EPA Risk Reference Dose (RfDs)	To be considered	RfDs are considered to be the levels unlikely to cause significant adverse health effects associated with a threshold mechanism of action in human exposure for a lifetime.	EPA RfDs are used to characterize risks due to noncarcinogens in various media. They were considered when developing target cleanup levels.
Federal Regulatory Requirements	RCRA - Subpart F Groundwater Protection Standards Maximum Concentration Limits (40 CFR 264.94)	Relevant and Appropriate	There are three possible standards (aside from MCLs and background concentrations) available under Subpart F for setting a cleanup level for remediating groundwater contamination from a RCRA facility.	These requirements are relevant and appropriate if exposure studies performed for the site indicate a risk level higher than acceptable levels using MCLs or MCLGs. Procedures for developing maximum concentration limits are outlined in RCRA Subpart F, Section 264.94.
Surface Water				
Federal Regulatory Requirements	CWA Ambient Water Quality Criteria (AWQC) (40 CFR 122.44)	Relevant and Appropriate	Remedial actions involving contaminated surface water or groundwater must consider the uses of the water and the circumstances of the release or threatened release.	The AWQC for compounds detected on-site were compared to the observed concentrations in the groundwater. The AWQC were used when developing PRG's for surface water.

TABLE 2-8. CHEMICAL-SPECIFIC ARARS, CRITERIA, ADVISORIES, AND GUIDANCE

Media/Authority	Requirements	Status	Requirement Synopsis	Action to be taken to attain ARAR
	Proposed Clean Water Act Ambient Water Quality Criteria (AWQC) (40 CFR 120)	To be Considered	Remedial actions involving contaminated surface water or groundwater must consider the uses of the water and the circumstances of the release or threatened release.	Proposed AWQC for compounds detected on-site were compared to the observed concentrations in the groundwater. These were used when developing PRGs for surface water.
State Regulatory Requirements	RI Water Quality Regulations for Water Pollution Control, pursuant to RI Water Pollution Control Law (RIGL Title 46, Chapter 12)	Applicable	Defines water quality standards and discharges, effluent limitations, and antidegradation policy.	Numerical standards listed in Tables I and II apply to the Saugatucket River and any discharges made thereto. These are used when developing and evaluating site remediation alternatives and surface water discharges.
Federal Criteria, Advisories and Guidance	EPA Groundwater Protection Strategy	To be considered	The Groundwater Protection Strategy provides a common reference for preserving clean groundwater and protecting the public health against the effects of past contamination. Guidelines for consistency in groundwater protection programs focus on the highest beneficial use of a groundwater aquifer and defines three classes of groundwater.	Class II groundwaters, potentially sources of drinking water, are protected at levels consistent with current sources of drinking water. Class III groundwater is not considered a potential source of drinking water based on yield or naturally-occurring contamination.
	EPA Carcinogen Assessment Group Potency Factors	To be considered	Carcinogenic effects present the most up-to-date information on cancer risk potency derived from EPA's cancer assessment group.	Carcinogen potency factors are used to compute the individual incremental cancer risk resulting from exposure to certain compounds.
	EPA Risk Reference Dose (RfDs)	To be considered	RfDs are considered to be the levels unlikely to cause significant adverse health effects associated with a threshold mechanism of action in human exposure for a lifetime.	EPA RfDs are used to characterize risks due to noncarcinogens in various media. They were considered when developing target cleanup levels.

TABLE 2-9. GROUNDWATER STANDARDS AND CRITERIA TO BE CONSIDERED

CHEMICAL OF CONCERN	MOST STRINGENT ARAR (mg/L)		MOST STRINGENT TBC (mg/L)		ARARs			TBCs		
					FEDERAL SDWA (mg/L) (1)	(2)	RI GW Quality Std. (mg/L) (3)	RI GW PAL (mg/L) (3)	FED. SDWA (mg/L) (4)	
Acrylamide	tt [5]	(1)	0	(4)	tt [5]	--	--	--	0	
Benzene	0.005	(1), (3)	0	(4)	0.005	--	0.0055	0.0025	0	
bis(2-ethylhexyl)phthalate (DEHP)	0.006	(1)	0	(4)	0.006	--	0.006	0.003	0	
Dichloroethene, cis-1,2-	0.07	(1), (2), (3)	0.035	(3)	0.07	0.07	0.07	0.035	--	
Pentachlorophenol	0.001	(1), (3)	0	(4)	0.001	--	0.001	0.0005	0	
Vinyl chloride	0.002	(1), (3)	0	(4)	0.002	--	0.002	0.001	0	
Antimony	0.006	(1), (2)	0.003	(3)	0.006	0.006	0.006	0.003	--	
Arsenic	0.05	(1), (3)	0.025	(3)	0.05	--	0.05	0.025	--	
Beryllium	0.004	(1), (2)	0.002	(3)	0.004	0.004	0.004	0.002	--	
Cadmium	0.005	(1), (2)	0.0025	(3)	0.005	0.005	0.005	0.0025	--	
Chromium (total)	0.1	(1), (3)	0.05	(3)	0.1	0.1	0.1	0.05	--	
Lead	0.015	(3), (6)	0	(4)	tt [6]	--	0.015	0.0075	0	
Manganese	--		0.05	(4)	--	--	--	--	0.05	SMCL
Nickel	0.1	(3)	0.05	(4)	--	--	0.1	0.05	--	
Zinc	--		5	(4)	--	--	--	--	5	SMCL

NOTES:

(1) National Primary Drinking Water Regulations pursuant to the Safe Drinking Water Act, 40 CFR Part 141, Subpart G, Maximum Contaminant Levels (MCLs)

(2) National Primary Drinking Water Regulations pursuant to the Safe Drinking Water Act, 40 CFR Part 141, Subpart F, Maximum Contaminant Level Goals (MCLGs). Zero MCLGs are considered TBCs rather than ARARs.

(3) Numerical groundwater quality standard and preventative action limits (PALs) for Class GA groundwater. DEM-GW-01-92, May 92. The quality standards are TBCs in disposal areas and ARARs outside of these areas. The PALs are TBCs in both areas.

(4) National Secondary Drinking Water Regulations, 40 CFR Part 143, Secondary Maximum Contaminant Levels (SMCLs) and zero MCLGs.

(5) Treatment technique for acrylamide: Maximum level of 0.05% at use rate of 1 ppm polyacrylamide. Treatment technique yields 0.0005 mg/L maximum residual.

(6) Treatment technique specifying an action level of 0.015 mg/l at the tap, 0.005 mg/l in system.

TABLE 2-10. SURFACE WATER STANDARDS AND CRITERIA TO BE CONSIDERED

CHEMICAL OF CONCERN	ARARs				TBCs	
	AWQC (mg/L)[1]		SDWA (mg/L)[2]		SDWA (mg/L)[3]	
	Freshwater Acute	Freshwater Chronic	MCL	MCLG		
Acrylamide	--	--	(5)	--	0	MCLG
Benzene	2.65E-01	5.90E-03	0.005	--	0	MCLG
bis(2-ethylhexyl)phthalate (DEHP)	5.55E-01	1.20E-02	--	--	0	MCLG
Dichloroethene, cis-1,2-	--	--	0.07	0.07	--	
Pentachlorophenol	(4)	(4)	0.001	--	0	MCLG
Vinyl chloride	--	--	0.002	--	0	MCLG
Antimony	4.5E-01	1.0E-02	0.006	0.006	--	
Arsenic	3.60E-01	1.90E-01	0.05	--	--	
Beryllium	7.50E-03	1.70E-04	0.004	0.004	--	
Cadmium	(4)	(4)	0.005	0.005	--	
Chromium VI	1.5E-02	1.0E-02	0.1	0.1	--	
Manganese	--	--	--	--	0.05	SMCL
Nickel	(4)	(4)	0.1	0.1	--	
Zinc	(4)	(4)	--	--	5	SMCL

NOTES:

(1) RIDEM Ambient Water Quality Criteria and Guidelines for Toxic Pollutants, August 6, 1997.

(2) National Primary Drinking Water Regulations pursuant to the Safe Drinking Water Act, 40 CFR Part 141, Subpart G, Maximum Contaminant Levels (MCLs) and Subpart F, Maximum Contaminant Level Goals (MCLGs)

(3) Zero MCLGs promulgated under the Safe Drinking Water Act and National Secondary Drinking Water Regulations, 40 CFR Part 143, Secondary Maximum Contaminant Levels (SMCLs).

(4) Hardness dependent criteria

(5) Treatment technique for acrylamide: Maximum level of 0.05% at use rate of 1 ppm polyacrylamide. Treatment technique yields 0.0005 mg/L maximum residual

TABLE 2-11. SELECTED AIR STANDARDS AND CRITERIA TO BE CONSIDERED

CHEMICAL	ARARS					TBCs	
	RHODE ISLAND AIR TOXICS RULES					ACGIH TLV	
	(a) ($\mu g/m^3$)		(b) ($\mu g/m^3$)		(c) (lbs/yr)	(d) ($\mu g/m^3$)	
Benzene	0.1	1-yr avg	1	1-yr avg	50	32,000	(e)
Dichloroethene, 1,1-	--		--		--	20,000	
Dichloroethene, cis-1,2-	--		--		--	793,000	(f)
Dichloroethene, trans-1,2-	--		--		--	--	(f)
Ethylbenzene	--		--		--	434,000	
1,1,2,2-Tetrachloroethane	--		--		--	6,900	
Methylene chloride	2	1-yr avg	20	1-yr avg	1000	103,000	(g)
Toluene	2000	1-hr avg			10,000	188,000	
	400	1-yr avg	400	1-yr avg			
Trichloroethene	0.3	1-yr avg	3	1-yr avg	200	269,000	
Vinyl chloride	--		--		--	13,000	
Xylenes	700	24-hr avg	700	24-hr avg	10,000	434,000	

NOTES:

(a) Rhode Island Air Toxic Regulations, No. 22. Table I. Acceptable Ambient Levels. Requires modeling to determine compliance.

(b) Rhode Island Air Toxic Regulations, No. 22. Table II, Acceptable Ambient Levels With LAER. Requires modeling.

(c) Rhode Island Air Toxic Regulations, No. 22. Table III, Minimum Quantities. Requires modeling to determine compliance.

(d) ACGIH Threshold Limit Values for Chemical Substances and Physical Agents. 1996.

(e) Notice of intended change for 1992 brings benzene criteria to 1600 ug/m3.

(f) Guidance does not distinguish between cis- and trans- isomers.

(g) Notice of intended change published.

-- Indicates no standard set for substance.

NA Not analyzed.

TABLE 2-12. LOCATION-SPECIFIC ARARS, CRITERIA, ADVISORIES, AND GUIDANCE

Site Feature/Authority	Requirements	Status/ System	Requirement Synopsis	Consideration in the RI/FS
Wetlands, Floodplains, Streams, or Water Body				
Federal Regulatory Requirements	Clean Water Act, Section 404(b)(1) Guidelines for Specification of Disposal Sites for Dredged or Fill Material (40 CFR Part 230, 231)	Applicable	Under this requirement, no activity that adversely affects a wetland shall be permitted if a practicable alternative with lesser effects is available. Controls discharges of dredged or fill material to protect aquatic ecosystems.	During the identification, screening and evaluation of the systems, the effects on wetlands are discussed.
	Executive Order 11990; Statement of Procedures on Wetlands Protection (40 CFR Part 6, Appendix A)	Applicable	Action to avoid, whenever possible, the long- and short-term impacts on wetlands and to preserve and enhance wetlands. Plans for action in wetlands must be submitted for public review.	All practicable means will be used to minimize harm to the wetlands. Wetlands disturbed by remedial activities will be mitigated in accordance with requirements.
	RCRA Location Standards (40 CFR 264.18)	TBC	This regulation places limitations on where RCRA TSDFs may be located. It also outlines the criteria for constructing a RCRA facility on a 100-year floodplain.	A facility located on a 100-year floodplain must be designed, constructed, operated, and maintained to prevent washout of any hazardous waste by a 100-year flood, unless waste may be removed safely before flooding.
	Fish and Wildlife Coordination Act (50 CFR 297)	Applicable	Any modification of a body of water requires consultation with the U.S. Fish and Wildlife Services and the appropriate state wildlife agency to develop measures to prevent, mitigate or compensate for losses of fish and wildlife. This requirement is addressed under CWA Section 404 requirements.	Requires federal and state coordination on fish and wildlife matters. Floodplain protection considerations must be incorporated into the planning and decision-making about remedial alternatives.
	Executive Order 11988; Statement of Procedures on Floodplain Management (40 CFR Part 6, Appendix A)	Applicable	Action to avoid, whenever possible, the long- and short-term impacts associated with the occupancy and modifications of floodplains development, wherever there is a practical alternative. Promotes the preservation and restoration of floodplains so that their natural and beneficial value can be realized.	Remedial actions that involve construction in the floodplain areas must include all practicable means to minimize harm to and preserve beneficial values of floodplains. Floodplains disturbed by excavation will be restored to their original conditions and utility.

TABLE 2-12. LOCATION-SPECIFIC ARARS, CRITERIA, ADVISORIES, AND GUIDANCE

Site Feature/Authority	Requirements	Status/ System	Requirement Synopsis	Consideration in the RI/FS
Federal Regulatory Requirements (cont.)	Rivers and Harbors Act of 1899 (33 U.S.C. 403)	Applicable	Protects navigable rivers from unauthorized discharges or from unauthorized obstruction or alteration. This requirement is addressed under CWA Section 404 requirements.	Actions that cause alteration of navigable rivers are discussed.
State Regulatory Requirements	Rules and Regulations Governing the Administration and Enforcement of the Freshwater Wetlands Act (12-100-003)	Applicable	Identification and protection of significant wetlands and their values and functions with the goal of no net loss.	Measures prescribed to mitigate adverse impacts on protected functions and achieve no net loss are considered for all remedial activities.
Archaeologic/Historic Sites				
Federal Regulatory Requirements	National Historic Preservation Act, (36 CFR 800); Archaeologic and Historical Preservation Act (36 CFR 65); and Historic Sites Building and Antiquities Act	Applicable	Several statutes which govern the preservation of historic, scientific, and archaeological sites and resources. Includes action to recover and preserve artifacts, preserve historic properties, and minimize harm to National Historic Landmarks.	Actions that cause alteration of terrain that threatens significant scientific, prehistorical, historical, or archaeological data must be minimized and work in conjunction with preservation agencies and societies.
State Regulatory Requirements	An Act Relating to Historic Cemetaries	Applicable	Prescribes provisions for altering land within 25 feet of historical human cemetaries.	Actions must be coordinated with appropriate agencies and organizations such as the Rhode Island Cemetaries Commission, town offices and the Historical Preservation Commission.
Endangered Species				
State Regulatory Requirements	Endangered Species Act	Applicable	Action to conserve identified local endangered or threatened species.	Consultation with RIDEM to ensure that remedial actions do not jeopardize the continued existence of endangered or threatened species, or adversely modify or destroy critical habitat.

TABLE 2-13. MEDIA POTENTIALLY REQUIRING REMEDIATION

Media	Location	Volume / Area Potentially Requiring Remediation	Comments
I. GROUNDWATER			
	Current Contaminant Plume		
	1. Areal extent: PRG exceedances	143.3 acres	Based on plume boundary, Fig. 2-1
	2. Affected property Lots:	Lot #	Refer to plume boundary, Fig. 2-1
	Plat # 33	29	121 Rose Hill Road
	33	30	Rose Hill Road
	33	32-35	Rose Hill Road
	33	36	349 Rose Hill Road
	33	42	278 Rose Hill Road
	33	43	Rose Hill Road
	33	44	220 Rose Hill Road
	33	46	163 Rose Hill Road
	Waste Volumes:		
	3. Solid Waste Area		
	a. Area extent:	22.9 acres	Refer to Figure 2-1
	b. Approximate waste volume:	880,000 bank yd³	Includes daily and final cover soils; actual waste volume estimated to be: 703,000 bank yd³
	4. Bulky Waste Area		
	a. Area extent:	7.4 acres	Refer to Figure 2-1
	b. Approximate waste volume:	130,000 bank yd³	Includes fill and cover materials; actual waste volume estimated to be: 104,000 bank yd³
	5. Sewage Sludge Area		
	a. Area extent:	8.9 acres	Refer to Figure 2-1
	b. Approximate waste volume:	unknown	Cannot be accurately estimated; one exploratory boring (BH-01) identified sludge depth to be 6 feet deep.
II. SURFACE SOIL			
	Bulky Waste Area		
	Volume of soil exceeding PRGs:	unknown yd³	PRG exceedance due to Manganese; may be isolated hot spot; further sampling would be needed to define volume.

TABLE 2-13. MEDIA POTENTIALLY REQUIRING REMEDIATION

Media	Location	Volume / Area Potentially Requiring Remediation		Comments
III. SURFACE WATER AND SEDIMENTS				
	Mitchell Brook			
	1. Solid Waste Area: estimated current leachate generation:	8.14	million gallons / yr	Refer to HELP model calculations, Appendix C.
	Saugatucket River			
	2. Bulky Waste Area: estimated current leachate generation:	2.31	million gallons / yr	Refer to HELP model calculations, Appendix C.
	3. Sewage Sludge Area: estimated current leachate generation:	1.87	million gallons / yr	Refer to HELP model calculations, Appendix C.
IV. AMBIENT AIR				
	1. Solid Waste Area - landfill gas generation rate:	31.1	MMcf / yr	Million cubic feet per year; refer to Appendix E
	2. Ambient air exceeding PRGs: Affected off-site areas --- Approximate Distance from center of site:			Modeled ambient air exceeding PRGs; See Fig. 2-1 for site center; refer to Appendix F for dispersion results.
	N	1.7	miles	
	NE	2.1	miles	
	E	1.9	miles	
	SE	2.1	miles	
	S	2.5	miles	
	SW	1.7	miles	
	W	1.3	miles	
	NW	0.9	miles	
V. SOIL GAS	**Off-Site Properties**			
	1. Solid Waste Area: property lots where soil gas methane exceeds ARAR limits:			Refer to plume boundary, Fig. 2-1
		Plat #	Lot #	
		33	33	339 Rose Hill Road; Lot includes portion of Solid Waste Area
		33	34	Rose Hill Road
		33	32	Rose Hill Road
		32	10	320 Rose Hill Road
		33	42	278 Rose Hill Road
		33	43	Rose Hill Road
		33	44	220 Rose Hill Road
		33	45	222 Rose Hill Road
		33	46	163 Rose Hill Road (Town of S. Kingstown Transfer Station)
		33	29	121 Rose Hill Road
		41-1	18	96 Rose Hill Road

TABLE 2-13. MEDIA POTENTIALLY REQUIRING REMEDIATION

Media	Location	Volume / Area Potentially Requiring Remediation	Comments
V. SOIL GAS	**Off-Site Properties (Continued)**		
	2. Bulky Waste Area: property lots where soil gas methane exceeds ARAR limits:	Lot #	Refer to plume boundary, Fig. 2-1
	Plat # 33	30	Rose Hill Road
	On-Site Structures		
	No locations where soil gas methane exceeds ARAR limits		Only current on-site structures are Town of S. Kingstown Solid Waste Transfer Station buildings.

TABLE 2-14. TECHNOLOGY & PROCESS OPTION SCREENING FOR GROUNDWATER & LEACHATE

GENERAL RESPONSE ACTIONS	REMEDIAL TECHNOLOGY	PROCESS OPTIONS	TECHNOLOGY DESCRIPTION	SCREENING
NO ACTION	NONE	NONE	No remedial or response action taken within the Site.	POTENTIALLY APPLICABLE: Required as a baseline evaluation by the NCP.
INSTITUTIONAL ACTIONS	ACCESS RESTRICTIONS	DEED RESTRICTIONS	Groundwater below property cannot be used as a potable water supply source; restrictions may include modifications to deeds, zoning and ordinances; typically combined with alternate water supply technologies.	POTENTIALLY APPLICABLE: Effective in mitigating site risk by cutting risk pathway to receptors; implementation will require close cooperation between Local, State and Federal officials.
	MONITORING	GROUNDWATER MONITORING	Analytical testing of residential and site monitoring wells to determine changes in groundwater quality.	POTENTIALLY APPLICABLE: Effective in confirming migration of contaminants, success of remedy and water quality in residential wells.
	EMINENT DOMAIN	PROPERTY AQUISITION	Acquisition of private property next to site with payment of compensation to the owner; may include closure of adjacent roadways as well.	NOT APPLICABLE: Effectiveness due to removal of receptors from area of concern; cost competitive with other remedial actions but implementation will require close cooperation between Local, State and Federal officials.
MANAGEMENT OF MIGRATION	VERTICAL CONTAINMENT	SLURRY WALL	Low permeability subsurface wall consisting of soil and bentonite mixture encircling waste disposal areas.	NOT APPLICABLE: Most effective in reducing lateral migration of contaminants as part of a pump & treat system and for diversion of clean groundwater. However, there are more effective options available for the site conditions.
		SHEET PILING	Low permeability subsurface wall consisting of sheet piling encircling waste disposal areas.	NOT APPLICABLE: Most effective in reducing lateral migration of contaminants as part of a pump & treat system and for diversion of clean groundwater. However, there are more effective options available for the site conditions.
		VERTICAL GEOMEMBRANE	Low permeability subsurface wall consisting of vertical geomembrane encircling waste disposal areas.	NOT APPLICABLE: Most effective in reducing lateral migration of contaminants as part of a pump & treat system and for diversion of clean groundwater. However, there are more effective options available for the site conditions.
		PRESSURE GROUTING	Low permeability subsurface wall consisting of adjacent grout injections encircling waste areas.	NOT APPLICABLE: Permeability of wall is uncertain due to heterogeneity of waste and subsurface strata.

TABLE 2-14. TECHNOLOGY & PROCESS OPTION SCREENING FOR GROUNDWATER & LEACHATE

GENERAL RESPONSE ACTIONS	REMEDIAL TECHNOLOGY	PROCESS OPTIONS	TECHNOLOGY DESCRIPTION	SCREENING
SOURCE CONTROL	HORIZONTAL CONTAINMENT	NATIVE SOIL CAP	Cover area of waste placement with common earth and vegetate.	NOT APPLICABLE: Not effective in significantly reducing infiltration into waste.
		SINGLE BARRIER CAP	Cover area of waste disposal with a low permeability soil or geomembrane cap.	NOT APPLICABLE: Limited effectiveness in reducing infiltration into waste, generation of leachate and contamination of groundwater.
		COMPOSITE/DOUBLE BARRIER CAP	Cover area of waste disposal with a low permeability double soil and / or geomembrane cap.	POTENTIALLY APPLICABLE: Effective in reducing infiltration into waste, generation of leachate and contamination of groundwater.
		HORIZONTAL GROUTING	Inject grout below the waste to create a bottom seal limiting the downward migration of leachate.	NOT APPLICABLE: Permeability of bottom seal uncertain due to heterogeneity of waste and subsurface stratta and uncertainty of waste depth. Technology has had limited application on hazardous waste sites.
	EXCAVATION & OFF-SITE DISPOSAL	RCRA SUBTITLE C FACILITY	Excavate hot spots and transport for disposal in RCRA Subtitle C Landfill	NOT APPLICABLE: Hot spots posing an elevated groundwater or leachate risk have not been identified. The volume of waste significantly exceeds the 100,000 cubic yard maximum considered feasible for waste removal (U.S. EPA, 1991a).
		RCRA SUBTITLE D FACILITY	Excavate hot spots and transport for disposal in RCRA Subtitle D Landfill	NOT APPLICABLE: Hot spots posing an elevated groundwater or leachate risk have not been identified. The volume of waste significantly exceeds the 100,000 cubic yard maximum considered feasible for waste removal (U.S. EPA, 1991a). Restrictions may prohibit disposal of waste in a Subtitle D landfill.
	EXCAVATION & OFF-SITE TREATMENT	RCRA OFF-SITE TSD FACILITY	Excavate hot spots and transport for treatment at RCRA TSD Facility.	NOT APPLICABLE: Hot spots posing an elevated groundwater or leachate risk have not been identified. The volume of waste significantly exceeds the 100,000 cubic yard maximum considered feasible for waste removal (U.S. EPA, 1991a).
	EXCAVATION & ON-SITE TREATMENT	RCRA ON-SITE TSD FACILITY	Excavate hot spots and treat in on-site RCRA TSD Facility.	NOT APPLICABLE: Hot spots posing an elevated groundwater or leachate risk have not been identified. The volume of waste significantly exceeds the 100,000 cubic yard maximum considered feasible for waste removal (U.S. EPA, 1991a).

TABLE 2-14. TECHNOLOGY & PROCESS OPTION SCREENING FOR GROUNDWATER & LEACHATE

GENERAL RESPONSE ACTIONS	REMEDIAL TECHNOLOGY	PROCESS OPTIONS	TECHNOLOGY DESCRIPTION	SCREENING
SOURCE CONTROL (continued)	EXCAVATION & CONSOLIDATION (LANDFILL MINING)		Remove waste from landfill, sorting out reuseable materials, and then consolidate in another location.	POTENTIALLY APPLICABLE: Effective in mitigating site risk through reduction/removal of source; may still require barrier cap after consolidation.
COLLECTION	EXTRACTION WELLS		Series of wells to extract contaminated groundwater and form migration barrier.	POTENTIALLY APPLICABLE: Effective and implementable; extraction wells can limit lateral migration of contaminated groundwater.
	SUBSURFACE DRAINS		High hydraulic conductivity trenches dug to intercept and collect contaminated groundwater.	POTENTIALLY APPLICABLE: Effective and implementable; subsurface drains can limit lateral migration of contaminated groundwater.
TREATMENT: IN-SITU	BIOLOGICAL TREATMENT	BIODEGRADATION	Enhancement of natural microbial breakdown by addition of nutrients, co-substrates and oxygen sources via injection wells;	NOT APPLICABLE: Limited effectiveness; technology cannot treat the inorganic COPCs (i.e. heavy metals) which constitute significant site risk.
	PHYSICAL TREATMENT	ADSORPTION TRENCH	Excavated trenches, placed perpendicular to groundwater flow & filled with adsorbant (such as activated carbon) which removes contaminants as groundwater passes through.	NOT APPLICABLE: Limited effectiveness in treating inorganic COPCs (i.e heavy metals) which constitute significant site risk.
TREATMENT: ON-SITE	PHYSICAL PROCESSES	SEDIMENTATION	Gravitational separation of suspended solids from contaminated water	NOT APPLICABLE: Not effective for media of concern; contaminated water is likely to contain suspended solids due to leachate content; however, solids are unlikely to be settleable by gravity.
		MEDIA FILTRATION	Reduction of suspended solids by passage through bed of various media. Mechanisms involved include straining, adsorption & coagulation/flocculation.	POTENTIALLY APPLICABLE: Effective pretreatment for removing contaminants adsorbed to suspended solids and to prevent plugging in other processes; applicable due to leachate content.
		ACTIVATED CARBON ADSORPTION	Removal of organics by flow through bed of activated carbon adsorbant.	NOT APPLICABLE: Not as effective as UV/chemical oxidation; generates more process residuals requiring disposal and is not a destruction technology, which is preferable (U.S. EPA, 1990).
		AIR STRIPPING	Removal of volatile organics from water into air by using packed tower air/water contactors.	NOT APPLICABLE: Limited effectiveness in treating semivolatile COPCs Best suited for volatile organics. Technology which removes all organic COPCs at once is more desirable.

TABLE 2-14. TECHNOLOGY & PROCESS OPTION SCREENING FOR GROUNDWATER & LEACHATE

GENERAL RESPONSE ACTIONS	REMEDIAL TECHNOLOGY	PROCESS OPTIONS	TECHNOLOGY DESCRIPTION	SCREENING
TREATMENT: ON-SITE (continued)	PHYSICAL PROCESSES (continued)	MEMBRANE SEPARATIONS TECHNOLOGY	Removal of metals, TDS and SS by very high pressure osmotic membranes; processes include reverse osmosis, ultra-filtration and electrodialysis.	NOT APPLICABLE: Although effective in removing residual inorganic contaminants, option is not needed to meet discharge limits of treated water.
		DISSOLVED AIR FLOATATION	Low pressure, microscopic bubble aeration for removal of free and emulsified oil and suspended solids (may be chemically enhanced with polymer).	NOT APPLICABLE: Not effective in removing the primary site COPCs; technology is primarily used for handling floating product such as oils, etc.
		DISTILLATION	Volatile organic COPCs removed by heating groundwater to the boiling point and collecting low boiling point organic vapors; typically, multiple distillation stages required.	NOT APPLICABLE: Limited effectiveness in treating semivolatile COPCs. Technology which removes all organic COPCs at once is more desirable. Not cost-effective when compared with other technologies for organic COPCs.
		EVAPORATION	Water separated from contaminants by boiling it off and recondensing; salts and inorganic COPCs are left behind as sludges/solids for disposal.	NOT APPLICABLE: Effective on all site COPCs, but not cost-effective with other technologies due to high energy requirements.
	BIOLOGICAL PROCESSES	PACT™ PROCESS	Use of powdered activated carbon and activated sludge to remove contaminants both by adsorption and microbial degradation.	NOT APPLICABLE: Not cost-effective when compared with other technologies with equal technical effectiveness. Provides higher level of treatment than needed for organic COPCs.
		FIXED FILM BIOREACTORS	Closed-system, aerobic microbial degradation of contaminants to non-toxic products.	NOT APPLICABLE: Limited effectiveness due to low substrate concentrations which may not support biomass.
		SUSPENDED-GROWTH AEROBIC PROCESSES	Use of biologically active microorganisms which convert contaminants to biomass, other oxidized compounds and gases.	NOT APPLICABLE: Limited effectiveness due to low substrate concentrations which may not support biomass. Not designed to prevent uncontrolled release of volatile organics.
		ANAEROBIC BIOREACTORS	Anaerobic microbial degradation of contaminants to non-toxic products	NOT APPLICABLE: Limited effectiveness due to low substrate concentrations which may not support biomass. High O&M costs as compared to other technologies.
		SPRAY IRRIGATION/ LAND FARMING	Treatment of contaminated groundwater by spraying onto fields or farmland, where natural microbial degradation occurs.	NOT APPLICABLE: May be difficult to implement due to land use requirements. Causes uncontrolled release of volatile organics.

TABLE 2-14. TECHNOLOGY & PROCESS OPTION SCREENING FOR GROUNDWATER & LEACHATE

GENERAL RESPONSE ACTIONS	REMEDIAL TECHNOLOGY	PROCESS OPTIONS	TECHNOLOGY DESCRIPTION	SCREENING
TREATMENT: ON-SITE (continued)	BIOLOGICAL PROCESSES (continued)	ENZYME DEGRADATION	Removal of contaminants by use of specific enzymes which function as catalysts in breaking down contaminants.	NOT APPLICABLE: Not cost-effective when compared with other technologies for organic COPCs.
	CHEMICAL PROCESSES	COAGULATION/ FLOCCULATION & PRECIPITATION	Removal of heavy metals as settleable solids by increasing pH and addition of flocculating agent.	POTENTIALLY APPLICABLE: Very effective for high concentration inorganic COPCs such as iron and manganese; also known to remove additional low concentration inorganic COPCs.
		SEQUESTERING	Addition of chemical binding agents to the water to prevent precipitation of inorganic COPCs such as iron and manganese;	NOT APPLICABLE: Iron and manganese will likely be removed along with other inorganic COPCs which pose unacceptable risk.
		ION EXCHANGE	Removal by exchange of heavy metal ions with non-toxic ions using columns containing resin beds.	NOT APPLICABLE: Limited effectiveness; coplex multiple resin beds would be required due to large number of inorganic COPCs present; additional inorganics technologies would likely be required.
		ULTRA-VIOLET/ CHEMICAL OXIDATION	Oxidation using UV light in combination w/oxidizing agents such as hydrogen peroxide and/or ozone (O3) to detoxify organic COPCs.	POTENTIALLY APPLICABLE: Effective in treating the organic COPCs; will need to be combined with a metals treatment technology; cost-competitive with other technologies, may need treatability testing to fully implement
		WET-AIR OXIDATION	Use of elevated pressure and temperature to oxidize organics in the liquid phase.	NOT APPLICABLE: Limited effectiveness in treating dilute volatile COPCs and highly chlorinated compounds. Best suited for concentrated, non-volatile, waste streams.
		CATALYTIC DE-CHLORINATION	Removal of chlorine from chlorinated organics by proprietory reagents to lessen the toxicity of the contaminants.	NOT APPLICABLE: Not effective in removing the primary site COPCs since only two are chlorinated.
		SOLVENT EXTRACTION	Removal of organic materials by dissolving the contaminant in a solvent which may be easily separated from water.	NOT APPLICABLE: Not effective in removing the primary site COPCs; typically suited for oily petroleum wastes.

TABLE 2-14. TECHNOLOGY & PROCESS OPTION SCREENING FOR GROUNDWATER & LEACHATE

GENERAL RESPONSE ACTIONS	REMEDIAL TECHNOLOGY	PROCESS OPTIONS	TECHNOLOGY DESCRIPTION	SCREENING
TREATMENT: ON-SITE (continued)	DISCHARGE OF TREATED WATER	TO GROUNDWATER: RECHARGE WELLS	Treated water is returned to the groundwater aquifer of origin using recharge wells or basins.	POTENTIALLY APPLICABLE: Easily implementable and cost effective; must ensure that on-site recharge does not cause "mounding" which may push groundwater plume into clean zones.
		TO SURFACE WATER	Treated water is discharged to a surface water body; Mitchell Brook or the Saugatucket River.	POTENTIALLY APPLICABLE: Cost effective and avoids problems associated with groundwater discharge (clogging, mounding) but implementation will require RIPDES permit.
		POTW	Discharge of treated water to the South Kingstown POTW via sewer lines or tanker truck.	NOT APPLICABLE: Not implementable; there are no sewer lines near the Rosehill landfill and the South Kingstown POTW can only accept domestic wastewater (M&E, 1993b)
TREATMENT: OFF-SITE	POTW	MULTIPLE PROCESSES	Discharge/disposal of contaminated water to the South Kingstown POTW via sewer lines or tanker truck.	NOT APPLICABLE: Not implementable; there are no sewer lines near the Rosehill landfill and the South Kingstown POTW can only accept domestic wastewater (M&E, 1993b)
	RCRA FACILITY	MULTIPLE PROCESSES	Transport contaminated water to RCRA facility for treatment & disposal via pipelines or tanker trucks.	NOT APPLICABLE: Not effective; other treatment technologies are more cost-effective with equivalent mitigation of risks.

KEY: Technology / Process Option screened from further evaluation.

TABLE 2-15. TECHNOLOGY & PROCESS OPTION SCREENING FOR LANDFILL GAS

GENERAL RESPONSE ACTIONS	REMEDIAL TECHNOLOGY	PROCESS OPTIONS	TECHNOLOGY DESCRIPTION	SCREENING
NO ACTION	NONE	NONE	No remedial or response action taken within the Site.	POTENTIALLY APPLICABLE: Required as a baseline evaluation by the NCP.
INSTITUTIONAL ACTIONS	ACCESS RESTRICTIONS	FENCING & SECURITY MEASURES	Placement of fencing, security alarms, etc. around the site boundary to limit Public exposure to migrating gases	POTENTIALLY APPLICABLE: Effective in mitigating on-site risk by resticting access to Site by human receptors.
	MONITORING	LANDFILL GAS MONITORING	Testing of landfill gas consituents at off-site and on-site locations; used to trigger remedial measures based on comparison with risk or ARARs criteria.	POTENTIALLY APPLICABLE: Monitoring is needed to characterize the effectiveness of remedial measures or to initiate implementation of remedial activities.
	RESIDENTIAL LFG CONTROL CONTINGENCY	ALARMS & CONTROLS	Installation of sensors and controls to detect methane, provide alarms to warn of explosive conditions and shut-off ignition sources such as pilot lights; only installed if monitoring indicates exceedence of risk or ARARs criteria.	POTENTIALLY APPLICABLE: Technology is effective in characterizing site risk due to presence of methane, easily implemented into existing residential/commercial wiring and low cost.
		GAS VENTING SYSTEMS	Small-scale systems for residential and commercial use to vent air below foundations or in basements if monitoring indicates exceedence of criteria; similar to systems for radon removal (USEPA, 1991b).	POTENTIALLY APPLICABLE: Effective in mitigating site risks if methane is acceptable indicator compound; easily implemented at reasonable cost.
	EMINENT DOMAIN	PROPERTY AQUISITION	Acquisition of private property next to site with payment of compensation to the owner; may include closure of adjacent roadways as well.	NOT APPLICABLE: Technology would require protracted negotiation between Local, State and Federal officials and respective legal counsel which may delay implementation; the effectiveness of the technology is minimal since no permanent reduction of contaminant toxicity occurs.

TABLE 2-15. TECHNOLOGY & PROCESS OPTION SCREENING FOR LANDFILL GAS

GENERAL RESPONSE ACTIONS	REMEDIAL TECHNOLOGY	PROCESS OPTIONS	TECHNOLOGY DESCRIPTION	SCREENING
MANAGEMENT OF MIGRATION: BARRIERS	PASSIVE BARRIERS: HORIZONTAL	NATIVE SOIL CAP	Cover area of waste disposal with common earth and vegitate.	NOT APPLICABLE: Not effective in significantly reducing upward migration of gases.
		SINGLE BARRIER CAP	Cover area of waste disposal with a low permeability soil or geomembrane cap.	POTENTIALLY APPLICABLE: Effective in reducing upward migration of gas.
		COMPOSITE/DOUBLE BARRIER CAP	Cover area of waste disposal with a low permeability soil and geomembrane cap.	POTENTIALLY APPLICABLE: Effective in reducing upward migration of gas.
	PASSIVE BARRIERS: VERTICAL	SLURRY WALL	Low permeability subsurface wall consisting of soil and bentonite mixture.	NOT APPLICABLE: Although effective in reducing lateral migration of gas, other options are as effective at lesser cost; excavation would be required in or near waste zones leading to more difficult implementation.
		SHEET PILING	Low permeability subsurface wall consisting of sheet piling.	NOT APPLICABLE: Although effective in reducing lateral migration of gas, other options are as effective at lesser cost; excavation would be required in or near waste zones leading to more difficult implementation.
		VERTICAL GEOMEMBRANE	Low permeability subsurface wall consisting of vertical geomembrane.	NOT APPLICABLE: Although effective in reducing lateral migration of gas, other options are as effective at lesser cost; excavation would be required in or near waste zones leading to more difficult implementation.
		PRESSURE GROUTING	Low permeability subsurface wall consisting of adjacent grout injections.	NOT APPLICABLE: Permeability of wall is uncertain due to heterogeneity of waste and subsurface stratta. Technology has had limited application on hazardous waste sites.
SOURCE CONTROL	EXCAVATION & CONSOLIDATION (LANDFILL MINING)		Remove waste from landfill, sorting out reuseable materials, and then consolidate in another location.	POTENTIALLY APPLICABLE: Effective in mitigating safety risks due to soil gas in the Bulky Waste Area.

TABLE 2-15. TECHNOLOGY & PROCESS OPTION SCREENING FOR LANDFILL GAS

GENERAL RESPONSE ACTIONS	REMEDIAL TECHNOLOGY	PROCESS OPTIONS	TECHNOLOGY DESCRIPTION	SCREENING
MANAGEMENT OF MIGRATION: COLLECTION	PERIMETER COLLECTION: PASSIVE	VENTING TRENCH	Trench dug to groundwater table and filled w/crushed stone or porous material that allows easy collection of gas; frequently combined with barrier technologies to prevent migration beyond the trench.	NOT APPLICABLE: Less effectiveness and higher cost than extraction wells (M&E, 1993a); less short-term effectiveness due to worker/public risk during installation; higher costs than extraction wells due to greater volume of soils requiring disposal.
	PERIMETER COLLECTION: ACTIVE	VERTICAL EXTRACTION WELLS	Lines of vapor extraction wells perpendicular to the direction of gas migration intercept subsurface gases and redirect them to a common header pipe for treatment/discharge.	POTENTIALLY APPLICABLE: Effective in mitigating migration if well spacing allows overlap of vacuum pressure zones; lower worker/public risk due to less subsurface soil disturbance; less cost due to less excavated soil for disposal (M&E, 1993a).
		HORIZONTAL EXTRACTION LATERALS	Same concept as vertical extraction wells except that perforated collection piping is placed in horizontal trenches; best suited for shallow groundwater table.	POTENTIALLY APPLICABLE: Same rationale as extraction wells; easier to implement than extraction wells in portions of the site perimeter with shallow groundwater table.
	INTERNAL COLLECTION: PASSIVE	VERTICAL WELLS/VENTS	Vertical wells placed within the boundary of refuse areas, gas is allowed to passively vent to the atmosphere.	POTENTIALLY APPLICABLE: Reduces internal landfill pressure and controls migration of landfill gas.
	INTERNAL COLLECTION: ACTIVE	EXTRACTION WELLS	Same concept as perimeter extraction wells except that landfill gas directly removed from zone of refuse thereby decreasing migration into air or adjacent soils (M&E, 1992a).	POTENTIALLY APPLICABLE: Effective in mitigating site risks; technology combined w/ treatment would reduce gas migration to off-site soils and ambient air; must avoid "overpulling" wells which draws air into fill and can potentially lead to undergound fires (M&E, 1992a).

TABLE 2-15. TECHNOLOGY & PROCESS OPTION SCREENING FOR LANDFILL GAS

GENERAL RESPONSE ACTIONS	REMEDIAL TECHNOLOGY	PROCESS OPTIONS	TECHNOLOGY DESCRIPTION	SCREENING
GAS TREATMENT:	NO TREATMENT: DIRECT DISCHARGE TO AMBIENT AIR	POINT SOURCE DISCHARGE: STACK(S)	Discharge of untreated gases to ambient air; dispersion is mechanism to meet risk and ARARs criteria; dispersion enhanced by stack height and gas exit velocity.	NOT APPLICABLE: Not effective in meeting site risk and ARARs criteria (M&E, 1993a).
	THERMAL PROCESSES	INCINERATION	Thermal destruction of landfill gas constituents at high temperatures with discharge of treated gas to ambient air. Very high DREs possible with secondary combustion chamber.	NOT APPLICABLE: More difficult to implement than other thermal techniques due to State, Community Acceptance; higher cost than other thermal treatment technologies such as flaring (M&E, 1990).
		ENCLOSED FLARE	Thermal destruction of gas contaminants by the same method as incineration; combustion gases discharged to ambient air; no secondary combustion occurs.	POTENTIALLY APPLICABLE: Technology is effective in mitigating site risk (M&E, 1993a), implementable and less costly than incineration; as effective in meeting site PRGs as incineration.
		INTERNAL ENGINE COMBUSTION/ POWER RECOVERY	Use of collected gas as fuel source for combustion engine; engine typically used to power electric generators; electricity sold to utilities to defray costs.	NOT APPLICABLE: More difficult to implement the power recovery option which is necessary to be cost-competitive with other technologies; not as effective in destroying LFG contaminants as other thermal technologies (M&E, 1990).
	PHYSICAL PROCESSES	ACTIVATED CARBON ADSORPTION	Removal of gas contaminants by adsorption onto activated carbon; treated gas then discharged to ambient air; spent activated carbon regenerated either on or off-site.	NOT APPLICABLE: Less effective treatment than thermal processes; significant waste residuals (spent carbon) are produced; Adsorption of COPCs may be hampered by high concentrations of methane and Carbon Dioxide Not effective for vinyl chloride
		UPGRADE TO NATURAL GAS	Removal of carbon dioxide, oxygen and other VOC contaminants leaving purified gas that is sold as substitute natural gas to utilities.	NOT APPLICABLE: Difficult to implement since utility must be willing to purchase upgraded gas; cost feasibility highly sensitive to purchase price; significant waste residuals are generated which require RCRA disposal.
	PHYSICAL/ CHEMICAL PROCESSES	PHOTOCATALYTIC OXIDATION	Destruction of VOC contaminants through catalyst-initiated oxidation; treated gas discharged to ambient air.	POTENTIALLY APPLICABLE: Technology is effective in reducing site risk from VOCs; implementable and less costly than flaring; may require enhanced dispersion methods such as stack height and gas exit velocity modifications.

KEY: Technology / Process Option screened from further evaluation.

Section Three

TABLE 3-1. ON-SITE GROUNDWATER AND LEACHATE TREATMENT: TECHNICAL RATIONALE AND ASSUMPTIONS		
Technical Aspect	Value/Criteria	Rationale/Assumptions
1. Media Filtration		
a) Suspended Solids	• TSS < 100 mg/L	• "Granular media filtration should be preceded by gravity separation or other pretreatment processes for suspended solids concentration greater than about 100 mg/l. Otherwise, premature plugging and excessive backwashing will occur." (M&E, 1985)
b) Media Material	• sand, anthracite, or garnet	• Multi-media with different densities will allow for less maintenance and higher efficiency after backwashing: final selection based on flow scheme
2. Precipitation		
a) Feed stream pH	• pH must be adjusted to precipitate out or keep specific constituents in solution	• Specific inorganics require different pH values to precipitate out of solution.
b) Solids removal	• operated to maintain design criteria	• Assume approximately 3% solids out of the thickener and 30% solids in the filter cake. (U.S. Filter, 1993)

TABLE 3-1. ON-SITE GROUNDWATER AND LEACHATE TREATMENT: TECHNICAL RATIONALE AND ASSUMPTIONS		
Technical Aspect	Value/Criteria	Rationale/Assumptions
3. UV/Chemical Oxidation		
a) selection of oxidizing agent	• ozone (O_3) or hydrogen peroxide (H_2O_2) are the usual compounds used	• both compounds are able to generate the hydroxyl radicals necessary for oxidation of refractory organics (Topudurti *et al*, 1993); other oxidizing agents that can produce the radicals would be applicable as well
b) applicability	• limited to wastewater streams with less than 100 mg/L total organic compounds	• not cost effective for higher strength wastes
c) interfering constituents	• iron and manganese and other precipitating compounds	• precipitating agents block contact of the UV light with the wastewater thus greatly reducting treatment efficiency; removal of these compounds prior to treatment is required (Topudurti *et al*, 1993)
	• low BOD	• BOD should be low so that there is no added demand on oxidation requirements. Appendix D presents the site groundwater concentrations utilized.

TABLE 3-2. STANDARDS RELEVANT TO DISCHARGE OF TREATED WATER

Analyte	RIDEM Groundwater Quality Standard [1] (µg/L)	RIDEM Ambient Water Quality Criteria and Guidelines[2] Acute (µg/L)	Chronic (µg/L)
Acrylamide[8]	--	--	--
Benzene	5.5	265	5.9
bis(2-Ethylhexhl)phthalate	6	555	12
1,2-Dichloroethene (total)	70	--	--
Pentachlorophenol	1	(3)	(3)
Vinyl chloride	2	--	--
Aluminum	--	750 [7]	87 [7]
Ammonia	--	(6)	(6)
Antimony	6	450	10
Arsenic	50	360	190
Beryllium	4	7.5	0.17
Cadmium	5	(3)	(3)
Chromium	100 [4]	15 [5]	10 [5]
Copper	--	(3)	(3)
Iron	--	--	1,000
Lead	15	(3)	(3)
Manganese	--	--	--
Mercury	2	2.1	0.0122
Nickel	100	(3)	(3)
Zinc	--	(3)	(3)

(1) Numerical Groundwater Quality Standards for Class GAA and Class GA: Source; RI Rules and Regulations for Groundwater Quality May 1992; Regulation DEM-GW-01-92

(2) RIDEM Ambient Water Quality Criteria and Guidelines for Toxic Pollutants, August 6, 1997. Appendix B to RIDEM Regulation EVM 112-88.97-1.

(3) Ambient Water Quality Criteria and Guidelines are computed as a function of hardness as $CaCO_3$.

(4) Total chromium

(5) Chromium VI only

(6) ASQC for ammonia are temperature and pH dependent. If surface water discharge is to be an option, ammonia would require treatment to meet RIDEM AWQC.

(7) Criteria for aluminum are for waters in which the pH is between 6.5 and 9.

TABLE 3-3.
RESIDENTIAL LANDFILL GAS CONTROL CONTINGENCY: TECHNICAL RATIONALE AND ASSUMPTIONS

Technical Aspect	Value/Criteria	Rationale/Assumptions
Landfill Gas Control Components:		
1) Sensors for methane/COPCs	• Number required: - one sensor below basement slab - one sensor for basement indoor air	• sensors below slab provide better early warning of COPCs; methane sensors within indoor air zones (basement, etc.) not feasible due to high detection limits that result in significant exceedance of PRGs (Weston, 1993);
2) Vacuum blower(s)/fan(s), piping & vents	• typical residential-scale (USEPA, 1991b): - blower/fan size: 3-8 inches water column vacuum - blower discharge through piping (1½-3") to roof stack - suction vents: 2-6 per 1,000 ft^2 of slab area	• create vacuum (negative) pressure under basement slab to withdraw/redirect landfill gas to a safe ambient air discharge; blower(s)/fan(s) also provide mechanism for more frequent indoor air changes
3) Alarms & Controls	• sensor connections: - below slab sensor & venting system - indoor air sensor & alarm	• below slab sensors starts venting system if CH_4 detected; indoor air sensor starts alarm if CH_4 detected; sensor detection limit is 1,000 ppm as methane

TABLE 3-3.
RESIDENTIAL LANDFILL GAS CONTROL CONTINGENCY: TECHNICAL RATIONALE AND ASSUMPTIONS

Technical Aspect	Value/Criteria	Rationale/Assumptions
4) Indoor Air Changes	• increase number of indoor air changes	• frequent indoor air changes will minimize build-up of concentrations of COPCs
5) Energy Cost Allowance	• allowance to offset higher HVAC costs from more frequent indoor air changes	• see costs detailed in Section 4.2.2.7

TABLE 3-4. PERIMETER LANDFILL GAS COLLECTION: TECHNICAL RATIONALE AND ASSUMPTIONS		
Technical Aspect	Value/Criteria	Rationale/Assumptions
1. Perimeter Extraction System:		Detailed rationale described in M&E, 1993a
a) wells vs. laterals	• vertical extraction wells assumed	• horizontal laterals may be applicable for shallow groundwater areas
b) number of wells/spacing	• 26 wells with spacing of 60 feet between centers	• perimeter well system along Rose Hill Road section of Solid Waste Area only; well spacing within typical values in literature (Massman, 1989). In addition, spacing successfully used by M&E on two prior landfill gas migration control projects
c) well depth	• average depth 22 feet	• average depth to groundwater along Rose Hill Road

TABLE 3-4. PERIMETER LANDFILL GAS COLLECTION: TECHNICAL RATIONALE AND ASSUMPTIONS		
Technical Aspect	Value/Criteria	Rationale/Assumptions
2. Gas Estimates		
a) seasonal assumptions	• maximum perimeter migration towards Rose Hill Road assummed	• presumes worst-case winter conditions with frozen cap (no vertical migration)
b) flowrate	• Approximate flowrate of 810 standard cubic feet per minute (scfm)	• includes mixture of landfill gas and air drawn in by extraction well system; see M&E, 1993a for detailed calculations
c) hydraulic conductivity & vacuum applied at well	• vacuum at well head: 15 inches of water;	• instrinsic gas permeability of the vadose soil calculated from groundwater slug tests during the RI; Well head vacuum pressure in range used successfully by M&E on two prior landfill gas migration control projects
3. Condensate:		
a) generation rate	• 125 gallons per million standard ft^3 of extracted gas	• best estimate between the theoretical maximum (Maxwell, 1989) and lesser amounts documented from existing systems (RICL, 1993)
b) characterization	• condensate assumed to be RCRA hazardous waste	• likely to be RCRA-waste based on experience at other sites (M&E, 1993a and Maxwell, 1989)

TABLE 3-5.
INTERNAL LANDFILL GAS COLLECTION: TECHNICAL RATIONALE AND ASSUMPTIONS

Technical Aspect	Value/Criteria	Rationale/Assumptions
Extraction System:		
a) wells vs. laterals	• vertical extraction wells assumed	• horizontal laterals may be applicable due to the shallowness of the landfill but would generate more excavate for disposal than vertical wells
b) number of wells/spacing	• thirty-six (36) wells with spacing of approximately 150 to 200 feet between centers	• closer spacing than typically required due to thickness of refuse disposed in the Solid Waste Area; detailed calculations shown in Appendix E.
c) well depth	• screened interval in well to be two-thirds of the depth of waste fill (average well depth: 25 feet)	• approximate engineering rule-of-thumb for maintaining adequate gas removal

TABLE 3-6. LANDFILL GAS FLARE: TECHNICAL RATIONALE AND ASSUMPTIONS

Technical Aspect	Value/Criteria	Rationale/Assumptions
1. <u>Feed Gas Conditions:</u>		Detailed rationale described in M&E, 1993a
a) flowrate (1997 estimate)	• approximately 850 scfm	• perimeter gas flowrate from Table 3-4 utilized as combustion air; this flowrate would change if extraction system changed
b) estimated composition	• Internal LFG: - 50% methane - 50% carbon dioxide • Perimeter gas: - 1% methane - 1% carbon dioxide - 77% nitrogen - balance oxygen	• derived by mass balance based on assumed perimeter gas composition; refer to Appendix E
2. <u>Flare Operating Requirements:</u>		
a) operating temperature	• 1,500°F	• good engineering practice for complete combustion
b) residence time	• approximately 1.0 second	• good engineering practice for complete combustion
c) combustion air requirement	• 130% of the theoretical (i.e. stoichiometric) minimum air required	• based on operating experience from typical systems (John Zink, 1993)

TABLE 3-6. LANDFILL GAS FLARE: TECHNICAL RATIONALE AND ASSUMPTIONS		
Technical Aspect	Value/Criteria	Rationale/Assumptions
3. Auxiliary Fuel Requirements:		
a) minimum Btu content for stable combustion	• equivalent Btu content in flare feed gas of 25% methane by volume (approximately 1.5 MMBtu/hr)	• rule-of-thumb requirement based on typical operating experience (John Zink, 1993 & 1997)
b) auxiliary gas type	• propane	• easiest available auxiliary fuel is liquid propane; nearest natural gas service line is approx. 5,000 ft away; propane has higher heating value and is more cost effective
c) auxiliary gas flowrate required	• small amount (approximately 2.7 scfm) required upon initial operation; maximum estimated at approximately 6 scfm	• based on heat balance required to meet minimum Btu content for stable combustion
4. Flare Size & Anticipated Operation:		
a) Flare size at temperature and residence time requirements	• Flare dimensions	• (John Zink, 1997); flare size driven by amount of perimeter gas collected
- diameter - total height	- 3.5 feet - 30 feet	
b) stack velocity	• 11.9 feet/sec	

TABLE 3-7. PHOTOCATALYTIC OXIDATION: TECHNICAL RATIONALE AND ASSUMPTIONS		
Technical Aspect	Value/Criteria	Rationale/Assumptions
1. <u>Feed Gas Conditions:</u>		
a) flowrate	• approximately 850 scfm	• flowrate includes landfill gas and air from perimeter and internal gas collection systems; no auxiliary fuel required
b) estimated composition	• composition: - 3.5% methane - 3.5% carbon dioxide - 73.5% nitrogen - 19.5% oxygen - 83 ppmv vinyl chloride - See Appendix E for other VOCs	• derived by mass balance based on maximum VOC detections in landfill gas and assumed perimeter gas composition; refer to Appendix E
2. <u>Operating Requirements:</u>		
a) destruction/removal efficiencies (DREs) high enough to meet preliminary remediation goals	• minimum DRE for vinyl chloride of 98% at original design basis concentration of 150 ppmv	• dispersion modeling (Appendix F) indicates that 98% DRE is needed to attain the PRG for vinyl chloride at the site boundary with a reasonably sized stack and blower; DRE can be reduced if blower and stack size are increased
b) limit emission of toxic oxidation byproduct (HCl) to less than the Rhode Island permit trigger limit	• HCl limit is 1.14 lb/hour; remove by scrubbing if potential exists to exceed limit	• mass balance indicates that the HCl limit will not be approached in the exhaust from the photocatalytic oxidation unit (Appendix E); hence no scrubber required

TABLE 3-7. PHOTOCATALYTIC OXIDATION: TECHNICAL RATIONALE AND ASSUMPTIONS		
Technical Aspect	Value/Criteria	Rationale/Assumptions
2. <u>Operating Requirements (cont.):</u> c) Limit potential for explosive conditions due to methane	• Lower explosive limit (LEL) for methane is 5%	• Explosion-proof system may not be required because estimated influent methane concentration is 3.5%, which is below the LEL
3. <u>Size:</u> a) Size dependent on residence time required and specific vendor configurations	• Full-scale units typically fit in a trailer (12' x 8')	• Discussions with vendors indicate that a mobile trailer-size system would be sufficient for this application (KSE, Inc. 1997; Matrix Photocatalytic, 1997). On-site pilot testing is recommended to establish size.

TABLE 3-8. REMEDIAL ALTERNATIVES AND COMPONENTS

Alternative #1: **No Action**

Components of this alternative include:

- Environmental monitoring
- Five-year reviews of site conditions
- Community relations activities

Alternative #2: **Limited Action**

Components of this alternative include:

- Groundwater access restrictions
- Landfill gas access restrictions - Solid Waste Area
- Residential landfill gas control contingency (alarms & controls, gas venting system)
- Environmental monitoring
- Five-year reviews of site conditions
- Community relations activities

Alternative #3a: **Horizontal Containment of Solid Waste and Bulky Waste Areas, Gas Collection and Thermal Treatment**

Components of this alternative include:

- Groundwater access restrictions
- Horizontal containment - Solid Waste Area
- Horizontal containment - Bulky Waste Area
- Active perimeter LFG collection - Solid Waste Area
- Active internal LFG collection - Solid Waste Area
- Thermal LFG treatment (enclosed flare) - Solid Waste Area
- Passive internal LFG collection - Bulky Waste Area
- Environmental monitoring
- Five-year reviews of site conditions
- Community relations activities

TABLE 3-8. REMEDIAL ALTERNATIVES AND COMPONENTS

Alternative #3b: **Horizontal Containment of Solid Waste and Bulky Waste Areas, Gas Collection and Treatment by Photocatalytic Oxidation**

Components of this alternative include:

- Groundwater access restrictions
- Horizontal containment - Solid Waste Area
- Horizontal containment - Bulky Waste Area
- Active perimeter LFG collection - Solid Waste Area
- Active internal LFG collection - Solid Waste Area
- Physical/chemical LFG treatment (photocatalytic oxidation) - Solid Waste Area
- Passive internal LFG collection - Bulky Waste Area
- Environmental monitoring
- Five-year reviews of site conditions
- Community relations activities

Alternative #4a: **Horizontal Containment of Solid Waste and Bulky Waste Areas, Leachate Collection and On-Site Treatment, Gas Collection and Treatment**

Components of this alternative include:

- Groundwater access restrictions
- Horizontal containment - Solid Waste Area
- Horizontal containment - Bulky Waste Area
- Active perimeter LFG collection - Solid Waste Area
- Active internal LFG collection - Solid Waste Area
- Thermal LFG treatment (enclosed flare) - Solid Waste Area
- Passive internal LFG collection - Bulky Waste Area
- Leachate collection (wells/drains) - Bulky Waste Area
- On-site leachate treatment (precipitation, media filtration, and UV/chemical oxidation)
- Discharge of treated water (groundwater, surface water)
- Environmental monitoring
- Five-year reviews of site conditions
- Community relations activities

TABLE 3-8. REMEDIAL ALTERNATIVES AND COMPONENTS

Alternative #4b: **Horizontal Containment of Solid Waste Area, Landfill Mining of Bulky Waste Area, Leachate Collection and On-Site Treatment, Gas Collection and Treatment**

Components of this alternative include:

- Groundwater access restrictions
- Horizontal containment - Solid Waste Area
- Excavation & consolidation (landfill mining) - Bulky Waste Area
- Active perimeter LFG collection - Solid Waste Area
- Active internal LFG collection - Solid Waste Area
- Thermal LFG treatment (enclosed flare) - Solid Waste Area
- Leachate collection (wells/drains) - Bulky Waste Area
- On-site leachate treatment (precipitation, media filtration, and UV/chemical oxidation)
- Discharge of treated water (groundwater, surface water)
- Environmental monitoring
- Five-year reviews of site conditions
- Community relations activities

Alternative #5a: **Horizontal Containment of Solid Waste and Bulky Waste Areas, Groundwater and Leachate Collection and On-Site Treatment, Gas Collection and Treatment**

Components of this alternative include:

- Groundwater access restrictions
- Horizontal containment - Solid Waste Area
- Horizontal containment - Bulky Waste Area
- Active perimeter LFG collection - Solid Waste Area
- Active internal LFG collection - Solid Waste Area
- Thermal LFG treatment (enclosed flare) - Solid Waste Area
- Passive internal LFG collection - Bulky Waste Area
- Leachate collection (wells/drains) - Bulky Waste Area
- Groundwater collection system (wells/drains) - Solid Waste Area
- On-site groundwater and leachate treatment (precipitation, media filtration, and UV/chemical oxidation)
- Discharge of treated water (groundwater, surface water)
- Environmental monitoring
- Five-year reviews of site conditions
- Community relations activities

TABLE 3-8. REMEDIAL ALTERNATIVES AND COMPONENTS

Alternative #5b: **Horizontal Containment of Solid Waste Area, Landfill Mining of Bulky Waste Area, Groundwater and Leachate Collection and On-Site Treatment, Gas Collection and Treatment**

Components of this alternative include:

- Groundwater access restrictions
- Horizontal containment - Solid Waste Area
- Excavation & consolidation (landfill mining) - Bulky Waste Area
- Active perimeter LFG collection - Solid Waste Area
- Active internal LFG collection - Solid Waste Area
- Thermal LFG treatment (enclosed flare) - Solid Waste Area
- Leachate collection (wells/drains) - Bulky Waste Area
- Groundwater collection system (wells/drains) - Solid Waste Area
- On-site groundwater and leachate treatment (precipitation, media filtration, and UV/chemical oxidation)
- Discharge of treated water (groundwater, surface water)
- Environmental monitoring
- Five-year reviews of site conditions
- Community relations activities

Section Four

TABLE 4-1. NINE CRITERIA FOR DETAILED EVALUATION OF ALTERNATIVES

Threshold Criteria (A, B)

A. Overall Protection of Human Health and Environment

- Short- and long-term protection for unacceptable risks
- How each source of contamination is to be eliminated, reduced, or controlled
- How site risks are to be reduced
- Overall compliance with chemical-specific ARARs

B. Compliance with ARARs

- Compliance with chemical-specific ARARs
- Compliance with location-specific ARARs
- Compliance with action-specific ARARs
- Grounds for waivers, if appropriate

Balancing Criteria (C, D, E, F, G)

C. Long-Term Effectiveness and Permanence

- The magnitude of the residual risk to human and environmental receptors remaining from untreated waste or treatment residues at the completion of remedial activities
- An assessment of the type, degree, and adequacy of long-term management (including engineering controls, institutional controls, monitoring, and operation and maintenance) required for untreated waste or treatment residues remaining at the site
- An assessment of the long-term reliability of engineering and/or institutional controls to provide continued protection from untreated waste or treatment residues

- The potential need for replacement of the remedy and the continuing need for repairs to maintain the performance of the remedy

D. Reduction of Toxicity, Mobility, or Volume Through Treatment

- The treatment or recycling processes, the remedies they will employ, and the materials they will treat
- The amount of hazardous materials that will be destroyed, recycled or treated
- The degree of expected reduction in toxicity, mobility, or volume, including how the principal threat is addressed through treatment or recycling
- The degree to which the treatment will be irreversible
- The type and quality of treatment residuals that will remain following treatment

E. Short-Term Effectiveness

- Protection of community during remedial actions
- Protection of workers during remedial actions
- Environmental impacts during remedial actions
- Time until remedial response objectives are achieved

F. Implementability

- Technical Feasibility: The relative ease of implementing or completing an action abased on site-specific constraints, including the use of established technologies, including:
  - Ability to construct the alternative as a whole
  - Operational reliability, or the ability of a technology to meet specified process efficiencies or performance goals

- Ability to undertake future remedial actions that may be required
- Ability to monitor the effectiveness of the remedy

- Administrative Feasibility: The ability and time required to obtain any necessary approvals and permits from other agencies

- Availability of Services and Materials: The availability of the technologies, materials, or services required to implement an alternative, including:

  - Available capacity and location of needed treatment, storage, and disposal services
  - Availability of necessary equipment and specialists, and provisions to ensure any necessary additional resources
  - Timing of the availability of prospective technologies under consideration
  - Availability of services and materials, plus the potential for obtaining bids which are competitive (which may be particularly important for innovative technologies)

G. Cost

- Capital Costs: Capital costs consist of direct (construction) and indirect (non-construction and overhead) costs. Direct costs include costs for equipment, labor and materials incurred to develop, construct and implement a remedial action. Indirect costs are expenditures for engineering, financial, and other services that are not actually a part of construction, but are required to implement a remedial alternative. In this Feasibility Study, that will include the following items:

  - Health and safety items
  - Permitting and legal fees
  - Services during construction
  - Engineering and design

These items are included in the detailed cost analysis as separate line items, and are expressed as a percentage of direct capital costs. Additionally, two contingency factors (bid and scope) are also included in the cost estimates to account for factors that cannot be anticipated or estimated.

- Operation and Maintenance (O&M) Costs: O&M costs refer to post-construction costs necessary to ensure the continued effectiveness of a remedial action. They typically refer to long-term power and material costs (such as the operational costs of a water treatment facility), equipment replacement costs, and long-term monitoring costs.

- Operation and maintenance costs also include items for which quotes were obtained on a unit cost basis.

- Costs for Five-Year Review: CERCLA, as amended, Section 121(c) states that a five-year review of a remedial action is required if that remedial action results in hazardous contaminants remaining on-site. A discussion of costs associated with five-year reviews is presented, when applicable.

- Present Worth Analysis: This assessment is used to evaluate the capital and O&M costs of a remedial alternative on a present worth basis. Present worth analysis is a method of comparing expenditures for various alternatives that occur over different time periods. By discounting all costs to a common base year, the costs for different remedial action alternatives can be compared on the basis of a single cost figure for each alternative. The total present worth for a given alternative is equal to the full amount of all capital costs plus the series of expenditures in following years reduced by the appropriate future value/present worth discount factors. This analysis allows the comparison of remedial alternatives on the basis of a single cost representing an amount that, if invested in the base year and disbursed as needed, would be sufficient to cover all costs associated with the remedial action over its planned life. A 30-year performance period is assumed for present worth analyses. A discount rate of 10 percent and inflation rate of 5 percent is assumed for base calculations.

The cost elements for each remedial alternative are summarized in the cost analysis section. The "study estimate" costs provided for the alternatives are intended to reflect actual costs with an accuracy of -30 to +50 percent.

TABLE 4-1 (Continued). NINE CRITERIA FOR DETAILED EVALUATION OF ALTERNATIVES

Modifying Criteria (H, I)

H. and I. State and Community Acceptance

- The state's position and key concerns relative to the alternatives
- State comments on ARARs or the proposed use of waivers
- Formal comments made during previous phases of the RI/FS relative to technical and administrative issues and concerns should be considered and evaluated as part of this assessment. Eventually, state comments on the selection of remedy will be addressed in the ROD
- When community positions on specific alternative shave been documented during preparation of the RI/FS, the detailed analysis should address features of the remedial activities on which the community has expressed a position. Community positions on the selection of remedy will be addressed in the ROD.

TABLE 4-2. GROUNDWATER AND SURFACE WATER/SEDIMENT MONITORING: ALL ALTERNATIVES			
Activity	Location & Flow Zone	Analyses	Frequency
1. <u>Off-Site Groundwater Monitoring:</u> Tracking Off-Site Groundwater Plume Migration			
a) Perimeter Well Monitoring	• MW-03-01/02/03; SOB/DOB/BR MW-04-01/02/03; SOB/DOB/BR MW-05-01/02; SOB/DOB MW-06-01/02; SOB/DOB MW-07-01/02; DOB/BR MW-08-01/02; DOB/BR MW-09-01; DOB MW-10-01; DOB MW-11-01/02/03; SOB/DOB/BR MW-12-01/02; SOB/DOB MW-13-01/02; SOB/DOB MW-I through MW-V; all SOB OW-30; DOB	Volatile Organic Compounds (VOCs), Semivolatile Organic Compounds (SVOCs), Acrylamide, Total Metals - based on previous rounds of sampling	Quarterly during first year of remedy; reduced frequency thereafter (assumed semi-annual for this FS)
b) Residential Well Monitoring	• RES#1, SOB RES#6, BR RES#7, BR RES#8, BR RES#9, SOB RES#10, BR RES#11, BR *		
c) Background	• MW-01-01/02; SOB/BR		

TABLE 4-2. GROUNDWATER AND SURFACE WATER/SEDIMENT MONITORING: ALL ALTERNATIVES

Activity	Location & Flow Zone	Analyses	Frequency
2. <u>Disposal Area Groundwater Monitoring:</u> Monitoring Sources and Remediation Progress			
a) Solid Waste Area	• MW-14-01; DOB OW-25; DOB OW-27; DOB	VOCs, SVOCs, Acrylamide, Total Metals - based on previous rounds of sampling	Quarterly during first year of remedy; reduced frequency thereafter (assumed semi-annual for this FS)
b) Bulky Waste Area	• Alternatives #4b, #5b; three new extraction wells. All others; none.		
c) Sewage Sludge Area	• MW-02-01/02; SOB/DOB		
3. <u>Surface Water/Sediment Monitoring:</u> Monitoring Remediation Progress			
a) Saugatucket River	• SW/SD-02 through SW/SD-06 SW/SD-08 SW/SD-11 SW/SD-17 SW/SD-18	VOCs, SVOCs, Acrylamide, Total Metals - based on previous rounds of sampling	Quarterly during first year of remedy; reduced frequency thereafter (assumed semi-annual for this FS)
b) Mitchell Brook	• SW/SD-07 SW/SD-09 SW/SD-12 through SW/SD-16 SW/SD-01 (unnamed tributary)		
c) Unnamed Brook	• SW/SD-10		

* - Data not available to confirm the flow zone

SOB - Shallow Overburden
DOB - Deep Overburden
BR - Bedrock

TABLE 4-3. AMBIENT AIR AND SOIL GAS MONITORING: ALL ALTERNATIVES			
Activity	Location	Analyses	Frequency
1. <u>Ambient Air Monitoring:</u>			
a) Solid Waste Area	• three on-site stations: - junction of Rose Hill Road and Site Owner's Driveway - junction of Rose Hill Road and Transfer Station Road - eastern boundary of Solid Waste Area near road to Bulky Waste Area	- Volatile organics (i.e. TO-14) - Sulfur & odor causing compounds (mercaptans, H_2S) - Methane	Quarterly during first year of remedy; reduced frequency thereafter (assumed semi-annual for this FS)
b) Bulky Waste Area	• two stations along northwest and southeast Area boundaries		
c) Site Background	• one station at off-site, upwind location on day of sample collection		

TABLE 4-3. AMBIENT AIR AND SOIL GAS MONITORING: ALL ALTERNATIVES			
Activity	Location	Analyses	Frequency
2. <u>Soil Gas Monitoring:</u>			
a) Perimeter Soil Gas Monitoring - Solid Waste Area	• the northern, western and southern boundaries of the Solid Waste Area • Minimum of one point every 200 ft. for a total of 32 points	- Methane (CH_4) - Carbon dioxide (CO_2) - Oxygen (O_2) - Indicator VOCs (vinyl chloride)	Quarterly during first year of remedy; reduced frequency thereafter (assumed semi-annual for this FS)
b) Solid Waste Area	• two well locations; one at historical "hot" spot, one at lesser concentration location		
c) Bulky Waste Area	• one well location at historical "hot" spot		

Superfund Records Center
SITE: Rose Hill
BREAK: 4.5
OTHER:

TABLE 4-4. ACTION-SPECIFIC ARARS, CRITERIA AND GUIDANCE: ALTERNATIVE #1

Regulation	Status	Requirement	Action to be taken to attain ARARs
ACTION-SPECIFIC			
GROUNDWATER			
RCRA Groundwater Protection (40 CFR 264, Subpart F)	Implemented through RI regulations	Establishes requirements for solid waste management units (SWMUs) at RCRA regulated sites. Regulations include groundwater protection standard requirements for groundwater monitoring, detection monitoring and compliance monitoring and the corrective action program.	Because this is a no action remedy, groundwater cleanup will not be addressed and cleanup goals are not set; however, all alternatives will comply with the portions of the regulations which apply to installing groundwater monitoring wells and compliance monitoring.
Rhode Island Rules and Regulations for Hazardous Waste Management, RIDEM 4/92, Section 9.03	Applicable	Regulation outlines operation requirements for treatment, storage and disposal facilities, including a groundwater monitoring program.	Although this is a no action remedy which does not address groundwater, this alternative will comply with the regulations with respect to installation of groundwater monitoring wells and compliance monitoring.
RI Rules and Regs for Groundwater Quality, RIDEM 7/93, Sections 12.02 and 12.03.	Applicable	Regulations are designed to protect and restore the quality of the state's groundwater and include a groundwater monitoring program.	Although this is a no action remedy which does not address groundwater, this alternative will comply with the regulations with respect to installation of groundwater monitoring wells.

TABLE 4-4. ACTION-SPECIFIC ARARS, CRITERIA AND GUIDANCE: ALTERNATIVE #1

Regulation	Status	Requirement	Action to be taken to attain ARARs
Draft Interim Final OSWER Monitored Natural Attenuation Policy (OSWER Dir.9200.4-17)(12/1/97)	To Be Considered	Provides guidance on how EPA will implement national policy on use of monitored natural attenuation.	Decisions on use and efficacy of monitored natural attenuation will be consistent with guidance.
HAZARDOUS WASTE			
RI Rules and Regs for HW Management, Section 8, RIDEM 4/92.	Applicable	Outlines requirements for treatment, disposal and storage of hazardous waste by TSDFs.	Management and treatment of on-site treatment residues and waste derived from monitoring well installation will comply with these regulations.
RI Guidelines on the Management of Investigation-Derived Waste	To Be Considered	Guidance on management and disposal of materials generated during environmental investigations. Specifies action levels for soils and liquids below which investigation-derived waste may be disposed of on-site.	All sampling activities performed on-site will comply with this guidance.
SURFACE WATER			
RI PDES Regulations (12-190-003) and RI Water Quality Regs for Water Pollution Control (12-190-001)	Relevant & Appropriate	Sets AWQC standards for water discharged to surface waters.	Because this is a no action remedy, surface water cleanup will not be addressed; AWQC standards will be used to measure effectiveness of remedy with respect to leachate outbreaks to streams and other discharges to onsite surface water.

TABLE 4-4. ACTION-SPECIFIC ARARS, CRITERIA AND GUIDANCE: ALTERNATIVE #1

Regulation	Status	Requirement	Action to be taken to attain ARARs
CWA Ambient Water Quality Criteria (AWQC), 40 CFR 122.44	Relevant & Appropriate	Non-enforceable guidance used by states in conjunction with a designated use for a stream effluent to establish water quality standards. WQC levels for protection of human health from consuming fish and aquatic organisms have been developed for several contaminants. The standards are RA if there is no more stringent state rules for particular contaminants.	Because this is a no action remedy, surface water cleanup will not be addressed; WQC standards will be used to measure effectiveness of remedy with respect to leachate outbreaks to streams and other discharges to onsite surface water.
Proposed CWA Ambient Water Quality Criteria (AWQC), 40 CFR Part 120	To Be Considered	Remedial actions involving contaminated surface water or groundwater must consider the uses of the water and circumstances of release or threatened release.	Proposed AWQC for compounds detected onsite (Fe) were compared to observed concentrations in groundwater and used in developing PRGs for surface water; standards will be used to measure effectiveness of remedy with respect to leachate outbreaks to streams and other discharges to onsite surface water.
<u>CHEMICAL-SPECIFIC</u>			
EPA Human Health Assessment Cancer Slope Factors (CSFs)	To Be Considered	CSFs are developed by EPA for health effects assessments or evaluation by the Human Health Assessment Group.	The values present the most up-to-date cancer risk potency information. CSFs will be used to compute the individual cancer risk resulting from exposure to contaminants.

TABLE 4-4. ACTION-SPECIFIC ARARS, CRITERIA AND GUIDANCE: ALTERNATIVE #1

Regulation	Status	Requirement	Action to be taken to attain ARARs

Note 1: Because the remedy is no action, Safe Drinking Water Act, Maximum Contaminant Level Goals (MCLGs), 40 CFR Part 141, which are health goals for public water systems, are not ARARs for the alternative remedies at this site. Rather, they are used to measure performance of groundwater containment alternatives. The alternatives are expected to contain groundwater exceeding non-zero MCLGs within the compliance boundaries.

TABLE 4-5. ACTION-SPECIFIC ARARS, CRITERIA AND GUIDANCE: ALTERNATIVE #2

Regulation	Status	Requirement	Action to be taken to attain ARARs
ACTION-SPECIFIC			
GROUNDWATER			
RCRA Groundwater Protection (40 CFR 264, Subpart F)	Implemented through RI regulations	Establishes requirements for solid waste management units (SWMUs) at RCRA regulated sites. Regulations include groundwater protection standard requirements for groundwater monitoring, detection monitoring and compliance monitoring and the corrective action program.	Because this is a limited action remedy, groundwater cleanup will not be addressed and cleanup goals are not set; however, all alternatives will comply with the portions of the regulations which apply to installing groundwater monitoring wells and compliance monitoring.
Rhode Island Rules and Regulations for Hazardous Waste Management, RIDEM 4/92, Section 9.03	Applicable	Regulation outlines operation requirements for treatment, storage and disposal facilities, including a groundwater monitoring program.	Although this is a limited action remedy which does not address groundwater, this alternative will comply with the regulations with respect to installation of groundwater monitoring wells and compliance monitoring.
RI Rules and Regs for Groundwater Quality, RIDEM 7/93, Sections 12.02 and 12.03.	Applicable	Regulations are designed to protect and restore the quality of the state's groundwater and include a groundwater monitoring program.	Although this is a limited action remedy which does not address groundwater, this alternative will comply with the regulations with respect to installation of groundwater monitoring wells.

TABLE 4-5. ACTION-SPECIFIC ARARS, CRITERIA AND GUIDANCE: ALTERNATIVE #2

Regulation	Status	Requirement	Action to be taken to attain ARARs
Draft Interim Final OSWER Monitored Natural Attenuation Policy (OSWER Dir.9200.4-17)(12/1/97)	To Be Considered	Provides guidance on how EPA will implement national policy on use of monitored natural attenuation.	Decisions on use and efficacy of monitored natural attenuation will be consistent with guidance.
HAZARDOUS WASTE			
RI Rules and Regs for HW Management, Section 8, RIDEM 4/92.	Applicable	Outlines requirements for treatment, disposal and storage of hazardous waste by TSDFs.	Management and treatment of on-site treatment residues and waste derived from monitoring well installation will comply with these regulations.
RI Guidelines on the Management of Investigation-Derived Waste	To Be Considered	Guidance on management and disposal of materials generated during environmental investigations. Specifies action levels for soils and liquids below which investigation-derived waste may be disposed of on-site.	All sampling activities performed on-site will comply with this guidance.
SURFACE WATER			
RI PDES Regulations (12-190-003) and RI Water Quality Regs for Water Pollution Control (12-190-001)	Relevant & Appropriate	Sets AWQC standards for water discharged to surface waters.	Because this is a limited action remedy, surface water cleanup will not be addressed; AWQC standards will be used to measure effectiveness of remedy with respect to leachate outbreaks to streams and other discharges to onsite surface water.

TABLE 4-5. ACTION-SPECIFIC ARARS, CRITERIA AND GUIDANCE: ALTERNATIVE #2

Regulation	Status	Requirement	Action to be taken to attain ARARs
CWA Ambient Water Quality Criteria (AWQC), 40 CFR 122.44	Relevant & Appropriate	Non-enforceable guidance used by states in conjunction with a designated use for a stream effluent to establish water quality standards. WQC levels for protection of human health from consuming fish and aquatic organisms have been developed for several contaminants. The standards are RA if there is no more stringent state rules for particular contaminants.	Because this is a limited action remedy, surface water cleanup will not be addressed; WQC standards will be used to measure effectiveness of remedy with respect to leachate outbreaks to streams and other discharges to onsite surface water.
Proposed CWA Ambient Water Quality Criteria (AWQC), 40 CFR Part 120	To Be Considered	Remedial actions involving contaminated surface water or groundwater must consider the uses of the water and circumstances of release or threatened release.	Proposed AWQC for compounds detected onsite (Fe) were compared to observed concentrations in groundwater and used in developing PRGs for surface water; standards will be used to measure effectiveness of remedy with respect to leachate outbreaks to streams and other discharges to onsite surface water.
AIR			
RI Air Pollution Control Reg No. 22--Air Toxics	Applicable	Prohibits the emission of specified contaminants at rates which would result in ground level concentrations greater than acceptable ambient levels in the reg.	Because this is a limited action remedy, acceptable ambient levels for listed air toxics will not be met at source property boundaries; acceptable ambient levels will be used to calculate contingency residential action levels.

TABLE 4-5. ACTION-SPECIFIC ARARS, CRITERIA AND GUIDANCE: ALTERNATIVE #2

Regulation	Status	Requirement	Action to be taken to attain ARARs
CAA National Emissions Standards for Hazardous Air Pollutants (NESHAP) (40 CFR Part 61).	Relevant & Appropriate	Establishes emission levels for certain hazardous air pollutants, including vinyl chloride and benzene.	Because this is a limited action remedy, NESHAP emission limits will not be met; NESHAP levels will be used to calculated contingency residential action levels.
CHEMICAL-SPECIFIC			
EPA Human Health Assessment Cancer Slope Factors (CSFs)	To Be Considered	CSFs are developed by EPA for health effects assessments or evaluation by the Human Health Assessment Group.	The values present the most up-to-date cancer risk potency information. CSFs will be used to compute the individual cancer risk resulting from exposure to contaminants.

Note 1: Because the remedy is limited action only, Safe Drinking Water Act, Maximum Contaminant Level Goals (MCLGs), 40 CFR Part 141, which are health goals for public water systems, are not ARARs for the alternative remedies at this site. Rather, they are used to measure performance of groundwater containment alternatives. The alternatives are expected to contain groundwater exceeding non-zero MCLGs within the compliance boundaries.

TABLE 4-6. ACTION-SPECIFIC ARARS, CRITERIA AND GUIDANCE: ALTERNATIVE #3A

Regulation	Status	Requirement	Action to be taken to attain ARARs
ACTION-SPECIFIC			
GROUNDWATER			
RCRA Groundwater Protection (40 CFR 264, Subpart F)	Implemented through RI regulations	Establishes requirements for solid waste management units (SWMUs) at RCRA regulated sites. Regulations include groundwater protection standard requirements for groundwater monitoring, detection monitoring and compliance monitoring and the corrective action program.	Because this is a source control remedy, groundwater cleanup will not be addressed and cleanup goals are not set; however, all alternatives will comply with the portions of the regulations which apply to installing groundwater monitoring wells and compliance monitoring.
Rhode Island Rules and Regulations for Hazardous Waste Management, RIDEM 4/92, Section 9.03	Applicable	Regulation outlines operation requirements for treatment, storage and disposal facilities, including a groundwater monitoring program.	Although this is a source control remedy which does not address groundwater, this alternative will comply with the regulations with respect to installation of groundwater monitoring wells and compliance monitoring.
RI Rules and Regs for Groundwater Quality, RIDEM 7/93, Sections 12.02 and 12.03.	Applicable	Regulations are designed to protect and restore the quality of the state's groundwater and include a groundwater monitoring program.	Although this is a source control remedy which does not address groundwater, this alternative will comply with the regulations with respect to installation of groundwater monitoring wells.

TABLE 4-6. ACTION-SPECIFIC ARARS, CRITERIA AND GUIDANCE: ALTERNATIVE #3A

Regulation	Status	Requirement	Action to be taken to attain ARARs
Rhode Island Regs for Underground Storage Facilities used for Petroleum Products & Hazardous Material (USTs) (12-190-017)	Applicable	Establishes procedures & requirements for preventing, assessing and remediating releases from USTs.	Underground components of condensate collection system from flares will be installed and maintained in accordance with these requirements.
Draft Interim Final OSWER Monitored Natural Attenuation Policy (OSWER Dir.9200.4-17)(12/1/97)	To Be Considered	Provides guidance on how EPA will implement national policy on use of monitored natural attenuation.	Decisions on use and efficacy of monitored natural attenuation will be consistent with guidance.
<u>HAZARDOUS WASTE</u>			
RCRA-Hazardous Waste Identification, 40 CFR Part 261.	Implemented through RI regulations	Defines solid wastes that are subject to regulation as hazardous waste under 40 CFR Parts 262-265.	Requirements define RCRA regulated wastes. Acceptable management approaches for listed and characteristic hazardous waste will be met for this alternative.
RCRA-Closure and Post-Closure, 40 CFR Part 264, Subpart G	Implemented through RI regulations	Outlines the requirements for closure and post-closure care of hazardous waste management facilities.	Closure and post-closure care of the landfill will comply with these requirements.
RCRA-Standards for Permitted TSDFs; Thermal Treatment, 40 CFR Part 264, Subpart AA	Relevant & Appropriate	Air emission standards for process vents, closed vent systems and control devices at facilities that treat, store or dispose of hazardous wastes.	Alternatives which include on-site thermal treatment (enclosed flares) will meet these requirements.

TABLE 4-6. ACTION-SPECIFIC ARARS, CRITERIA AND GUIDANCE: ALTERNATIVE #3A

Regulation	Status	Requirement	Action to be taken to attain ARARs
EPA Technical Guidance for Final Covers on HW Landfills and Surface Impoundments, EPA/530-SW-047 (7/89)	To Be Considered	Guidance for landfill covers. Presents recommended technical specifications for multilayer landfill cover design.	Cap construction will be protective in accordance with the guidance.
EPA Technical Guidance memorandum regarding Alternative Cap Design for Unlined, Hazardous Waste Landfills in EPA Region I, From Dennis P. Gagne & Yoon-Jean Choi to OSRR, 9/30/97	To Be Considered	Guidance for landfill covers in EPA Region I. Presents recommended technical specifications for multilayer landfill cover design.	Cap construction will be protective in accordance with the guidance
EPA Technical Guidance on Management of Investigation-Derived Waste: Final covers on HW Landfills and surface Impoundments (EPA/530-SW-89-047)	To Be Considered	Guidance for landfill covers, recommending technical specifications for multi-layer landfill cover design.	Waste derived from cap construction will be managed in accordance with these standards.
RI Rules and Regs for HW Management, Section 8, RIDEM 4/92.	Applicable	Outlines requirements for treatment, disposal and storage of hazardous waste by TSDFs.	Management and treatment of on-site treatment residues and waste derived from cap construction will comply with these regulations.
RI Rules and Regs for HW Management, Sections 9 and 10.02, RIDEM 4/92.	Applicable	Outlines requirements for general waste analysis, security procedures, and management of hazardous waste. Sets design, construction and operational requirements for containers and tanks and closure requirements for hazardous waste facilities.	Identification and handling of hazardous waste and closure of hazardous waste landfill will comply with these requirements.

TABLE 4-6. ACTION-SPECIFIC ARARS, CRITERIA AND GUIDANCE: ALTERNATIVE #3A

Regulation	Status	Requirement	Action to be taken to attain ARARs
RI Guidelines on the Management of Investigation-Derived Waste	To Be Considered	Guidance on management and disposal of materials generated during environmental investigations. Specifies action levels for soils and liquids below which investigation-derived waste may be disposed of on-site.	All sampling activities performed on-site will comply with this guidance.
SURFACE WATER			
RI PDES Regulations (12-190-003) and RI Water Quality Regs for Water Pollution Control (12-190-001)	Relevant & Appropriate	Sets AWQC standards for water discharged to surface waters.	Because this is a source control remedy, surface water cleanup will not be addressed; AWQC standards will be used to measure effectiveness of remedy with respect to leachate outbreaks to streams and other discharges to onsite surface water.
CWA Ambient Water Quality Criteria (AWQC), 40 CFR 122.44	Relevant & Appropriate	Non-enforceable guidance used by states in conjunction with a designated use for a stream effluent to establish water quality standards. WQC levels for protection of human health from consuming fish and aquatic organisms have been developed for several contaminants. The standards are RA if there is no more stringent state rules for particular contaminants.	Because this is a source control remedy, surface water cleanup will not be addressed; WQC standards will be used to measure effectiveness of remedy with respect to leachate outbreaks to streams and other discharges to onsite surface water.

TABLE 4-6. ACTION-SPECIFIC ARARS, CRITERIA AND GUIDANCE: ALTERNATIVE #3A

Regulation	Status	Requirement	Action to be taken to attain ARARs
Proposed CWA Ambient Water Quality Criteria (AWQC), 40 CFR Part 120	To Be Considered	Remedial actions involving contaminated surface water or groundwater must consider the uses of the water and circumstances of release or threatened release.	Proposed AWQC for compounds detected onsite (Fe) were compared to observed concentrations in groundwater and used in developing PRGs for surface water; standards will be used to measure effectiveness of remedy with respect to leachate outbreaks to streams and other discharges to onsite surface water.
AIR			
Air Pollution Control Regs, RI Dept of Health, Div of Air Pollution Control, eff. 8/2/67, amended 5/20/91--Regulation No. 1 Visible Emissions	Applicable	Prohibits contaminant emissions for periods of more than 3 minutes in any one hour which are greater or equal to 20% opacity.	Air emissions from remedial actions will meet emission levels in regulations.
RI Air Pollution Control Reg No. 5--Fugitive Dust	Applicable	Requires reasonable precautions to prevent particulate matter from becoming airborne.	Operations will be performed in acc. with these rules.
RI Air Pollution Control Reg No. 7.1 and 7.2--Emission of Air Contaminants Detrimental to Person or Property	Applicable	Prohibits the emission of any contaminant which may be injurious to human, plant or animal life, or cause damage to property or interferes with the enjoyment of property.	Air emissions will meet all applicable standards, as set forth in RI Reg No. 22 and CAA NESHAPs, 40 CFR Part 61.
RI Air Pollution Control Reg No. 9--Permits	Applicable	Requires permitting for air pollution control systems and any new stationary sources which create an increase in pollutant emissions.	Air pollution control systems will be designed to meet all applicable standards, as set forth in RI Reg No. 22 and CAA NESHAPs, 40 CFR Part 61.

TABLE 4-6. ACTION-SPECIFIC ARARS, CRITERIA AND GUIDANCE: ALTERNATIVE #3A

Regulation	Status	Requirement	Action to be taken to attain ARARs
RI Air Pollution Control Reg No. 16--Operation of Air Pollution Control Systems	Applicable	Requires operation of air pollution control systems according to design specifications and defines malfunction reporting requirements.	Air pollution control systems will be operated and maintained in accordance with Operation and Maintenance Plan.
RI Air Pollution Control Reg No. 22--Air Toxics	Applicable	Prohibits the emission of specified contaminants at rates which would result in ground level concentrations greater than acceptable ambient levels in the reg.	Ambient air quality levels will be met for all technologies which emit air contaminants.
RI Guidance for Air Quality/Air Toxics Substances	To Be Considered	Provides guidelines for models and modeling procedures.	Guidance will be considered when modeling emissions from the LFG combustion stack.
CAA National Emissions Standards for Hazardous Air Pollutants (NESHAP) (40 CFR Part 61).	Relevant & Appropriate	Establishes emission levels for certain hazardous air pollutants, including vinyl chloride and benzene.	This remedy will attain NESHAP emission limits for hazardous air pollutants that result from treatment processes.
CAA Standards of Performance for Municipal Solid Waste Landfills (40 CFR Part 60, Subpart WWW).	Relevant & Appropriate	Establishes air emission limits for municipal solid waste landfills (MSWLF) and standards of performance for MSWLF gas collection and control systems.	Landfill gas collection and control systems will meet relevant and applicable performance standards.
<u>CHEMICAL-SPECIFIC</u>			
EPA Human Health Assessment Cancer Slope Factors (CSFs)	To Be Considered	CSFs are developed by EPA for health effects assessments or evaluation by the Human Health Assessment Group.	The values present the most up-to-date cancer risk potency information. CSFs will be used to compute the individual cancer risk resulting from exposure to contaminants.

TABLE 4-6. ACTION-SPECIFIC ARARS, CRITERIA AND GUIDANCE: ALTERNATIVE #3A

Regulation	Status	Requirement	Action to be taken to attain ARARs
LOCATION-SPECIFIC			
CWA Section 404(b)(1); Guidelines for Specification of Disposal Sites for Dredged or Fill Material (40 CFR Parts 230, 231)	Applicable	No activity that adversely affects a wetland is permitted if a practicable alternative with lesser effects is available. Controls discharges of dredged or fill material to protect aquatic ecosystems.	During the identification, screening and evaluation of the systems, the effects on wetlands will be considered, and no activity which adversely affects a wetland will be undertaken if a practicable alternative with lesser effects is available.
Executive Order 11990; Statement of Procedures on Wetlands Protection (40 CFR Part 6, App.A)	Applicable	Action to avoid, whenever possible, the long and short-term impacts on wetlands and to preserve and enhance wetlands. Plans for action in wetlands must be submitted for public review.	All practicable means will be used to minimize harm to the wetlands. Wetlands disturbed by remedial activities will be mitigated in accordance with requirements if no practicable alternative exists.
Fish and Wildlife Coordination Act; 16 U.S.C. 661, 40 CFR Section 6.302	Applicable	Any modification of a body of water requires consultation with US Fish and Wildlife Service and appropriate state wildlife agency to develop measures to prevent, mitigate or compensate for losses of fish and wildlife. This requirement is addressed under CWA Section 404 requirements.	Requires federal and state coordination on fish and wildlife matters. Will consult as required.

TABLE 4-6. ACTION-SPECIFIC ARARS, CRITERIA AND GUIDANCE: ALTERNATIVE #3A

Regulation	Status	Requirement	Action to be taken to attain ARARs
Executive Order 11988; Statement of Procedures on Floodplain Management (40 CFR Part 6, App. A)	Applicable	Action should avoid, whenever possible, the long and short-term impacts associated with occupancy and modifications of floodplains development, wherever there is a practicable alternative. Promotes preservation and restoration of floodplains so that their natural and beneficial value can be realized.	Remedial actions that involve construction in the floodplain areas will include all practicable means to minimize harm to and preserve beneficial values of floodplains. Floodplains disturbed by excavation will be restored to original conditions and utility.
Rules and Regulations governing administration and enforcement of Freshwater Wetlands Act (12-100-003)(8/90)	Applicable	Identifies and protects significant wetlands and their values and functions with the goal of no net loss.	Remedial actions will includes measures to mitigate adverse impacts on protected functions and achieve no net loss.
An Act Relating to Historic Cemeteries	Applicable	Restrictions on altering land within 25 feet of historical human cemeteries.	Plat 35 is a historic cemetery; actions must be coordinated with appropriate agencies such as RI Cemeteries Commission, town offices, and Historical Preservation Commission.
RI Endangered Species Act	Applicable	Actions must conserve identified local endangered or threatened species.	Consultation with RIDEM will ensure that remedial actions do not jeopardize the existence of endangered or threatened species or adversely modify or destroy critical habitat.

TABLE 4-6. ACTION-SPECIFIC ARARS, CRITERIA AND GUIDANCE: ALTERNATIVE #3A

Regulation	Status	Requirement	Action to be taken to attain ARARs

Note 1: Because the remedy is source control only, Safe Drinking Water Act, Maximum Contaminant Level Goals (MCLGs), 40 CFR Part 141, which are health goals for public water systems, are not ARARs for the alternative remedies at this site. Rather, they are used to measure performance of groundwater containment alternatives. The alternatives are expected to contain groundwater exceeding non-zero MCLGs within the compliance boundaries.

Note 2: RI Air Pollution Control Reg No. 17–Odors. RI Regulation No. 17, which prohibits emissions of air contaminants that create an objectionable odor beyond the property line, does not fall within the definition of an ARAR as set forth in the NCP, in EPA's view, because it falls within the category of nuisance laws rather than environmental cleanup or control standards. Therefore, it is not listed as an ARAR for this site. However, EPA views this rule to be a regulation which, like those promulgated under OSHA, must nonetheless be complied with in the performance of any remedy.

TABLE 4-7. ACTION-SPECIFIC ARARS, CRITERIA AND GUIDANCE: ALTERNATIVE #3B

Regulation	Status	Requirement	Action to be taken to attain ARARs
ACTION-SPECIFIC			
GROUNDWATER			
RCRA Groundwater Protection (40 CFR 264, Subpart F)	Implemented through RI regulations	Establishes requirements for solid waste management units (SWMUs) at RCRA regulated sites. Regulations include groundwater protection standard requirements for groundwater monitoring, detection monitoring and compliance monitoring and the corrective action program.	Because this is a source control remedy, groundwater cleanup will not be addressed and cleanup goals are not set; however, all alternatives will comply with the portions of the regulations which apply to installing groundwater monitoring wells and compliance monitoring.
Rhode Island Rules and Regulations for Hazardous Waste Management, RIDEM 4/92, Section 9.03	Applicable	Regulation outlines operation requirements for treatment, storage and disposal facilities, including a groundwater monitoring program.	Although this is a source control remedy which does not address groundwater, this alternative will comply with the regulations with respect to installation of groundwater monitoring wells and compliance monitoring.
RI Rules and Regs for Groundwater Quality, RIDEM 7/93, Sections 12.02 and 12.03.	Applicable	Regulations are designed to protect and restore the quality of the state's groundwater and include a groundwater monitoring program.	Although this is a source control remedy which does not address groundwater, this alternative will comply with the regulations with respect to installation of groundwater monitoring wells.

TABLE 4-7. ACTION-SPECIFIC ARARS, CRITERIA AND GUIDANCE: ALTERNATIVE #3B

Regulation	Status	Requirement	Action to be taken to attain ARARs
Rhode Island Regs for Underground Storage Facilities used for Petroleum Products & Hazardous Material (USTs) (12-190-017)	Applicable	Establishes procedures & requirements for preventing, assessing and remediating releases from USTs.	Underground components of condensate collection system from flares will be installed and maintained in accordance with these requirements.
Draft Interim Final OSWER Monitored Natural Attenuation Policy (OSWER Dir.9200.4-17)(12/1/97)	To Be Considered	Provides guidance on how EPA will implement national policy on use of monitored natural attenuation.	Decisions on use and efficacy of monitored natural attenuation will be consistent with guidance.
<u>HAZARDOUS WASTE</u>			
RCRA-Hazardous Waste Identification, 40 CFR Part 261.	Implemented through RI regulations	Defines solid wastes that are subject to regulation as hazardous waste under 40 CFR Parts 262-265.	Requirements define RCRA regulated wastes. Acceptable management approaches for listed and characteristic hazardous waste will be met for this alternative.
RCRA-Closure and Post-Closure, 40 CFR Part 264, Subpart G	Implemented through RI regulations	Outlines the requirements for closure and post-closure care of hazardous waste management facilities.	Closure and post-closure care of the landfill will comply with these requirements.
RCRA-Standards for Permitted TSDFs; Thermal Treatment, 40 CFR Part 264, Subpart AA	Relevant & Appropriate	Air emission standards for process vents, closed vent systems and control devices at facilities that treat, store or dispose of hazardous wastes.	Alternatives which include on-site thermal treatment (enclosed flares) will meet these requirements.

TABLE 4-7. ACTION-SPECIFIC ARARS, CRITERIA AND GUIDANCE: ALTERNATIVE #3B

Regulation	Status	Requirement	Action to be taken to attain ARARs
EPA Technical Guidance for Final Covers on HW Landfills and Surface Impoundments, EPA/530-SW-047 (7/89)	To Be Considered	Guidance for landfill covers. Presents recommended technical specifications for multilayer landfill cover design.	Cap construction will be protective in accordance with the guidance.
EPA Technical Guidance memorandum regarding Alternative Cap Design for Unlined, Hazardous Waste Landfills in EPA Region I, From Dennis P. Gagne & Yoon-Jean Choi to OSRR, 9/30/97	To Be Considered	Guidance for landfill covers in EPA Region I. Presents recommended technical specifications for multilayer landfill cover design.	Cap construction will be protective in accordance with the guidance
EPA Technical Guidance on Management of Investigation-Derived Waste: Final covers on HW Landfills and surface Impoundments (EPA/530-SW-89-047)	To Be Considered	Guidance for landfill covers, recommending technical specifications for multi-layer landfill cover design.	Waste derived from cap construction will be managed in accordance with these standards.
RI Rules and Regs for HW Management, Section 8, RIDEM 4/92.	Applicable	Outlines requirements for treatment, disposal and storage of hazardous waste by TSDFs.	Management and treatment of on-site treatment residues and waste derived from cap construction will comply with these regulations.
RI Rules and Regs for HW Management, Sections 9 and 10.02, RIDEM 4/92.	Applicable	Outlines requirements for general waste analysis, security procedures, and management of hazardous waste. Sets design, construction and operational requirements for containers and tanks and closure requirements for hazardous waste facilities.	Identification and handling of hazardous waste and closure of hazardous waste landfill will comply with these requirements.

TABLE 4-7. ACTION-SPECIFIC ARARS, CRITERIA AND GUIDANCE: ALTERNATIVE #3B

Regulation	Status	Requirement	Action to be taken to attain ARARs
RI Guidelines on the Management of Investigation-Derived Waste	To Be Considered	Guidance on management and disposal of materials generated during environmental investigations. Specifies action levels for soils and liquids below which investigation-derived waste may be disposed of on-site.	All sampling activities performed on-site will comply with this guidance.
SURFACE WATER			
RI PDES Regulations (12-190-003) and RI Water Quality Regs for Water Pollution Control (12-190-001)	Relevant & Appropriate	Sets AWQC standards for water discharged to surface waters.	Because this is a source control remedy, surface water cleanup will not be addressed; AWQC standards will be used to measure effectiveness of remedy with respect to leachate outbreaks to streams and other discharges to onsite surface water.
CWA Ambient Water Quality Criteria (AWQC), 40 CFR 122.44	Relevant & Appropriate	Non-enforceable guidance used by states in conjunction with a designated use for a stream effluent to establish water quality standards. WQC levels for protection of human health from consuming fish and aquatic organisms have been developed for several contaminants. The standards are RA if there is no more stringent state rules for particular contaminants.	Because this is a source control remedy, surface water cleanup will not be addressed; WQC standards will be used to measure effectiveness of remedy with respect to leachate outbreaks to streams and other discharges to onsite surface water.

TABLE 4-7. ACTION-SPECIFIC ARARS, CRITERIA AND GUIDANCE: ALTERNATIVE #3B

Regulation	Status	Requirement	Action to be taken to attain ARARs
Proposed CWA Ambient Water Quality Criteria (AWQC), 40 CFR Part 120	To Be Considered	Remedial actions involving contaminated surface water or groundwater must consider the uses of the water and circumstances of release or threatened release.	Proposed AWQC for compounds detected onsite (Fe) were compared to observed concentrations in groundwater and used in developing PRGs for surface water; standards will be used to measure effectiveness of remedy with respect to leachate outbreaks to streams and other discharges to onsite surface water.
AIR			
Air Pollution Control Regs, RI Dept of Health, Div of Air Pollution Control, eff. 8/2/67, amended 5/20/91--Regulation No. 1 Visible Emissions	Applicable	Prohibits contaminant emissions for periods of more than 3 minutes in any one hour which are greater or equal to 20% opacity.	Air emissions from remedial actions will meet emission levels in regulations.
RI Air Pollution Control Reg No. 5--Fugitive Dust	Applicable	Requires reasonable precautions to prevent particulate matter from becoming airborne.	Operations will be performed in acc. with these rules.
RI Air Pollution Control Reg No. 7.1 and 7.2--Emission of Air Contaminants Detrimental to Person or Property	Applicable	Prohibits the emission of any contaminant which may be injurious to human, plant or animal life, or cause damage to property or interferes with the enjoyment of property.	Air emissions will meet all applicable standards, as set forth in RI Reg No. 22 and CAA NESHAPs, 40 CFR Part 61.
RI Air Pollution Control Reg No. 9--Permits	Applicable	Requires permitting for air pollution control systems and any new stationary sources which create an increase in pollutant emissions.	Air pollution control systems will be designed to meet all applicable standards, as set forth in RI Reg No. 22 and CAA NESHAPs, 40 CFR Part 61.

TABLE 4-7. ACTION-SPECIFIC ARARS, CRITERIA AND GUIDANCE: ALTERNATIVE #3B

Regulation	Status	Requirement	Action to be taken to attain ARARs
RI Air Pollution Control Reg No. 16--Operation of Air Pollution Control Systems	Applicable	Requires operation of air pollution control systems according to design specifications and defines malfunction reporting requirements.	Air pollution control systems will be operated and maintained in accordance with Operation and Maintenance Plan.
RI Air Pollution Control Reg No. 22--Air Toxics	Applicable	Prohibits the emission of specified contaminants at rates which would result in ground level concentrations greater than acceptable ambient levels in the reg.	Ambient air quality levels will be met for all technologies which emit air contaminants.
RI Guidance for Air Quality/Air Toxics Substances	To Be Considered	Provides guidelines for models and modeling procedures.	Guidance will be considered when modeling emissions from the LFG combustion stack.
CAA National Emissions Standards for Hazardous Air Pollutants (NESHAP) (40 CFR Part 61).	Relevant & Appropriate	Establishes emission levels for certain hazardous air pollutants, including vinyl chloride and benzene.	This remedy will attain NESHAP emission limits for hazardous air pollutants that result from treatment processes.
CAA Standards of Performance for Municipal Solid Waste Landfills (40 CFR Part 60, Subpart WWW).	Relevant & Appropriate	Establishes air emission limits for municipal solid waste landfills (MSWLF) and standards of performance for MSWLF gas collection and control systems.	Landfill gas collection and control systems will meet relevant and applicable performance standards.
<u>CHEMICAL-SPECIFIC</u>			
EPA Human Health Assessment Cancer Slope Factors (CSFs)	To Be Considered	CSFs are developed by EPA for health effects assessments or evaluation by the Human Health Assessment Group.	The values present the most up-to-date cancer risk potency information. CSFs will be used to compute the individual cancer risk resulting from exposure to contaminants.

TABLE 4-7. ACTION-SPECIFIC ARARS, CRITERIA AND GUIDANCE: ALTERNATIVE #3B

Regulation	Status	Requirement	Action to be taken to attain ARARs
LOCATION-SPECIFIC			
CWA Section 404(b)(1); Guidelines for Specification of Disposal Sites for Dredged or Fill Material (40 CFR Parts 230, 231)	Applicable	No activity that adversely affects a wetland is permitted if a practicable alternative with lesser effects is available. Controls discharges of dredged or fill material to protect aquatic ecosystems.	During the identification, screening and evaluation of the systems, the effects on wetlands will be considered, and no activity which adversely affects a wetland will be undertaken if a practicable alternative with lesser effects is available.
Executive Order 11990; Statement of Procedures on Wetlands Protection (40 CFR Part 6, App.A)	Applicable	Action to avoid, whenever possible, the long and short-term impacts on wetlands and to preserve and enhance wetlands. Plans for action in wetlands must be submitted for public review.	All practicable means will be used to minimize harm to the wetlands. Wetlands disturbed by remedial activities will be mitigated in accordance with requirements if no practicable alternative exists.
Fish and Wildlife Coordination Act; 16 U.S.C. 661, 40 CFR Section 6.302	Applicable	Any modification of a body of water requires consultation with US Fish and Wildlife Service and appropriate state wildlife agency to develop measures to prevent, mitigate or compensate for losses of fish and wildlife. This requirement is addressed under CWA Section 404 requirements.	Requires federal and state coordination on fish and wildlife matters. Will consult as required.

TABLE 4-7. ACTION-SPECIFIC ARARS, CRITERIA AND GUIDANCE: ALTERNATIVE #3B

Regulation	Status	Requirement	Action to be taken to attain ARARs
Executive Order 11988; Statement of Procedures on Floodplain Management (40 CFR Part 6, App. A)	Applicable	Action should avoid, whenever possible, the long and short-term impacts associated with occupancy and modifications of floodplains development, wherever there is a practicable alternative. Promotes preservation and restoration of floodplains so that their natural and beneficial value can be realized.	Remedial actions that involve construction in the floodplain areas will include all practicable means to minimize harm to and preserve beneficial values of floodplains. Floodplains disturbed by excavation will be restored to original conditions and utility.
Rules and Regulations governing administration and enforcement of Freshwater Wetlands Act (12-100-003)(8/90)	Applicable	Identifies and protects significant wetlands and their values and functions with the goal of no net loss.	Remedial actions will includes measures to mitigate adverse impacts on protected functions and achieve no net loss.
An Act Relating to Historic Cemeteries	Applicable	Restrictions on altering land within 25 feet of historical human cemeteries.	Plat 35 is a historic cemetery; actions must be coordinated with appropriate agencies such as RI Cemeteries Commission, town offices, and Historical Preservation Commission.
RI Endangered Species Act	Applicable	Actions must conserve identified local endangered or threatened species.	Consultation with RIDEM will ensure that remedial actions do not jeopardize the existence of endangered or threatened species or adversely modify or destroy critical habitat.

TABLE 4-7. ACTION-SPECIFIC ARARS, CRITERIA AND GUIDANCE: ALTERNATIVE #3B

Regulation	Status	Requirement	Action to be taken to attain ARARs

Note 1: Because the remedy is source control only, Safe Drinking Water Act, Maximum Contaminant Level Goals (MCLGs), 40 CFR Part 141, which are health goals for public water systems, are not ARARs for the alternative remedies at this site. Rather, they are used to measure performance of groundwater containment alternatives. The alternatives are expected to contain groundwater exceeding non-zero MCLGs within the compliance boundaries.

Note 2: RI Air Pollution Control Reg No. 17–Odors. RI Regulation No. 17, which prohibits emissions of air contaminants that create an objectionable odor beyond the property line, does not fall within the definition of an ARAR as set forth in the NCP, in EPA's view, because it falls within the category of nuisance laws rather than environmental cleanup or control standards. Therefore, it is not listed as an ARAR for this site. However, EPA views this rule to be a regulation which, like those promulgated under OSHA, must nonetheless be complied with in the performance of any remedy.

TABLE 4-8. ACTION-SPECIFIC ARARS, CRITERIA AND GUIDANCE: ALTERNATIVE #4A

Regulation	Status	Requirement	Action to be taken to attain ARARs
ACTION-SPECIFIC			
GROUNDWATER			
RCRA Groundwater Protection (40 CFR 264, Subpart F)	Implemented through RI regulations	Establishes requirements for solid waste management units (SWMUs) at RCRA regulated sites. Regulations include groundwater protection standard requirements for groundwater monitoring, detection monitoring and compliance monitoring and the corrective action program.	Because this is a source control remedy, groundwater cleanup will not be addressed and cleanup goals are not set; however, all alternatives will comply with the portions of the regulations which apply to installing groundwater monitoring wells and compliance monitoring.
Rhode Island Rules and Regulations for Hazardous Waste Management, RIDEM 4/92, Section 9.03	Applicable	Regulation outlines operation requirements for treatment, storage and disposal facilities, including a groundwater monitoring program.	Although this is a source control remedy which does not address groundwater, this alternative will comply with the regulations with respect to installation of groundwater monitoring wells and compliance monitoring.
RI Rules and Regs for Groundwater Quality, RIDEM 7/93, Sections 12.02 and 12.03.	Applicable	Regulations are designed to protect and restore the quality of the state's groundwater and include a groundwater monitoring program.	Although this is a source control remedy which does not address groundwater, this alternative will comply with the regulations with respect to installation of groundwater monitoring wells.

TABLE 4-8. ACTION-SPECIFIC ARARS, CRITERIA AND GUIDANCE: ALTERNATIVE #4A

Regulation	Status	Requirement	Action to be taken to attain ARARs
RI Rules and Regs for Underground Injection Control Program	Applicable	Regulations are designed to assure proper location, design, construction, maintenance and operation of injection wells and other subsurface disposal systems to prevent GW contamination.	The portions of this alternative which include on-site treatment of leachate, requiring discharge of treated water to GW recharge wells, will comply with UICP requirements.
Rhode Island Regs for Underground Storage Facilities used for Petroleum Products & Hazardous Material (USTs) (12-190-017)	Applicable	Establishes procedures & requirements for preventing, assessing and remediating releases from USTs.	Underground components of condensate collection system from flares will be installed and maintained in accordance with these requirements.
Draft Interim Final OSWER Monitored Natural Attenuation Policy (OSWER Dir.9200.4-17)(12/1/97)	To Be Considered	Provides guidance on how EPA will implement national policy on use of monitored natural attenuation.	Decisions on use and efficacy of monitored natural attenuation will be consistent with guidance.
<u>HAZARDOUS WASTE</u>			
RCRA-Hazardous Waste Identification, 40 CFR Part 261.	Implemented through RI regulations	Defines solid wastes that are subject to regulation as hazardous waste under 40 CFR Parts 262-265.	Requirements define RCRA regulated wastes. Acceptable management approaches for listed and characteristic hazardous waste will be met for this alternative.
RCRA-Closure and Post-Closure, 40 CFR Part 264, Subpart G	Implemented through RI regulations	Outlines the requirements for closure and post-closure care of hazardous waste management facilities.	Closure and post-closure care of the landfill will comply with these requirements.

TABLE 4-8. ACTION-SPECIFIC ARARS, CRITERIA AND GUIDANCE: ALTERNATIVE #4A

Regulation	Status	Requirement	Action to be taken to attain ARARs
RCRA Tank Systems Requirements, 40 CFR Part 264 Subpart J	Implemented through RI regulations	Sets standards for storage and treatment of hazardous waste in tanks, including pipes and ancillary equipment.	On-site treatment of leachate will comply with these standards.
RCRA-Standards for Permitted TSDFs; Thermal Treatment, 40 CFR Part 264, Subpart AA	Relevant & Appropriate	Air emission standards for process vents, closed vent systems and control devices at facilities that treat, store or dispose of hazardous wastes.	Alternatives which include on-site thermal treatment (enclosed flares) will meet these requirements.
EPA Technical Guidance for Final Covers on HW Landfills and Surface Impoundments, EPA/530-SW-047 (7/89)	To Be Considered	Guidance for landfill covers. Presents recommended technical specifications for multilayer landfill cover design.	Cap construction will be protective in accordance with the guidance.
EPA Technical Guidance memorandum regarding Alternative Cap Design for Unlined, Hazardous Waste Landfills in EPA Region I, From Dennis P. Gagne & Yoon-Jean Choi to OSRR, 9/30/97	To Be Considered	Guidance for landfill covers in EPA Region I. Presents recommended technical specifications for multilayer landfill cover design.	Cap construction will be protective in accordance with the guidance
EPA Technical Guidance on Management of Investigation-Derived Waste: Final covers on HW Landfills and surface Impoundments (EPA/530-SW-89-047)	To Be Considered	Guidance for landfill covers, recommending technical specifications for multi-layer landfill cover design.	Waste derived from cap construction will be managed in accordance with these standards.
RI Rules and Regs for HW Management, Section 8, RIDEM 4/92.	Applicable	Outlines requirements for treatment, disposal and storage of hazardous waste by TSDFs.	Management and treatment of on-site treatment residues and waste derived from cap construction will comply with these regulations.

TABLE 4-8. ACTION-SPECIFIC ARARS, CRITERIA AND GUIDANCE: ALTERNATIVE #4A

Regulation	Status	Requirement	Action to be taken to attain ARARs
RI Rules and Regs for HW Management, Sections 9 and 10.02, RIDEM 4/92.	Applicable	Outlines requirements for general waste analysis, security procedures, and management of hazardous waste. Sets design, construction and operational requirements for containers and tanks and closure requirements for hazardous waste facilities.	Identification and handling of hazardous waste and closure of hazardous waste landfill will comply with these requirements.
RI Guidelines on the Management of Investigation-Derived Waste	To Be Considered	Guidance on management and disposal of materials generated during environmental investigations. Specifies action levels for soils and liquids below which investigation-derived waste may be disposed of on-site.	All sampling activities performed on-site will comply with this guidance.
SURFACE WATER			
RI PDES Regulations (12-190-003) and RI Water Quality Regs for Water Pollution Control (12-190-001)	Relevant & Appropriate	Sets AWQC standards for water discharged to surface waters.	Because this is a source control remedy, surface water cleanup will not be addressed; AWQC standards will be used to measure effectiveness of remedy with respect to leachate outbreaks to streams and other discharges to onsite surface water.

TABLE 4-8. ACTION-SPECIFIC ARARS, CRITERIA AND GUIDANCE: ALTERNATIVE #4A

Regulation	Status	Requirement	Action to be taken to attain ARARs
CWA Ambient Water Quality Criteria (AWQC), 40 CFR 122.44	Relevant & Appropriate	Non-enforceable guidance used by states in conjunction with a designated use for a stream effluent to establish water quality standards. WQC levels for protection of human health from consuming fish and aquatic organisms have been developed for several contaminants. The standards are RA if there is no more stringent state rules for particular contaminants.	Because this is a source control remedy, surface water cleanup will not be addressed; WQC standards will be used to measure effectiveness of remedy with respect to leachate outbreaks to streams and other discharges to onsite surface water.
Proposed CWA Ambient Water Quality Criteria (AWQC), 40 CFR Part 120	To Be Considered	Remedial actions involving contaminated surface water or groundwater must consider the uses of the water and circumstances of release or threatened release.	Proposed AWQC for compounds detected onsite (Fe) were compared to observed concentrations in groundwater and used in developing PRGs for surface water; standards will be used to measure effectiveness of remedy with respect to leachate outbreaks to streams and other discharges to onsite surface water.
AIR			
Air Pollution Control Regs, RI Dept of Health, Div of Air Pollution Control, eff. 8/2/67, amended 5/20/91--Regulation No. 1 Visible Emissions	Applicable	Prohibits contaminant emissions for periods of more than 3 minutes in any one hour which are greater or equal to 20% opacity.	Air emissions from remedial actions will meet emission levels in regulations.
RI Air Pollution Control Reg No. 5--Fugitive Dust	Applicable	Requires reasonable precautions to prevent particulate matter from becoming airborne.	Operations will be performed in acc. with these rules.

TABLE 4-8. ACTION-SPECIFIC ARARS, CRITERIA AND GUIDANCE: ALTERNATIVE #4A

Regulation	Status	Requirement	Action to be taken to attain ARARs
RI Air Pollution Control Reg No. 7.1 and 7.2--Emission of Air Contaminants Detrimental to Person or Property	Applicable	Prohibits the emission of any contaminant which may be injurious to human, plant or animal life, or cause damage to property or interferes with the enjoyment of property.	Air emissions will meet all applicable standards, as set forth in RI Reg No. 22 and CAA NESHAPs, 40 CFR Part 61.
RI Air Pollution Control Reg No. 9--Permits	Applicable	Requires permitting for air pollution control systems and any new stationary sources which create an increase in pollutant emissions.	Air pollution control systems will be designed to meet all applicable standards, as set forth in RI Reg No. 22 and CAA NESHAPs, 40 CFR Part 61.
RI Air Pollution Control Reg No. 16--Operation of Air Pollution Control Systems	Applicable	Requires operation of air pollution control systems according to design specifications and defines malfunction reporting requirements.	Air pollution control systems will be operated and maintained in accordance with Operation and Maintenance Plan.
RI Air Pollution Control Reg No. 22--Air Toxics	Applicable	Prohibits the emission of specified contaminants at rates which would result in ground level concentrations greater than acceptable ambient levels in the reg.	Ambient air quality levels will be met for all technologies which emit air contaminants.
RI Guidance for Air Quality/Air Toxics Substances	To Be Considered	Provides guidelines for models and modeling procedures.	Guidance will be considered when modeling emissions from the LFG combustion stack.
CAA National Emissions Standards for Hazardous Air Pollutants (NESHAP) (40 CFR Part 61).	Relevant & Appropriate	Establishes emission levels for certain hazardous air pollutants, including vinyl chloride and benzene.	This remedy will attain NESHAP emission limits for hazardous air pollutants that result from treatment processes.

TABLE 4-8. ACTION-SPECIFIC ARARS, CRITERIA AND GUIDANCE: ALTERNATIVE #4A

Regulation	Status	Requirement	Action to be taken to attain ARARs
CAA Standards of Performance for Municipal Solid Waste Landfills (40 CFR Part 60, Subpart WWW).	Relevant & Appropriate	Establishes air emission limits for municipal solid waste landfills (MSWLF) and standards of performance for MSWLF gas collection and control systems.	Landfill gas collection and control systems will meet relevant and applicable performance standards.
CHEMICAL-SPECIFIC			
EPA Human Health Assessment Cancer Slope Factors (CSFs)	To Be Considered	CSFs are developed by EPA for health effects assessments or evaluation by the Human Health Assessment Group.	The values present the most up-to-date cancer risk potency information. CSFs will be used to compute the individual cancer risk resulting from exposure to contaminants.
LOCATION-SPECIFIC			
CWA Section 404(b)(1); Guidelines for Specification of Disposal Sites for Dredged or Fill Material (40 CFR Parts 230, 231)	Applicable	No activity that adversely affects a wetland is permitted if a practicable alternative with lesser effects is available. Controls discharges of dredged or fill material to protect aquatic ecosystems.	During the identification, screening and evaluation of the systems, the effects on wetlands will be considered, and no activity which adversely affects a wetland will be undertaken if a practicable alternative with lesser effects is available.
Executive Order 11990; Statement of Procedures on Wetlands Protection (40 CFR Part 6, App.A)	Applicable	Action to avoid, whenever possible, the long and short-term impacts on wetlands and to preserve and enhance wetlands. Plans for action in wetlands must be submitted for public review.	All practicable means will be used to minimize harm to the wetlands. Wetlands disturbed by remedial activities will be mitigated in accordance with requirements if no practicable alternative exists.

TABLE 4-8. ACTION-SPECIFIC ARARS, CRITERIA AND GUIDANCE: ALTERNATIVE #4A

Regulation	Status	Requirement	Action to be taken to attain ARARs
Fish and Wildlife Coordination Act; 16 U.S.C. 661, 40 CFR Section 6.302	Applicable	Any modification of a body of water requires consultation with US Fish and Wildlife Service and appropriate state wildlife agency to develop measures to prevent, mitigate or compensate for losses of fish and wildlife. This requirement is addressed under CWA Section 404 requirements.	Requires federal and state coordination on fish and wildlife matters. Will consult as required.
Executive Order 11988; Statement of Procedures on Floodplain Management (40 CFR Part 6, App. A)	Applicable	Action should avoid, whenever possible, the long and short-term impacts associated with occupancy and modifications of floodplains development, wherever there is a practicable alternative. Promotes preservation and restoration of floodplains so that their natural and beneficial value can be realized.	Remedial actions that involve construction in the floodplain areas will include all practicable means to minimize harm to and preserve beneficial values of floodplains. Floodplains disturbed by excavation will be restored to original conditions and utility.
Rules and Regulations governing administration and enforcement of Freshwater Wetlands Act (12-100-003)(8/90)	Applicable	Identifies and protects significant wetlands and their values and functions with the goal of no net loss.	Remedial actions will includes measures to mitigate adverse impacts on protected functions and achieve no net loss.
An Act Relating to Historic Cemeteries	Applicable	Restrictions on altering land within 25 feet of historical human cemeteries.	Plat 35 is a historic cemetery; actions must be coordinated with appropriate agencies such as RI Cemeteries Commission, town offices, and Historical Preservation Commission.

TABLE 4-8. ACTION-SPECIFIC ARARS, CRITERIA AND GUIDANCE: ALTERNATIVE #4A

Regulation	Status	Requirement	Action to be taken to attain ARARs
RI Endangered Species Act	Applicable	Actions must conserve identified local endangered or threatened species.	Consultation with RIDEM will ensure that remedial actions do not jeopardize the existence of endangered or threatened species or adversely modify or destroy critical habitat.

Note 1: Because the remedy is source control only, Safe Drinking Water Act, Maximum Contaminant Level Goals (MCLGs), 40 CFR Part 141, which are health goals for public water systems, are not ARARs for the alternative remedies at this site. Rather, they are used to measure performance of groundwater containment alternatives. The alternatives are expected to contain groundwater exceeding non-zero MCLGs within the compliance boundaries.

Note 2: RI Air Pollution Control Reg No. 17–Odors. RI Regulation No. 17, which prohibits emissions of air contaminants that create an objectionable odor beyond the property line, does not fall within the definition of an ARAR as set forth in the NCP, in EPA's view, because it falls within the category of nuisance laws rather than environmental cleanup or control standards. Therefore, it is not listed as an ARAR for this site. However, EPA views this rule to be a regulation which, like those promulgated under OSHA, must nonetheless be complied with in the performance of any remedy.

TABLE 4-9. ACTION-SPECIFIC ARARS, CRITERIA AND GUIDANCE: ALTERNATIVE #4B

Regulation	Status	Requirement	Action to be taken to attain ARARs
ACTION-SPECIFIC			
GROUNDWATER			
RCRA Groundwater Protection (40 CFR 264, Subpart F)	Implemented through RI regulations	Establishes requirements for solid waste management units (SWMUs) at RCRA regulated sites. Regulations include groundwater protection standard requirements for groundwater monitoring, detection monitoring and compliance monitoring and the corrective action program.	Because this is a source control remedy, groundwater cleanup will not be addressed and cleanup goals are not set; however, all alternatives will comply with the portions of the regulations which apply to installing groundwater monitoring wells and compliance monitoring.
Rhode Island Rules and Regulations for Hazardous Waste Management, RIDEM 4/92, Section 9.03	Applicable	Regulation outlines operation requirements for treatment, storage and disposal facilities, including a groundwater monitoring program.	Although this is a source control remedy which does not address groundwater, this alternative will comply with the regulations with respect to installation of groundwater monitoring wells and compliance monitoring.
RI Rules and Regs for Groundwater Quality, RIDEM 7/93, Sections 12.02 and 12.03.	Applicable	Regulations are designed to protect and restore the quality of the state's groundwater and include a groundwater monitoring program.	Although this is a source control remedy which does not address groundwater, this alternative will comply with the regulations with respect to installation of groundwater monitoring wells.

TABLE 4-9. ACTION-SPECIFIC ARARS, CRITERIA AND GUIDANCE: ALTERNATIVE #4B

Regulation	Status	Requirement	Action to be taken to attain ARARs
RI Rules and Regs for Underground Injection Control Program	Applicable	Regulations are designed to assure proper location, design, construction, maintenance and operation of injection wells and other subsurface disposal systems to prevent GW contamination.	The portions of this alternative which include on-site treatment of leachate, requiring discharge of treated water to GW recharge wells, will comply with UICP requirements.
Rhode Island Regs for Underground Storage Facilities used for Petroleum Products & Hazardous Material (USTs) (12-190-017)	Applicable	Establishes procedures & requirements for preventing, assessing and remediating releases from USTs.	Underground components of condensate collection system from flares will be installed and maintained in accordance with these requirements.
Draft Interim Final OSWER Monitored Natural Attenuation Policy (OSWER Dir.9200.4-17)(12/1/97)	To Be Considered	Provides guidance on how EPA will implement national policy on use of monitored natural attenuation.	Decisions on use and efficacy of monitored natural attenuation will be consistent with guidance.
<u>HAZARDOUS WASTE</u>			
RCRA-Hazardous Waste Identification, 40 CFR Part 261.	Implemented through RI regulations	Defines solid wastes that are subject to regulation as hazardous waste under 40 CFR Parts 262-265.	Requirements define RCRA regulated wastes. Acceptable management approaches for listed and characteristic hazardous waste will be met for this alternative.
RCRA-Closure and Post-Closure, 40 CFR Part 264, Subpart G	Implemented through RI regulations	Outlines the requirements for closure and post-closure care of hazardous waste management facilities.	Closure and post-closure care of the landfill will comply with these requirements.

TABLE 4-9. ACTION-SPECIFIC ARARS, CRITERIA AND GUIDANCE: ALTERNATIVE #4B

Regulation	Status	Requirement	Action to be taken to attain ARARs
RCRA Tank Systems Requirements, 40 CFR Part 264 Subpart J	Implemented through RI regulations	Sets standards for storage and treatment of hazardous waste in tanks, including pipes and ancillary equipment.	On-site treatment of leachate will comply with these standards.
RCRA-Standards for Permitted TSDFs; Thermal Treatment, 40 CFR Part 264, Subpart AA	Relevant & Appropriate	Air emission standards for process vents, closed vent systems and control devices at facilities that treat, store or dispose of hazardous wastes.	Alternatives which include on-site thermal treatment (enclosed flares) will meet these requirements.
EPA Technical Guidance for Final Covers on HW Landfills and Surface Impoundments, EPA/530-SW-047 (7/89)	To Be Considered	Guidance for landfill covers. Presents recommended technical specifications for multilayer landfill cover design.	Cap construction will be protective in accordance with the guidance.
EPA Technical Guidance memorandum regarding Alternative Cap Design for Unlined, Hazardous Waste Landfills in EPA Region I, From Dennis P. Gagne & Yoon-Jean Choi to OSRR, 9/30/97	To Be Considered	Guidance for landfill covers in EPA Region I. Presents recommended technical specifications for multilayer landfill cover design.	Cap construction will be protective in accordance with the guidance
EPA Technical Guidance on Management of Investigation-Derived Waste: Final covers on HW Landfills and surface Impoundments (EPA/530-SW-89-047)	To Be Considered	Guidance for landfill covers, recommending technical specifications for multi-layer landfill cover design.	Waste derived from cap construction will be managed in accordance with these standards.
RI Rules and Regs for HW Management, Section 8, RIDEM 4/92.	Applicable	Outlines requirements for treatment, disposal and storage of hazardous waste by TSDFs.	Management and treatment of on-site treatment residues and waste derived from cap construction will comply with these regulations.

TABLE 4-9. ACTION-SPECIFIC ARARS, CRITERIA AND GUIDANCE: ALTERNATIVE #4B

Regulation	Status	Requirement	Action to be taken to attain ARARs
RI Rules and Regs for HW Management, Sections 9 and 10.02, RIDEM 4/92.	Applicable	Outlines requirements for general waste analysis, security procedures, and management of hazardous waste. Sets design, construction and operational requirements for containers and tanks and closure requirements for hazardous waste facilities.	Identification and handling of hazardous waste and closure of hazardous waste landfill will comply with these requirements.
RI Guidelines on the Management of Investigation-Derived Waste	To Be Considered	Guidance on management and disposal of materials generated during environmental investigations. Specifies action levels for soils and liquids below which investigation-derived waste may be disposed of on-site.	All sampling activities performed on-site will comply with this guidance.
SURFACE WATER			
RI PDES Regulations (12-190-003) and RI Water Quality Regs for Water Pollution Control (12-190-001)	Relevant & Appropriate	Sets AWQC standards for water discharged to surface waters.	Because this is a source control remedy, surface water cleanup will not be addressed; AWQC standards will be used to measure effectiveness of remedy with respect to leachate outbreaks to streams and other discharges to onsite surface water.

TABLE 4-9. ACTION-SPECIFIC ARARS, CRITERIA AND GUIDANCE: ALTERNATIVE #4B

Regulation	Status	Requirement	Action to be taken to attain ARARs
CWA Ambient Water Quality Criteria (AWQC), 40 CFR 122.44	Relevant & Appropriate	Non-enforceable guidance used by states in conjunction with a designated use for a stream effluent to establish water quality standards. WQC levels for protection of human health from consuming fish and aquatic organisms have been developed for several contaminants. The standards are RA if there is no more stringent state rules for particular contaminants.	Because this is a source control remedy, surface water cleanup will not be addressed; WQC standards will be used to measure effectiveness of remedy with respect to leachate outbreaks to streams and other discharges to onsite surface water.
Proposed CWA Ambient Water Quality Criteria (AWQC), 40 CFR Part 120	To Be Considered	Remedial actions involving contaminated surface water or groundwater must consider the uses of the water and circumstances of release or threatened release.	Proposed AWQC for compounds detected onsite (Fe) were compared to observed concentrations in groundwater and used in developing PRGs for surface water; standards will be used to measure effectiveness of remedy with respect to leachate outbreaks to streams and other discharges to onsite surface water.
AIR			
Air Pollution Control Regs, RI Dept of Health, Div of Air Pollution Control, eff. 8/2/67, amended 5/20/91--Regulation No. 1 Visible Emissions	Applicable	Prohibits contaminant emissions for periods of more than 3 minutes in any one hour which are greater or equal to 20% opacity.	Air emissions from remedial actions will meet emission levels in regulations.
RI Air Pollution Control Reg No. 5--Fugitive Dust	Applicable	Requires reasonable precautions to prevent particulate matter from becoming airborne.	Operations will be performed in acc. with these rules.

TABLE 4-9. ACTION-SPECIFIC ARARS, CRITERIA AND GUIDANCE: ALTERNATIVE #4B

Regulation	Status	Requirement	Action to be taken to attain ARARs
RI Air Pollution Control Reg No. 7.1 and 7.2--Emission of Air Contaminants Detrimental to Person or Property	Applicable	Prohibits the emission of any contaminant which may be injurious to human, plant or animal life, or cause damage to property or interferes with the enjoyment of property.	Air emissions will meet all applicable standards, as set forth in RI Reg No. 22 and CAA NESHAPs, 40 CFR Part 61.
RI Air Pollution Control Reg No. 9--Permits	Applicable	Requires permitting for air pollution control systems and any new stationary sources which create an increase in pollutant emissions.	Air pollution control systems will be designed to meet all applicable standards, as set forth in RI Reg No. 22 and CAA NESHAPs, 40 CFR Part 61.
RI Air Pollution Control Reg No. 16--Operation of Air Pollution Control Systems	Applicable	Requires operation of air pollution control systems according to design specifications and defines malfunction reporting requirements.	Air pollution control systems will be operated and maintained in accordance with Operation and Maintenance Plan.
RI Air Pollution Control Reg No. 22--Air Toxics	Applicable	Prohibits the emission of specified contaminants at rates which would result in ground level concentrations greater than acceptable ambient levels in the reg.	Ambient air quality levels will be met for all technologies which emit air contaminants.
RI Guidance for Air Quality/Air Toxics Substances	To Be Considered	Provides guidelines for models and modeling procedures.	Guidance will be considered when modeling emissions from the LFG combustion stack.
CAA National Emissions Standards for Hazardous Air Pollutants (NESHAP) (40 CFR Part 61).	Relevant & Appropriate	Establishes emission levels for certain hazardous air pollutants, including vinyl chloride and benzene.	This remedy will attain NESHAP emission limits for hazardous air pollutants that result from treatment processes.

TABLE 4-9. ACTION-SPECIFIC ARARS, CRITERIA AND GUIDANCE: ALTERNATIVE #4B

Regulation	Status	Requirement	Action to be taken to attain ARARs
CAA Standards of Performance for Municipal Solid Waste Landfills (40 CFR Part 60, Subpart WWW).	Relevant & Appropriate	Establishes air emission limits for municipal solid waste landfills (MSWLF) and standards of performance for MSWLF gas collection and control systems.	Landfill gas collection and control systems will meet relevant and applicable performance standards.
CHEMICAL-SPECIFIC			
EPA Human Health Assessment Cancer Slope Factors (CSFs)	To Be Considered	CSFs are developed by EPA for health effects assessments or evaluation by the Human Health Assessment Group.	The values present the most up-to-date cancer risk potency information. CSFs will be used to compute the individual cancer risk resulting from exposure to contaminants.
LOCATION-SPECIFIC			
CWA Section 404(b)(1); Guidelines for Specification of Disposal Sites for Dredged or Fill Material (40 CFR Parts 230, 231)	Applicable	No activity that adversely affects a wetland is permitted if a practicable alternative with lesser effects is available. Controls discharges of dredged or fill material to protect aquatic ecosystems.	During the identification, screening and evaluation of the systems, the effects on wetlands will be considered, and no activity which adversely affects a wetland will be undertaken if a practicable alternative with lesser effects is available.
Executive Order 11990; Statement of Procedures on Wetlands Protection (40 CFR Part 6, App.A)	Applicable	Action to avoid, whenever possible, the long and short-term impacts on wetlands and to preserve and enhance wetlands. Plans for action in wetlands must be submitted for public review.	All practicable means will be used to minimize harm to the wetlands. Wetlands disturbed by remedial activities will be mitigated in accordance with requirements if no practicable alternative exists.

TABLE 4-9. ACTION-SPECIFIC ARARS, CRITERIA AND GUIDANCE: ALTERNATIVE #4B

Regulation	Status	Requirement	Action to be taken to attain ARARs
Fish and Wildlife Coordination Act; 16 U.S.C. 661, 40 CFR Section 6.302	Applicable	Any modification of a body of water requires consultation with US Fish and Wildlife Service and appropriate state wildlife agency to develop measures to prevent, mitigate or compensate for losses of fish and wildlife. This requirement is addressed under CWA Section 404 requirements.	Requires federal and state coordination on fish and wildlife matters. Will consult as required.
Executive Order 11988; Statement of Procedures on Floodplain Management (40 CFR Part 6, App. A)	Applicable	Action should avoid, whenever possible, the long and short-term impacts associated with occupancy and modifications of floodplains development, wherever there is a practicable alternative. Promotes preservation and restoration of floodplains so that their natural and beneficial value can be realized.	Remedial actions that involve construction in the floodplain areas will include all practicable means to minimize harm to and preserve beneficial values of floodplains. Floodplains disturbed by excavation will be restored to original conditions and utility.
Rules and Regulations governing administration and enforcement of Freshwater Wetlands Act (12-100-003)(8/90)	Applicable	Identifies and protects significant wetlands and their values and functions with the goal of no net loss.	Remedial actions will includes measures to mitigate adverse impacts on protected functions and achieve no net loss.
An Act Relating to Historic Cemeteries	Applicable	Restrictions on altering land within 25 feet of historical human cemeteries.	Plat 35 is a historic cemetery; actions must be coordinated with appropriate agencies such as RI Cemeteries Commission, town offices, and Historical Preservation Commission.

TABLE 4-9. ACTION-SPECIFIC ARARS, CRITERIA AND GUIDANCE: ALTERNATIVE #4B

Regulation	Status	Requirement	Action to be taken to attain ARARs
RI Endangered Species Act	Applicable	Actions must conserve identified local endangered or threatened species.	Consultation with RIDEM will ensure that remedial actions do not jeopardize the existence of endangered or threatened species or adversely modify or destroy critical habitat.

Note 1: Because the remedy is source control only, Safe Drinking Water Act, Maximum Contaminant Level Goals (MCLGs), 40 CFR Part 141, which are health goals for public water systems, are not ARARs for the alternative remedies at this site. Rather, they are used to measure performance of groundwater containment alternatives. The alternatives are expected to contain groundwater exceeding non-zero MCLGs within the compliance boundaries.

Note 2: RI Air Pollution Control Reg No. 17–Odors. RI Regulation No. 17, which prohibits emissions of air contaminants that create an objectionable odor beyond the property line, does not fall within the definition of an ARAR as set forth in the NCP, in EPA's view, because it falls within the category of nuisance laws rather than environmental cleanup or control standards. Therefore, it is not listed as an ARAR for this site. However, EPA views this rule to be a regulation which, like those promulgated under OSHA, must nonetheless be complied with in the performance of any remedy.

TABLE 4-10. ACTION-SPECIFIC ARARS, CRITERIA AND GUIDANCE: ALTERNATIVE #5A

Regulation	Status	Requirement	Action to be taken to attain ARARs
ACTION-SPECIFIC			
GROUNDWATER			
RCRA Groundwater Protection (40 CFR 264, Subpart F)	Implemented through RI regulations	Establishes requirements for solid waste management units (SWMUs) at RCRA regulated sites. Regulations include groundwater protection standard requirements for groundwater monitoring, detection monitoring and compliance monitoring and the corrective action program.	Because this is a source control remedy, groundwater cleanup will not be addressed and cleanup goals are not set; however, all alternatives will comply with the portions of the regulations which apply to installing groundwater monitoring wells and compliance monitoring.
Rhode Island Rules and Regulations for Hazardous Waste Management, RIDEM 4/92, Section 9.03	Applicable	Regulation outlines operation requirements for treatment, storage and disposal facilities, including a groundwater monitoring program.	Although this is a source control remedy which does not address groundwater, the groundwater containment component of this alternative will comply with the regulations with respect to installation of groundwater monitoring wells and compliance monitoring.
RI Rules and Regs for Groundwater Quality, RIDEM 7/93, Sections 12.02 and 12.03.	Applicable	Regulations are designed to protect and restore the quality of the state's groundwater and include a groundwater monitoring program.	Although this is a source control remedy which does not address groundwater, the groundwater containment component of this alternative will comply with the regulations with respect to installation of groundwater monitoring wells.

TABLE 4-10. ACTION-SPECIFIC ARARS, CRITERIA AND GUIDANCE: ALTERNATIVE #5A

Regulation	Status	Requirement	Action to be taken to attain ARARs
RI Rules and Regs for Underground Injection Control Program	Applicable	Regulations are designed to assure proper location, design, construction, maintenance and operation of injection wells and other subsurface disposal systems to prevent GW contamination.	The portions of this alternative which include on-site treatment of GW and leachate, requiring discharge of treated water to GW recharge wells, will comply with UICP requirements.
Rhode Island Regs for Underground Storage Facilities used for Petroleum Products & Hazardous Material (USTs) (12-190-017)	Applicable	Establishes procedures & requirements for preventing, assessing and remediating releases from USTs.	Underground components of condensate collection system from flares will be installed and maintained in accordance with these requirements.
Draft Interim Final OSWER Monitored Natural Attenuation Policy (OSWER Dir.9200.4-17)(12/1/97)	To Be Considered	Provides guidance on how EPA will implement national policy on use of monitored natural attenuation.	Decisions on use and efficacy of monitored natural attenuation will be consistent with guidance.
<u>HAZARDOUS WASTE</u>			
RCRA-Hazardous Waste Identification, 40 CFR Part 261.	Implemented through RI regulations	Defines solid wastes that are subject to regulation as hazardous waste under 40 CFR Parts 262-265.	Requirements define RCRA regulated wastes. Acceptable management approaches for listed and characteristic hazardous waste will be met for this alternative.
RCRA-Closure and Post-Closure, 40 CFR Part 264, Subpart G	Implemented through RI regulations	Outlines the requirements for closure and post-closure care of hazardous waste management facilities.	Closure and post-closure care of the landfill will comply with these requirements.

TABLE 4-10. ACTION-SPECIFIC ARARS, CRITERIA AND GUIDANCE: ALTERNATIVE #5A

Regulation	Status	Requirement	Action to be taken to attain ARARs
RCRA Tank Systems Requirements, 40 CFR Part 264 Subpart J	Implemented through RI regulations	Sets standards for storage and treatment of hazardous waste in tanks, including pipes and ancillary equipment.	On-site treatment of leachate and groundwater will comply with these standards.
RCRA-Standards for Permitted TSDFs; Thermal Treatment, 40 CFR Part 264, Subpart AA	Relevant & Appropriate	Air emission standards for process vents, closed vent systems and control devices at facilities that treat, store or dispose of hazardous wastes.	Alternatives which include on-site thermal treatment (enclosed flares) will meet these requirements.
EPA Technical Guidance for Final Covers on HW Landfills and Surface Impoundments, EPA/530-SW-047 (7/89)	To Be Considered	Guidance for landfill covers. Presents recommended technical specifications for multilayer landfill cover design.	Cap construction will be protective in accordance with the guidance.
EPA Technical Guidance memorandum regarding Alternative Cap Design for Unlined, Hazardous Waste Landfills in EPA Region I, From Dennis P. Gagne & Yoon-Jean Choi to OSRR, 9/30/97	To Be Considered	Guidance for landfill covers in EPA Region I. Presents recommended technical specifications for multilayer landfill cover design.	Cap construction will be protective in accordance with the guidance
EPA Technical Guidance on Management of Investigation-Derived Waste: Final covers on HW Landfills and surface Impoundments (EPA/530-SW-89-047)	To Be Considered	Guidance for landfill covers, recommending technical specifications for multi-layer landfill cover design.	Waste derived from cap construction will be managed in accordance with these standards.
RI Rules and Regs for HW Management, Section 8, RIDEM 4/92.	Applicable	Outlines requirements for treatment, disposal and storage of hazardous waste by TSDFs.	Management and treatment of on-site treatment residues and waste derived from cap construction will comply with these regulations.

TABLE 4-10. ACTION-SPECIFIC ARARS, CRITERIA AND GUIDANCE: ALTERNATIVE #5A

Regulation	Status	Requirement	Action to be taken to attain ARARs
RI Rules and Regs for HW Management, Sections 9 and 10.02, RIDEM 4/92.	Applicable	Outlines requirements for general waste analysis, security procedures, and management of hazardous waste. Sets design, construction and operational requirements for containers and tanks and closure requirements for hazardous waste facilities.	Identification and handling of hazardous waste and closure of hazardous waste landfill will comply with these requirements.
RI Guidelines on the Management of Investigation-Derived Waste	To Be Considered	Guidance on management and disposal of materials generated during environmental investigations. Specifies action levels for soils and liquids below which investigation-derived waste may be disposed of on-site.	All sampling activities performed on-site will comply with this guidance.
SURFACE WATER			
RI PDES Regulations (12-190-003) and RI Water Quality Regs for Water Pollution Control (12-190-001)	Relevant & Appropriate	Sets AWQC standards for water discharged to surface waters.	Because this is a source control remedy, surface water cleanup will not be addressed; AWQC standards will be used to measure effectiveness of remedy with respect to leachate outbreaks to streams and other discharges to onsite surface water.

TABLE 4-10. ACTION-SPECIFIC ARARS, CRITERIA AND GUIDANCE: ALTERNATIVE #5A

Regulation	Status	Requirement	Action to be taken to attain ARARs
CWA Ambient Water Quality Criteria (AWQC), 40 CFR 122.44	Relevant & Appropriate	Non-enforceable guidance used by states in conjunction with a designated use for a stream effluent to establish water quality standards. WQC levels for protection of human health from consuming fish and aquatic organisms have been developed for several contaminants. The standards are RA if there is no more stringent state rules for particular contaminants.	Because this is a source control remedy, surface water cleanup will not be addressed; WQC standards will be used to measure effectiveness of remedy with respect to leachate outbreaks to streams and other discharges to onsite surface water.
Proposed CWA Ambient Water Quality Criteria (AWQC), 40 CFR Part 120	To Be Considered	Remedial actions involving contaminated surface water or groundwater must consider the uses of the water and circumstances of release or threatened release.	Proposed AWQC for compounds detected onsite (Fe) were compared to observed concentrations in groundwater and used in developing PRGs for surface water; standards will be used to measure effectiveness of remedy with respect to leachate outbreaks to streams and other discharges to onsite surface water.
AIR			
Air Pollution Control Regs, RI Dept of Health, Div of Air Pollution Control, eff. 8/2/67, amended 5/20/91--Regulation No. 1 Visible Emissions	Applicable	Prohibits contaminant emissions for periods of more than 3 minutes in any one hour which are greater or equal to 20% opacity.	Air emissions from remedial actions will meet emission levels in regulations.
RI Air Pollution Control Reg No. 5--Fugitive Dust	Applicable	Requires reasonable precautions to prevent particulate matter from becoming airborne.	Operations will be performed in acc. with these rules.

TABLE 4-10. ACTION-SPECIFIC ARARS, CRITERIA AND GUIDANCE: ALTERNATIVE #5A

Regulation	Status	Requirement	Action to be taken to attain ARARs
RI Air Pollution Control Reg No. 7.1 and 7.2--Emission of Air Contaminants Detrimental to Person or Property	Applicable	Prohibits the emission of any contaminant which may be injurious to human, plant or animal life, or cause damage to property or interferes with the enjoyment of property.	Air emissions will meet all applicable standards, as set forth in RI Reg No. 22 and CAA NESHAPs, 40 CFR Part 61.
RI Air Pollution Control Reg No. 9--Permits	Applicable	Requires permitting for air pollution control systems and any new stationary sources which create an increase in pollutant emissions.	Air pollution control systems will be designed to meet all applicable standards, as set forth in RI Reg No. 22 and CAA NESHAPs, 40 CFR Part 61.
RI Air Pollution Control Reg No. 16--Operation of Air Pollution Control Systems	Applicable	Requires operation of air pollution control systems according to design specifications and defines malfunction reporting requirements.	Air pollution control systems will be operated and maintained in accordance with Operation and Maintenance Plan.
RI Air Pollution Control Reg No. 22--Air Toxics	Applicable	Prohibits the emission of specified contaminants at rates which would result in ground level concentrations greater than acceptable ambient levels in the reg.	Ambient air quality levels will be met for all technologies which emit air contaminants.
RI Guidance for Air Quality/Air Toxics Substances	To Be Considered	Provides guidelines for models and modeling procedures.	Guidance will be considered when modeling emissions from the LFG combustion stack.
CAA National Emissions Standards for Hazardous Air Pollutants (NESHAP) (40 CFR Part 61).	Relevant & Appropriate	Establishes emission levels for certain hazardous air pollutants, including vinyl chloride and benzene.	This remedy will attain NESHAP emission limits for hazardous air pollutants that result from treatment processes.

TABLE 4-10. ACTION-SPECIFIC ARARS, CRITERIA AND GUIDANCE: ALTERNATIVE #5A

Regulation	Status	Requirement	Action to be taken to attain ARARs
CAA Standards of Performance for Municipal Solid Waste Landfills (40 CFR Part 60, Subpart WWW).	Relevant & Appropriate	Establishes air emission limits for municipal solid waste landfills (MSWLF) and standards of performance for MSWLF gas collection and control systems.	Landfill gas collection and control systems will meet relevant and applicable performance standards.
CHEMICAL-SPECIFIC			
EPA Human Health Assessment Cancer Slope Factors (CSFs)	To Be Considered	CSFs are developed by EPA for health effects assessments or evaluation by the Human Health Assessment Group.	The values present the most up-to-date cancer risk potency information. CSFs will be used to compute the individual cancer risk resulting from exposure to contaminants.
LOCATION-SPECIFIC			
CWA Section 404(b)(1); Guidelines for Specification of Disposal Sites for Dredged or Fill Material (40 CFR Parts 230, 231)	Applicable	No activity that adversely affects a wetland is permitted if a practicable alternative with lesser effects is available. Controls discharges of dredged or fill material to protect aquatic ecosystems.	During the identification, screening and evaluation of the systems, the effects on wetlands will be considered, and no activity which adversely affects a wetland will be undertaken if a practicable alternative with lesser effects is available.
Executive Order 11990; Statement of Procedures on Wetlands Protection (40 CFR Part 6, App.A)	Applicable	Action to avoid, whenever possible, the long and short-term impacts on wetlands and to preserve and enhance wetlands. Plans for action in wetlands must be submitted for public review.	All practicable means will be used to minimize harm to the wetlands. Wetlands disturbed by remedial activities will be mitigated in accordance with requirements if no practicable alternative exists.

TABLE 4-10. ACTION-SPECIFIC ARARS, CRITERIA AND GUIDANCE: ALTERNATIVE #5A

Regulation	Status	Requirement	Action to be taken to attain ARARs
Fish and Wildlife Coordination Act; 16 U.S.C. 661, 40 CFR Section 6.302	Applicable	Any modification of a body of water requires consultation with US Fish and Wildlife Service and appropriate state wildlife agency to develop measures to prevent, mitigate or compensate for losses of fish and wildlife. This requirement is addressed under CWA Section 404 requirements.	Requires federal and state coordination on fish and wildlife matters. Will consult as required.
Executive Order 11988; Statement of Procedures on Floodplain Management (40 CFR Part 6, App. A)	Applicable	Action should avoid, whenever possible, the long and short-term impacts associated with occupancy and modifications of floodplains development, wherever there is a practicable alternative. Promotes preservation and restoration of floodplains so that their natural and beneficial value can be realized.	Remedial actions that involve construction in the floodplain areas will include all practicable means to minimize harm to and preserve beneficial values of floodplains. Floodplains disturbed by excavation will be restored to original conditions and utility.
Rules and Regulations governing administration and enforcement of Freshwater Wetlands Act (12-100-003)(8/90)	Applicable	Identifies and protects significant wetlands and their values and functions with the goal of no net loss.	Remedial actions will includes measures to mitigate adverse impacts on protected functions and achieve no net loss.
An Act Relating to Historic Cemeteries	Applicable	Restrictions on altering land within 25 feet of historical human cemeteries.	Plat 35 is a historic cemetery; actions must be coordinated with appropriate agencies such as RI Cemeteries Commission, town offices, and Historical Preservation Commission.

TABLE 4-10. ACTION-SPECIFIC ARARS, CRITERIA AND GUIDANCE: ALTERNATIVE #5A

Regulation	Status	Requirement	Action to be taken to attain ARARs
RI Endangered Species Act	Applicable	Actions must conserve identified local endangered or threatened species.	Consultation with RIDEM will ensure that remedial actions do not jeopardize the existence of endangered or threatened species or adversely modify or destroy critical habitat.

Note 1: Because the remedy is source control only, Safe Drinking Water Act, Maximum Contaminant Level Goals (MCLGs), 40 CFR Part 141, which are health goals for public water systems, are not ARARs for the alternative remedies at this site. Rather, they are used to measure performance of groundwater containment alternatives. The alternatives are expected to contain groundwater exceeding non-zero MCLGs within the compliance boundaries.

Note 2: RI Air Pollution Control Reg No. 17–Odors. RI Regulation No. 17, which prohibits emissions of air contaminants that create an objectionable odor beyond the property line, does not fall within the definition of an ARAR as set forth in the NCP, in EPA's view, because it falls within the category of nuisance laws rather than environmental cleanup or control standards. Therefore, it is not listed as an ARAR for this site. However, EPA views this rule to be a regulation which, like those promulgated under OSHA, must nonetheless be complied with in the performance of any remedy.

TABLE 4-11. ACTION-SPECIFIC ARARS, CRITERIA AND GUIDANCE: ALTERNATIVE #5B

Regulation	Status	Requirement	Action to be taken to attain ARARs
ACTION-SPECIFIC			
GROUNDWATER			
RCRA Groundwater Protection (40 CFR 264, Subpart F)	Implemented through RI regulations	Establishes requirements for solid waste management units (SWMUs) at RCRA regulated sites. Regulations include groundwater protection standard requirements for groundwater monitoring, detection monitoring and compliance monitoring and the corrective action program.	Because this is a source control remedy, groundwater cleanup will not be addressed and cleanup goals are not set; however, all alternatives will comply with the portions of the regulations which apply to installing groundwater monitoring wells and compliance monitoring.
Rhode Island Rules and Regulations for Hazardous Waste Management, RIDEM 4/92, Section 9.03	Applicable	Regulation outlines operation requirements for treatment, storage and disposal facilities, including a groundwater monitoring program.	Although this is a source control remedy which does not address groundwater, the groundwater containment component of this alternative will comply with the regulations with respect to installation of groundwater monitoring wells and compliance monitoring.
RI Rules and Regs for Groundwater Quality, RIDEM 7/93, Sections 12.02 and 12.03.	Applicable	Regulations are designed to protect and restore the quality of the state's groundwater and include a groundwater monitoring program.	Although this is a source control remedy which does not address groundwater, the groundwater containment component of this alternative will comply with the regulations with respect to installation of groundwater monitoring wells.

TABLE 4-11. ACTION-SPECIFIC ARARS, CRITERIA AND GUIDANCE: ALTERNATIVE #5B

Regulation	Status	Requirement	Action to be taken to attain ARARs
RI Rules and Regs for Underground Injection Control Program	Applicable	Regulations are designed to assure proper location, design, construction, maintenance and operation of injection wells and other subsurface disposal systems to prevent GW contamination.	The portions of this alternative which include on-site treatment of GW and leachate, requiring discharge of treated water to GW recharge wells, will comply with UICP requirements.
Rhode Island Regs for Underground Storage Facilities used for Petroleum Products & Hazardous Material (USTs) (12-190-017)	Applicable	Establishes procedures & requirements for preventing, assessing and remediating releases from USTs.	Underground components of condensate collection system from flares will be installed and maintained in accordance with these requirements.
Draft Interim Final OSWER Monitored Natural Attenuation Policy (OSWER Dir.9200.4-17)(12/1/97)	To Be Considered	Provides guidance on how EPA will implement national policy on use of monitored natural attenuation.	Decisions on use and efficacy of monitored natural attenuation will be consistent with guidance.
HAZARDOUS WASTE			
RCRA-Hazardous Waste Identification, 40 CFR Part 261.	Implemented through RI regulations	Defines solid wastes that are subject to regulation as hazardous waste under 40 CFR Parts 262-265.	Requirements define RCRA regulated wastes. Acceptable management approaches for listed and characteristic hazardous waste will be met for this alternative.
RCRA-Closure and Post-Closure, 40 CFR Part 264, Subpart G	Implemented through RI regulations	Outlines the requirements for closure and post-closure care of hazardous waste management facilities.	Closure and post-closure care of the landfill will comply with these requirements.

TABLE 4-11. ACTION-SPECIFIC ARARS, CRITERIA AND GUIDANCE: ALTERNATIVE #5B

Regulation	Status	Requirement	Action to be taken to attain ARARs
RCRA Tank Systems Requirements, 40 CFR Part 264 Subpart J	Implemented through RI regulations	Sets standards for storage and treatment of hazardous waste in tanks, including pipes and ancillary equipment.	On-site treatment of leachate and groundwater will comply with these standards.
RCRA-Standards for Permitted TSDFs; Thermal Treatment, 40 CFR Part 264, Subpart AA	Relevant & Appropriate	Air emission standards for process vents, closed vent systems and control devices at facilities that treat, store or dispose of hazardous wastes.	Alternatives which include on-site thermal treatment (enclosed flares) will meet these requirements.
EPA Technical Guidance for Final Covers on HW Landfills and Surface Impoundments, EPA/530-SW-047 (7/89)	To Be Considered	Guidance for landfill covers. Presents recommended technical specifications for multilayer landfill cover design.	Cap construction will be protective in accordance with the guidance.
EPA Technical Guidance memorandum regarding Alternative Cap Design for Unlined, Hazardous Waste Landfills in EPA Region I, From Dennis P. Gagne & Yoon-Jean Choi to OSRR, 9/30/97	To Be Considered	Guidance for landfill covers in EPA Region I. Presents recommended technical specifications for multilayer landfill cover design.	Cap construction will be protective in accordance with the guidance
EPA Technical Guidance on Management of Investigation-Derived Waste: Final covers on HW Landfills and surface Impoundments (EPA/530-SW-89-047)	To Be Considered	Guidance for landfill covers, recommending technical specifications for multi-layer landfill cover design.	Waste derived from cap construction will be managed in accordance with these standards.
RI Rules and Regs for HW Management, Section 8, RIDEM 4/92.	Applicable	Outlines requirements for treatment, disposal and storage of hazardous waste by TSDFs.	Management and treatment of on-site treatment residues and waste derived from cap construction will comply with these regulations.

TABLE 4-11. ACTION-SPECIFIC ARARS, CRITERIA AND GUIDANCE: ALTERNATIVE #5B

Regulation	Status	Requirement	Action to be taken to attain ARARs
RI Rules and Regs for HW Management, Sections 9 and 10.02, RIDEM 4/92.	Applicable	Outlines requirements for general waste analysis, security procedures, and management of hazardous waste. Sets design, construction and operational requirements for containers and tanks and closure requirements for hazardous waste facilities.	Identification and handling of hazardous waste and closure of hazardous waste landfill will comply with these requirements.
RI Guidelines on the Management of Investigation-Derived Waste	To Be Considered	Guidance on management and disposal of materials generated during environmental investigations. Specifies action levels for soils and liquids below which investigation-derived waste may be disposed of on-site.	All sampling activities performed on-site will comply with this guidance.
SURFACE WATER			
RI PDES Regulations (12-190-003) and RI Water Quality Regs for Water Pollution Control (12-190-001)	Relevant & Appropriate	Sets AWQC standards for water discharged to surface waters.	Because this is a source control remedy, surface water cleanup will not be addressed; AWQC standards will be used to measure effectiveness of remedy with respect to leachate outbreaks to streams and other discharges to onsite surface water.

TABLE 4-11. ACTION-SPECIFIC ARARS, CRITERIA AND GUIDANCE: ALTERNATIVE #5B

Regulation	Status	Requirement	Action to be taken to attain ARARs
CWA Ambient Water Quality Criteria (AWQC), 40 CFR 122.44	Relevant & Appropriate	Non-enforceable guidance used by states in conjunction with a designated use for a stream effluent to establish water quality standards. WQC levels for protection of human health from consuming fish and aquatic organisms have been developed for several contaminants. The standards are RA if there is no more stringent state rules for particular contaminants.	Because this is a source control remedy, surface water cleanup will not be addressed; WQC standards will be used to measure effectiveness of remedy with respect to leachate outbreaks to streams and other discharges to onsite surface water.
Proposed CWA Ambient Water Quality Criteria (AWQC), 40 CFR Part 120	To Be Considered	Remedial actions involving contaminated surface water or groundwater must consider the uses of the water and circumstances of release or threatened release.	Proposed AWQC for compounds detected onsite (Fe) were compared to observed concentrations in groundwater and used in developing PRGs for surface water; standards will be used to measure effectiveness of remedy with respect to leachate outbreaks to streams and other discharges to onsite surface water.
AIR			
Air Pollution Control Regs, RI Dept of Health, Div of Air Pollution Control, eff. 8/2/67, amended 5/20/91--Regulation No. 1 Visible Emissions	Applicable	Prohibits contaminant emissions for periods of more than 3 minutes in any one hour which are greater or equal to 20% opacity.	Air emissions from remedial actions will meet emission levels in regulations.
RI Air Pollution Control Reg No. 5--Fugitive Dust	Applicable	Requires reasonable precautions to prevent particulate matter from becoming airborne.	Operations will be performed in acc. with these rules.

TABLE 4-11. ACTION-SPECIFIC ARARS, CRITERIA AND GUIDANCE: ALTERNATIVE #5B

Regulation	Status	Requirement	Action to be taken to attain ARARs
RI Air Pollution Control Reg No. 7.1 and 7.2--Emission of Air Contaminants Detrimental to Person or Property	Applicable	Prohibits the emission of any contaminant which may be injurious to human, plant or animal life, or cause damage to property or interferes with the enjoyment of property.	Air emissions will meet all applicable standards, as set forth in RI Reg No. 22 and CAA NESHAPs, 40 CFR Part 61.
RI Air Pollution Control Reg No. 9--Permits	Applicable	Requires permitting for air pollution control systems and any new stationary sources which create an increase in pollutant emissions.	Air pollution control systems will be designed to meet all applicable standards, as set forth in RI Reg No. 22 and CAA NESHAPs, 40 CFR Part 61.
RI Air Pollution Control Reg No. 16--Operation of Air Pollution Control Systems	Applicable	Requires operation of air pollution control systems according to design specifications and defines malfunction reporting requirements.	Air pollution control systems will be operated and maintained in accordance with Operation and Maintenance Plan.
RI Air Pollution Control Reg No. 22--Air Toxics	Applicable	Prohibits the emission of specified contaminants at rates which would result in ground level concentrations greater than acceptable ambient levels in the reg.	Ambient air quality levels will be met for all technologies which emit air contaminants.
RI Guidance for Air Quality/Air Toxics Substances	To Be Considered	Provides guidelines for models and modeling procedures.	Guidance will be considered when modeling emissions from the LFG combustion stack.
CAA National Emissions Standards for Hazardous Air Pollutants (NESHAP) (40 CFR Part 61).	Relevant & Appropriate	Establishes emission levels for certain hazardous air pollutants, including vinyl chloride and benzene.	This remedy will attain NESHAP emission limits for hazardous air pollutants that result from treatment processes.

TABLE 4-11. ACTION-SPECIFIC ARARS, CRITERIA AND GUIDANCE: ALTERNATIVE #5B

Regulation	Status	Requirement	Action to be taken to attain ARARs
CAA Standards of Performance for Municipal Solid Waste Landfills (40 CFR Part 60, Subpart WWW).	Relevant & Appropriate	Establishes air emission limits for municipal solid waste landfills (MSWLF) and standards of performance for MSWLF gas collection and control systems.	Landfill gas collection and control systems will meet relevant and applicable performance standards.
CHEMICAL-SPECIFIC			
EPA Human Health Assessment Cancer Slope Factors (CSFs)	To Be Considered	CSFs are developed by EPA for health effects assessments or evaluation by the Human Health Assessment Group.	The values present the most up-to-date cancer risk potency information. CSFs will be used to compute the individual cancer risk resulting from exposure to contaminants.
LOCATION-SPECIFIC			
CWA Section 404(b)(1); Guidelines for Specification of Disposal Sites for Dredged or Fill Material (40 CFR Parts 230, 231)	Applicable	No activity that adversely affects a wetland is permitted if a practicable alternative with lesser effects is available. Controls discharges of dredged or fill material to protect aquatic ecosystems.	During the identification, screening and evaluation of the systems, the effects on wetlands will be considered, and no activity which adversely affects a wetland will be undertaken if a practicable alternative with lesser effects is available.
Executive Order 11990; Statement of Procedures on Wetlands Protection (40 CFR Part 6, App.A)	Applicable	Action to avoid, whenever possible, the long and short-term impacts on wetlands and to preserve and enhance wetlands. Plans for action in wetlands must be submitted for public review.	All practicable means will be used to minimize harm to the wetlands. Wetlands disturbed by remedial activities will be mitigated in accordance with requirements if no practicable alternative exists.

TABLE 4-11. ACTION-SPECIFIC ARARS, CRITERIA AND GUIDANCE: ALTERNATIVE #5B

Regulation	Status	Requirement	Action to be taken to attain ARARs
Fish and Wildlife Coordination Act; 16 U.S.C. 661, 40 CFR Section 6.302	Applicable	Any modification of a body of water requires consultation with US Fish and Wildlife Service and appropriate state wildlife agency to develop measures to prevent, mitigate or compensate for losses of fish and wildlife. This requirement is addressed under CWA Section 404 requirements.	Requires federal and state coordination on fish and wildlife matters. Will consult as required.
Executive Order 11988; Statement of Procedures on Floodplain Management (40 CFR Part 6, App. A)	Applicable	Action should avoid, whenever possible, the long and short-term impacts associated with occupancy and modifications of floodplains development, wherever there is a practicable alternative. Promotes preservation and restoration of floodplains so that their natural and beneficial value can be realized.	Remedial actions that involve construction in the floodplain areas will include all practicable means to minimize harm to and preserve beneficial values of floodplains. Floodplains disturbed by excavation will be restored to original conditions and utility.
Rules and Regulations governing administration and enforcement of Freshwater Wetlands Act (12-100-003)(8/90)	Applicable	Identifies and protects significant wetlands and their values and functions with the goal of no net loss.	Remedial actions will includes measures to mitigate adverse impacts on protected functions and achieve no net loss.
An Act Relating to Historic Cemeteries	Applicable	Restrictions on altering land within 25 feet of historical human cemeteries.	Plat 35 is a historic cemetery; actions must be coordinated with appropriate agencies such as RI Cemeteries Commission, town offices, and Historical Preservation Commission.

TABLE 4-11. ACTION-SPECIFIC ARARS, CRITERIA AND GUIDANCE: ALTERNATIVE #5B

Regulation	Status	Requirement	Action to be taken to attain ARARs
RI Endangered Species Act	Applicable	Actions must conserve identified local endangered or threatened species.	Consultation with RIDEM will ensure that remedial actions do not jeopardize the existence of endangered or threatened species or adversely modify or destroy critical habitat.

Note 1: Because the remedy is source control only, Safe Drinking Water Act, Maximum Contaminant Level Goals (MCLGs), 40 CFR Part 141, which are health goals for public water systems, are not ARARs for the alternative remedies at this site. Rather, they are used to measure performance of groundwater containment alternatives. The alternatives are expected to contain groundwater exceeding non-zero MCLGs within the compliance boundaries.

Note 2: RI Air Pollution Control Reg No. 17–Odors. RI Regulation No. 17, which prohibits emissions of air contaminants that create an objectionable odor beyond the property line, does not fall within the definition of an ARAR as set forth in the NCP, in EPA's view, because it falls within the category of nuisance laws rather than environmental cleanup or control standards. Therefore, it is not listed as an ARAR for this site. However, EPA views this rule to be a regulation which, like those promulgated under OSHA, must nonetheless be complied with in the performance of any remedy.

Section Five

TABLE 5-1. NINE-POINT SUMMARY OF COMPARATIVE ANALYSIS

A. OVERALL PROTECTION OF HUMAN HEALTH AND THE ENVIRONMENT

Human Health Protection

Alternative #1
- No overall protection of human health

Alternative #2
- Access restrictions (fencing) reduce on-site ambient air exposures
- Groundwater access restrictions reduce the potential for exposures
- Residential LFG control contingency reduces indoor air and soil gas exposures in residences

Alternative #3a
- Access restrictions (fencing) reduce on-site ambient air exposures
- Groundwater access restrictions reduce exposure to groundwater COPCs
- Horizontal containment limits exposure to on-site surface soils and reduce generation of leachate
- Horizontal containment, LFG collection and thermal treatment reduce risk from inhalation exposures of VOC COPCs
- Short-term risks to remediation workers can be mitigated with PPE

Alternative #3b
Same as Alternative #3a except:
- LFG collection/treatment non-thermally reduce the risk from inhalation exposures to VOC COPCs by may result in increased on-site safety risk due to remaining methane emissions

Alternative #4a
Same as Alternative #3a except:
- Leachate collection and on-site treatment further reduces groundwater contamination impacts at the Site

Alternative #4b
Same as Alternative #4a except:
- Landfill mining further reduces groundwater contamination impacts at the Site

Alternative #5a
Same as Alternative #4a except:
- Groundwater depression system and on-site treatment further reduces groundwater contamination impacts at the Site

Alternative #5b
Same as Alternative #5a except:
- Landfill mining further reduces groundwater contamination impacts at the Site

TABLE 5-1 (Continued). NINE-POINT SUMMARY OF COMPARATIVE ANALYSIS

Ecological Protection

Alternative #1 No reduction in short- or long-term risks relative to baseline (existing) conditions

Alternative #2 Same as Alternative #1

Alternative #3a
- Horizontal containment (capping) reduces leachate generation, and therefore, site COPC migration to surface water/sediment thereby reducing ecological exposure
- Potential impacts to wetland and brook/river hydrology will be addressed during design

Alternative #3b Same as Alternative #3a

Alternative #4a Same as Alternative #3a except:
- Impacts to wetland and aquatic areas are essentially eliminated by horizontal containment and leachate collection/treatment

Alternative #4b Same as Alternative #4a except:
- Landfill mining of the Bulky Waste Area removes a long-term source of ecological impacts

Alternative #5a Same as Alternative #4a except:
- Site COPC migration will be further reduced by the groundwater collection/depression and on-site treatment

Alternative #5b Same as Alternative #5a
- Landfill mining of the Bulky Waste Area removes a long-term source of ecological impacts

B. COMPLIANCE WITH ARARS

Chemical-Specific ARARs

Alternative #1
- On-site groundwater will continue to exceed chemical-specific ARARs for most COPCs
- Leachate will continue to impact surface waterbodies and cause exceedance of surface water ARARs
- Air pollution control regulations and LFG control requirements are not met

TABLE 5-1 (Continued). NINE-POINT SUMMARY OF COMPARATIVE ANALYSIS

Alternative #2 Same as Alternative #1

Alternative #3a
- Capping of the Solid Waste and Bulky Waste Areas will reduce precipitation infiltration and leachate generation. Monitoring will be used as an indicator of compliance with groundwater and surface water ARARs. Further actions may be necessary.
- Air quality ARARs will be met through use of horizontal containment and LFG collection/treatment systems

Alternative #3b Same as Alternative #3a

Alternative #4a Same as Alternative #3a except:
- Leachate collection and treatment further mitigates exceedance of groundwater and surface water ARARs. Leachate will be treated to attain chemical-specific ARARs

Alternative #4b Same as Alternative #4a except:
- Landfill mining of the Bulky Waste Area further mitigates exceedance of groundwater ARARs

Alternative #5a Same as Alternative #4a except:
- Groundwater depression/treatment system further mitigates exceedance of groundwater ARARs

Alternative #5b Same as Alternative #5a except:
- Landfill mining of the Bulky Waste Area further mitigates exceedance of groundwater ARARs

<u>Location-Specific ARARs</u>

Alternative #1 Location-specific ARARs are not affected by this alternative except for
- Leachate will continue degrading ecological habitats

Alternative #2 Same as Alternative #1

Alternative #3a Same as Alternative #2 except:
- Actions must be taken during construction to protect (or mitigate unavoidable impacts to) wetlands, surface waterbodies, the floodplain, and the nearby cemetery

Alternative #3b Same as Alternative #3a

Alternative #4a Same as Alternative #3b

Alternative #4b Same as Alternative #4a

Alternative #5a Same as Alternative #4b

Alternative #5b Same as Alternative #5a

Action-Specific ARARs

Alternative #1

- Groundwater Quality Rules and Regulations - Because this is a no action remedy, groundwater cleanup will not be addressed and cleanup goals are not set; however, all alternatives will comply with the portions of the portions of the regulations which apply to installing groundwater monitoring wells and compliance monitoring.
- Water Quality Rules and Regulations - Because this is a no action remedy, surface water cleanup will not be addressed; water quality standards will be used to measure effectiveness of the remedy

Alternative #2

- Groundwater Quality Rules and Regulations - Because this is a limited action remedy, groundwater cleanup will not be addressed and cleanup goals are not set; however, all alternatives will comply with the portions of the portions of the regulations which apply to installing groundwater monitoring wells and compliance monitoring.
- Water Quality Rules and Regulations - Because this is a limited action remedy, surface water cleanup will not be addressed; water quality standards will be used to measure effectiveness of the remedy

Alternative #3a

- Groundwater Quality Rules and Regulations - Because this is a source control remedy, groundwater cleanup will not be addressed and cleanup goals are not set; however, all alternatives will comply with the portions of the portions of the regulations which apply to installing groundwater monitoring wells and compliance monitoring.
- Water Quality Rules and Regulations - Because this is a source control remedy, surface water cleanup will not be addressed; water quality standards will be used to measure effectiveness of the remedy
- RCRA and Rhode Island Hazardous Waste Rules and Regulations for closure and post-closure requirements are met for the Solid Waste and Bulky Waste Areas

- State and Federal ARARs for Ambient Air/Soil Gas are attained

Alternative #3b Same as Alternative #3a

Alternative #4a Same as Alternative #3a

Alternative #4b Same as Alternative #3a

Alternative #5a Same as Alternative #3a

Alternative #5b Same as Alternative #3a

C. LONG-TERM EFFECTIVENESS AND PERMANENCE

Magnitude of Residual Risk

Alternative #1

- Neither long-term effectiveness nor permanence provided. Residual health risks in excess of the EPA target risk range continue to persist
- No reduction from baseline ecological risks due to exposure to landfill leachate discharged to Mitchell Brook and the Saugatucket River

Alternative #2

- Health risks: limited by institutional controls; permanence of controls is unknown
- Reductions is residual human health risks by groundwater access restrictions depend on effectiveness
- Access restrictions (fencing) reduce risk from on-site inhalation exposures
- Residential LFG control contingency expected to reduce risk from exposure to vinyl chloride in indoor air below 2×10^{-4}. Groundwater access restrictions reduce the potential risk from ingestion of groundwater COPCs
- Ecological risks: same as Alternative #1

Alternative #3a

- Increased long-term effectiveness and permanence provided by controlling LFG
- LFG collection/treatment and access restrictions are expected to reduce risk from inhalation exposures to vinyl chloride in ambient air and carcinogenic risk at nearby residences to within the EPA target risk range

- Engineering controls, required operating procedures, and PPE specified during the design should minimize potential residual risks to community and workers from exposures to combustion by-products, LFG condensate waste and leaks and safety risks from maintenance and potential explosion hazard by methane gas and/or auxiliary fuel.

- Horizontal containment (capping) reduces risks from groundwater

- Surface water contamination and ecological risks are reduced by horizontal containment (capping). However, discharge of leachate and contaminated groundwater to surface waterbodies will continue

Alternative #3b Same as Alternative #3a except:

- Non-thermal treatment of LFG does not reduce on-site methane emissions and a residual safety risk of explosion remains

Alternative #4a Same as Alternative #3a except:

- The leachate collection/treatment system further increases long-term effectiveness and permanence

- The leachate collection system further reduces migration of site COPCs to groundwater and surface water

- The leachate collection system further reduces ecological risk by eliminating the release of leachate to surface water bodies

- Engineering controls, PPE, and required operating procedures specified during the design should minimize potential residual risks to the community and workers from concentration waste from water treatment

Alternative #4b Same as Alternative #4a except:

- Source removal of the Bulky Waste Area further reduces groundwater and surface water/sediment impacts

Alternative #5a Same as Alternative #4a except:

- The groundwater depression/treatment system further reduces migration of site COPCs

- An additional potential for risks due to generation of larger quantities of water treatment residuals is expected to be mitigated by engineering controls, PPE, and required operating procedures

Alternative #5b Same as Alternatives #5a and #4b

TABLE 5-1 (Continued). NINE-POINT SUMMARY OF COMPARATIVE ANALYSIS

Adequacy and Reliability of Controls

Alternative #1

- No measures beyond environmental monitoring
- Natural attenuation is minimal protection against untreated waste or treatment residuals
- Monitoring will provide measure of a remedy's success and effectiveness and reliability of monitoring is dependent on proper sampling and analytical procedures

Alternative #2

Same as Alternative #1 except:

- Groundwater access restrictions will be effective and reliable if implemented appropriately
- Residential LFG control contingency will be effective and reliable assuming proper operation
- Access restrictions (fencing) will reliably maintain security around the Solid Waste Area

Alternative #3a

Same as Alternative #2 except:

- Horizontal containment (capping) will be effective and reliable in mitigating surface soil risks and controlling leachate generation, provided long-term maintenance is followed
- Landfill gas will effectively be captured by horizontal containment, active internal and perimeter collection systems at Solid Waste Area, with greater than 95% DRE by enclosed flare. Effective LFG capture will be achieved by proper operation and maintenance
- Passive venting at Bulky Waste Area will effectively and reliably remove LFG

Alternative #3b

Same as Alternative #3a except:

- Non-thermal DRE of 95% is expected for VOCs, assuming proper operation and maintenance. Reliability of photocatylitic oxidation, an innovative technology, is not well qualified, but on-site pilot tests or review of applications at other facilities can be used to evaluate relevant factors

Alternative #4a Same as Alternative #3a except:

- The collection system will adequately eliminate leachate discharge and treatment will effectively remove COPCs, provided that proper operation and maintenance are performed and that residuals created during construction and treatment are properly disposed of

Alternative #4b Same as Alternative #4a except:

- Landfill mining will be effective and reliable in providing source control in the Bulky Waste Area assuming 100% source removal is accomplished

Alternative #5a Same as Alternative #4a except:

- Effectiveness and reliability of the groundwater depression system in the Solid Waste Area is not well qualified, however, proper design, well installation, and operation will facilitate source control

Alternative #5b Same as Alternative #4b and #5a

Need for Five-Year Reviews

All Alternatives Five-year reviews will be required

D. REDUCTION OF TOXICITY, MOBILITY, OR VOLUME THROUGH TREATMENT

Treatment/Recycling Processes Utilized

Alternative #1 No treatment processes utilized

Alternative #2

- Residential LFG control contingency

Alternative #3a

- Horizontal containment (capping) for Solid Waste and Bulky Waste Areas
- Active perimeter and internal LFG collection and LFG thermal treatment (enclosed flare) for the Solid Waste Area
- Passive internal LFG collection for the Bulky Waste Area

Alternative #3b Same as Alternative #3a except:

- LFG non-thermal treatment (photocatylitic oxidation) for the Solid Waste Area

Alternative #4a Same as Alternative #3a except:

- Leachate collection/treatment system for the Bulky Waste Area

- Discharge of treated water

Alternative #4b Same as Alternative #4a except:
- Landfill Mining of the Bulky Waste Area used as a recycling process

Alternative #5a Same as Alternative #4a except:
- Groundwater collection/depression system and on-site groundwater/leachate treatment for the Solid Waste Area

Alternative #5b Same as Alternative #5a except:
- Landfill Mining of the Bulky Waste Area used as a recycling process

Amount of Hazardous Materials Treated or Recycled

Alternative #1 None

Alternative #2
- Small fraction of migrating LFG redirected through residential control contingency

Alternative #3a
- Leachate (through horizontal containment): 100% reduction for both the Solid Waste and Bulky Waste Areas
- LFG - 95% reduction (minimum) of COPCs into ambient air in the Solid Waste Area and redirect LFG from subsurface environment to ambient air in the Bulky Waste Area, but no reductions in toxicity or mobility beyond natural attenuation
- Surface soil - risk mitigated by horizontal containment

Alternative #3b Same Alternative #3a except:
- 98% reduction of VOC COPCs into ambient air in the Solid Waste Area

Alternative #4a Same as Alternative #3a except:
- Leachate collection/treatment system will capture and treat 5 gpm of leachate

Alternative #4b Same as Alternative #4a except:
- Landfill mining: estimated recycling of over 30,000 yd^3 of metal waste and over 40,000 yd^3 of reusable soil, which should be confirmed during the remedial design

TABLE 5-1 (Continued). NINE-POINT SUMMARY OF COMPARATIVE ANALYSIS

Alternative #5a Same as Alternative #4a except:

- Groundwater collection/depression system will capture 45 gpm of groundwater from the Solid Waste Area, which will be treated in an on-site groundwater/ leachate treatment system

Alternative #5b Same as Alternative #5a and #4b

Degree of Expected Reductions in Toxicity, Mobility, or Volume

Alternative #1 None except for natural attenuation

Alternative #2 Same as Alternative #1

Alternative #3a Same as Alternative #1 except:

- Groundwater/Leachate: No reduction in toxicity, but reduction in mobility due to horizontal containment (capping)
- LFG: Reduction in toxicity proportionate with flare DREs and reduction in mobility proportionate with collection system efficiency

Alternative #3b Same as Alternative #3a except:

- LFG: Reduction in toxicity proportionate with non-thermal DREs

Alternative #4a Same as Alternative #3a except:

- Leachate: Reduction in toxicity equal to on-site treatment efficiency (85% metals and 90% VOCs) and reduction in mobility proportionate to treatment efficiencies

Alternative #4b Same as Alternative #4a except:

- Landfill mining: Over the long-term, reduction in toxicity and mobility will be achieved to the degree that the waste sources are removed. However, there may be increased mobility due to disturbances over the short-term

Alternative #5a Same as Alternative #4a except:

- Groundwater: Reduction in toxicity equal to on-site treatment efficiency and further reduction in mobility for the Solid Waste Area

Alternative #5b Same as Alternative #5a and #4b

Irreversibility

Alternative #1 Not applicable

TABLE 5-1 (Continued). NINE-POINT SUMMARY OF COMPARATIVE ANALYSIS

Alternative #2 Same as Alternative #1 except a slight degree of irreversibility due to residential LFG control contingency

Alternative #3a
- Leachate: Horizontal containment (capping) improved over existing site conditions, but only temporary if cap is removed or compromised
- LFG: Not reversible for quantity treated
- Surface soil: risk mitigation 100% reversible if cap is removed

Alternative #3b Same as Alternative #3a

Alternative #4a Same as Alternative #3a except:
- On-site leachate treatment is irreversible for quantity treated

Alternative #4b Same as Alternative #4a except:
- Landfill mining is irreversible for quantity removed

Alternative #5a Same as Alternative #4a except:
- On-site groundwater treatment is irreversible for quantity treated

Alternative #5a Same as Alternatives #5a and #4b

<u>Type and Quantity of Residuals</u>

Alternative #1 Not Applicable

Alternative #2 No Residuals

Alternative #3a
- Landfill gas condensate is expected to be generated at a rate of 125 gal/10^6 ft^3 extracted gas
- Non-thermal by-products: trace nitrogen and sulfur oxides, carbon monoxide, hydrogen peroxide, and potentially dioxins

Alternative #3b
- Non-thermal by-products: methane, carbon dioxide, HCl and chlorine gas, undestroyed/partially destroyed odor-causing compounds

Alternative #4a Same as Alternative #3a except:
- Leachate collection system: Drilling/construction soils

- Leachate treatment system: Metals sludge filter cake and undestroyed VOCs in off-gas of UV/chemical oxidation. Sludge rate is expected to be 2 ft^3 day

Alternative #4b Same as Alternative #4a except:

- Landfill Mining: reusable soil and non-recyclable wastes

Alternative #5a Same as Alternative #4a except:

- Larger on-site treatment plant and soil residuals from collection systems
- Sludge generation rate is expected to be 9 ft^3 day

Alternative #5b Same as Alternatives #5a and #4b

E. SHORT-TERM EFFECTIVENESS

Community and Worker Protection

Alternative #1

- No increase in short-term human health risks

Alternative #2

- Nominal increases in short-term human health risks to workers during fence installation and residential LFG control contingency

Alternative #3a Same as Alternative #2 except:

- Potential inhalation hazard to workers and adjacent residents during invasive construction activities (grading and installation of horizontal containment and LFG systems)

Alternative #3b Same as Alternative #3a

Alternative #4a Same as Alternative #3a except:

- Additional invasive construction activities for during installation of the leachate collection system

Alternative #4b Same as Alternative #4a except:

- Increased risks to workers and adjacent residents for approximately 1 year from landfill mining activities, which include exposure of wastes, additional odors, noise, and dust. Additional worker risks may include contact with vermin, landfill gas exposure, and potential for explosions.

Alternative #5a Same as Alternative #4a except:

- Increased short-term risks to workers and adjacent residents due to larger on-site treatment plant and construction of the groundwater depression/collection system.

Alternative #5b Same as Alternatives #5a and #4b

Environmental Impacts

Alternative #1

- No increase or reduction in short-term environmental risks
- No disturbance of wetlands or other habitats

Alternative #2

- Minor short-term disturbances to some wetland buffer zone during fence installation

Alternative #3a

- Short-term risks for ecological receptors may increase somewhat from remedial activities
- Some mortality of upland organisms during capping operations
- One wetland filled inside limits of Solid Waste Area will require mitigation (<0.15 acres)
- Minor ecological disturbances by roadway, fence, and plant construction along with minor clearing of trees and shrubs
- Cap placement will disturb approximately 30 acres of grassland habitats, requiring restoration following capping
- Increased erosion and sedimentation potential during remedial construction
- Changes in infiltration to groundwater and surface water recharge as a result of remedial activities (primarily horizontal containment)

Alternative #3b Same as Alternative #3a

Alternative #4a Same as Alternative #3a except:

- Increase in areal extent of upland and wetland impacts because of the leachate collection system

TABLE 5-1 (Continued). NINE-POINT SUMMARY OF COMPARATIVE ANALYSIS

Alternative #4b Same as Alternative #4a except:

- Potential environmental impact from increased surface run-off, erosion, and dust as well as increased iron releases from disturbance of soil/waste during landfill mining operations

Alternative #5a Same as Alternative #4a except:

- Larger area affected by construction of groundwater depression/collection system
- Increased potential for impacts to hydrology of Mitchell Brook, Saugatucket River and bordering wetlands

Alternative #5b Same as Alternatives #5a and #4b

Time Until Remedial Action Objectives are Achieved

Alternative #1

- Groundwater - Natural attenuation of source areas; likely to be as long as FS default duration of 30 years
- Surface Soil - No natural attenuation
- Surface Water/Sediment - Same as groundwater
- Ambient Air - Natural attenuation - 5 to 15 years, depending on LFG generation
- Soil Gas - Same as ambient air

Alternative #2

- Groundwater - Within 1 year of remedy implementation
- Surface Soil - Same as Alternative #1
- Surface Water/Sediment - Same as Alternative #1
- Ambient Air - Same as Alternative #1
- Soil Gas - Within 1 year of remedy implementation

Alternative #3a

- Groundwater - Within 2 years of remedy implementation
- Surface Soil - Same as groundwater

- Surface Water/Sediment - Same as groundwater
- Ambient Air - Within 1 to 2 years of remedy implementation
- Soil Gas - Same as ambient air

Alternative #3b
- Groundwater - Same as Alternative #3a
- Surface Soil - Same as groundwater
- Surface Water/Sediment - Same as groundwater
- Ambient Air - Same as Alternative #3a
- Soil Gas - Same as ambient air

Alternative #4a
- Groundwater - Same as Alternative #3a
- Surface Soil - Same as groundwater
- Surface Water/Sediment - Within 1 to 2 years of remedy implementation
- Ambient Air - Same as Alternative #3a
- Soil Gas - Same as ambient air

Alternative #4b
- Groundwater - Same as Alternative #4a
- Surface Soil - Same as groundwater
- Surface Water/Sediment - Within 2 years of remedy implementation
- Ambient Air - Same as Alternative #4a
- Soil Gas - Same as ambient air

Alternative #5a
- Groundwater - Within 1 to 2 years of remedy implementation
- Surface Soil - Same as Alternative #3a
- Surface Water/Sediment - Same as Alternative #4a

- Ambient Air - Same as Alternative #3a
- Soil Gas - Same as ambient air

Alternative #5b

- Groundwater - Same as Alternative #5a
- Surface Soil - Same as Alternative #3a
- Surface Water/Sediment - Same as Alternative #4b
- Ambient Air - Same as Alternative #3a
- Soil Gas - Same as ambient air

F. IMPLEMENTABILITY

Technical Feasibility

Alternative #1

- Construction: No construction. Labor only required for conversion of soil gas points and for monitoring
- RAOs: RAOs will not be met
- Additional Actions: Future actions can be taken to increase alternative's effectiveness
- Monitoring: Monitoring will measure effectiveness of groundwater natural attenuation and indirect effectiveness of LFG natural attenuation

Alternative #2

- Construction: Groundwater/leachate - No construction

  LFG - Installation of residential LFG control contingency, if necessary; minor maintenance requirements
- RAOs: Groundwater/leachate - Groundwater access restriction reliability is dependent on implementation/observance.

  LFG - Soil gas RAOs reliably met with residential LFG control contingency. Reliability of fencing to meet ambient air RAOs is limited
- Additional Actions: Additions could be made to increase alternative's effectiveness

- Monitoring: Monitoring will measure effectiveness of groundwater natural attenuation. It will also indirectly measure effectiveness of LFG natural attenuation and the effectiveness of residential LFG control contingency.

Alternative #3a

- Construction: Groundwater/leachate - Same as Alternative #2 except construction of landfill caps. Access road improvements may be required. Five piezometers will be installed; requires coordination with cap installation

  LFG - Construction & operation of enclosed flare and LFG collection systems; must be coordinated with cap installation. LFG emissions must be minimized during subsurface work

- RAOs: Groundwater/leachate - Same as Alternative #2 except for addition of landfill caps which provide permanent and effective way to meet RAOs. Reliability dependent on cap maintenance and inspections.

  LFG - Reliability meets ambient air and soil gas RAOs. Effectiveness of flare dependent on operation and maintenance.

- Additional Actions: Additions could be made to increase alternative's effectiveness, such as extraction wells or trenches to capture groundwater/leachate or internal or perimeter LFG wells if gas capture is inadequate.

- Monitoring: Groundwater - Similar to Alternative #2 with the addition of 5 piezometers

  LFG - Monitoring will measure the effectiveness of the LFG collection/treatment systems.

Alternative #3b

- Groundwater/Leachate: Construction, achievement of RAOs, additional actions and monitoring - are the same as Alternative #3a.

- LFG: Construction - is the same as Alternative #3a except, on-site pilot study of the photocatylitic oxidation technology would be needed prior to design and installation, and the installed system operated and maintained properly. RAOs, additional actions and monitoring - are the same as Alternative #3a.

Alternative #4a

- Construction: Groundwater/leachate - Same as Alternative #3a except construction of leachate collection and treatment systems: building construction, utility hookup, and piping from collection system.

  LFG - Same as Alternative #3a

- RAOs: Groundwater/leachate - Same as Alternative #3a except for addition of leachate collection/treatment which provides improved reliability in meeting Surface water/Sediment RAOs.

  LFG - Same as Alternative #3a

- Additional Actions: Additions could be made to increase alternative's effectiveness

- Monitoring: Same as Alternative #3a

Alternative #4b

- Construction: Groundwater/leachate - Same as Alternative #4a except a pilot study will be needed prior to commencement of landfill mining to determine waste types, water table levels, and reusability/recycling of wastes.

  LFG - Same as Alternative #3a

- RAOs: Groundwater/leachate - Same as Alternative #4a except the removal of waste from the Bulky Waste Area will reduce leachate discharge and further improve RAOs for surface water/sediment.

  LFG - Same as Alternative #3a

- Additional Actions: Same as Alternative #4a

- Monitoring: Same as Alternative #3a

Alternative #5a

- Construction: Groundwater/leachate - Same as Alternative #4a except construction. of groundwater depression system and larger on-site treatment system: building construction, utility hookup, and piping from collection system.

  LFG - Same as Alternative #3a

- RAOs: Groundwater/leachate - Same as Alternative #4a except for addition of groundwater depression system which provides improved reliability in meeting groundwater and surface water/sediment RAOs.

  LFG - Same as Alternative #3a

- Additional Actions: Additions could be made to increase alternative's effectiveness

- Monitoring: Same as Alternative #4a

Alternative #5b

- Construction: Groundwater/leachate - Same as Alternatives #5a and #4b

  LFG - Same as Alternative #3a

- RAOs: Groundwater/leachate - Same as Alternative #4b

  LFG - Same as Alternative #3a

- Additional Actions: Additions could be made to increase alternative's effectiveness

- Monitoring: Same as Alternative #4a

Administrative Feasibility

Alternative #1

- No regulatory approvals or permits required. Coordination with state and local authorities required for monitoring

Alternative #2

- Groundwater/leachate - Same as Alternative #1 except for significant coordination for implementation of access restrictions

- LFG - Same as Alternative #1 except for coordination for implementation of access restrictions (fencing) and residential LFG control contingency

Alternative #3a

- Groundwater/leachate - Same as Alternative #2 except for any permits required prior to cap construction. Coordination necessary for cap maintenance

- LFG - Similar to Groundwater/Leachate for cap construction, cap maintenance and monitoring. Coordination required for enclosed flare design and operation. UST installation rules must be followed. Local ordinances need to be followed during flare system construction

Alternative #3b

- Groundwater/leachate - Same as Alternative #3a

- LFG - Same as Alternative #3a except for coordination required for photocatylitic oxidation system design and operation

Alternative #4a

- Groundwater/leachate - Same as Alterative #3a except for State approval required prior to treated water discharge

TABLE 5-1 (Continued). NINE-POINT SUMMARY OF COMPARATIVE ANALYSIS

- LFG - Same as Alternative #3a

Alternative #4b
- Groundwater/leachate - Same as Alternative #4a except for additional State approval and coordination on landfill mining
- LFG - Same as Alternative #3a

Alternative #5a
- Groundwater/Leachate - Same as Alternative #4a except for State approval required prior to discharge of a larger volume of treated water
- LFG - Same as Alternative #3a

Alternative #5b
- Groundwater/Leachate - Same as Alternatives #5a and #4b
- LFG - Same as Alternative #3a

<u>Availability of Services and Materials</u>

Alternative #1
- Groundwater/leachate - Consultants and firms are available to conduct monitoring
- LFG - Consultants and firms are available to conduct monitoring

Alternative #2
- Groundwater/leachate - Same as Alternative #1

  LFG - Same as Alternative #1 except services and materials for installation of fencing are readily available and contractors familiar with LFG applications are required for residential LFG control systems

Alternative #3a
- Groundwater/Leachate - Same as Alternative #2 except that materials necessary for cap construction should be obtained from as near the Site as possible

  LFG - Same as Alternative #2 for fencing and monitoring. Also, construction contractors familiar with methane safety and fugitive vapors/COPCs are required, and fabrication of flare requires significant lead time and may be limited to specific, specialty contractors

Alternative #3b
- Groundwater/Leachate - Same as Alternative #3a

TABLE 5-1 (Continued). NINE-POINT SUMMARY OF COMPARATIVE ANALYSIS

		LFG - Same as Alternative #3a except that fabrication of photocatylitic oxidation system requires significant lead time and may be limited to specific, specialty contractors
Alternative #4a	•	Groundwater/leachate - Same as Alternative #3a except that a TSDF is likely needed for the precipitation process. Consultants, equipment and services are commonly available for leachate collection and treatment design and O&M
		LFG - Same as Alternative #3a
Alternative #4b	•	Groundwater/leachate - Same as Alternative #4a except that a contractor experienced in landfill mining with OSHA-trained employees is required, a TSDF will be needed for any hazardous wastes being transported offsite, and a recycling facility to receive recyclable metal wastes will need to be located.
		LFG - Same as Alternative #3a
Alternative #5a	•	Groundwater/leachate - Same as Alternative #4a
		LFG - Same as Alternative #3a
Alternative #5b	•	Groundwater/leachate - Same as Alternatives #5a and #4b
		LFG - Same as Alternative #3a

TABLE 5-1 (Continued). NINE-POINT SUMMARY OF COMPARATIVE ANALYSIS

G. COST

(Annual costs = total present worth operation and maintenance costs)

Alternative #1	Capital: $110,000	Annual: $3,460,000	Total: $3,570,000
Alternative #2	Capital: $360,000	Annual: $3,480,000	Total: $3,840,000
Alternative #3a	Capital: $6,420,000	Annual: $7,000,000	Total: $13,420,000
Alternative #3b	Capital: $6,560,000	Annual: $6,630,000	Total: $13,190,000
Alternative #4a	Capital: $7,240,000	Annual: $8,830,000	Total: $16,070,000
Alternative #4b	Capital: $9,820,000	Annual: $7,100,000	Total: $16,920,000
Alternative #5a	Capital: $8,430,000	Annual: $11,810,000	Total: $20,240,000
Alternative #5b	Capital: $11,010,000	Annual: $11,810,000	Total: $22,820,000

H & I. STATE AND COMMUNITY ACCEPTANCE

All Alternatives	Comments from the State, Town and citizens of the community regarding this alternative will be addressed after the public comment period

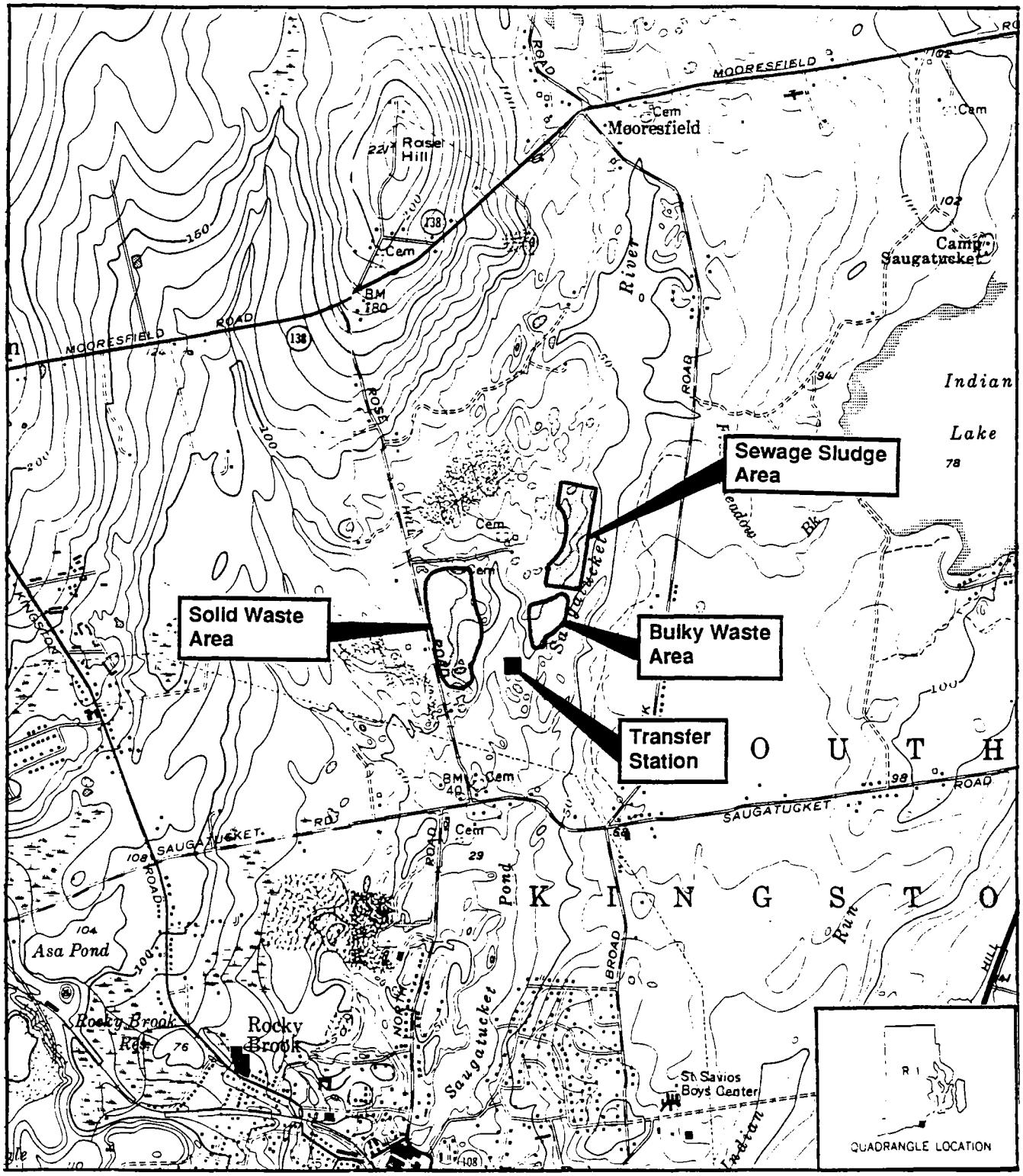
TABLE 5-2. COST SENSITIVITY ANALYSIS SUMMARY

VARIABLE		TOTAL ALTERNATIVE COSTS (in $1,000's)							
	ALT #	1	2	3a	3b	4a	4b	5a	5b
Discount Rate	5%	4,517	4,798	14,939	14,643	18,101	18,437	23,133	25,713
	7%	**3,568**	**3,845**	**13,425**	**13,187**	**16,064**	**16,922**	**20,239**	**22,819**
	9%	2,900	3,175	12,303	12,111	14,577	15,798	18,154	20,734
Total Capital Cost	-30%	3,534	3,736	11,499	11,220	13,893	13,977	17,711	19,517
	0%	**3,568**	**3,845**	**13,425**	**13,187**	**16,064**	**16,922**	**20,239**	**22,819**
	+50%	3,623	4,027	16,635	16,464	19,682	21,830	24,451	28,322
Total Annual Cost	-30%	2,531	2,801	11,324	11,197	13,415	14,790	16,695	19,275
	0%	**3,568**	**3,845**	**13,425**	**13,187**	**16,064**	**16,922**	**20,239**	**22,819**
	+50%	5,296	5,587	16,928	16,502	20,478	20,474	26,145	28,725
Contingency	15%	3,419	3,685	12,866	12,637	15,395	16,216	19,395	21,868
	20%	**3,568**	**3,845**	**13,425**	**13,187**	**16,064**	**16,922**	**20,239**	**22,819**
	25%	3,716	4,006	13,985	13,736	16,733	17,627	21,082	23,770
LFG Operation	5 years	3,262	3,273	4,799	4,650	6,622	4,899	9,607	9,607
	10 years	3,369	3,388	6,007	5,735	7,830	6,107	10,815	10,815
	15 years	**3,568**	**3,845**	**13,425**	**13,187**	**16,064**	**16,922**	**20,239**	**22,819**
Overall	Low	2,531	2,801	4,799	4,650	6,622	4,899	9,607	9,607
	Baseline	**3,568**	**3,845**	**13,425**	**13,187**	**16,064**	**16,922**	**20,239**	**22,819**
	High	5,296	5,587	16,928	16,502	20,478	21,830	26,145	28,725

Notes:

Boldface indicates base case conditions for the alternative

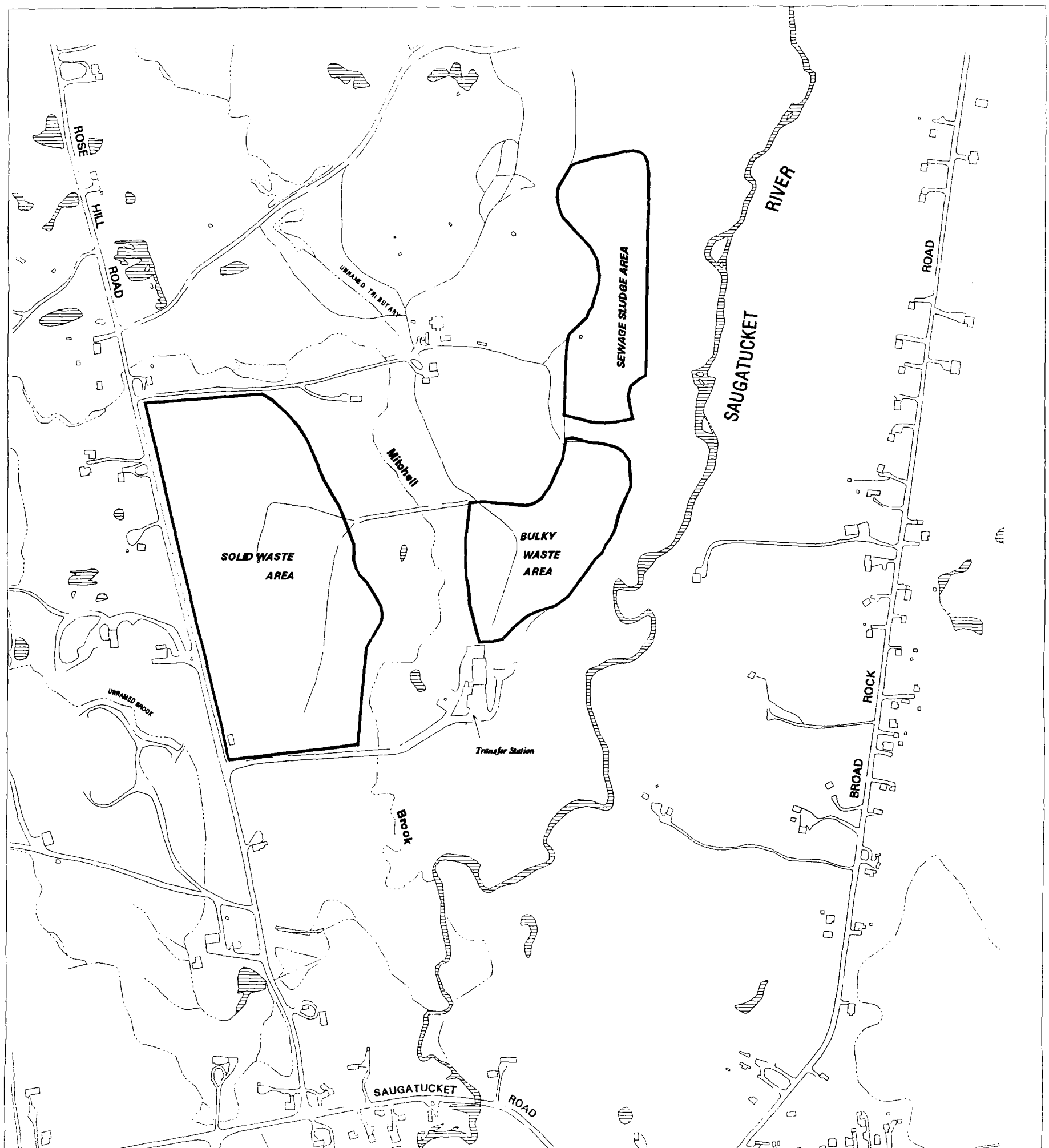
Section One



SOURCE: USGS TOPOGRAPHIC MAPS
KINGSTON, RI, 1970
NARRGANSETT PIER, RI, 1975

2000 0 2000
SCALE IN FEET

FIGURE 1-1. LOCATION OF THE ROSE HILL REGIONAL LANDFILL SITE



LEGEND

- Primary Road
- Secondary Road
- Stream or Brook
- Disposal Area
- Lake, Pond, or River

500 0 500

SCALE IN FEET

FIGURE 1-2.

ROSE HILL REGIONAL LANDFILL SITE

ROSE HILL REGIONAL LANDFILL SITE

SOUTH KINGSTOWN, RI

FSTUDY1.WAT(SEPT. 1996)

METCALF & EDDY

Section Two

FIGURE 2-1
WETLAND RESOURCE AREAS

ROSE HILL REGIONAL LANDFILL SITE
SOUTH KINGSTOWN, RI

LEGEND

- Primary Road
- Secondary Road
- Stream or Brook
- Boundary of Area Protected Under Rhode Island Freshwater Wetlands Act
- Limit of Waste Placement Delineated
- Lake, Pond or River
- Field-Verified Wetland
- Wetland As Indicated by Available Literature

FIGURE 2-1
WETLAND RESOURCE AREAS

ROSE HILL REGIONAL LANDFILL SITE
SOUTH KINGSTOWN, RI

METCALF & EDDY

200 0 200
SCALE IN FEET

WATRES98.AML (RES. 1998)

FIGURE 2-2
AREA OF CONTAMINATED MEDIA DELINEATED

ROSE HILL REGIONAL LANDFILL SITE
SOUTH KINGSTOWN, RI

LEGEND

- Primary Road
- Secondary Road
- Stream or Brook
- Property Boundary
- 44 Property Lot No.
- Site Center
- Limit of Waste Placement Delineated
- Lake, Pond or River
- 100-Year Flood Plain
- Areal Extent of Soil GAs PRG Exceedance
- Areal Extent of Groundwater PRG Exceedance
- Vicinity of Leachate Seeps
- Site Monitoring Well
- Residential Monitoring Well

FIGURE 2-2
AREA OF CONTAMINATED MEDIA DELINEATED

BASED ON PRELIMANARY REMEDIATION GOALS
ROSE HILL REGIONAL LANDFILL SITE
SOUTH KINGSTOWN, RI

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200 0 200
SCALE IN FEET

Note: Preliminary Remediation Goal(PRG) Exceedances Based on Groundwater and Soil Gas Data Presented in the RI Report (M&E, 1994).
* Groundwater PRG Exceedances Do Not Include Manganese as Discussed in Section 1.0

ACMD1198.AML (RES. 1996)

Section Three

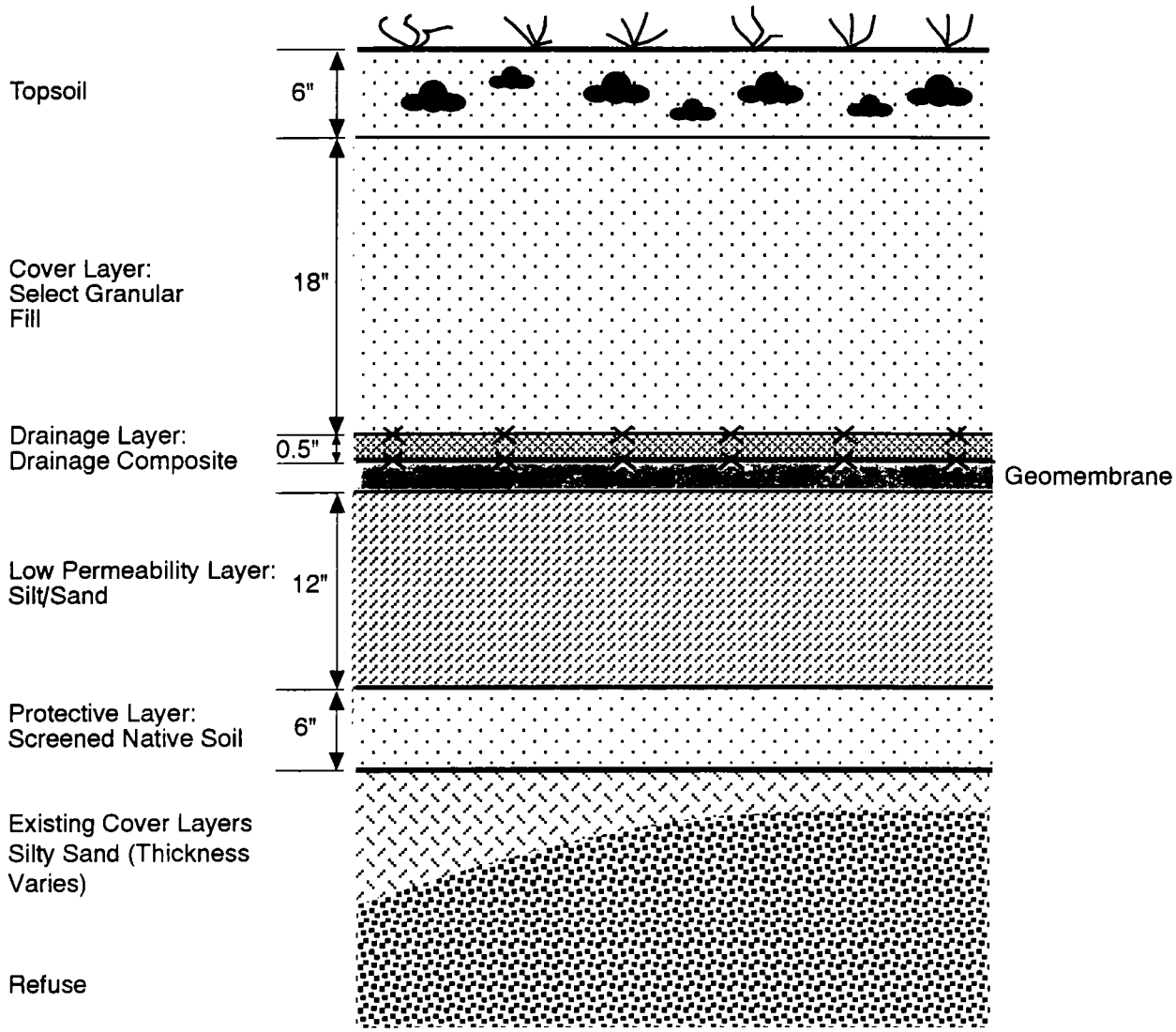


FIGURE 3-1. PROTECTIVE CAP: SOLID WASTE AREA

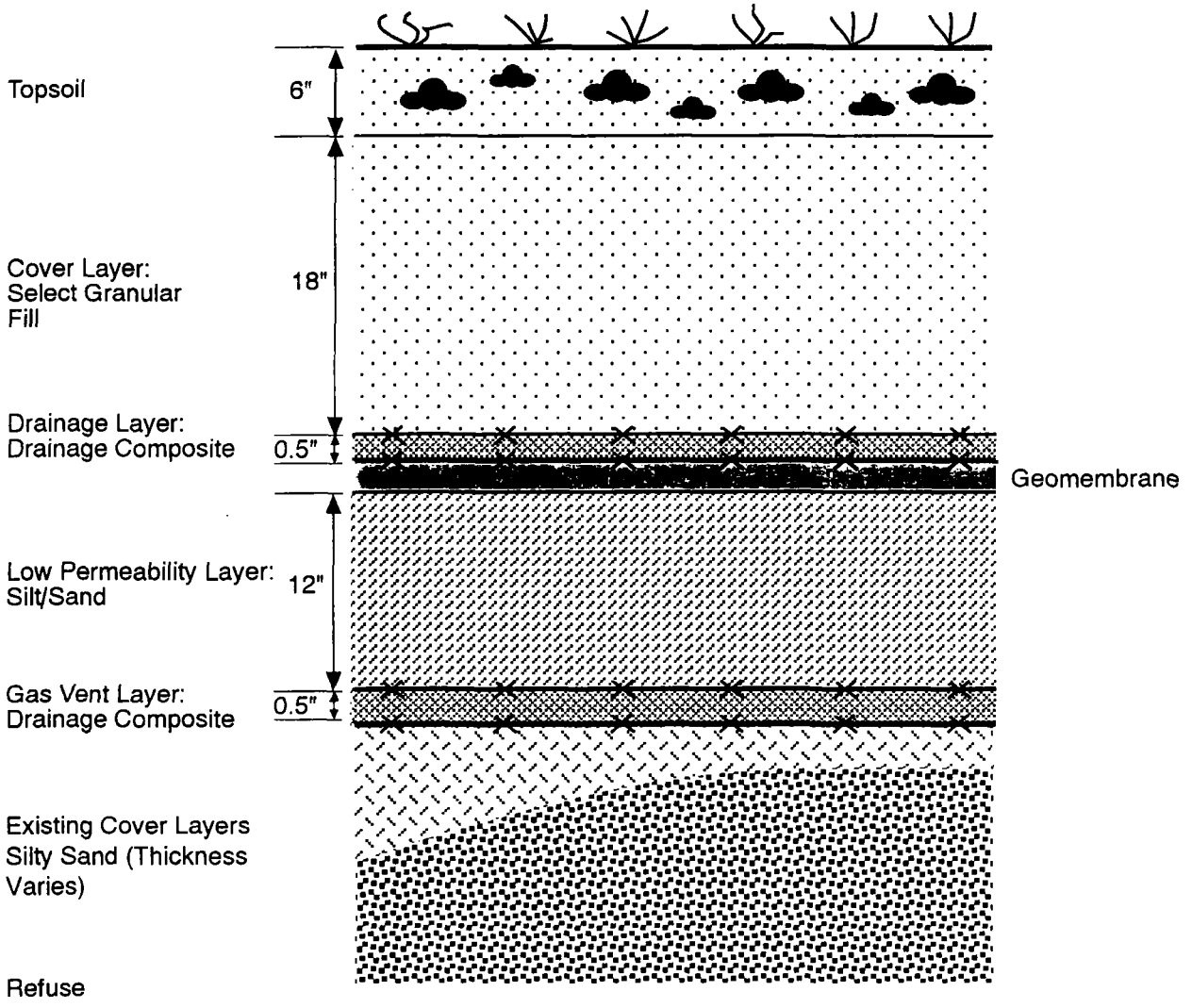


FIGURE 3-2. PROTECTIVE CAP: BULKY WASTE AREA

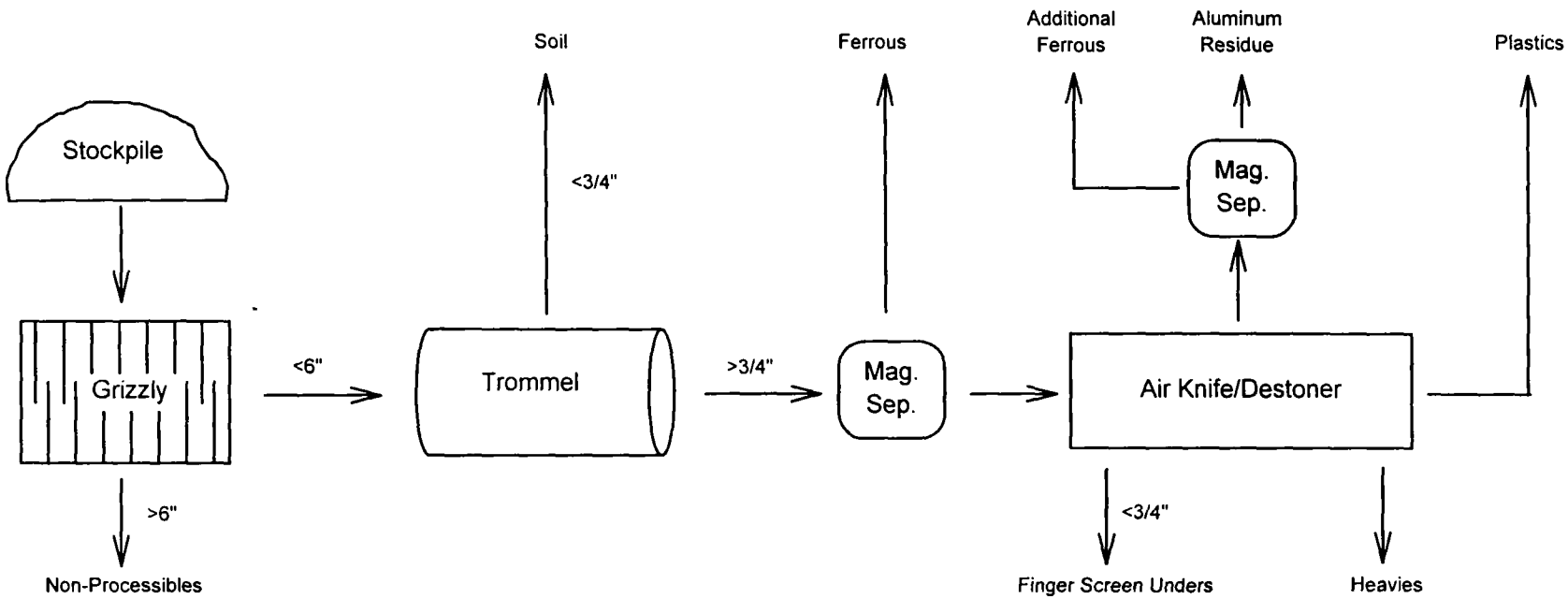


FIGURE 3-3. SCHEMATIC OF PROCESSING SYSTEM USED IN THE COLLIER COUNTY, FLORIDA LANDFILL MINING DEMONSTRATION PROJECT (Source: Dickinson, 1995)

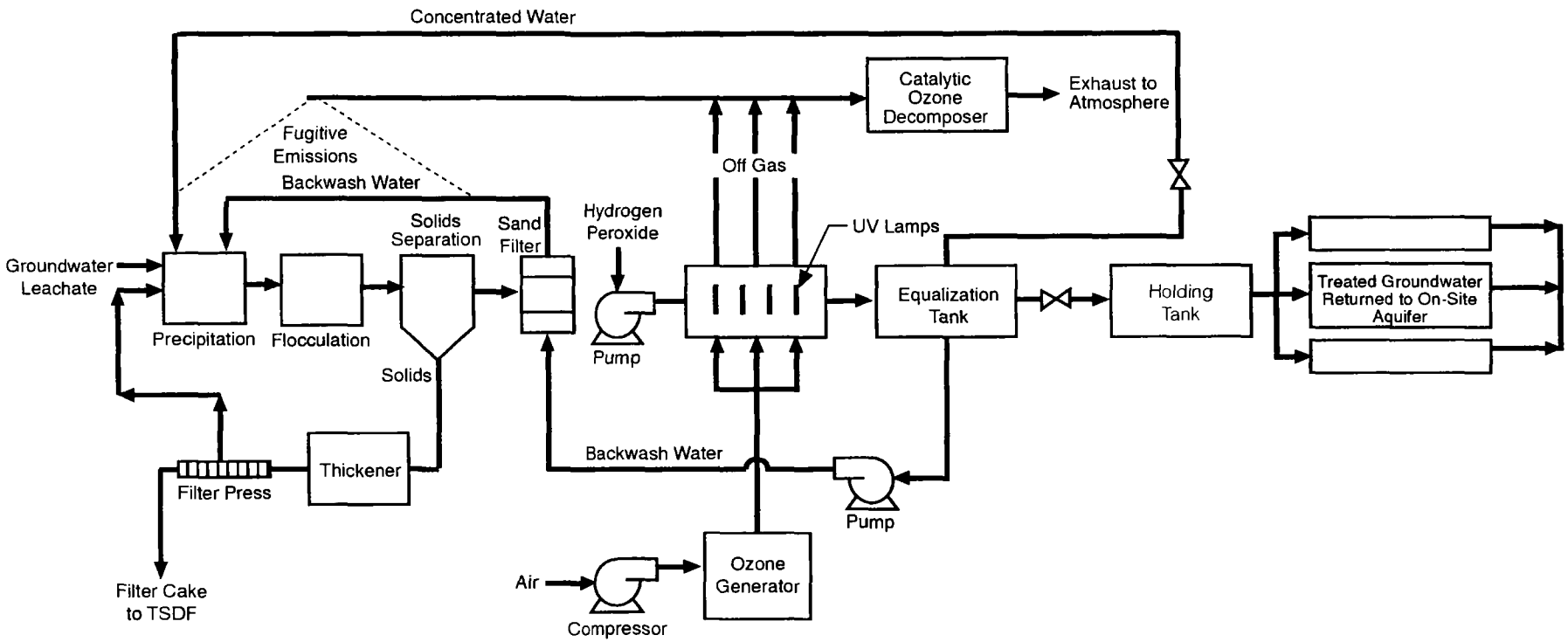


FIGURE 3-4. PROCESS FLOW DIAGRAM: ON-SITE GROUNDWATER/LEACHATE TREATMENT

dt/3151-1A

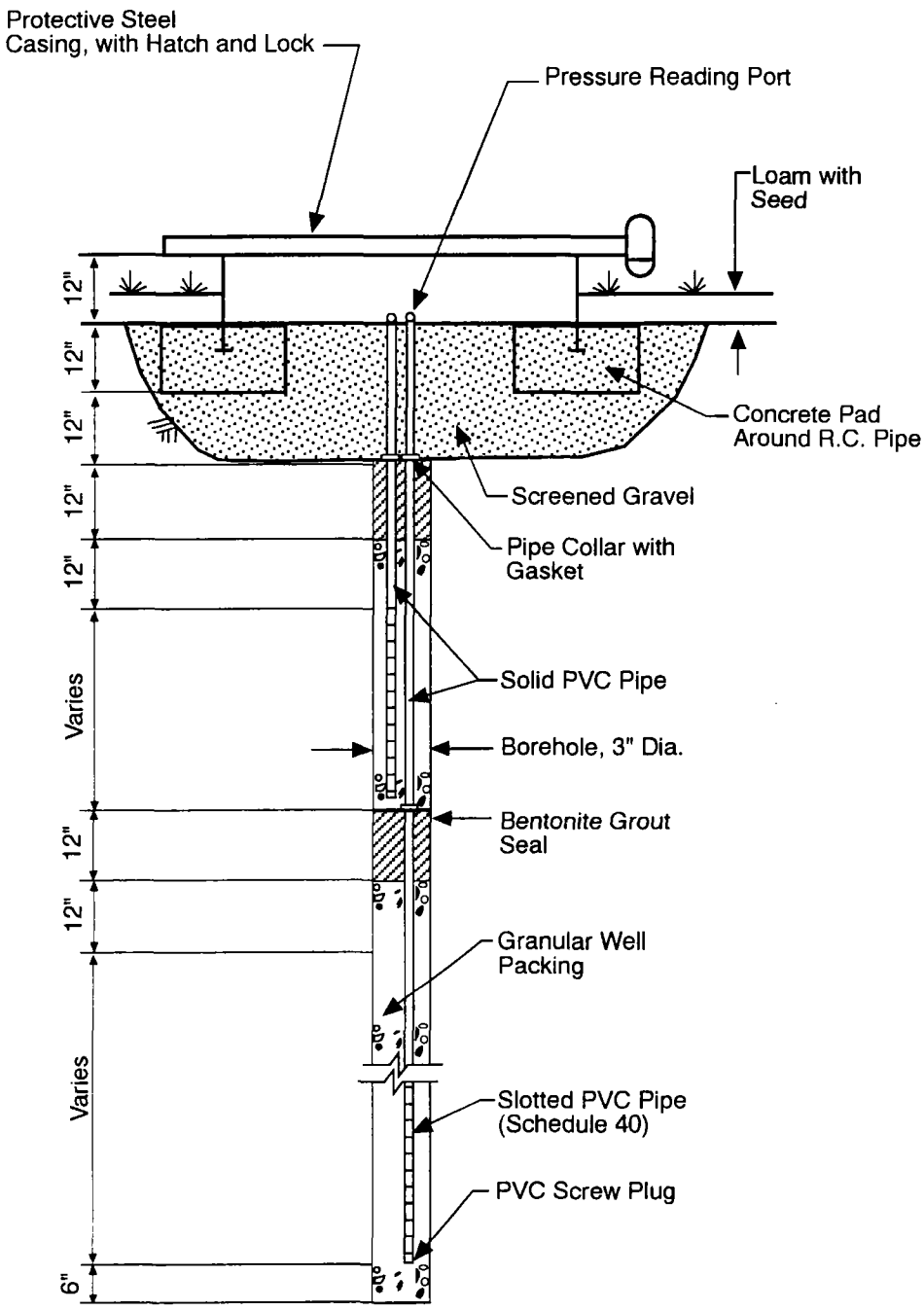


FIGURE 3-5. MULTI-LEVEL GAS MONITORING WELL SECTION

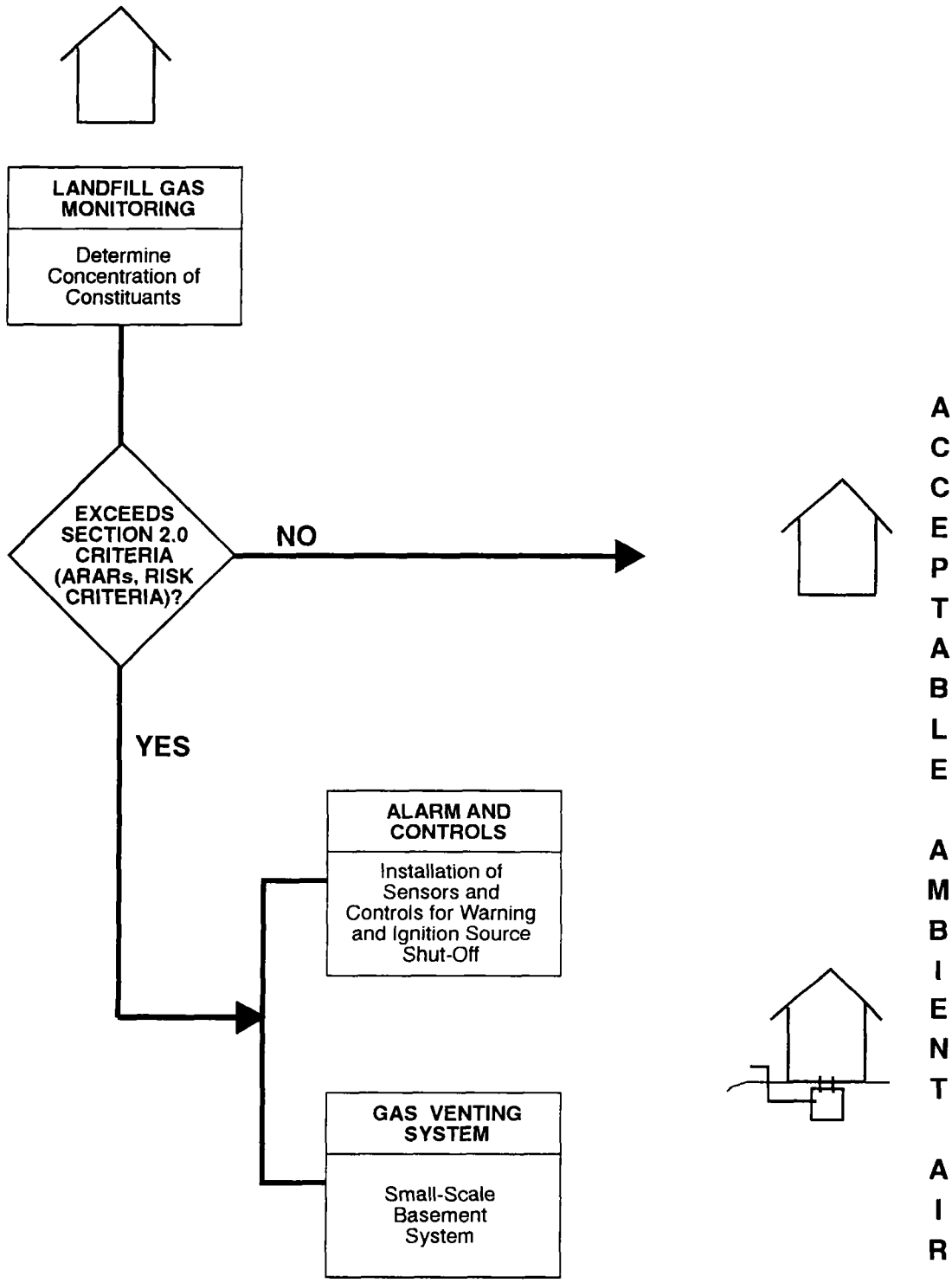
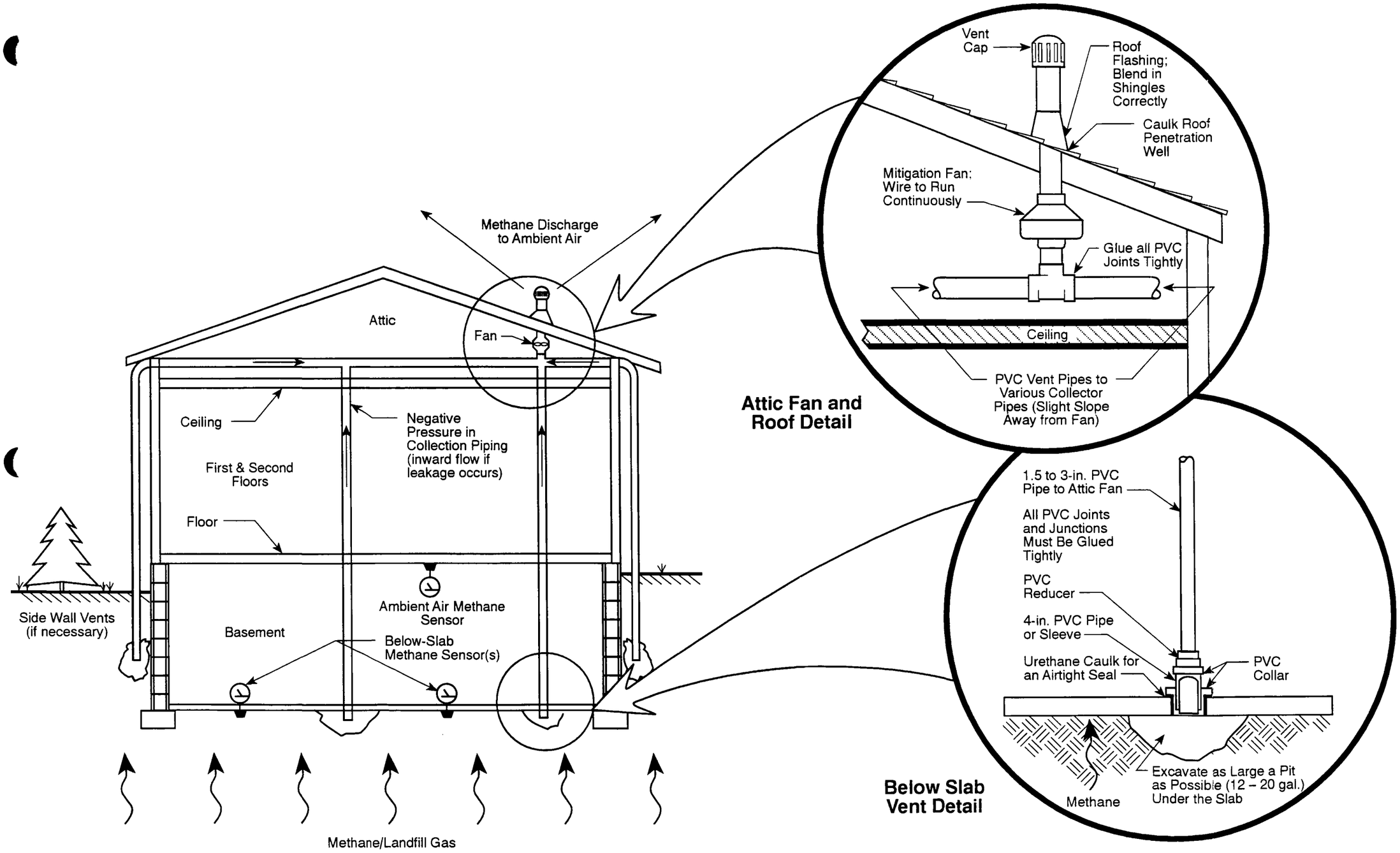


FIGURE 3-6. RESIDENTIAL LANDFILL GAS CONTROL CONTINGENCY



Notes:

1. Diagram Source: (U.S. EPA, 1991b)
2. Diagrams Not to Scale

FIGURE 3-7. RESIDENTIAL LANDFILL GAS CONTROL SYSTEM

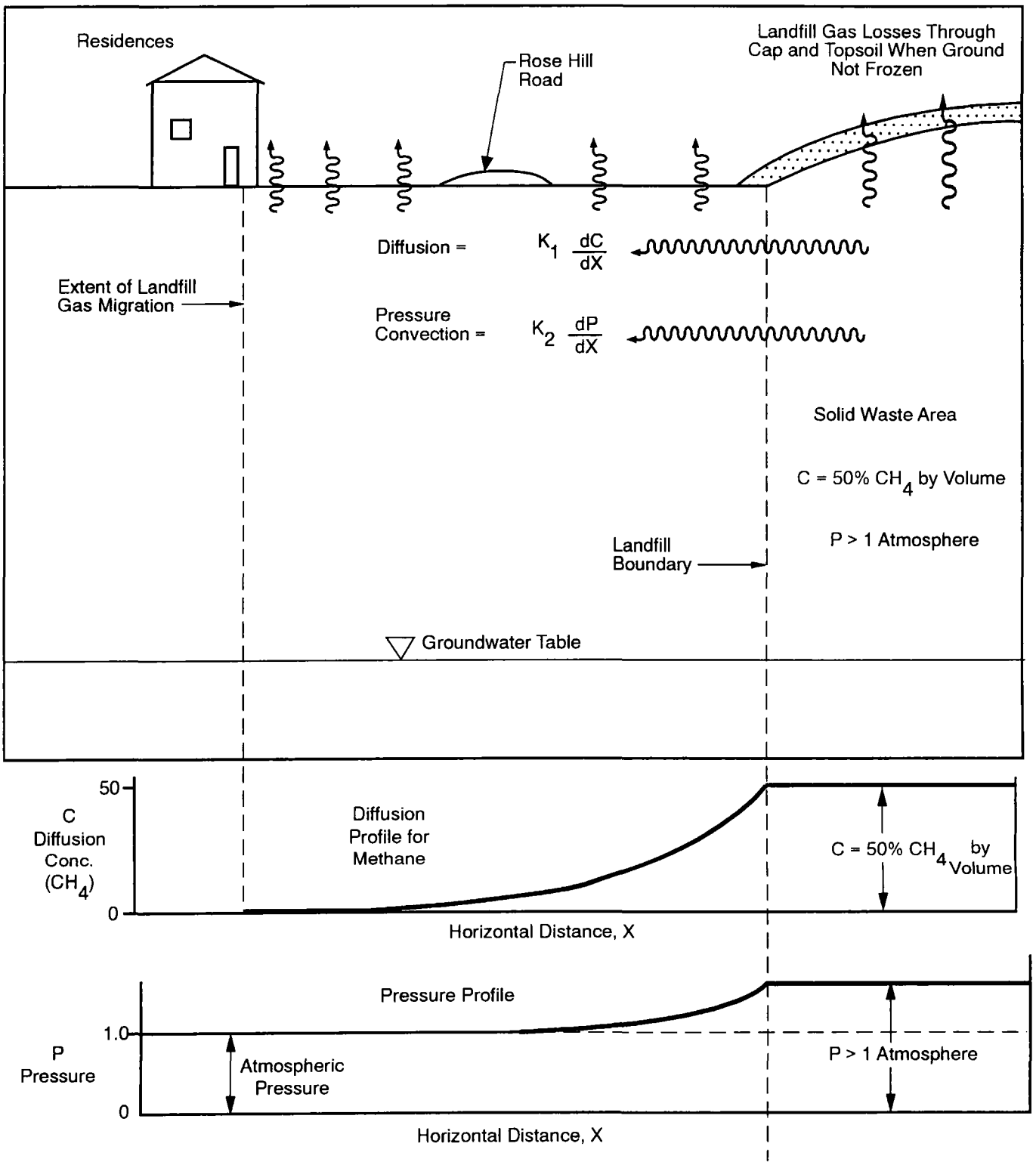


FIGURE 3-8. METHANE MIGRATION MECHANISMS

08.2/3152jp

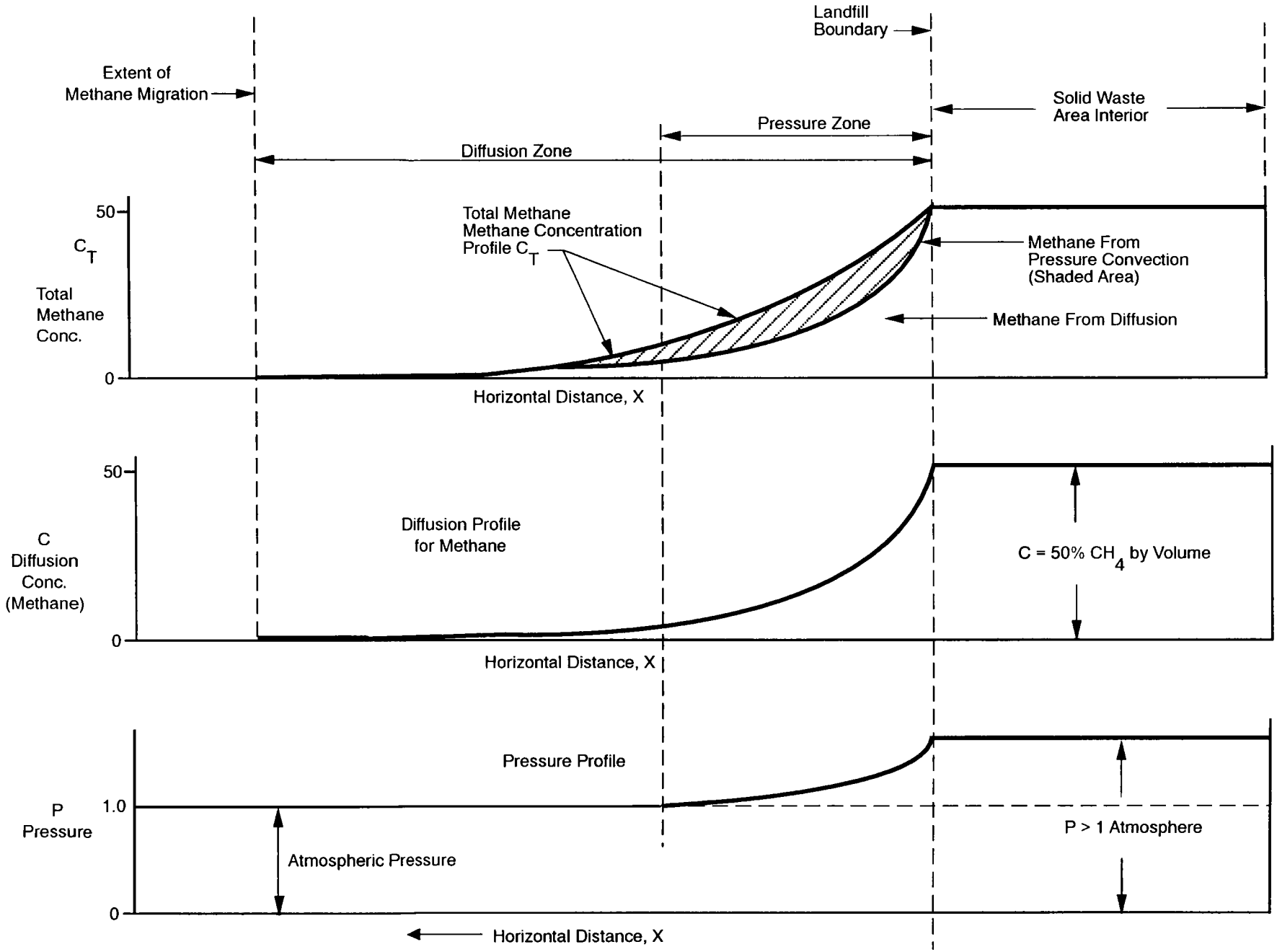


FIGURE 3-9. DERIVATION OF METHANE CONCENTRATION PROFILE

09 2/3152

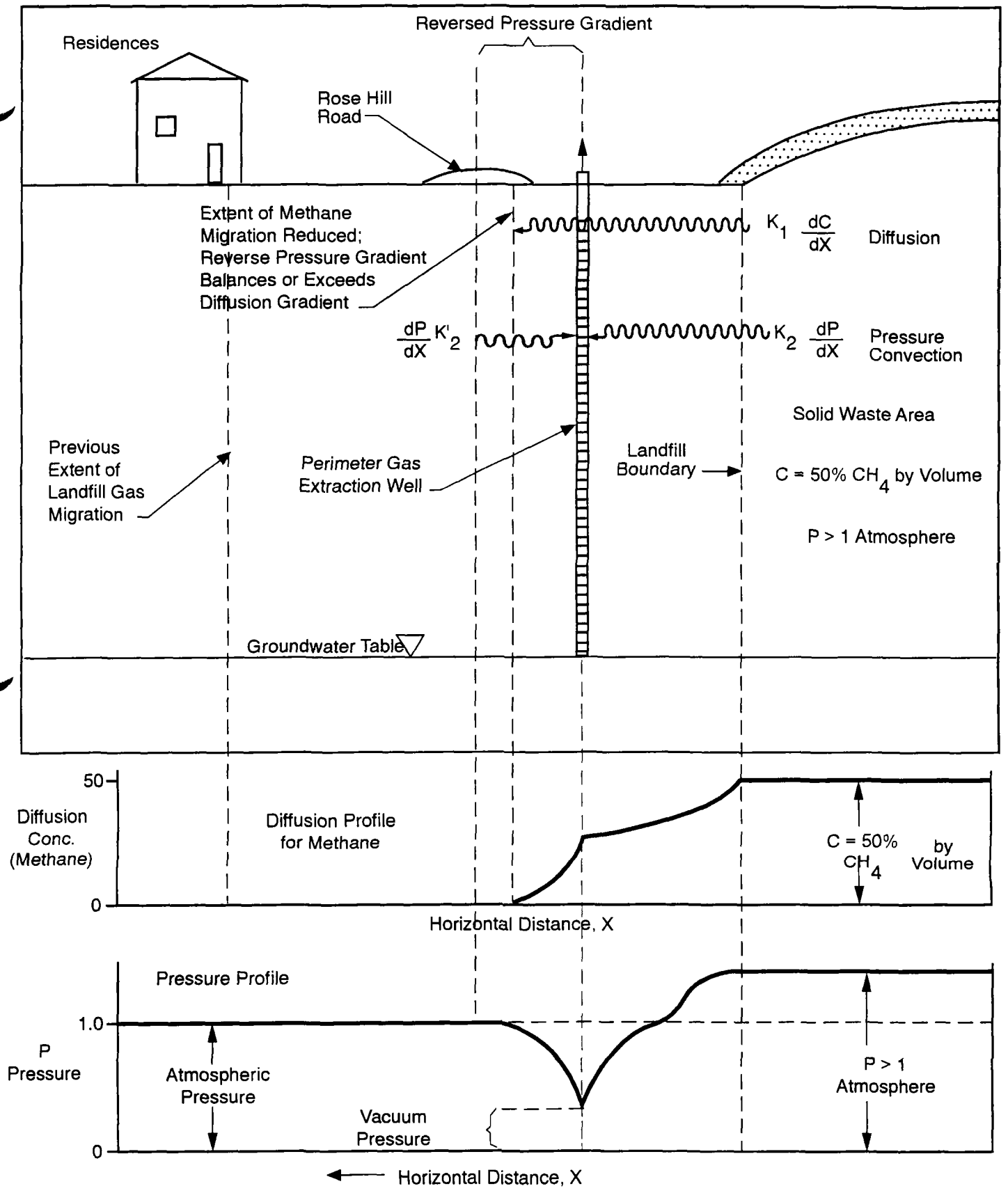


FIGURE 3-10. EFFECT OF PERIMETER ACTIVE BARRIER

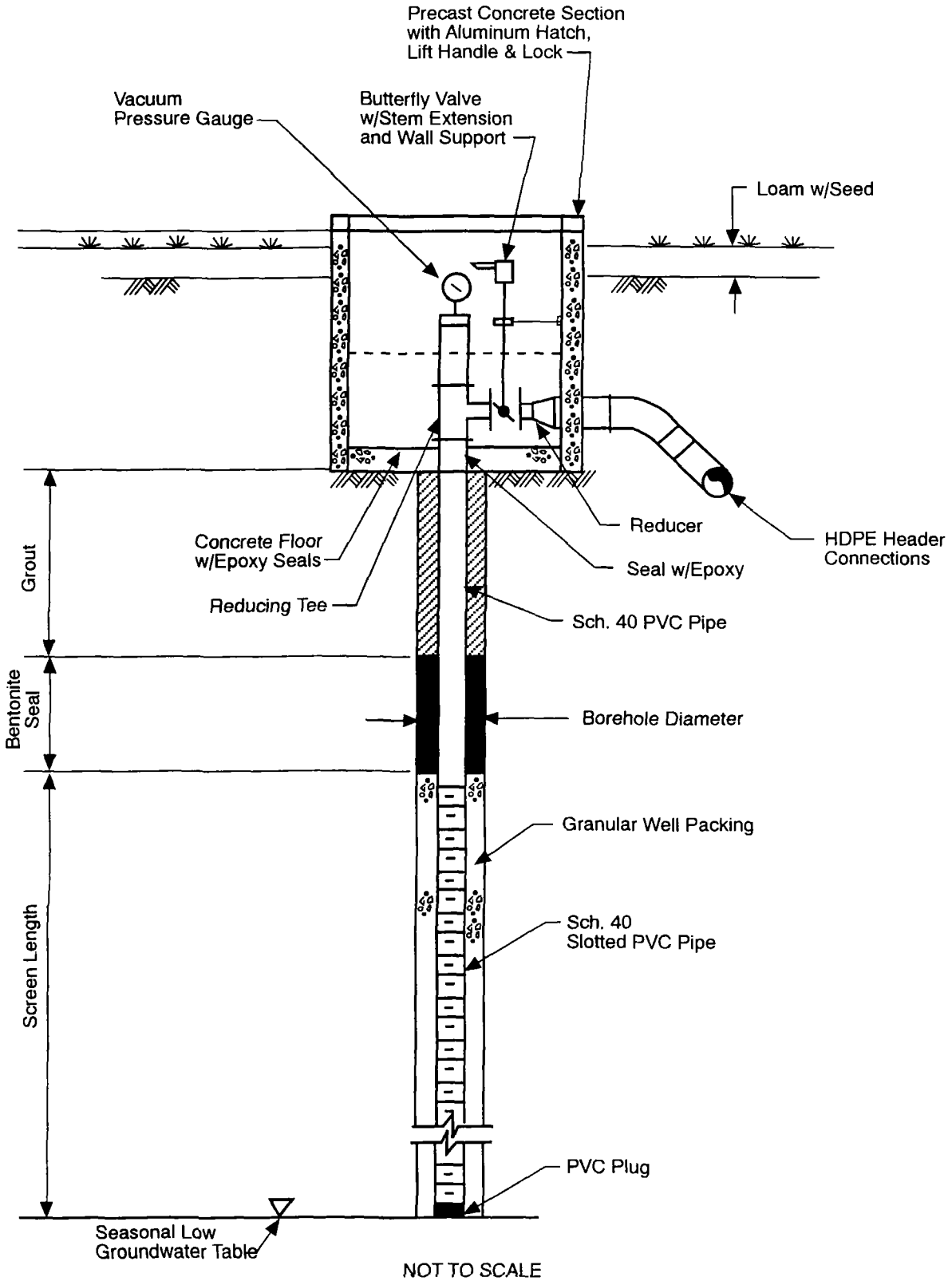


FIGURE 3-11. TYPICAL PERIMETER GAS EXTRACTION WELL

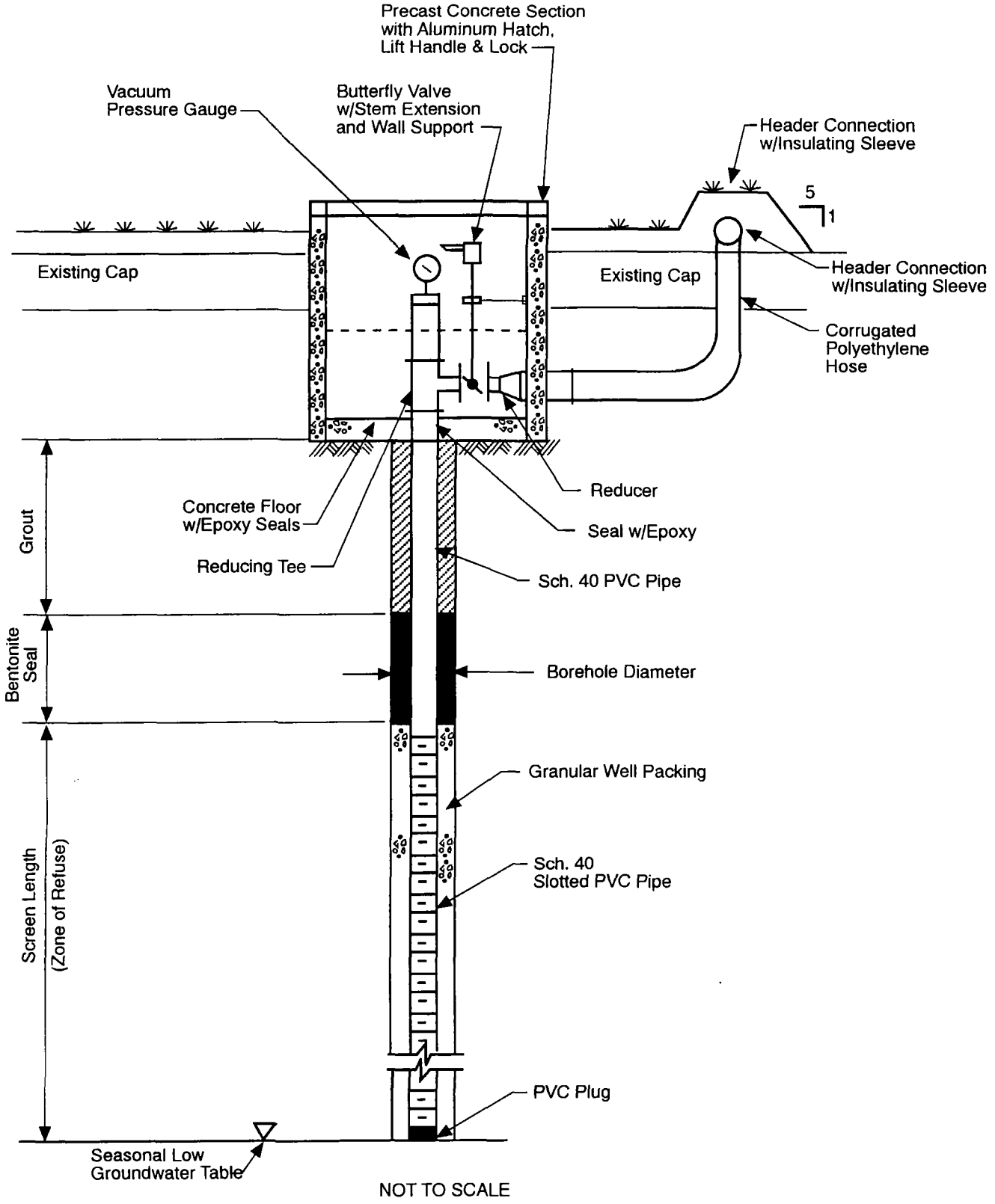


FIGURE 3-12. TYPICAL INTERNAL GAS EXTRACTION WELL

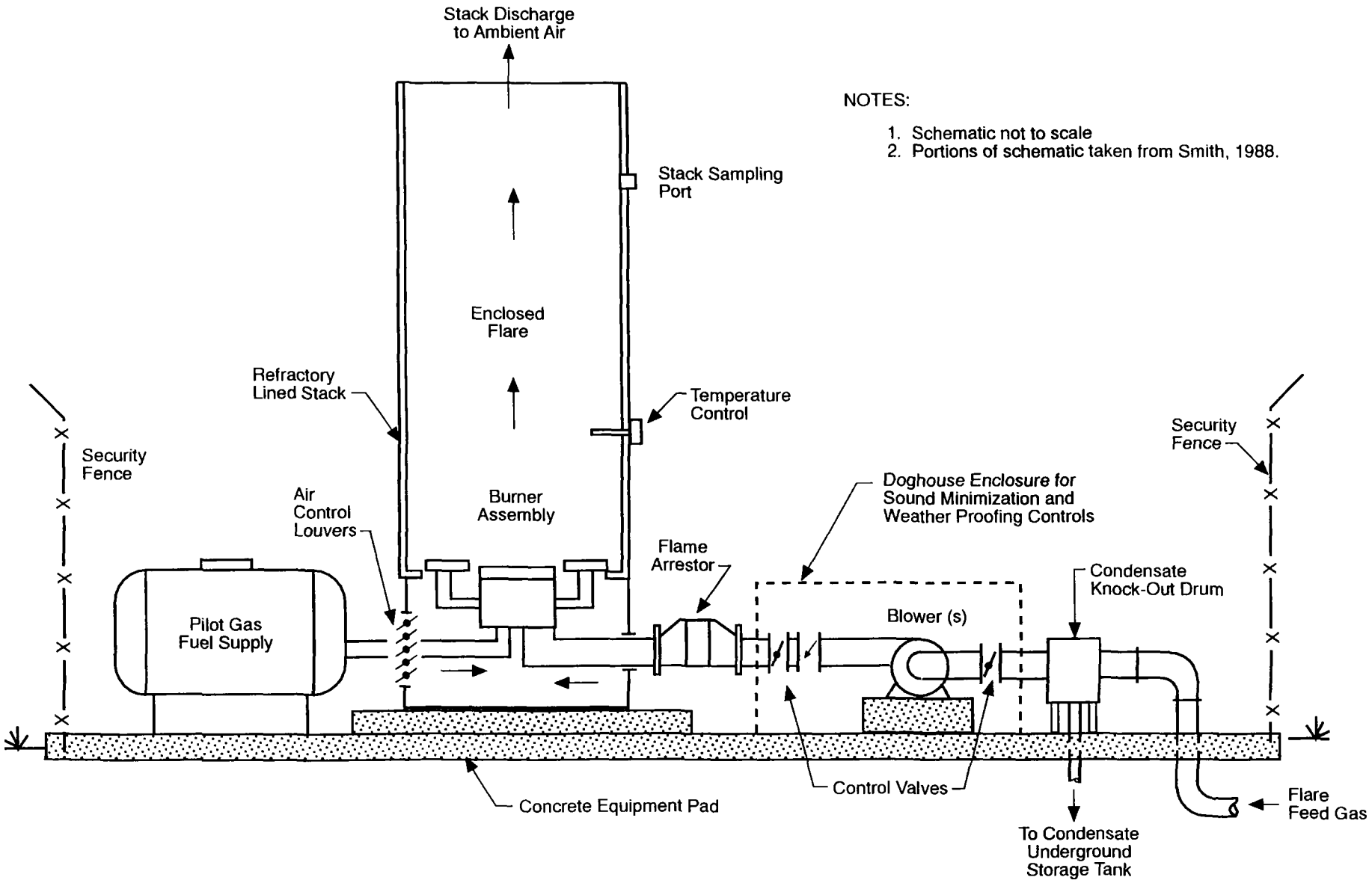


FIGURE 3-13. ENCLOSED FLARE SCHEMATIC

13/3152JP

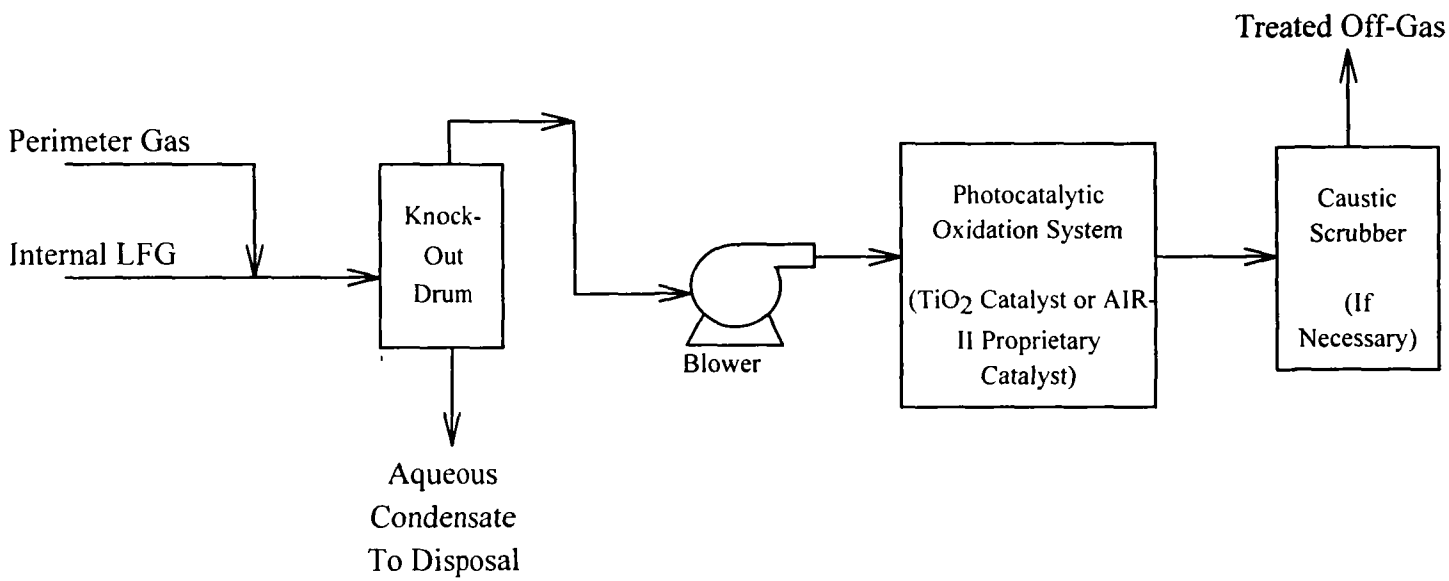


FIGURE 3-14. PHOTOCATALYTIC OXIDATION PROCESS FLOW DIAGRAM

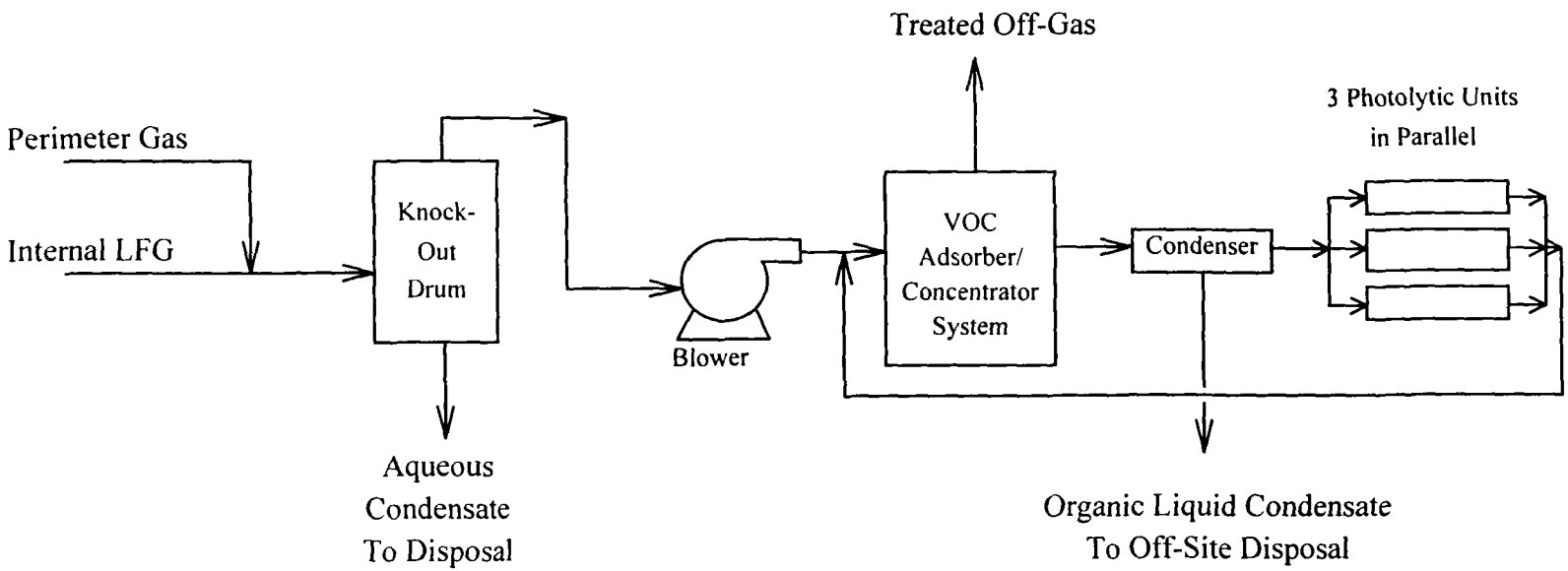


FIGURE 3-15. PHOTOLYTIC OXIDATION PROCESS FLOW DIAGRAM

Section Four

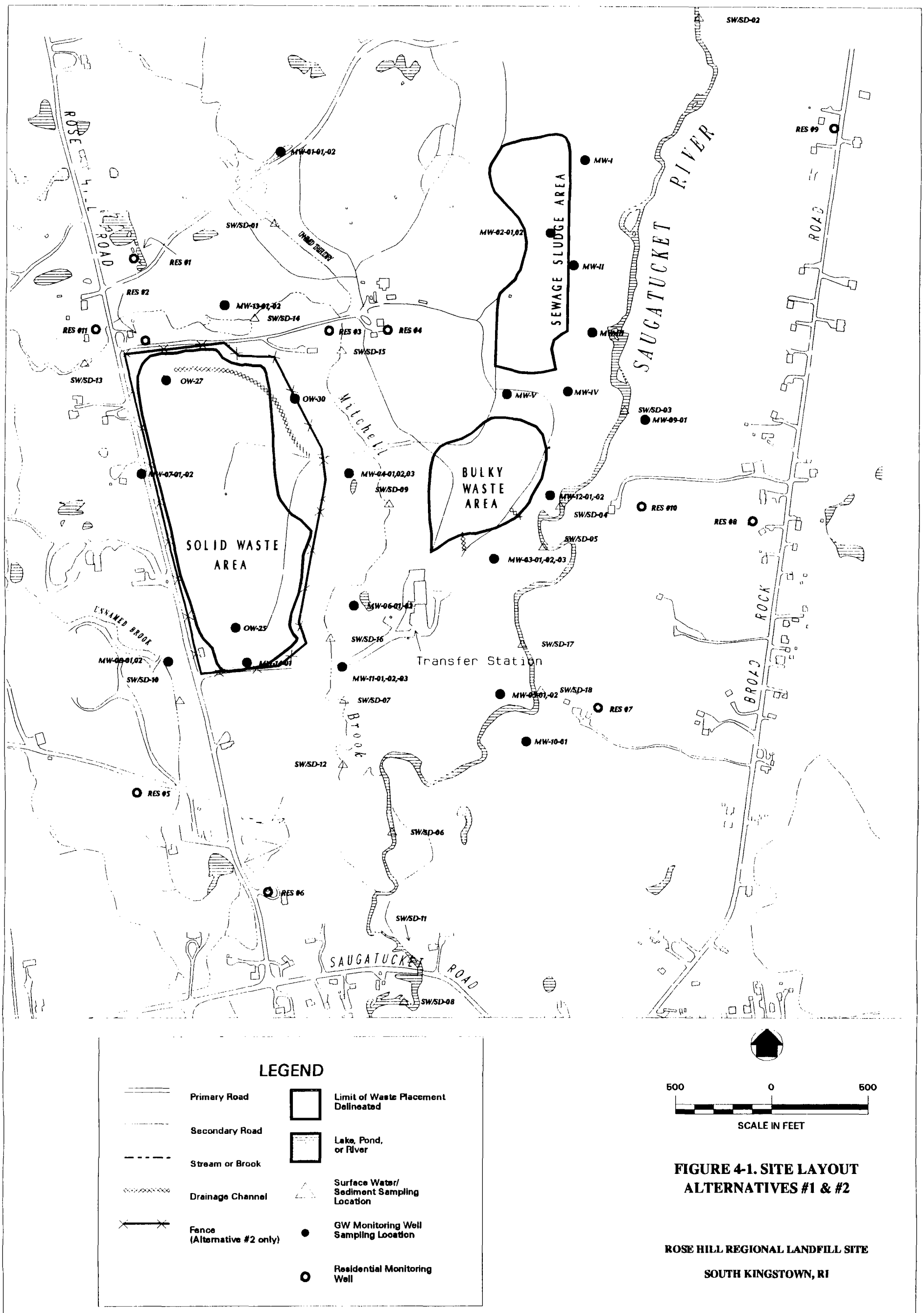


FIGURE 4-1. SITE LAYOUT ALTERNATIVES #1 & #2

ROSE HILL REGIONAL LANDFILL SITE

SOUTH KINGSTOWN, RI

FSTUDY4.WAT(SEPT. 1996)

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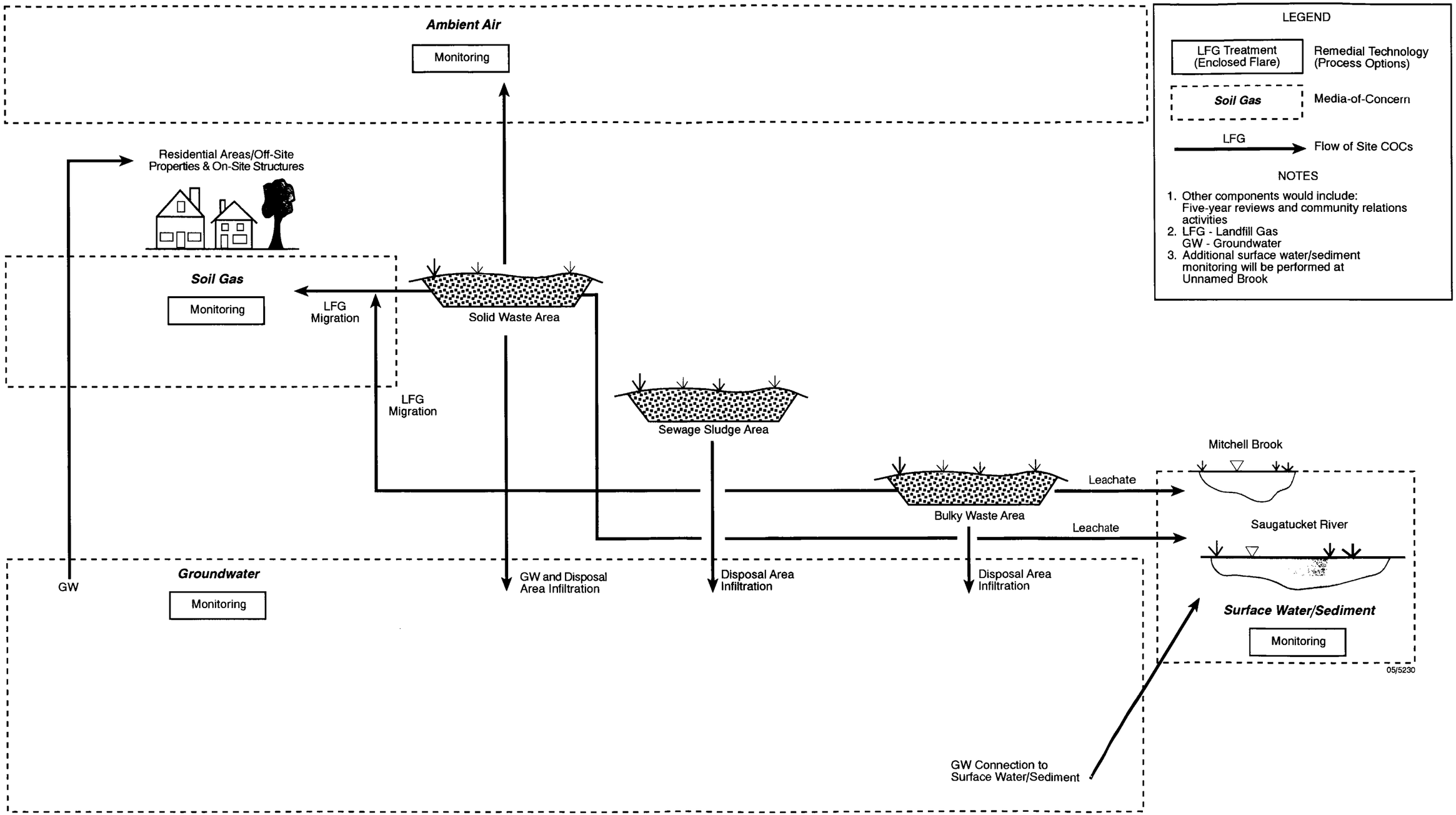


**FIGURE 4-2.
SCHEMATIC OF
ALTERNATIVE #1 COMPONENTS**

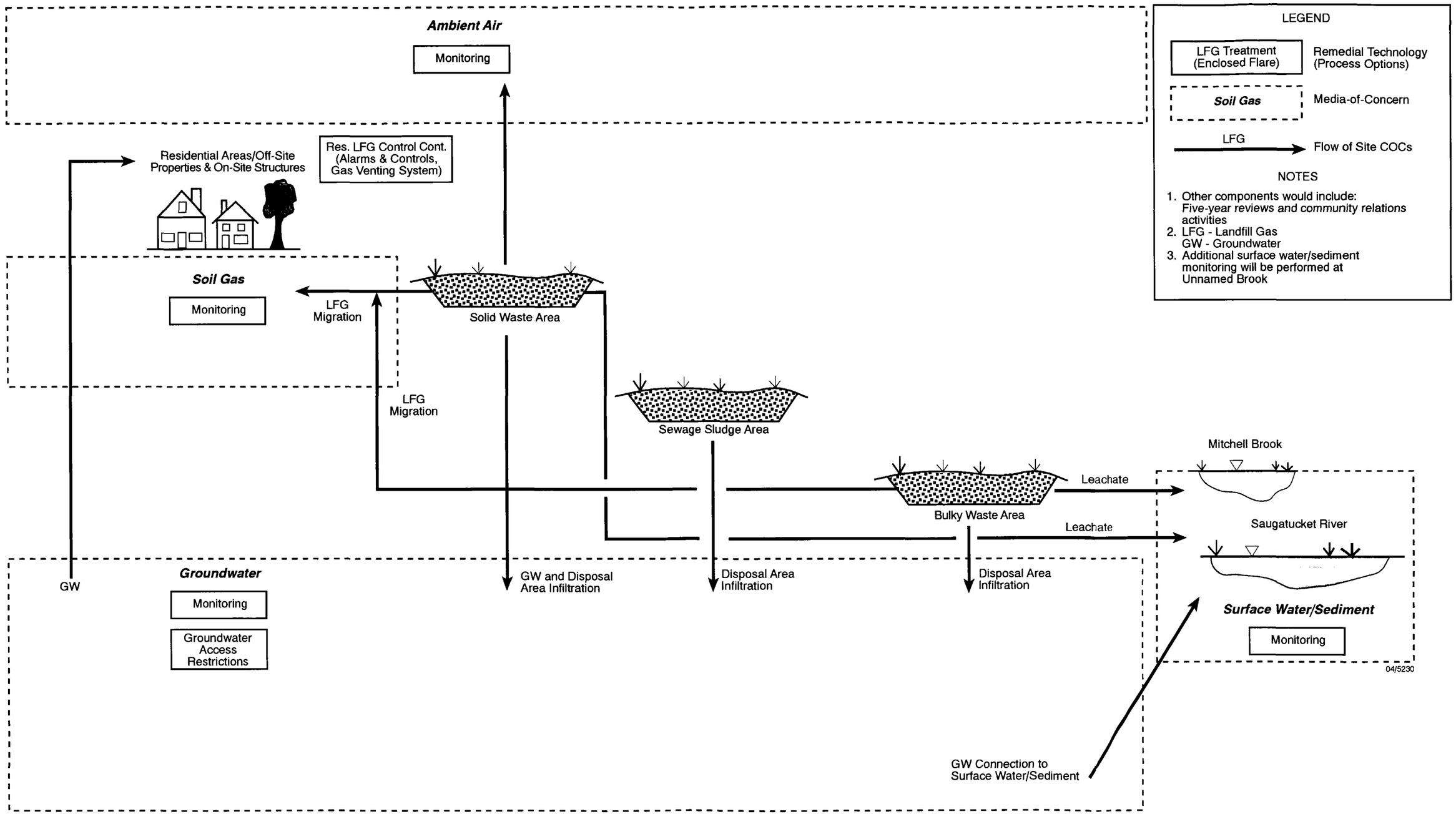
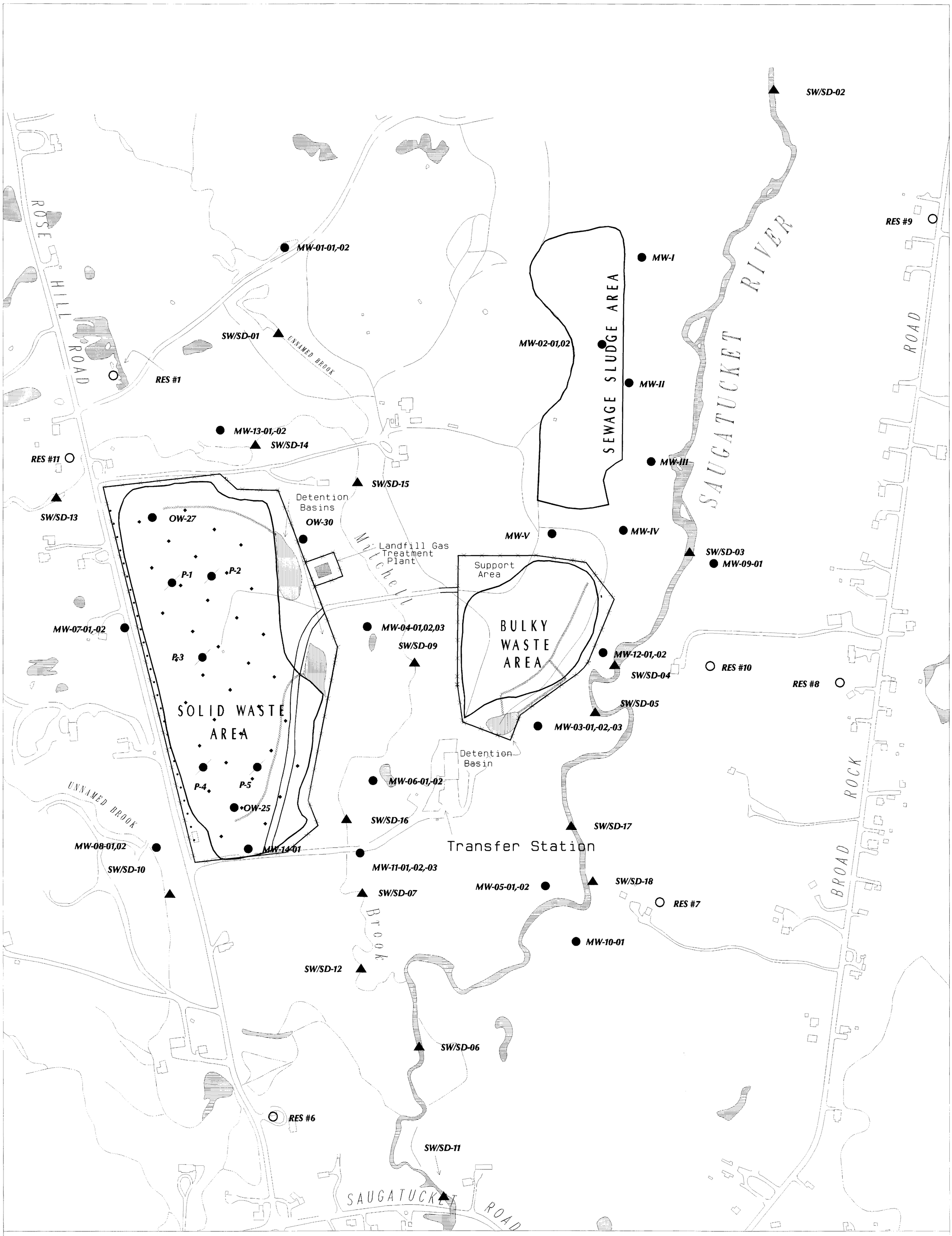


**FIGURE 4-3.
SCHEMATIC OF
ALTERNATIVE #2 COMPONENTS**



LEGEND

- Primary Road
- Secondary Road
- Stream or Brook
- Drainage Channel
- Fence
- Relative Location of Active Internal Gas Extraction Well
- Relative Location of Active Perimeter Gas Extraction Well
- Area to be Capped
- Lake, Pond, or River
- Surface Water/Sediment Sampling Location
- GW Monitoring Well Sampling Location
- Residential Well Sampling Location
- Piezometer

FIGURE 4-4. SITE LAYOUT - ALTERNATIVES #3a AND 3b

ROSE HILL REGIONAL LANDFILL SITE
SOUTH KINGSTOWN, RI

FIGURE 4-4.
SITE LAYOUT - ALTERNATIVE #3a AND 3b

ROSE HILL REGIONAL LANDFILL SITE
SOUTH KINGSTOWN, RI
METCALF & EDDY

200 0 200
SCALE IN FEET

ALT3AB98.WAT(NOV. 1998)

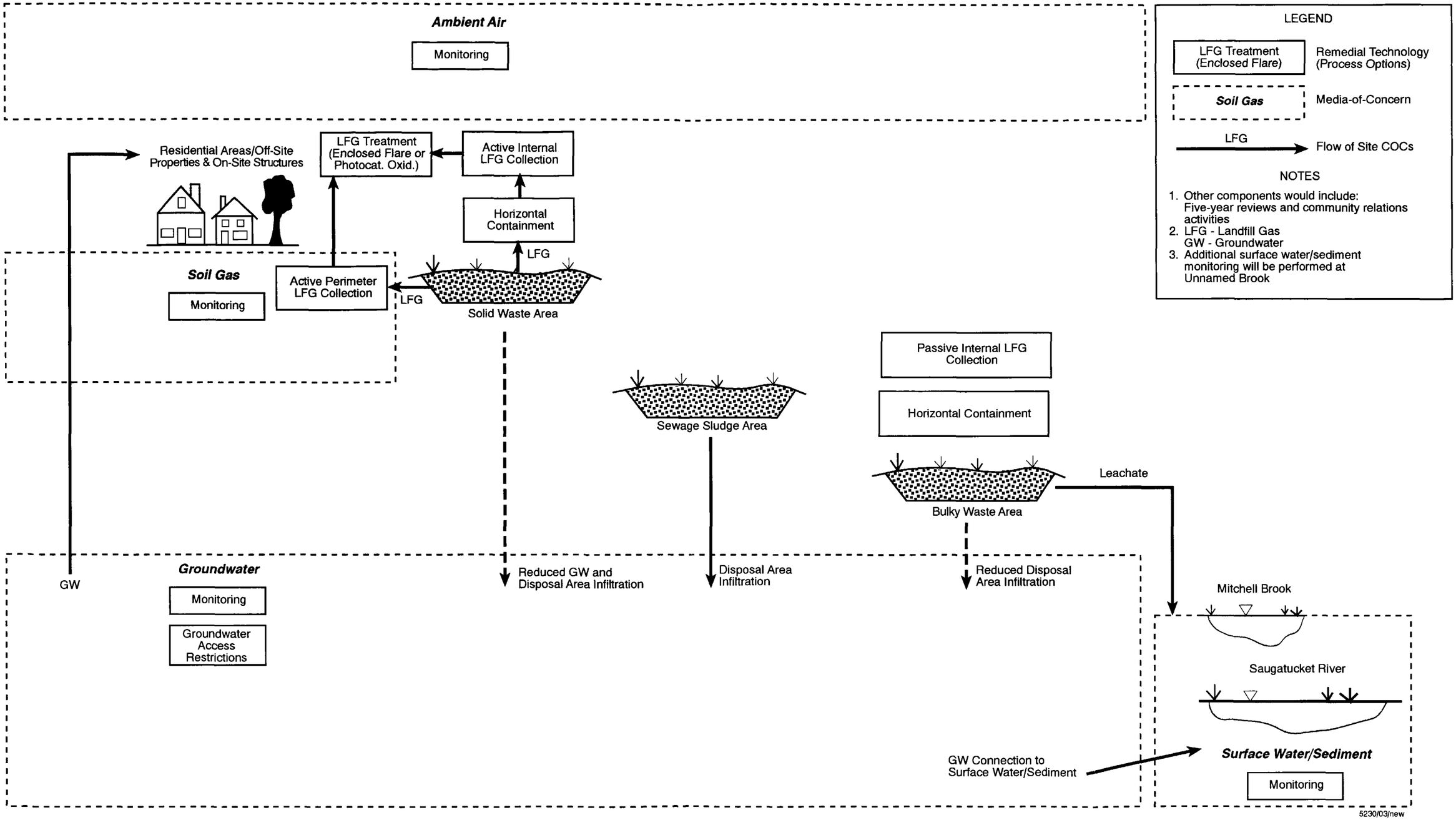


FIGURE 4-5.
SCHEMATIC OF ALTERNATIVES
#3a and 3b COMPONENTS

SW/SD-02
RES #9
MW-01-01,-02
MW-I
SEWAGE SLUDGE AREA
RIVER
SAUGATUCKET
ROSE HILL ROAD
ROAD
SW/SD-01
UNNAMED BROOK
MW-02-01,02
RES #1
MW-II
MW-13-01,-02
SW/SD-14
RES #11
MW-III
SW/SD-15
Detention Basins
Leachate Treatment Plant
SW/SD-13
OW-27
OW-30
MW-V
MW-IV
Landfill Gas Treatment Plant
Mitchell
SW/SD-03
MW-09-01
Support Area
(Alt. #4a only)
Subsurface Drains/ Extraction Wells
P-1
P-2
MW-07-01,-02
MW-04-01,02,03
SW/SD-09
BULKY WASTE AREA
MW-12-01,-02
RES #10
P-3
SW/SD-04
RES #8
SW/SD-05
SOLID WASTE AREA
MW-03-01,-02,-03
Detention Basin (Alt. #4a only)
P-4
P-5
MW-06-01,-02
UNNAMED BROOK
OW-25
SW/SD-16
SW/SD-17
ROCK
MW-08-01,02
MW-14-01
Transfer Station
SW/SD-10
MW-11-01,-02,-03
MW-05-01,-02
SW/SD-18
BROAD
SW/SD-07
RES #7
Brook
MW-10-01
SW/SD-12
SW/SD-06
RES #6
SW/SD-11
SAUGATUCKET ROAD

LEGEND

- Primary Road
- Secondary Road
- Stream or Brook
- Drainage Channel
- Fence
- Relative Location of Active Internal Gas Extraction Well
- Relative Location of Active Perimeter Gas Extraction Well
- Area to be Capped
- Lake, Pond, or River
- Surface Water/Sediment Sampling Location
- GW Monitoring Well Sampling Location
- Residential Well Sampling Location
- Piezometer

FIGURE 4-6. SITE LAYOUT - ALTERNATIVES #4a AND 4b

ROSE HILL REGIONAL LANDFILL SITE
SOUTH KINGSTOWN, RI

FIGURE 4-6.
SITE LAYOUT - ALTERNATIVE #4a AND 4b

ROSE HILL REGIONAL LANDFILL SITE
SOUTH KINGSTOWN, RI
METCALF & EDDY

200 0 200
SCALE IN FEET

ALT4AB98.WAT(NOV. 1998)

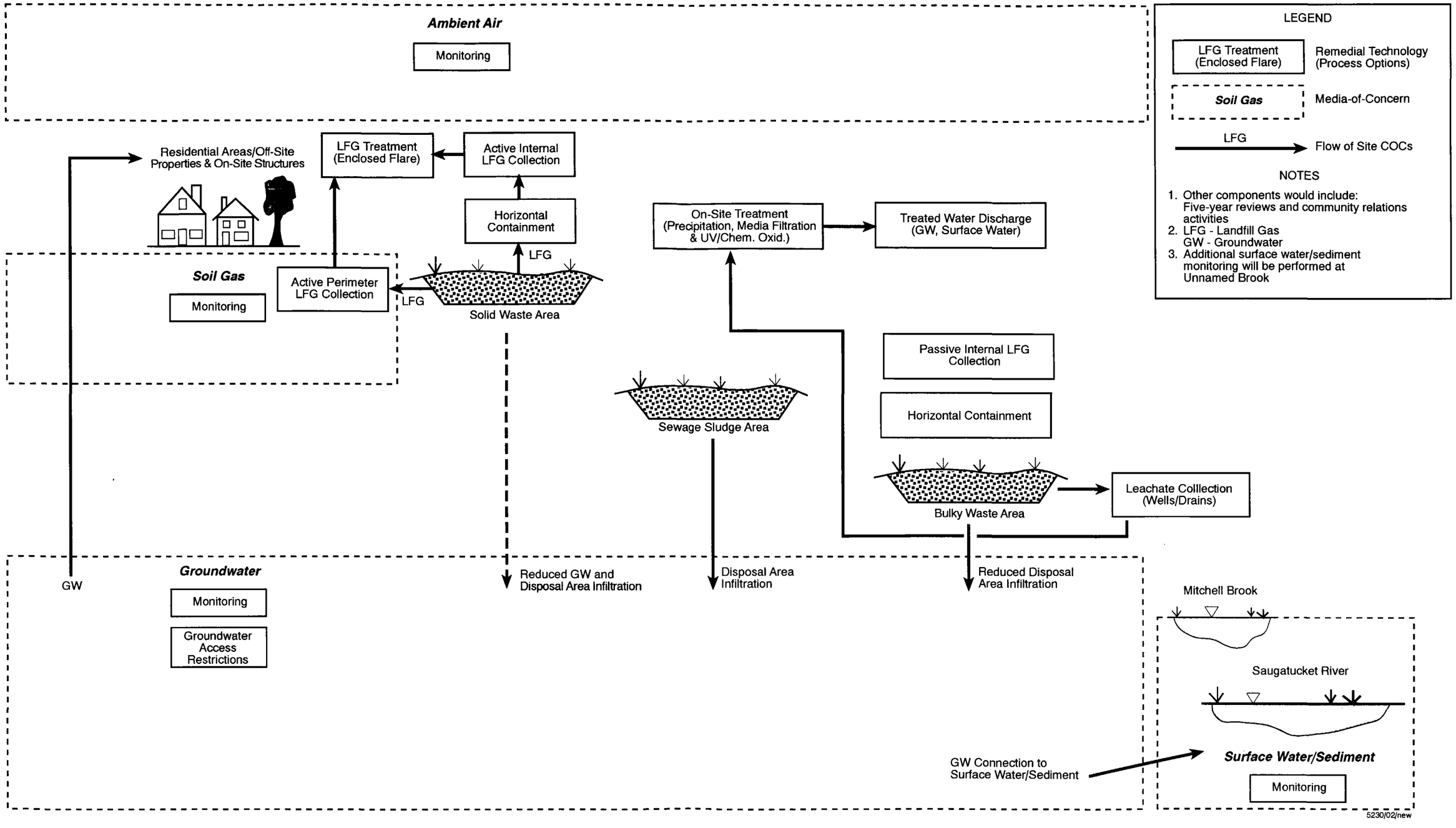


**FIGURE 4-7.
SCHEMATIC OF
ALTERNATIVE #4a COMPONENTS**

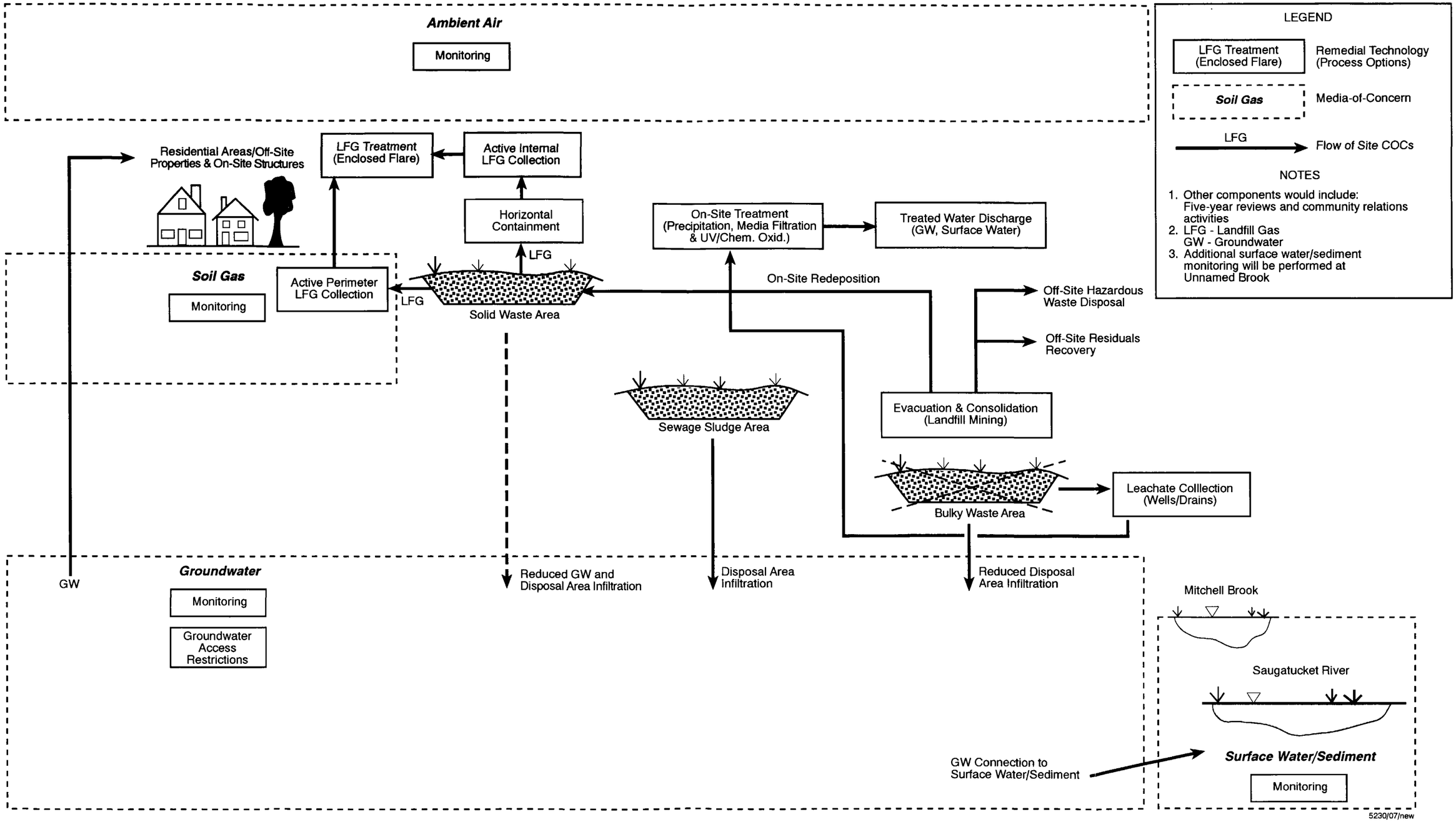
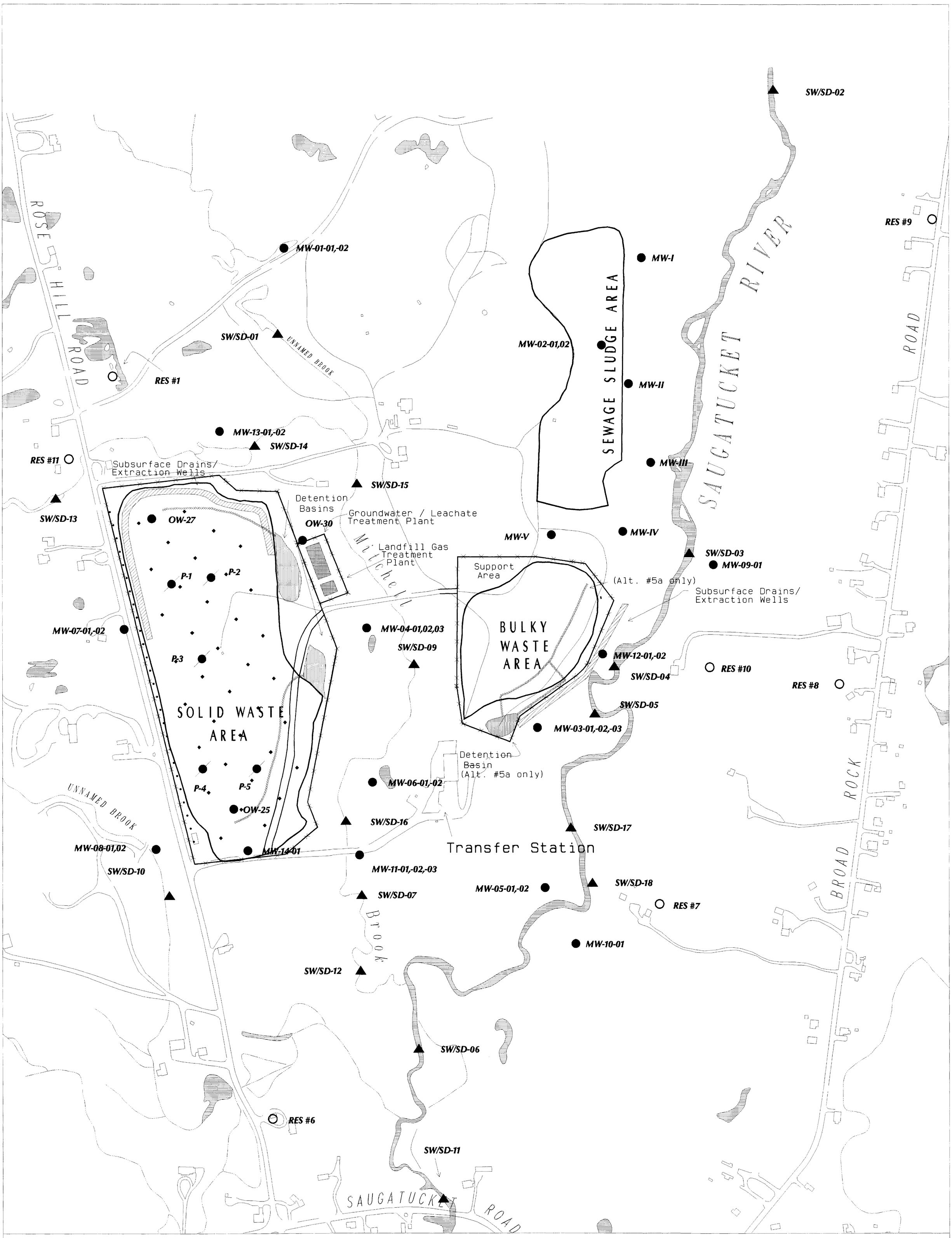


**FIGURE 4-8.
SCHEMATIC OF
ALTERNATIVE #4b COMPONENTS**



LEGEND

- Primary Road
- Secondary Road
- Stream or Brook
- Drainage Channel
- Fence
- Relative Location of Active Internal Gas Extraction Well
- Relative Location of Active Perimeter Gas Extraction Well
- Area to be Capped
- Lake, Pond, or River
- Surface Water/Sediment Sampling Location
- GW Monitoring Well Sampling Location
- Residential Well Sampling Location
- Piezometer

FIGURE 4-9. SITE LAYOUT - ALTERNATIVES #5a AND 5b

ROSE HILL REGIONAL LANDFILL SITE
SOUTH KINGSTOWN, RI

FIGURE 4-9.
SITE LAYOUT - ALTERNATIVE #5a AND 5b

ROSE HILL REGIONAL LANDFILL SITE
SOUTH KINGSTOWN, RI
METCALF & EDDY

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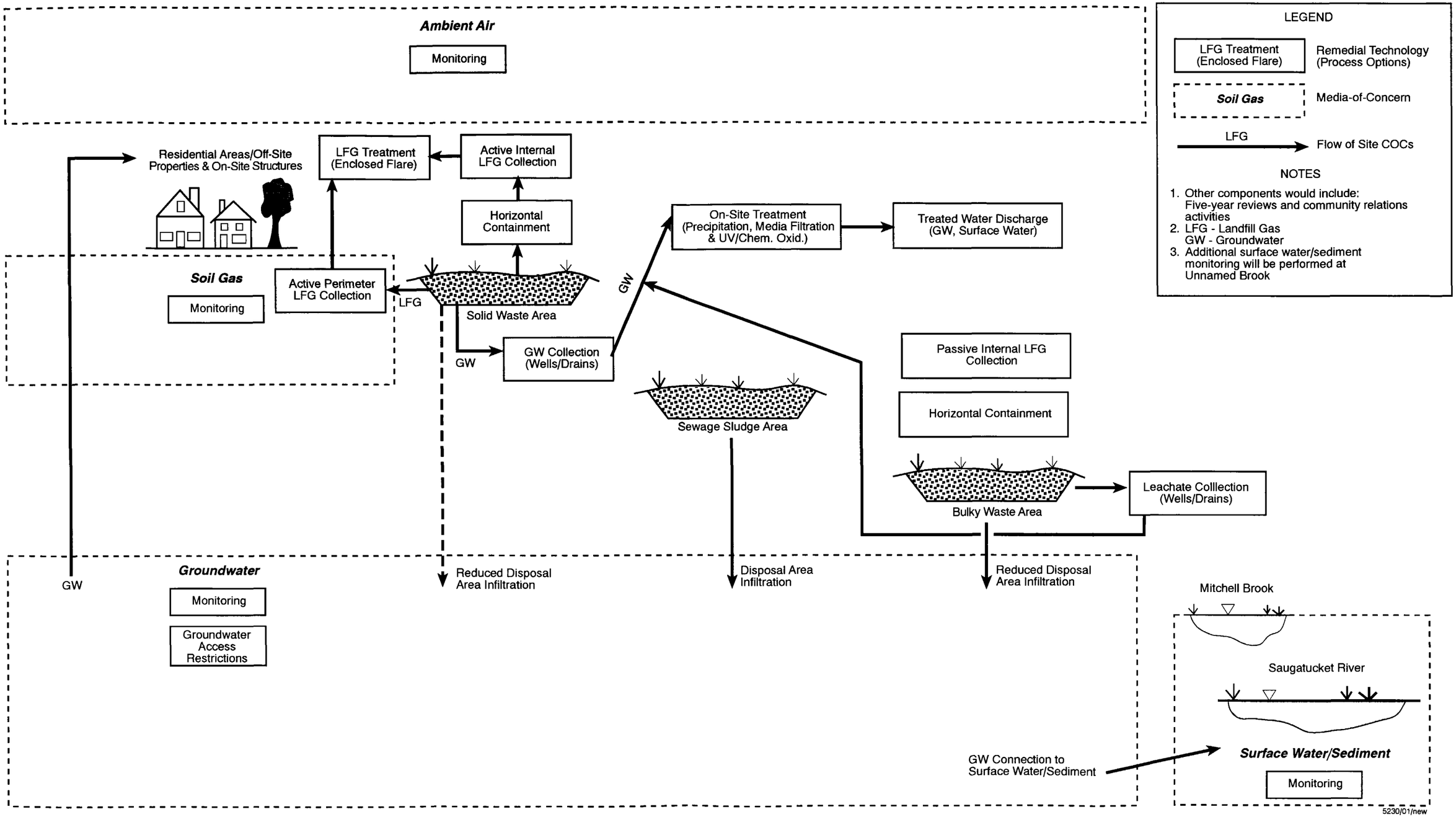

**FIGURE 4-10.
SCHEMATIC OF
ALTERNATIVE #5a COMPONENTS**

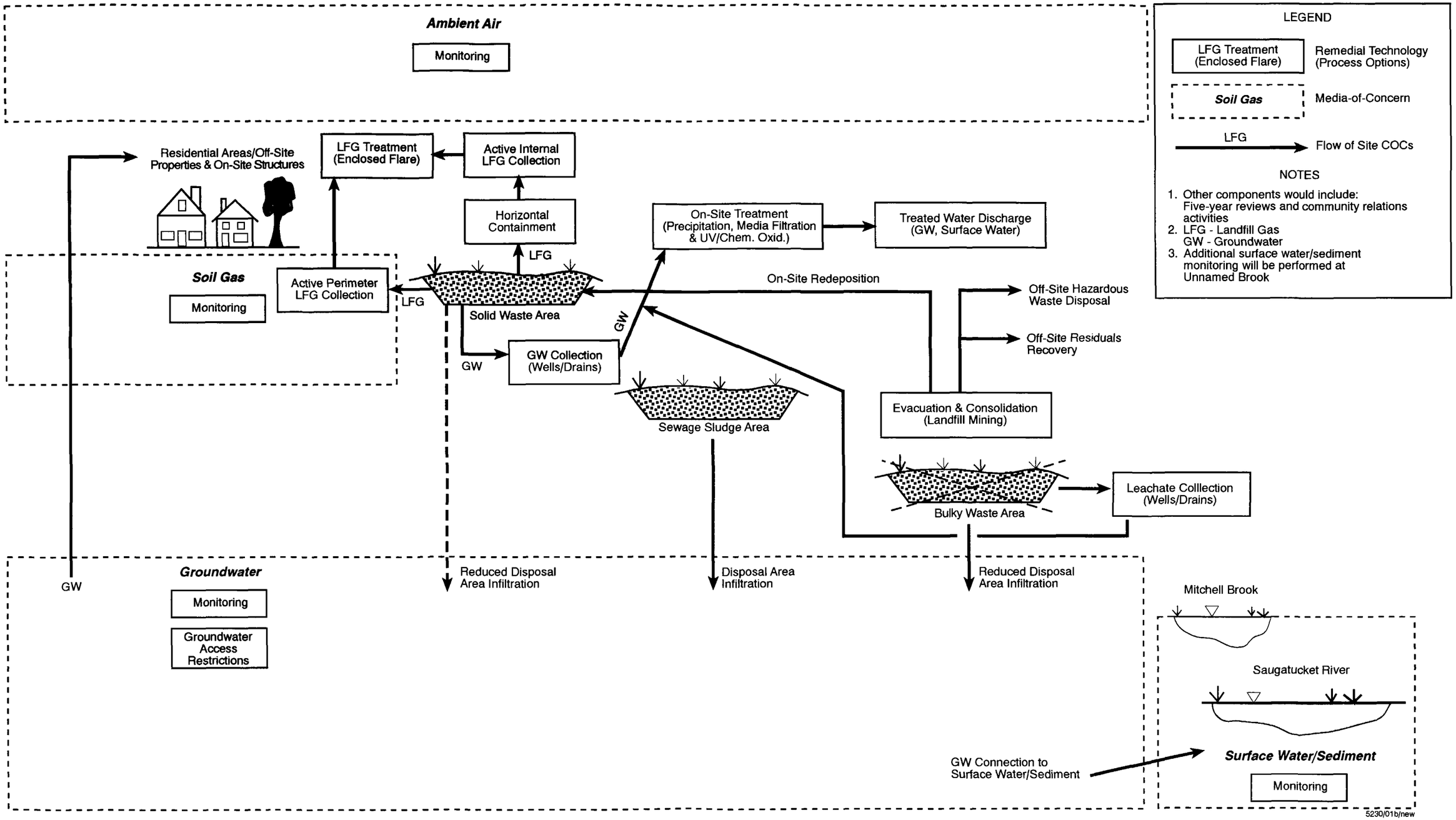

**FIGURE 4-11.
SCHEMATIC OF
ALTERNATIVE #5b COMPONENTS**

Rose Hill
#91 3/9

EPA Contract No. 68-W9-0042
EPA Work Assignment No. 007-RICO-01A5

EPA Deputy Project Officer: Diana King
EPA Remedial Project Manager: David Newton

FEASIBILITY STUDY
FINAL REPORT

VOLUME III of III
APPENDICES

Rose Hill Regional Landfill Superfund Site
South Kingstown, Rhode Island

November 1998

ROSE HILL REGIONAL LANDFILL SUPERFUND SITE
FINAL FEASIBILITY STUDY

VOLUME III OF III
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A-2 Responses to RIDEM Comments

A-1 Technology Screening Options TechnicalMemorandum (June 1997)

EPA Contract No. 68-W6-0042
EPA Work Assignment No. 007-RICO-01A5

EPA Project Officer: Diana King
EPA Remedial Project Manager: David Newton

TECHNOLOGY SCREENING OPTIONS TECHNICAL MEMORANDUM

Rose Hill Regional Landfill Superfund Site
South Kingstown, Rhode Island

June 1997

TECHNOLOGY SCREENING OPTIONS TECHNICAL MEMORANDUM
June 1997

1.0 INTRODUCTION

Metcalf & Eddy received Work Assignment No. 007-RICO-01A5 under EPA's Response Action Contract (RAC) to provide technical assistance in finalizing the Feasibility Study (FS) for the Rose Hill Regional Superfund Site in South Kingstown, Rhode Island. The first technical task of this work assignment has been undertaken in response to EPA's Statement of Work (SOW) dated February 10, 1997, and involved research (i.e. literature reviews and vendor contacts) and evaluation of three innovative technologies for their potential inclusion as part of one or more remedial alternatives in the Final FS report. The results of that research are reported in this technical memorandum.

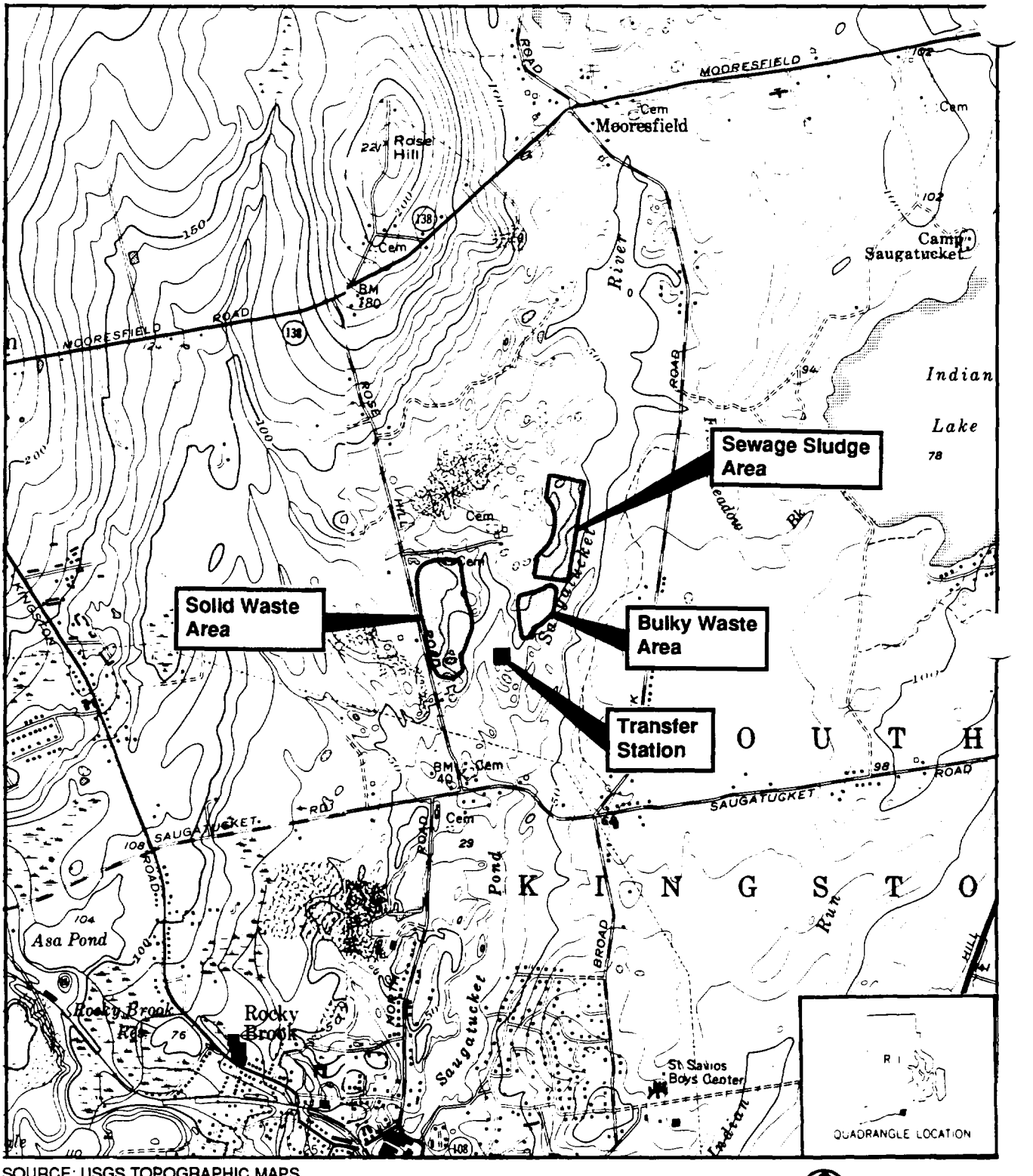
1.1 Project Background

The site history and M&E's previous activities at the Site under the EPA Alternate Remedial Contracting Strategy (ARCS) contract are briefly summarized in this section. In May, 1994 M&E completed the Remedial Investigation (RI) for the Site and submitted the Final RI report (M&E, 1994). In October 1996, M&E submitted the Draft Final FS report (M&E, 1996b), which updated the previous Draft FS report (M&E, 1993) based on direction and comments from EPA and the Rhode Island Department of Environmental Protection (RIDEM). During the comment period for the Draft Final FS report, RIDEM submitted comments requesting EPA to have three additional innovative technologies evaluated as part of the remedy selection process: photocatalytic oxidation and biofiltration for treatment of landfill gases collected from the Solid Waste Area, and landfill mining (source removal) for remediation of the Bulky Waste Area. As a result, M&E has conducted focused research on the technologies as described in Sections 2.0, 3.0, 4.0, and 5.0 of this memorandum.

The following sections briefly summarize site conditions and site history. The information is taken primarily from the Draft Final FS report (M&E, 1996b). A more comprehensive discussion of the site history, including previous studies and reports, and site characteristics can be found in the Final RI report (M&E, 1994) and the Draft Final FS report (M&E, 1996b).

1.2 Site Description and History

The Rose Hill Regional Landfill is located within the town of South Kingstown, Rhode Island, in the village of Peace Dale (Figure 1). It lies about 5 miles inland from Narragansett Bay and 2 miles north of Wakefield, Rhode Island. The Site is bordered by Rose Hill Road to the west, the Saugatucket River to the east, and residential private property to the north and south.



SOURCE: USGS TOPOGRAPHIC MAPS
KINGSTON, RI, 1970
NARRGANSETT PIER, RI, 1975

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FIGURE 1. LOCATION OF THE ROSE HILL REGIONAL LANDFILL SITE

METCALF & EDDY

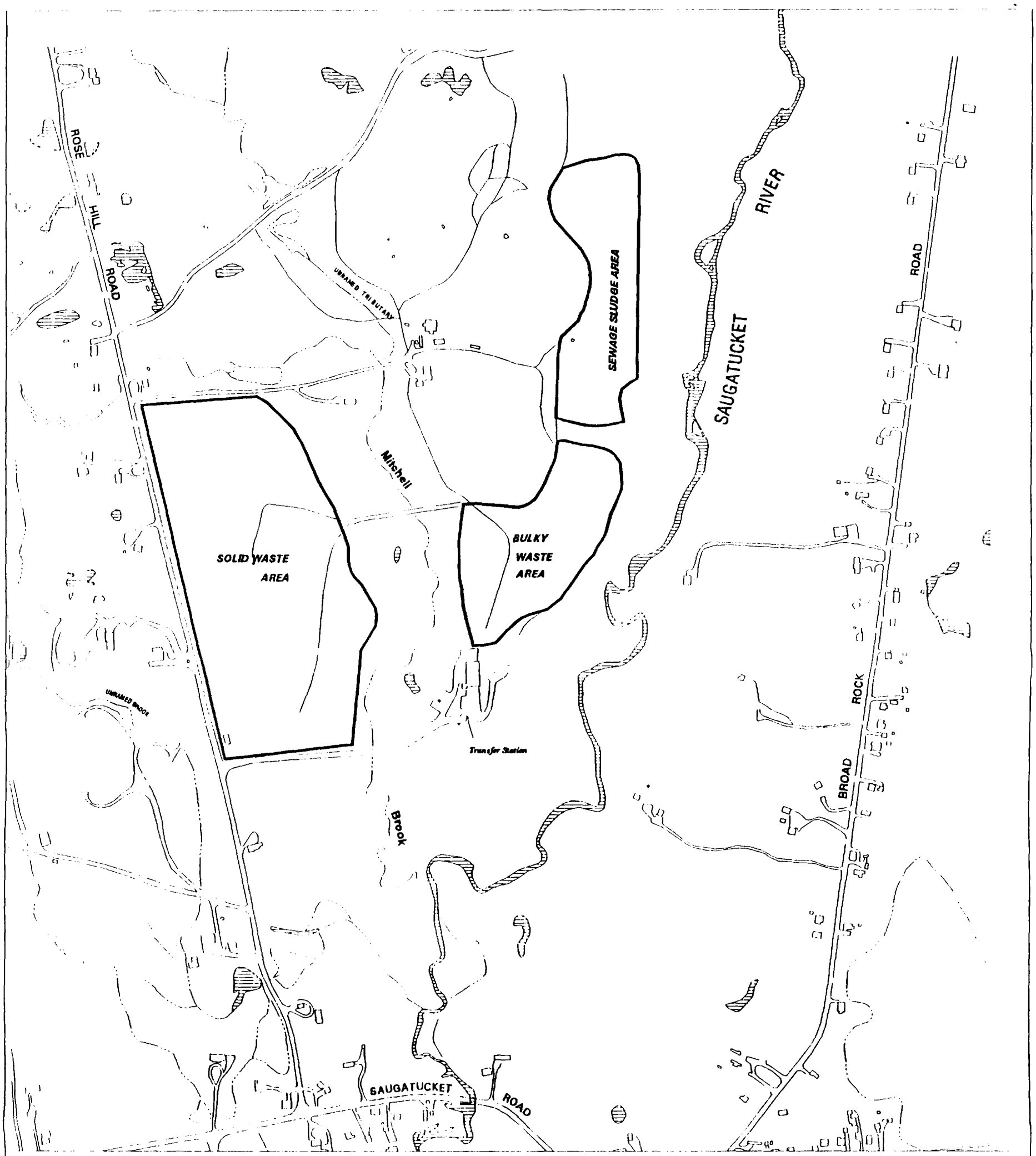
The Site includes an abandoned sand and gravel quarry that encompasses approximately 70 acres. As shown in Figure 2, the Site contains three separate and inactive disposal areas (landfills): a Solid Waste Area, a Bulky Waste Area, and a Sewage Sludge Area. An active transfer station, south of the disposal areas, is also located on the Site, south of the Bulky Waste Area.

Prior to 1941, the Site was used for agriculture. Sand and gravel excavation operations were conducted at the Site from at least 1948 through 1963. The Site began operation as a landfill in 1967 in the area previously used for sand and gravel excavation. The landfill was operated by the town of South Kingstown under state permit from RIDEM that was renewable annually. For approximately 16 years, it received domestic and industrial wastes from residents and industries in South Kingstown and Narragansett. The waste handling practices conducted at the landfill consisted of the disposal of municipal refuse and industrial refuse including the disposal of industrial wastes. The exact quantity and location(s) of hazardous substances disposed of at the Site throughout the landfill's operation are unknown. In October 1983, the landfill reached its state-permitted maximum capacity and active landfilling operations were ceased. During that year, a transfer station for municipal refuse was located south of the Bulky Waste Area. The transfer station is currently active. For the past 50 years, the landfill owner has conducted organized small game hunts involving birds and dogs at the Site.

1.3 Site Characteristics

Several geologic features that impact the movement of groundwater across the Site have been identified. The behavior of groundwater in the bedrock has been found to be influenced by bedrock topography, with recharge and discharge occurring at bedrock high and low areas, respectively. The predominant flow of groundwater in bedrock is to the southeast along regional fractures. The overburden groundwater flow is predominately to the south-southeast, and mounding of groundwater in the northwest corner of the Solid Waste Area is evident. Groundwater interactions between the Site and the Saugatucket River and Mitchell Brook are also evident. Weathered and fractured bedrock south and west of the Solid Waste Area appears to facilitate interconnection of the overburden and bedrock flow systems.

Significant ecological habitats within the Site include the Saugatucket River and Mitchell Brook, their associated tributaries and forested wetlands, and the adjacent forested and old field upland habitats.



LEGEND

- Primary Road
- Secondary Road
- Stream or Brook
- Disposal Area
- Lake, Pond, or River

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FIGURE 2.

ROSE HILL REGIONAL LANDFILL SITE

ROSE HILL REGIONAL LANDFILL SITE

SOUTH KINGSTOWN, RI

FSTUDY1.WAI (SEPT. 1996)

METCALF & EDDY

Organic compounds, primarily chlorinated and aromatic volatiles and ketones, and elevated metal concentrations have been detected across the Site in the media evaluated: surface and subsurface soil, groundwater, surface water, sediment, and soil gas. Refuse and landfill gas from the disposal areas, primarily the Solid Waste Area, were found to be the principal source contaminants in the different media. Elevated iron concentrations were found near leachate seeps, and elevated lead was found throughout the Site. The contaminants responsible for the majority of the human health and ecological risk at the Site include 1,2-dichloroethene, vinyl chloride, acrylamide, aluminum, antimony, arsenic, beryllium, cadmium, copper, lead, manganese, and zinc.

1.4 Project Objective

During the comment period for the Draft Final FS report (M&E, 1996b), RIDEM submitted comments requesting EPA to evaluate three additional innovative technologies as part of the remedy selection process: photocatalytic oxidation and biofiltration for treatment of landfill gases in the Solid Waste Area, and landfill mining (source removal) for the Bulky Waste Area. The objective of this task is to conduct focused research and preliminary evaluation of the three innovative technologies as they may be directly applicable to the Site. The technical approach to conducting this work consisted of: 1) gathering data to support the findings, including but not limited to vendor contacts, technical descriptions, cost estimates, and useful performance data as may be available, and 2) presenting these findings in a technical memorandum for EPA and RIDEM use for consideration of these technologies for potential further development and/or inclusion in one or more remedial alternatives presented in a future FS. The goal of this work was to broaden the technology information base so as to support the selection of an approach for site remediation and then to use this data to develop a well-supported ROD. Landfill mining for the Bulky Waste Area was previously reviewed in a technical brief prepared by M&E (M&E, 1996b). This memorandum investigates the technology further based on more recent information. Reviews of photocatalytic oxidation, biofiltration, and landfill mining are presented in Sections 2.0, 3.0, and 5.0, respectively. Section 4.0 includes a brief discussion of a fourth approach to reducing projected operation and maintenance (O&M) costs for treatment of landfill gas -- an alternative flare design to that included in the Draft Final FS report. Section 6.0 presents recommendations as to which technologies should be incorporated into the Final FS report. References and supporting calculations and documentation are included in Section 7.0 and the attachments, respectively.

2.0 PHOTOCATALYTIC OXIDATION

Photocatalytic oxidation is an innovative treatment technology that removes and destroys organic contaminants in gaseous or aqueous streams using a fixed bed catalyst activated by ultraviolet (UV) light. Since the application of this technology at the Rose Hill Site is for treatment of landfill gas, this discussion is confined to applications of the technology to gaseous streams. Several variations of the technology for treatment of contaminated air streams have been demonstrated as part of EPA's SITE (Superfund Innovative Technology Evaluation) Program (U.S. EPA, 1994).

2.1 General Process Description

In general terms, the contaminated air stream is fed into a reactor containing a solid catalyst material that is illuminated by UV light. Organic contaminants in the air may adsorb to the solid material and may also absorb UV light; such absorption may cause the contaminant to decompose or become more susceptible to oxidation. The primary purpose of the UV light, however, is to activate the catalyst by exciting electrons on the catalyst surface, freeing them to react with adsorbed organic contaminants. Free electrons, or free radicals such as the hydroxyl radical (•OH) or the chlorine free radical (•Cl), are formed. These radicals initiate a series of chain oxidation reactions that ultimately result in the complete destruction of an organic contaminant into carbon dioxide, hydrogen chloride, and chlorine gas (Nimlos et al., 1995). The hydrogen chloride and chlorine gas can be removed, if necessary, by a caustic scrubber before the treated gas is exhausted to the atmosphere. Research has shown that organic products of incomplete oxidation are also formed, but these products can themselves be oxidized given sufficient residence time in the reactor (Nimlos et al., 1995). In a variation of the technology developed by Process Technologies, Inc., it is claimed that the formation of harmful intermediate oxidation products, hydrogen chloride, and chlorine gas is inhibited by the solid material in the reactor (U.S. EPA, 1994).

2.2 Technology Applications

The primary application of the technology with respect to site remediation is for treatment of off-gases from air strippers and soil vapor extraction systems to remove volatile organic compounds (VOCs). The technology is being developed and marketed as an alternative to activated carbon adsorption and catalytic or thermal oxidation for destruction of VOCs in these contaminated air streams. Advantages of the technology over carbon adsorption, catalytic oxidation, and thermal oxidation that are cited by the technology developers include: the ability to destroy VOCs at ambient temperature, eliminating the need for auxiliary fuel; no production of undesirable nitrogen oxides (as occurs during high temperature oxidation); and minimal generation of secondary wastes requiring regeneration or disposal (as occurs for carbon treatment systems). Other applications of the technology include treatment of various industrial emissions sources, such as paint spray booths (BTEX compounds), bakeries and breweries (ethanol), the polystyrene industry (pentane), and contact lens manufacturing (hexane) (Nimlos et al., 1995; Kittrell et al., 1996a and b; Matrix Photocatalytic, Inc., 1997).

Three developers of photocatalytic oxidation technologies were contacted for general information on their processes as well as to discuss the specific application of their technologies for treatment of landfill gas. None of the technologies are currently developed for destruction of methane, but they have been demonstrated for destruction of other VOCs of concern at the Rose Hill site. One developer (KSE, Inc.) is currently constructing a prototype unit for NASA that is intended for the oxidation of methane. However, given the early stage of development of the prototype, it is not possible to evaluate the effectiveness, implementability, and cost of this technology for methane destruction. Hence, photocatalytic oxidation will be screened with respect to its ability to destroy VOCs of concern, in particular vinyl chloride. To provide complete treatment of

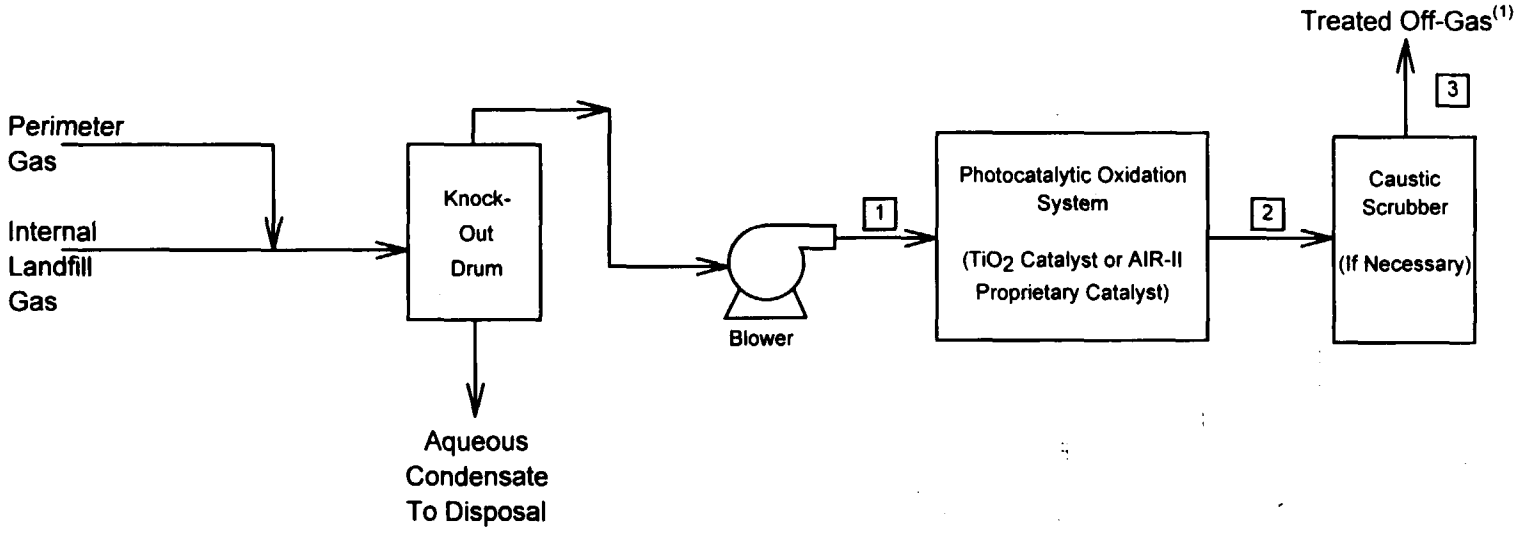
landfill gas, photocatalytic oxidation will need to be coupled with a system for destruction/removal of methane (e.g., a flare or other thermal destruction technology) (RIDEM, 1996).

Specific Technology Descriptions. Two technologies, the Matrix Photocatalytic system and the KSE AIR-II system, are described by their developers as "photocatalytic oxidation" systems and are similar in concept. The technology developed by Process Technologies, Inc. (PTI) is called a "photolytic" system as opposed to a "photocatalytic" system, and is sufficiently different from the other two systems that a separate description and flow diagram are presented.

Photocatalytic Systems. The Matrix Photocatalytic system and the KSE AIR-II system are illustrated jointly in Figure 3. A system for collection of both perimeter and internal landfill gas is installed, and the combined gas streams are collected and drawn into the photocatalytic system by a blower (or blowers). The perimeter gas and internal landfill gas would pass through a knock-out drum to remove entrained water droplets before entering the photocatalytic reactor. The primary difference between the two systems is the catalyst material used. The Matrix Photocatalytic system uses titanium dioxide (TiO_2) as the catalyst. For certain applications, the Matrix Photocatalytic system also adds a small amount of ozone gas to the gas stream to be treated. The purpose of the ozone is to create more free radicals within the reactor, thereby enhancing contaminant destruction.

The KSE AIR-II system uses a proprietary catalyst that adsorbs the VOCs of concern where they are then oxidized by the combined action of the UV light and the catalyst. The developer claims that this catalyst has a higher activity, stability, and selectivity than the competing TiO_2 catalyst, resulting in lower capital and operating costs.

The oxidation of the halogenated organic compounds present in the landfill gas, such as vinyl chloride, will result in the production of hydrogen chloride (HCl) and chlorine gas (Cl_2). According to KSE, Inc., for their system a gas stream containing 150 ppmv of vinyl chloride would typically yield 70 ppmv of chlorine gas and 10 ppmv of hydrogen chloride. The exhaust from the photocatalytic reactor would be treated by scrubbing with caustic to remove these gases. Removal of these gases is necessary to protect downstream equipment from corrosion.



	Flow (cfm)	CH_4 (%)	Vinyl Chloride(2) (ppbv)	HCl(3) (ppbv)	Cl_2(3) (ppbv)
1	890	6.2	148,571	0	0
2	890	6.2	7,429	9,409	65,866
3	890	6.2	7,429	470	3,293

Notes:

(1) Treated off-gas is sent to methane destruction/removal system.

(2) Assumed worst-case of 95% destruction removal efficiency (DRE) in the photocatalytic oxidation system

(3) a. Oxidation of 150 ppmv vinyl chloride yields approximately 70 ppmv Cl_2 and 10 ppmv HCl (vendor communication- KSE, 1997)

b. Assumed 95% removal of HCl and Cl_2 in caustic scrubber

FIGURE 3. PHOTOCATALYTIC OXIDATION PROCESS FLOW DIAGRAM

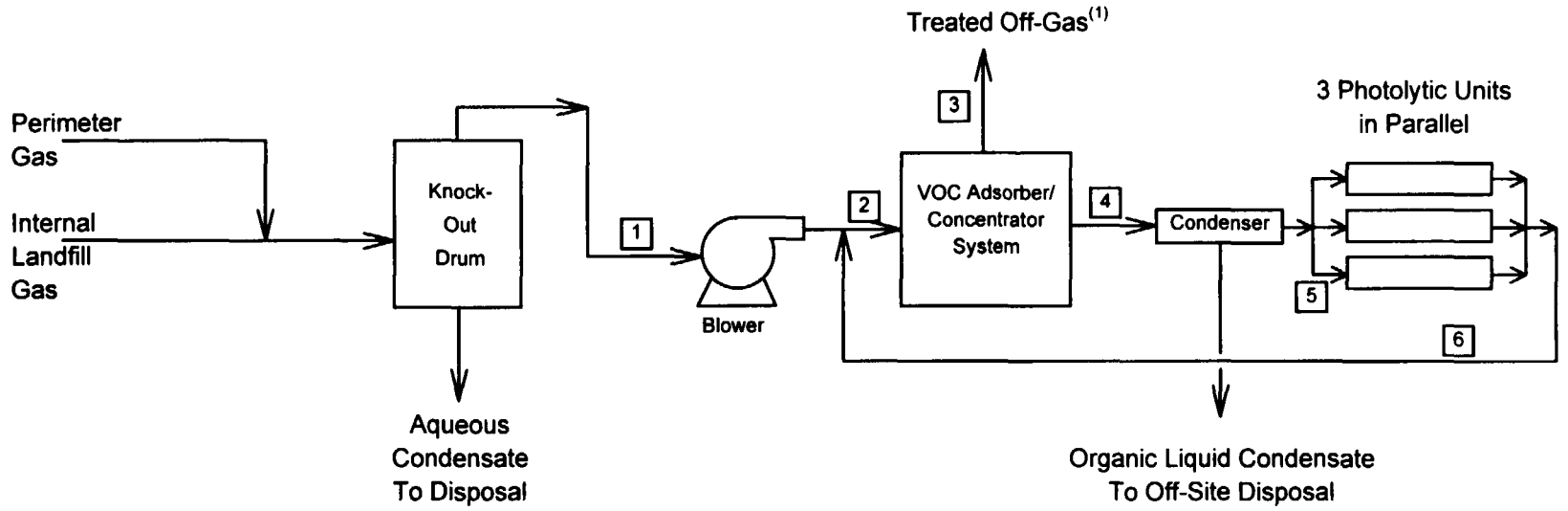
Finally, it may be necessary to remove and/or destroy methane remaining in the gas before discharge to the atmosphere. Methane will pass essentially unchanged through the photocatalytic reactor and the caustic scrubber. A methane destruction/removal system is therefore included after the caustic scrubber. The specific system to be used would need to be defined during detailed evaluation of the photocatalytic oxidation alternative, should it be retained for further analysis.

Photolytic System. The photolytic system of PTI, Inc. is illustrated schematically in Figure 4. The PTI system differs from the photocatalytic systems in two respects: (1) the influent gas stream is concentrated to reduce the flow rate and increase contaminant concentrations before treatment and (2) the solid material within the photolytic units is technically not a catalyst, in that the material (a proprietary cementitious liner material) is a consumable that has to be replaced. However, catalysts also require replacement at intervals due to deactivation over time, and the difference between "photocatalytic" and "photolytic" is more one of reaction mechanism and semantics rather than a significant process difference.

The adsorber/concentrator, supplied by PTI as part of their overall system, works by adsorbing organic contaminants on an adsorbent material (i.e. carbon), and then desorbing them using a much smaller gas flow rate. After treatment in the adsorber/concentrator, the bulk of the landfill gas (approximately 90% of the influent flow) is sent to a system for the removal/destruction of methane, since methane is not adsorbed in the adsorber/concentrator. The concentrated gas stream containing desorbed organic contaminants (approximately 10% of the total influent flow) is routed to a condenser. The condenser removes some of the concentrated organic contaminants as a liquid. This liquid would need to be disposed of offsite. The combination of the adsorber/concentrator and the condenser is not mandatory, but it generally results in a lower lifecycle cost than photolytically treating the dilute gas stream directly, because it reduces the number/size of photolytic units needed and increases their efficiency. After treatment in the photolytic units to destroy the organic contaminants that are not condensed, the gas is recycled to the adsorber/concentrator.

2.3 Applicability of Photocatalytic or Photolytic Oxidation Processes to Rose Hill Regional Landfill

Presented below is a discussion of the technology's effectiveness, implementability and associated costs as they apply to the Site.



	Flow (cfm)	CH_4 (%)	Vinyl Chloride(2) (ppbv)	Chloride(3) (ppbv)
1	890	6.2	148,571	0
2	899	6.2	147,228	72,952
3	890	6.2	2,945	72,952
4	9	6.2	14,428,352	72,952
5	9	6.2	14,428,352	72,952
6	9	6.2	14,428	7,287,128

Notes:

(1) Treated off-gas is sent to methane destruction/removal system.

(2) Assumed 99.9% destruction removal efficiency (DRE) in the photolytic oxidation system; 98% removal efficiency and 99% concentration of vinyl chloride in the adsorber/concentrator system (vendor communication-PTI, 1997a); no condensation of vinyl chloride

(3) 50% of chloride moles are captured in photolytic system, leaving 50% to exit in the treated off-gas or to be scrubbed (vendor communication-PTI, 1997b)

FIGURE 4. PHOTOLYTIC OXIDATION PROCESS FLOW DIAGRAM

Effectiveness. Photocatalytic or photolytic oxidation processes are effective for the destruction of organic contaminants of concern, particularly vinyl chloride, in gas streams generated from air strippers, soil vapor extraction systems, and industrial process vents. The processes have not been demonstrated on landfill gas, however. A demonstration test at the Site would be needed to develop specific design parameters and identify any potential problems unique to treatment of landfill gas. The processes have not been developed for the destruction of methane. The stability of the methane molecule, and the absence of a double bond or halogen atoms, makes it a difficult candidate for ambient-temperature oxidation methods that are dependent upon free radical attack. One developer (KSE, Inc.) is building a prototype for NASA that is intended to destroy methane, but data are not yet available to determine whether it will be effective. An effective alternative that includes photocatalytic or photolytic oxidation will also need to include a separate system for the destruction/removal of methane, if it is determined that methane destruction/removal is necessary to attain ARARs (RIDEM, 1996). This determination will be made when this alternative is further evaluated as part of the FS.

Implementability. A number of suppliers are available to provide a system that will destroy vinyl chloride and other contaminants of concern in the landfill gas. Since the suppliers do not have previous experience with treating landfill gas, there may be implementation problems that are not readily apparent now that may be revealed during demonstration testing. If a methane destruction/removal system is not included, for safety reasons the discharge from the photocatalytic system will need to be diluted with excess air to reduce the methane concentration in the discharge to less than 25% of the Lower Explosive Limit. The photocatalytic oxidation system itself will need to be explosion proof.

Cost. Order-of-magnitude cost estimates for treatment of landfill gas at the Site were obtained from three developers. The gas flow rates and compositions upon which the estimates were based, correspondence with the developers, and a summary of their estimates are provided in Attachment A. The costs include capital and operating costs for the oxidation systems only. Costs for other system components, such as the methane destruction/removal system and the caustic scrubber, are not included. Costs for the perimeter and internal landfill gas collection systems are also not included.

The capital cost estimates ranged from $75,000 to $350,000 and the operation and maintenance costs ranged from $10,800 to $54,000 per year. These are order-of-magnitude costs that are subject to a large degree of uncertainty, particularly because none of the systems have been tested on landfill gas to date. Demonstration testing would be needed to obtain actual costs.

3.0 BIOFILTRATION

Biofiltration is an innovative treatment technology that utilizes microorganisms to remove and destroy organic contaminants in gaseous or aqueous streams. Since the application of this technology at the Rose Hill Site is for treatment of perimeter and internal landfill gas, this discussion is confined to applications of the technology to gaseous streams.

3.1 General Process Description

Biofiltration is a simple biological process in which naturally-occurring microorganisms, including bacteria, fungi and actinomycetes, are used to oxidize VOCs into carbon dioxide, water and salts by harnessing the metabolic ability of the microbes to biodegrade these compounds. This can be accomplished by controlling the living conditions (i.e., oxygen supply, humidity, temperature range, and pH) of the microorganisms.

Biofiltration typically occurs in a biofilter (Figure 5) which consists of a packed bed in which microorganisms grow. The microorganisms are immobilized within biofilms attached to the packing material. The gases to be treated (perimeter and internal landfill gases) are collected, humidified if necessary, and forced to rise through the packed bed, where they come into contact with the biofilm on the packing material and with biomass particles trapped in the void spaces within the packing material. The packing material used in the biofilter may consist of soil, compost, peat, or heather, which may be supplemented with bark, wood chips or synthetic materials such as polystyrene to provide bulking and structural stability (Corsi and Seed, 1995; Vembu and Walker, 1995).

Adsorption and oxidation of the VOCs present in the influent landfill gas occur simultaneously within the biofilter. Upon contact with the microorganisms, the organic contaminants are absorbed and biodegraded by the microbes which use the VOCs for food (substrate). Adsorption by the packing material also occurs in those areas of the filter which are not yet covered by the biofilm. This sorbed substrate is continually oxidized by the microbes as their biomass increases. Some contaminants which are not easily biodegraded may be captured by adsorption within the filter bed or may be released unchanged with the gas exiting the biofilter.

3.2 Technology Applications

Biofiltration has been used and is being used at many industrial facilities in Europe, and has more recently come into use in the United States. The most common applications within the United States have been at wastewater treatment plants for the removal of odors and hydrogen sulfide, and at industrial facilities to reduce/remove VOCs and odors from process gas streams. Review of available literature and conversations with biofilter vendors did not indicate that much work has been done using biofiltration to remove chlorinated compounds from gas streams, especially compounds which contain more than two chlorine atoms.

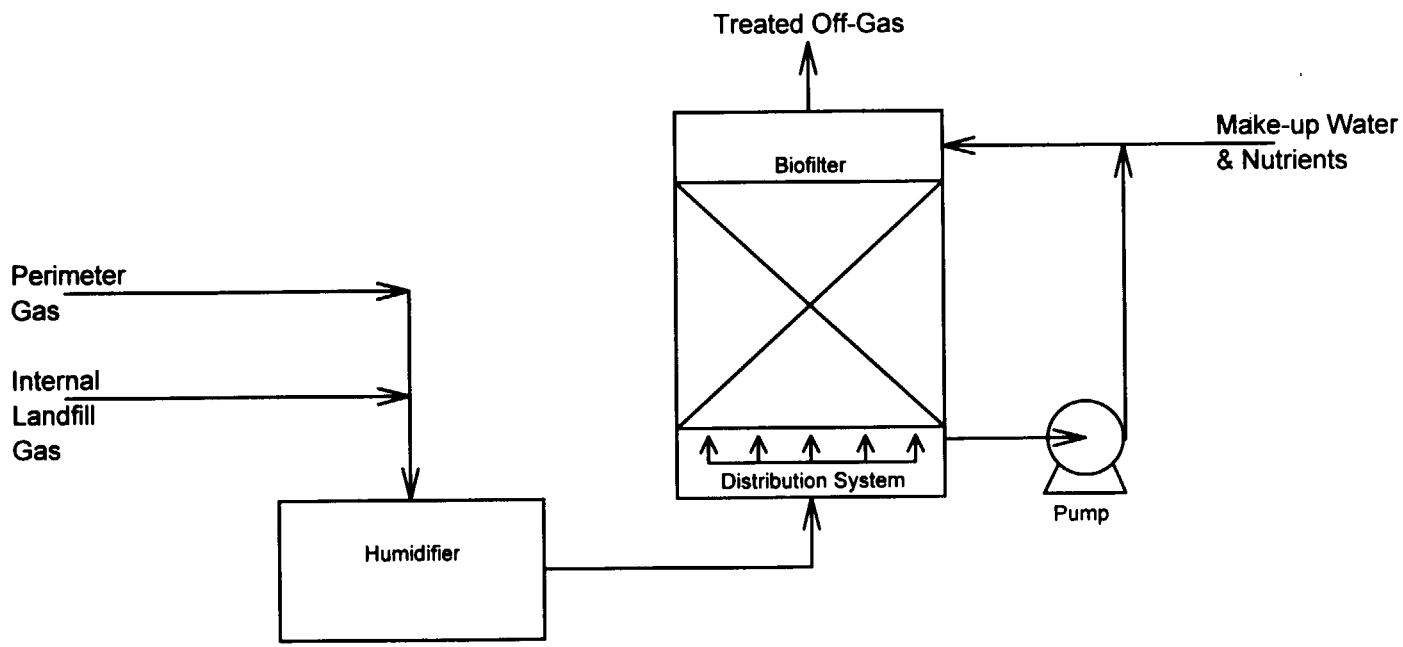


FIGURE 5. BIOFILTRATION PROCESS FLOW DIAGRAM

Biofiltration has been used more widely to treat streams containing alcohols, aldehydes, ketones, carboxylic acids and esters, furans, organic sulfides and polysulfides, styrene, BTEX, hydrogen sulfide, mercaptans, and basic nitrogen compounds (Werner et al., 1986). Biofiltration has also been more effective in applications with low-concentration, quick-degrading contaminants.

Industries noted by vendors as making use of the technology to control odors and organic contaminants in process gas streams include the petroleum industry, chemical processing, wood and paper processing, printing, flavor and fragrance manufacturing, and corn processing. Other applications include tank filling operations and treatment of off-gases from sewage treatment and soil vapor extraction remediation systems. Compounds reportedly treated in these applications include alcohols, BTEX, ketones, hydrogen sulfide, carbon disulfide, organic acids, mercaptans, phenols, and other VOCs.

Experience with the treatment of halogenated VOCs using biofiltration is more limited. One author reported that "at high raw gas concentrations, less than 40% removal is achieved for halogenated compounds" (Werner et al., 1986). Webster et al. (1996) reported on bench- and pilot-scale studies of biofiltration for treatment of off-gases from the headworks of a publicly owned treatment works. Different packing materials and retention times were tested. Removal efficiencies ranged from 53 to 98% for aromatic compounds, 43 to 96% for aldehydes and ketones, and 0 to 98% for chlorinated compounds. Generally, the more soluble chlorinated compounds were removed more effectively. Removal efficiencies for vinyl chloride ranged from 0 to 56%.

3.3 Applicability of Biofiltration to Rose Hill Regional Landfill

Although biofiltration is a proven technology for use in certain applications, the anticipated landfill gas waste stream at the Rose Hill Site contains specific contaminants which are not readily removed by existing biofiltration systems. Based upon review of available literature and conversations with biofiltration vendors (Matrix Environmental Technologies, 1997; Biodigester Technologies, 1997; PPC Biofilter, 1997; RETEC, 1997; Monsanto Enviro-Chem Systems, Inc., 1997), the applicability of biofiltration to the landfill gas waste stream is presented below.

Effectiveness. Volatile organic contaminants that have been detected in the landfill gas can be categorized as follows: aromatic compounds (benzene, toluene, ethylbenzene, xylenes, trimethylbenzenes), ketones (4-methyl-2-pentanone, acetone), sulfur compounds (carbon disulfide), and halogenated organics (e.g. vinyl chloride, trichloroethylene). Biofiltration is generally effective for removal of aromatic compounds, ketones, and sulfur compounds, but effectiveness is limited for halogenated organic compounds such as vinyl chloride. The literature indicates that removal efficiencies on the order of 50% are attainable for vinyl chloride, but a much higher removal efficiency (at least 95%) will be needed to attain the Preliminary Remediation Goal (PRG) for vinyl chloride.

Due to the high concentrations of chlorinated compounds present in the landfill gas, a long retention time (and therefore a large biofilter) would be needed to attain even moderate

removal/destruction of these compounds. Vendors were also concerned that at these concentrations, the chlorinated compounds might be toxic to the microorganisms. Acidification (i.e. hydrochloric acid formation) would be expected, and since the optimal pH range for effective biofiltration is the neutral range (6-8 pH units), it would be necessary to constantly buffer the filter bed or change the media, thereby increasing O&M costs. Corrosion of the biofilter housing may result and scrubbing or other post treatment of the exit gas stream may be required.

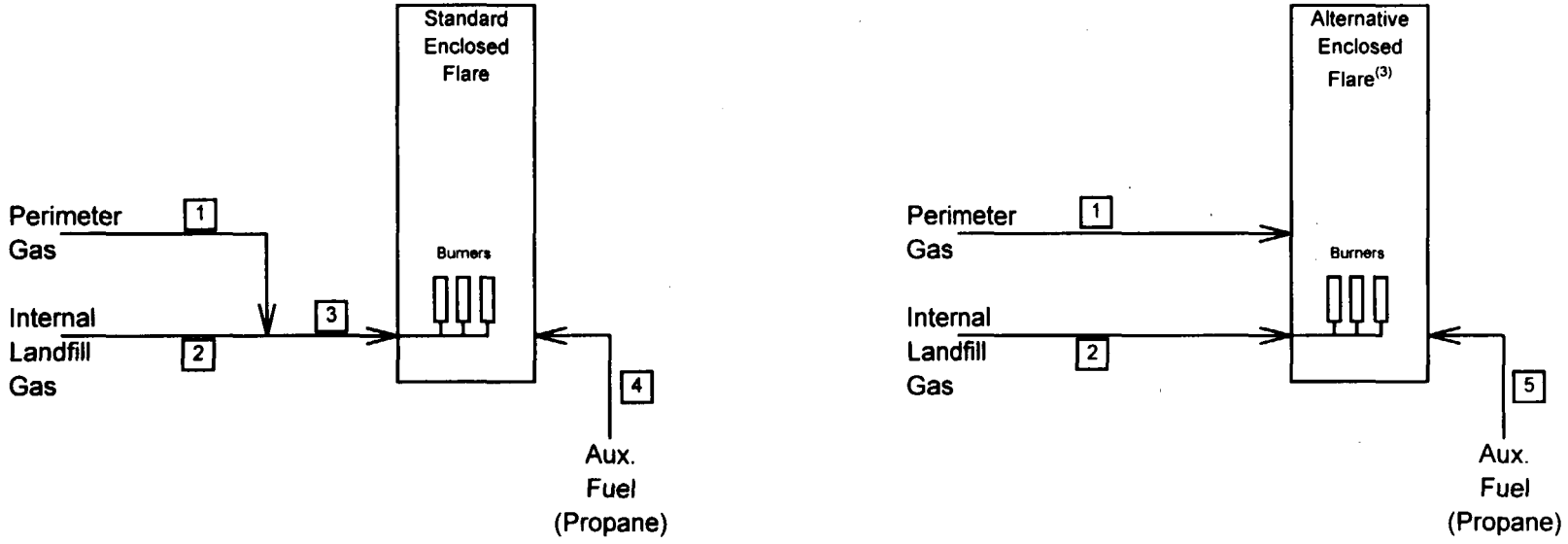
Existing biofiltration systems will not remove compounds such as methane. The methane component of the landfill gas stream is at a concentration which will most likely require reduction prior to discharge. Therefore, an additional treatment technology would be required to specifically remove or destroy methane, if such removal/destruction is determined to be necesssary.

Implementability. The biofiltration technology is well developed and there are a number of vendors available who could supply a system and also provide pilot testing services and assistance with start up and O&M. However, because the technology has not been developed for treatment of chlorinated VOCs or landfill gas in particular, vendors expressed some reluctance to recommend further investigation of the technology. Out of five vendors contacted, two immediately stated that biofiltration would not be a good option for treatment of the landfill gas, and recommended that thermal treatment options be explored. All five vendors agreed that the composition of the gas stream is complex and may require more than a simple biofilter for treatment. Three of the five vendors suggested that a pilot study would be necessary to determine the feasibility of treating this stream using a biofilter, and expressed doubt that the main compounds of concern could be removed to the degree necessary to attain PRGs. Even if a pilot study were conducted that demonstrated sufficient effectiveness, it could still be difficult to obtain a performance guarantee for a biofiltration system since the technology is not normally applied to landfill gas treatment.

Cost. No costs were developed, because it is recommended that the biofiltration technology be eliminated at the technology screening stage due to ineffectiveness for both the primary contaminants of concern (halogenated VOCs) and methane.

4.0 ALTERNATIVE FLARE DESIGN

In response to a request for review of landfill gas treatment options which could reduce projected operation and maintenance costs at the Site, M&E briefly discussed options with a flare vendor (John Zink Company, 1997). In the time that has passed since the Draft Final FS report was prepared, improved alternative flares have been designed to handle landfill gas systems which include diluted perimeter gas. According to the vendor, a system such as this would increase capital costs (+$20,000), but would greatly reduce the need for supplemental fuel for a system that is treating perimeter landfill gas, thereby reducing O&M costs by approximately $350,000 per year. Figure 6 presents schematics of both standard and alternative flare design systems.



	Flow(1) (cfm)	CH_4(1) (%)
1	811	2
2	77	50
3	888	6
4	75	--
5	25(2)	--

Notes:

(1) All flows and methane percentages taken from the Draft Final FS report, October 1996 except the propane flow for the alternative flare.

(2) Preliminary estimate based on methane concentration (50%) of internal landfill gas feed stream. Vendor communication indicated that the alternative flare design would use approximately 1/3 of the auxiliary fuel required for the standard flare (John Zink Company, 1997).

(2) The size of the alternative flare and associated appurtenances will be designed to provide destruction removal efficiencies similar to those associated with the standard flare.

FIGURE 6. COMPARISON OF STANDARD AND ALTERNATIVE FLARE DESIGNS

Due to the potential need for methane destruction or removal in addition to VOC removal, an alternative flare design appears to be a solution which would reduce landfill gas treatment O&M costs as well as achieve all PRGs. Further review of this technology would be required during the next phase of the FS.

5.0 LANDFILL MINING

Landfill mining, also known as landfill reclamation or landfill remodeling, is a landfill management technology that employs conventional surface mining techniques to excavate and sort buried waste material. This process can reduce the size of or eliminate old landfills, extend the life of operating facilities, and recover recyclables (Nelson, 1994). The application of this technology at the Rose Hill Site is to mine the Bulky Waste Area to remove and recycle soils and scrap metal, and re-dispose of non-recyclable wastes at the Solid Waste Area. The ultimate objective is to defray the projected costs associated with capping and on-going monitoring of the Bulky Waste Area by removing the waste, so that a cap and long-term monitoring will not be necessary.

5.1 General Process Description

There are a number of objectives that can be met by landfill mining, including: reclamation of land for reuse, extension of the life of an active landfill by creating additional space, deferral of landfill closure and monitoring costs, reduction of closure costs by reducing the size of the landfill, recovery of daily cover soil for reuse, recovery of waste that can be burned as fuel, and recovery of recyclable materials (e.g. steel, aluminum, and plastic) (Cobb and Ruckstuhl, 1988; Dickinson, 1995). Objectives that are applicable to the Bulky Waste Area are reduction of capping costs, potential recovery of soil, and potential recovery of recyclable materials. General advantages and disadvantages of landfill mining are presented in Table 1.

The equipment used for landfill mining is site-specific but in general it consists of backhoes or excavators, dump trucks, and various screening equipment. An example of a processing system used at the Collier County, Florida Landfill is presented in Figure 7. Initially the waste is sorted through a large grizzly screen with 6-inch spacing to screen out the larger waste materials. The waste is further classified using a trommel screen. Further screening is used as necessary to attain a higher level of size segregation. Magnetic drums may be used to help separate recyclable metals (i.e. ferrous metals).

5.2 Technology Applications

Landfill mining has been in use since 1986 in at least five states: Florida, Pennsylvania, New York, Connecticut, and Massachusetts. Projects are also ongoing in Ontario, Canada and a project is in the permitting stage in Vermont. Representative on-going or planned projects are summarized in Table 2. Three representative projects (Lancaster County, PA; Collier County, FL; and Newbury, MA) are discussed in more detail below.

Table 1. General Landfill Mining Advantages and Disadvantages

ADVANTAGES	DISADVANTAGES
• Extend the life of the landfill by increasing the amount of available space through development of a lined landfill in the displaced area	• Not all landfills are suitable for mining implementation.
• Reduce the closure costs by reducing the area of the landfill.	• Excavation may unearth hazardous materials which could incur expensive disposal costs.
• Transfer of waste from unlined landfill to a lined landfill may reduce future liability.	• Subsoil and groundwater contamination may limit the possibilities for land reuse or require remediation.
• Reclaimed land may be converted to other uses such as municipal recreational parks.	• Odors and landfill gases could be emitted to the atmosphere and affect the surrounding community.
• Mined waste could potentially be used as a fuel supply for waste-to-energy plants to produce electricity.	• Presence of high water table or submerged refuse may negatively effect economics and technical feasibility of implementation.
• Recovered soil may be used as landfill cover material, capping soil or, if suitable, for off-site fill.	• Difficult working conditions associated with excavating a landfill.
• Revenue may be generated from sale of recyclable materials such as ferrous and non-ferrous metals.	• Possibility of contaminant release due to excavation process.

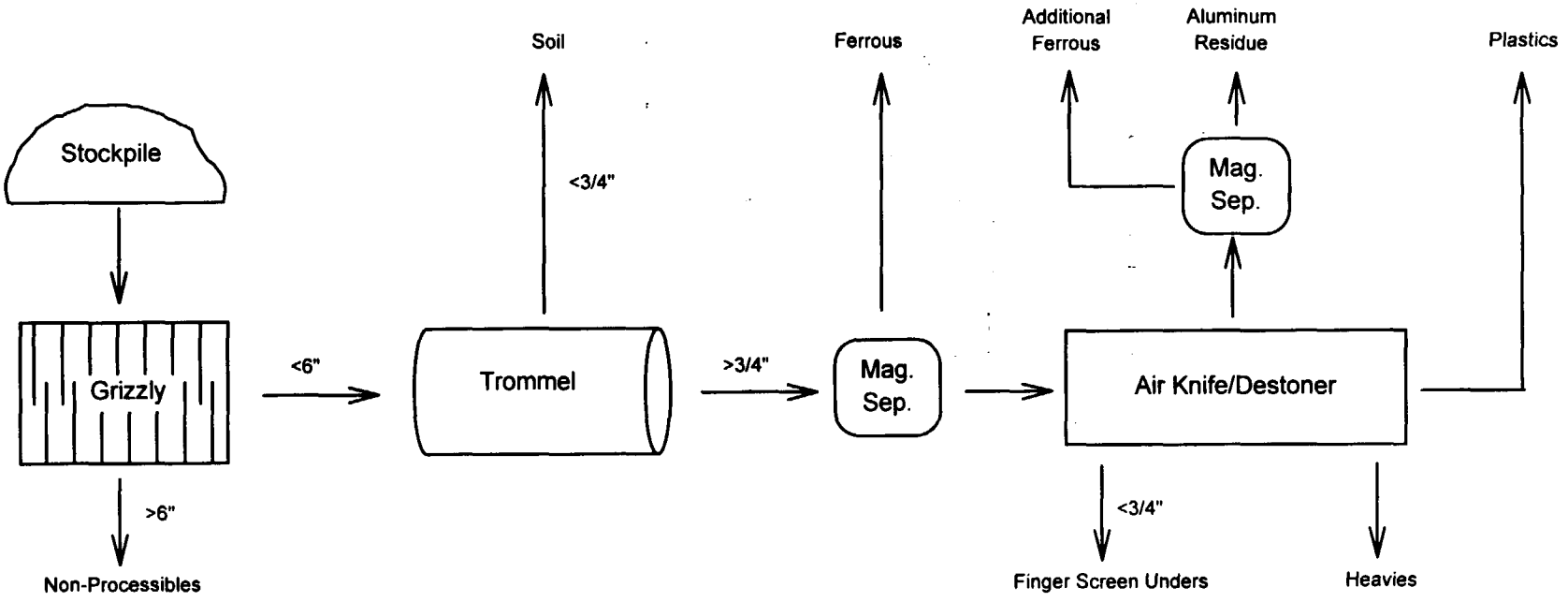


FIGURE 7. SCHEMATIC OF PROCESSING SYSTEM USED IN THE COLLIER COUNTY, FLORIDA LANDFILL MINING DEMONSTRATION PROJECT (Source: Dickinson, 1995)

Table 2. Representative Landfill Mining Projects

Project	Start	Finish	Size (acres)	Comments	Notes
Collier County, Florida: Naples Landfill	April 1986	Assumed ongoing	28	Main objectives are soil recovery and reclamation of landfill capacity. Have mined 10 acres in 9 years. Initially burned plastics and sold metal, but this is now economically infeasible.	2, 3, 4, 5
Lancaster County, PA: Frey Farm Landfill	January 1991	Assumed ongoing	100	Objectives are to reclaim landfill capacity and use waste for fuel. Material recovery was ultimately not economically feasible. Eighteen acres mined.	1, 2
Fairhaven, MA	1995	Ongoing	28	Expected to take 10 years and cost $60 million. Processing 400 tons/hour. Odor problems and some community resistance. PCB soils were placed in landfill previously; this along with odors spurred community resistance. Contractor is Waste Systems International (formerly known as BioSafe).	7, 8
Newbury, MA	1993	Ongoing	12	Three acres of waste has been excavated from old landfill; new liner to be placed late this summer. Waste estimated to contain 50 to 60% wood. No hazardous materials have been encountered. Metals, tires, lead batteries, and soil are being recovered and recycled off-site. Soil taken to adjacent town (Salisbury); metal to Portsmouth, NH; tires to Littleton, MA. Volume reduction attained is on the order of 60 to 70%.	10, 11, 12
Barre, MA	NA	NA	NA	During pilot testing, it was found that the waste had hardly decomposed due to lack of water contact. Project did not proceed.	9

Table 2 (Continued). Representative Landfill Mining Projects

Project	Start	Finish	Size (acres)	Comments	Notes
Bethlehem, PA: Bethlehem Landfill	December 1991	NA	4	Moved 175,000 tons of waste to adjacent new lined landfill.	2
Edinburg, NY: Edinburg Landfill	November 1990	NA	5	Demonstration project. Reduced landfill size to 2 acres. White goods require cleaning to remove soil before sale. Reclaimed soil acceptable for off-site reuse.	2, 6, 9
Hague, NY	October 1994	NA	7	Waste removed to develop site for other uses. Cost was $1.3 million, more costly than capping but town wanted to avoid long-term monitoring costs and potential liability.	2, 6
East Hampton, NY	November 1994	NA	NA	Feasibility study was being performed to remove waste and reuse land for recycling center. Status unknown.	2
Thompson, CT: Martone Landfill	1987	1988	2	Objective was to reclaim landfill space. Landfill contained bulky waste.	2, 9
Bethlehem, NH	NA	NA	NA	Expansion and relocation of waste from old, unlined landfill. Mining of old landfill not allowed during summer due to odors. Masking agents used during other time periods.	9
McDougall, Ontario, Canada	March 1994	Assumed ongoing	NA	Waste is being removed, a liner placed, and landfill refilled.	2
Moretown, VT	October 1996	Ongoing	200	Source: BioSafe International, Inc. press release, January 21, 1997	

Table 2 (Continued). Representative Landfill Mining Projects

Project	Start	Finish	Size (acres)	Comments	Notes
Buckland, MA	1997	NA	10	Source: Internet home page, BioSafe International, Inc.	
South Hadley, MA	1997	NA	26	Source: Internet home page, BioSafe International, Inc.	
Orange, MA	1997	NA	NA	Source: Internet home page, BioSafe International, Inc. Planned rate is 400 tons/day.	
Nantucket, MA	1997	NA	NA	Source: Internet home page, BioSafe International, Inc. Planned rate is 25,000 tons/year.	
Rushville, PA	1997	NA	500	Source: Internet home page, BioSafe International, Inc. Planned rate is 2,000 tons/day.	

Notes:
1. Lancaster County Solid Waste Authority, 1996. Personal communications between H. Flosdorf and B. Norris (Lancaster County Solid Waste Authority) and S. Higgins and N. Bergeron (M&E).
2. Dickinson, W., 1995. *Landfill Mining Comes of Age.* Solid Waste Technologies, March/April 1995, pp. 42-47.
3. Naber, T., 1987. *Mining the Landfill: The Ultimate in Resource Recovery.* Waste Age, Nov. 1987, pp. 196-197.
4. Cobb, C. E. And K. Ruckstuhl, 1988. *Mining and Reclaiming Existing Sanitary Landfills*, Proceedings of the 1988 National Waste Processing Conference, American Society of Mechanical Engineers, held at Philadelphia, PA, May 1-4.
5. U.S. EPA, 1993. *EPA Evaluation of the Collier County Florida Landfill Mining Demonstration.* U.S. Environmental Protection Agency, Office of Research and Development, EPA/600/R-93/163, September.
6. Nelson, H., 1994. *Mining Resources: Landfill Reclamation Strategies,* BioCycle, October 1994, pp. 40-44.
7. MADEP Division of Solid Waste Management, 1995. *Massachusetts Solid Waste Master Plan, Draft 1995 Update.* June 29, 1995.
8. Local newspaper articles regarding the Fairhaven project, 1995-1996.
9. PRISM - World Resource Foundation Technical Brief: Landfill Mining. Internet address http://www.wrfound.org.uk./wrftblfm.html, last modified April 1997.
10. Pearson, R., 1997. Personal Communication with S. Czarniecki (M&E). February 21.
11. Newbury Department of Health, 1997. Personal communication between A. Machiros (Department of Health) and D. Simone (M&E).
12. Massachusetts Department of Environmental Protection, 1997. Personal Communication between R. Tanzer (MADEP) and D. Simone (M&E).

NA Not available or not applicable.

Lancaster County, PA: Frey Farm Landfill. The Lancaster County Solid Waste Management Authority (the Authority) operates the Frey Farm Landfill. The description below is based on information provided by Herbert Flosdorf and Brooks Norris of the Authority (Lancaster County Solid Waste Management Authority, 1996). In 1990, the Authority constructed a resource recovery facility to burn waste to reduce the volume of waste entering the landfill, with the goal of extending the landfill's operational life. In 1991, it began mining the landfill with the goal of recovering waste for use as fuel in the resource recovery facility. In three years of operation, 188,590 tons of waste were reclaimed from the landfill, making 370,000 yd^3 of space available for reuse.

Initially, reclaimed waste was sent directly to the resource recovery facility, without any attempt to recover soil. The presence of large amounts of soil reduced the fuel value of the reclaimed waste. To address this issue, the Authority purchased a trommel to separate soil from the waste. In addition to increasing the fuel value of the waste, removal of soil allows for its reuse as cover.

Odor and air emissions at the landfill are negative aspects of the project, but the Authority believes these aspects are outweighed by the benefits of reclaimed landfill space, additional energy production in the resource recovery facility, and recovery of cover soil and ferrous metals. Average costs for excavating, sorting, and trommeling the waste were $2.63 per cubic yard during the period January 1992 - December 1993. The cost for transportation of waste to the resource recovery facility was $2 per cubic yard. The average weekly excavation volume for the period was 2,478 yd^3 (1,476 tons). Reclaimed soil represented approximately 73% of the total mass of waste excavated and processed. The Authority assigned a value of $2 per ton to the reclaimed soil.

Collier County, FL: Naples Landfill. This project is the longest on-going landfill mining operation in the United States. Ten acres of the landfill have been mined since 1986. The primary purpose of the project is to recover and reuse the soil as daily cover for an adjacent, lined landfill cell. The cost of producing the soil from the mined waste is estimated at approximately $2 per ton. Ferrous material was also initially recovered and sold as scrap, but this was discontinued due to the low market value of the material (Dickinson, 1995).

In 1992, EPA sponsored a two-week demonstration project as part of the county's mining program. During the demonstration, approximately 60% of the recovered material by weight was soil. Ferrous material and plastics were also recovered but these materials were not pure enough to render them marketable, in comparison to the purity of materials available from source-separation programs (Dickinson, 1995).

Newbury, MA Town Landfill. The town of Newbury has been mining its old, 12-acre unlined landfill since 1993. The objective is to install a composite liner in the landfill and use it for long-term disposal of town waste (MADEP, 1995). Reclaimed soil is sent to an adjacent town (Salisbury) at this time. The reduction in waste volume that is being attained is on the order of 65 to 70% (Pearson, 1997). No hazardous materials have been encountered during mining

activities (Newbury Department of Health, 1997). Tires and metal are recycled offsite. The landfill waste is reported to be 50-60% wood based on test pit observations (MADEP, 1997).

According to program cost estimates prepared by Port Engineering for the Town of Newbury and submitted to MADEP (Port Engineering, 1996), landfill mining is planned to occur through fiscal year 1999, when the lined landfill construction is also anticipated to be completed. The estimated cost for the landfill mining component of the work (mining, tire removal, construction of haul roads and fencing, supervision/monitoring, and engineering design) was $2.98 million, and estimated costs for mining (excavation and sorting only) ranged from $8 per cubic yard to $10 per cubic yard, depending on the phase of the project. The projected rate of mining was 1,200 cubic yards per day for 250 days, for a total of 300,000 cubic yards between 1997 and 1999 (Port Engineering, 1996). Three acres of the 12-acre landfill have been mined since 1993 (MADEP, 1997).

5.3 Pilot Study/Feasibility Analysis

The conditions at any given landfill dictate the feasibility of successfully implementing landfill mining. Since every landfill may not be a potential candidate for landfill mining, some information must be gathered initially and used to determine the applicability of the technology to each particular site. This initial data gathering and analysis is performed in the pilot study/feasibility phase.

The pilot study information gathering consists of historical reviews and on-site investigative operations. Historical reviews would include such activities as reviewing landfill daily logs and evaluating available aerial photographs taken over the lifespan of the landfill. The on-site investigation would involve digging test pits and/or drilling borings in the landfill to characterize the waste and sample the soil. The use of test pits or drilling would depend on the depth of the waste layer in the landfill. The number of test pits or boreholes would depend on the size of the landfill and the degree of confidence that would be required to characterize the landfill. Four test pits per acre were performed at the Newbury, MA landfill (Newbury Department of Health, 1997).

The information obtained from these activities includes: 1) the types and quantities of wastes in the landfill; 2) the locations and concentrations of various wastes; 3) the condition of the waste; 4) the depth of waste in all parts of the landfill; 5) the depth to groundwater; and 6) the possibility of hazardous waste existing in the landfill.

This information would then be evaluated to determine if landfill mining is feasible. Some of the conditions that would present a significant obstacle to the success of landfill mining include the presence of wastes below the groundwater table, the presence of hazardous waste, and the possibility of releasing large amounts of landfill gases and objectionable odors.

Associated activities for the pilot study would include the preparation of a site-specific health and safety plan, an air monitoring plan, an operational plan, and a hazardous materials

management plan in case hazardous materials or conditions are found.

An economic evaluation is also performed to determine the feasibility of the technology. The cost of the project is most likely to be the major decision making criterion for the implementation of the process. A cost/benefit analysis would compare the projected costs for capping or closing a landfill without mining; with the costs associated with landfill mining and re-disposing of non-recyclable wastes, the anticipated savings from reducing the size of or eliminating the need for a cap, and the anticipated revenue from recyclable materials. For existing, active landfills, the potential value of reclaimed landfill space is also a factor.

5.4 Applicability of Landfill Mining to Rose Hill Regional Landfill

Landfill mining is being considered for the Bulky Waste Area at the Rose Hill Site. This 7-acre disposal area contains an estimated 114,000 yd^3 of material and is located east of the Solid Waste Area and southwest of the Sewage Sludge Area approximately 200 feet east of Mitchell Brook and 250 feet west of the Saugatucket River (Figure 2). This landfill was in operation from 1978 to 1983. Solid waste was also reportedly disposed of in the Bulky Waste Area during this period between closure of the Solid Waste Area and construction of the transfer station. Currently some vegetation, primarily grasses overlying natural fill materials, provide cover for this area (M&E, 1994).

A landfill cap is required for the Bulky Waste Area if the waste is to be left in place. Alternatively, landfill mining could be used to extract the waste and recycle soil and other recyclable materials. Non-recyclable, non-hazardous waste would be disposed of at the Solid Waste Area before it is capped as part of a separate source control action. If hazardous wastes are encountered, they would need to be containerized in drums for off-site treatment/disposal at a RCRA Treatment, Storage, and Disposal Facility (TSDF). The Bulky Waste Area would be backfilled with recycled soil (supplemented as necessary with clean fill) and graded once all the waste had been removed and recycled or re-disposed.

A pilot study would need to be conducted to fully evaluate the applicability of landfill mining for the Bulky Waste Area. As discussed above, it is important to collect data on the types and quantities of wastes present; the locations and concentrations of various wastes; the condition of the waste; the depth of waste and depth to groundwater; and the likelihood of encountering hazardous waste. The evaluation of these factors for the Bulky Waste Area that is presented here is preliminary and should be revised after a pilot study is performed. Also, in the Draft Final FS report it was stated that a localized investigation of the Bulky Waste Area may be warranted due to a single surface soil sample which had a high manganese concentration. This area should be further sampled during the pilot study.

Types and Quantities of Wastes. The types and quantities of wastes disposed in this area may be amenable to landfill mining if recyclable items such as white goods are a significant component of the waste. The town of South Kingstown is currently using Metals Recycling in Johnston, RI to recycle scrap metal (South Kingstown transfer station staff, 1997). Metals

Recycling was contacted for pricing information. If the scrap material is sufficiently free of dirt, if chlorofluorocarbons or capacitors have already been removed, and if the material is delivered to Metals Recycling, the scrap value is $40.00 per ton. If Metals Recycling must pick up the dirt-free materials and remove chlorofluorocarbons and capacitors, the scrap value is negated by transportation and handling charges (Metals Recycling, 1997). A preliminary estimate of the quantity of recyclable metal waste in the Bulky Waste Area is 37,500 yd^3, which is 33% of the estimated total waste volume of 114,000 yd^3 (M&E, 1996a). It is further estimated that 40% of the 114,000 yd^3 is non-contaminated soil that can be used for backfilling the Bulky Waste Area. The remaining 27% of the total waste volume is assumed to consist of non-recyclable waste that will need to be re-disposed at the Solid Waste Area. It is assumed that the volume of hazardous waste encountered will be minimal.

Locations, Concentrations, Condition, and Depth of Wastes. The composition and condition of the waste is not fully known. Also, previous investigative activities in the vicinity of the Bulky Waste Area have resulted in inconclusive evidence with regard to whether or not landfilled materials are in contact with groundwater. Test pit excavations and/or soil borings would be conducted during the pilot study to determine the type, location, and condition of the waste, verify the depth of the bottom of the waste in relation to the water table, and determine the need for dewatering. The scope of the subsurface investigation program should be extensive enough to characterize the waste/groundwater relationship in detail as only a portion of the area may need to be dewatered.

Once the bottom of the waste horizon has been delineated, a contour map would be generated and compared with existing water table conditions. If dewatering is deemed necessary, the groundwater flow model that was used to simulate FS alternatives could be used to optimize the locations and extraction rates of dewatering wells.

Management of Dewatering Water. Groundwater extracted during any dewatering would be treated if necessary and reinjected. A possible location for reinjection may be between the downgradient edge of the Bulky Waste Area and the Saugatucket River. The groundwater flow model is discretized with sufficient detail to also evaluate the location and impact of reinjection wells.

Assuming that dewatering is necessary to conduct the landfill mining operation, RIDEM rules under the Underground Injection Control Program would apply. Assuming that dewatering operations last more than one month, it would be necessary to provide RIDEM with plans, specifications, sample analyses and other information that shows that the injection will be designed, constructed and operated so as to prevent pollution or endangerment of groundwater quality in Rhode Island.

According to a letter from Mark Dennen, RIDEM (12/19/96), the groundwater underlying the Rose Hill area should be considered a medium-use aquifer, or classification GA. If the groundwater is shown to be clean, treatment would not be necessary. In the case of the Bulky Waste Area, it appears that groundwater has substantial levels of metals, with beryllium and lead

above regulatory objectives. RIDEM Rules and Regulations for the Investigation and Remediation of Hazardous Material Releases (Remediation Regulations) identify GA groundwater objectives. A comparison of these objectives to data for the Bulky Waste Area (M&E, 1996a) is presented in Table 3.

Table 3. Comparison of RIDEM GA Groundwater Objectives to Data for the Bulky Waste Area

Analyte	Objective (mg/l)	Average Concentration in Bulky Waste Area (mg/l)	Maximum Concentration in Bulky Waste Area (mg/l)
Antimony	0.006	ND	ND
Barium	2	0.51	2.12
Beryllium	0.004	0.002	0.009
Cadmium	0.005	0.002	0.005
Chromium (total)	0.1	ND	ND
Lead	0.015	0.037	0.174
Mercury	0.002	0.00011	0.00020
Nickel	0.1	0.005	0.014
Selenium	0.05	NA	NA
Thallium	0.002	NA	NA
Cyanide	0.2	NA	NA

Notes: ND - Not Detected
NA - Not Analyzed or Not Available

For the order-of-magnitude estimate of the landfill mining alternative, a cost of $50,000 has been assigned for wells and associated piping, assuming three dewatering wells and two to three injection wells. A cost of $375,000 has been assigned for treatment of dewatering water, that is comprised of a $350,000 capital cost for a five gallon per minute metals precipitation system and a $25,000 O&M cost to operate the system for no more than one year. This was included because the available data indicate that the average concentration of lead in groundwater at the Bulky Waste Area will be above the RIDEM GA groundwater objective.

Likelihood of Encountering Hazardous Waste. The likelihood of encountering hazardous waste during landfill mining is judged to be low to moderate. As noted above, for estimating

purposes it is assumed that 30,900 yd^3 of waste will be non-recyclable and that this waste will be re-disposed at the Solid Waste Area, which is to be capped with a RCRA Subtitle C cap under a separate source control action. An allowance of $10,000 is included in the order-of-magnitude cost estimate to account for the potential need to drum and dispose of a limited amount of hazardous waste at an off-site RCRA TSDF. A further allowance of $37,000 is included for employee training, personal protective equipment, continuous monitoring equipment, and decontamination facilities and supplies in the event that hazardous waste is encountered.

The assumptions regarding waste types and volumes strongly influence the feasibility of landfill mining as a remedial alternative for the Bulky Waste Area. Depending on the pilot study results, it may be feasible to excavate the entire Bulky Waste Area as described above, or it may be advantageous to consider mining only a portion of the landfill. If it is found that a significant quantity of hazardous waste is present, and/or if a large percentage of the waste is non-recyclable, capping the Bulky Waste Area could potentially be more cost-effective than mining the waste and re-disposing of it at the Solid Waste Area or offsite.

Likelihood of Waste Below the Water Table. The issue of whether waste is present below the water table is a significant factor in determining the feasibility of mining the Bulky Waste Area. Dewatering costs and costs for treatment of the water before discharge or reinjection may be substantial if waste is present below the water table. Pilot study data are needed to address this concern. For the purpose of this order-of-magnitude cost estimate, it is assumed that some dewatering will be needed and the water will need to be treated before reinjection, but the extent of the dewatering will be minimal.

5.5 Effectiveness

The landfill mining alternative should be effective in the long term for remediation of the Bulky Waste Area, when coupled with relocation of non-recyclable wastes to the Solid Waste Area and capping of the latter area with a RCRA Subtitle C cap. Any hazardous wastes that are encountered would be disposed offsite at a RCRA TSDF. Wastes would be completely removed from the Bulky Waste Area; hence eliminating continuing sources of groundwater and surface water contamination in this area. Monitoring would be needed for a time after mining activities are completed, to confirm that source removal was attained.

There are potential short-term risks to workers and nearby residents that would exist during the landfill mining phase of the alternative. Safety issues associated with landfill mining may include the following:

- Oxygen depletion in the work zone (landfill gas is expected to be anaerobic)
- Ignition of landfill gas (methane expected)
- Collapse of excavation sidewalls (waste materials may be unstable)
- Crushing from heavy equipment or bulky items
- Laceration or puncture from metal or glass waste materials

- Heat and cold stress to equipment operators

Health issues associated with landfill mining may include the following:

- Worker exposure to odors from the landfill
- Increased odors in the neighborhood of the landfill
- Worker exposure to VOCs from the landfill
- Increased exposure to VOCs in the neighborhood of the landfill
- Worker exposure to dust generated during excavation, screening, and backfill
- Skin contact with hazardous liquids and leachate
- Attraction of vermin able to access exhumed/uncovered garbage

If it is determined that there are no hazardous substances in the soil and groundwater that could result in employee exposure, then work would proceed as a conventional construction operation. However, if at any time during the mining process an accumulation of hazardous substances in the soil or groundwater is identified that results in the reasonable possibility for employee exposure to safety or health hazards, then all the requirements of 29 CFR 1910.120 Hazardous Waste Operations and Emergency Response would need to be met. At a minimum this would require: generation of a site-specific health and safety plan, initial training for general site workers, management training for supervisory personnel, training of several individuals in First Aid/CPR, higher levels of personal protective equipment, continuous use of exposure monitoring equipment, decontamination facilities and supplies, and emergency response equipment.

Potential short-term and long-term ecological risks of landfill mining must also be considered when evaluating its effectiveness. Emergent wetlands, forested wetlands, and two lotic waterbodies are located within 100 meters of the eastern and western boundaries of the Bulky Waste Area. The main ecological concern associated with landfill mining is the potential impact of surface runoff and dust from landfill operations on these aquatic resources. If erosion/dust suppression controls are not implemented, sedimentation could take place in wetland resources. Sedimentation would decrease water depth and could change both the temperature regime and the character of the substrate. Runoff or dust reaching the Saugatucket River and Mitchell Brook would increase sediment loads and suspended solids levels. Runoff and dust are potential problems regardless of whether the materials are contaminated. The risk to receptor communities would only be compounded if hazardous materials were released to aquatic resources via dust, runoff, or through groundwater discharge to surface water. Noise may also be factor that would discourage wildlife from nesting near the landfill.

Mitigation measures would need to be developed to address potential safety concerns, short-term human health risks, and ecological risks if the landfill mining alternative is implemented.

5.6 Implementability

Contractors are available in New England with experience in landfill mining technology. There is a metal recycling facility near the Site that would accept scrap metal, provided it is cleaned

sufficiently to remove dirt and other waste debris and any chlorofluorocarbons or capacitors are removed. A pilot study is needed to determine whether there is material within the Bulky Waste Area that can be made acceptable for recycling in a cost-effective manner. If substantial cleaning is required, recycling may not provide a net cost benefit over re-landfilling the material at the Solid Waste Area or leaving the material in place and capping it. Similarly, the results of the pilot study are needed to evaluate whether recovered soil would be suitable for use as backfill.

Management of water generated during dewatering activities by treatment (as necessary) and reinjection should be implementable, if RIDEM concurs with the landfill mining alternative. RIDEM would determine the acceptability of reinjection and the need for treatment according to the Rhode Island Underground Injection Control Program rules.

5.7 Cost

The cost of this alternative is highly dependent on a number of factors, including: the quantity of recyclables and reusable soil present, whether it will be possible to eliminate the need for a cap, whether or not hazardous waste is present, and the depth of the waste and the water table. An order-of-magnitude estimate has been derived that is based on a set of assumptions and utilizes cost estimates for the Newbury, MA landfill (Port Engineering, 1996), previous estimates included in the Draft Final FS report (M&E, 1996a), and a price for scrap metal obtained from Metals Recycling (Metals Recycling, 1997). The major assumptions on which the cost estimate is based are as follows:

Volumes of Waste in the Bulky Waste Area

Total waste volume:	114,000 cubic yards
Recyclable scrap metal volume:	37,500 cubic yards
Reusable soil volume:	45,600 cubic yards
Non-recyclable waste volume:	30,900 cubic yards

Fate of Mined Wastes

- Recyclable scrap metal: Transport to Metals Recycling, Johnston, RI; scrap metal is cleaned and capacitors and chlorofluorocarbons are removed onsite.

- Reusable soil: Use as backfill to restore Bulky Waste Area when mining is complete

- Non-recyclable waste: Place in Solid Waste Area under RCRA Subtitle C cap; it is assumed that this will increase the previously estimated cost for the Solid Waste Area cap, as presented in the Draft FS, by approximately 10% ($240,000). Note: Based on recent EPA comments

on the Draft Final FS report, a Subtitle C cap will be required for the Solid Waste Area. For this reason this technical memorandum has assumed a Subtitle C cap.

- Hazardous waste: A limited amount of hazardous waste will be encountered; an allowance of $10,000 is included for off-site disposal of hazardous waste at a RCRA TSDF.

Other Assumptions

- A minimal amount of waste is present below the water table; an allowance of $50,000 is included for dewatering and reinjection.

- An allowance of $375,000 ($350,000 capital plus $25,000 for one year of operation) is included for treatment of water to meet RIDEM GA groundwater objectives before reinjection.

- Hazardous waste will be encountered, triggering the requirements of 29 CFR 1910.120. An allowance of $37,000 is included for health and safety plans, training and equipment.

The order-of-magnitude capital cost estimate derived from these assumptions is $2.4 million. Details are presented in Attachment B. This estimate is within an order of magnitude of the capital cost estimate of $1.1 million for capping the Bulky Waste Area as was presented in the Draft Final FS report. However, O&M costs for the landfill mining alternative are expected to be less than those for the capping alternative. O&M costs for the landfill mining alternative include operation and maintenance of the water treatment system (estimated at $25,000 per year for one year), and groundwater monitoring to demonstrate that source removal has been accomplished. For the capping alternative, long-term groundwater monitoring would be required. It is assumed that the five existing monitoring wells in the vicinity of the Bulky Waste Area (MW-03-01, MW-03-02, MW-03-03, MW-12-01, and MW-12-02) would be used to monitor the effectiveness of the capping alternative, and that monitoring would take place for 30 years. For comparison, it is assumed that monitoring for the landfill mining alternative would consist of sampling of ten wells (the five existing wells, plus three extraction (dewatering) wells and two reinjection wells) for a period of five years. Based on these assumptions the duration of monitoring would be a factor of six smaller for the landfill mining alternative, but the number of wells is doubled so the overall cost for monitoring is approximately three times lower than that for the capping alternative.

Even if the lower O&M cost of the landfill mining alternative is not taken into account, the order-of-magnitude costs for the capping and landfill mining alternatives are not substantially different, given the accuracy of screening level estimates. The landfill mining alternative would therefore not be screened out at this stage, on the basis of cost alone.

5.8 Summary

Some of the advantages that could be expected from applying landfill mining at the Bulky Waste Area are summarized below.

- Mining this area may eliminate the need for a cap.
- Mining would also recover soil which could be reused for capping the Solid Waste Area or restoring the Bulky Waste Area.
- A limited amount of revenue could be generated from recycling of scrap metal.

Some of the disadvantages to applying landfill mining technology at the Bulky Waste Area are:

- The type and quantity of waste is not known. There is always a possibility that hazardous materials may be encountered. Hazardous materials would need to be containerized separately and disposed of off-site at a RCRA TSDF.
- It is possible that dewatering and treatment of the liquid would be necessary during excavation operations. Mobilization of an on-site treatment unit to treat the liquid would be costly.
- Any excavated recyclables that were found to be hazardous would require decontamination to remove any residual accumulations on the material and this rinsate would require on- or off-site treatment.
- All waste and any contaminated soil must be removed in order to eliminate the cap. Any non-recyclable, non-hazardous wastes would be placed on the Solid Waste Area, which would increase the cost of the cap of that area. If dewatering is needed, it may not be possible to excavate all the waste from the Bulky Waste Area in a cost-effective manner.
- Landfill mining does not have strong public support. Excavation of the landfill could cause the release of and/or further migration of potentially hazardous materials or nuisance odors.
- Resolution of significant permitting issues may be required for re-opening and re-closing the landfill. It is not clear if the disposal areas would remain "grandfathered" under past solid waste closure regulations or if more recent stringent requirements would apply.

The most important advantage to implementing landfill mining is the potential to eliminate the need to cap the Bulky Waste Area. However, it is not certain whether this will be possible. It is possible that some of the waste is below the current water level. Excavating below the

water table would require dewatering measures. Dewatering a landfill with a possibility of hazardous contamination would be very expensive. For the cap to be eliminated, all the waste including that below the water table would have to be removed, and any hazardous waste that is encountered would need to be disposed of at an off-site RCRA TSDF. The costs associated with off-site hazardous waste disposal or any required dewatering and treatment measures could outweigh the possible cap elimination savings.

6.0 CONCLUSIONS

Based on the results of this additional technology evaluation, it is concluded that the alternative flare design should be retained for further evaluation in the FS for treatment of landfill gas. The alternative flare design is effective and implementable, and is likely to provide a substantial operations and maintenance savings over the conventional flare design presented in the Draft Final FS report.

Further evaluation of the photocatalytic oxidation technology for treatment of landfill gas is also recommended. If it is determined that methane destruction is needed (RIDEM, 1996), the photocatalytic oxidation technology would be screened out because it does not effectively destroy methane. Another technology (such as a flare) would need to be employed in series with the photocatalytic oxidation system to destroy the methane. The use of both a photocatalytic oxidation system and a flare or other methane destruction system would be more costly than use of a flare alone. In this latter case, therefore, photocatalytic oxidation would be screened out because it would provide no increase in either effectiveness or implementability over a flare alone, while costing more.

Biofiltration is not recommended for further consideration due to lack of effectiveness in removing chlorinated VOCs to the degree needed to attain PRGs, as well as lack of effectiveness in removing methane.

With respect to landfill mining, it is concluded that the technology merits further evaluation as a component of alternatives for remediation of the Bulky Waste Area. While the capital costs for landfill mining are higher than that for a cap, O&M costs will be lower. Further development of costs will be performed as part of the detailed evaluation of alternatives. Costs are subject to a large degree of uncertainty due to the limited data available regarding the landfill contents. A pilot study will be needed to make a definitive conclusion regarding the suitability of landfill mining for the Bulky Waste Area.

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ATTACHMENT A:

PHOTOCATALYTIC OXIDATION

PHOTOCST.XLS

I. INFLUENT GAS CHARACTERIZATION ON WHICH ESTIMATES ARE BASED

FLOW RATE OF INFLUENT GAS TO PHOTOCATALYTIC UNIT = 420,000 cm^3/s = 890 scfm

RELATIVE HUMIDITY = 100%

Contaminants:	MW	Landfill Gas Concentrations Maximum Detection (ppbv) [1]	(mg/m^3)	Photocatalytic Oxidation Unit Influent Concentrations Maximum Detection (ppbv) [1]	(mg/m^3)
Benzene	78.1	2,500	8.0	310	0.99
1,1-Dichloroethene	97	8,100	32	1,003	3.98
cis-1,2-Dichloroethene	97	5,900,000	23,000	730,476	2,848
trans-1,2-Dichloroethene	97	6,700	27	830	3.29
Ethylbenzene	106.2	5,800	25	718	3.12
Methylene Chloride	84.9	19,000	66	2,352	8.17
Toluene	92.1	62,000	230	7,676	28.48
Trichloroethene	131.4	5,700	31	706	3.79
Vinyl Chloride	**62.5**	**1,200,000**	**3,100**	**148,571**	**383.81**
m,p-Xylene	106.2	9,400	41	1,164	5.06
o-Xylene	106.2	2,500	11	310	1.34
Carbon Disulfide	76.1	280	0.87	35	0.11
Dichlorodifluoromethane	120.9	22,000	110 [2]	2,724	13.62
1,1-Dichloroethane	99	34,000	140	4,210	17.33
4-Methyl-2-pentanone	100.2	1,600	6.6	198	0.81
1,1,2,2-Tetrachloroethane	167.9	0 *	0	0	0
1,1,1-Trichloroethane	133.4	1,900	10	235	1.28
1,2,4-Trimethylbenzene	120.2	500	2	62	0.30
1,3,5-Trimethylbenzene	120.2	870	4.3	108	0.53
Acetone	58.1	0 *	0	0	0
1,2,4-Trichlorobenzene	181.5	0 *	0	0	0

PHOTOCST.XLS

Major Components of Influent Gas to the Photocatalytic Oxidation System are: Methane, Carbon Dioxide, Nitrogen, and Oxygen

The percentages (by volume) of these gases [from spreadsheet COMPOSIT.WK1, dated 8/26/96, prepared by S. Czarniecki] are:

Percent by volume Methane (CH_4):	6.18
Percent by volume Carbon Dioxide (CO_2):	6.18
Percent by volume Nitrogen (N_2):	69.24
Percent by volume Oxygen (O_2):	18.41

II. REQUIRED DESTRUCTION AND REMOVAL EFFICIENCIES

Vendors were requested to base their estimates on a minimum acceptable DRE of 95% for Vinyl Chloride.

III. VENDORS CONTACTED WHO PROVIDED RESPONSES

1. KSE, Inc.
   P.O. Box 368
   Amherst, MA 01004
   Dr. James Kittrell, President
   Phone: 413-549-5506
   Fax: 413-549-5788

2. Matrix Photocatalytic, Inc.
   22 Pegler Street
   London, Ontario, Canada
   N5Z 2B5
   Mr. Doug Garside
   Phone: 519-660-8669
   Fax: 519-660-8525

3. PTI, Inc.
   P.O. Box 476
   Boise, ID 83701-0476
   Mr. Barry Brooks
   Phone: 208-385-0900
   Fax: 208-385-0994

Notes: * Not detected in solid waste area SUMMA canister samples, but were chemicals of concern in RI report (M&E, 1994)
(1) Maximum of four samples. Duplicate samples not averaged prior to identifying maximum.
(2) Shows as 100 mg/m^3 on analytical sheet possibly due to calculation at different temperature.

PHOTOCST.XLS

IV. COST SUMMARY FOR KSE, INC. SYSTEM: Adsorption-Integrated-Reaction (AIR-II) Process

CAPITAL ITEMS		COST
AIR Unit, 6 ft. L x 6 ft. W x 6 ft (includes explosion-proof blower and shell around unit)	TOTAL CAPITAL:	$75,000

Scrubber - Assumed not necessary based on KSE's experience at Stamina Mills Site, N. Smithfield, RI.

OPERATION AND MAINTENANCE	COST/MONTH	COST/ 30 YEARS
Includes electricity, bulb replacement, and catalyst replacement, according to KSE	$900	$324,000

CAPITAL + 30 YEARS O&M:	$399,000

V. COST SUMMARY FOR PROCESS TECHNOLOGIES, INC. (PTI) PHOTOLYTIC SYSTEM

CAPITAL ITEMS		COST
Adsorber/concentrator, condenser, and 3 photolytic units [Adsorber/concentrator adsorbs VOCs, then they are desorbed with a low flow of gas; purpose is to concentrate the VOCs so a low-flow, high concentration stream is treated in the photolytic units. The condenser is included after the adsorber/ concentrator to drop out some organics.]	TOTAL CAPITAL:	$350,000

OPERATION AND MAINTENANCE	COST/MONTH	COST/ 30 YEARS
Cost is $1,500 per month per photolytic unit, need 3 units Costs for disposal of condensate are not included.	$4,500	$1,620,000

CAPITAL + 30 YEARS O&M:	$1,970,000

PHOTOCST.XLS

VI. COST SUMMARY FOR MATRIX PHOTOCATALYTIC, INC. SYSTEM: TiO_2 Photocatalytic Technology

CAPITAL ITEMS			COST
Matrix Air Phase Photocatalytic Unit (5 pieces)			$268,000
Irreversible Electron Acceptor System (5 pieces)			$18,000
Caustic Scrubber			$22,000
Matrix Aqueous Phase Unit (to treat knock-out drum liquids)			$2,000
Total cost, excluding scrubber and aqueous treatment unit (to be on same basis as KSE quote):		TOTAL CAPITAL:	$286,000

OPERATION AND MAINTENANCE		COST/MONTH	COST/ 30 YEARS
Electricity, 10 kW +15% for ancillary equipment, $0.10/kWh, 24 hr/day, 30 days/mo		$828	$298,080
UV lamp change out: 240 lamps, change out all lamps every 10,000 hours of operation, cost is $25 per lamp, labor is 4 hours per change out			
Change outs/mo = (24 hr/day x 30 days/mo)/(10,000 hr/change out) =	0.072		
Cost per change out = 240 lamps x $25/lamp + 4 hr x $60/hr =	$6,240		
Cost/month = change outs/month x cost per change out =		$449	$161,741
TiO2 catalyst change out: once per 3 years = once per 36 months; 245 sections at $150 each, labor is 12 hours per change out			
Change outs/mo = 1 changeout/(3 years x 12 mo/year) =	0.0278		
Cost per change out = 245 sections x $150/each + 12 hr x $60/hr =	$37,470		
Cost/month = change outs/month x cost per change out =		$1,041	$374,700
	TOTAL O&M:	$2,318	$834,521
	CAPITAL + 30 YEARS O&M:		$1,120,521

Metcalf & Eddy
An Air & Water Technologies Company

020617-0010

April 15, 1997

Dr. James Kittrell
KSE, Inc.
P.O. Box 368
Amherst, Massachusetts 01004

Subject: **Rose Hill Regional Landfill Superfund Site: Request for Budgetary Estimate and Process Configuration for Treatment of Landfill Gas**

Dear Dr.Kittrell:

Metcalf & Eddy (M&E) has been retained by the U.S. EPA to evaluate several promising, innovative treatment technologies for management of landfill gas generated at the Rose Hill Superfund Site in South Kingstown, RI.

A technology developed by your firm, photocatalytic oxidation, has been identified as a technology to be included in M&E's evaluation. The evaluation is at the feasibility study level.

Characteristics of the gas to be treated are provided in the enclosed spreadsheet and process schematic. If this alternative is implemented, gas will be withdrawn using two collection systems: a perimeter system and an internal system. The perimeter system collects both landfill gas and air; the internal system collects predominantly landfill gas. The gas treatment technology will be implemented to treat the combined gas flows from both systems.

Contaminants of primary concern in the gas are vinyl chloride (influent concentration approximately 149 ppmv) and methane (influent concentration approximately 6 percent by volume). The gas flow rate is estimated to be on the order of 890 standard cubic feet per minute. Relative humidity will approach 100 percent. Hydrogen sulfide and organic sulfide compounds are likely to be present in the gas, in addition to the contaminants identified in the enclosed spreadsheet.

It is understood from the literature that the photocatalytic oxidation technology will not destroy methane, but that it can destroy vinyl chloride and other contaminants of concern effectively. If this understanding is incorrect, and the technology is applicable to methane as well, please bring it to my attention. Note that the gas will be an explosive mixture given the methane concentration (the Lower Explosive Limit for methane is 5%), so explosion-proof equipment will be required.

30 Harvard Mill Square, Wakefield, MA 01880-5371 • Mailing Address: PO Box 4071, Wakefield, MA 01880-5371
TEL: 617-246-5200 FAX: 617-245-6293

Recycled Paper

M&E requests recommended sizing, cut sheets, and budgetary capital and operating costs for a photocatalytic oxidation system that will treat the influent gas to attain at least 95% destruction of vinyl chloride. Please also define any ancillary equipment requirements. The enclosed process schematic is M&E's attempt to do this; your input would be greatly appreciated.

Please call me at (617) 224-6608 if you have any questions.

Very truly yours,

METCALF & EDDY, INC.

Barbara A. Weir

Barbara A. Weir
Project Engineer

Enclosures

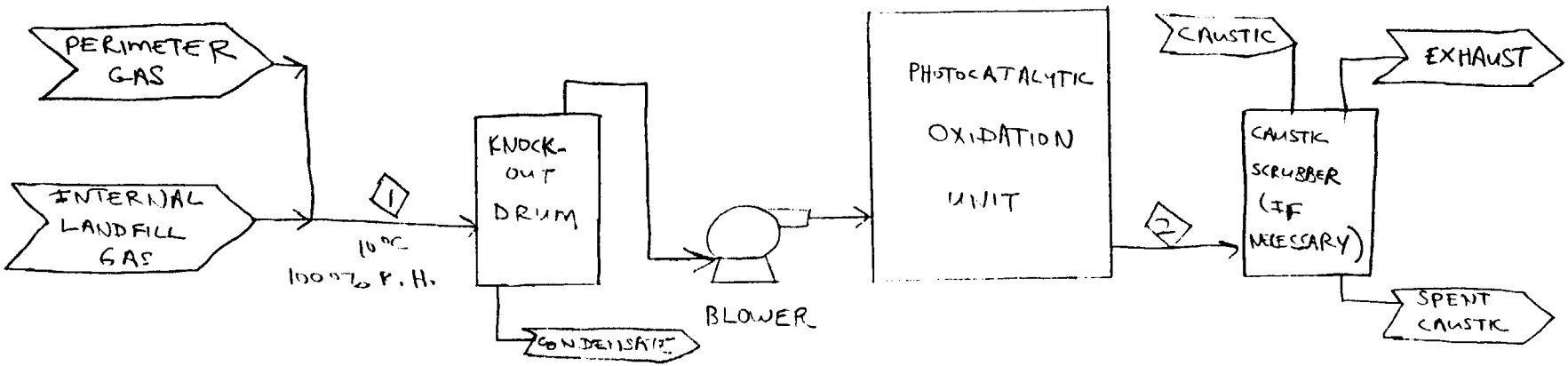
cc: S. Czarniecki
D. Simone

METCALF & EDDY, ENGINEERS

ROSE HILL TECHNOLOGY SCREENING

LANDFILL GAS ALTERNATIVES:

PHOTO CATALYTIC OXIDATION PROCESS SCHEMATIC



GAS STREAM	FLOW, scm^3/s	FLOW, scfm	CH_4 %	CO_2 %	N_2 %	O_2 %	VINYL CHLORIDE mg/m^3	VINYL CHLORIDE ppbv
1	420,000	890	6.18	6.18	69.24	18.41	384	148,571
2	420,000	890	6.18	6.18	69.24	18.41	19.2	7,428

ASSUMES NEGLIGIBLE CHANGES THROUGH PHOTOCATALYTIC SYSTEM

ASSUMES 95% DESTRUCTION

Project: ROSE HILL FS
Subject: PHOTOCATALYTIC OXIDATION
Detail: SCHEMATIC
Ck'd. By:
Date:
Acct. No.: 0205117.0010
Compd. By: B. WEIR
Date: 4/14/97
Page: 1 of 1

INFLDAT.XLS

Data from Appendix D in the Remedial Investigation Report (M&E, 1994) was used for contaminant concentrations in the Solid Waste Area. Attachment A presents these results as well as a map showing sampling locations. Presented below are conversion calculations for ppbv to mg/m^3, followed by conversion of these concentrations to account for dilution by air that will also be drawn in during gas extraction (the sample data are for "pure" landfill gas, and must be adjusted to account for the air collected by the perimeter and internal collection systems). Contaminants shown were selected by risk assessment personnel.

Locations sampled:
SG-SW(13+300)-12
SG-SW(11+500)-05
SG-SWD(13+300)-12
SG-SW(03+300)-06

Conversion from ppbv to mg/m^3: [from spreadsheet SUMMA.WK1, 8/14/96, prepared by S. Czarniecki]

Based on 760 torr (1 atm.) barometric pressure at 25°C and where 24.45 = molar volume in liters

mg/m^3 = (ppbv * gram molecular weight of substance) / (24.45 * 1000)

Conversion to account for dilution by extracted air:

Assumptions and Calculations:

1. The air does not contain any of the contaminants of concern.
2. The volumetric flow rate of air without landfill gas is 368,000 cm^3/s
   [from calculation by S. Czarniecki dated 8/26/96, spreadsheet COMPOSIT.WK1]
3. The volumetric flow rateof air + landfill gas = total influent to photocatalytic oxidation unit
   = 420,000 cm^3/s
4. Therefore the volumetric flow rate of landfill gas = 420,000 - 368,000
   = 52,000 cm^3/s
5. Concentration of contaminant in influent gas (air + landfill gas) = concentration in landfill gas x (landfill gas flow rate/air + landfill gas flow rate) = concentration x 52,000/420,000

INFLDAT.XLS

Contaminants:	MW	Landfill Gas Concentrations Maximum Detection (ppbv) [1]	(mg/m^3)	Photocatalytic Oxidation Unit Influent Concentrations Maximum Detection (ppbv) [1]	(mg/m^3)
Benzene	78.1	2,500	8.0	310	0.99
1,1-Dichloroethene	97	8,100	32	1,003	3.98
cis-1,2-Dichloroethene	97	5,900,000	23,000	730,476	2,848
trans-1,2-Dichloroethene	97	6,700	27	830	3.29
Ethylbenzene	106.2	5,800	25	718	3.12
Methylene Chloride	84.9	19,000	66	2,352	8.17
Toluene	92.1	62,000	230	7,676	28.48
Trichloroethene	131.4	5,700	31	706	3.79
Vinyl Chloride	**62.5**	**1,200,000**	**3,100**	**148,571**	**383.81**
m,p-Xylene	106.2	9,400	41	1,164	5.06
o-Xylene	106.2	2,500	11	310	1.34
Carbon Disulfide	76.1	280	0.87	35	0.11
Dichlorodifluoromethane	120.9	22,000	110 [2]	2,724	13.62
1,1-Dichloroethane	99	34,000	140	4,210	17.33
4-Methyl-2-pentanone	100.2	1,600	6.6	198	0.81
1,1,2,2-Tetrachloroethane	167.9	0 *	0	0	0
1,1,1-Trichloroethane	133.4	1,900	10	235	1.28
1,2,4-Trimethylbenzene	120.2	500	2	62	0.30
1,3,5-Trimethylbenzene	120.2	870	4.3	108	0.53
Acetone	58.1	0 *	0	0	0
1,2,4-Trichlorobenzene	181.5	0 *	0	0	0

INFLDAT.XLS

Major Components of Influent Gas to the Photocatalytic Oxidation System are: Methane, Carbon Dioxide, Nitrogen, and Oxygen

The percentages (by volume) of these gases [from spreadsheet COMPOSIT.WK1, dated 8/26/96, prepared by S. Czarniecki] are:

Percent by volume Methane (CH_4):	6.18
Percent by volume Carbon Dioxide (CO_2):	6.18
Percent by volume Nitrogen (N_2):	69.24
Percent by volume Oxygen (O_2):	18.41

Relative Humidity and Temperature of Influent Gas to the Photocatalytic Oxidation System:

Given the source of the gas, it is assumed that the relative humidity will approach 100% and the temperature will not drop below 10° C.

REQUIRED DESTRUCTION AND REMOVAL EFFICIENCIES:

The contaminant that drives the design of the gas treatment system is **vinyl chloride**.

System designs are to be based on a minimum DRE for vinyl chloride of 95% (the DRE attainable by an enclosed flare).

Notes:

* Not detected in solid waste area SUMMA canister samples, but were chemicals of concern in RI report (M&E, 1994)

(1) Maximum of four samples. Duplicate samples not averaged prior to identifying maximum.

(2) Shows as 100 mg/m^3 on analytical sheet possibly due to calculation at different temperature.

Metcalf & Eddy, Inc.

30 Harvard Mill Square
Post Office Box 4071
Wakefield, Massachusetts 01880 - 5371 U.S.A.
TEL (617) 246-5200 FAX (617) 224-5927

TELECOPIER TRANSMITTAL SHEET -- PLEASE DELIVER AT ONCE

Date: April 15, 1997

Please deliver the following page(s) to:

Name: Dr. James Kittrell

Location: KSE, Inc.

From: Barbara Weir

FAX TELEPHONE NUMBER IF NOT M&E: (413)-549-5788

Message: Please see attached information that may help when you return my telephone call.
I will be out of the office on Wed. and Fri. all day; in on Tues. and Thurs.
I hope we can talk this week. If not, we can try next week or you can fax me something if more convenient.

TOTAL number of pages being transmitted (including this cover) : 7

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JOB # 020617-0010 DEPT # 2114

Version: 10 / 93

INC.

P.O. BOX 368
AMHERST, MASSACHUSETTS 01004 U.S.A.
(413) 549-5506

April 23, 1997

Ms. Barbara A. Weir
Metcalf & Eddy, Inc.
P.O. Box 4071
Wakefield, Massachusetts 01880-5371

Dear Barbara:

Thank you for your inquiry regarding KSE's **AIR** Process for the photocatalytic destruction of vinyl chloride at the Rose Hill Regional Landfill Superfund Site. As summarized in the enclosures, KSE has experience with a broad range of applications. These include low concentration applications, such as treating the offgas from a groundwater stripper containing chlorinated hydrocarbons. More concentrated streams have also been successfully treated, including soil vapor extraction applications, and industrial process and storage tank vents. During 1996, the technology was demonstrated in the U.S. EPA Superfund Innovative Technology Evaluation (SITE) ETP Program

Based on your letter of April 15, 1997, you wish to treat about 890 SCFM of air, to achieve about 95% destruction of vinyl chloride. A budget estimate for an **AIR** unit would be $75,000 for this application. Operating costs for electricity, and bulb and catalyst replacement, would be about $900 per month, at $0.10/kWh. Of course, you can turn off part of the bulbs to save operating costs as the concentration of vinyl chloride declines during the project operation. Chlorine atoms are converted primarily to chlorine gas. The unit would be confined in a shell of a nominal size of 6 feet cubed, which is to be purged with clean air to provide a system meeting Class I, Division II requirements, for the explosion proofing which we discussed by telephone. An explosion proof blower is included. If these requirements prove unnecessary, the investment would be reduced.

As we discussed, we are now constructing a prototype unit for NASA to oxidize methane, which may ultimately be of interest for your application. Please call me if you have any questions or require additional information.

Sincerely,

J.R. Kittrell
President

Enclosures
JRK/gk

KSE, INC.
Adsorption-Integrated-Reaction (AIR-II) Process

TECHNOLOGY DESCRIPTION:

The Adsorption-Integrated-Reaction (**AIR-II**) Process combines two unit operations, adsorption and chemical reaction, to treat air streams containing volatile organic compounds (VOC's), including chlorinated and nonchlorinated compounds. Such air streams are often found at hazardous waste sites undergoing remediation. For example, groundwater stripping or soil vapor extraction produce large volumes of air containing VOC's that must be removed.

The contaminated air stream containing VOC's flows into the photocatalytic reactor. The VOC's are trapped on the surface of a proprietary catalytic adsorbent. This catalytic adsorbent is continuously illuminated with ultraviolet (UV) light, destroying the concentrated VOC's trapped on the surface by enhanced photocatalytic oxidation. This system design thus simultaneously destroys VOC's and continuously regenerates the catalytic adsorbent. It operates at ambient temperature, as the catalyst is activated by UV light. Only oxygen in the air is needed as a reactant. The reactor design can be varied to include packed beds, annular reactors, or monolithic reactors.

The cleansed effluent air contains carbon dioxide and water, which are carried out in the air stream exiting the reactor. For chlorinated VOC's, the chlorine atoms are converted to hydrogen chloride with some chlorine gas. If needed, these can be removed from the air stream using conventional scrubbers or adsorbents.

The **AIR-II** Process offers advantages over other photocatalytic techniques, due to the high activity, stability, and selectivity of the photocatalyst. The control system is smaller, and offers lower capital investment and power cost. Because the catalytic adsorbent is continuously regenerated, it does not require disposal or regeneration as does traditional carbon adsorption. The **AIR-II** process produces no residual wastes or by-products needing further treatment or disposal as hazardous waste. The process is self-contained and mobile, requires a small amount of space, and requires less energy than thermal incineration or catalytic oxidation. In addition, it has lower total system costs than these traditional technologies.

WASTE APPLICABILITY:

The **AIR-II** Process is designed to treat a wide range of VOC's in air, present at low concentrations from less than 1 ppm to thousands of ppm. VOC's include chlorinated hydrocarbons, aromatic and aliphatic hydrocarbons, alcohols, ethers, ketones, and aldehydes. The **AIR-II** Process is designed to completely destroy these VOC's.

For soil and groundwater remediation, the **AIR-II** Process can be integrated with existing technologies such as thermal desorption, vapor extraction, or

(continued on back)

KSE

air stripping. Hence, the technology destroys VOC's and/or TAP's in the secondary air emissions arising from these remediation methods. The process can also be applied directly for emissions control in process exhausts at industrial facilities.

STATUS:

The **AIR-II** Process has been tested extensively at the laboratory scale and has been field demonstrated in prototype units at concentrations from 1 ppm to over 3000 ppm. Contaminants destroyed include chlorinated hydrocarbons, aliphatic and aromatic hydrocarbons, oxygenates, and ammonia. The process was field demonstrated as part of a groundwater remediation demonstration project at Dover Air Force Base in Dover, DE in 1994. Test results on treating the effluent air from a groundwater stripper showed over 99 percent removal of dichloroethane, from air initially containing about 1 ppm DCA and saturated with water vapor.

The **AIR-II** Process has proven highly effective in control of industrial emissions. Over 99.9% destruction has been achieved for such difficult compounds as methyl chloride, vinyl chloride, and pentane. Of course, traditional carbon adsorption is ineffective for methyl chloride and vinyl chloride. Industrial plant emissions control demonstrations have been conducted for both chlorinated and nonchlorinated contaminants in a pharmaceutical plant, and for pentane emissions control in the expandable polystyrene industry. Indoor air quality control has also been demonstrated.

In 1996, a full scale **AIR-II** Process unit was field demonstrated on a soil vapor extraction (SVE) application at Loring Air Force Base under the Superfund Innovative Technology Evaluation (SITE) Emerging Technology Program. The SVE system operated at the base laundry where the soil was contaminated with tetrachloroethene (PCE). Inlet PCE concentrations started at 100 ppm, and declined as the soil was cleansed. Destruction efficiencies up to 99.8% removal of PCE from the SVE vent gas were demonstrated. A commercial unit is scheduled for use in TCE destruction arising from a SVE application at another Superfund site in 1997.

Studies on the economics of the **AIR-II** Process have shown cost advantages over carbon adsorption for many applications. Investment payout of 1 to 3 months has been shown for TCE in air from a groundwater stripper. The technology is also economically superior to catalytic oxidation, due to operation of the photocatalytic reactor at ambient temperature.

TECHNOLOGY CONTACT:

Dr. J.R. Kittrell, President
KSE, Inc.
P.O. Box 368
Amherst, MA 01004
413-549-5506
413-549-5788 (Fax)

KSE

Air Purification Products Based on Photocatalysis

Features, Advantages and Benefits

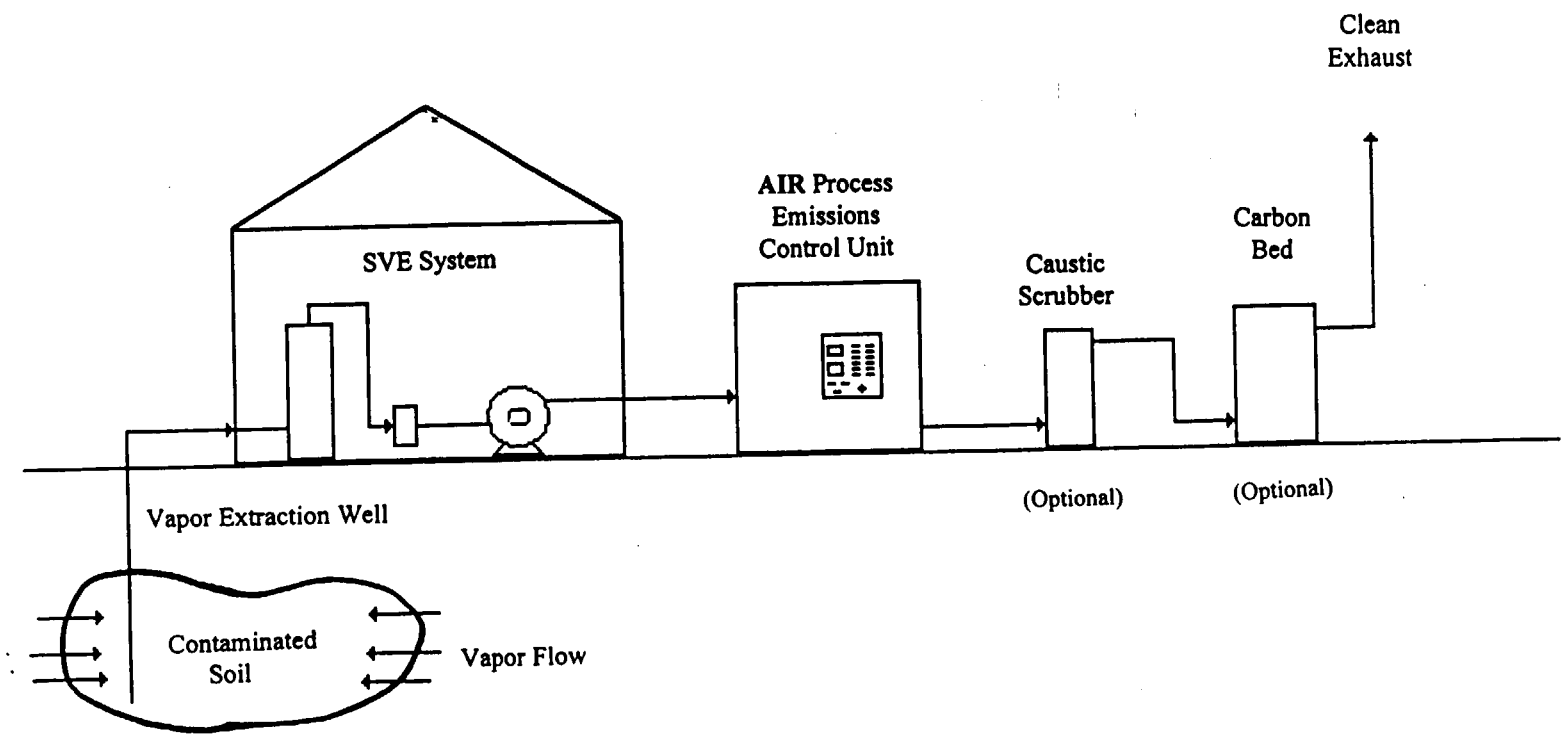
Feature	Advantage	Benefit
UV Light Initiated	Ambient Temperature & Instant ON/OFF	Simplicity & Intermittent Use
High Catalyst Performance	Small Size & Low Energy	Low Cost & IAQ Use
No By-Products	Safety	Regulatory Acceptance

KSE Photocatalytic Applications

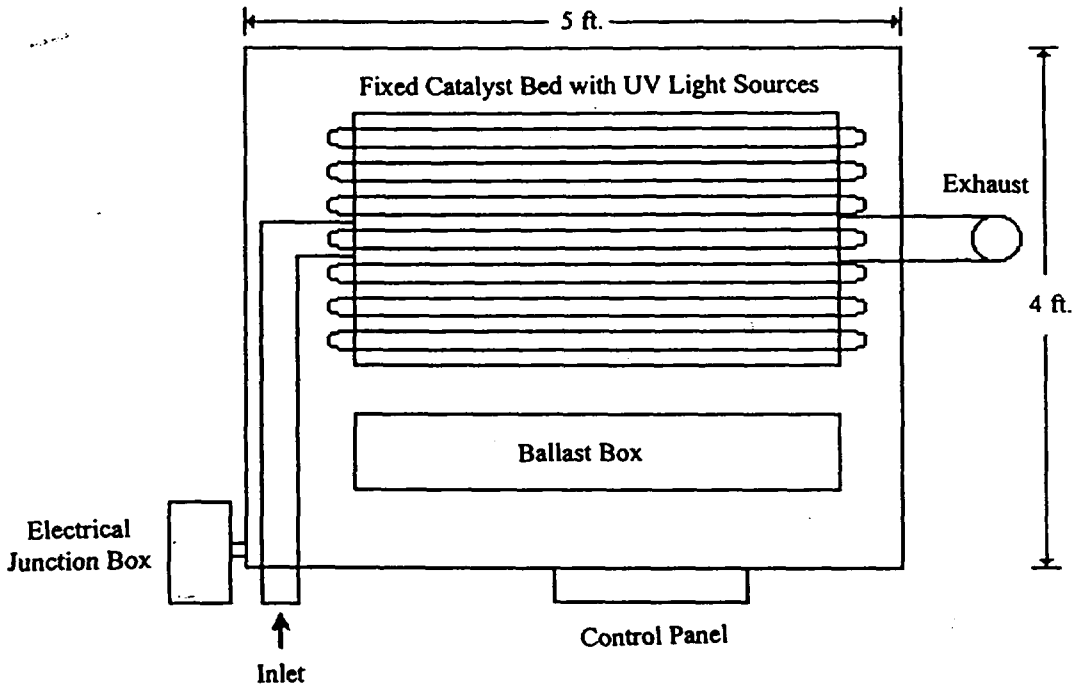
Customer	VOCs Destroyed
Collins & Aikman/Ensafe Superfund SVE (1997)	TCE, DCE, PCE, VC, MC, CB (SVE)
USAF/Battelle/Dover AFB	Dichloroethane (GWS)
USAF/EPA SITE/Loring AFB	Tetrachloroethylene (SVE)
USAF/Misawa AFB (1997)	Carbon Tetrachloride (GWS)
NASA SBIR	Spacecraft Air Revitalization
U.S. EPA SITE (ETP)	Remediation Site Demonstrations
U.S. EPA SBIR	High Selectivity Detection Monitor
NSF SBIR	Solar Destruction of TCE
Schering Plough Corp.	Hexane
Schering Plough Corp.	Methylene Chloride, Methyl Chloride, Butane, Alcohols, Ethers, Ketones
BASF Corporation	Pentane
Tri Manufacturing Corp.	Pentane
Ford Motor Co.	n.d.
Trane Corporation	n.d.

KSE

Schematic of Full Scale **AIR** Photocatalytic Emissions Control System



Cut Sheet for **AIR** Photocatalytic Reactor



Benefits of Innovative Superfund Technology

Superfund Site SVE System

Cost Element	AIR Process	Disposable Carbon(1)
Inlet TCE (Declines)	500 to 50 ppm	500 to 50 ppm
Investment	$50,000	$50,000
Operating Cost	$2,000/yr	$355,000/project

Basis: 8,000 Hours per year
No Caustic Scrubber
Power @ $0.10/kWh
Carbon @ $2/Pound
(1) Source: Remediation Consulting Engineers

KSE

METCALF & EDDY, INC.

TELECON MEMORANDUM

JOB NO. 020617-0010 DATE: 4/24/97

SUBJECT: Rose Hill - Photocatalytic Oxidation

M&E ENGINEER: B. Weir OUTSIDE PARTY: Dr. James Kittrell

MADE CALL ( ) KSE Inc.

REC'D CALL (✓) 413-549-5506

COMMENTS

SUMMARY OF CONVERSATION:

JK: Sent fax w his estimate to me.
Additional Info. he wanted to pass on:
Vinyl Chloride goes mostly to Cl_2 in their unit; less HCl. Experience w Stamina Mills site: RI limits are 2.28 lb Cl_2/hour and ~~2.28~~ 1.14 lb HCl/hour. With conc'n of VC at levels we have, and our flow rate, Cl_2/HCl limits would not be approached. Therefore a scrubber not necessary.
150 ppmv VC → approx. 70 ppmv Cl_2 and 10 ppmv HCl.

CC:

M&E FORM NO. 196 (9/78)

Metcalf & Eddy, Inc.

30 Harvard Mill Square
Post Office Box 4071
Wakefield, Massachusetts 01880 - 5371 U.S.A.
TEL (617) 246-5200 FAX (617) 224-5927

TELECOPIER TRANSMITTAL SHEET -- PLEASE DELIVER AT ONCE

Date: April 15, 1997

Please deliver the following page(s) to:

Name: Mr. Barry Brooks

Location: Process Technologies, Inc.

From: Barbara Weir

FAX TELEPHONE NUMBER IF NOT M&E: (208) 385-0994

Message: Please see attached information regarding Rose Hill that we discussed on the phone.
I will be out of the office on Wed. and Fri. all day; in on Tues. and Thurs. in case you have any questions.

TOTAL number of pages being transmitted (including this cover) : 7

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JOB # 020617-0010 DEPT # 2114

Version: 10 / 93

Metcalf & Eddy
An Air & Water Technologies Company

020617-0010

April 15, 1997

Mr. Barry Brooks
Process Technologies, Inc.
P.O. Box 476
Boise, ID 83701-0476

Subject: **Rose Hill Regional Landfill Superfund Site: Request for Budgetary Estimate and Process Configuration for Treatment of Landfill Gas**

Dear Mr. Brooks:

Metcalf & Eddy (M&E) has been retained by the U.S. EPA to evaluate several promising, innovative treatment technologies for management of landfill gas generated at the Rose Hill Superfund Site in South Kingstown, RI.

A technology developed by your firm, photolytic oxidation, has been identified as a technology to be included in M&E's evaluation. The evaluation is at the feasibility study level.

Characteristics of the gas to be treated are provided in the enclosed spreadsheet and process schematic. If this alternative is implemented, gas will be withdrawn using two collection systems: a perimeter system and an internal system. The perimeter system collects both landfill gas and air; the internal system collects predominantly landfill gas. The gas treatment technology will be implemented to treat the combined gas flows from both systems.

Contaminants of primary concern in the gas are vinyl chloride (influent concentration approximately 149 ppmv) and methane (influent concentration approximately 6 percent by volume). The gas flow rate is estimated to be on the order of 890 standard cubic feet per minute. Relative humidity will approach 100 percent. Hydrogen sulfide and organic sulfide compounds are likely to be present in the gas, in addition to the contaminants identified in the enclosed spreadsheet.

It is understood from the literature that the photocatalytic oxidation technology will not destroy methane, but that it can destroy vinyl chloride and other contaminants of concern effectively. If this understanding is incorrect, and the technology is applicable to methane as well, please bring it to my attention. Note that the gas will be an explosive mixture given the methane concentration (the Lower Explosive Limit for methane is 5%), so explosion-proof equipment will be required.

30 Harvard Mill Square, Wakefield, MA 01880-5371 • Mailing Address: PO Box 4071, Wakefield, MA 01880-5371
TEL: 617-246-5200 FAX: 617-245-6293

Recycled Paper

M&E requests recommended sizing, cut sheets, and budgetary capital and operating costs for a photolytic oxidation system that will treat the influent gas to attain at least 95% destruction of vinyl chloride. Please also define any ancillary equipment requirements. The enclosed process schematic is M&E's attempt to do this; your input would be greatly appreciated.

Please call me at (617) 224-6608 if you have any questions.

Very truly yours,

METCALF & EDDY, INC.

Barbara A. Weir

Barbara A. Weir
Project Engineer

Enclosures

cc: S. Czarniecki
D. Simone

INFLDAT.XLS

Data from Appendix D in the Remedial Investigation Report (M&E, 1994) was used for contaminant concentrations in the Solid Waste Area. Attachment A presents these results as well as a map showing sampling locations. Presented below are conversion calculations for ppbv to mg/m^3, followed by conversion of these concentrations to account for dilution by air that will also be drawn in during gas extraction (the sample data are for "pure" landfill gas, and must be adjusted to account for the air collected by the perimeter and internal collection systems). Contaminants shown were selected by risk assessment personnel.

Locations sampled:
SG-SW(13+300)-12
SG-SW(11+500)-05
SG-SWD(13+300)-12
SG-SW(03+300)-06

Conversion from ppbv to mg/m^3: [from spreadsheet SUMMA.WK1, 8/14/96, prepared by S. Czarniecki]

Based on 760 torr (1 atm.) barometric pressure at 25°C and where 24.45 = molar volume in liters

mg/m^3 = (ppbv * gram molecular weight of substance) / (24.45 * 1000)

Conversion to account for dilution by extracted air:

Assumptions and Calculations:

1. The air does not contain any of the contaminants of concern.
2. The volumetric flow rate of air without landfill gas is 368,000 cm^3/s
   [from calculation by S. Czarniecki dated 8/26/96, spreadsheet COMPOSIT.WK1]
3. The volumetric flow rateof air + landfill gas = total influent to photocatalytic oxidation unit
   = 420,000 cm^3/s
4. Therefore the volumetric flow rate of landfill gas = 420,000 - 368,000
   = 52,000 cm^3/s
5. Concentration of contaminant in influent gas (air + landfill gas) = concentration in landfill gas x (landfill gas flow rate/air + landfill gas flow rate) = concentration x 52,000/420,000

INFLDAT.XLS

Contaminants:	MW	Landfill Gas Concentrations Maximum Detection (ppbv) [1]	(mg/m^3)	Photocatalytic Oxidation Unit Influent Concentrations Maximum Detection (ppbv) [1]	(mg/m^3)
Benzene	78.1	2,500	8.0	310	0.99
1,1-Dichloroethene	97	8,100	32	1,003	3.98
cis-1,2-Dichloroethene	97	5,900,000	23,000	730,476	2,848
trans-1,2-Dichloroethene	97	6,700	27	830	3.29
Ethylbenzene	106.2	5,800	25	718	3.12
Methylene Chloride	84.9	19,000	66	2,352	8.17
Toluene	92.1	62,000	230	7,676	28.48
Trichloroethene	131.4	5,700	31	706	3.79
Vinyl Chloride	**62.5**	**1,200,000**	**3,100**	**148,571**	**383.81**
m,p-Xylene	106.2	9,400	41	1,164	5.06
o-Xylene	106.2	2,500	11	310	1.34
Carbon Disulfide	76.1	280	0.87	35	0.11
Dichlorodifluoromethane	120.9	22,000	110 [2]	2,724	13.62
1,1-Dichloroethane	99	34,000	140	4,210	17.33
4-Methyl-2-pentanone	100.2	1,600	6.6	198	0.81
1,1,2,2-Tetrachloroethane	167.9	0 *	0	0	0
1,1,1-Trichloroethane	133.4	1,900	10	235	1.28
1,2,4-Trimethylbenzene	120.2	500	2	62	0.30
1,3,5-Trimethylbenzene	120.2	870	4.3	108	0.53
Acetone	58.1	0 *	0	0	0
1,2,4-Trichlorobenzene	181.5	0 *	0	0	0

INFLDAT.XLS

Major Components of Influent Gas to the Photocatalytic Oxidation System are: Methane, Carbon Dioxide, Nitrogen, and Oxygen

The percentages (by volume) of these gases [from spreadsheet COMPOSIT.WK1, dated 8/26/96, prepared by S. Czarniecki] are:

Percent by volume Methane (CH_4):	6.18
Percent by volume Carbon Dioxide (CO_2):	6.18
Percent by volume Nitrogen (N_2):	69.24
Percent by volume Oxygen (O_2):	18.41

Relative Humidity and Temperature of Influent Gas to the Photocatalytic Oxidation System:

Given the source of the gas, it is assumed that the relative humidity will approach 100% and the temperature will not drop below 10° C.

REQUIRED DESTRUCTION AND REMOVAL EFFICIENCIES:

The contaminant that drives the design of the gas treatment system is **vinyl chloride**.

System designs are to be based on a minimum DRE for vinyl chloride of 95% (the DRE attainable by an enclosed flare).

Notes:

* Not detected in solid waste area SUMMA canister samples, but were chemicals of concern in RI report (M&E, 1994)

(1) Maximum of four samples. Duplicate samples not averaged prior to identifying maximum.

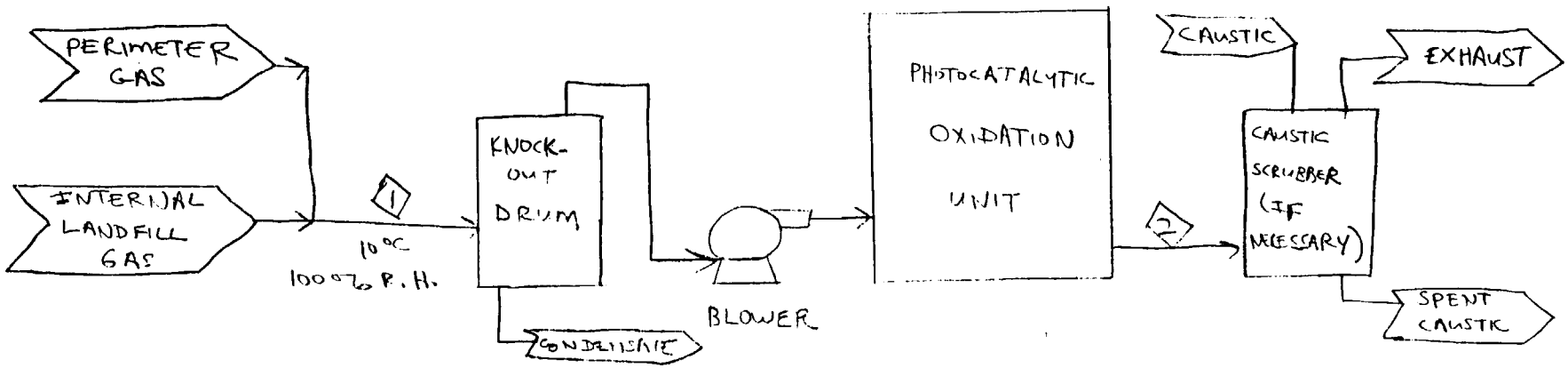
(2) Shows as 100 mg/m^3 on analytical sheet possibly due to calculation at different temperature.

METCALF & EDDY, ENGINEERS

ROSE HILL TECHNOLOGY SCREENING

LANDFILL GAS ALTERNATIVES:

PHOTO CATALYTIC OXIDATION PROCESS SCHEMATIC



GAS STREAM	FLOW, scm^3/s	FLOW, scfm	CH_4 %	CO_2 %	N_2 %	O_2 %	VINYL CHLORIDE mg/m^3	VINYL CHLORIDE ppbv
1	420,000	890	6.18	6.18	69.24	18.41	384	148,571
2	420,000	890	6.18	6.18	69.24	18.41	19.2	7,428

ASSUMES NEGLIGIBLE CHANGES THROUGH PHOTOCATALYTIC SYSTEM

ASSUMES 95% DESTRUCTION

Project: ROSE HILL FS
Subject: PHOTOCATALYTIC OXIDATION
Detail: SCHEMATIC
Acct. No.: 02361-0010
Compd. By: B. WEIR
Ck'd. By:
Date: 4/14/97
Page 1 of 1

Double-Sided

TELECON MEMORANDUM

METCALF & EDDY, INC.

JOB NO. 020617-0010 DATE: 4/23/97

SUBJECT: Rose Hill - Photolytic Oxidation - Follow Up Call

M&E ENGINEER: B. Weir OUTSIDE PARTY: Barry Brooks

MADE CALL (✓) PTI, Inc.

REC'D CALL ( ) 208-385-0900

COMMENTS

SUMMARY OF CONVERSATION:

B. Brooks reviewed my fax. 2 options he thinks feasible:

(1) Pretreat to remove CH_4 (Bioreactor) → VOC adsorber/concentrator → 9 Photolytic Units (in parallel) to destroy VOCs.

Capital cost (9 photolytic units + adsorber/concentrator) = $500K.

Operating cost: $1500/month/photolytic unit.

(2) Pretreat to remove CH_4 (Bioreactor) → VOC adsorber/concentrator → Condenser → condensate to off-site disposal; Condenser → Condenser off-gas → 3 Photolytic Units (in parallel) to destroy VOCs

CC:

over →

Capital cost (absorber/concentrator + condenser + 3 photolytic units) = \$350K

Op. cost: \$1500/month/photo. unit
[Does not include cost to dispose of condensate].

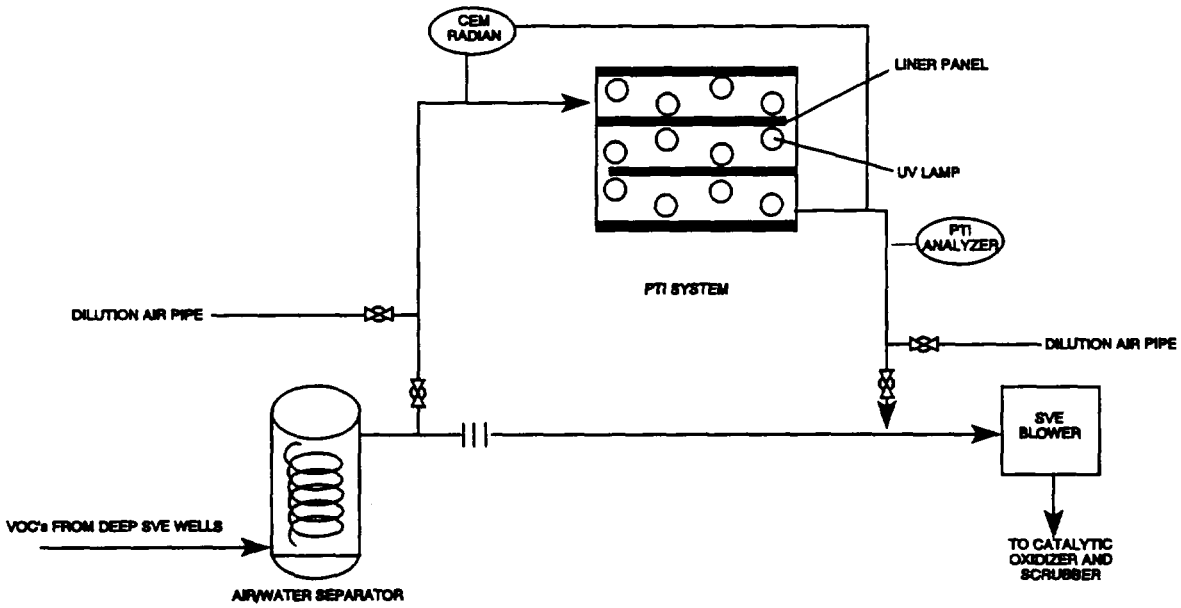
Option (2) is generally preferred.
With Option (1), sometimes have to dilute gas stream to stay below 25% LEL so need more units.
Probably cheaper [unless can't get rid of condensate economically - we discussed - cost probably not prohibitive unless it's classified as RCRA F-listed waste.

PROCESS TECHNOLOGIES, INC.
(Photolytic Destruction for SVE Off-Gases)

TECHNOLOGY DESCRIPTION:

Process Technologies, Inc.'s (PTI), halocarbon and volatile organic compound (VOC) destruction technology photolyzes vapor-phase halogens. The resulting radicals react with cementitious liners to produce a clean air stream. One of the key features and advantages of the technology is its simplicity - there are no moving parts, and its modular design allows for easy scale-up.

During the demonstration, off-gas from an existing soil vapor extraction system (SVE) will be treated by the PTI photolytic process. PTI's equipment operates using low pressure mercury lamps. High intensity UV light at 185 and 254 nanometers generated by the mercury lamps destabilizes and facilitates the breakdown of VOC contamination in the SVE exhaust gas stream. A proprietary liner material present in the light zone captures and neutralizes the resulting process by-products. Extensive testing has proven that the use of the cementitious liner material prevents the formation of undesirable species, such as chlorine, phosgene, and hydrochloric acid. This design is unique to PTI's photolytic process. The gaseous products exiting the system include air, water vapor, and carbon dioxide. The liners are replaced as needed and PTI claims that the cementitious material can be recycled as an ingredient in cement or disposed of as nonhazardous waste, regulations permitting.



Simplified Schematic Process Flow Diagram
of Photolytic Destruction

The SITE Program assesses but does not approve or endorse technologies.

WASTE APPLICABILITY:

The PTI technology treats air and gases contaminated with VOCs, including chlorinated VOCs, and chlorofluorocarbons.

STATUS:

The PTI technology was accepted into the SITE Demonstration Program in summer 1994. The demonstration began in September 1994 at McClellan Air Force Base, in Sacramento, California.

FOR FURTHER INFORMATION:

EPA PROJECT MANAGER:
Laurel Staley
U.S. EPA
Risk Reduction Engineering Laboratory
26 West Martin Luther King Drive
Cincinnati, OH 45268
513-569-7863
Fax: 513-569-7620

TECHNOLOGY DEVELOPER CONTACT:
Mike Swan
Process Technologies, Inc.
P.O. Box 476
Boise, ID 83701-0476
208-385-0900
Fax: 208-385-0994

Steve Hodge
SM-ALC/EMR
5050 Dudley Boulevard
Suite 3
McClellan AFB, CA 95652-1389
916-643-0830
Fax: 916-643-0827

The SITE Program assesses but does not approve or endorse technologies.

Metcalf & Eddy, Inc.

30 Harvard Mill Square
Post Office Box 4071
Wakefield, Massachusetts 01880 - 5371 U.S.A.
TEL (617) 246-5200 FAX (617) 224-5927

TELECOPIER TRANSMITTAL SHEET -- PLEASE DELIVER AT ONCE

Date: April 15, 1997

Please deliver the following page(s) to:

Name: Mr. Doug Garside

Location: Matrix Photocatalytic Inc.

From: Barbara Weir

FAX TELEPHONE NUMBER IF NOT M&E: 519- (509) 660-8525

Message: Please see attached information regarding Rose Hill that we discussed on the phone.
I will be out of the office on Wed. and Fri. all day; in on Tues. and Thurs. in case you have any questions.

TOTAL number of pages being transmitted (including this cover) : 7

PLEASE TELEPHONE THE M&E MAILROOM IF YOU DO NOT RECEIVE THE CORRECT NUMBER OF PAGES -- 617 / 224 - 6296

FOR WAKEFIELD USE ONLY:

DO YOU WANT ORIGINAL BACK ? YES [XXX] NO [ ]

JOB # 020617-0010 DEPT # 2114

Version: 10 / 93

Metcalf & Eddy
An Air & Water Technologies Company

020617-0010

April 15, 1997

Mr. Doug Garside
Matrix Photocatalytic, Inc.
22 Pegler Street
London, Ontario, Canada
N5Z 2B5

Subject: **Rose Hill Regional Landfill Superfund Site: Request for Budgetary Estimate and Process Configuration for Treatment of Landfill Gas**

Dear Mr. Garside:

Metcalf & Eddy (M&E) has been retained by the U.S. EPA to evaluate several promising, innovative treatment technologies for management of landfill gas generated at the Rose Hill Superfund Site in South Kingstown, RI.

A technology developed by your firm, photocatalytic oxidation, has been identified as a technology to be included in M&E's evaluation. The evaluation is at the feasibility study level.

Characteristics of the gas to be treated are provided in the enclosed spreadsheet and process schematic. If this alternative is implemented, gas will be withdrawn using two collection systems: a perimeter system and an internal system. The perimeter system collects both landfill gas and air; the internal system collects predominantly landfill gas. The gas treatment technology will be implemented to treat the combined gas flows from both systems.

Contaminants of primary concern in the gas are vinyl chloride (influent concentration approximately 149 ppmv) and methane (influent concentration approximately 6 percent by volume). The gas flow rate is estimated to be on the order of 890 standard cubic feet per minute. Relative humidity will approach 100 percent. Hydrogen sulfide and organic sulfide compounds are likely to be present in the gas, in addition to the contaminants identified in the enclosed spreadsheet.

It is understood from the literature that the photocatalytic oxidation technology will not destroy methane, but that it can destroy vinyl chloride and other contaminants of concern effectively. If this understanding is incorrect, and the technology is applicable to methane as well, please bring it to my attention. Note that the gas will be an explosive mixture given the methane concentration (the Lower Explosive Limit for methane is 5%), so explosion-proof equipment will be required.

30 Harvard Mill Square, Wakefield, MA 01880-5371 • Mailing Address: PO Box 4071, Wakefield, MA 01880-5371
TEL: 617-246-5200 FAX: 617-245-6293

Recycled Paper

M&E requests recommended sizing, cut sheets, and budgetary capital and operating costs for a photocatalytic oxidation system that will treat the influent gas to attain at least 95% destruction of vinyl chloride. Please also define any ancillary equipment requirements. The enclosed process schematic is M&E's attempt to do this; your input would be greatly appreciated.

Please call me at (617) 224-6608 if you have any questions.

Very truly yours,

METCALF & EDDY, INC.

Barbara A. Weir

Barbara A. Weir
Project Engineer

Enclosures

cc: S. Czarniecki
D. Simone

INFLDAT.XLS

Data from Appendix D in the Remedial Investigation Report (M&E, 1994) was used for contaminant concentrations in the Solid Waste Area. Attachment A presents these results as well as a map showing sampling locations. Presented below are conversion calculations for ppbv to mg/m^3, followed by conversion of these concentrations to account for dilution by air that will also be drawn in during gas extraction (the sample data are for "pure" landfill gas, and must be adjusted to account for the air collected by the perimeter and internal collection systems). Contaminants shown were selected by risk assessment personnel.

Locations sampled:
SG-SW(13+300)-12
SG-SW(11+500)-05
SG-SWD(13+300)-12
SG-SW(03+300)-06

Conversion from ppbv to mg/m^3: **[from spreadsheet SUMMA.WK1, 8/14/96, prepared by S. Czarniecki]**

Based on 760 torr (1 atm.) barometric pressure at 25°C and where 24.45 = molar volume in liters

mg/m^3 = (ppbv * gram molecular weight of substance) / (24.45 * 1000)

Conversion to account for dilution by extracted air:

Assumptions and Calculations:

1. The air does not contain any of the contaminants of concern.
2. The volumetric flow rate of air without landfill gas is 368,000 cm^3/s
   [from calculation by S. Czarniecki dated 8/26/96, spreadsheet COMPOSIT.WK1]
3. The volumetric flow rateof air + landfill gas = total influent to photocatalytic oxidation unit
   = 420,000 cm^3/s
4. Therefore the volumetric flow rate of landfill gas = 420,000 - 368,000
   = 52,000 cm^3/s
5. Concentration of contaminant in influent gas (air + landfill gas) = concentration in landfill gas x (landfill gas flow rate/air + landfill gas flow rate) = concentration x 52,000/420,000

INFLDAT.XLS

Contaminants:	MW	Landfill Gas Concentrations Maximum Detection (ppbv) [1]	(mg/m³)	Photocatalytic Oxidation Unit Influent Concentrations Maximum Detection (ppbv) [1]	(mg/m³)
Benzene	78.1	2,500	8.0	310	0.99
1,1-Dichloroethene	97	8,100	32	1,003	3.98
cis-1,2-Dichloroethene	97	5,900,000	23,000	730,476	2,848
trans-1,2-Dichloroethene	97	6,700	27	830	3.29
Ethylbenzene	106.2	5,800	25	718	3.12
Methylene Chloride	84.9	19,000	66	2,352	8.17
Toluene	92.1	62,000	230	7,676	28.48
Trichloroethene	131.4	5,700	31	706	3.79
Vinyl Chloride	**62.5**	**1,200,000**	**3,100**	**148,571**	**383.81**
m,p-Xylene	106.2	9,400	41	1,164	5.06
o-Xylene	106.2	2,500	11	310	1.34
Carbon Disulfide	76.1	280	0.87	35	0.11
Dichlorodifluoromethane	120.9	22,000	110 [2]	2,724	13.62
1,1-Dichloroethane	99	34,000	140	4,210	17.33
4-Methyl-2-pentanone	100.2	1,600	6.6	198	0.81
1,1,2,2-Tetrachloroethane	167.9	0 *	0	0	0
1,1,1-Trichloroethane	133.4	1,900	10	235	1.28
1,2,4-Trimethylbenzene	120.2	500	2	62	0.30
1,3,5-Trimethylbenzene	120.2	870	4.3	108	0.53
Acetone	58.1	0 *	0	0	0
1,2,4-Trichlorobenzene	181.5	0 *	0	0	0

INFLDAT.XLS

Major Components of Influent Gas to the Photocatalytic Oxidation System are: Methane, Carbon Dioxide, Nitrogen, and Oxygen

The percentages (by volume) of these gases [from spreadsheet COMPOSIT.WK1, dated 8/26/96, prepared by S. Czarniecki] are:

Percent by volume Methane (CH_4):	6.18
Percent by volume Carbon Dioxide (CO_2):	6.18
Percent by volume Nitrogen (N_2):	69.24
Percent by volume Oxygen (O_2):	18.41

Relative Humidity and Temperature of Influent Gas to the Photocatalytic Oxidation System:

Given the source of the gas, it is assumed that the relative humidity will approach 100% and the temperature will not drop below 10° C.

REQUIRED DESTRUCTION AND REMOVAL EFFICIENCIES:

The contaminant that drives the design of the gas treatment system is **vinyl chloride**.

System designs are to be based on a minimum DRE for vinyl chloride of 95% (the DRE attainable by an enclosed flare).

Notes:

* Not detected in solid waste area SUMMA canister samples, but were chemicals of concern in RI report (M&E, 1994)

(1) Maximum of four samples. Duplicate samples not averaged prior to identifying maximum.

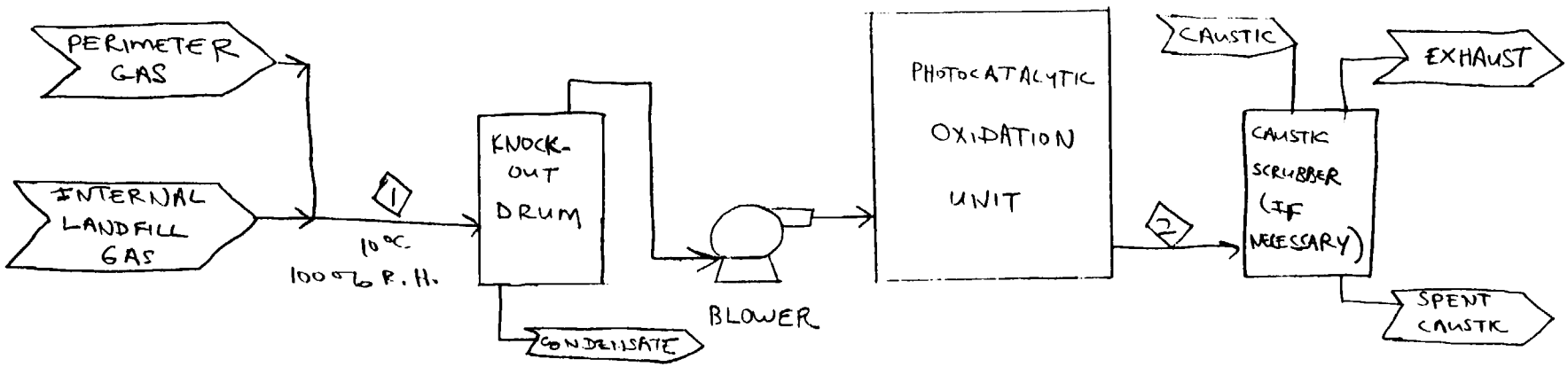
(2) Shows as 100 mg/m^3 on analytical sheet possibly due to calculation at different temperature.

METCALF & EDDY, ENGINEERS

ROSE HILL TECHNOLOGY SCREENING

LANDFILL GAS ALTERNATIVES:

PHOTO CATALYTIC OXIDATION PROCESS SCHEMATIC



GAS STREAM	FLOW, scm^3/s	FLOW, scfm	CH_4 %	CO_2 %	N_2 %	O_2 %	VINYL CHLORIDE mg/m³	VINYL CHLORIDE ppbv
1	420,000	890	6.18	6.18	69.24	18.41	384	148,571
2	420,000	890	6.18	6.18	69.24	18.41	19.2	7,428

ASSUMES NEGLIGIBLE CHANGES THROUGH PHOTOCATALYTIC SYSTEM

ASSUMES 95% DESTRUCTION

Project: ROSE HILL FS
Subject: PHOTO CATALYTIC OXIDATION
Detail: SCHEMATIC
Ck'd. By:
Date:
Acct. No.: 020617-0010
Compd. By: B. WEIR
Date: 4/14/97
Page: 1 of 1

MATRIX
PHOTOCATALYTIC INC.

FACSIMILE COMMUNICATION

Date: April 24/97 **Fax Number:** (617) 224-5927

PLEASE DELIVER MESSAGE

[redacted] **Company Name:** METCALF & EDDY

From: Doug Garside **# of Pages Including Cover:** 9

MESSAGE

PLEASE FIND FOLLOWING OUR QUOTE FOR YOUR ROSE HILL PROJECT. DO NOT HESITATE TO CONTACT ME WITH ANY NEEDS. I LOOK FORWARD TO WORKING TOGETHER.

BEST REGARDS,

22 Pegler Street, London, Ontario, Canada N5Z 2B5 • phone (519) 660-8669 fax (519) 660-8525

MATRIX
PHOTOCATALYTIC INC.

April 24, 1997

Ms. Barbara Weir
Metcalf and Eddy, Inc.
30 Harvard Mill Square
Post Office Box 4071
Wakefield, MA
01880-5371, USA

Fax To: (617) 224-5927

RE: Rose Hill Landfill Superfund Site

Dear Ms. Weir,

Thank you for the opportunity to provide a quote for your project.

Technical Overview

I. Summary

Matrix Photocatalytic Inc. has successfully developed an innovative TiO_2 Photocatalytic Technology for the destruction of organics in air. Landfill gas contaminated with vinyl chloride would provide an excellent application for this powerful, on-site remediation alternative.

The TiO_2 photocatalytic technology would cleave organic bonds using both reductive and oxidative mechanisms to destroy hazardous contaminants present in the gas by breaking them down into low molecular weight, building block constituents. The technology is effective with a wide variety of contaminants, over a broad range of concentrations, and operates at ambient temperatures. The Matrix TiO_2 Photocatalytic Technology performs exceedingly well on unsaturated aliphatic, aromatic, and chlorinated compounds. Contaminants are remediated on site, producing no secondary wastes or sludges. The equipment is quiet, intrinsically safe, and particularly robust in its design.

22 Pegler Street, London, Ontario, Canada N5Z 2B5 • phone (519) 660-8669 fax (519) 660-8525

Rose Hill Landfill (cont'd)

Existing oxidation technologies traditionally use large energy inputs to achieve the high thermal states required to oxidize gaseous contaminants, and will produce nitrous oxide by-products from fossil fuels used. Chlorinated solvents are known to present difficulties for thermal oxidation technologies due to a relatively low combustion value. Also, numerous chlorinates rapidly breakthrough carbon adsorption beds reducing their feasibility.

Matrix has overcome these traditional technology drawbacks through the utilization of a extremely "active" and robust TiO_2 photocatalyst in a fully optimized reactor. Sizable treatment savings are achievable over existing technologies.

On-site demonstrations may be performed with a Matrix Photocatalytic TiO_2 Mobile Unit, containing full scale equipment, inside a 16' x 8' trailer which is towed by a pickup truck or shipped to site. Once on site, the Matrix Mobile Unit may be plumbed inline, connected to 240VAC/single phase/100Amp electrical service, and operational in the same day. The Mobile equipment is designed for rapid optimization of the technology. Retention time, flow rate and chemical input are all variable. The same equipment may be used to test a variety of different streams or scenarios when applicable.

II. Objectives

1. Demonstrate the ability of the Matrix Photocatalytic TiO_2 Technology to remediate landfill gas contaminated with vinyl chloride.

2. Distinguish the numerous advantages of the technology's use in remediation of air borne vinyl chloride.

3. Establish cost savings over baseline technologies.

III. Development History of the Matrix Photocatalytic TiO_2 Technology

The Matrix Photocatalytic TiO_2 Technology was invented in 1988, and was subsequently patented January, 1990 (US Patent #4,892,712) followed with associated enhancement patents (US Patents (4,966,759), (5,032,241), and (5,126,111).

Matrix Photocatalytic Inc. (formerly Nutech Environmental) is an organization with a proven track record of developing new "high technology" products and bringing them to market. Matrix has successfully finished, ahead of schedule, and within budget, Co-

Rose Hill Landfill (cont'd)

funded Research and Development projects in TiO_2 photocatalysis with the United States Environmental Protection Agency (US EPA), National Research Council of Canada (NRC), and the Ontario Ministry of the Environment and Energy (MOEE). This prior work has totalled over $3 million, 50% of which has been company funded. The company has also successfully organized the First International Conference on TiO_2 Photocatalytic Purification and Treatment of Water and Air, with over 250 attendees. Support for the conference was received from the US DOD , among others.

Matrix has conducted or supplied equipment for 15 on-site pilot demonstrations which include: McClellan AFB, Wastewater Technology International (WTI, part of the Canadian Center for Inland Waters), Atomic Energy Canada Limited (AECL), K-25 Site (DOE), Tyndall AFB, Wurtsmith AFB, Savannah River (DOE), NASA Houston, Nuclear Fuel Services (NFS), State of Maine, and others over the past few years, all with great success.

IV. Process Chemistry of the Matrix Photocatalytic TiO_2 Technology

The Matrix Photocatalytic TiO_2 Technology is a state-of-the-art environmental technology designed to destroy organic contaminants in fluids (water and air). The technology utilizes the semiconductor properties of TiO_2 to photo-generate a wide variety of oxidative and reductive species which readily cleave the component bonds of organic contaminants. When incident light, of sufficient wavelength, irradiates the TiO_2 catalyst, an electron is emitted from the valence orbital into the conductive orbital where it may participate in oxidative reactions. The hole remaining in the valence orbital, from the electron elevation, may participate in reductive reactions. The elevated electron is in an energized, unstable state and will return to the valence band if not immediately consumed. The employment of Irreversible Electron Acceptors (IEA's) is used to prevent electron - hole recombination and substantially increase photon utilization efficiency. IEA's, such as ozone consume the orbital electrons to generate additional oxidation species, and leave the powerful electron - holes which can act to tear apart organics. The Matrix system has shown dramatically increased reaction rates with the addition of small amounts of an IEA.

Key Advantages of the Matrix Photocatalytic TiO_2 Technology are:

- the use of a highly refined and extremely "active" sol-gel TiO_2 catalyst
- utilization of its patented glass cloth substrate to provide enormous surface area for catalyst/contaminant reaction interface
- the implementation of a fully optimized photocatalytic reactor design

Rose Hill Landfill (cont'd)

- 10 years of "hands on" photocatalysis expertise, a pioneer in the field
- destruction of pollutants at source (eliminates handling)
- very low life cycle costs because of high reliability, minimal maintenance, and no operator requirement.
- utilizes standard electrical input (220VAC/single phase)
- quiet, low profile aesthetic solution
- proven capable of remediating a wide range of contaminants in varying concentrations
- TiO_2 is an extremely stable compound with extremely low toxicity
- dechlorination is faster than any other technology
- modular reactor design allows easy scaling for future concentration fluctuations
- continuous research and enhancements .

V. Equipment Specifications

i) Raw Equipment Requirements:

1. 5 pieces - Matrix Air Phase TiO_2 Photocatalytic Units - plumbed in parallel, explosion proof, shipped ready for "flick of the switch" operation (see profile drawing)

2. Irreversible Electron Acceptor System - Ozone Generators and Injection System

3. Post Treatment: Caustic Scrubber - Spray Tower
   - sensing, valve, and pump to self adjust to varying acidic outputs

4. Aux. Treatment: Matrix Aqueous Phase TiO_2 Photocatalytic Unit
   - small system to remediate liquid condensate from knock out on site.

ii) Equipment Cost - Outright Purchase

1. Matrix Air Phase Photocatalytic Units -	$US 268,000.00	(5 pieces)
2. Irreversible Electron Acceptor System -	$US 18,000.00	(5 pieces)
3. Caustic Scrubber -	$US 22,000.00	(1 piece)
4. Matrix Aqueous Phase Unit -	$US 2,000.00	(1 piece)

* Rental options may be negotiated

Rose Hill Landfill (cont'd)

iii) Estimated Direct Remediation Cost

Electrical Consumption - each Matrix Unit rated at 2kW - total = 10kW
assume - +15% additional for auxiliary usage
- electricity cost @ $0.08 per kWh
$ US 0.92 per hour of operation at full capacity

iv) Estimated Annual Maintenance Cost

1. UV Lamp Change Out - manufacturer recommends 10,000hr life span
   240 lamps @ $ US 25.00ea. = $ US 6,000.00/10,000hrs. use
   - estimated labor 4 hours for 1 technician

2. TiO_2 Catalyst Change Out - variable with stream conditions, average every 3 years
   245 TiO_2 catalyst sections @ $ US 150.00ea. = $ US 12,250.00/a.
   - estimated labor 12 hours for 1 technician

- equipment provided with technical training for operation and servicing
- equipment warranted for 1 year against defects in workmanship for all parts, except those covered by a separate manufacturers warranty, under Matrix authorized operation.

VI. Recommendations:

On-site demonstration with full scale Matrix equipment.

Rose Hill Landfill (cont'd)

This is an excellent opportunity for the Matrix TiO2 Photocatalytic Technology and we are eager to proceed with the project. The quote ideally gives a solid outline of the technology, should you require any further information or have an questions do not hesitate to contact me.

Sincerely,

Doug Garside

MATRIX PHOTOCATALYTIC INC.
(formerly NUTECH ENVIRONMENTAL)
(TiO_2 Photocatalytic Air Treatment)

TECHNOLOGY DESCRIPTION:

Matrix Photocatalytic Inc., formerly Nutech Environmental, is developing a titanium dioxide (TiO_2) photocatalytic air treatment technology that removes and destroys volatile organic compounds (VOC) and semivolatile organic compounds from air streams. During treatment, contaminated air at ambient temperatures flows through a fixed TiO_2 catalyst bed activated by light. Typically, organic contaminants are destroyed in fractions of a second.

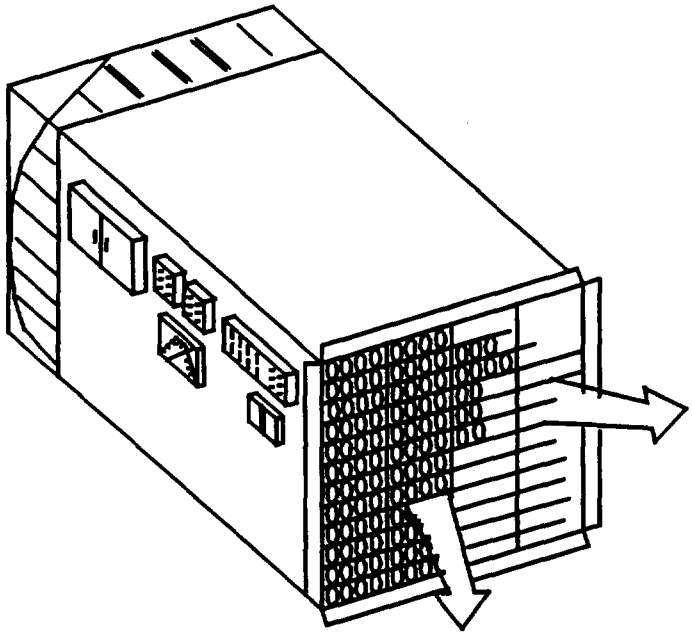
Major technology advantages include the following:

- Very robust equipment
- No residual toxins
- No ignition source
- Unattended operation
- Low direct treatment cost

The technology has been tested on benzene, toluene, ethylbenzene, and xylene; trichloroethene (TCE); tetrachlorethene (PCE); isopropyl alcohol; acetone; chloroform; methanol; and methyl ethyl ketone. Some full-scale and field-scale systems are shown in the figures below and on the next page, respectively.

WASTE APPLICABILITY:

The TiO_2 photocatalytic air treatment technology can effectively treat dry or moist air. The technology has been demonstrated to purify steam directly, thus eliminating the need to condense. Systems of 100 cubic feet per minute have been successfully tested on vapor extraction operations, air stripper emissions, steam from desorption processes, and VOC emissions from manufacturing facilities. Other potential applications include odor removal, stack gas



Full-Scale Photocatalytic Air Treatment System

The SITE Program assesses but does not approve or endorse technologies.

treatment, soil venting, and manufacturing ultra-pure air for residential, automotive, instrument, and medical needs. Systems up to about 1000 cubic foot per meter can be cost competitive with thermal destruction systems.

STATUS:

The TiO_2 photocatalytic air technology was accepted into SITE Emerging Technology Program in October 1992. Program advancements include the following:

- Ability to destroy carbon tetrachloride and other saturated compounds
- Sustained destruction of PCE and TCE of high concentration without generating phosgene
- Effective destruction of oxygenates (ketones, alcohols)

FOR FURTHER INFORMATION:

EPA PROJECT MANAGER:
John Ireland
U.S. EPA
Risk Reduction Engineering Laboratory
26 West Martin Luther King Drive
Cincinnati, OH 45268
513-569-7413
Fax: 513-569-7185

TECHNOLOGY DEVELOPER CONTACT:
Bob Henderson
Matrix Photocatalytic Inc.
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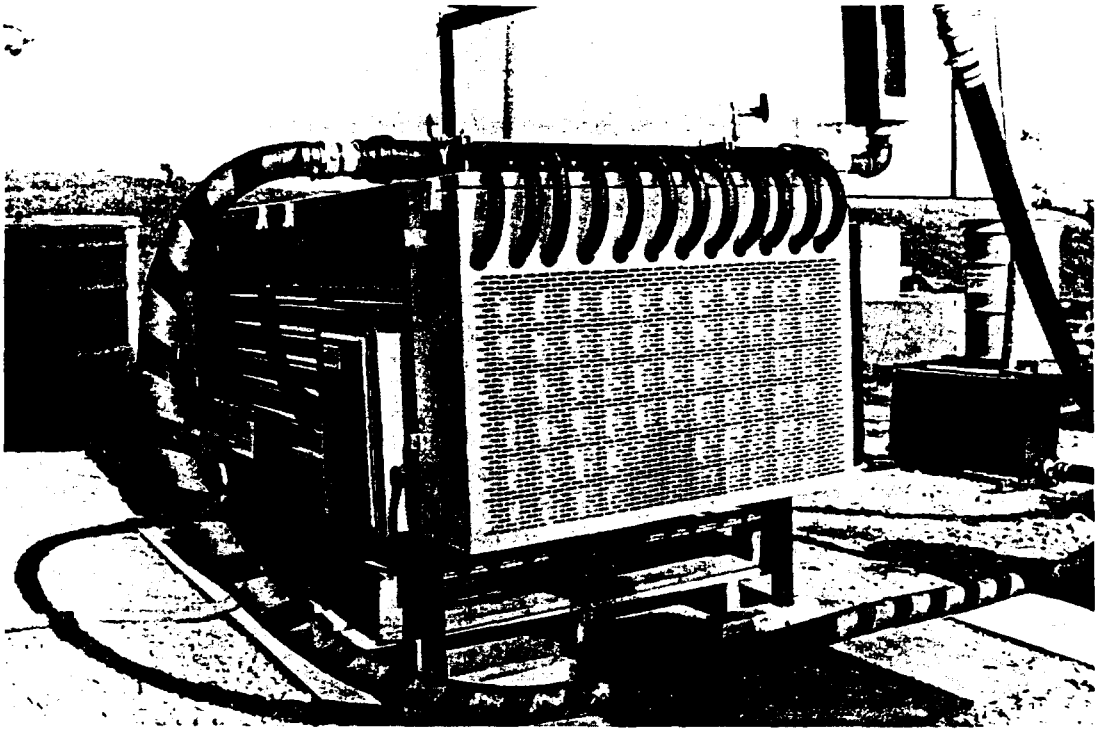
London, Ontario, Canada
N5Z 2B5
519-660-8669
Fax: 519-660-8525



Field-Scale Photocatalytic Air Treatment System Treating TCE and PCE on a Soil Vapor Extraction Site at Savannah River

The SITE Program assesses but does not approve or endorse technologies.

ATTACHMENT B:

LANDFILL MINING COST ESTIMATE

Project	Rose Hill Technology Screening	Acct. No.	020617-0010	Page	1 of 3
Subject	Landfill Mining Alternative	Comptd. By	B. Weir	Date	June 2, 1997
Detail	Order-of-Magnitude Cost Estimate	Ck'd.By	S. Czarniecki	Date	June 5, 1997

BASIS OF ESTIMATE:

	Cubic Yards
Recyclable scrap metal volume	37,500
Reusable soil volume	45,600
Non-recyclable waste volume	30,900
Total waste volume	114,000

Item	Activity	Unit	Unit Cost	Quantity	Total Cost	Source
1.0	Site Preparation: Bulky Waste Area					
	1.1 Chain Link Fencing	lf	13.77	2,020	$27,815	M&E, 1996
	1.2 Clearing and Grubbing	acre	297	7	$2,079	M&E, 1996
	1.3 Silt Fencing	lf	1.16	2,796	$3,243	M&E, 1996
2.0	Haul Road to Solid Waste Area (24 ft x 600 ft)					
	2.1 Geotextile filter fabric	sy	2.7	1,600	$4,320	Port Engineering, 1996
	2.2 Crushed stone, 12" thick	cy	20	533	$10,667	Port Engineering, 1996
3.0	Landfill Mining Operation					
	Remove waste from landfill and segregate into 3 types	cy	9	114,000	$1,026,000	Port Engineering, 1996; Phase IV value
4.0	Disposition of Mined Wastes					
	4.1 Transport scrap metal to Metals Recycling, Johnston, RI 20 cy per load, 2 hours per load, $50/hour = $5/cy	cy	5	37,500	$187,500	Goldberg, H., 1997
	4.2 Transport non-recyclables to Solid Waste Area: 20 cy per load, 1 hour per load, $30/hour = $1.50 /cy	cy	1.50	30,900	$46,350	M&E estimate

Project	Rose Hill Technology Screening	Acct. No.	020617-0010	Page	2 of 3
Subject	Landfill Mining Alternative	Comptd. By	B. Weir	Date	June 2, 1997
Detail	Order-of-Magnitude Cost Estimate	Ck'd.By	S. Czarniecki	Date	June 5, 1997

Item	Activity	Unit	Unit Cost	Quantity	Total Cost	Source
5.0	Supervision and Monitoring of Mining 114,000 cy at 1,000 cy/day = 114 days	day	300	114	$34,200	Port Engineering, 1996
6.0	Restoration of Bulky Waste Area					
	6.1 Backfill with reclaimed soil	cy	2.15	45,600	$98,040	M&E, 1996
	6.2 Backfill with clean fill	cy	7.15	50,000	$357,500	M&E, 1996 (quant. assumed)
	6.3 Vegetation	msf	47.52	322	$15,301	M&E, 1996
7.0	Allowances					
	7.1 Increased size of Solid Waste Area cap @ 10% of previous cap cost estimate	ls			$198,300	M&E, 1996
	7.2 Hazardous waste disposal	ls			$10,000	
	7.3 Extraction/reinjection system for dewatering (not incl. treatment)	ls			$50,000	
	7.4 Health & safety training, equipment	ls			$37,000	
	7.5 Water Treatment (capital + 1 yr. O&M)	ls			$375,000	M&E estimate
	TOTAL ITEMS 1 THROUGH 7				$2,483,316	
8.0	Revenue from Sale of Scrap Metal $0.02 per lb; 800 lb metal/cy; 37,500 cy scrap	lb	0.02	30,000,000	$600,000	Goldberg, 1997
	ITEMS 1 THROUGH 7, LESS 8				$1,883,316	
	Engineering at 6% of total				$112,999	
	Contingency at 20% of total				$376,663	
	GRAND TOTAL				$2,372,978	

SOURCES

Port Engineering, 1996. Newbury Municipal Solid Waste Program Landfill Reclamation Mining Demonstration Phase III Final Report - August 27, 1994 through November 9, 1994. Report from Paul D. Turbide, Port Engineering Associates, Inc., to Edward H. MacDonald, Regional Engineer for Waste Protection, Commonwealth of Massachusetts, Department of Environmental Protection, Northeast Regional Office. July 12, 1996. Attachment: Solid Waste Program Cost Estimates.

Goldberg, H., 1997. Personal communication, H. Goldberg, Metals Recycling and S. Czarniecki, M&E.

M&E, 1996. Draft Final Feasibility Study Report, Rose Hill Regional Landfill. October 1996.

COMMONWEALTH OF MASSACHUSETTS
EXECUTIVE OFFICE OF ENVIRONMENTAL AFFAIRS
DEPARTMENT OF ENVIRONMENTAL PROTECTION
METROPOLITAN BOSTON - NORTHEAST REGIONAL OFFICE

WILLIAM F. WELD
Governor

ARGEO PAUL CELLUCCI
Lt. Governor

TRUDY COXE
Secretary

DAVID B. STRUHS
Commissioner

NERO FACSIMILE TRANSMITTAL FORM

DATE ___ / ___ / ___

TO:

Company: M+F

Contact Name: Debora Simone Phone: _____

Fax Phone #: 617 245 6293

Company Phone #: _____

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DEP Division: _____

Contact Name: _____ Phone: _____

COMMENTS: _____

Transmittal Form plus 5 pages

To report transmission problems, call Tony at 617-932-7602

10 Commerce Way • Woburn, Massachusetts 01801 • FAX (617) 932-7615 • Telephone (617) 932-7600 • TDD # (617) 932-7679

Town of Newbury Solid Waste Management Facility
Solid Waste Disposal Options

PROGRAM COST ESTIMATES

OPTION 1

Full Program for Landfill Mining
Lined Sanitary Landfill Construction & Operation
Cap & Close Facility FY 2019

COMPONENTS

1. Continue Unlined Landfill Operation thru FY 1997.
2. Landfill Mine Phase III FY 97.
3. Landfill Mine Phase IV FY 98.
4. Landfill Mine Phase V FY 99.
5. Lined Landfill construction Phase I FY 97.
6. Lined Landfill construction Phase II FY 98.
7. Lined Landfill construction Phase III FY 99.
8. Create vegetative buffer / habitat corridor
9. Lined Landfill operation fy 98 THRU FY 2018 (Minimum).
10. Continue Expanded Recycling Facility operation
11. Environmental Monitoring Landfill Operation
12. Engineering Supervision.
13. Cap and closure FY 2019 (annual set aside reserve fund)
14. Post Closure Annual Monitoring and Maintenance (30 years FY 2019 - FY 2048)
15. Post Closure Site Remediation Contingency Reserve Fund as per MGL c 44, s 28(c)

PORT ENGINEERING

Civil Engineers & Land Surveyors

One Harris Street
Newburyport, MA
01950
(508) 465-8591

Town of Newbury Solid Waste Management Facility
Solid Waste Disposal Options

OPTION 1

Full Program for Landfill Mining
Lined Sanitary Landfill Construction & Operation
Cap & Close Facility FY 2019

COST ESTIMATES

CAPITAL COSTS

Landfill Mining			**$ 2,975,750**
Landfill Mining Operation		$ 2,515,750	
Tire removal		$ 300,000	
Misc. haul roads, fencing etc.		$ 35,000	
Supervision/Monitoring		$ 75,000	
Engineering Design		$ 50,000	
	SUB TOTAL	$ 2,975,750	
Lined Landfill Construction			**$ 1,452,500**
Liner Construction 3 Phases		$ 1,062,500	
Engineering Design		$ 130,000	
QA / QC Supervision		$ 130,000	
Landscape Buffer Construction		$ 125,000	
Misc. fencing / silt control / roadways		$ 5,000	
	SUB TOTAL	$ 1,452,500	
	TOTAL CAPITAL COSTS		**$ 4,428,250**

TOTAL BOND AMOUNT $ 4,430,000

PORT ENGINEERING

Civil Engineers & Land Surveyors

One Harris Street
Newburyport, MA
01950
(508) 465-8594

Town of Newbury Solid Waste Management Facility
Solid Waste Disposal Options

OPTION 1

Full Program for Landfill Mining
Lined Sanitary Landfill Construction & Operation
Cap & Close Facility FY 2019

COST ESTIMATES

CAPITAL COSTS

Landfill Mining $ 2,975,750

1. Landfill Mining Operation $ 2,515,750

Estimated 234,900 cy + 25% cont. = 293,625 CY
@ PH III = $8/cy PH IV = $9 /CY PH V = $10 /CY
PHASE III = 136,875 CY x $ 8 / CY = $ 1,095,000
PHASE IV = 146,750 CY x $ 9 / CY = $ 1,320,750
PHASE V = 10,000 CY x $10 /CY = $ 100,000
SUB TOTAL = $ 2,515,750

2. Tire removal $ 300,000

From landfill mining phases II & IIIA

Phase #	Qty Mined	Tires (T)	Cost	Rate
II	31,000 cy	115.43 T	$ 14,428.75	0.004 T/cy
III A	28,000 cy	218.37 T	$ 27,296.25	0.008 T/cy
Total	59,000 cy	333.90 T	$ 41,725.00	0.006 T/cy

Assume: 0.008 T/cy tires for 293,625 cy = 2,349 T
@ $ 125 /T = $ 293,625

3. Misc. haul roads, fencing etc. $ 35,000

Haul Roads (3 @ 24' x 200')
Geotextile filter fabric 1600 sy @ $2.70 = $ 4,320
Crushed stone (12" th 533 cy @ $ 20 = $10,660
$ 14,980

Chain Link Fencing (300 lf movable)
6' CLF fencing reusable 300 lf @ $ 15 = $ 4,500
Corner posts 3" D galv steel 6 @ $ 88 = $ 528
Line Posts PH IV / V 60 @ $ 70 = $ 4,200
Gate (30' wide pair) = $ 3,500
$12,728

Siltation Fencing / Hay Bales
Silt fence 2,000 lf @ $ 0.80 = $ 1,600
Hay Bales backing 1,000 bales @ $ 3 = $ 3,000
$ 4,600

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Town of Newbury Solid Waste Management Facility
Solid Waste Disposal Options

PROGRAM COST ESTIMATES

OPTION 1
(continued)

CAPITAL COSTS

Landfill Mining (continued)

4.	Supervision/Monitoring @ 1,200 cy/day=250 days mining x $300/day	$ 75,000
5.	Engineering Design	$ 50,000
	Lined Landfill Construction 3 phases; 7.5 acres	$ 1,452,500
1.	Liner etc. @ $175,000 per acre Estimate from table 8.54 page 8.135 Standard Handbook of Environmental Engineering add clay liner (4' thick) & blasting @ 20,000 cy / acre Phase I 1.5 ac @ $ 175,000 = $ 250,000 *(Included In $ 750,000 Fy 95 Bond)* Phase II 3.0 ac @ $ 175,000 = $ 525,000 Phase III 3.0 ac @ $ 175,000 = $ 525,000 $ 1,062,500	$ 1,062,500
2.	Engineering @ 10% construction cost	$ 130,000
3.	QA / QC (@ 10%)	$ 130,000
4.	Landscape buffer (1,000 lf x 100; 2.5 AC @ $50,000)	$ 125,000
5.	Misc. fencing / silt control	$ 5,000
		$ 1,452,500

TOTAL CAPITAL COSTS $ 4,428,250

TOTAL BOND AMOUNT $ 4,430,000

PORT ENGINEERING
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Town of Newbury Solid Waste Management Facility
Solid Waste Disposal Options

OPTION 1

Full Program for Landfill Mining
Lined Sanitary Landfill Construction & Operation
Cap & Close Facility FY 2019

COST ESTIMATES

ANNUAL COSTS

Facility Operation		$ 188,990
Unlined Landfill Operation (Fy 97)	$ 97,390	
Recycling Facility operation (Fy 97 Thru FY 2018 Min)	$ 55,650	
Environmental monitoring (Fy 97 Thru FY 2018 Min)	$ 14,800	
Engineering Supervision (FY 97 Thru FY 2018 Min)	$ 21,150	
TOTAL INITIAL ANNUAL COST FY 97	$ 188,990	
Cap & Closure Costs Set Aside Reserve Fund FY 2019		$ 50,600
(CAPITAL COSTS REQUIRED FY 2019)		
(Set aside equal annual amount to establish fund in FY 2019)		
Comprehensive Site Assessment	$ 150,000	
Closure Design	$ 95,000	
Closure Construction Cost	$ 950,000	
Site Remediation Contingency Reserve Fund	$ 1,000,000	
(CAPITAL COSTS REQUIRED FY 2019) TOTAL	$ 2,195,000	
Equivalent Annual Payment (20 years @ 7.5% RR)	$ 50,600	
Post Closure Maint. & Monitoring Set Aside Reserve Fund FY 2019		$ 27,000
(ANNUAL COSTS FY 2020 thru 2050)		
(Set aside equal annual amount to establish fund in FY 2019 for a 7.5 + acre capped and closed facility)		
LF inspection (Quarterly)	$ 3,000	
Surface Maintenance (mow/repair/regrade)	$ 5,000	
Leachate collection / treatment	$ 20,000	
Environmental monitoring (water / gas / air, Semi-Annual)	$ 25,000	
	$ 53,000	
30 yr ANNUAL COSTS Fund Required FY 2019	$ 1,141,429	
Equivalent Annual Payment (20 years @ 7.5% RR)	$ 27,000	

TOTAL ANNUAL COSTS $ 266,590

PORT ENGINEERING
Civil Engineers & Land Surveyors
One Harris Street
Newburyport, MA
01950
(508) 465-8594

M&E
METCALF & EDDY, INC.

TELECON MEMORANDUM

JOB NO. 020617-0010 DATE: 5/6/97

SUBJECT: Rose Hill LF Mining – Metals Recycling

M&E ENGINEER: S. Czarnecki OUTSIDE PARTY: Harry Goldberg

MADE CALL (X) Metals Recycling

REC'D CALL ( ) 401-831-7799

COMMENTS

I looked on the map and it is probably about 15-20 miles away.

SUMMARY OF CONVERSATION:

I explained our situation. He gave us 2 options:

(1) We take out CFCs + capacitors and deliver to them. We would get $0.02/lb in this case.

(2) They come & pick up the items and handle the CFCs + capacitors. We pay $50/hr for freight from the time the vehicle leaves their facility to when it gets back. That number could probably be worked out lower.

Dirt must be cleaned off as good as possible or he will have to reject the load.

CC:

M&E FORM NO. 196 (9/78)

For the purposes of this cost estimate, it is assumed that treatment costs will be similar to those presented in the Draft Final FS (M&E, 1996) for leachate treatment, but will only include treatment for metals based on reinjection ARARs. Although the flow rate used for leachate treatment in the Draft Final FS (5 gpm) may be low compared to any required dewatering flows (at this time unknown), for the purposes of this cost estimate, 5 gpm will be assumed and the length of operation will be assumed to be 1 year.

Capital Costs

From Alternative #4, 5 gpm water treatment plant capital costs =	$425,000
Capital costs for UV/chem oxidation items (including instrumentation) =	$89,889
Therefore, capital costs for metals precipitation system =	$335,111
To account for higher flows, use	$350,000

O&M costs

	Unit	Unit Cost	1-Year Quantity	1-Year Cost
Feed Chemicals	1000 US gal	$0.56	2628	$1,472
Residuals Disposal	1000 US gal	$0.35	2628	$920
Labor	hr	$35.00	520	$18,200
Electricity	1000 US gal	$0.05 (Assumed based on FS costs)	2628	$131
Total				$20,723
To account for higher flows, use				$25,000

METCALF & EDDY

For the purposes of this comparison, it is assumed that monitoring wells MW-03-01/02/03 and MW-12-01/02 will be used to monitor the effectiveness of any remedial action at the Bulky Waste Area.

Groundwater Monitoring for the Cap Alternative

Assume 5 wells sampled for 30 years plus required QA/QC samples

Groundwater Monitoring for the Landfill Mining Alternative

Assume the 5 wells noted above will be sampled as well as the 3 extraction (dewatering) wells and 2 injection wells.
Assume the length of monitoring for these wells will be 5 years.
Assume the required QA/QC samples are the same as for the cap alternative.

This summarizes to 10 wells being sampled for 5 years plus required QA/QC samples.

Comparison Between Alternatives

For comparison purposes, the landfill mining alternative could be assumed to be 5 wells being sampled for 10 years plus required QA/QC samples.

This results in monitoring costs being approximately 3 times lower for the landfill mining alternative.

METCALF & EDDY

Metcalf & Eddy
An Air & Water Technologies Company

Memorandum

FILE: Rose Hill **DATE:** May 28, 1997
TO: S. Czarniecki **OFFICE:** Wakefield
FROM: R. Renzi **COMPANY:** M&E
SUBJECT: Rose Hill Health and Safety Issues

If it is determined that there are no hazardous substances in the soil and groundwater that could result in an employee exposure then work would procede as a conventional construction operation. At a minimum this would include:

1.) Several individuals trained in first aid/CPR (8 hours).
(2 individuals x $50 course each = $100)
2.) Personnel protective equipment would include at a minimum hard hat, safety glasses, work gloves and steel toed shoes.
(10 individuals x $150/person = $1,500)
3.) Emergency response equipment would include a fire extinguisher, first aid kit air horn and cell phone.
($425)
Total estimated cost for safety related items = $2025

However, if at any time during the process an accumulation of hazardous substances in the soil or groundwater is identified and results in employee exposure or the reasonable possibility for employee exposure to safety or health hazards, then all the requirements of 29 CFR 1910.120 Hazardous Waste Operations and Emergency Response (HAZWOPER) would be required. At a minimun this would include the following:

1.) Generation of a written safety and health program.
(Assume contractor has one developed.)
2.) Generation of a site specific safety and health plan.
(Cost to generate $4,500)
3.) Initial training for general site workers (40 hours off site and 24 hours on site).
(10 individuals x $450/course = $4,500)
4.) Management training for supervisory personnel (8 hours off site).
(2 individuals x $150/course = $300)
5.) Several individuals trained in first aid/CPR (8 hours).
(2 individuals x $50 course each = $100)
6.) Higher levels of personnel protective equipment. At a minimum Level D, modidfied Level D and Level C. This would require the purchase of full-length coveralls (eg. Tyvek), iner and outer chemical resistant gloves, chemical resistant steel-toed, steel shank boots, hard hat, safety glasses, and air purifying respirators.

(10 individuals x $150/person = $1,500)
(10 individuals x $50/day x 40 days = $20,000)

7.) Continuous use of exposure monitoring equipment. At a minimum to include a photoionization detector, combustible gas indicator with oxygen and hydrogen sulfide sensors, an aerosol meter and a radiation detector.

(PID $1200 + CGI $280 + Aerosol $1600 + RAD $550 = $3630)

8.) Decontamination facilities and supplies for both personel and equipment.

($2000)

9.) Emergency response equipment. At a minimum to include eye wash/shower station, fire extinguishers, first aid kit, air horn and cell phone.

($425)

Total estimated cost for safety related items = $36,955

A-2 Responses to RIDEM Comments

Metcalf & Eddy Responses to

RIDEM COMMENTS (September 2, 1997)
on

ROSE HILL REGIONAL LANDFILL
TECHNICAL SCREENING OPTIONS TECHNICAL MEMORANDUM
prepared June 1997

Comment 1: Section 5.3, Pilot Study/Feasibility Analysis, Page 25, Paragraph 1 - An economic evaluation is also performed to determine the feasibility of the technology. The cost of the project is most likely to be the major decision making criterion for the implementation of the process. A cost/benefit analysis would compare the projected cost for capping and closing a landfill without mining; with the costs associated with the landfill mining and re-disposing of non-recyclable wastes, the anticipated savings from reducing the size of or eliminating the need for a cap, and the anticipated revenue from recyclable materials.

As stated in the cover letter to these comments, this report failed to evaluate the economic and ecological factors with regard to natural resource damages. This paragraph clearly indicates that NRD was not considered.

Response: A statement has been added to the FS which addresses NRD considerations in the alternatives.

Comment 2: Section 5.5, Effectiveness, Page 29, Paragraph 2 - "*Potential short-term and long-term ecological risks of landfill mining must also be considered when evaluating its effectiveness. Emergent wetlands....*" This paragraph discusses the short-term risks of landfill mining at length, however, it fails to mention any of the long-term benefits to the environment. In order to be unbiased, the report must mention the benefits as well as the risks.

Response: M&E agrees that for the report to be unbiased it must mention the benefits as well as the risks of landfill mining. These benefits are indicated in the FS report.

Comment 3: Section 5.7, Cost - This section fails to factor two major variables into the cost calculations, 1. the cost savings (i.e. decreased damages and resulting compensation resulting from continued release) resulting from the reduced long-term impacts to the environment if the bulky waste area was removed and 2. the potential costs associated with leachate collection and treatment if it is determined necessary.

RIDEM understands the difficulty of determining the potential costs associated with NRD, however, it should at a minimum be mentioned as a variable. The costs for leachate collection and treatment were estimated in the draft FS and should be included in the evaluation process.

Response: The costs for leachate collection and treatment have been added to alternatives utilizing landfill mining in the FS report. Please refer to Comment 1 regarding NRD costs.

Comment 4: Section 5.8, Summary - *Advantages:* Two major advantages that the report failed to mention are 1. Reduced NRD and 2. Eliminate the need for long-term leachate collection and treatment.

***Disadvantages:* With regard to disadvantages, the statement regarding the lack of public support for landfill mining must be qualified and referenced. Was the local community surveyed? Were they given all of the information regarding the pros-and cons?**

***"The most important advantage to implementing landfill mining is the potential to eliminate the need to cap the Bulky Waste Area."* RIDEM strongly disagrees with this statement. From a Trustee perspective, the most significant advantage would be the elimination of long-term impacts to the environment. As previously stated in past correspondence and restated in this letter, RIDEM must also consider its position as Natural Resource trustee when evaluating remedial alternatives.**

Response: The statement regarding lack of public support for landfill mining has been better qualified and referenced. The statement was originally made based on other landfill mining projects which have had community relations problems, such as Fairhaven, MA, and will not be included in the FS report.

M&E notes that the "most important advantage" is subjective. A comprehensive list of advantages/disadvantages of landfill mining has not been included in the FS report as it is not part of standard FS detailed evaluation. Therefore, a summary statement such as the one discussed is also not presented.

B. DRAINAGE AND SLOPE STABILITY CALCULATIONS

B-1 Solid Waste Area - General Assumptions
B-2 Solid Waste Area - Detention Basin Development and Sizing
- Detention Basin #1: Pre-Development
- Detention Basin #1: Post-Development
- Detention Basin #1: Sizing
- Detention Basin #2: Pre-Development
- Detention Basin #2: Post-Development
- Detention Basin #2: Sizing

B-3 Bulky Waste Area - Detention Basin Sizing
B-4 Slope Stability: Cover and Soil Slippage
B-5 Cover Stress Evaluation

B-1 Solid Waste Area - General Assumptions

Detention basin requirements were reviewed for the Solid Waste Area using the TR-55 method. As discussed in the *Rhode Island Soil Erosion and Sediment Control Handbook* (RIDEM, 1989), basins should control 25-year frequency, 24-hour duration, Type III distribution storms.

Control of the peak discharge from a 100-year, 24-hour storm event is also required if it is determined that downstream impacts would be significant.

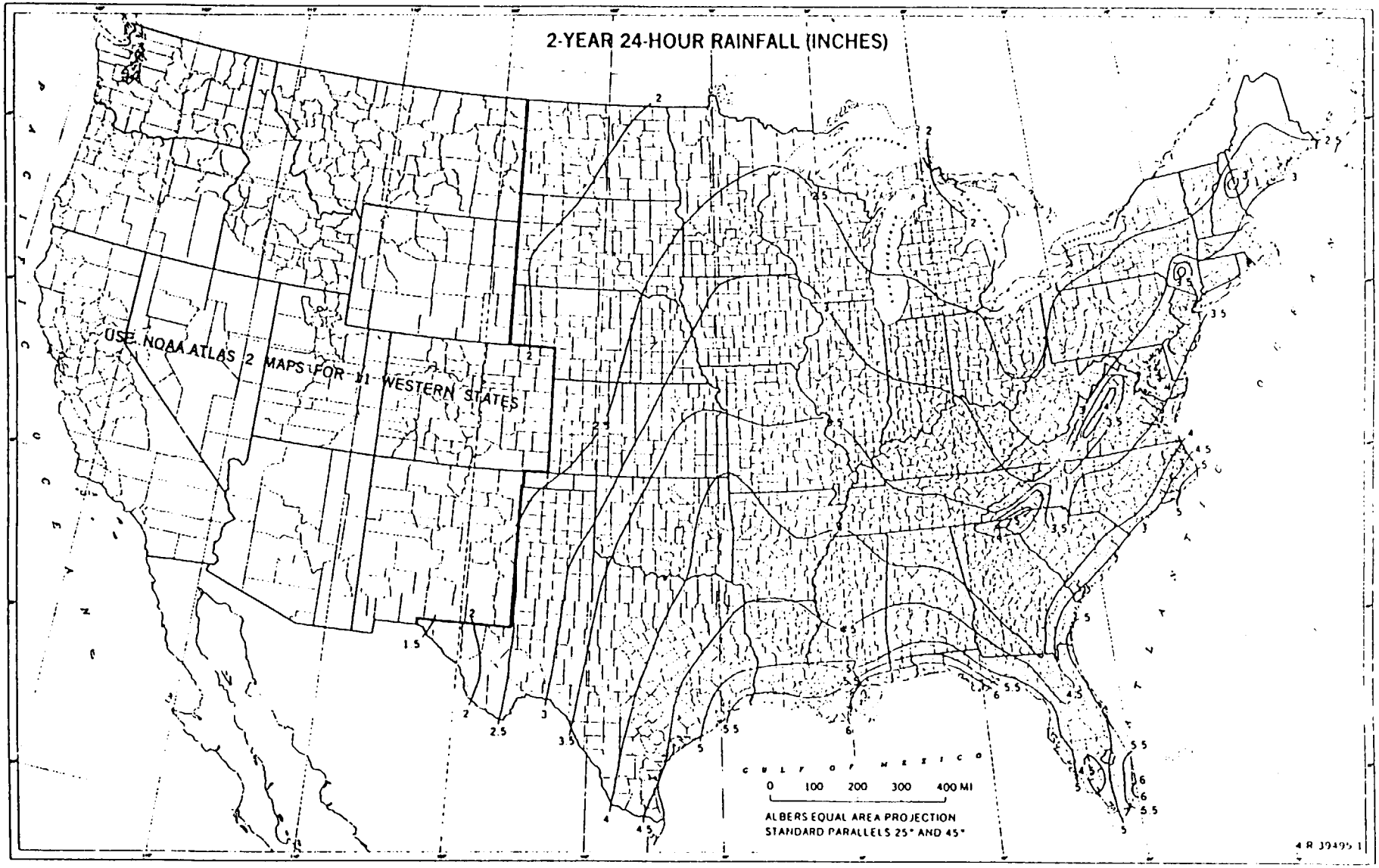
Estimates of rainfall: (From S.C.S. TR-55, revised 1986 - Attached)

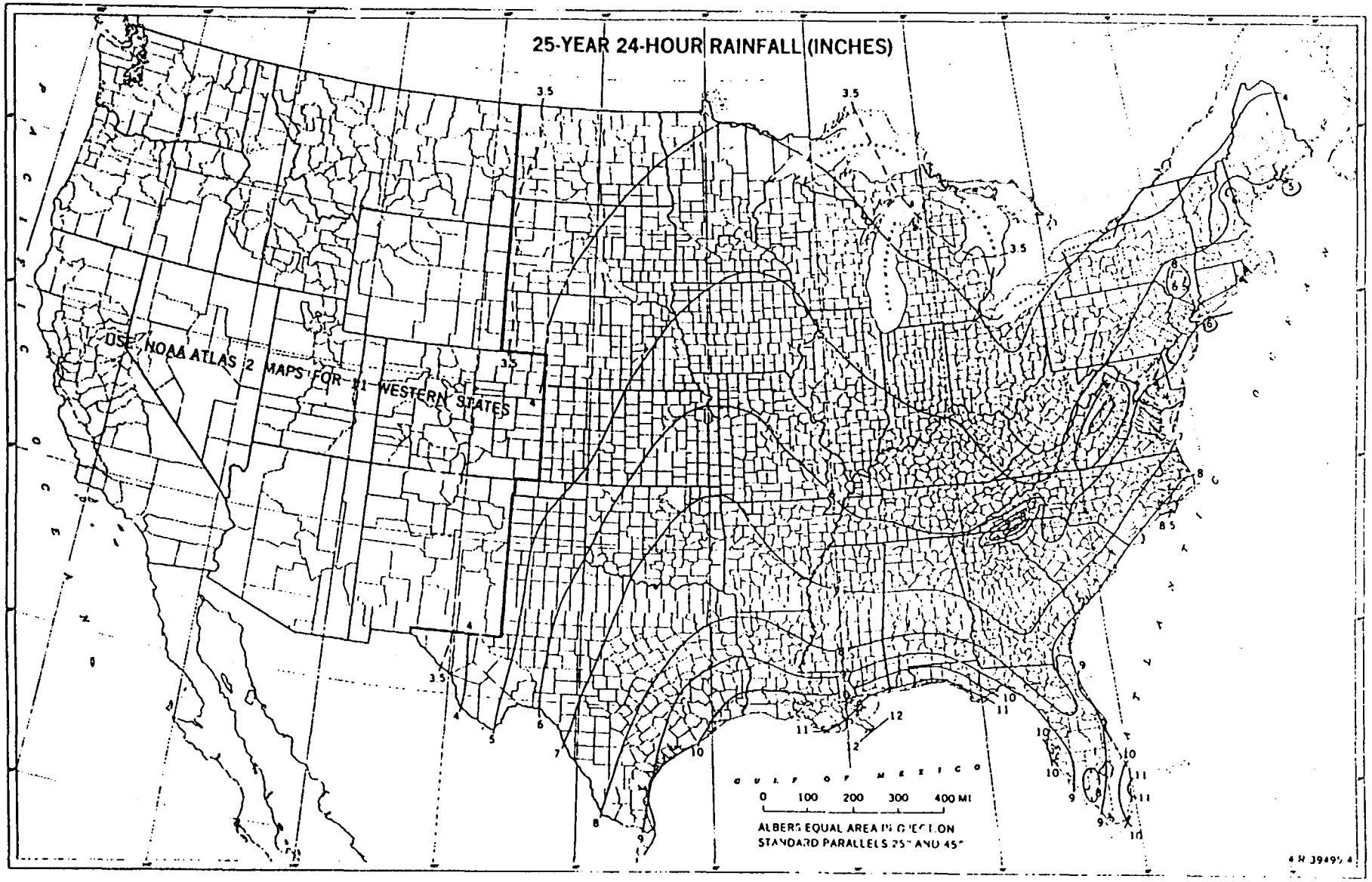
2-year, 24-hour:	3.5 in.
25-year, 24-hour:	5 in.
100-year, 24-hour:	7 in.

Sizing in the following sections are based on the 25-year, 24-hour storm. For the purposes of basin sizing, downstream impacts from a 100-year, 24-hour storm are currently assumed to be insignificant so that costs are not the most conservative. This should be reviewed further in pre-design stages.

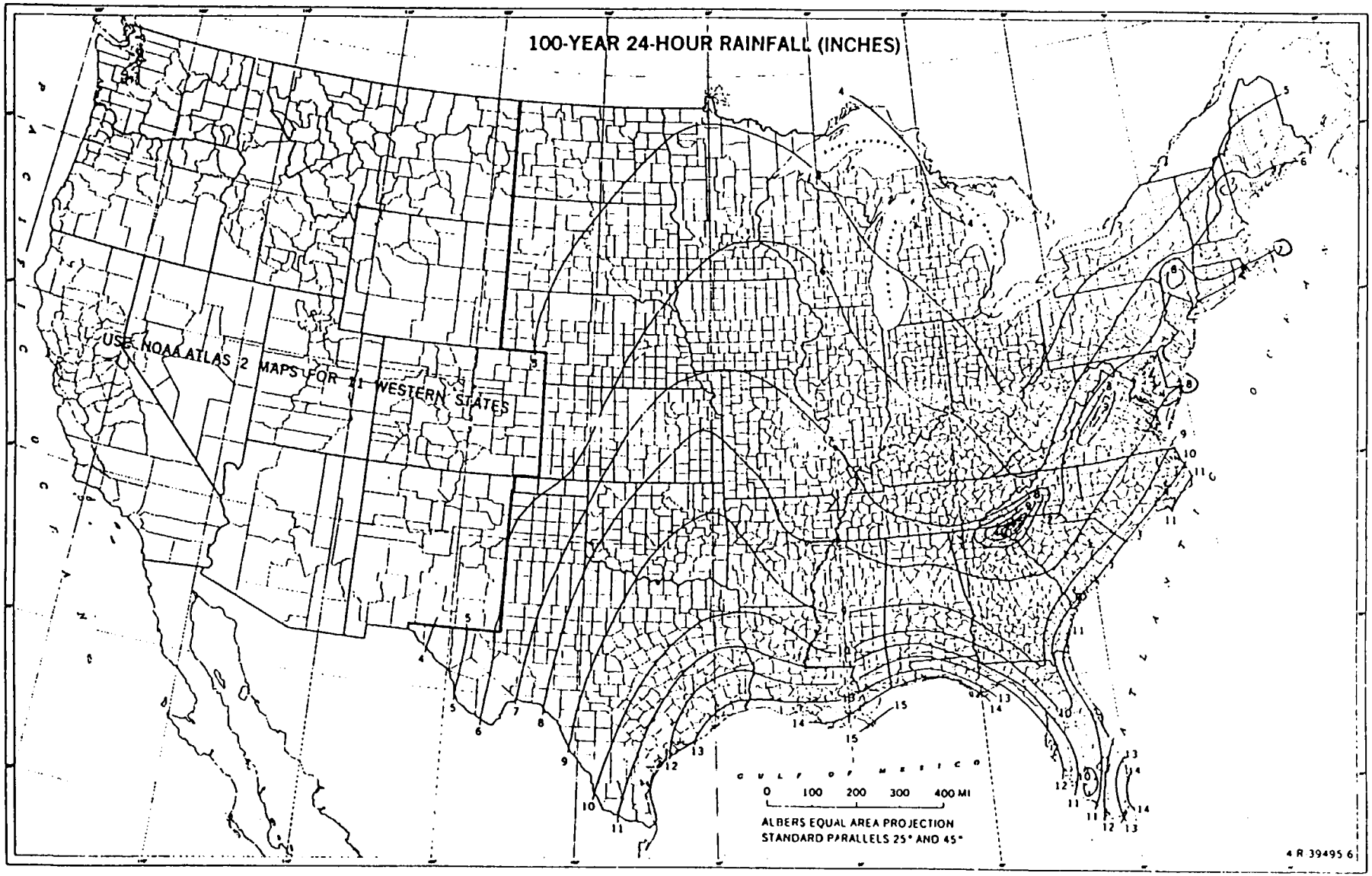
A simplifying assumption is also made during Time of Concentration calculations that only sheet flow occurs even though run lengths may exist greater than 300 ft.

Detention basins are sized to reduce post-capping runoff flows to pre-capping flows.

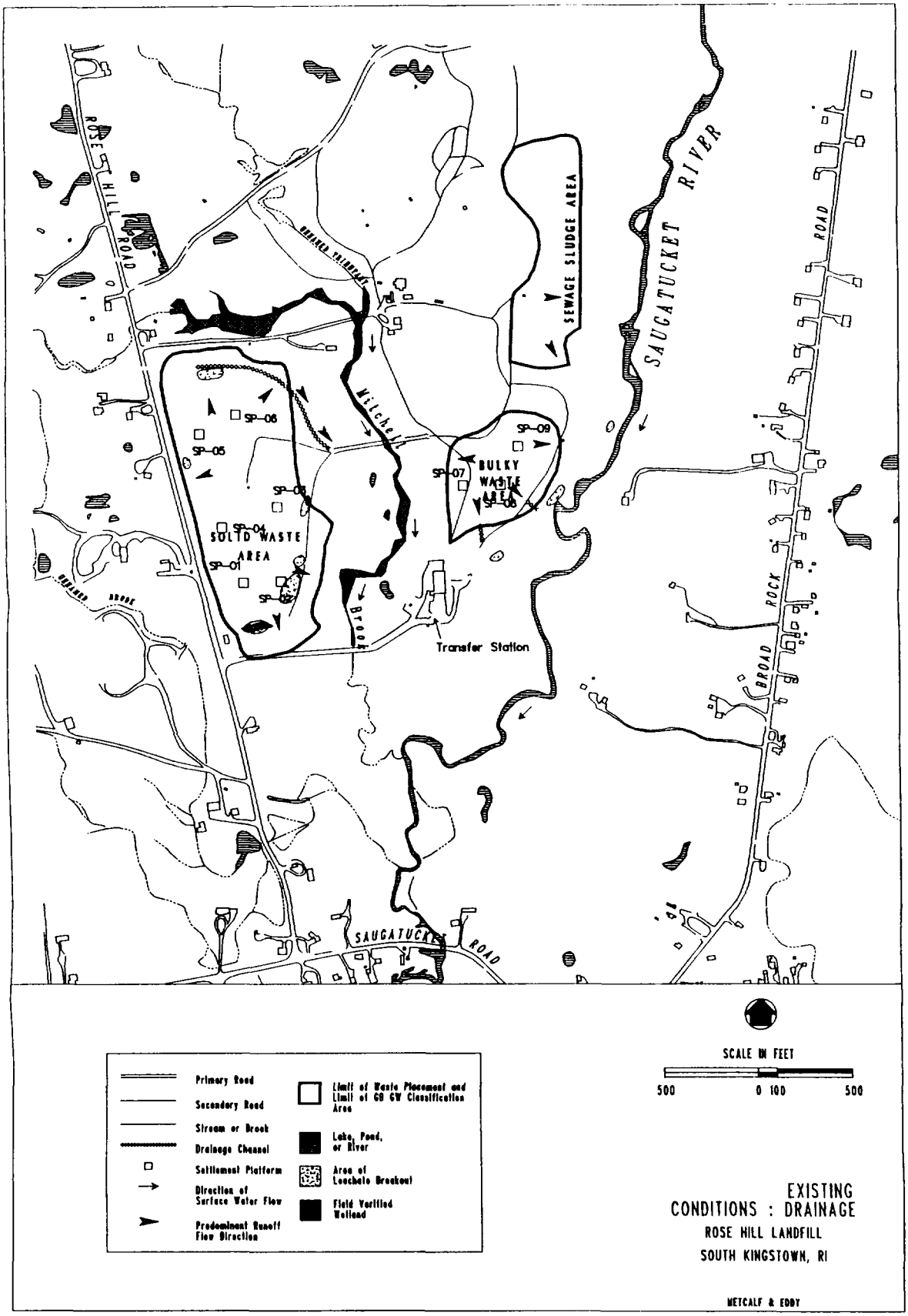

2-YEAR 24-HOUR RAINFALL (INCHES)
USE NOAA ATLAS 2 MAPS FOR 11 WESTERN STATES
GULF OF MEXICO
0 100 200 300 400 MI
ALBERS EQUAL AREA PROJECTION
STANDARD PARALLELS 25° AND 45°



This appendix reprinted from S.C.S. TR-55, revised 1986.



This appendix reprinted from S.C.S. TR-55, revised 1986.


ROSE HILL ROAD
SAUGATUCKET RIVER
SEWAGE SLUDGE AREA
Mitchell Brook
SP-06
SP-05
SP-03
SP-04
SP-01
SP-02
SOLID WASTE AREA
SP-09
SP-07
SP-08
BULKY WASTE AREA
Transfer Station
ROCK ROAD
BROAD ROAD
SAUGATUCKET ROAD
Primary Road
Secondary Road
Stream or Brook
Drainage Channel
Settlement Platform
Direction of Surface Water Flow
Predominant Runoff Flow Direction
Limit of Waste Placement and Limit of GB GW Classification Area
Lake, Pond, or River
Area of Leachate Breakout
Field Verified Wetland
SCALE IN FEET
500
0 100
500
EXISTING CONDITIONS : DRAINAGE
ROSE HILL LANDFILL
SOUTH KINGSTOWN, RI
METCALF & EDDY

B-2 Solid Waste Area - Detention Basin Development and Sizing

- Detention Basin #1: Pre-Development
- Detention Basin #1: Post-Development
- Detention Basin #1: Sizing
- Detention Basin #2: Pre-Development
- Detention Basin #2: Post-Development
- Detention Basin #2: Sizing

Solid Waste Area
Detention Basin #1: Pre-Development

Worksheet 2: Runoff curve number and runoff

Project Rose Hill FS By DTC Date 3/30/93

Location Solid Waste L.F. Drainage Area I Checked SC Date 8/22/96

Circle one: (Present) Developed

1. Runoff curve number (CN)

Soil name and hydrologic group (appendix A)	Cover description (cover type, treatment, and hydrologic condition; percent impervious; unconnected/connected impervious area ratio)	CN 1/ Table 2-2	CN 1/ Fig. 2-3	CN 1/ Fig. 2-4	Area ☐ acres ☒ mi^2 ☐ %	Product of CN x area
Sand, A	Good	39			0.015	5.9
	Totals =					

0.25

1/ Use only one CN source per line.

CN (weighted) = $\frac{\text{total product}}{\text{total area}}$ = ____ = ____; Use CN = 39

2. Runoff

		Storm #1	Storm #2	Storm #3
Frequency	yr	25		
Rainfall, P (24-hour)	in	5		
Runoff, Q (Use P and CN with table 2-1, fig. 2-1, or eqs. 2-3 and 2-4.)	in	0.2		

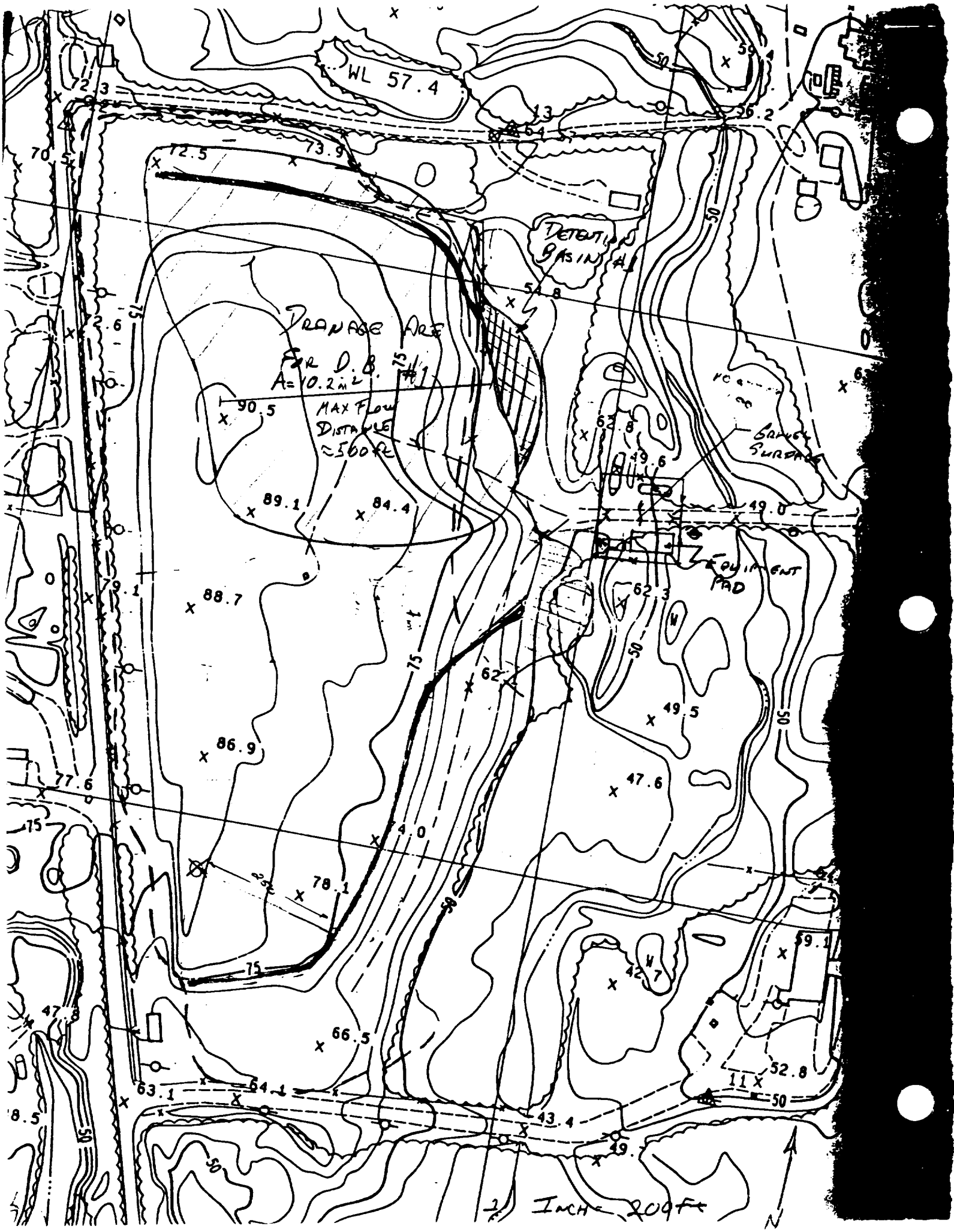

WL 57.4
DRAINAGE AREA
FOR D.B. #1
A=10.2 mi²
MAX FLOW
DISTANCE
≈560 FT
DETENTION
BASIN #1
GRAVEL
SURFACE
EQUIPMENT
PAD
1 INCH = 200 FT
N

Table 2-2a.—Runoff curve numbers for urban areas[1]

Cover description		Curve numbers for hydrologic soil group—			
Cover type and hydrologic condition	Average percent impervious area[2]	A	B	C	D
Fully developed urban areas (vegetation established)					
Open space (lawns, parks, golf courses, cemeteries, etc.)[3]:					
Poor condition (grass cover < 50%)		68	79	86	89
Fair condition (grass cover 50% to 75%)		49	69	79	84
Good condition (grass cover > 75%)		39	61	74	80
Impervious areas:					
Paved parking lots, roofs, driveways, etc. (excluding right-of-way)		98	98	98	98
Streets and roads:					
Paved; curbs and storm sewers (excluding right-of-way)		98	98	98	98
Paved; open ditches (including right-of-way)		83	89	92	93
Gravel (including right-of-way)		76	85	89	91
Dirt (including right-of-way)		72	82	87	89
Western desert urban areas:					
Natural desert landscaping (pervious areas only)[4]		63	77	85	88
Artificial desert landscaping (impervious weed barrier, desert shrub with 1- to 2-inch sand or gravel mulch and basin borders)		96	96	96	96
Urban districts:					
Commercial and business	85	89	92	94	95
Industrial	72	81	88	91	93
Residential districts by average lot size:					
1/8 acre or less (town houses)	65	77	85	90	92
1/4 acre	38	61	75	83	87
1/3 acre	30	57	72	81	86
1/2 acre	25	54	70	80	85
1 acre	20	51	68	79	84
2 acres	12	46	65	77	82
Developing urban areas					
Newly graded areas (pervious areas only, no vegetation)[5]		77	86	91	94
Idle lands (CN's are determined using cover types similar to those in table 2-2c).					

[1]Average runoff condition, and $I_a = 0.2S$.
[2]The average percent impervious area shown was used to develop the composite CN's. Other assumptions are as follows: impervious areas are directly connected to the drainage system, impervious areas have a CN of 98, and pervious areas are considered equivalent to open space in good hydrologic condition. CN's for other combinations of conditions may be computed using figure 2-3 or 2-4.
[3]CN's shown are equivalent to those of pasture. Composite CN's may be computed for other combinations of open space cover type.
[4]Composite CN's for natural desert landscaping should be computed using figures 2-3 or 2-4 based on the impervious area percentage (CN = 98) and the pervious area CN. The pervious area CN's are assumed equivalent to desert shrub in poor hydrologic condition.
[5]Composite CN's to use for the design of temporary measures during grading and construction should be computed using figure 2-3 or 2-4, based on the degree of development (impervious area percentage) and the CN's for the newly graded pervious areas.

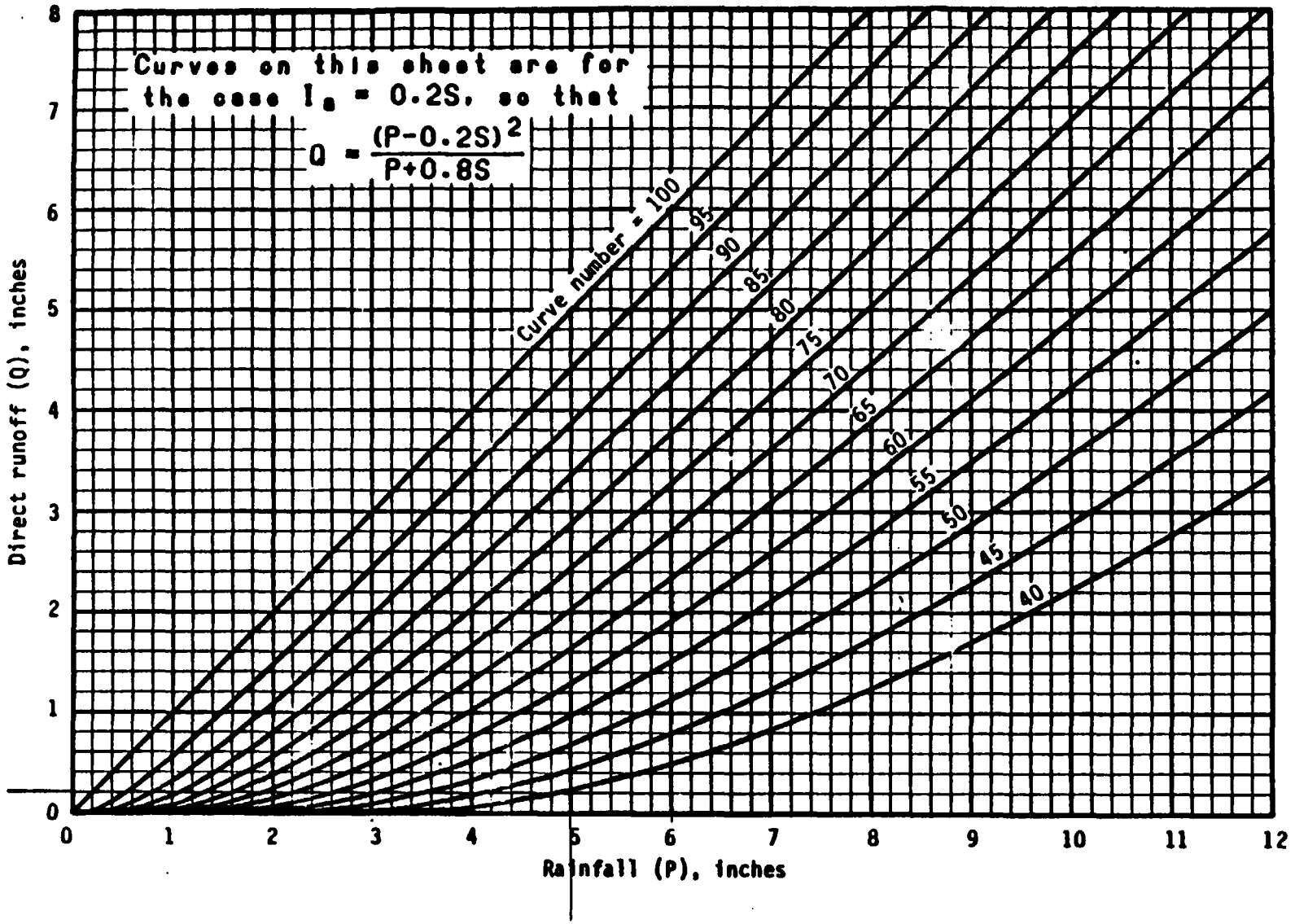


Figure 2-1.—Solution of runoff equation.

Worksheet 3: Time of concentration (T_c) or travel time (T_t)

Project Rose Hill FS By DTC Date 8/30/93

Location Solid Waste L.F. Drainage Area 1 Checked SC Date 8/22/96

Circle one: Present Developed

Circle one: T_c T_t through subarea

NOTES: Space for as many as two segments per flow type can be used for each worksheet.

Include a map, schematic, or description of flow segments.

Sheet flow (Applicable to T_c only)	Segment ID			
1. Surface description (table 3-1)		SHORT GRASS		
2. Manning's roughness coeff., n (table 3-1) ..		0.15		
3. Flow length, L (total L ≤ 300 ft) ..... ft		500		
4. Two-yr 24-hr rainfall, P_2 ..... in		3.5		
5. Land slope, s ..... ft/ft		0.07		
6. $T_t = \frac{0.007\,(nL)^{0.8}}{P_2^{0.5}\,s^{0.4}}$ Compute T_t ..... hr		0.34	+	= 0.34

Shallow concentrated flow	Segment ID			
7. Surface description (paved or unpaved)				
8. Flow length, L ..... ft				
9. Watercourse slope, s ..... ft/ft				
10. Average velocity, V (figure 3-1) ..... ft/s				
11. $T_t = \frac{L}{3600\,V}$ Compute T_t ..... hr			+	=

MAKE SIMPLIFYING ASSUMPTION THAT ONLY SHEET FLOW OCCURS - THOUGH FLOW LENGTH INDICATES SHALLOW CONC. FLOW

Channel flow	Segment ID			
12. Cross sectional flow area, a ..... ft^2				
13. Wetted perimeter, p_w ..... ft				
14. Hydraulic radius, $r = \frac{a}{p_w}$ Compute r ..... ft				
15. Channel slope, s ..... ft/ft				
16. Manning's roughness coeff., n				
17. $V = \frac{1.49\,r^{2/3}\,s^{1/2}}{n}$ Compute V ..... ft/s				
18. Flow length, L ..... ft				
19. $T_t = \frac{L}{3600\,V}$ Compute T_t ..... hr			+	=

MAKE SIMPLIFYING ASSUMPTION AND ASSUME ONLY SHEET FLOW - THOUGH A CHANNEL EXISTS

20. Watershed or subarea T_c or T_t (add T_t in steps 6, 11, and 19) ..... hr 0.34

Sheet flow

Sheet flow is flow over plane surfaces. It usually occurs in the headwater of streams. With sheet flow, the friction value (Manning's n) is an effective roughness coefficient that includes the effect of raindrop impact; drag over the plane surface; obstacles such as litter, crop ridges, and rocks; and erosion and transportation of sediment. These n values are for very shallow flow depths of about 0.1 foot or so. Table 3-1 gives Manning's n values for sheet flow for various surface conditions.

For sheet flow of less than 300 feet, use Manning's kinematic solution (Overton and Meadows 1976) to compute T_t:

$$T_t = \frac{0.007\,(nL)^{0.8}}{(P_2)^{0.5}\,s^{0.4}} \qquad \text{[Eq. 3-3]}$$

Table 3-1.—Roughness coefficients (Manning's n) for sheet flow

Surface description	n[1]
Smooth surfaces (concrete, asphalt, gravel, or bare soil)	0.011
Fallow (no residue)	0.05
Cultivated soils:	
Residue cover ≤20%	0.06
Residue cover >20%	0.17
Grass:	
Short grass prairie	0.15
Dense grasses[2]	0.24
Bermudagrass	0.41
Range (natural)	0.13
Woods:[3]	
Light underbrush	0.40
Dense underbrush	0.80

[1]The n values are a composite of information compiled by Engman (1986).
[2]Includes species such as weeping lovegrass, bluegrass, buffalo grass, blue grama grass, and native grass mixtures.
[3]When selecting n, consider cover to a height of about 0.1 ft. This is the only part of the plant cover that will obstruct sheet flow.

where

T_t = travel time (hr),
n = Manning's roughness coefficient (table 3-1),
L = flow length (ft),
P_2 = 2-year, 24-hour rainfall (in), and
s = slope of hydraulic grade line (land slope, ft/ft).

This simplified form of the Manning's kinematic solution is based on the following: (1) shallow steady uniform flow, (2) constant intensity of rainfall excess (that part of a rain available for runoff), (3) rainfall duration of 24 hours, and (4) minor effect of infiltration on travel time. Rainfall depth can be obtained from appendix B.

Shallow concentrated flow

After a maximum of 300 feet, sheet flow usually becomes shallow concentrated flow. The average velocity for this flow can be determined from figure 3-1, in which average velocity is a function of watercourse slope and type of channel. For slope less than 0.005 ft/ft, use equations given in appendix F for figure 3-1. Tillage can affect the direction of shallow concentrated flow. Flow may not always be directly down the watershed slope if tillage runs across the slope.

After determining average velocity in figure 3-1, use equation 3-1 to estimate travel time for the shallow concentrated flow segment.

Open channels

Open channels are assumed to begin where surveyed cross section information has been obtained, where channels are visible on aerial photographs, or where blue lines (indicating streams) appear on United States Geological Survey (USGS) quadrangle sheets. Manning's equation or water surface profile information can be used to estimate average flow velocity. Average flow velocity is usually determined for bank-full elevation.

Worksheet 4: Graphical Peak Discharge method

Project Rose Hill FS By DTC Date 3/30/93

Location Solid Waste LF Drainage Area I Checked SC Date 8/22/96

Circle one: Present Developed

1. Data:

Drainage area ..... A_m = 0.015 mi^2 (acres/640)

Runoff curve number .... CN = 39 (From worksheet 2)

Time of concentration .. T_c = 0.34 hr (From worksheet 3)

Rainfall distribution type = III (I, IA, II, III)

Pond and swamp areas spread throughout watershed ..... = _____ percent of A_m (____ acres or mi^2 covered)

		Storm #1	Storm #2	Storm #3
2. Frequency	yr	25		
3. Rainfall, P (24-hour)	in	5		
4. Initial abstraction, I_a ..... (Use CN with table 4-1.)	in	3		
5. Compute I_a/P		0.6		
6. Unit peak discharge, q_u ..... (Use T_c and I_a/P with exhibit 4-____)	csm/in	≈200		
7. Runoff, Q ..... (From worksheet 2).	in	0.2		
8. Pond and swamp adjustment factor, F_p .... (Use percent pond and swamp area with table 4-2. Factor is 1.0 for zero percent pond and swamp area.)		—		
9. Peak discharge, q_p ..... (Where $q_p = q_u A_m Q F_p$)	cfs	0.6		

Chapter 4: Graphical Peak Discharge method

This chapter presents the Graphical Peak Discharge method for computing peak discharge from rural and urban areas. The Graphical method was developed from hydrograph analyses using TR-20, "Computer Program for Project Formulation—Hydrology" (SCS 1983). The peak discharge equation used is

$$q_p = q_u A_m Q F_p \qquad \text{[Eq. 4-1]}$$

where

q_p = peak discharge (cfs);
q_u = unit peak discharge (csm/in);
A_m = drainage area (mi²);
Q = runoff (in); and
F_p = pond and swamp adjustment factor.

The input requirements for the Graphical method are as follows: (1) T_c (hr), (2) drainage area (mi²), (3) appropriate rainfall distribution (I, IA, II, or III), (4) 24-hour rainfall (in), and (5) CN. If pond and swamp areas are spread throughout the watershed and are not considered in the T_c computation, an adjustment for pond and swamp areas is also needed.

Peak discharge computation

For a selected rainfall frequency, the 24-hour rainfall (P) is obtained from appendix B or more detailed local precipitation maps. CN and total runoff (Q) for the watershed are computed according to the methods outlined in chapter 2. The CN is used to determine the initial abstraction (I_a) from table 4-1. I_a/P is then computed.

If the computed I_a/P ratio is outside the range shown in exhibit 4 (4-I, 4-IA, 4-II, and 4-III) for the rainfall distribution of interest, then the limiting value should be used. If the ratio falls between the limiting values, use linear interpolation. Figure 4-1 illustrates the sensitivity of I_a/P to CN and P.

Peak discharge per square mile per inch of runoff (q_u) is obtained from exhibit 4-I, 4-IA, 4-II, or 4-III by using T_c (chapter 3), rainfall distribution type, and I_a/P ratio. The pond and swamp adjustment factor is obtained from table 4-2 (rounded to the nearest table value). Use worksheet 4 in appendix D to aid in computing the peak discharge using the Graphical method.

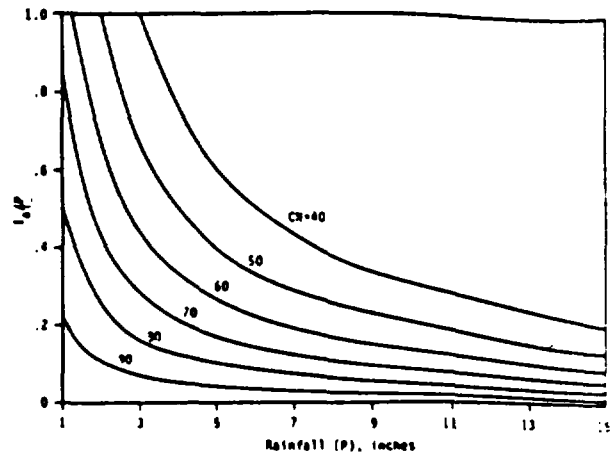
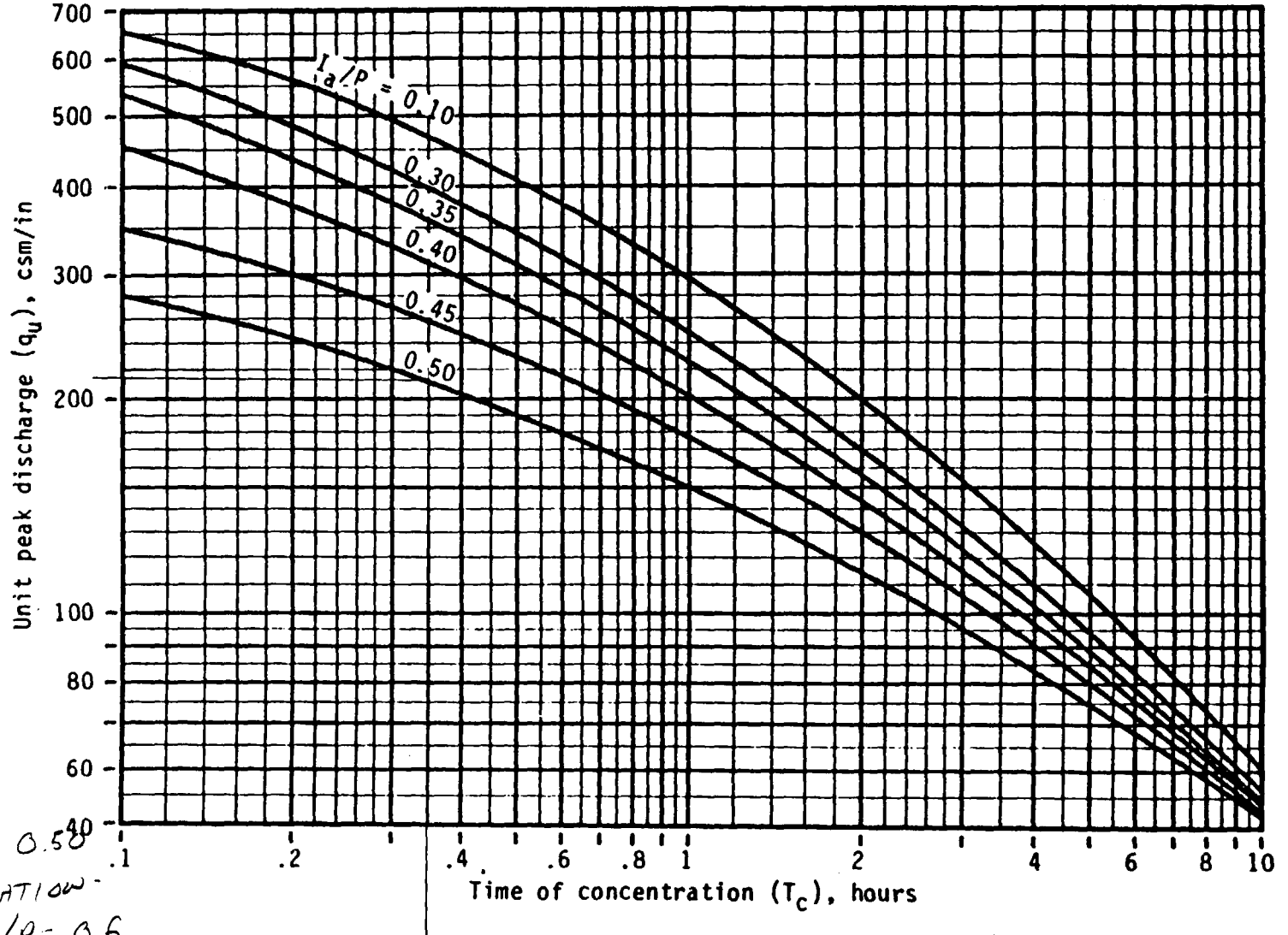


Figure 4-1.—Variation of I_a/P for P and CN.

Table 4-1.—I_a values for runoff curve numbers

Curve number	I_a (in)	Curve number	I_a (in)
40	3.000	70	0.[illegible]
41	2.878	71	[illegible]
42	2.762	72	0.[illegible]
43	2.651	73	0.740
44	2.545	74	0.703
45	2.444	75	0.667
46	2.348	76	0.632
47	2.255	77	0.597
48	2.167	78	0.564
49	2.082	79	0.532
50	2.000	80	0.500
51	1.922	81	0.469
52	1.846	82	0.439
53	1.774	83	0.410
54	1.704	84	0.381
55	1.636	85	0.353
56	1.571	86	0.326
57	1.509	87	0.299
58	1.448	88	0.273
59	1.390	89	0.247
60	1.333	90	0.222
61	1.279	91	0.198
62	1.226	92	0.174
63	1.175	93	0.151
64	1.125	94	0.128
65	1.077	95	0.105
66	1.030	96	0.083
67	0.985	97	0.062
68	0.941	98	0.041
69	0.899		

Exhibit 4-III: Unit peak discharge (q_u) for SCS type III rainfall distribution



USE $I_a/P = 0.50$
AS APPROXIMATION.
ACTUAL $I_a/P = 0.6$

Solid Waste Area
Detention Basin #1: Post-Development

Worksheet 2: Runoff curve number and runoff

Project Rose Hill ES By SJC Date 3/31/93

Location Silo Lake LF Drainage Area I Checked SC Date 8/22/96

Circle one: Present (Developed)

1. Runoff curve number (CN)

Soil name and hydrologic group (appendix A)	Cover description (cover type, treatment, and hydrologic condition; percent impervious; unconnected/connected impervious area ratio)	CN 1/ Table 2-2	CN 1/ Fig. 2-3	CN 1/ Fig. 2-4	Area ☐ acres ☒ mi^2 ☐ %	Product of CN x area
Loam, B		61			0.015	

1/ Use only one CN source per line. Totals =

CN (weighted) = $\frac{\text{total product}}{\text{total area}}$ = ____ = _____; Use CN = 61

2. Runoff

		Storm #1	Storm #2	Storm #3
Frequency	yr	25		
Rainfall, P (24-hour)	in	5		
Runoff, Q ..... (Use P and CN with table 2-1, fig. 2-1, or eqs. 2-3 and 2-4.)	in	1.3		

Table 2-2a.—Runoff curve numbers for urban areas[1]

Cover description		Curve numbers for hydrologic soil group—			
Cover type and hydrologic condition	Average percent impervious area[2]	A	B	C	D
Fully developed urban areas (vegetation established)					
Open space (lawns, parks, golf courses, cemeteries, etc.)[3]:					
Poor condition (grass cover < 50%)		68	79	86	89
Fair condition (grass cover 50% to 75%)		49	69	79	84
Good condition (grass cover > 75%)		39	61	74	80
Impervious areas:					
Paved parking lots, roofs, driveways, etc. (excluding right-of-way)		98	98	98	98
Streets and roads:					
Paved; curbs and storm sewers (excluding right-of-way)		98	98	98	98
Paved; open ditches (including right-of-way)		83	89	92	93
Gravel (including right-of-way)		76	85	89	91
Dirt (including right-of-way)		72	82	87	89
Western desert urban areas:					
Natural desert landscaping (pervious areas only)[4]		63	77	85	88
Artificial desert landscaping (impervious weed barrier, desert shrub with 1- to 2-inch sand or gravel mulch and basin borders)		96	96	96	96
Urban districts:					
Commercial and business	85	89	92	94	95
Industrial	72	81	88	91	93
Residential districts by average lot size:					
1/8 acre or less (town houses)	65	77	85	90	92
1/4 acre	38	61	75	83	87
1/3 acre	30	57	72	81	86
1/2 acre	25	54	70	80	85
1 acre	20	51	68	79	84
2 acres	12	46	65	77	82
Developing urban areas					
Newly graded areas (pervious areas only, no vegetation)[5]		77	86	91	94
Idle lands (CN's are determined using cover types similar to those in table 2-2c).					

[1]Average runoff condition, and $I_a = 0.2S$.
[2]The average percent impervious area shown was used to develop the composite CN's. Other assumptions are as follows: impervious areas are directly connected to the drainage system, impervious areas have a CN of 98, and pervious areas are considered equivalent to open space in good hydrologic condition. CN's for other combinations of conditions may be computed using figure 2-3 or 2-4.
[3]CN's shown are equivalent to those of pasture. Composite CN's may be computed for other combinations of open space cover type.
[4]Composite CN's for natural desert landscaping should be computed using figures 2-3 or 2-4 based on the impervious area percentage (CN = 98) and the pervious area CN. The pervious area CN's are assumed equivalent to desert shrub in poor hydrologic condition.
[5]Composite CN's to use for the design of temporary measures during grading and construction should be computed using figure 2-3 or 2-4, based on the degree of development (impervious area percentage) and the CN's for the newly graded pervious areas.

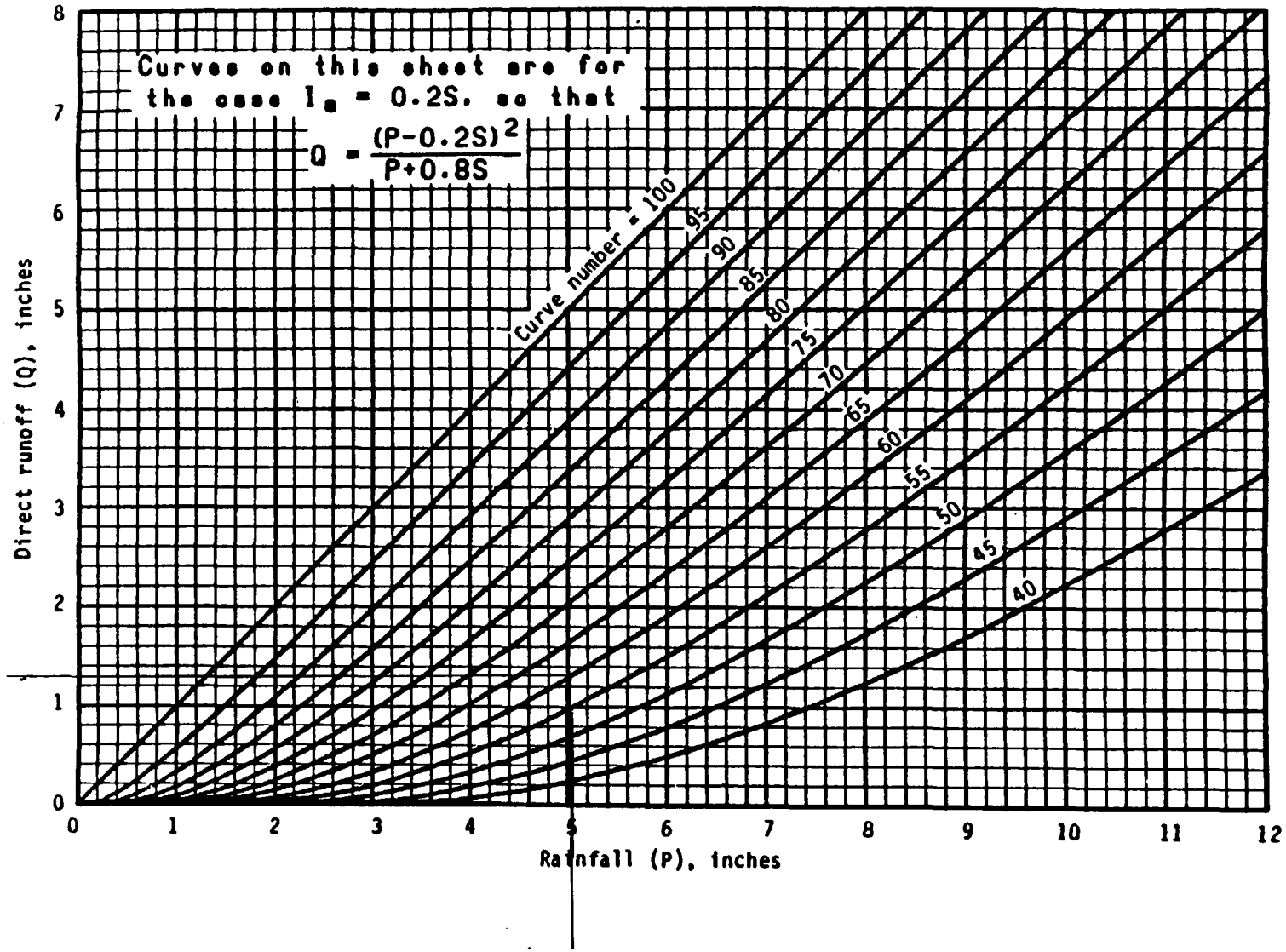


Figure 2-1.—Solution of runoff equation.

Worksheet 3: Time of concentration (T_c) or travel time (T_t)

Project _____ By ____ Date _____

Location _____ Checked SC Date 8/22/96

Circle one: Present Developed _____

Circle one: T_c T_t through subarea _____

NOTES: Space for as many as two segments per flow type can be used for each worksheet.

Include a map, schematic, or description of flow segments.

Sheet flow (Applicable to T_c only)		Segment ID			
1. Surface description (table 3-1)		SHORT GRASS			
2. Manning's roughness coeff., n (table 3-1) ..		0.15			
3. Flow length, L (total L ≤ 300 ft)	ft	500			
4. Two-yr 24-hr rainfall, P_2	in	3.5			
5. Land slope, s	ft/ft	0.07			
6. $T_t = \frac{0.007\,(nL)^{0.8}}{P_2^{0.5}\,s^{0.4}}$ Compute T_t	hr	0.34	+		= 0.34

Shallow concentrated flow		Segment ID			
7. Surface description (paved or unpaved)					
8. Flow length, L	ft				
9. Watercourse slope, s	ft/ft				
10. Average velocity, V (figure 3-1)	ft/s				
11. $T_t = \frac{L}{3600\,V}$ Compute T_t	hr		+		=

Channel flow		Segment ID			
12. Cross sectional flow area, a	ft^2				
13. Wetted perimeter, p_w	ft				
14. Hydraulic radius, $r = \frac{a}{p_w}$ Compute r	ft				
15. Channel slope, s	ft/ft				
16. Manning's roughness coeff., n					
17. $V = \frac{1.49\,r^{2/3}\,s^{1/2}}{n}$ Compute V	ft/s				
18. Flow length, L	ft				
19. $T_t = \frac{L}{3600\,V}$ Compute T_t	hr		+		=
20. Watershed or subarea T_c or T_t (add T_t in steps 6, 11, and 19)	hr				0.34

Sheet flow

Sheet flow is flow over plane surfaces. It usually occurs in the headwater of streams. With sheet flow, the friction value (Manning's n) is an effective roughness coefficient that includes the effect of raindrop impact; drag over the plane surface; obstacles such as litter, crop ridges, and rocks; and erosion and transportation of sediment. These n values are for very shallow flow depths of about 0.1 foot or so. Table 3-1 gives Manning's n values for sheet flow for various surface conditions.

For sheet flow of less than 300 feet, use Manning's kinematic solution (Overton and Meadows 1976) to compute T_t:

$$T_t = \frac{0.007\,(nL)^{0.8}}{(P_2)^{0.5}\,s^{0.4}} \qquad \text{[Eq. 3-3]}$$

Table 3-1.—Roughness coefficients (Manning's n) for sheet flow

Surface description	n[1]
Smooth surfaces (concrete, asphalt, gravel, or bare soil)	0.011
Fallow (no residue)	0.05
Cultivated soils:	
Residue cover ≤20%	0.06
Residue cover >20%	0.17
Grass:	
Short grass prairie	0.15
Dense grasses[2]	0.24
Bermudagrass	0.41
Range (natural)	0.13
Woods:[3]	
Light underbrush	0.40
Dense underbrush	0.80

[1]The n values are a composite of information compiled by Engman (1986).
[2]Includes species such as weeping lovegrass, bluegrass, buffalo grass, blue grama grass, and native grass mixtures.
[3]When selecting n, consider cover to a height of about 0.1 ft. This is the only part of the plant cover that will obstruct sheet flow.

where

T_t = travel time (hr),
n = Manning's roughness coefficient (table 3-1),
L = flow length (ft),
P_2 = 2-year, 24-hour rainfall (in), and
s = slope of hydraulic grade line (land slope, ft/ft).

This simplified form of the Manning's kinematic solution is based on the following: (1) shallow steady uniform flow, (2) constant intensity of rainfall excess (that part of a rain available for runoff), (3) rainfall duration of 24 hours, and (4) minor effect of infiltration on travel time. Rainfall depth can be obtained from appendix B.

Shallow concentrated flow

After a maximum of 300 feet, sheet flow usually becomes shallow concentrated flow. The average velocity for this flow can be determined from figure 3-1, in which average velocity is a function of watercourse slope and type of channel. For slopes less than 0.005 ft/ft, use equations given in appendix F for figure 3-1. Tillage can affect the direction of shallow concentrated flow. Flow may not always be directly down the watershed slope if tillage runs across the slope.

After determining average velocity in figure 3-1, use equation 3-1 to estimate travel time for the shallow concentrated flow segment.

Open channels

Open channels are assumed to begin where surveyed cross section information has been obtained, where channels are visible on aerial photographs, or where blue lines (indicating streams) appear on United States Geological Survey (USGS) quadrangle sheets. Manning's equation or water surface profile information can be used to estimate average flow velocity. Average flow velocity is usually determined for bank-full elevation.

Worksheet 4: Graphical Peak Discharge method

Project _____ By ____ Date _____

Location _____ Checked SC Date 8/22/96

Circle one: Present Developed _____

1. Data:

Drainage area ..... A_m = 0.015 mi^2 (acres/640)

Runoff curve number .... CN = 61 (From worksheet 2)

Time of concentration .. T_c = 0.34 hr (From worksheet 3)

Rainfall distribution type = III (I, IA, II, III)

Pond and swamp areas spread throughout watershed ..... = _____ percent of A_m (____ acres or mi^2 covered)

		Storm #1	Storm #2	Storm #3
2. Frequency	yr	25		
3. Rainfall, P (24-hour)	in	5		
4. Initial abstraction, I_a ..... (Use CN with table 4-1.)	in	1.3		
5. Compute I_a/P		0.26		
6. Unit peak discharge, q_u ..... (Use T_c and I_a/P with exhibit 4-____)	csm/in	425		
7. Runoff, Q ..... (From worksheet 2).	in	1.3		
8. Pond and swamp adjustment factor, F_p .... (Use percent pond and swamp area with table 4-2. Factor is 1.0 for zero percent pond and swamp area.)				
9. Peak discharge, q_p ..... (Where $q_p = q_u A_m Q F_p$)	cfs	8.3		

Chapter 4: Graphical Peak Discharge method

This chapter presents the Graphical Peak Discharge method for computing peak discharge from rural and urban areas. The Graphical method was developed from hydrograph analyses using TR-20, "Computer Program for Project Formulation—Hydrology" (SCS 1983). The peak discharge equation used is

$$q_p = q_u A_m Q F_p \qquad \text{[Eq. 4-1]}$$

where

q_p = peak discharge (cfs);
q_u = unit peak discharge (csm/in);
A_m = drainage area (mi^2);
Q = runoff (in); and
F_p = pond and swamp adjustment factor.

The input requirements for the Graphical method are as follows: (1) T_c (hr), (2) drainage area (mi^2), (3) appropriate rainfall distribution (I, IA, II, or III), (4) 24-hour rainfall (in), and (5) CN. If pond and swamp areas are spread throughout the watershed and are not considered in the T_c computation, an adjustment for pond and swamp areas is also needed.

Peak discharge computation

For a selected rainfall frequency, the 24-hour rainfall (P) is obtained from appendix B or more detailed local precipitation maps. CN and total runoff (Q) for the watershed are computed according to the methods outlined in chapter 2. The CN is used to determine the initial abstraction (I_a) from table 4-1. I_a/P is then computed.

If the computed I_a/P ratio is outside the range shown in exhibit 4 (4-I, 4-IA, 4-II, and 4-III) for the rainfall distribution of interest, then the limiting value should be used. If the ratio falls between the limiting values, use linear interpolation. Figure 4-1 illustrates the sensitivity of I_a/P to CN and P.

Peak discharge per square mile per inch of runoff (q_u) is obtained from exhibit 4-I, 4-IA, 4-II, or 4-III by using T_c (chapter 3), rainfall distribution type, and I_a/P ratio. The pond and swamp adjustment factor is obtained from table 4-2 (rounded to the nearest table value). Use worksheet 4 in appendix D to aid in computing the peak discharge using the Graphical method.

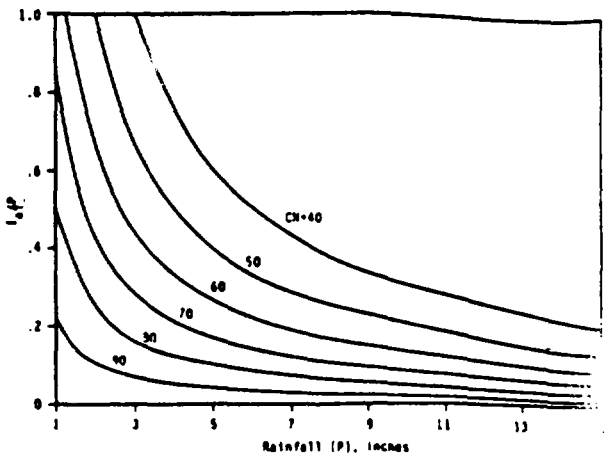
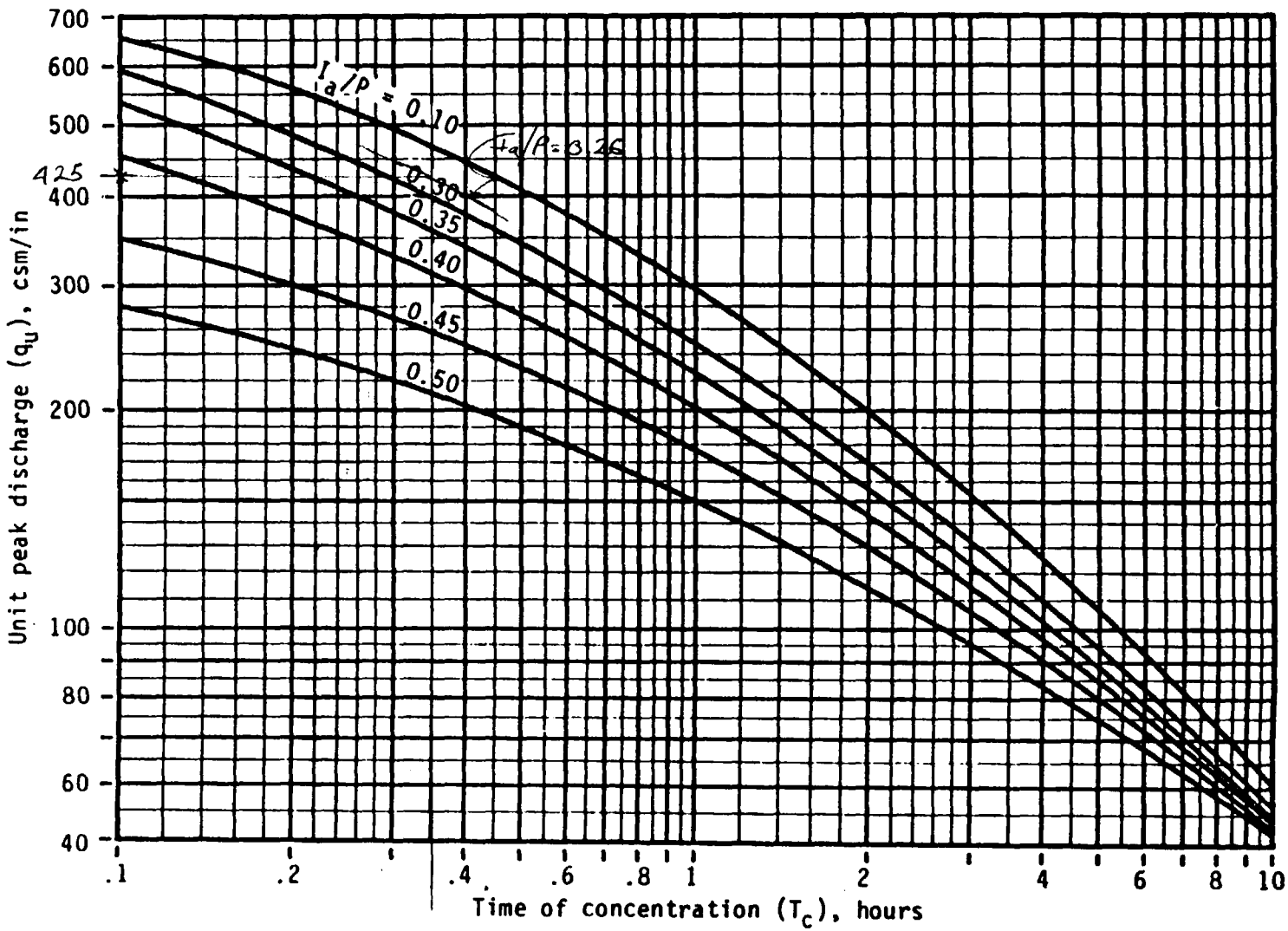


Figure 4-1.—Variation of I_a/P for P and CN.

Table 4-1.—I_a values for runoff curve numbers

Curve number	I_a (in)	Curve number	I_a (in)
40	3.000	70	0.857
41	2.878	71	0.817
42	2.762	72	0.778
43	2.651	73	0.740
44	2.545	74	0.703
45	2.444	75	0.667
46	2.348	76	0.632
47	2.255	77	0.597
48	2.167	78	0.564
49	2.082	79	0.532
50	2.000	80	0.500
51	1.922	81	0.469
52	1.846	82	0.439
53	1.774	83	0.410
54	1.704	84	0.381
55	1.636	85	0.353
56	1.571	86	0.326
57	1.509	87	0.299
58	1.448	88	0.273
59	1.390	89	0.247
60	1.333	90	0.222
61	1.279	91	0.198
62	1.226	92	0.174
63	1.175	93	0.151
64	1.125	94	0.128
65	1.077	95	0.105
66	1.030	96	0.083
67	0.985	97	0.062
68	0.941	98	0.041
69	0.899		

Exhibit 4-III: Unit peak discharge (q_u) for SCS type III rainfall distribution



Solid Waste Area
Detention Basin #1: Sizing

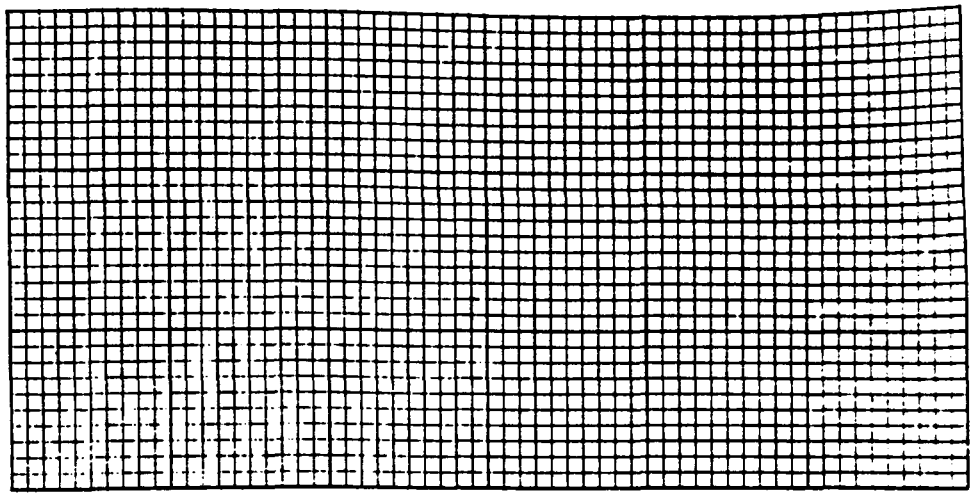
Worksheet 6a: Detention basin storage, peak outflow discharge (q_o) known

Project Rose Hill ES By ____ Date ____

Location Detention Basin I Checked SC Date 8/22/96

Circle one: Present Developed

Elevation or stage



Detention basin storage

1. Data:
   Drainage area ..... A_m = 0.015 mi^2
   Rainfall distribution type (I, IA, II, III) = III

	1st stage	2nd stage
2. Frequency ..... yr	25	
3. Peak inflow discharge, q_i .... cfs (From worksheet 4 or 5b)	8.3	
4. Peak outflow discharge, q_o .... cfs 1/	0.6	
5. Compute $\frac{q_o}{q_i}$	0.07	
6. $\frac{V_s}{V_r}$ ..... (Use $\frac{q_o}{q_i}$ with figure 6-1)	0.6	
7. Runoff, Q ..... in (From worksheet 2)	1.3	
8. Runoff volume, V_r ..... ac-ft ($V_r = QA_m 53.33$)	1.04	
9. Storage volume, V_s ..... ac-ft ($V_s = V_r(\frac{V_s}{V_r})$)	0.62	
10. Maximum stage, E_{max} (From plot)		

1/ 2nd stage q_o includes 1st stage q_o.

Input requirements and procedures

Use figure 6-1 to estimate storage volume (V_s) required or peak outflow discharge (q_o). The most frequent application is to estimate V_s, for which the required inputs are runoff volume (V_r), q_o, and peak inflow discharge (q_i). To estimate q_o, the required inputs are V_r, V_s, and q_i.

ACTUAL $\frac{q_o}{q_i} = 0.7$; APPROXIMATE EXTRAPOLATION YIELDS $\frac{V_s}{V_R} \approx 0.6$

Estimating V_s

Use worksheet 6a to estimate V_s, storage volume required, by the following procedure.

1. Determine q_o. Many factors may dictate the selection of peak outflow discharge. The most common is to limit downstream discharges to a desired level, such as predevelopment discharge. Another factor may be that the outflow device has already been selected.
2. Estimate q_i by procedures in chapters 4 or 5. Do not use peak discharges developed by any other procedure. When using the Tabular Hydrograph method to estimate q_i for a subarea, only use

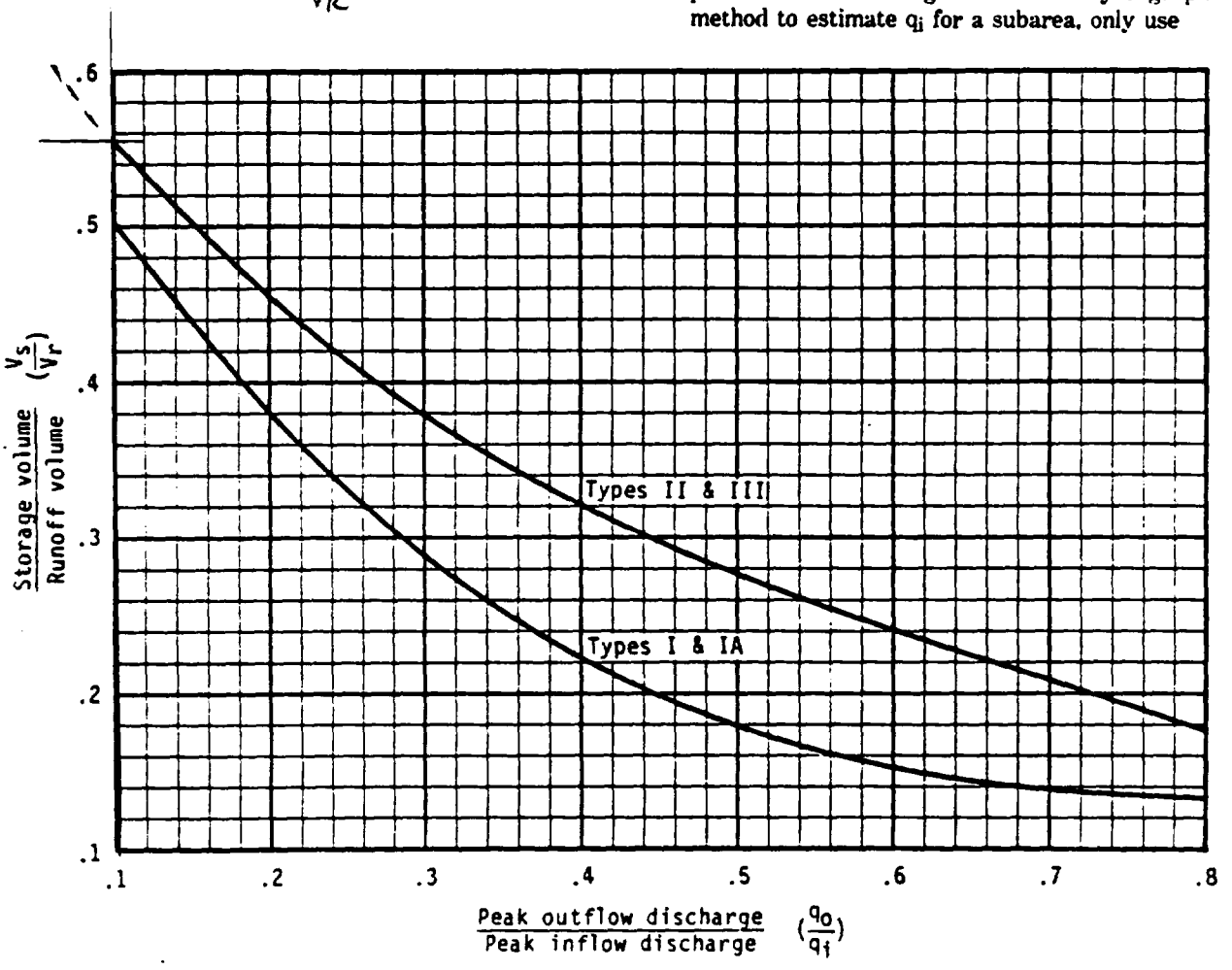


Figure 6-1.—Approximate detention basin routing for rainfall types I, IA, II, and III.

Solid Waste Area
Detention Basin #2: Pre-Development

Worksheet 2: Runoff curve number and runoff

Project Rose Hill FS By DTC Date 3/31/93

Location Solid Waste LF Det. Bas. II Checked SC Date 8/22/96

Circle one: (Present) Developed

1. Runoff curve number (CN)

Soil name and hydrologic group (appendix A)	Cover description (cover type, treatment, and hydrologic condition; percent impervious; unconnected/connected impervious area ratio)	CN 1/ Table 2-2	CN 1/ Fig. 2-3	CN 1/ Fig. 2-4	Area ☐ acres ☒ mi^2 ☐ %	Product of CN x area
Soil A	Grass	39			0.004	
				Totals =		

1/ Use only one CN source per line.

CN (weighted) = $\frac{\text{total product}}{\text{total area}}$ = ____ = ____; Use CN = 39

2. Runoff

		Storm #1	Storm #2	Storm #3
Frequency	yr	25		
Rainfall, P (24-hour)	in	5		
Runoff, Q ..... (Use P and CN with table 2-1, fig. 2-1, or eqs. 2-3 and 2-4.)	in	0.2		

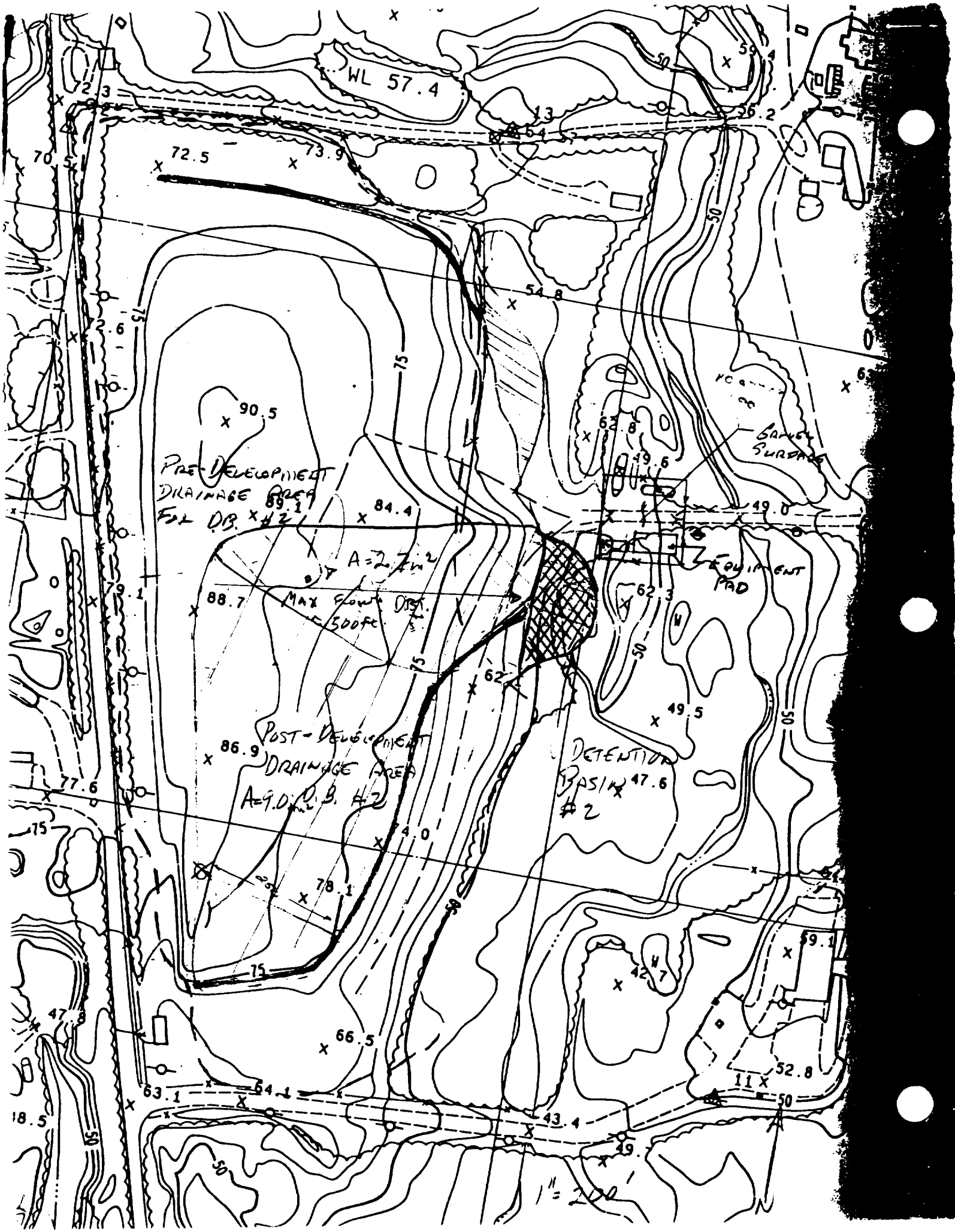

WL 57.4
PRE-DEVELOPMENT
DRAINAGE AREA
FOR D.B. #2
A=2.7 in²
MAX FLOW DIST.
=500 ft.
POST-DEVELOPMENT
DRAINAGE AREA
A=9.0 in² D.B. #2
DETENTION
BASIN
#2
EQUIPMENT
PAD
GRAVEL
SURFACE
1" = 200'

Table 2-2a.—Runoff curve numbers for urban areas[1]

Cover description		Curve numbers for hydrologic soil group—			
Cover type and hydrologic condition	Average percent impervious area[2]	A	B	C	D
Fully developed urban areas (vegetation established)					
Open space (lawns, parks, golf courses, cemeteries, etc.)[3]:					
Poor condition (grass cover < 50%)		68	79	86	89
Fair condition (grass cover 50% to 75%)		49	69	79	84
Good condition (grass cover > 75%)		39	61	74	80
Impervious areas:					
Paved parking lots, roofs, driveways, etc. (excluding right-of-way)		98	98	98	98
Streets and roads:					
Paved; curbs and storm sewers (excluding right-of-way)		98	98	98	98
Paved; open ditches (including right-of-way)		83	89	92	93
Gravel (including right-of-way)		76	85	89	91
Dirt (including right-of-way)		72	82	87	89
Western desert urban areas:					
Natural desert landscaping (pervious areas only)[4]		63	77	85	88
Artificial desert landscaping (impervious weed barrier, desert shrub with 1- to 2-inch sand or gravel mulch and basin borders)		96	96	96	96
Urban districts:					
Commercial and business	85	89	92	94	95
Industrial	72	81	88	91	93
Residential districts by average lot size:					
1/8 acre or less (town houses)	65	77	85	90	92
1/4 acre	38	61	75	83	87
1/3 acre	30	57	72	81	86
1/2 acre	25	54	70	80	85
1 acre	20	51	68	79	84
2 acres	12	46	65	77	82
Developing urban areas					
Newly graded areas (pervious areas only, no vegetation)[5]		77	86	91	94
Idle lands (CN's are determined using cover types similar to those in table 2-2c).					

[1]Average runoff condition, and $I_a = 0.2S$.
[2]The average percent impervious area shown was used to develop the composite CN's. Other assumptions are as follows: impervious areas are directly connected to the drainage system, impervious areas have a CN of 98, and pervious areas are considered equivalent to open space in good hydrologic condition. CN's for other combinations of conditions may be computed using figure 2-3 or 2-4.
[3]CN's shown are equivalent to those of pasture. Composite CN's may be computed for other combinations of open space cover type.
[4]Composite CN's for natural desert landscaping should be computed using figures 2-3 or 2-4 based on the impervious area percentage (CN = 98) and the pervious area CN. The pervious area CN's are assumed equivalent to desert shrub in poor hydrologic condition.
[5]Composite CN's to use for the design of temporary measures during grading and construction should be computed using figure 2-3 or 2-4, based on the degree of development (impervious area percentage) and the CN's for the newly graded pervious areas.

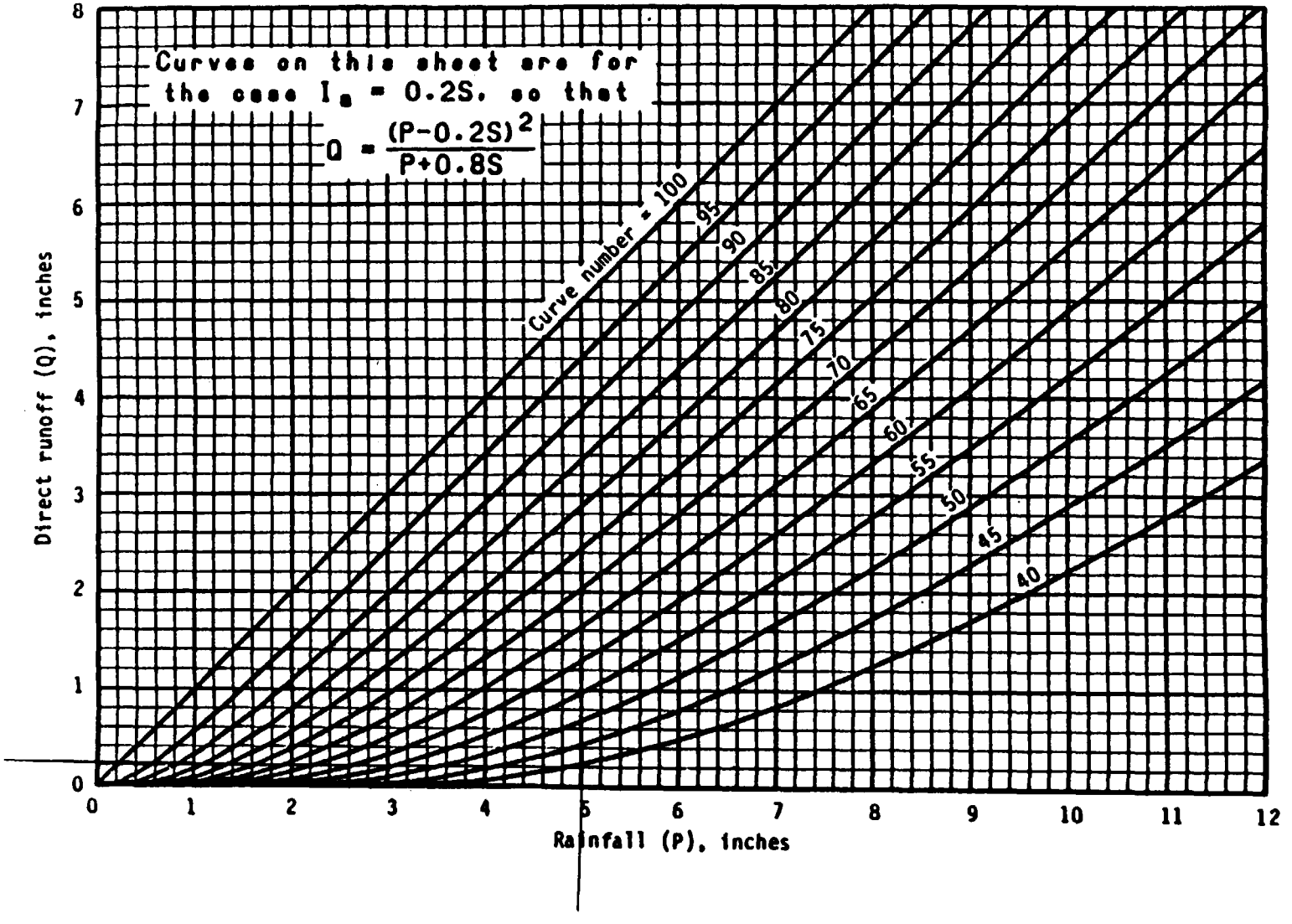


Figure 2-1.—Solution of runoff equation.

Worksheet 3: Time of concentration (T_c) or travel time (T_t)

Project _____ By _____ Date _____

Location _____ Checked SC Date 8/22/96

Circle one: Present Developed _____

Circle one: T_c T_t through subarea _____

NOTES: Space for as many as two segments per flow type can be used for each worksheet.

Include a map, schematic, or description of flow segments.

Sheet flow (Applicable to T_c only)		Segment ID		
1. Surface description (table 3-1)		SHORT GRASS		
2. Manning's roughness coeff., n (table 3-1) ..		0.15		
3. Flow length, L (total L ≤ 300 ft)	ft	500		
4. Two-yr 24-hr rainfall, P_2	in	3.5		
5. Land slope, s	ft/ft	0.07		
6. $T_t = \frac{0.007\ (nL)^{0.8}}{P_2^{0.5}\ s^{0.4}}$ Compute T_t	hr	0.34	+	= 0.34

Shallow concentrated flow		Segment ID		
7. Surface description (paved or unpaved)				
8. Flow length, L	ft			
9. Watercourse slope, s	ft/ft			
10. Average velocity, V (figure 3-1)	ft/s			
11. $T_t = \frac{L}{3600\ V}$ Compute T_t	hr		+	=

MAKE SIMPLIFYING ASSUMPTION THAT ONLY SHEET FLOW BEGINS THROUGH RUN LENGTHS ARE LONG ENOUGH FOR SHALLOW CONC. FLOW

Channel flow		Segment ID		
12. Cross sectional flow area, a	ft^2			
13. Wetted perimeter, p_w	ft			
14. Hydraulic radius, $r = \frac{a}{p_w}$ Compute r	ft			
15. Channel slope, s	ft/ft			
16. Manning's roughness coeff., n				
17. $V = \frac{1.49\ r^{2/3}\ s^{1/2}}{n}$ Compute V	ft/s			
18. Flow length, L	ft			
19. $T_t = \frac{L}{3600\ V}$ Compute T_t	hr		+	=

ASSUME ONLY SHEET FLOW THROUGH CHANNELS MAY EXIST.

20. Watershed or subarea T_c or T_t (add T_t in steps 6, 11, and 19) ..... hr 0.34

Sheet flow

Sheet flow is flow over plane surfaces. It usually occurs in the headwater of streams. With sheet flow, the friction value (Manning's n) is an effective roughness coefficient that includes the effect of raindrop impact; drag over the plane surface; obstacles such as litter, crop ridges, and rocks; and erosion and transportation of sediment. These n values are for very shallow flow depths of about 0.1 foot or so. Table 3-1 gives Manning's n values for sheet flow for various surface conditions.

For sheet flow of less than 300 feet, use Manning's kinematic solution (Overton and Meadows 1976) to compute T_t:

$$T_t = \frac{0.007\,(nL)^{0.8}}{(P_2)^{0.5}\,s^{0.4}} \qquad \text{[Eq. 3-3]}$$

Table 3-1.—Roughness coefficients (Manning's n) for sheet flow

Surface description	n[1]
Smooth surfaces (concrete, asphalt, gravel, or bare soil)	0.011
Fallow (no residue)	0.05
Cultivated soils:	
Residue cover ≤20%	0.06
Residue cover >20%	0.17
Grass:	
Short grass prairie	0.15
Dense grasses[2]	0.24
Bermudagrass	0.41
Range (natural)	0.13
Woods:[3]	
Light underbrush	0.40
Dense underbrush	0.80

[1]The n values are a composite of information compiled by Engman (1986).
[2]Includes species such as weeping lovegrass, bluegrass, buffalo grass, blue grama grass, and native grass mixtures.
[3]When selecting n, consider cover to a height of about 0.1 ft. This is the only part of the plant cover that will obstruct sheet flow.

where

T_t = travel time (hr),
n = Manning's roughness coefficient (table 3-1),
L = flow length (ft),
P_2 = 2-year, 24-hour rainfall (in), and
s = slope of hydraulic grade line (land slope, ft/ft).

This simplified form of the Manning's kinematic solution is based on the following: (1) shallow steady uniform flow, (2) constant intensity of rainfall excess (that part of a rain available for runoff), (3) rainfall duration of 24 hours, and (4) minor effect of infiltration on travel time. Rainfall depth can be obtained from appendix B.

Shallow concentrated flow

After a maximum of 300 feet, sheet flow usually becomes shallow concentrated flow. The average velocity for this flow can be determined from figure 3-1, in which average velocity is a function of watercourse slope and type of channel. For slopes less than 0.005 ft/ft, use equations given in appendix F for figure 3-1. Tillage can affect the direction of shallow concentrated flow. Flow may not always be directly down the watershed slope if tillage runs across the slope.

After determining average velocity in figure 3-1, use equation 3-1 to estimate travel time for the shallow concentrated flow segment.

Open channels

Open channels are assumed to begin where surveyed cross section information has been obtained, where channels are visible on aerial photographs, or where blue lines (indicating streams) appear on United States Geological Survey (USGS) quadrangle sheets. Manning's equation or water surface profile information can be used to estimate average flow velocity. Average flow velocity is usually determined for bank-full elevation.

Worksheet 4: Graphical Peak Discharge method

Project _____ By ____ Date _____

Location _____ Checked SC Date 8/22/96

Circle one: Present Developed _____

1. Data:

Drainage area ..... A_m = 0.004 mi^2 (acres/640)

Runoff curve number .... CN = 39 (From worksheet 2)

Time of concentration .. T_c = 0.34 hr (From worksheet 3)

Rainfall distribution type = III (I, IA, II, III)

Pond and swamp areas spread throughout watershed ..... = _____ percent of A_m (____ acres or mi^2 covered)

		Storm #1	Storm #2	Storm #3
2. Frequency	yr	25		
3. Rainfall, P (24-hour)	in	5		
4. Initial abstraction, I_a ..... (Use CN with table 4-1.)	in	3		
5. Compute I_a/P		0.6		
6. Unit peak discharge, q_u ..... (Use T_c and I_a/P with exhibit 4-____)	csm/in	≈ 200		
7. Runoff, Q ..... (From worksheet 2).	in	0.2		
8. Pond and swamp adjustment factor, F_p .... (Use percent pond and swamp area with table 4-2. Factor is 1.0 for zero percent pond and swamp area.)				
9. Peak discharge, q_p ..... (Where $q_p = q_u A_m Q F_p$)	cfs	0.16		

Chapter 4: Graphical Peak Discharge method

This chapter presents the Graphical Peak Discharge method for computing peak discharge from rural and urban areas. The Graphical method was developed from hydrograph analyses using TR-20, "Computer Program for Project Formulation—Hydrology" (SCS 1983). The peak discharge equation used is

$$q_p = q_u A_m Q F_p \qquad \text{[Eq. 4-1]}$$

where

q_p = peak discharge (cfs);
q_u = unit peak discharge (csm/in);
A_m = drainage area (mi²);
Q = runoff (in); and
F_p = pond and swamp adjustment factor.

The input requirements for the Graphical method are as follows: (1) T_c (hr), (2) drainage area (mi²), (3) appropriate rainfall distribution (I, IA, II, or III), (4) 24-hour rainfall (in), and (5) CN. If pond and swamp areas are spread throughout the watershed and are not considered in the T_c computation, an adjustment for pond and swamp areas is also needed.

Peak discharge computation

For a selected rainfall frequency, the 24-hour rainfall (P) is obtained from appendix B or more detailed local precipitation maps. CN and total runoff (Q) for the watershed are computed according to the methods outlined in chapter 2. The CN is used to determine the initial abstraction (I_a) from table 4-1. I_a/P is then computed.

If the computed I_a/P ratio is outside the range shown in exhibit 4 (4-I, 4-IA, 4-II, and 4-III) for the rainfall distribution of interest, then the limiting value should be used. If the ratio falls between the limiting values, use linear interpolation. Figure 4-1 illustrates the sensitivity of I_a/P to CN and P.

Peak discharge per square mile per inch of runoff (q_u) is obtained from exhibit 4-I, 4-IA, 4-II, or 4-III by using T_c (chapter 3), rainfall distribution type, and I_a/P ratio. The pond and swamp adjustment factor is obtained from table 4-2 (rounded to the nearest table value). Use worksheet 4 in appendix D to aid in computing the peak discharge using the Graphical method.

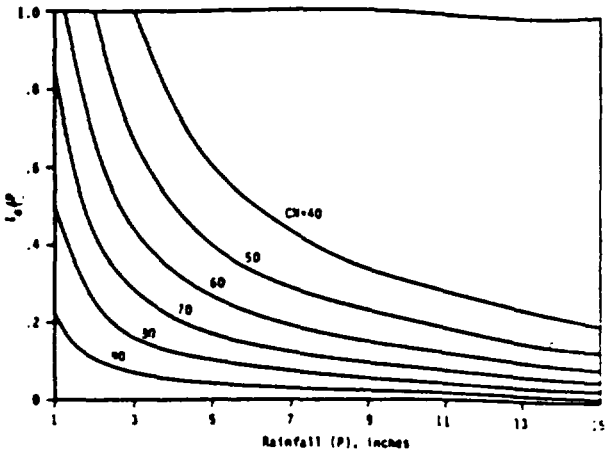
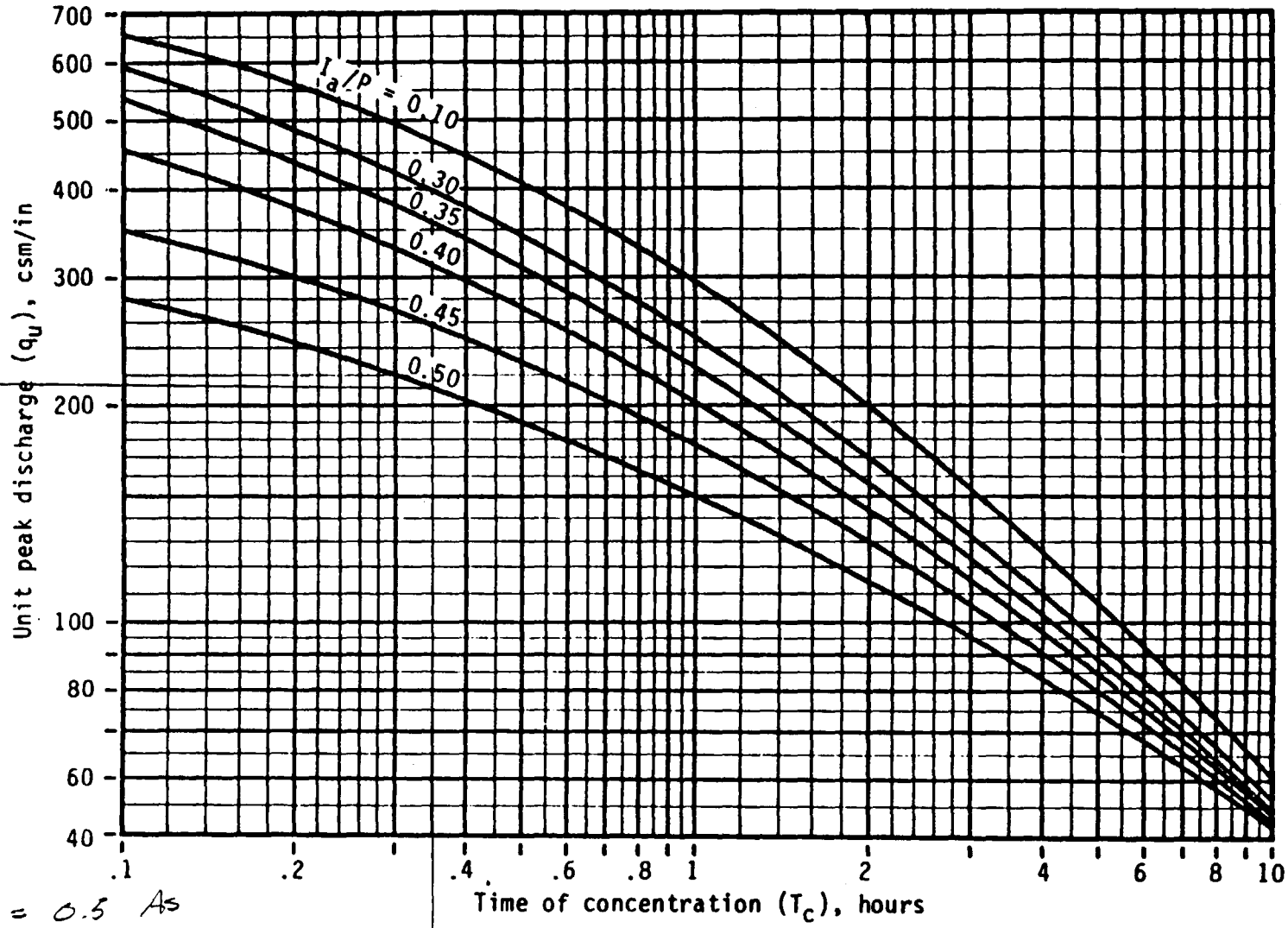


Figure 4-1.—Variation of I_a/P for P and CN.

Table 4-1.—I_a values for runoff curve numbers

Curve number	I_a (in)	Curve number	I_a (in)
40	3.000	70	0.8[illegible]
41	2.878	71	0.[illegible]
42	2.762	72	0.77[illegible]
43	2.651	73	0.740
44	2.545	74	0.703
45	2.444	75	0.667
46	2.348	76	0.632
47	2.255	77	0.597
48	2.167	78	0.564
49	2.082	79	0.532
50	2.000	80	0.500
51	1.922	81	0.469
52	1.846	82	0.439
53	1.774	83	0.410
54	1.704	84	0.381
55	1.636	85	0.353
56	1.571	86	0.326
57	1.509	87	0.299
58	1.448	88	0.273
59	1.390	89	0.247
60	1.333	90	0.222
61	1.279	91	0.198
62	1.226	92	0.174
63	1.175	93	0.151
64	1.125	94	0.128
65	1.077	95	0.105
66	1.030	96	0.083
67	0.985	97	0.062
68	0.941	98	0.041
69	0.899		

Exhibit 4-III: Unit peak discharge (q_u) for SCS type III rainfall distribution



USE Ia/P = 0.5 AS
APPROXIMATION - ACTUAL
Ia/P = 0.6

Solid Waste Area
Detention Basin #2: Post-Development

Worksheet 2: Runoff curve number and runoff

Project Rose Hill ES By DTC Date _____

Location Solid Waste & Recycling Area II Checked SC Date 8/22/96

Circle one: Present (Developed) _____

1. Runoff curve number (CN)

Soil name and hydrologic group (appendix A)	Cover description (cover type, treatment, and hydrologic condition; percent impervious; unconnected/connected impervious area ratio)	CN 1/ Table 2-2	CN 1/ Fig. 2-3	CN 1/ Fig. 2-4	Area ☐ acres ☒ mi^2 ☐ %	Product of CN x area
Loam, B		61			0.013	
	Totals =					

1/ Use only one CN source per line.

CN (weighted) = $\frac{\text{total product}}{\text{total area}}$ = _____ = _____; Use CN = 61

2. Runoff

	Storm #1	Storm #2	Storm #3
Frequency ..... yr	25		
Rainfall, P (24-hour) ..... in	5		
Runoff, Q ..... in (Use P and CN with table 2-1, fig. 2-1, or eqs. 2-3 and 2-4.)	1.3		

Table 2-2a.—Runoff curve numbers for urban areas[1]

Cover description		Curve numbers for hydrologic soil group—			
Cover type and hydrologic condition	Average percent impervious area[2]	A	B	C	D
Fully developed urban areas (vegetation established)					
Open space (lawns, parks, golf courses, cemeteries, etc.)[3]:					
Poor condition (grass cover < 50%)		68	79	86	89
Fair condition (grass cover 50% to 75%)		49	69	79	84
Good condition (grass cover > 75%)		39	61	74	80
Impervious areas:					
Paved parking lots, roofs, driveways, etc. (excluding right-of-way)		98	98	98	98
Streets and roads:					
Paved; curbs and storm sewers (excluding right-of-way)		98	98	98	98
Paved; open ditches (including right-of-way)		83	89	92	93
Gravel (including right-of-way)		76	85	89	91
Dirt (including right-of-way)		72	82	87	89
Western desert urban areas:					
Natural desert landscaping (pervious areas only)[4]		63	77	85	88
Artificial desert landscaping (impervious weed barrier, desert shrub with 1- to 2-inch sand or gravel mulch and basin borders)		96	96	96	96
Urban districts:					
Commercial and business	85	89	92	94	95
Industrial	72	81	88	91	93
Residential districts by average lot size:					
1/8 acre or less (town houses)	65	77	85	90	92
1/4 acre	38	61	75	83	87
1/3 acre	30	57	72	81	86
1/2 acre	25	54	70	80	85
1 acre	20	51	68	79	84
2 acres	12	46	65	77	82
Developing urban areas					
Newly graded areas (pervious areas only, no vegetation)[5]		77	86	91	94
Idle lands (CN's are determined using cover types similar to those in table 2-2c).					

[1]Average runoff condition, and $I_a = 0.2S$.
[2]The average percent impervious area shown was used to develop the composite CN's. Other assumptions are as follows: impervious areas are directly connected to the drainage system, impervious areas have a CN of 98, and pervious areas are considered equivalent to open space in good hydrologic condition. CN's for other combinations of conditions may be computed using figure 2-3 or 2-4.
[3]CN's shown are equivalent to those of pasture. Composite CN's may be computed for other combinations of open space cover type.
[4]Composite CN's for natural desert landscaping should be computed using figures 2-3 or 2-4 based on the impervious area percentage (CN = 98) and the pervious area CN. The pervious area CN's are assumed equivalent to desert shrub in poor hydrologic condition.
[5]Composite CN's to use for the design of temporary measures during grading and construction should be computed using figure 2-3 or 2-4, based on the degree of development (impervious area percentage) and the CN's for the newly graded pervious areas.

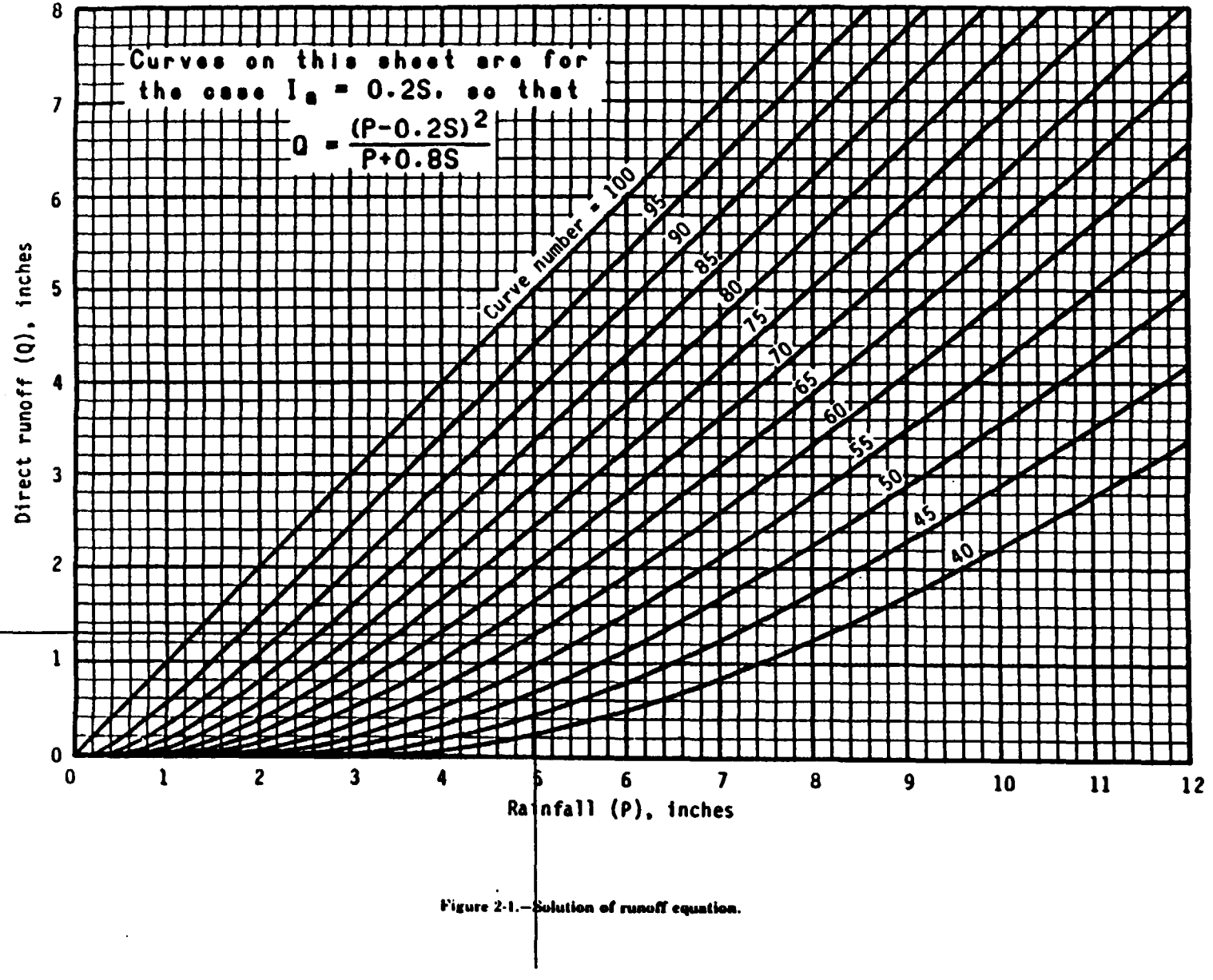


Figure 2-1.—Solution of runoff equation.

Worksheet 3: Time of concentration (T_c) or travel time (T_t)

Project _____ By ____ Date _____

Location _____ Checked SC Date 8/22/96

Circle one: Present Developed _____

Circle one: T_c T_t through subarea _____

NOTES: Space for as many as two segments per flow type can be used for each worksheet.

Include a map, schematic, or description of flow segments.

Sheet flow (Applicable to T_c only)		Segment ID		
1. Surface description (table 3-1)		SHORT GRASS		
2. Manning's roughness coeff., n (table 3-1) ..		0.15		
3. Flow length, L (total L ≤ 300 ft)	ft	600		
4. Two-yr 24-hr rainfall, P_2	in	3.5		
5. Land slope, s	ft/ft	≈ 0.07		
6. $T_t = \frac{0.007\ (nL)^{0.8}}{P_2^{0.5}\ s^{0.4}}$ Compute T_t	hr	0.40	+	= 0.40

Shallow concentrated flow		Segment ID		
7. Surface description (paved or unpaved)				
8. Flow length, L	ft			
9. Watercourse slope, s	ft/ft			
10. Average velocity, V (figure 3-1)	ft/s			
11. $T_t = \frac{L}{3600\ V}$ Compute T_t	hr		+	=

MAKE SIMPLIFYING ASSUMPTION THAT ONLY SHALLOW FLOW OCCURS THROUGH RUN LENGTHS ARE LONG ENOUGH FOR SHALLOW CONCENTRATED FLOW

Channel flow		Segment ID		
12. Cross sectional flow area, a	ft^2			
13. Wetted perimeter, p_w	ft			
14. Hydraulic radius, $r = \frac{a}{p_w}$ Compute r	ft			
15. Channel slope, s	ft/ft			
16. Manning's roughness coeff., n				
17. $V = \frac{1.49\ r^{2/3}\ s^{1/2}}{n}$ Compute V	ft/s			
18. Flow length, L	ft			
19. $T_t = \frac{L}{3600\ V}$ Compute T_t	hr		+	=

20. Watershed or subarea T_c or T_t (add T_t in steps 6, 11, and 19) ..... hr 0.40

Sheet flow

Sheet flow is flow over plane surfaces. It usually occurs in the headwater of streams. With sheet flow, the friction value (Manning's n) is an effective roughness coefficient that includes the effect of raindrop impact; drag over the plane surface; obstacles such as litter, crop ridges, and rocks; and erosion and transportation of sediment. These n values are for very shallow flow depths of about 0.1 foot or so. Table 3-1 gives Manning's n values for sheet flow for various surface conditions.

For sheet flow of less than 300 feet, use Manning's kinematic solution (Overton and Meadows 1976) to compute T_t:

$$T_t = \frac{0.007\,(nL)^{0.8}}{(P_2)^{0.5}\,s^{0.4}} \qquad \text{[Eq. 3-3]}$$

Table 3-1.—Roughness coefficients (Manning's n) for sheet flow

Surface description	n[1]
Smooth surfaces (concrete, asphalt, gravel, or bare soil)	0.011
Fallow (no residue)	0.05
Cultivated soils:	
Residue cover ≤20%	0.06
Residue cover >20%	0.17
Grass:	
Short grass prairie	0.15
Dense grasses[2]	0.24
Bermudagrass	0.41
Range (natural)	0.13
Woods:[3]	
Light underbrush	0.40
Dense underbrush	0.80

[1]The n values are a composite of information compiled by Engman (1986).
[2]Includes species such as weeping lovegrass, bluegrass, buffalo grass, blue grama grass, and native grass mixtures.
[3]When selecting n, consider cover to a height of about 0.1 ft. This is the only part of the plant cover that will obstruct sheet flow.

where

T_t = travel time (hr),
n = Manning's roughness coefficient (table 3-1),
L = flow length (ft),
P_2 = 2-year, 24-hour rainfall (in), and
s = slope of hydraulic grade line (land slope, ft/ft).

This simplified form of the Manning's kinematic solution is based on the following: (1) shallow steady uniform flow, (2) constant intensity of rainfall excess (that part of a rain available for runoff), (3) rainfall duration of 24 hours, and (4) minor effect of infiltration on travel time. Rainfall depth can be obtained from appendix B.

Shallow concentrated flow

After a maximum of 300 feet, sheet flow usually becomes shallow concentrated flow. The average velocity for this flow can be determined from figure 3-1, in which average velocity is a function of watercourse slope and type of channel. For slopes less than 0.005 ft/ft, use equations given in appendix F for figure 3-1. Tillage can affect the direction of shallow concentrated flow. Flow may not always be directly down the watershed slope if tillage runs across the slope.

After determining average velocity in figure 3-1, use equation 3-1 to estimate travel time for the shallow concentrated flow segment.

Open channels

Open channels are assumed to begin where surveyed cross section information has been obtained, where channels are visible on aerial photographs, or where blue lines (indicating streams) appear on United States Geological Survey (USGS) quadrangle sheets. Manning's equation or water surface profile information can be used to estimate average flow velocity. Average flow velocity is usually determined for bank-full elevation.

Worksheet 4: Graphical Peak Discharge method

Project _____ By ____ Date _____

Location _____ Checked SC Date 8/22/96

Circle one: Present Developed _____

1. Data:

Drainage area ..... A_m = 0.013 mi^2 (acres/640)

Runoff curve number .... CN = 61 (From worksheet 2)

Time of concentration .. T_c = 0.40 hr (From worksheet 3)

Rainfall distribution type = III (I, IA, II, III)

Pond and swamp areas spread throughout watershed ..... = — percent of A_m (____ acres or mi^2 covered)

		Storm #1	Storm #2	Storm #3
2. Frequency	yr	25		
3. Rainfall, P (24-hour)	in	5		
4. Initial abstraction, I_a ..... (Use CN with table 4-1.)	in	1.3		
5. Compute I_a/P		0.26		
6. Unit peak discharge, q_u ..... (Use T_c and I_a/P with exhibit 4-____)	csm/in	400		
7. Runoff, Q ..... (From worksheet 2).	in	1.3		
8. Pond and swamp adjustment factor, F_p .... (Use percent pond and swamp area with table 4-2. Factor is 1.0 for zero percent pond and swamp area.)				
9. Peak discharge, q_p ..... (Where $q_p = q_u A_m Q F_p$)	cfs	6.8		

Chapter 4: Graphical Peak Discharge method

This chapter presents the Graphical Peak Discharge method for computing peak discharge from rural and urban areas. The Graphical method was developed from hydrograph analyses using TR-20, "Computer Program for Project Formulation—Hydrology" (SCS 1983). The peak discharge equation used is

$$q_p = q_u A_m Q F_p \qquad \text{[Eq. 4-1]}$$

where

q_p = peak discharge (cfs);
q_u = unit peak discharge (csm/in);
A_m = drainage area (mi²);
Q = runoff (in); and
F_p = pond and swamp adjustment factor.

The input requirements for the Graphical method are as follows: (1) T_c (hr), (2) drainage area (mi²), (3) appropriate rainfall distribution (I, IA, II, or III), (4) 24-hour rainfall (in), and (5) CN. If pond and swamp areas are spread throughout the watershed and are not considered in the T_c computation, an adjustment for pond and swamp areas is also needed.

Peak discharge computation

For a selected rainfall frequency, the 24-hour rainfall (P) is obtained from appendix B or more detailed local precipitation maps. CN and total runoff (Q) for the watershed are computed according to the methods outlined in chapter 2. The CN is used to determine the initial abstraction (I_a) from table 4-1. I_a/P is then computed.

If the computed I_a/P ratio is outside the range shown in exhibit 4 (4-I, 4-IA, 4-II, and 4-III) for the rainfall distribution of interest, then the limiting value should be used. If the ratio falls between the limiting values, use linear interpolation. Figure 4-1 illustrates the sensitivity of I_a/P to CN and P.

Peak discharge per square mile per inch of runoff (q_u) is obtained from exhibit 4-I, 4-IA, 4-II, or 4-III by using T_c (chapter 3), rainfall distribution type, and I_a/P ratio. The pond and swamp adjustment factor is obtained from table 4-2 (rounded to the nearest table value). Use worksheet 4 in appendix D to aid in computing the peak discharge using the Graphical method.

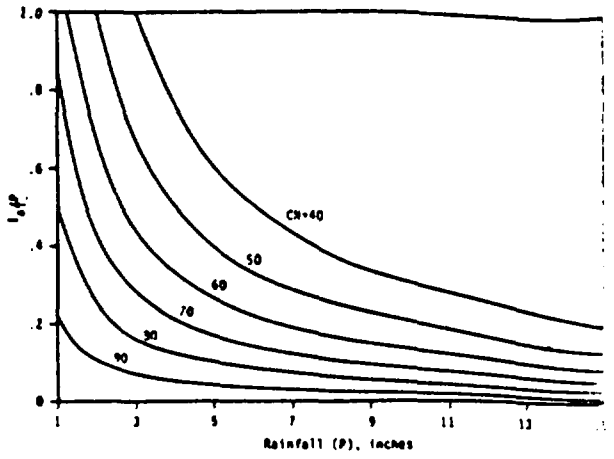
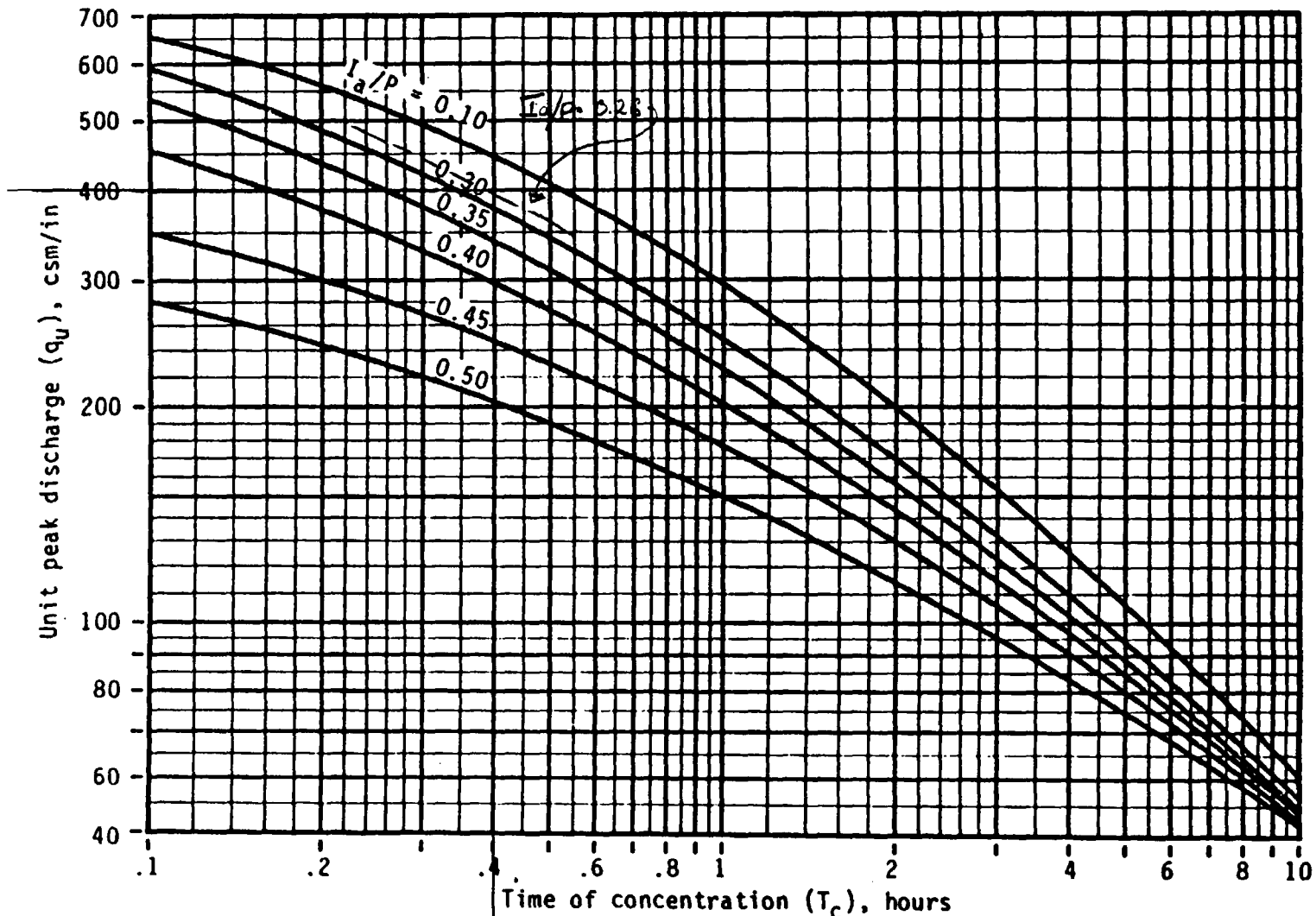


Figure 4-1.—Variation of I_a/P for P and CN.

Table 4-1.—I_a values for runoff curve numbers

Curve number	I_a (in)	Curve number	I_a (in)
40	3.000	70	0.857
41	2.878	71	0.817
42	2.762	72	0.778
43	2.651	73	0.740
44	2.545	74	0.703
45	2.444	75	0.667
46	2.348	76	0.632
47	2.255	77	0.597
48	2.167	78	0.564
49	2.082	79	0.532
50	2.000	80	0.500
51	1.922	81	0.469
52	1.846	82	0.439
53	1.774	83	0.410
54	1.704	84	0.381
55	1.636	85	0.353
56	1.571	86	0.326
57	1.509	87	0.299
58	1.448	88	0.273
59	1.390	89	0.247
60	1.333	90	0.222
61	1.279	91	0.198
62	1.226	92	0.174
63	1.175	93	0.151
64	1.125	94	0.128
65	1.077	95	0.105
66	1.030	96	0.083
67	0.985	97	0.062
68	0.941	98	0.041
69	0.899		

Exhibit 4-III: Unit peak discharge (q_u) for SCS type III rainfall distribution



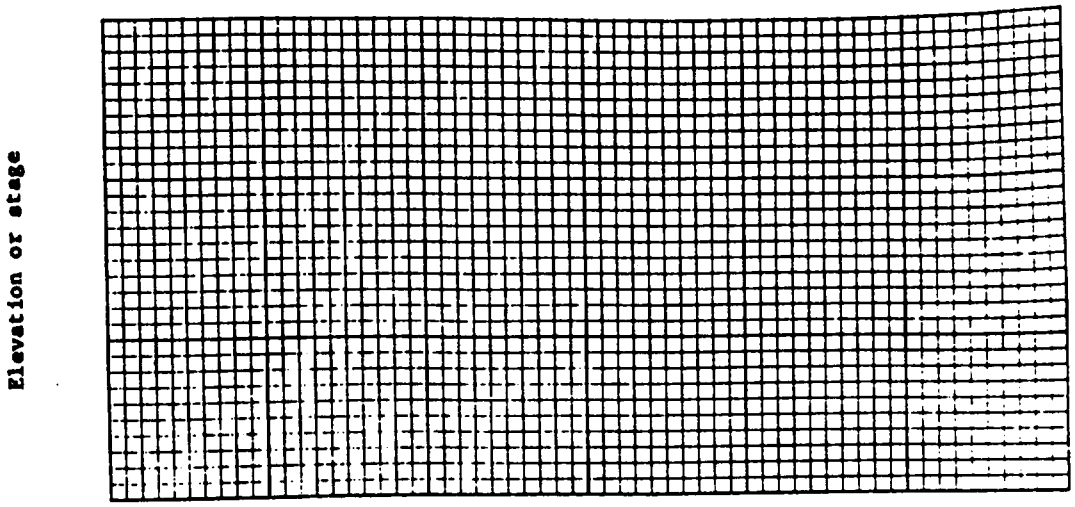
Solid Waste Area
Detention Basin #2: Sizing

Worksheet 6a: Detention basin storage, peak outflow discharge (q_o) known

Project Rose Hill ES By DTC Date 3/30/93

Location Detention Basin #2 Checked SC Date 8/22/96

Circle one: Present Developed



Detention basin storage

1. Data:
   Drainage area ..... A_m = 0.013 mi^2
   Rainfall distribution type (I, IA, II, III) = III

	1st stage	2nd stage
2. Frequency ..... yr	25	
3. Peak inflow discharge, q_i .... cfs (From worksheet 4 or 5b)	6.8	
4. Peak outflow discharge, q_o .... cfs 1/	0.16	
5. Compute $\frac{q_o}{q_i}$	0.02	
6. $\frac{V_s}{V_r}$ ..... (Use $\frac{q_o}{q_i}$ with figure 6-1)	≈0.7	
7. Runoff, Q ..... in (From worksheet 2)	1.3	
8. Runoff volume, V_r ..... ac-ft ($V_r = QA_m 53.33$)	0.90	
9. Storage volume, V_s ..... ac-ft ($V_s = V_r(\frac{V_s}{V_r})$)	0.63	
10. Maximum stage, E_{max} (From plot)		

1/ 2nd stage q_o includes 1st stage q_o.

Input requirements and procedures

Use figure 6-1 to estimate storage volume (V_s) required or peak outflow discharge (q_o). The most frequent application is to estimate V_s, for which the required inputs are runoff volume (V_r), q_o, and peak inflow discharge (q_i). To estimate q_o, the required inputs are V_r, V_s, and q_i.

ACTUAL $\frac{q_o}{q_i} = 0.02$ which is off the graph

Assume $\frac{V_s}{V_R} \approx 0.7$

Estimating V_s

Use worksheet 6a to estimate V_s, storage volume required, by the following procedure.

1. Determine q_o. Many factors may dictate the selection of peak outflow discharge. The most common is to limit downstream discharges to a desired level, such as predevelopment discharge. Another factor may be that the outflow device has already been selected.
2. Estimate q_i by procedures in chapters 4 or 5. Do not use peak discharges developed by any other procedure. When using the Tabular Hydrograph method to estimate q_i for a subarea, only use

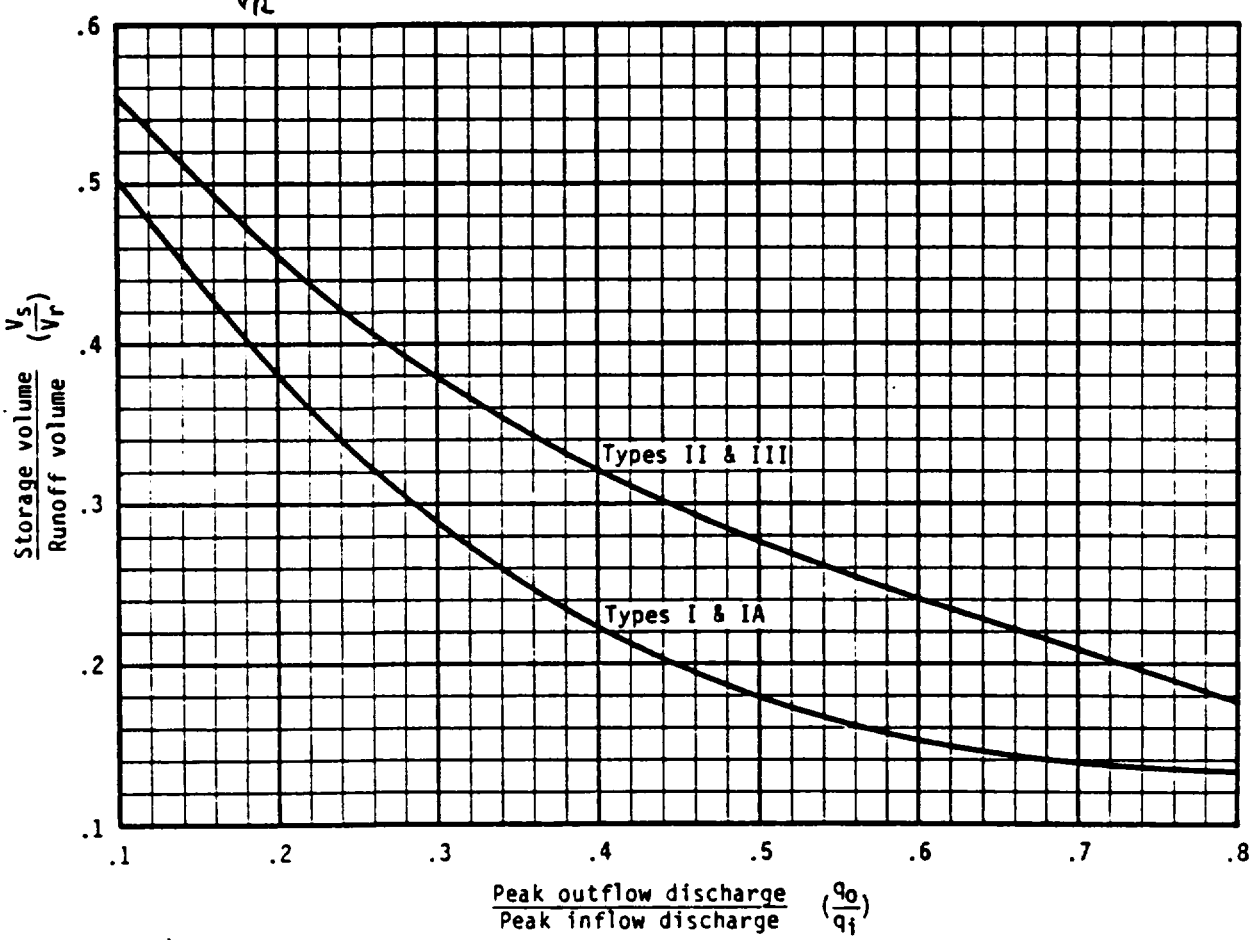


Figure 6-1.—Approximate detention basin routing for rainfall types I, IA, II, and III.

B-3 Bulky Waste Area - Detention Basin Sizing

Project	Rose Hill FS	Acct. No.	4609-18-10-11	Page	1 of 1
Subject	Drainage/Slope Stability	Comptd. By	S. Czarniecki	Date	08/19/96
Detail	Bulky Waste Area	Ck'd. By	N. Bergeron	Date	08/23/96

P:\NE\ROSEHILL\FS\APPX-H\DRAIN

Detention basin requirements for the Bulky Waste Area are calculated below based on the same assumptions presented previously for the Solid Waste Area.

Pre-development

TR-55 Wrksht #			
2	Area approximately 750' x 150'	112,500 ft^2	Estimate for half of the landfill
	A_m	0.004 mi^2	
2	Runoff Curve Number, CN	39	see Table 2-2 in Solid Waste Area calcs.
2	Rainfall, P (25-yr, 24-hr)	5	charts - see Solid Waste Area calculations
2	Runoff, Q	0.2 in.	see Fig. 2-1 in Solid Waste Area calculations
3	Manning's coeff., n	0.15	see Table 3-1 in Solid Waste Area calcs.
3	Flow Length, L	250 ft	Approximate length to assumed basin area
3	Two-yr 24-hr rainfall, P_2	3.5 in.	see attached chart
3	Land slope, s	0.1	Estimate from topographic figure - 25'/250'
3	$T_t = 0.007(nL)^{0.8}/P_2^{0.5}s^{0.4}$	0.17 hr	
4	Initial Abstraction, I_a	3 in.	see Table 4-1 in Solid Waste Area calcs.
4	I_a/P	0.6	
4	Unit peak discharge, q_u	150 cms/in	see exhibit 4-III in Solid Waste Area calcs.
4	Pond & Swamp Factor, F_p	1	Assume zero % pond and swamp area
4	Peak Discharge, q_p	0.12 cfs	$q_p = q_u A_m Q F_p$

Post-development

TR-55 Wrksht #			
2	Area approximately 750' x 150'	112,500 ft^2	Estimate for half of the landfill
	A_m	0.004 mi^2	
2	Runoff Curve Number, CN	61	see Table 2-2 in Solid Waste Area calcs.
2	Rainfall, P (25-yr, 24-hr)	5	charts - see Solid Waste Area calculations
2	Runoff, Q	1.4 in.	see Fig. 2-1 in Solid Waste Area calculations
3	Manning's coeff., n	0.15	see Table 3-1 in Solid Waste Area calcs.
3	Flow Length, L	250 ft	Approximate length to assumed basin area
3	Two-yr 24-hr rainfall, P_2	3.5 in.	see attached chart
3	Land slope, s	0.1	Estimate from topographic figure - 25'/250'
3	$T_t = 0.007(nL)^{0.8}/P_2^{0.5}s^{0.4}$	0.17 hr	
4	Initial Abstraction, I_a	1.279 in.	see Table 4-1 in Solid Waste Area calcs.
4	I_a/P	0.26	
4	Unit peak discharge, q_u	525 cms/in	see exhibit 4-III in Solid Waste Area calcs.
4	Pond & Swamp Factor, F_p	1	Assume zero % pond and swamp area
4	Peak Discharge, q_p	2.97 cfs	$q_p = q_u A_m Q F_p$

Sizing

TR-55 Wrksht #			
6a	$q_o/q_i = q_p(pre)/q_p(post)$	0.04081	
	V_s/V_r	0.38	see Fig. 6-1 in Solid Waste Area calcs.
	Runoff Volume, V_r	0.30 ac-ft	$V_r = QA_m 53.33$
	Storage Volume, V_s	0.11 ac-ft	$V_s = V_r(V_s/V_r)$

For cost purposes, use estimate of 0.2 ac-ft for basin to account for other half of landfill.

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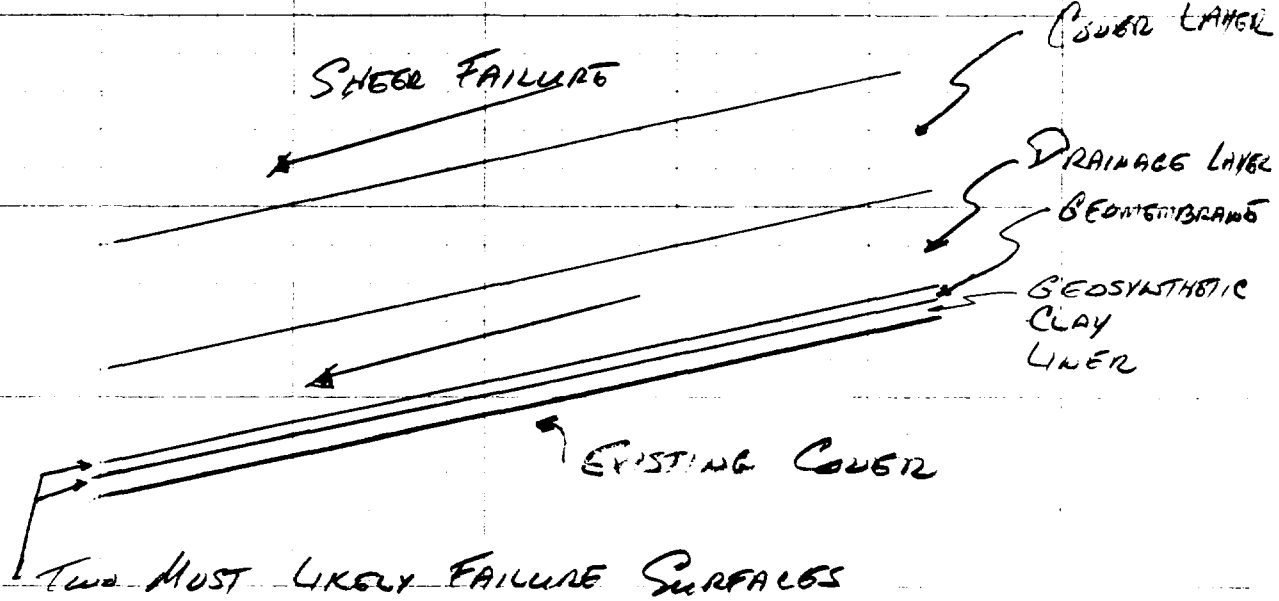
B-4 Slope Stability: Cover and Soil Slippage

Project ROSE HILL FS Acct. No 3AG09-0012-016-003 Page ___ of ___
Subject SLOPE STABILITY: COVER Comptd. By CTC Date 12/16/92
Detail SOIL SLIPPAGE Ck'd. By FHD Date 7/16/93

OBJECTIVE:

THE OBJECTIVE OF THIS ANALYSIS IS TO CHECK THE SLOPE STABILITY OF THE PROPOSED CAP SYSTEM AT THE CONCEPTUAL DESIGN LEVEL TO EVALUATE IF THE DESIGN IS IMPLEMENTABLE AS PROPOSED OR WILL REQUIRE ADDITIONAL SLOP STABILIZING MEASURES. THE FAILURE MECHANISM TO BE EVALUATED IS SHEER FAILURE ALONG THE INTERFACES IN THE PROPOSED SYSTEM.



TWO MOST LIKELY FAILURE SURFACES

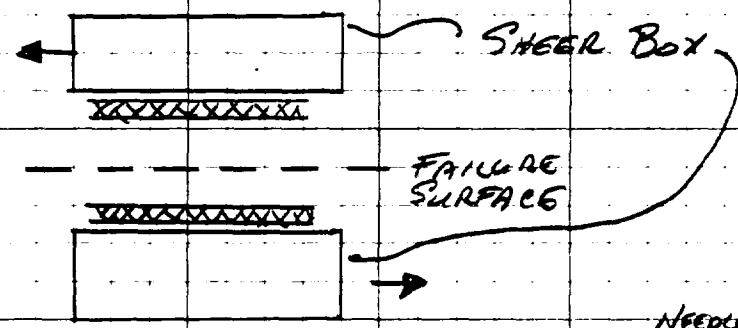
GEOMEMBRANE/GCL & GEOMEMBRANE/DRAINAGE LAYER

NONREPRODUCIBLE GRID FORM 145
METCALF & EDDY, ENGINEERS

Project Rose Hill FS | Acct. No. 4609-18-11-3 | Page ___ of ___
Subject Slope Stability: Cover | Comptd. By DTC | Date 12/16/92
Detail Soil Slippage | Ck'd. By PKD | Date 7/16/93

1) STABILITY OF BENTONITE BLANKET: INTERNAL STRENGTH OF BENTONITE BLANKET

FRICTION ANGLE BASED UPON DIRECT SHEAR TEST



NEEDLEPUNCH w/ NON-WOVEN GEOTEXTILE ON BOTH SIDES

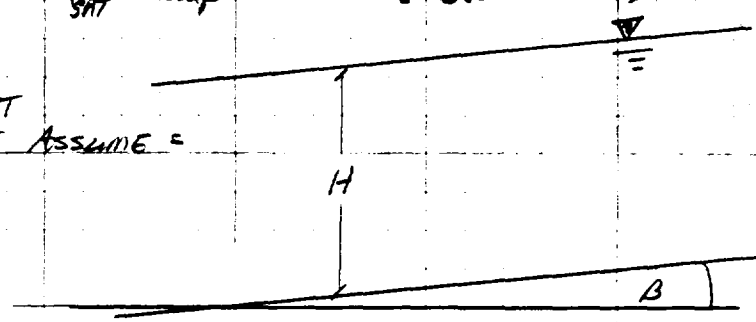
MEASUREMENT OF FRICTION ANGLE = 26° [ASSUMING BENTOMAX - COHESION C = 4.3 psi

[DE DANIEL, HYSHAN RESULTS OF DIRECT SHEAR TESTS ON BENTOMAT, CLAYMAX & GUNDSEAL]

CALCULATE FACTOR OF SAFETY:

ASSUME INFINITE SLOPE MODEL WITH SEEPAGE. MORE PRECISE FINITE SLOPE FAILURE MODELS ARE AVAILABLE BUT ARE NOT CONSIDERED NECESSARY AT THE CONCEPTUAL DESIGN LEVEL.

$$F_S = \frac{c}{\gamma_{SAT} H \cos^2\beta \cdot \tan\beta} + \frac{\gamma'}{\gamma_{SAT}} \frac{\tan\phi}{\tan\beta} \qquad \beta = \tan^{-1}\left(\frac{15}{100}\right) = 8.5$$



C = COHESION
γ_{SAT} = SATURATE UNIT WEIGHT
γ' = EFFECTIVE UNIT WEIGHT ASSUME =
β = ANGLE OF SLOPE
ϕ = FRICTION ANGLE
F_S = FACTOR OF SAFETY

ASSUME $H = 2'$
$\gamma_{SAT} = 130\ lb/ft^3$
$\gamma' = 130\ lb/ft^3 - 62.4\ lb/ft^3 = 67.6\ lb/ft^3$
$\beta =$

$$F_S = \frac{4.3\ lb/in^2 \times 144\ in^2/ft^2}{130\ lb/ft^3 \times 2ft \times (\cos^2 8.5) \times \tan(8.5)} + \frac{67.6\ lb/ft^3}{130\ lb/ft^3} \frac{\tan(26°)}{\tan(8.5°)}$$

$= 16.3 + 1.70$

$= 18.0 > F_{S\,MIN} = 1.3$ OK

NONREPRODUCIBLE GRID FORM 145
METCALF & EDDY, ENGINEERS

Project Rose Hill F-3 Acct. No. 4604-18-16-3 Page ____ of ____
Subject Slope Stability: Cover Comptd. By DTC Date 12/3/92
Detail Soil Slippage Ck'd. By FKD Date 7/16/93

2) INTERFACE BETWEEN TEXTURED HDPE AND BENTOMAT: PROPOSED CAP IS VLDPE BUT ASSUME SIMILAR PERFORMANCE

$$F_S = \frac{C}{\gamma_{SAT} H \cos^2\beta \tan\beta} + \frac{\tan\phi}{\tan\beta}$$

ASSUME DRAINED CONDITION IMPERMEABLE BARRIER ABOVE

ASSUME $C = 0$, $\phi = 16°$ } PHYSICAL PROPERTIES TEST RESULTS BENTOMITE NW/SS/W/ COMPOSITE

$$F_S = \frac{\tan(16°)}{\tan(8.5°)}$$

$$= 1.92$$

3) INTERFACE BETWEEN TEXTURED HDPE AND ~~BENTOMAT~~ DRAINAGE LAYER

$$F_S = \frac{C}{\gamma_{SAT} H \cos^2\beta \tan\beta} + \frac{\gamma'}{\gamma_{SAT}} \frac{\tan\phi}{\tan\beta}$$

ASSUME $C = 0$ FOR SAND MATERIAL

$$F_S = \frac{67.6\ lb/ft^3}{130\ lb/ft^3} * \frac{\tan(26°)}{\tan(8.5°)}$$

$$= 1.70 > F_{S,MIN} = 1.3 \quad OK.$$

NONREPRODUCIBLE GRID FORM 145
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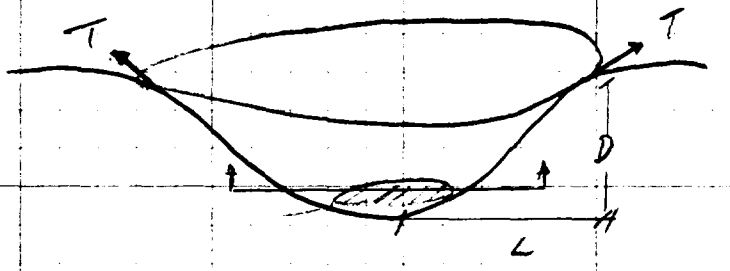
B-5 Cover Stress Evaluation

Project ROSE HILL FEASIBILITY STUDY Acct. No 001509-0018-010-009 Page ____ of ____
Subject STRESS EVALUATION Comptd. By CTC Date 12/16/91
Detail BUT OF PLANE-BIAXIAL STRESS Ck'd. By EXD Date 2/16/93

AS THE LANDFILL SETTLES THE COVER WILL BE SUBJECTED TO BIAXIAL STRESSES AS SHOWN IN THE DIAGRAM BELOW



THE FOLLOWING FORMULA WAS DERIVED TO DETERMINE THE REQUIRED GEOMEMBRANE STRENGTH

$$\sigma_{REQD} = \frac{2 D L^2 \gamma_{CS} H_{CS}}{3 t (D^2 + L^2)}$$

γ_{CS} = UNIT WEIGHT OF COVER SOIL ASSUME = 130 lb/ft³
H_{CS} = HEIGHT OF COVER SOIL = 2 ft
t = THICKNESS OF GEOMEMBRANE = 40 mil
D = DEPTH OF SETTLEMENT ASSUME 1 ft
L = RADIUS OF DEPRESSION ASSUME 5 ft

$$\sigma = \frac{2(2ft)(5ft)^2 130\,lb/ft^3 * 2ft}{3(0.040in) * 1ft/12in\,((1ft)^2 + (5ft)^2) *}$$

$= 52{,}000\ lb/ft^2$

$= 361\ psi$

ASSUME: YIELD POINT OF VLDPE 50% OF TENSILE BREAK POINT = 1,500 psi

$$FS = \frac{\sigma_{AVAILABLE}}{\sigma_{REQ}}$$

$$= \frac{1{,}500\ psi}{361\ psi}$$

$$= \underline{\underline{4.2}}$$

NONREPRODUCIBLE GRID FORM 145
METCALF & EDDY, ENGINEERS

C. GROUNDWATER AND LEACHATE CALCULATIONS

C-1 HELP Model Simulations
C-2 MODFLOW Model Simulations

C-1 HELP Model Simulations

The following soil classifications will be used for input to the HELP3 model for the protective caps:

Existing Materials	Further Information	USCS Class.	HELP3 Default #	Reason for Selection
Solid Waste Cover	Described in RI as silty sand.	SM	7	Closest to perm. x 5
Bulky Waste Cover	Described in RI as silty sand.	SM	7	Closest to perm. x 5
Solid Waste	Assume compacted	--	18	Attach. C description
Bulky Waste	Assume compacted	--	18	Attach. C description
Capping Materials				
Loam & Native Soil	Use sand-silt mixture	SM	4	Assume good drainage
Drainage Composite	Drainage Net	--	20	Capping assumption
Native Soil	Silty sand	SM	7	Similar to existing cover
Silt/Sand (Low Perm)	Silty sand	SM	7	Attach. C description
Geomembrane	Use LLDPE	--	36	Capping assumption

Liner Thickness	Assume 60 mil (Good Engineering) ->	0.06	inches
Pinhole Density	Assume 0.75 per acre (Attachment C)		
Installation Defect Density	Assume 4 per acre (Attachment C)		
Placement Quality	Assume Good		

Use thicknesses as shown on attached figures and other input as for previous runs.

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	Further HELP3 Descriptions	Texture #
Vegetative Support Layer Loam & Native Soil Thickness = 24 in.	Vertical Percolation Layer	4
Drainage Layer Drainage Composite Thickness = 0.5 in.	Lateral Drainage Layer Slope = 7.5%	20
Geomembrane Layer LLDPE Thickness = 0.06 in.	Flexible Membrane Liner	36
Low Permeability Layer Silt/Sand Hydr. Conductivity = 1×10^{-4} cm/s Thickness = 12 in.	Barrier Soil Liner	7
Gas Vent Layer Drainage Composite Thickness = 0.5 in.	Vertical Percolation Layer	20
Existing Cover Layer Hydr. Conductivity = 9.2×10^{-4} cm/s Thickness = 34 in.	Vertical Percolation Layer	7
Waste Layer Hydr. Conductivity = 1.4×10^{-4} cm/s Thickness = 120 in.	Vertical Percolation Layer	18

BULKY WASTE AREA
PROTECTIVE CAP

	Further HELP3 Descriptions	Texture #
Vegetative Support Layer Loam & Native Soil Thickness = 24 in.	Vertical Percolation Layer	4
Drainage Layer Drainage Composite Thickness = 0.5 in.	Lateral Drainage Layer Slope = 7.5%	20
Geomembrane Layer LLDPE Thickness = 0.06 in.	Flexible Membrane Liner	36
Low Permeability Layer Silt/Sand Hydr. Conductivity = $1x10^{-4}$ cm/s Thickness = 12 in.	Barrier Soil Liner	7
Protective Layer Native Soil Thickness = 6 in.	Vertical Percolation Layer	7
Existing Cover Layer Hydr. Conductivity = $5.8x10^{-4}$ cm/s Thickness = 18 in.	Vertical Percolation Layer	7
Waste Layer Hydr. Conductivity = $1x10^{-3}$ cm/s Thickness = 360 in.	Vertical Percolation Layer	18

SOLID WASTE AREA
PROTECTIVE CAP

Results of HELP3 runs on Protective Caps for both Bulky Waste and Solid Waste Areas.

SUMMARY

		Percolation Through Barrier Layers		
Solid Waste Area		ft^3/yr	gal/yr	gpm
Existing Conditions		1,074,573	8,037,806	15.3
Protective Cap	Avg. Liner ->	120	900	1.71E-03
Bulky Waste Area				
Existing Conditions		313,014	2,341,345	4.5
Protective Cap	Avg. Liner ->	21	156	2.97E-04

Solid Waste Area	
Protective Cap Flow Reduction	100.0%
Bulky Waste Area	
Protective Cap Flow Reduction	100.0%

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The following soil classifications will be used for input to the HELP3 model:

Table 3-6 of the RI report (M&E, 1994) contains permeability results for the waste areas. (Attachment A)

Assume No Action on the Sewage Sludge Area, so the HELP3 model will not be run for it.

Conversion from ft/day to cm/sec: ft/day x 30.48 cm/ft x day/24 hrs x hr/60 min x min/60 sec

	Permeability (ft/day)	Perm.(cm/sec)	Perm.(cm/sec) x 5
Solid Waste Cover	0.165 (Average of 4 samples)	5.8E-05	2.9E-04
Bulky Waste Cover	0.26	9.2E-05	4.6E-04
Solid Waste	0.29	1.0E-04	5.1E-04
Bulky Waste	0.04	1.4E-05	7.1E-05

Using these numbers and capping assumptions, layers will be assigned USCS classifications (Attachment B) and/or Default Soil Option numbers from HELP3 (Attachment C) for model input. As a general rule, laboratory permeabilities may be 2 to 10 times lower than the horizontal hydraulic conductivity. Therefore, default model values will initially be used, but a range of values will also be run.

Existing Materials	Further Information	USCS Class.	HELP3 Default #	Reason for Selection
Solid Waste Cover	Described in RI as silty sand.	SM	7	Closest to perm. x 5
Bulky Waste Cover	Described in RI as silty sand.	SM	7	Closest to perm. x 5
Solid Waste	Assume compacted	--	18	Attach. C description
Bulky Waste	Assume compacted	--	18	Attach. C description
Capping Materials				
Loam & Native Soil	Use sand-silt mixture	SM	4	Assume good drainage
Sand	Use well graded sand	SP	1	Assume good drainage
Native Soil	Silty sand	SM	7	Similar to existing cover
Clay	Barrier Soil	--	16	Attach. C description
Geomembrane	Use HDPE	--	35	Capping assumption

The HELP3 model requires the user to input the geomembrane liner thickness, pinhole density, installation defect density, placement quality and transmissivity of any geotextiles. Assumptions are shown below.

Liner Thickness	Assume 40 mil (Good Engineering) ->	0.04	inches
	(Regs require 60 mil HDPE - 40 mil is conservative for infiltration purposes)		
Pinhole Density	Assume 0.75 per acre (Attachment C), but run range from 0.5 to 1.0		
Installation Defect Density	Assume 4 per acre (Attachment C), but run range from 1 to 10		
Placement Quality	Assume Good, but run Excellent and Worst Case for sensitivity		

Existing Cover Thicknesses:

Solid Waste Area - Average from settlement platform logbook (Attachment D) -> 1.5 ft

Use 18 inches

Bulky Waste Area - Average from settlement platform logbook (Attachment D) -> 2.8 ft

Use 34 inches

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TABLE 3-6. PERMEABILITY RESULTS FOR SOILS *

Boring Location	Disposal Area	Depth Of Sample (feet bgs)	Geologic Strata	Permeability (feet/day)
Landfill Analytical Boring Samples:**				
BH-01	Sewage Sludge	2-8	Fill/Sludge	0.16
BH-03	Sewage Sludge	16-20	Fill & Disturbed Soils	0.60
BH-05	Background	10-16	Outwash	0.04
BH-06	Bulky Waste	6-10	Outwash	0.04
BH-07	Solid Waste	4-14	Solid Waste	0.29
Landfill Cover Material Samples:				
PT-01	Solid Waste	0-2	Cover	0.26
PT-02	Solid Waste	0-2	Cover	0.28
PT-03	Solid Waste	0-2	Cover	0.10
PT-04	Solid Waste	0-2	Cover	0.02
PT-05	Bulky Waste	0-2	Cover	0.26
			Cover Material Average	0.18

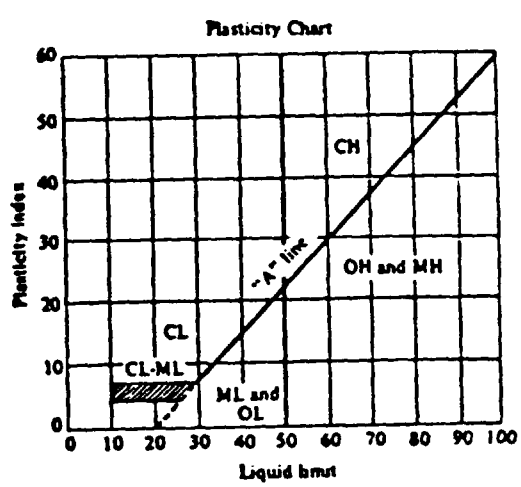
bgs below ground surface
Cover Landfill Cover Material
* Based on laboratory analysis of soils.
** Samples from BH-02 and BH-04 were not submitted for analysis.

ATTACHMENT A

ATTACHMENT B
FT-6.02

UNIFIED SOIL CLASSIFICATION SYSTEM. (ASTM D-2487)

Major Divisions			Group Symbols	Typical Names	Laboratory Classification Criteria		
Coarse-grained soils (More than half of material is larger than No. 200 sieve size)	Gravels (More than half of coarse fraction is larger than No. 4 sieve size)	Clean gravels (Little or no fines)	GW	Well-graded gravels, gravel-sand mixtures, little or no fines	Determine percentages of sand and gravel from grain-size curve. Depending on percentage of fines (fraction smaller than No. 200 sieve size), coarse-grained soils are classified as follows: Less than 5 per cent: GW, GP, SW, SP. More than 12 per cent: GM, GC, SM, SC. 5 to 12 per cent: Borderline cases requiring dual symbols[b]	$C_u = \frac{D_{60}}{D_{10}}$ greater than 4; $C_c = \frac{(D_{30})^2}{D_{10} \times D_{60}}$ between 1 and 3	
			GP	Poorly graded gravels, gravel-sand mixtures, little or no fines		Not meeting all gradation requirements for GW	
		Gravels with fines (Appreciable amount of fines)	GM[a] d / u	Silty gravels, gravel-sand-silt mixtures		Atterberg limits below "A" line or P.I. less than 4	Above "A" line with P.I. between 4 and 7 are borderline cases requiring use of dual symbols
			GC	Clayey gravels, gravel-sand-clay mixtures		Atterberg limits below "A" line with P.I. greater than 7	
	Sands (More than half of coarse fraction is smaller than No. 4 sieve size)	Clean sands (Little or no fines)	SW	Well-graded sands, gravelly sands, little or no fines		$C_u = \frac{D_{60}}{D_{10}}$ greater than 6; $C_c = \frac{(D_{30})^2}{D_{10} \times D_{60}}$ between 1 and 3	
			SP	Poorly graded sands, gravelly sands, little or no fines		Not meeting all gradation requirements for SW	
		Sands with fines (Appreciable amount of fines)	SM[a] d / u	Silty sands, sand-silt mixtures		Atterberg limits above "A" line or P.I. less than 4	Limits plotting in hatched zone with P.I. between 4 and 7 are borderline cases requiring use of dual symbols
			SC	Clayey sands, sand-clay mixtures		Atterberg limits above "A" line with P.I. greater than 7	
Fine-grained soils (More than half material is smaller than No. 200 sieve)	Silts and clays (Liquid limit less than 50)		ML	Inorganic silts and very fine sands, rock flour, silty or clayey fine sands, or clayey silts with slight plasticity			
			CL	Inorganic clays of low to medium plasticity, gravelly clays, sandy clays, silty clays, lean clays			
			OL	Organic silts and organic silty clays of low plasticity			
	Silts and clays (Liquid limit greater than 50)		MH	Inorganic silts, micaceous or diatomaceous fine sandy or silty soils, elastic silts			
			CH	Inorganic clays of high plasticity, fat clays			
			OH	Organic clays of medium to high plasticity, organic silts			
	Highly organic soils		Pt	Peat and other highly organic soils			



[a] Division of GM and SM groups into subdivisions of d and u are for roads and airfields only. Subdivision is based on Atterberg limits; suffix d used when L.L. is 28 or less and the P.I. is 6 or less; the suffix u used when L.L. is greater than 28.
[b] Borderline classifications, used for soils possessing characteristics of two groups, are designated by combinations of group symbols. For example GW-GC, well-graded gravel-sand mixture with clay binder.

Adapted From: Foundation Engineering Handbook, 1975, Winterkorn and Fang (ed.)

ATTACHMENT C

$$K_e = \frac{T_e}{\sum_{i=1}^{n} \frac{T_i}{K_i}} = \frac{T_1 + T_2}{\frac{T_1}{K_1} + \frac{T_2}{K_2}} \qquad (1)$$

where

K_e = effective saturated hydraulic conductivity of combined liner
T_e = effective thickness of combined liner
T_i = thickness of liner soil i
K_i = saturated hydraulic conductivity of liner soil i
n = number of liner soils in the combined liner

For computational purposes, the soil profile is partitioned into subprofiles. Subprofiles are defined in relation to the location of the liners. The first (top) subprofile shown on Figure 1 extends from the landfill surface to the bottom of the highest liner system (bottom of the composite liner, Layer 4) upper barrier soil layer. The second subprofile extends from the top of the layer (Layer 5) below the bottom of the first liner system to the base of the second liner system (Layer 8). The third (bottom) subprofile extends from the top of the layer below the second liner system (the leakage detection drainage layer, Layer 9) to the base of the lowest liner (Layer 11). The program allows up to five liner systems and, therefore, five subprofiles plus an additional subprofile of vertical percolation layers below the bottom liner system. The program models the flow of water through one subprofile at a time from top to bottom, with the percolation or leakage from one subprofile serving as the inflow to the underlying subprofile.

3.5 SOIL CHARACTERISTICS

The user can assign soil characteristics to a layer using the default option, the user defined soil option, or the manual option. Table 4 shows the default characteristics for 42 soil/material types. The soil texture types are classified according to two standard systems, the U.S. Department of Agriculture textural classification system and the Unified Soil Classification System. The default characteristics of types 1 through 15 are typical of surficial and disturbed agricultural soils, which may be less consolidated and more aerated than soils typically placed in landfills (Breazeale and McGeorge, 1949; England, 1970; Lutton et al., 1979; Rawls et al., 1982). Clays and silts in landfills would generally be compacted except within the vegetative layer, which might be tilled to promote vegetative growth. Untilled vegetative layers may be more compacted than the loams listed in Table 4. Soil texture types 22 through 29 are compacted soils. Type 18 is representative of typical municipal solid waste that has been compacted; type 19 is the same waste but it accounts for 65 percent of the waste being in dead zones not contributing to drainage and storage. Soil types 16 and 17 denote very well compacted clay soils that might be used for barrier soil liners. The user assigns default soil characteristics to a layer by specifying the appropriate number for the material type. The

TABLE 4. DEFAULT SOIL, WASTE, AND GEOSYNTHETIC CHARACTERISTICS

Classification			Total Porosity	Field Capacity	Wilting Point	Saturated Hydraulic Conductivity
HELP	USDA	USCS	vol/vol	vol/vol	vol/vol	cm/sec
1	CoS	SP	0.417	0.045	0.018	1.0×10^{-2}
2	S	SW	0.437	0.062	0.024	5.8×10^{-3}
3	FS	SW	0.457	0.083	0.033	3.1×10^{-3}
4	LS	SM	0.437	0.105	0.047	1.7×10^{-3}
5	LFS	SM	0.457	0.131	0.058	1.0×10^{-3}
6	SL	SM	0.453	0.190	0.085	7.2×10^{-4}
7	FSL	SM	0.473	0.222	0.104	5.2×10^{-4}
8	L	ML	0.463	0.232	0.116	3.7×10^{-4}
9	SiL	ML	0.501	0.284	0.135	1.9×10^{-4}
10	SCL	SC	0.398	0.244	0.136	1.2×10^{-4}
11	CL	CL	0.464	0.310	0.187	6.4×10^{-5}
12	SiCL	CL	0.471	0.342	0.210	4.2×10^{-5}
13	SC	SC	0.430	0.321	0.221	3.3×10^{-5}
14	SiC	CH	0.479	0.371	0.251	2.5×10^{-5}
15	C	CH	0.475	0.378	0.265	1.7×10^{-5}
16	Barrier Soil		0.427	0.418	0.367	1.0×10^{-7}
17	Bentonite Mat (0.6 cm)		0.750	0.747	0.400	3.0×10^{-9}
18	Municipal Waste (900 lb/yd^3 or 312 kg/m^3)		0.671	0.292	0.077	1.0×10^{-3}
19	Municipal Waste (channeling and dead zones)		0.168	0.073	0.019	1.0×10^{-3}
20	Drainage Net (0.5 cm)		0.850	0.010	0.005	$1.0 \times 10^{+1}$
21	Gravel		0.397	0.032	0.013	3.0×10^{-1}
22	L*	ML	0.419	0.307	0.180	1.9×10^{-5}
23	SiL*	ML	0.461	0.360	0.203	9.0×10^{-6}
24	SCL*	SC	0.365	0.305	0.202	2.7×10^{-6}
25	CL*	CL	0.437	0.373	0.266	3.6×10^{-6}
26	SiCL*	CL	0.445	0.393	0.277	1.9×10^{-6}
27	SC*	SC	0.400	0.366	0.288	7.8×10^{-7}
28	SiC*	CH	0.452	0.411	0.311	1.2×10^{-6}
29	C*	CH	0.451	0.419	0.332	6.8×10^{-7}
30	Coal-Burning Electric Plant Fly Ash*		0.541	0.187	0.047	5.0×10^{-5}
31	Coal-Burning Electric Plant Bottom Ash*		0.578	0.076	0.025	4.1×10^{-3}
32	Municipal Incinerator Fly Ash*		0.450	0.116	0.049	1.0×10^{-2}
33	Fine Copper Slag*		0.375	0.055	0.020	4.1×10^{-2}
34	Drainage Net (0.6 cm)		0.850	0.010	0.005	$3.3 \times 10^{+1}$

* Moderately Compacted

(Continued)

TABLE 4 (continued). DEFAULT SOIL, WASTE, AND GEOSYNTHETIC CHARACTERISTICS

Classification		Total Porosity	Field Capacity	Wilting Point	Saturated Hydraulic Conductivity
HELP	Geomembrane Material	vol/vol	vol/vol	vol/vol	cm/sec
35	High Density Polyethylene (HDPE)				2.0×10^{-13}
36	Low Density Polyethylene (LDPE)				4.0×10^{-13}
37	Polyvinyl Chloride (PVC)				2.0×10^{-11}
38	Butyl Rubber				1.0×10^{-12}
39	Chlorinated Polyethylene (CPE)				4.0×10^{-12}
40	Hypalon or Chlorosulfonated Polyethylene (CSPE)				3.0×10^{-12}
41	Ethylene-Propylene Diene Monomer (EPDM)				2.0×10^{-12}
42	Neoprene				3.0×10^{-12}

(concluded)

user-defined soil option accepts non-default soil characteristics for layers assigned soil type numbers greater than 42. This is especially convenient for specifying characteristics of waste layers. User-specified soil characteristics can be assigned any soil type number greater than 42.

When a default soil type is used to describe the top soil layer, the program adjusts the saturated hydraulic conductivities of the soils in the top half of the evaporative zone for the effects of root channels. The saturated hydraulic conductivity value is multiplied by an empirical factor that is computed as a function of the user-specified maximum leaf area index. Example values of this factor are 1.0 for a maximum LAI of 0 (bare ground), 1.8 for a maximum LAI of 1 (poor stand of grass), 3.0 for a maximum LAI of 2 (fair stand of grass), 4.2 for a maximum LAI of 3.3 (good stand of grass) and 5.0 for a maximum LAI of 5 (excellent stand of grass).

The manual option requires values for porosity, field capacity, wilting point, and saturated hydraulic conductivity. These and related soil properties are defined below.

Soil Water Storage (Volumetric Content): the ratio of the volume of water in a soil to the total volume occupied by the soil, water and voids.

Total Porosity: the soil water storage/volumetric content at saturation (fraction of total volume).

Field Capacity: the soil water storage/volumetric content after a prolonged period of gravity drainage from saturation corresponding to the soil water storage when a soil exerts a soil suction of 1/3 bar.

Wilting Point: the lowest soil water storage/volumetric content that can be achieved by plant transpiration or air-drying, that is the moisture content where a plant will be permanently wilted corresponding to the soil water storage when a soil exerts a soil suction of 15 bars.

Saturated Hydraulic Conductivity: the rate at which water drains through a saturated soil under a unit pressure gradient.

Porosity, field capacity and wilting point are all dimensionless numbers between 0 and 1. Porosity must be greater than field capacity, which in turn must be greater than the wilting point. The wilting point must be greater than zero. The values for porosity, field capacity and wilting point are not used for liners, except for initializing the soil water storage of liners to the porosity value.

The soil moisture retention properties of a layer should be adjusted downward if some volume of the layer does not participate in the drainage and storage of infiltrated water. This condition commonly exists in shallow layers of municipal solid waste because municipal solid waste is very heterogeneous and poorly compacted. The plastics in the waste also channels the drainage, limits the spreading of infiltration, and restricts the wetting of the waste and, therefore, the storage. Default soil texture number 19 provides adjusted retention values for a municipal solid waste with significant channeling; it assumes that only 25 percent of the volume is actively involved in drainage and storage of infiltration. As the values were computed by multiplying the values for municipal solid waste (default texture number 18) by 0.25; the initial soil water content would also be multiply by 0.25.

The HELP user has the option of specifying the initial volumetric water storage (content) of all layers except liners. Liners are assumed to remain saturated at all times. If the user chooses not to specify initial water contents, the program estimates values near steady-state and then runs one year of initialization to refine the estimates before starting the simulation. The soil water contents at the end of this year of initialization are taken as the initial values for the simulation period. The program then runs the complete simulation, starting again from the beginning of the first year of data. The results for the initialization period are not reported. To improve initialization to steady-state moisture storage, the user should replace thick vertical percolation and lateral drainage layers, that are below the evaporative zone and above the saturated zone above liners, with thin layers. Then, run the simulation for a number of years until steady-state is approximated. The final dimensionless water storage values after nearing steady-state should then be specified as the initial water contents in your actual simulation using the true dimensions of the layers.

The initial moisture content of municipal solid waste is a function of the composition of the waste; reported values for fresh wastes range from about 0.08 to 0.20 vol/vol. The average value is about 0.12 vol/vol for compacted municipal solid waste. If using default waste texture 19, where 75% of the volume is inactive, the initial moisture content should be that of only the active portion, 25% of the values reported above.

The soil water storage or content used in the HELP model is on a per volume basis (θ), volume of water (V_w) per total (bulk--soil, water and air) soil volume ($V_t = V_s + V_w + V_a$), which is characteristic of practice in agronomy and soil physics. Engineers more commonly express moisture content on a per mass basis (w), mass of water (M_w) per mass of soil (M_s). The two can be related to each other by knowing the dry bulk density (ρ_{db}), dry bulk specific gravity (Γ_{db}) of the soil (ratio of dry bulk density to water density (ρ_w)), wet bulk density (ρ_{wb}), wet bulk specific gravity (Γ_{wb}) of the soil (ratio of wet bulk density to water density.

$$\theta = w \frac{\rho_{db}}{\rho_w} = w \Gamma_{db} \tag{2}$$

$$\theta = \frac{w}{1 + w} \frac{\rho_{wb}}{\rho_w} = \frac{w}{1 + w} \Gamma_{wb} \tag{3}$$

3.6 GEOMEMBRANE CHARACTERISTICS

The user can assign geomembrane liner characteristics (vapor diffusivity/saturated hydraulic conductivity) to a layer using the default option, the user-defined soil option, or the manual option. Saturated hydraulic conductivity for geomembranes is defined in terms of its equivalence to the vapor diffusivity. The porosity, field capacity, wilting point and intial moisture content are not needed for geomembranes. Table 4 shows the default characteristics for 12 geomembrane liners. The user assigns default soil characteristics to a layer simply by specifying the appropriate geomembrane liner texture number. The user-defined option accepts user specified geomembrane liner characteristics for layers assigned textures greater than 42. Manual geomembrane liner characteristics can be assigned any texture greater than 42.

Regardless of the method of specifying the geomembrane "soil" characteristics, the program also requires values for geomembrane liner thickness, pinhole density, installation defect density, geomembrane placement quality, and the transmissivity of geotextiles separating geomembranes and drainage limiting soils. These parameters are defined below.

Pinhole Density: the number of defects (diameter of hole equal to or smaller than the geomembrane thickness; hole estimated as 1 mm in diameter) in a given area generally resulting from manufacturing flaws such as polymerization deficiencies.

Installation Defect Density: the number of defects (diameter of hole larger than the geomembrane thickness; hole estimated as 1 cm^2 in area) per acre resulting primarily from seaming faults and punctures during installation.

Geotextile Transmissivity: the product of the in-plane saturated hydraulic conductivity and thickness of the geotextile.

The density of pinholes and installation defects is a subject of speculation. Ideally, geomembranes would not have any defects. If any were known to exist during construction, the defects would be repaired. However, geomembranes are known to leak and therefore reasonably conservative estimates of the defect densities should be specified to determine the maximum probable leakage quantities.

The density of defects has been measured at a number of landfills and other facilities and reported in the literature. These findings provide guidance for estimating the defect densities. Typical geomembranes may have about 0.5 to 1 pinholes per acre (1 to 2 pinholes per hectare) from manufacturing defects. The density of installation defects is a function of the quality of installation, testing, materials, surface preparation, equipment, and QA/QC program. Representative installation defect densities as a function of the quality of installation are given below for landfills being built today with the state-of-the-art in materials, equipment and QA/QC. In the last column the frequency of achieving a particular installation quality is given. The estimates are based on limited data but are characteristic of the recommendations provided in the literature.

Installation Quality	Defect Density (number per acre)	Frequency (percent)
Excellent	Up to 1	10
Good	1 to 4	40
Fair	4 to 10	40
Poor	10 to 20*	10

* Higher defect densities have been reported for older landfills with poor installation operations and materials; however, these high densities are not characteristic of modern practice.

The user must also enter the placement quality of the geomembrane liner if pinholes or installation defects are reported. There are six different possible entries for the geomembrane liner placement quality. The program selects which equation will be used to compute the geomembrane based on the placement quality specified and the saturated hydraulic conductivity of the lower permeability soil (drainage limiting soil) adjacent to

the geomembrane. The program has different equations for three ranges of saturated hydraulic conductivity: greater than or equal to 0.1 cm/sec; less than 0.1 and greater than or equal to 0.0001 cm/sec; and less than 0.0001 cm/sec.

1. *Perfect*: Assumes perfect contact between geomembrane and adjacent soil that limits drainage rate (no gap, "sprayed-on" seal between membrane and soil formed in place).

2. *Excellent*: Assumes exceptional contact between geomembrane and adjacent soil that limits drainage rate (typically achievable only in the lab or small field lysimeters).

3. *Good*: Assumes good field installation with well-prepared, smooth soil surface and geomembrane wrinkle control to insure good contact between geomembrane and adjacent soil that limits drainage rate.

4. *Poor*: Assumes poor field installation with a less well-prepared soil surface and/or geomembrane wrinkling providing poor contact between geomembrane and adjacent soil that limits drainage rate, resulting in a larger gap for spreading and greater leakage.

5. *Worst Case*: Assumes that contact between geomembrane and adjacent soil does not limit drainage rate, resulting in a leakage rate controlled only by the hole.

6. *Geotextile separating geomembrane liner and drainage limiting soil*: Assumes leakage spreading and rate is controlled by the in-plane transmissivity of the geotextile separating the geomembrane and the adjacent soil layer that would have otherwise limited the drainage. This quality would not normally be used with a geosynthetic clay liner (GCL) as the controlling soil layer. Upon wetting, the bentonite swells and extrudes into the geotextile, filling its voids and reducing its transmissivity below the point where it can contribute significantly to spreading of leakage. GCL's, when properly placed, tend to have intimate contact with the geomembrane (Harpur et al., 1993).

3.7 SITE CHARACTERISTICS

The user must also supply a value of the Soil Conservation Service (SCS) runoff curve number for Antecedent Moisture Condition II (AMC-II) or provide information so that a curve number can be computed. Unlike Version 2 of the HELP model, Version 3 accounts for surface slope effects on curve number and runoff. In Version 3 of the HELP model, there are three different options by which a curve number can be obtained.

1. A curve number defined by the user

SP#1/SP#2

with ~~g~~ alternating layers of garbage and grey very fine-fine sand: tr-silt. Excavation is now down 5.0 feet and is being squared off.

0	Topsoil Silt: tr-sand, clay organic
1.0'	~~Garbage~~ F-Sand: tr-silt, fine gravel.
1.5	Garbage
2.0'	Vry-F-Sand: little-trace silt
3.5	Garbage
4.0	Vry-f-fine Sand: little-trace silt
5.0'	gulley.
6.0'	

10:08 SP#2 3+206 of soil gas grid
photo view west SP#1 in background.
- Garbage encountered ≈ 1.5-feet below ground.
- Hole now 3.0 feet below ground

PID All zeros = 0.0 CGI. O_2: 20.9

SP#2

	Topsoil Brown: Silt: little-trace very fine sand
1.0'	Grey Fine-Very Fine Sandy silt: dirty tr-clay, tr-f-red gravel.
1.5-2.0'	Garbage mixed with lesser amounts of ~~Silt: little~~ F-Sandy silt, silty-Fine Sand, and Very Fine Sand: some-trace-silt.
5.5	

CEC = 0.0
Garbage consists mainly of ~~tr~~ paper and plastic products along with lesser amounts of corn and leather.
Photo: 04 Front page recovered from 2.0-feet down ~~at~~ dated 03-25-82.

ATTACHMENT D

SP#2/SP#3

Photo taken looking down into SP#2. Excavation in row 5.5-feet deep.

10:48 SP#3 Begin @ 7+200 of soil gas grid.

10:57 All PID/CGI readings are @ background levels but landfill type odour are very strong.

11:00 Photo taken sort of crumpled up drum and tires that were removed from the landfill.

11:01 Most of the garbage removed consists processed wood debris (2x4, 0") etc. and paper products.

11:10 Very little sediment was found with the garbage the sediment that was encountered was

SP#3

SP#3

0 Brown pebbly cobbly Topsoil: silt: little clay, tr-fine sand

.75' Grey pebbly cobbly Fine sand: little silt

1.5' Cobbles

3.0' ~~Large tires encountered~~ Coarse fines encountered. and a few pine trees

4.0 Some fiberboard is encountered.

trace of dark brown fine sandy silt: slimoist, little cobbles and pebbles

5.67' Bottom of excavation.

SP# 4

11:17 SP# 4 @ 6+500 begin @ 11:17
wind is northerly so the rig has been set up on the north sides of the excavation.

11:34 Two photos of the pipe that had smoke coming out of it with 74 ppm volatiles. Above 3.0 feet most of garbage is paper + plastic. Below 3.0 feet most of refuse is wood.

11:44 Excavation of SP# 4 is stopped because of ambiguous readings from SP# 4. Readings were bouncing up and down most likely as a result of the humidity and heat. Temp must be presently about 90°F

11:53 PID readings are now about 0.0 → 0.4 so work continues again.

11:57 MW14-01 is complete
• 7.0 (94 lb) ~~of grout~~ bags of grout Portland II cement
• 25 lbs of bentonite Quik Gel
7 gallons of H2O/Bag of mix/per ##

SP# 4

0.0	Brown Topsoil: same as previous decreasing rootlets downwards holes, 5% moist
1.25	Brownish Grey Silty Fine Sand & little pebbles and cobbles. 5% moist
1.75'	Garbage begin
2.0'	— oil filter du can, A Prowlend
2.5'	— Sunday Journal from 1981, July 19th was encountered. ~2.5 and a piece of plywood a length of pipe was encountered as well that has smoke coming out of one end of it. It began smoking a few minutes after being encountered.
3.0	— A lot of processed woody material is now encountered
5.25'	→ Bottom of excavation

SP#5

12:13 SP#5 @ 11+600 of soil gas grid begins
Garbage begins ~ 1.25-feet below ground. No grey silty-fine sand observed here below the topsoil which extends to ~ 1.25. The garbage consists mostly of paper, lesser amounts of plastic and even lesser amounts of glass bottles and cans.

☆ The ground level exposed portion of ~~[illegible]~~ the hole have dimensions of ~ 4 X 8.0-feet

One photo taken view east of the pit wall

SP#5

0 Brown Topsoil: same as in the other holes

1.25 Garbage: appears to be somewhat layered with silty sands and sandy silts layers that cannot really be distinguished because they are so thin and interrupted by garbage.

6.25 Bottom of the hole

SP#6

12:34 SP#6 Begins @ 12+400
photo view west of.
Backhoe stopped removing
garbage
Photo view south of the pit.
13:04 SP#6 Ends no upgrades to
Level C were required for
any of the SPs on
the solid waste landfill.

SP#6

0	Topsoil: some cut precursor holes
.5'	Variable thickness ranging from 0 – .75 feet. Greenish Grey clayey silty Fine sand: stiff, compact, dry
1.25	Garbage mostly paper bottles and plastic little metallic debris
2.67	Grey silty Fine Sand: little clay sli-plastic, little fine gravel, occ. cobbles and boulders.
4.67	Garbage: mostly processed wood, plastic and a little metallic debris. ▽ H_2O encountered @ ~5.0'
5.0	End of excavation @ 5.0' below ground

8/29/91 SP#7/SP#8

found Wall Street Journal dated 9/6/83 at ~ 4.5 depth

SP#8 start 15:51

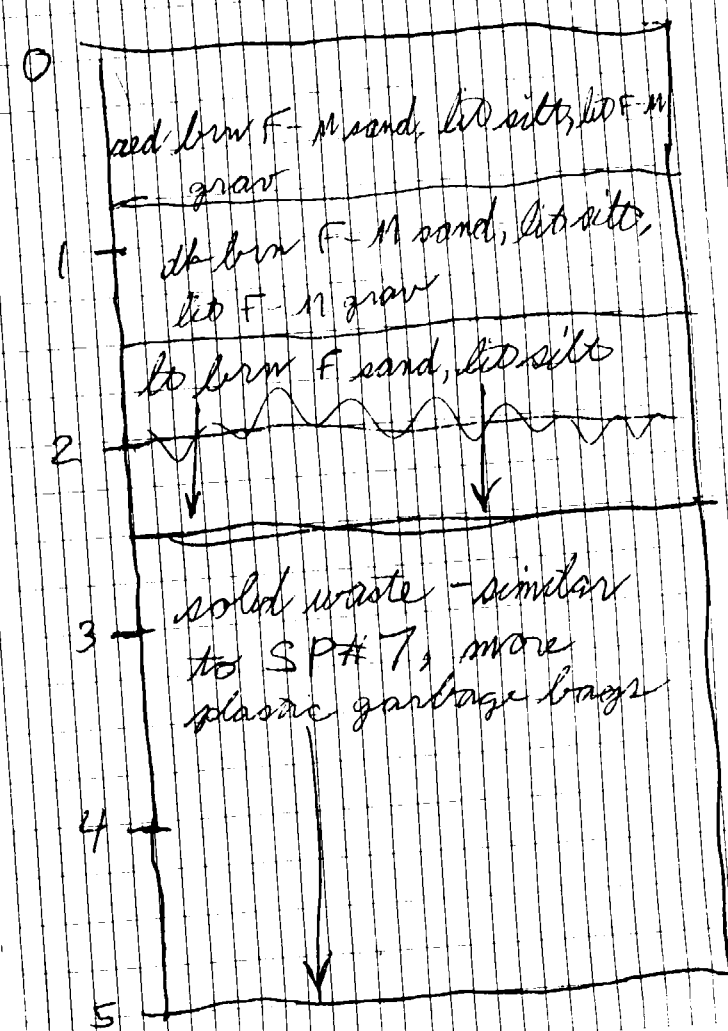
time	depth	LEL	O_2	PID
15:54	2.5	0	21.2	0.0
15:54	BZ	0	21.2	0.0
15:56	3 bucket sample	1%	21.2	24
15:59	BZ	0	21.2	0.0

16:05 low battery on LEL/O_2

nasty odor!

8/29 SP#8

SP-8



8/29/91 15:00 DJF
Jim Fitting, Don Donovan

excavating test pits in bulky waste area

SP#7 3+100
SP#8 3+300
SP#9 5+400

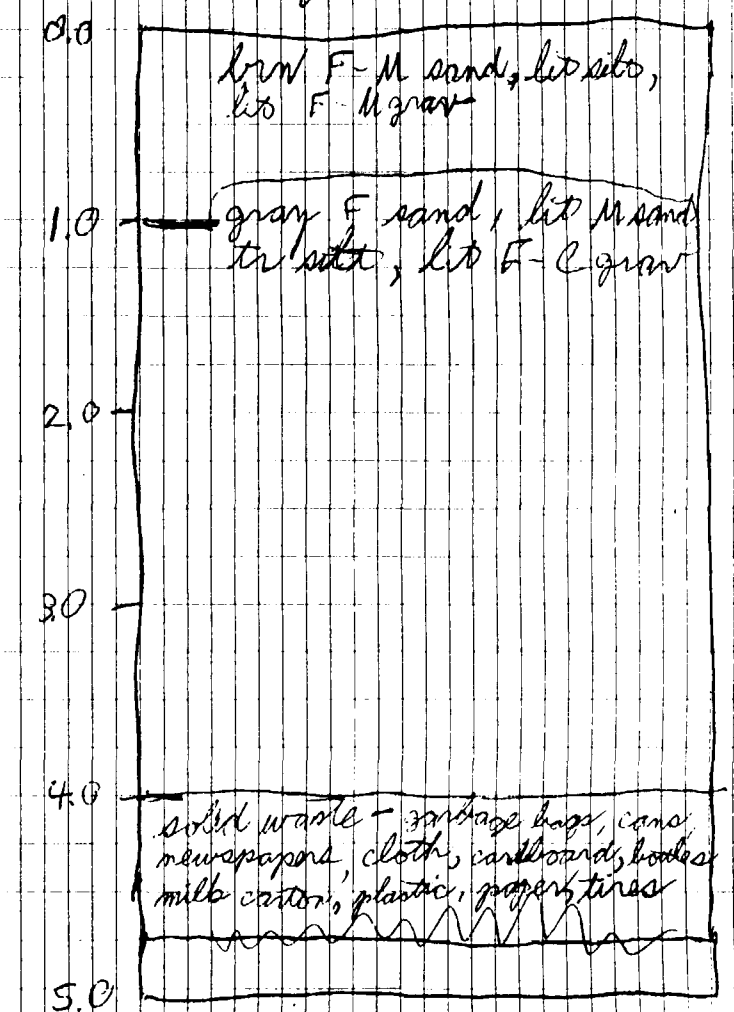
time	depth	% LEL	O_2	PID
15:01	2' PID in backhoe bucket	0.0	21.1	0.0
15:03	3'	0.0	21.1	20.
15:08	~4.5	2.5%	~~21.1~~ 21.1	31.1
15:17	BZ	0	21.2	0.0
15:24	BZ downwind	0	21.2	0.0

very nasty odor!

sour, acid, organic, rotten odor, stimulates gagging reflex

8/29/91 SP#7

log SP#7



8/29 SP#9

SP#9 start 16:35

time	depth ~~PID~~	PID
16:37	3' bucket sample	22.
16:39	BZ	ND
16:44	BZ	ND

nasty odor

done digging 16:45

finished logging, taking photos 16:58

test pits 2.0 hr 15:00-17:00

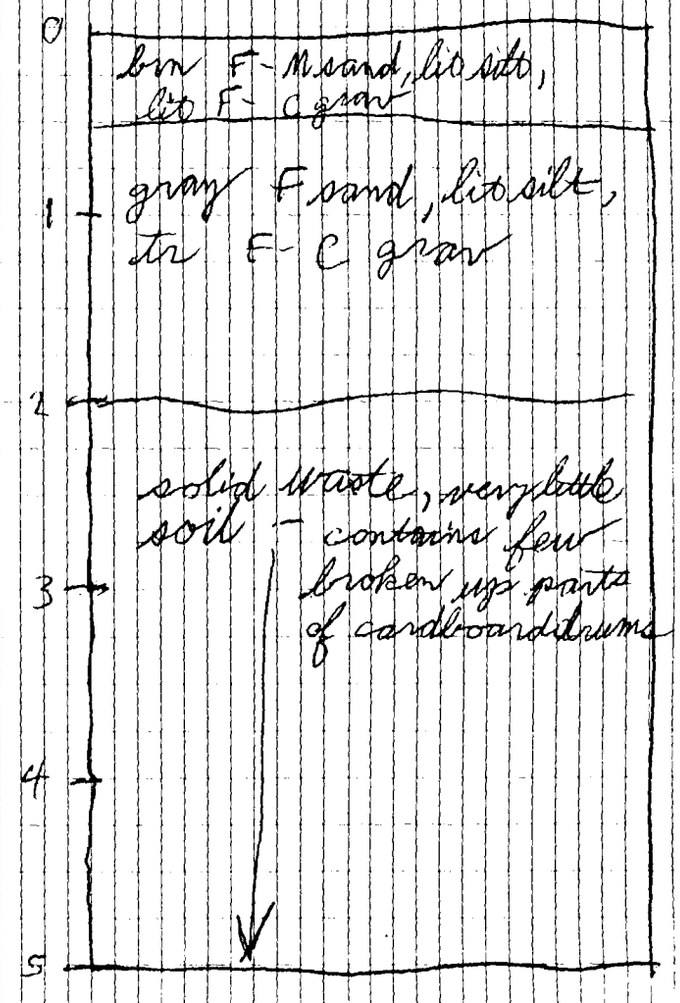
steam clean backhoe 17:00-17:30

decon 0.5

staked test pits w/ caution flagging

8/29 SP#9

SP#9



Weather Data

Precipitation	Default Providence values used.
Temperature	Use Synthetic Providence values generated by HELP3
Solar Radiation	Use Synthetic Providence values generated by HELP3
Evapotranspiration	Default Providence values initially used.

Evaporative Zone Depth	20 in.	Bare-8, Fair-20, Excellent-36

Even though this is the input depth, HELP3 only uses a depth up to the first barrier layer. The depth the model uses is presented in model output.

Maximum Leaf Area Index	3.3	
Start of Growing Season	121	Around May 1
End of Growing Season	290	Around October 18
Average Wind Speed	10.6	
Relative Humidity	64-72%	

Soil Data (Excluding classification)

Assuming Waste Areas can be defined with one drainage slope

Solid Waste Landfill Area	22.9 acres	Based on topo map
Bulky Waste Landfill Area	7.4 acres	Based on topo map
% of area where runoff is possible	100 %	Assumption

Allow HELP3 to initialize moisture contents to approximately steady-state

Solid Waste Drain Length	500 ft	Based on topo map
Bulky Waste Drain Length	250 ft	Based on topo map
Solid Waste Existing Drainage Slope	7 %	Existing top slopes - 3-5% (use 4%) Side slopes ~ 10% (from topo map) Use average
Solid Waste Capped Drainage Slope	7.5 %	Min. top slope based on regs - 5% Keep side as 10% - Use average
Bulky Waste Existing Drainage Slope	6.5 %	Existing top slopes - 2.5-5% (use 3%) Side slopes ~ 10% (from topo map) Use average
Bulky Waste Capped Drainage Slope	7.5 %	Min. top slope based on regs - 5% Keep side as 10% - Use average

Assuming Solid Waste Area needs to be defined as two drainage areas

Solid Waste Top-of-Landfill Area	5.7 acres	Estimate from topo map
Solid Waste Side Slope Area	17.2 acres	22.9 minus top-of-landfill area
Top-of-Landfill Drain Length	150 ft	Estimate from topo map
Side Slope Drain Length	200 ft	Estimate from topo map
Top-of-Landfill Drainage Slope	4 %	See above
Side Slope Drainage Slope	10 %	See above

SCS Runoff Curve Number

HELP3 now allows for 3 options - User Specified, User Specified but altered by slope % and length, and a Calculated Value based on slope, soil texture and vegetation. At this time, we will select User Specified values. Attachment A presents curve number descriptions.

	Curve Number	
Existing Conditions	39	Assumes soil group A (loose), Open Space with grass cover > 75%
Capped Conditions	61	Assumes soil group B (tighter), Open Space with grass cover > 75%

ATTACHMENT A

Appendix A: RUNOFF CURVE NUMBERS

Runoff curve numbers for urban areas[1]

Cover description		Curve numbers for hydrologic soil group—			
Cover type and hydrologic condition	Average percent impervious area[2]	A	B	C	D
Fully developed urban areas (vegetation established)					
Open space (lawns, parks, golf courses, cemeteries, etc.)[3]:					
Poor condition (grass cover < 50%)		68	79	86	89
Fair condition (grass cover 50% to 75%)		49	69	79	84
Good condition (grass cover > 75%)		39	61	74	80
Impervious areas:					
Paved parking lots, roofs, driveways, etc. (excluding right-of-way)		98	98	98	98
Streets and roads:					
Paved; curbs and storm sewers (excluding right-of-way)		98	98	98	98
Paved; open ditches (including right-of-way)		83	89	92	93
Gravel (including right-of-way)		76	85	89	91
Dirt (including right-of-way)		72	82	87	89
Western desert urban areas:					
Natural desert landscaping (pervious areas only)[4]		63	77	85	88
Artificial desert landscaping (impervious weed barrier, desert shrub with 1- to 2-inch sand or gravel mulch and basin borders)		96	96	96	96
Urban districts:					
Commercial and business	85	89	92	94	95
Industrial	72	81	88	91	93
Residential districts by average lot size:					
1/8 acre or less (town houses)	65	77	85	90	92
1/4 acre	38	61	75	83	87
1/3 acre	30	57	72	81	86
1/2 acre	25	54	70	80	85
1 acre	20	51	68	79	84
2 acres	12	46	65	77	82
Developing urban areas					
Newly graded areas (pervious areas only, no vegetation)[5]		77	86	91	94
Idle lands (CN's are determined using cover types similar to those in table 2-2c).					

[1]Average runoff condition, and $I_a = 0.2S$.
[2]The average percent impervious area shown was used to develop the composite CN's. Other assumptions are as follows: impervious areas are directly connected to the drainage system, impervious areas have a CN of 98, and pervious areas are considered equivalent to open space in good hydrologic condition. CN's for other combinations of conditions may be computed using figure 2-3 or 2-4.
[3]CN's shown are equivalent to those of pasture. Composite CN's may be computed for other combinations of open space cover type.
[4]Composite CN's for natural desert landscaping should be computed using figures 2-3 or 2-4 based on the impervious area percentage (CN = 98) and the pervious area CN. The pervious area CN's are assumed equivalent to desert shrub in poor hydrologic condition.
[5]Composite CN's to use for the design of temporary measures during grading and construction should be computed using figure 2-3 or 2-4, based on the degree of development (impervious area percentage) and the CN's for the newly graded pervious areas.

This appendix reprinted from S.C.S. TR-55, revised 1986.

Attachment A shows layers utilized for each run. Use percolation through barrier layers for comparisons.

Amount of water percolating through the waste layers are used for MODFLOW input, but will reduce each year following cap installation as entrained water drains from waste & soils below cap.

	Percolation Through Barrier Layers			
	in./yr	ft^3/yr	gal/yr	gpm
Runs to determine difference between calling the existing top layer a vertical percolation layer or a lateral drainage layer.				
RUN 1 - SW Existing, Default HCs[1], lateral drainage	13.97	1,161,315	8,686,636	16.5
RUN 2 - SW Existing, Default HCs, vertical perc.	13.97	1,161,361	8,686,980	16.5
RUN 7 - BW Existing, Default HCs, lateral drainage	11.94	320,881	2,400,190	4.6
RUN 8 - BW Existing, Default HCs, vertical perc.	11.94	320,891	2,400,265	4.6
Vertical percolation will be used since the difference is minor, and this is a common top layer definition.				
Runs to determine the best assumption for hydraulic conductivity in the existing soils.				
RUN 5 - SW Existing, HC = 2 x lab perm.	11.85	984,878	7,366,887	14.0
RUN 6 - SW Existing, HC = 10 x lab perm.	12.93	1,074,573	8,037,806	15.3
RUN 9 - BW Existing, HC = 2 x lab perm.	11.30	303,589	2,270,846	4.3
RUN 10 - BW Existing, HC = 10 x lab perm.	11.65	313,014	2,341,345	4.5
Default values are slightly above the 10X values, but the 10X values will be used since they are the most conservative of the site-specific numbers.				
Runs to determine if modeling the SW Area would be more accurate if it were split into 2 areas.				
RUN 11 - SW Existing, Top of Landfill	12.93	267,470	2,000,676	3.8
RUN 12 - SW Existing, Side Slopes of Landfill	12.93	807,103	6,037,130	11.5
	Total ->	1,074,573		
RUN 11a - SW Existing, Top of LF, Lateral Layer 1	12.93	267,464	2,000,631	3.8
RUN 12a - SW Existing, Side Slopes, Lateral Layer 1	12.93	807,056	6,036,779	11.5
	Total ->	1,074,520		
When comparing the totals to RUN 6, their differences are insignificant. Therefore, modeling the SW Area as one area will be assumed adequate.				
Sensitivity Runs for Drainage Layer Hydraulic Conductivity SW SINGLE BARRIER CAP				
RUN 13 - Sand, 12 in., 1 x 10^{-3} cm/s	2.99	248,519	1,858,922	3.5
RUN 13a - Sand, 12 in., 1 x 10^{-2} cm/s	1.34	111,115	831,139	1.6
This shows that the higher HC provides better protection and will be used for these modeling efforts.				
Runs to determine the effect of placement quality changes in the model. SW SINGLE BARRIER CAP				
RUN 13a - Pinholes(0.75/acre), Defects(4/acre), Good Quality	1.34	111,115	831,139	1.6
RUN 14 - Pinholes(0.75/acre), Defects(4/acre), Excellent Quality	1.34	111,115	831,139	1.6
RUN 15 - Pinholes(0.75/acre), Defects(4/acre), Worst Case Quality	12.89	1,071,231	8,012,808	15.2
RUN 16 - Pinholes(0.75/acre), Defects(4/acre), Poor Quality	1.34	111,115	831,139	1.6
Worst case installation and anything above excellent (perfect) are not expected, so the choice of Good is adequate.				

[1] HC - Hydraulic Conductivity

METCALF & EDDY

	Percolation Through Barrier Layers			
Further SW SINGLE BARRIER CAP sensitivity runs.	in./yr	ft^3/yr	gal/yr	gpm
RUN 17 - Pinholes(1/acre), Defects(10/acre), (Semi-Poor Liner)	2.94	244,550	1,829,234	3.5
RUN 18 - Pinholes(0.5/acre), Defects(1/acre), (Decent Liner)	0.36	30,050	224,774	0.4
SW COMPOSITE CAP sensitivity runs.				
RUN 19 - Pinholes(0.75/acre), Defects(4/acre), (Average Liner)	0.008	693	5,184	0.01
RUN 20 - Pinholes(1/acre), Defects(10/acre), (Semi-Poor Liner)	0.020	1,627	12,170	0.02
RUN 21 - Pinholes(0.5/acre), Defects(1/acre), (Decent Liner)	0.003	215	1,608	0.00
BW SINGLE BARRIER CAP runs.				
RUN 22 - Pinholes(0.75/acre), Defects(4/acre), (Average Liner)	3.31	88,838	664,508	1.3
RUN 23 - Pinholes(1/acre), Defects(10/acre), (Semi-Poor Liner)	6.02	161,666	1,209,262	2.3
RUN 24 - Pinholes(0.5/acre), Defects(1/acre), (Decent Liner)	1.03	27,720	207,346	0.4
BW COMPOSITE CAP runs.				
RUN 25 - Pinholes(0.75/acre), Defects(4/acre), (Average Liner)	0.004	119	890	0.002
RUN 26 - Pinholes(1/acre), Defects(10/acre), (Semi-Poor Liner)	0.010	278	2,079	0.004
RUN 27 - Pinholes(0.5/acre), Defects(1/acre), (Decent Liner)	0.001	37	277	0.001

SUMMARY

			Percolation Through Barrier Layers		
Solid Waste Area			ft^3/yr	gal/yr	gpm
Existing Conditions			1,074,573	8,037,806	15.3
Single Barrier Cap	Range - 30,050 to 244,550 ft^3/yr	Avg. Liner ->	111,115	831,139	1.6
Composite Cap	Range - 215 to 1,627 ft^3/yr	Avg. Liner ->	693	5,184	0.01
Bulky Waste Area					
Existing Conditions			313,014	2,341,345	4.5
Single Barrier Cap	Range - 27,720 to 161,666 ft^3/yr	Avg. Liner ->	88,838	664,508	1.3
Composite Cap	Range - 37 to 278 ft^3/yr	Avg. Liner ->	119	890	0.002

These runs are presented in Attachment A.

Solid Waste Area	
Single Barrier Cap Flow Reduction	89.7%
Composite Cap Flow Reduction	99.9%
Bulky Waste Area	
Single Barrier Cap Flow Reduction	71.6%
Composite Cap Flow Reduction	100.0%

METCALF & EDDY

ATTACHMENT A

		Further HELP3 Descriptions	Texture #
Existing Cover Layer Hydr. Conductivity = 5.8×10^{-4} cm/s Thickness = 18 in.	9 in.	Vertical Percolation Layer	7
	9 in.	Barrier Soil Liner	7
Waste Layer Hydr. Conductivity = 1×10^{-3} cm/s Thickness = 360 in.		Vertical Percolation Layer	18

SOLID WASTE AREA
EXISTING CONDITIONS

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**                                                                          **
**                                                                          **
**              HYDROLOGIC EVALUATION OF LANDFILL PERFORMANCE               **
**               HELP MODEL VERSION 3.01   (14 OCTOBER 1994)                **
**                  DEVELOPED BY ENVIRONMENTAL LABORATORY                   **
**                    USAE WATERWAYS EXPERIMENT STATION                     **
**             FOR USEPA RISK REDUCTION ENGINEERING LABORATORY              **
**                                                                          **
**                                                                          **
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PRECIPITATION DATA FILE:     C:\HELP3\RHPRECIP.D4
TEMPERATURE DATA FILE:       C:\HELP3\RHTEMP.D7
SOLAR RADIATION DATA FILE:   C:\HELP3\RHSOLAR.D13
EVAPOTRANSPIRATION DATA:     C:\HELP3\RHEVAP.D11
SOIL AND DESIGN DATA FILE:   C:\HELP3\RHSOIL1.D10
OUTPUT DATA FILE:            C:\HELP3\RUN6.OUT


TIME:  10:15     DATE:   8/21/1996


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     TITLE:  Rose Hill - Solid Waste Existing Conditions - 10X lab perm

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     NOTE:  INITIAL MOISTURE CONTENT OF THE LAYERS AND SNOW WATER WERE
              COMPUTED AS NEARLY STEADY-STATE VALUES BY THE PROGRAM.


                                LAYER  1
                                --------

                     TYPE 1 - VERTICAL PERCOLATION LAYER
                         MATERIAL TEXTURE NUMBER   0
          THICKNESS                    =      9.00   INCHES
          POROSITY                     =      0.4730 VOL/VOL
          FIELD CAPACITY               =      0.2220 VOL/VOL
          WILTING POINT                =      0.1040 VOL/VOL
          INITIAL SOIL WATER CONTENT   =      0.2317 VOL/VOL
          EFFECTIVE SAT. HYD. COND.    =  0.579999993000E-03 CM/SEC


                                LAYER  2
                                --------

                         TYPE 3 - BARRIER SOIL LINER
                         MATERIAL TEXTURE NUMBER   0
          THICKNESS                    =      9.00   INCHES
          POROSITY                     =      0.4730 VOL/VOL
          FIELD CAPACITY               =      0.2220 VOL/VOL
          WILTING POINT                =      0.1040 VOL/VOL
          INITIAL SOIL WATER CONTENT   =      0.4730 VOL/VOL
          EFFECTIVE SAT. HYD. COND.    =  0.579999993000E-03 CM/SEC


                                LAYER  3
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          TYPE 1 - VERTICAL PERCOLATION LAYER
              MATERIAL TEXTURE NUMBER   0
  THICKNESS                    =    360.00   INCHES
  POROSITY                     =      0.6710 VOL/VOL
  FIELD CAPACITY               =      0.2920 VOL/VOL
  WILTING POINT                =      0.0770 VOL/VOL
  INITIAL SOIL WATER CONTENT   =      0.2884 VOL/VOL
  EFFECTIVE SAT. HYD. COND.    =  0.100000005000E-02 CM/SEC


          GENERAL DESIGN AND EVAPORATIVE ZONE DATA
          ----------------------------------------

   NOTE:  SCS RUNOFF CURVE NUMBER WAS USER-SPECIFIED.

  SCS RUNOFF CURVE NUMBER              =     39.00
  FRACTION OF AREA ALLOWING RUNOFF     =    100.0    PERCENT
  AREA PROJECTED ON HORIZONTAL PLANE   =     22.900  ACRES
  EVAPORATIVE ZONE DEPTH               =      9.0    INCHES
  INITIAL WATER IN EVAPORATIVE ZONE    =      2.085  INCHES
  UPPER LIMIT OF EVAPORATIVE STORAGE   =      4.257  INCHES
  LOWER LIMIT OF EVAPORATIVE STORAGE   =      0.936  INCHES
  INITIAL SNOW WATER                   =      0.000  INCHES
  INITIAL WATER IN LAYER MATERIALS     =    110.177  INCHES
  TOTAL INITIAL WATER                  =    110.177  INCHES
  TOTAL SUBSURFACE INFLOW              =      0.00   INCHES/YEAR


          EVAPOTRANSPIRATION AND WEATHER DATA
          -----------------------------------

   NOTE:  EVAPOTRANSPIRATION DATA WAS OBTAINED FROM
            PROVIDENCE          RHODE ISLAND

      MAXIMUM LEAF AREA INDEX                  =  3.30
      START OF GROWING SEASON (JULIAN DATE)    =   121
      END OF GROWING SEASON (JULIAN DATE)      =   290
      AVERAGE ANNUAL WIND SPEED                = 10.60 MPH
      AVERAGE 1ST QUARTER RELATIVE HUMIDITY    = 64.00 %
      AVERAGE 2ND QUARTER RELATIVE HUMIDITY    = 65.00 %
      AVERAGE 3RD QUARTER RELATIVE HUMIDITY    = 72.00 %
      AVERAGE 4TH QUARTER RELATIVE HUMIDITY    = 70.00 %


   NOTE:  PRECIPITATION DATA FOR     PROVIDENCE             RHODE ISLAND
            WAS ENTERED FROM THE DEFAULT DATA FILE.


   NOTE:  TEMPERATURE DATA WAS SYNTHETICALLY GENERATED USING
            COEFFICIENTS FOR     PROVIDENCE          RHODE ISLAND

       NORMAL MEAN MONTHLY TEMPERATURE (DEGREES FAHRENHEIT)

 JAN/JUL     FEB/AUG     MAR/SEP     APR/OCT     MAY/NOV     JUN/DEC
 -------     -------     -------     -------     -------     -------
  28.20       29.30       37.40       47.90       57.60       66.80
  72.50       71.10       63.50       53.20       43.40       32.20


   NOTE:  SOLAR RADIATION DATA WAS SYNTHETICALLY GENERATED USING
            COEFFICIENTS FOR     PROVIDENCE          RHODE ISLAND

                STATION LATITUDE  = 41.73 DEGREES
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ANNUAL TOTALS FOR YEAR 1974

	INCHES	CU. FEET	PERCENT
PRECIPITATION	40.66	3379944.000	100.00
RUNOFF	4.327	359654.469	10.64
EVAPOTRANSPIRATION	23.952	1991040.620	58.91
PERC./LEAKAGE THROUGH LAYER 2	12.381224	1029213.940	30.45
AVG. HEAD ON TOP OF LAYER 2	0.0168		
PERC./LEAKAGE THROUGH LAYER 3	12.749429	1059821.750	31.36
CHANGE IN WATER STORAGE	-0.368	-30572.029	-0.90
SOIL WATER AT START OF YEAR	110.177	9158652.000	
SOIL WATER AT END OF YEAR	109.809	9128080.000	
SNOW WATER AT START OF YEAR	0.000	0.000	0.00
SNOW WATER AT END OF YEAR	0.000	0.000	0.00
ANNUAL WATER BUDGET BALANCE	0.0000	-0.713	0.00

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ANNUAL TOTALS FOR YEAR 1975

	INCHES	CU. FEET	PERCENT
PRECIPITATION	50.83	4225347.000	100.00
RUNOFF	8.926	741997.437	17.56
EVAPOTRANSPIRATION	24.858	2066379.870	48.90
PERC./LEAKAGE THROUGH LAYER 2	15.877962	1319887.370	31.24
AVG. HEAD ON TOP OF LAYER 2	0.0223		
PERC./LEAKAGE THROUGH LAYER 3	12.830191	1066535.250	25.24
CHANGE IN WATER STORAGE	4.216	350432.625	8.29
SOIL WATER AT START OF YEAR	109.809	9128080.000	
SOIL WATER AT END OF YEAR	114.024	9478512.000	
SNOW WATER AT START OF YEAR	0.000	0.000	0.00
SNOW WATER AT END OF YEAR	0.000	0.000	0.00
ANNUAL WATER BUDGET BALANCE	0.0000	1.665	0.00

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ANNUAL TOTALS FOR YEAR 1976

	INCHES	CU. FEET	PERCENT
PRECIPITATION	46.31	3849611.500	100.00
RUNOFF	9.742	809845.812	21.04
EVAPOTRANSPIRATION	24.467	2033894.870	52.83
PERC./LEAKAGE THROUGH LAYER 2	11.847011	984806.437	25.58
AVG. HEAD ON TOP OF LAYER 2	0.0203		
PERC./LEAKAGE THROUGH LAYER 3	14.870744	1236160.250	32.11
CHANGE IN WATER STORAGE	-2.770	-230288.937	-5.98
SOIL WATER AT START OF YEAR	114.024	9478512.000	
SOIL WATER AT END OF YEAR	110.484	9184189.000	
SNOW WATER AT START OF YEAR	0.000	0.000	0.00
SNOW WATER AT END OF YEAR	0.770	64033.992	1.66
ANNUAL WATER BUDGET BALANCE	0.0000	-0.555	0.00

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ANNUAL TOTALS FOR YEAR 1977

	INCHES	CU. FEET	PERCENT
PRECIPITATION	48.81	4057428.250	100.00
RUNOFF	10.967	911683.000	22.47
EVAPOTRANSPIRATION	24.497	2036402.370	50.19
PERC./LEAKAGE THROUGH LAYER 2	13.793162	1146584.120	28.26
AVG. HEAD ON TOP OF LAYER 2	0.0167		
PERC./LEAKAGE THROUGH LAYER 3	12.176536	1012198.870	24.95
CHANGE IN WATER STORAGE	1.169	97145.070	2.39
SOIL WATER AT START OF YEAR	110.484	9184189.000	
SOIL WATER AT END OF YEAR	112.423	9345369.000	
SNOW WATER AT START OF YEAR	0.770	64033.988	1.58
SNOW WATER AT END OF YEAR	0.000	0.000	0.00
ANNUAL WATER BUDGET BALANCE	0.0000	-0.951	0.00

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ANNUAL TOTALS FOR YEAR 1978

	INCHES	CU. FEET	PERCENT

PRECIPITATION	47.00	3906969.000	100.00
RUNOFF	10.534	875628.250	22.41
EVAPOTRANSPIRATION	26.576	2209224.750	56.55
PERC./LEAKAGE THROUGH LAYER 2	10.735036	892371.312	22.84
AVG. HEAD ON TOP OF LAYER 2	0.0135		
PERC./LEAKAGE THROUGH LAYER 3	12.816323	1065382.500	27.27
CHANGE IN WATER STORAGE	-2.926	-243266.594	-6.23
SOIL WATER AT START OF YEAR	112.423	9345369.000	
SOIL WATER AT END OF YEAR	109.496	9102102.000	
SNOW WATER AT START OF YEAR	0.000	0.000	0.00
SNOW WATER AT END OF YEAR	0.000	0.000	0.00
ANNUAL WATER BUDGET BALANCE	0.0000	0.159	0.00

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AVERAGE MONTHLY VALUES IN INCHES FOR YEARS 1974 THROUGH 1978

	JAN/JUL	FEB/AUG	MAR/SEP	APR/OCT	MAY/NOV	JUN/DEC
PRECIPITATION						
TOTALS	6.19	2.98	3.95	2.75	3.21	3.10
	3.56	4.08	4.37	4.82	2.78	4.93
STD. DEVIATIONS	2.07	0.30	1.11	0.52	1.25	1.31
	2.62	2.27	2.21	1.87	2.13	0.98
RUNOFF						
TOTALS	3.599	2.073	1.952	0.453	0.000	0.000
	0.000	0.084	0.000	0.010	0.000	0.729
STD. DEVIATIONS	3.017	1.662	1.090	0.723	0.000	0.000
	0.000	0.188	0.000	0.021	0.000	0.947
EVAPOTRANSPIRATION						
TOTALS	1.019	1.278	2.202	2.546	2.706	2.739
	2.733	2.462	2.544	2.230	1.529	0.883
STD. DEVIATIONS	0.154	0.156	0.394	0.262	0.723	1.067
	1.034	1.511	0.528	0.333	0.161	0.196
PERCOLATION/LEAKAGE THROUGH LAYER 2						
TOTALS	0.1846	0.6441	0.5412	1.1338	0.4569	0.5265
	0.7086	1.2389	1.5836	2.2193	1.3445	2.3448
STD. DEVIATIONS	0.2828	0.9296	0.5687	0.1919	0.5289	0.5373
	1.3707	1.3807	1.5002	1.7416	2.0250	1.5811
PERCOLATION/LEAKAGE THROUGH LAYER 3						
TOTALS	1.4008	1.1516	1.1315	0.9933	1.1162	1.0396

	1.0663	0.9566	1.0272	0.9334	1.0694	1.2027
STD. DEVIATIONS	0.4661	0.0617	0.1086	0.1172	0.1204	0.0775
	0.0379	0.0807	0.2119	0.2514	0.1665	0.3600

AVERAGES OF MONTHLY AVERAGED DAILY HEADS (INCHES)

DAILY AVERAGE HEAD ACROSS LAYER 2

AVERAGES	0.0037	0.0108	0.0083	0.0189	0.0067	0.0088
	0.0167	0.0254	0.0256	0.0285	0.0255	0.0358
STD. DEVIATIONS	0.0054	0.0153	0.0086	0.0050	0.0076	0.0091
	0.0344	0.0337	0.0246	0.0235	0.0426	0.0251

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AVERAGE ANNUAL TOTALS & (STD. DEVIATIONS) FOR YEARS 1974 THROUGH 1978

	INCHES		CU. FEET	PERCENT
PRECIPITATION	46.72	(3.815)	3883860.0	100.00
RUNOFF	8.899	(2.6725)	739761.75	19.047
EVAPOTRANSPIRATION	24.870	(1.0070)	2067388.50	53.230
PERCOLATION/LEAKAGE THROUGH FROM LAYER 2	12.92688	(1.98288)	1074572.750	27.66765
AVERAGE HEAD ACROSS TOP OF LAYER 2	0.018	(0.003)		
PERCOLATION/LEAKAGE THROUGH FROM LAYER 3	13.08864	(1.03245)	1088019.750	28.01388
CHANGE IN WATER STORAGE	-0.136	(2.9757)	-11309.97	-0.291

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PEAK DAILY VALUES FOR YEARS 1974 THROUGH 1978

	(INCHES)	(CU. FT.)
PRECIPITATION	4.78	397347.062
RUNOFF	3.353	278757.5310
PERCOLATION/LEAKAGE THROUGH LAYER 2	1.854850	154188.15600
AVERAGE HEAD ACROSS LAYER 2	2.405	
PERCOLATION/LEAKAGE THROUGH LAYER 3	0.143786	11952.47660
SNOW WATER	6.35	528163.8120

MAXIMUM VEG. SOIL WATER (VOL/VOL) 0.4323

MINIMUM VEG. SOIL WATER (VOL/VOL) 0.0595

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FINAL WATER STORAGE AT END OF YEAR 1978

LAYER	(INCHES)	(VOL/VOL)
1	2.2134	0.2459
2	4.2570	0.4730
3	103.0260	0.2862
SNOW WATER	0.000	

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	Further HELP3 Descriptions	Texture #
Vegetative Support Layer Loam & Native Soil Thickness = 12 in.	Vertical Percolation Layer	4
Drainage Layer Sand Thickness = 12 in.	Lateral Drainage Layer Slope = 7.5%	1
Geomembrane Layer HDPE Thickness = 0.04 in.	Flexible Membrane Liner	35
Protective Layer Native Soil Thickness = 12 in.	Vertical Percolation Layer	7
Existing Cover Layer Hydr. Conductivity = 5.8×10^{-4} cm/s Thickness = 18 in.	Vertical Percolation Layer	7
Waste Layer Hydr. Conductivity = 1×10^{-3} cm/s Thickness = 360 in.	Vertical Percolation Layer	18

SOLID WASTE AREA
SINGLE BARRIER CAP

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**                                                                          **
**                                                                          **
**              HYDROLOGIC EVALUATION OF LANDFILL PERFORMANCE               **
**               HELP MODEL VERSION 3.01    (14 OCTOBER 1994)               **
**                  DEVELOPED BY ENVIRONMENTAL LABORATORY                   **
**                    USAE WATERWAYS EXPERIMENT STATION                     **
**             FOR USEPA RISK REDUCTION ENGINEERING LABORATORY              **
**                                                                          **
**                                                                          **
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PRECIPITATION DATA FILE:     C:\RH\HELP\HELP3\RHPRECIP.D4
TEMPERATURE DATA FILE:       C:\RH\HELP\HELP3\RHTEMP.D7
SOLAR RADIATION DATA FILE:   C:\RH\HELP\HELP3\RHSOLAR.D13
EVAPOTRANSPIRATION DATA:     C:\RH\HELP\HELP3\RHEVAP.D11
SOIL AND DESIGN DATA FILE:   C:\RH\HELP\HELP3\RHSOIL2A.D10
OUTPUT DATA FILE:            C:\RH\HELP\HELP3\RUN13a.OUT


TIME:  13:26     DATE:  10/ 6/1997


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     TITLE:  Rose Hill - SW Area Good Single Barrier Cap -Good liner

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     NOTE:  INITIAL MOISTURE CONTENT OF THE LAYERS AND SNOW WATER WERE
              COMPUTED AS NEARLY STEADY-STATE VALUES BY THE PROGRAM.


                                  LAYER  1
                                  --------

                     TYPE 1 - VERTICAL PERCOLATION LAYER
                        MATERIAL TEXTURE NUMBER   4
          THICKNESS                  =     12.00   INCHES
          POROSITY                   =      0.4370 VOL/VOL
          FIELD CAPACITY             =      0.1050 VOL/VOL
          WILTING POINT              =      0.0470 VOL/VOL
          INITIAL SOIL WATER CONTENT =      0.1497 VOL/VOL
          EFFECTIVE SAT. HYD. COND.  =  0.170000002000E-02 CM/SEC
        NOTE:  SATURATED HYDRAULIC CONDUCTIVITY IS MULTIPLIED BY  4.48
                 FOR ROOT CHANNELS IN TOP HALF OF EVAPORATIVE ZONE.


                                  LAYER  2
                                  --------

                    TYPE 2 - LATERAL DRAINAGE LAYER
                      MATERIAL TEXTURE NUMBER   1
          THICKNESS                  =     12.00   INCHES
          POROSITY                   =      0.4170 VOL/VOL
          FIELD CAPACITY             =      0.0450 VOL/VOL
          WILTING POINT              =      0.0180 VOL/VOL
          INITIAL SOIL WATER CONTENT =      0.2752 VOL/VOL
          EFFECTIVE SAT. HYD. COND.  =  0.999999978000E-02 CM/SEC
          SLOPE                      =      7.50   PERCENT
          DRAINAGE LENGTH            =    500.0    FEET
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                         LAYER  3
                         --------

             TYPE 4 - FLEXIBLE MEMBRANE LINER
               MATERIAL TEXTURE NUMBER  35
THICKNESS                    =      0.04   INCHES
POROSITY                     =      0.0000 VOL/VOL
FIELD CAPACITY               =      0.0000 VOL/VOL
WILTING POINT                =      0.0000 VOL/VOL
INITIAL SOIL WATER CONTENT   =      0.0000 VOL/VOL
EFFECTIVE SAT. HYD. COND.    =  0.199999996000E-12 CM/SEC
FML PINHOLE DENSITY          =      0.75   HOLES/ACRE
FML INSTALLATION DEFECTS     =      4.00   HOLES/ACRE
FML PLACEMENT QUALITY        =  3 - GOOD


                         LAYER  4
                         --------

           TYPE 1 - VERTICAL PERCOLATION LAYER
               MATERIAL TEXTURE NUMBER   7
THICKNESS                    =     12.00   INCHES
POROSITY                     =      0.4730 VOL/VOL
FIELD CAPACITY               =      0.2220 VOL/VOL
WILTING POINT                =      0.1040 VOL/VOL
INITIAL SOIL WATER CONTENT   =      0.2299 VOL/VOL
EFFECTIVE SAT. HYD. COND.    =  0.520000001000E-03 CM/SEC


                         LAYER  5
                         --------

           TYPE 1 - VERTICAL PERCOLATION LAYER
               MATERIAL TEXTURE NUMBER   0
THICKNESS                    =     18.00   INCHES
POROSITY                     =      0.4730 VOL/VOL
FIELD CAPACITY               =      0.2220 VOL/VOL
WILTING POINT                =      0.1040 VOL/VOL
INITIAL SOIL WATER CONTENT   =      0.2197 VOL/VOL
EFFECTIVE SAT. HYD. COND.    =  0.579999993000E-03 CM/SEC


                         LAYER  6
                         --------

           TYPE 1 - VERTICAL PERCOLATION LAYER
               MATERIAL TEXTURE NUMBER  18
THICKNESS                    =    360.00   INCHES
POROSITY                     =      0.6710 VOL/VOL
FIELD CAPACITY               =      0.2920 VOL/VOL
WILTING POINT                =      0.0770 VOL/VOL
INITIAL SOIL WATER CONTENT   =      0.2632 VOL/VOL
EFFECTIVE SAT. HYD. COND.    =  0.100000005000E-02 CM/SEC


          GENERAL DESIGN AND EVAPORATIVE ZONE DATA
          ----------------------------------------

 NOTE:  SCS RUNOFF CURVE NUMBER WAS USER-SPECIFIED.

SCS RUNOFF CURVE NUMBER              =     61.00
```

FRACTION OF AREA ALLOWING RUNOFF	=	100.0	PERCENT
AREA PROJECTED ON HORIZONTAL PLANE	=	22.900	ACRES
EVAPORATIVE ZONE DEPTH	=	20.0	INCHES
INITIAL WATER IN EVAPORATIVE ZONE	=	3.431	INCHES
UPPER LIMIT OF EVAPORATIVE STORAGE	=	8.580	INCHES
LOWER LIMIT OF EVAPORATIVE STORAGE	=	0.708	INCHES
INITIAL SNOW WATER	=	0.000	INCHES
INITIAL WATER IN LAYER MATERIALS	=	106.580	INCHES
TOTAL INITIAL WATER	=	106.580	INCHES
TOTAL SUBSURFACE INFLOW	=	0.00	INCHES/YEAR

EVAPOTRANSPIRATION AND WEATHER DATA

NOTE: EVAPOTRANSPIRATION DATA WAS OBTAINED FROM
PROVIDENCE RHODE ISLAND

MAXIMUM LEAF AREA INDEX	=	3.30
START OF GROWING SEASON (JULIAN DATE)	=	121
END OF GROWING SEASON (JULIAN DATE)	=	290
AVERAGE ANNUAL WIND SPEED	=	10.60 MPH
AVERAGE 1ST QUARTER RELATIVE HUMIDITY	=	64.00 %
AVERAGE 2ND QUARTER RELATIVE HUMIDITY	=	65.00 %
AVERAGE 3RD QUARTER RELATIVE HUMIDITY	=	72.00 %
AVERAGE 4TH QUARTER RELATIVE HUMIDITY	=	70.00 %

NOTE: PRECIPITATION DATA FOR PROVIDENCE RHODE ISLAND
WAS ENTERED FROM THE DEFAULT DATA FILE.

NOTE: TEMPERATURE DATA WAS SYNTHETICALLY GENERATED USING
COEFFICIENTS FOR PROVIDENCE RHODE ISLAND

NORMAL MEAN MONTHLY TEMPERATURE (DEGREES FAHRENHEIT)

JAN/JUL	FEB/AUG	MAR/SEP	APR/OCT	MAY/NOV	JUN/DEC
28.20	29.30	37.40	47.90	57.60	66.80
72.50	71.10	63.50	53.20	43.40	32.20

NOTE: SOLAR RADIATION DATA WAS SYNTHETICALLY GENERATED USING
COEFFICIENTS FOR PROVIDENCE RHODE ISLAND

STATION LATITUDE = 41.73 DEGREES

****

ANNUAL TOTALS FOR YEAR 1974

	INCHES	CU. FEET	PERCENT
PRECIPITATION	40.66	3379944.000	100.00
RUNOFF	3.765	312972.500	9.26
EVAPOTRANSPIRATION	25.270	2100599.750	62.15
DRAINAGE COLLECTED FROM LAYER 2	10.4808	871239.000	25.78
PERC./LEAKAGE THROUGH LAYER 3	1.182892	98330.258	2.91
AVG. HEAD ON TOP OF LAYER 3	3.4047		

PERC./LEAKAGE THROUGH LAYER 6	5.989988	497929.719	14.73
CHANGE IN WATER STORAGE	-4.846	-402796.719	-11.92
SOIL WATER AT START OF YEAR	109.244	9081091.000	
SOIL WATER AT END OF YEAR	104.398	8678294.000	
SNOW WATER AT START OF YEAR	0.000	0.000	0.00
SNOW WATER AT END OF YEAR	0.000	0.000	0.00
ANNUAL WATER BUDGET BALANCE	0.0000	-0.238	0.00

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ANNUAL TOTALS FOR YEAR 1975

	INCHES	CU. FEET	PERCENT
PRECIPITATION	50.83	4225347.000	100.00
RUNOFF	7.890	655906.250	15.52
EVAPOTRANSPIRATION	25.565	2125104.250	50.29
DRAINAGE COLLECTED FROM LAYER 2	12.6666	1052938.000	24.92
PERC./LEAKAGE THROUGH LAYER 3	1.471367	122310.359	2.89
AVG. HEAD ON TOP OF LAYER 3	4.5295		
PERC./LEAKAGE THROUGH LAYER 6	4.178403	347338.125	8.22
CHANGE IN WATER STORAGE	0.530	44059.109	1.04
SOIL WATER AT START OF YEAR	104.398	8678294.000	
SOIL WATER AT END OF YEAR	104.928	8722353.000	
SNOW WATER AT START OF YEAR	0.000	0.000	0.00
SNOW WATER AT END OF YEAR	0.000	0.000	0.00
ANNUAL WATER BUDGET BALANCE	0.0000	1.110	0.00

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ANNUAL TOTALS FOR YEAR 1976

	INCHES	CU. FEET	PERCENT
PRECIPITATION	46.31	3849611.500	100.00
RUNOFF	9.164	761783.062	19.79
EVAPOTRANSPIRATION	24.754	2057700.250	53.45
DRAINAGE COLLECTED FROM LAYER 2	13.7131	1139925.370	29.61
PERC./LEAKAGE THROUGH LAYER 3	1.575338	130953.156	3.40
AVG. HEAD ON TOP OF LAYER 3	4.8914		

PERC./LEAKAGE THROUGH LAYER 6	3.324411	276348.312	7.18
CHANGE IN WATER STORAGE	-4.645	-386146.344	-10.03
SOIL WATER AT START OF YEAR	104.928	8722353.000	
SOIL WATER AT END OF YEAR	99.512	8272172.500	
SNOW WATER AT START OF YEAR	0.000	0.000	0.00
SNOW WATER AT END OF YEAR	0.770	64033.992	1.66
ANNUAL WATER BUDGET BALANCE	0.0000	0.832	0.00

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ANNUAL TOTALS FOR YEAR 1977

	INCHES	CU. FEET	PERCENT
PRECIPITATION	48.81	4057428.250	100.00
RUNOFF	9.177	762849.000	18.80
EVAPOTRANSPIRATION	25.034	2080987.120	51.29
DRAINAGE COLLECTED FROM LAYER 2	12.1185	1007376.440	24.83
PERC./LEAKAGE THROUGH LAYER 3	1.312330	109090.023	2.69
AVG. HEAD ON TOP OF LAYER 3	3.9404		
PERC./LEAKAGE THROUGH LAYER 6	2.862932	237986.922	5.87
CHANGE IN WATER STORAGE	-0.382	-31769.256	-0.78
SOIL WATER AT START OF YEAR	99.512	8272172.500	
SOIL WATER AT END OF YEAR	99.901	8304437.500	
SNOW WATER AT START OF YEAR	0.770	64033.988	1.58
SNOW WATER AT END OF YEAR	0.000	0.000	0.00
ANNUAL WATER BUDGET BALANCE	0.0000	-1.863	0.00

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ANNUAL TOTALS FOR YEAR 1978

	INCHES	CU. FEET	PERCENT
PRECIPITATION	47.00	3906969.000	100.00
RUNOFF	10.121	841313.187	21.53
EVAPOTRANSPIRATION	25.736	2139382.250	54.76
DRAINAGE COLLECTED FROM LAYER 2	10.1923	847257.687	21.69
PERC./LEAKAGE THROUGH LAYER 3	1.141509	94890.219	2.43
AVG. HEAD ON TOP OF LAYER 3	3.2889		

PERC./LEAKAGE THROUGH LAYER 6	2.485915	206646.672	5.29
CHANGE IN WATER STORAGE	-1.535	-127631.328	-3.27
SOIL WATER AT START OF YEAR	99.901	8304437.500	
SOIL WATER AT END OF YEAR	98.365	8176806.000	
SNOW WATER AT START OF YEAR	0.000	0.000	0.00
SNOW WATER AT END OF YEAR	0.000	0.000	0.00
ANNUAL WATER BUDGET BALANCE	0.0000	0.476	0.00

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AVERAGE MONTHLY VALUES IN INCHES FOR YEARS 1974 THROUGH 1978

	JAN/JUL	FEB/AUG	MAR/SEP	APR/OCT	MAY/NOV	JUN/DEC
PRECIPITATION						
TOTALS	6.19	2.98	3.95	2.75	3.21	3.10
	3.56	4.08	4.37	4.82	2.78	4.93
STD. DEVIATIONS	2.07	0.30	1.11	0.52	1.25	1.31
	2.62	2.27	2.21	1.87	2.13	0.98
RUNOFF						
TOTALS	3.145	1.922	1.813	0.432	0.000	0.000
	0.018	0.000	0.000	0.000	0.000	0.692
STD. DEVIATIONS	2.796	1.543	0.762	0.646	0.000	0.000
	0.041	0.001	0.000	0.000	0.000	0.908
EVAPOTRANSPIRATION						
TOTALS	1.011	1.264	1.903	2.070	2.788	3.506
	2.686	2.541	2.946	2.306	1.388	0.862
STD. DEVIATIONS	0.151	0.161	0.311	0.403	0.588	1.079
	1.066	1.375	0.536	0.388	0.133	0.190
LATERAL DRAINAGE COLLECTED FROM LAYER 2						
TOTALS	0.7202	0.4220	0.7947	1.7867	1.3309	0.8381
	0.4676	0.6982	0.8249	1.2223	1.2867	1.4420
STD. DEVIATIONS	0.2818	0.3207	0.4739	0.3356	0.2746	0.2205
	0.1037	0.8428	0.6739	0.6621	0.9475	0.5276
PERCOLATION/LEAKAGE THROUGH LAYER 3						
TOTALS	0.0862	0.0536	0.0881	0.1857	0.1420	0.0972
	0.0619	0.0952	0.0912	0.1318	0.1419	0.1618
STD. DEVIATIONS	0.0266	0.0308	0.0459	0.0389	0.0239	0.0201
	0.0108	0.1117	0.0631	0.0608	0.0966	0.0686
PERCOLATION/LEAKAGE THROUGH LAYER 6						
TOTALS	0.3642	0.3185	0.3461	0.3255	0.3306	0.3092
	0.3136	0.3075	0.2921	0.2960	0.2801	0.2848
STD. DEVIATIONS	0.1604	0.1367	0.1426	0.1256	0.1246	0.1144

	0.1126	0.1082	0.0974	0.0966	0.0897	0.0848

AVERAGES OF MONTHLY AVERAGED DAILY HEADS (INCHES)

DAILY AVERAGE HEAD ACROSS LAYER 3

AVERAGES	2.7321	1.7822	3.0315	7.3915	5.0769	3.3038
	1.7836	3.4283	3.2517	4.7350	5.5243	6.0910
STD. DEVIATIONS	1.0813	1.3544	1.8077	1.8929	1.0475	0.8691
	0.3956	4.8913	2.6563	2.6528	4.3083	3.1461

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AVERAGE ANNUAL TOTALS & (STD. DEVIATIONS) FOR YEARS 1974 THROUGH 1978

	INCHES		CU. FEET	PERCENT
PRECIPITATION	46.72	(3.815)	3883860.0	100.00
RUNOFF	8.023	(2.5091)	666964.75	17.173
EVAPOTRANSPIRATION	25.272	(0.3957)	2100754.75	54.089
LATERAL DRAINAGE COLLECTED FROM LAYER 2	11.83427	(1.48586)	983747.312	25.32911
PERCOLATION/LEAKAGE THROUGH FROM LAYER 3	1.33669	(0.18536)	111114.805	2.86094
AVERAGE HEAD ACROSS TOP OF LAYER 3	4.011	(0.696)		
PERCOLATION/LEAKAGE THROUGH FROM LAYER 6	3.76833	(1.39332)	313249.937	8.06543
CHANGE IN WATER STORAGE	-2.176	(2.4584)	-180856.91	-4.657

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PEAK DAILY VALUES FOR YEARS 1974 THROUGH 1978

	(INCHES)	(CU. FT.)
PRECIPITATION	4.78	397347.062
RUNOFF	3.189	265054.4690
DRAINAGE COLLECTED FROM LAYER 2	0.10179	8461.86426
PERCOLATION/LEAKAGE THROUGH LAYER 3	0.012658	1052.23718
AVERAGE HEAD ACROSS LAYER 3	16.935	
PERCOLATION/LEAKAGE THROUGH LAYER 6	0.022134	1839.95520
SNOW WATER	6.35	528163.8120

MAXIMUM VEG. SOIL WATER (VOL/VOL) 0.3985

MINIMUM VEG. SOIL WATER (VOL/VOL) 0.0269

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FINAL WATER STORAGE AT END OF YEAR 1978

LAYER	(INCHES)	(VOL/VOL)
1	2.0101	0.1675
2	4.3682	0.3640
3	0.0000	0.0000
4	2.7572	0.2298
5	3.8849	0.2158
6	82.6808	0.2297
SNOW WATER	0.000	

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	Further HELP3 Descriptions	Texture #
Vegetative Support Layer Loam & Native Soil Thickness = 12 in.	Vertical Percolation Layer	4
Drainage Layer Sand Thickness = 12 in.	Lateral Drainage Layer Slope = 7.5%	1
Geomembrane Layer HDPE Thickness = 0.04 in.	Flexible Membrane Liner	35
Geosynthetic Liner Clay Thickness = 0.5 in.	Barrier Soil Liner	16
Protective Layer Native Soil Thickness = 12 in.	Vertical Percolation Layer	7
Existing Cover Layer Hydr. Conductivity = 5.8×10^{-4} cm/s Thickness = 18 in.	Vertical Percolation Layer	7
Waste Layer Hydr. Conductivity = 1×10^{-3} cm/s Thickness = 360 in.	Vertical Percolation Layer	18

SOLID WASTE AREA
COMPOSITE CAP

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******************************************************************************
******************************************************************************
**                                                                          **
**                                                                          **
**              HYDROLOGIC EVALUATION OF LANDFILL PERFORMANCE               **
**               HELP MODEL VERSION 3.01   (14 OCTOBER 1994)                **
**                  DEVELOPED BY ENVIRONMENTAL LABORATORY                   **
**                    USAE WATERWAYS EXPERIMENT STATION                     **
**             FOR USEPA RISK REDUCTION ENGINEERING LABORATORY              **
**                                                                          **
**                                                                          **
******************************************************************************
******************************************************************************


PRECIPITATION DATA FILE:     C:\RH\HELP\HELP3\RHPRECIP.D4
TEMPERATURE DATA FILE:       C:\RH\HELP\HELP3\RHTEMP.D7
SOLAR RADIATION DATA FILE:   C:\RH\HELP\HELP3\RHSOLAR.D13
EVAPOTRANSPIRATION DATA:     C:\RH\HELP\HELP3\RHEVAP.D11
SOIL AND DESIGN DATA FILE:   C:\RH\HELP\HELP3\RHSOIL7.D10
OUTPUT DATA FILE:            C:\RH\HELP\HELP3\RUN19.OUT


TIME:  13:34     DATE:  10/ 6/1997


******************************************************************************

     TITLE:  Rose Hill - SW Area Good Composite Cap - Good liner

******************************************************************************


     NOTE:  INITIAL MOISTURE CONTENT OF THE LAYERS AND SNOW WATER WERE
              COMPUTED AS NEARLY STEADY-STATE VALUES BY THE PROGRAM.


                                  LAYER  1
                                  --------

                   TYPE 1 - VERTICAL PERCOLATION LAYER
                       MATERIAL TEXTURE NUMBER   4
          THICKNESS                    =     12.00   INCHES
          POROSITY                     =      0.4370 VOL/VOL
          FIELD CAPACITY               =      0.1050 VOL/VOL
          WILTING POINT                =      0.0470 VOL/VOL
          INITIAL SOIL WATER CONTENT   =      0.1497 VOL/VOL
          EFFECTIVE SAT. HYD. COND.    =  0.170000002000E-02 CM/SEC
        NOTE:  SATURATED HYDRAULIC CONDUCTIVITY IS MULTIPLIED BY  4.48
                 FOR ROOT CHANNELS IN TOP HALF OF EVAPORATIVE ZONE.


                                  LAYER  2
                                  --------

                  TYPE 2 - LATERAL DRAINAGE LAYER
                     MATERIAL TEXTURE NUMBER   1
          THICKNESS                    =     12.00   INCHES
          POROSITY                     =      0.4170 VOL/VOL
          FIELD CAPACITY               =      0.0450 VOL/VOL
          WILTING POINT                =      0.0180 VOL/VOL
          INITIAL SOIL WATER CONTENT   =      0.2874 VOL/VOL
          EFFECTIVE SAT. HYD. COND.    =  0.999999978000E-02 CM/SEC
          SLOPE                        =      7.50   PERCENT
          DRAINAGE LENGTH              =    500.0    FEET
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                        LAYER  3
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            TYPE 4 - FLEXIBLE MEMBRANE LINER
              MATERIAL TEXTURE NUMBER  35
THICKNESS                    =      0.04   INCHES
POROSITY                     =      0.0000 VOL/VOL
FIELD CAPACITY               =      0.0000 VOL/VOL
WILTING POINT                =      0.0000 VOL/VOL
INITIAL SOIL WATER CONTENT   =      0.0000 VOL/VOL
EFFECTIVE SAT. HYD. COND.    =  0.199999996000E-12 CM/SEC
FML PINHOLE DENSITY          =      0.75   HOLES/ACRE
FML INSTALLATION DEFECTS     =      4.00   HOLES/ACRE
FML PLACEMENT QUALITY        =  3 - GOOD


                        LAYER  4
                        --------

              TYPE 3 - BARRIER SOIL LINER
              MATERIAL TEXTURE NUMBER  16
THICKNESS                    =      0.50   INCHES
POROSITY                     =      0.4270 VOL/VOL
FIELD CAPACITY               =      0.4180 VOL/VOL
WILTING POINT                =      0.3670 VOL/VOL
INITIAL SOIL WATER CONTENT   =      0.4270 VOL/VOL
EFFECTIVE SAT. HYD. COND.    =  0.100000001000E-06 CM/SEC


                        LAYER  5
                        --------

          TYPE 1 - VERTICAL PERCOLATION LAYER
              MATERIAL TEXTURE NUMBER   7
THICKNESS                    =     12.00   INCHES
POROSITY                     =      0.4730 VOL/VOL
FIELD CAPACITY               =      0.2220 VOL/VOL
WILTING POINT                =      0.1040 VOL/VOL
INITIAL SOIL WATER CONTENT   =      0.2094 VOL/VOL
EFFECTIVE SAT. HYD. COND.    =  0.520000001000E-03 CM/SEC


                        LAYER  6
                        --------

          TYPE 1 - VERTICAL PERCOLATION LAYER
              MATERIAL TEXTURE NUMBER   0
THICKNESS                    =     18.00   INCHES
POROSITY                     =      0.4730 VOL/VOL
FIELD CAPACITY               =      0.2220 VOL/VOL
WILTING POINT                =      0.1040 VOL/VOL
INITIAL SOIL WATER CONTENT   =      0.2094 VOL/VOL
EFFECTIVE SAT. HYD. COND.    =  0.579999993000E-03 CM/SEC


                        LAYER  7
                        --------

          TYPE 1 - VERTICAL PERCOLATION LAYER
              MATERIAL TEXTURE NUMBER  18
THICKNESS                    =    360.00   INCHES
POROSITY                     =      0.6710 VOL/VOL
```

```
FIELD CAPACITY              =      0.2920 VOL/VOL
WILTING POINT               =      0.0770 VOL/VOL
INITIAL SOIL WATER CONTENT  =      0.2623 VOL/VOL
EFFECTIVE SAT. HYD. COND.   =  0.100000005000E-02 CM/SEC
```

GENERAL DESIGN AND EVAPORATIVE ZONE DATA

NOTE: SCS RUNOFF CURVE NUMBER WAS USER-SPECIFIED.

```
SCS RUNOFF CURVE NUMBER             =     61.00
FRACTION OF AREA ALLOWING RUNOFF    =    100.0    PERCENT
AREA PROJECTED ON HORIZONTAL PLANE  =     22.900  ACRES
EVAPORATIVE ZONE DEPTH              =     20.0    INCHES
INITIAL WATER IN EVAPORATIVE ZONE   =      3.577  INCHES
UPPER LIMIT OF EVAPORATIVE STORAGE  =      8.580  INCHES
LOWER LIMIT OF EVAPORATIVE STORAGE  =      0.708  INCHES
INITIAL SNOW WATER                  =      0.000  INCHES
INITIAL WATER IN LAYER MATERIALS    =    106.151  INCHES
TOTAL INITIAL WATER                 =    106.151  INCHES
TOTAL SUBSURFACE INFLOW             =      0.00   INCHES/YEAR
```

EVAPOTRANSPIRATION AND WEATHER DATA

NOTE: EVAPOTRANSPIRATION DATA WAS OBTAINED FROM
PROVIDENCE RHODE ISLAND

```
MAXIMUM LEAF AREA INDEX                =  3.30
START OF GROWING SEASON (JULIAN DATE)  =   121
END OF GROWING SEASON (JULIAN DATE)    =   290
AVERAGE ANNUAL WIND SPEED              = 10.60 MPH
AVERAGE 1ST QUARTER RELATIVE HUMIDITY  = 64.00 %
AVERAGE 2ND QUARTER RELATIVE HUMIDITY  = 65.00 %
AVERAGE 3RD QUARTER RELATIVE HUMIDITY  = 72.00 %
AVERAGE 4TH QUARTER RELATIVE HUMIDITY  = 70.00 %
```

NOTE: PRECIPITATION DATA FOR PROVIDENCE RHODE ISLAND
WAS ENTERED FROM THE DEFAULT DATA FILE.

NOTE: TEMPERATURE DATA WAS SYNTHETICALLY GENERATED USING
COEFFICIENTS FOR PROVIDENCE RHODE ISLAND

NORMAL MEAN MONTHLY TEMPERATURE (DEGREES FAHRENHEIT)

JAN/JUL	FEB/AUG	MAR/SEP	APR/OCT	MAY/NOV	JUN/DEC
28.20	29.30	37.40	47.90	57.60	66.80
72.50	71.10	63.50	53.20	43.40	32.20

NOTE: SOLAR RADIATION DATA WAS SYNTHETICALLY GENERATED USING
COEFFICIENTS FOR PROVIDENCE RHODE ISLAND

STATION LATITUDE = 41.73 DEGREES

****

ANNUAL TOTALS FOR YEAR 1974

	INCHES	CU. FEET	PERCENT
PRECIPITATION	40.66	3379944.000	100.00
RUNOFF	3.781	314274.844	9.30
EVAPOTRANSPIRATION	25.250	2098980.750	62.10
DRAINAGE COLLECTED FROM LAYER 2	11.6655	969715.187	28.69
PERC./LEAKAGE THROUGH LAYER 4	0.006086	505.927	0.01
AVG. HEAD ON TOP OF LAYER 4	3.7902		
PERC./LEAKAGE THROUGH LAYER 7	5.637188	468602.500	13.86
CHANGE IN WATER STORAGE	-5.674	-471629.906	-13.95
SOIL WATER AT START OF YEAR	106.151	8824053.000	
SOIL WATER AT END OF YEAR	100.478	8352423.000	
SNOW WATER AT START OF YEAR	0.000	0.000	0.00
SNOW WATER AT END OF YEAR	0.000	0.000	0.00
ANNUAL WATER BUDGET BALANCE	0.0000	0.793	0.00

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ANNUAL TOTALS FOR YEAR 1975

	INCHES	CU. FEET	PERCENT
PRECIPITATION	50.83	4225347.000	100.00
RUNOFF	8.129	675698.687	15.99
EVAPOTRANSPIRATION	25.681	2134813.250	50.52
DRAINAGE COLLECTED FROM LAYER 2	12.9120	1073332.870	25.40
PERC./LEAKAGE THROUGH LAYER 4	0.010381	862.967	0.02
AVG. HEAD ON TOP OF LAYER 4	5.1084		
PERC./LEAKAGE THROUGH LAYER 7	3.719516	309192.156	7.32
CHANGE IN WATER STORAGE	0.389	32307.225	0.76
SOIL WATER AT START OF YEAR	100.478	8352423.000	
SOIL WATER AT END OF YEAR	100.867	8384730.000	
SNOW WATER AT START OF YEAR	0.000	0.000	0.00
SNOW WATER AT END OF YEAR	0.000	0.000	0.00
ANNUAL WATER BUDGET BALANCE	0.0000	2.557	0.00

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ANNUAL TOTALS FOR YEAR 1976

	INCHES	CU. FEET	PERCENT
PRECIPITATION	46.31	3849611.500	100.00
RUNOFF	10.118	841085.562	21.85
EVAPOTRANSPIRATION	24.927	2072120.620	53.83
DRAINAGE COLLECTED FROM LAYER 2	15.0202	1248582.250	32.43
PERC./LEAKAGE THROUGH LAYER 4	0.011199	930.948	0.02
AVG. HEAD ON TOP OF LAYER 4	5.5755		
PERC./LEAKAGE THROUGH LAYER 7	2.753399	228881.812	5.95
CHANGE IN WATER STORAGE	-6.509	-541058.812	-14.05
SOIL WATER AT START OF YEAR	100.867	8384730.000	
SOIL WATER AT END OF YEAR	93.587	7779637.500	
SNOW WATER AT START OF YEAR	0.000	0.000	0.00
SNOW WATER AT END OF YEAR	0.770	64033.992	1.66
ANNUAL WATER BUDGET BALANCE	0.0000	-0.020	0.00

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ANNUAL TOTALS FOR YEAR 1977

	INCHES	CU. FEET	PERCENT
PRECIPITATION	48.81	4057428.250	100.00
RUNOFF	9.204	765127.750	18.86
EVAPOTRANSPIRATION	25.107	2087087.250	51.44
DRAINAGE COLLECTED FROM LAYER 2	13.1637	1094258.370	26.97
PERC./LEAKAGE THROUGH LAYER 4	0.007836	651.362	0.02
AVG. HEAD ON TOP OF LAYER 4	4.2949		
PERC./LEAKAGE THROUGH LAYER 7	2.160227	179573.187	4.43
CHANGE IN WATER STORAGE	-0.825	-68616.781	-1.69
SOIL WATER AT START OF YEAR	93.587	7779637.500	
SOIL WATER AT END OF YEAR	93.532	7775054.500	
SNOW WATER AT START OF YEAR	0.770	64033.988	1.58
SNOW WATER AT END OF YEAR	0.000	0.000	0.00
ANNUAL WATER BUDGET BALANCE	0.0000	-1.368	0.00

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ANNUAL TOTALS FOR YEAR 1978

	INCHES	CU. FEET	PERCENT
PRECIPITATION	47.00	3906969.000	100.00
RUNOFF	10.170	845379.500	21.64
EVAPOTRANSPIRATION	25.876	2151014.250	55.06
DRAINAGE COLLECTED FROM LAYER 2	11.3032	939604.000	24.05
PERC./LEAKAGE THROUGH LAYER 4	0.006168	512.699	0.01
AVG. HEAD ON TOP OF LAYER 4	3.6486		
PERC./LEAKAGE THROUGH LAYER 7	1.770498	147176.187	3.77
CHANGE IN WATER STORAGE	-2.120	-176204.734	-4.51
SOIL WATER AT START OF YEAR	93.532	7775054.500	
SOIL WATER AT END OF YEAR	91.413	7598850.000	
SNOW WATER AT START OF YEAR	0.000	0.000	0.00
SNOW WATER AT END OF YEAR	0.000	0.000	0.00
ANNUAL WATER BUDGET BALANCE	0.0000	-0.139	0.00

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AVERAGE MONTHLY VALUES IN INCHES FOR YEARS 1974 THROUGH 1978

	JAN/JUL	FEB/AUG	MAR/SEP	APR/OCT	MAY/NOV	JUN/DEC
PRECIPITATION						
TOTALS	6.19	2.98	3.95	2.75	3.21	3.10
	3.56	4.08	4.37	4.82	2.78	4.93
STD. DEVIATIONS	2.07	0.30	1.11	0.52	1.25	1.31
	2.62	2.27	2.21	1.87	2.13	0.98
RUNOFF						
TOTALS	3.278	1.943	1.861	0.442	0.000	0.000
	0.018	0.000	0.000	0.000	0.000	0.738
STD. DEVIATIONS	2.899	1.543	0.776	0.653	0.000	0.000
	0.041	0.001	0.000	0.000	0.000	0.969
EVAPOTRANSPIRATION						
TOTALS	1.010	1.260	1.849	2.047	2.787	3.650
	2.683	2.547	2.929	2.363	1.378	0.867
STD. DEVIATIONS	0.152	0.158	0.398	0.448	0.587	0.986
	1.055	1.401	0.558	0.351	0.141	0.183
LATERAL DRAINAGE COLLECTED FROM LAYER 2						
TOTALS	0.7698	0.4827	0.8594	1.9162	1.5509	0.9451
	0.5351	0.7406	0.9096	1.3204	1.3245	1.4588
STD. DEVIATIONS	0.2741	0.3570	0.4951	0.3168	0.3898	0.2211
	0.0876	0.8069	0.7279	0.6687	0.9249	0.4082

PERCOLATION/LEAKAGE THROUGH LAYER 4

TOTALS	0.0004	0.0002	0.0005	0.0014	0.0009	0.0005
	0.0002	0.0007	0.0005	0.0008	0.0010	0.0012
STD. DEVIATIONS	0.0002	0.0002	0.0003	0.0007	0.0003	0.0001
	0.0000	0.0011	0.0005	0.0006	0.0010	0.0011

PERCOLATION/LEAKAGE THROUGH LAYER 7

TOTALS	0.3222	0.2799	0.3001	0.2816	0.2821	0.2648
	0.2660	0.2584	0.2435	0.2454	0.2311	0.2332
STD. DEVIATIONS	0.1753	0.1496	0.1561	0.1423	0.1388	0.1273
	0.1246	0.1182	0.1088	0.1067	0.0989	0.0974

AVERAGES OF MONTHLY AVERAGED DAILY HEADS (INCHES)

DAILY AVERAGE HEAD ACROSS LAYER 4

AVERAGES	2.9205	2.0385	3.2782	8.3725	5.9161	3.7253
	2.0411	3.7497	3.5873	5.1317	6.1239	6.9177
STD. DEVIATIONS	1.0536	1.5076	1.8886	2.4813	1.4870	0.8716
	0.3341	5.1043	2.8726	2.7137	4.6690	4.0910

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AVERAGE ANNUAL TOTALS & (STD. DEVIATIONS) FOR YEARS 1974 THROUGH 1978

	INCHES		CU. FEET	PERCENT
PRECIPITATION	46.72	(3.815)	3883860.0	100.00
RUNOFF	8.280	(2.6491)	688313.25	17.722
EVAPOTRANSPIRATION	25.368	(0.3977)	2108803.00	54.297
LATERAL DRAINAGE COLLECTED FROM LAYER 2	12.81291	(1.46634)	1065098.500	27.42371
PERCOLATION/LEAKAGE THROUGH FROM LAYER 4	0.00833	(0.00237)	692.781	0.01784
AVERAGE HEAD ACROSS TOP OF LAYER 4	4.484	(0.836)		
PERCOLATION/LEAKAGE THROUGH FROM LAYER 7	3.20817	(1.54382)	266685.156	6.86650
CHANGE IN WATER STORAGE	-2.948	(3.0180)	-245040.59	-6.309

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PEAK DAILY VALUES FOR YEARS 1974 THROUGH 1978

	(INCHES)	(CU. FT.)
PRECIPITATION	4.78	397347.062

RUNOFF	3.193	265431.7810
DRAINAGE COLLECTED FROM LAYER 2	0.10186	8467.23926
PERCOLATION/LEAKAGE THROUGH LAYER 4	0.000155	12.91451
AVERAGE HEAD ACROSS LAYER 4	19.009	
PERCOLATION/LEAKAGE THROUGH LAYER 7	0.019930	1656.71350
SNOW WATER	6.35	528163.8120

MAXIMUM VEG. SOIL WATER (VOL/VOL)	0.4187
MINIMUM VEG. SOIL WATER (VOL/VOL)	0.0271

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FINAL WATER STORAGE AT END OF YEAR 1978

LAYER	(INCHES)	(VOL/VOL)
1	2.0106	0.1675
2	4.4942	0.3745
3	0.0000	0.0000
4	0.2135	0.4270
5	2.2798	0.1900
6	3.4198	0.1900
7	78.9947	0.2194
SNOW WATER	0.000	

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		Further HELP3 Descriptions	Texture #
Existing Cover Layer Hydr. Conductivity = 9.2×10^{-4} cm/s Thickness = 34 in.	17 in. 17 in.	Vertical Percolation Layer Barrier Soil Liner	7 7
Waste Layer Hydr. Conductivity = 1.4×10^{-4} cm/s Thickness = 120 in.		Vertical Percolation Layer	18

BULKY WASTE AREA
EXISTING CONDITIONS

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**                                                                          **
**                                                                          **
**              HYDROLOGIC EVALUATION OF LANDFILL PERFORMANCE               **
**               HELP MODEL VERSION 3.01   (14 OCTOBER 1994)                **
**                  DEVELOPED BY ENVIRONMENTAL LABORATORY                   **
**                    USAE WATERWAYS EXPERIMENT STATION                     **
**             FOR USEPA RISK REDUCTION ENGINEERING LABORATORY              **
**                                                                          **
**                                                                          **
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PRECIPITATION DATA FILE:     C:\HELP3\RHPRECIP.D4
TEMPERATURE DATA FILE:       C:\HELP3\RHTEMP.D7
SOLAR RADIATION DATA FILE:   C:\HELP3\RHSOLAR.D13
EVAPOTRANSPIRATION DATA:     C:\HELP3\RHEVAP.D11
SOIL AND DESIGN DATA FILE:   C:\HELP3\RHSOIL3.D10
OUTPUT DATA FILE:            C:\HELP3\RUN10.OUT


TIME:  11:22     DATE:   8/21/1996


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     TITLE:  Rose Hill - Bulky Waste Existing Conditions - 10X lab perm

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     NOTE:  INITIAL MOISTURE CONTENT OF THE LAYERS AND SNOW WATER WERE
              COMPUTED AS NEARLY STEADY-STATE VALUES BY THE PROGRAM.


                                LAYER  1
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                   TYPE 1 - VERTICAL PERCOLATION LAYER
                       MATERIAL TEXTURE NUMBER   0
          THICKNESS                    =     17.00   INCHES
          POROSITY                     =      0.4730 VOL/VOL
          FIELD CAPACITY               =      0.2220 VOL/VOL
          WILTING POINT                =      0.1040 VOL/VOL
          INITIAL SOIL WATER CONTENT   =      0.2384 VOL/VOL
          EFFECTIVE SAT. HYD. COND.    =  0.920000020000E-03 CM/SEC


                                LAYER  2
                                --------

                       TYPE 3 - BARRIER SOIL LINER
                       MATERIAL TEXTURE NUMBER   0
          THICKNESS                    =     17.00   INCHES
          POROSITY                     =      0.4730 VOL/VOL
          FIELD CAPACITY               =      0.2220 VOL/VOL
          WILTING POINT                =      0.1040 VOL/VOL
          INITIAL SOIL WATER CONTENT   =      0.4730 VOL/VOL
          EFFECTIVE SAT. HYD. COND.    =  0.920000020000E-03 CM/SEC


                                LAYER  3
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          TYPE 1 - VERTICAL PERCOLATION LAYER
              MATERIAL TEXTURE NUMBER   0
  THICKNESS                    =    120.00   INCHES
  POROSITY                     =      0.6710 VOL/VOL
  FIELD CAPACITY               =      0.2920 VOL/VOL
  WILTING POINT                =      0.0770 VOL/VOL
  INITIAL SOIL WATER CONTENT   =      0.3366 VOL/VOL
  EFFECTIVE SAT. HYD. COND.    =  0.140000004000E-03 CM/SEC


          GENERAL DESIGN AND EVAPORATIVE ZONE DATA
          ----------------------------------------

   NOTE:  SCS RUNOFF CURVE NUMBER WAS USER-SPECIFIED.

  SCS RUNOFF CURVE NUMBER              =     39.00
  FRACTION OF AREA ALLOWING RUNOFF     =    100.0    PERCENT
  AREA PROJECTED ON HORIZONTAL PLANE   =      7.400  ACRES
  EVAPORATIVE ZONE DEPTH               =     17.0    INCHES
  INITIAL WATER IN EVAPORATIVE ZONE    =      4.053  INCHES
  UPPER LIMIT OF EVAPORATIVE STORAGE   =      8.041  INCHES
  LOWER LIMIT OF EVAPORATIVE STORAGE   =      1.768  INCHES
  INITIAL SNOW WATER                   =      0.000  INCHES
  INITIAL WATER IN LAYER MATERIALS     =     52.482  INCHES
  TOTAL INITIAL WATER                  =     52.482  INCHES
  TOTAL SUBSURFACE INFLOW              =      0.00   INCHES/YEAR


           EVAPOTRANSPIRATION AND WEATHER DATA
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   NOTE:  EVAPOTRANSPIRATION DATA WAS OBTAINED FROM
            PROVIDENCE          RHODE ISLAND

      MAXIMUM LEAF AREA INDEX                  =  3.30
      START OF GROWING SEASON (JULIAN DATE)    =   121
      END OF GROWING SEASON (JULIAN DATE)      =   290
      AVERAGE ANNUAL WIND SPEED                = 10.60 MPH
      AVERAGE 1ST QUARTER RELATIVE HUMIDITY    = 64.00 %
      AVERAGE 2ND QUARTER RELATIVE HUMIDITY    = 65.00 %
      AVERAGE 3RD QUARTER RELATIVE HUMIDITY    = 72.00 %
      AVERAGE 4TH QUARTER RELATIVE HUMIDITY    = 70.00 %


   NOTE:  PRECIPITATION DATA FOR     PROVIDENCE             RHODE ISLAND
            WAS ENTERED FROM THE DEFAULT DATA FILE.


   NOTE:  TEMPERATURE DATA WAS SYNTHETICALLY GENERATED USING
            COEFFICIENTS FOR     PROVIDENCE          RHODE ISLAND

       NORMAL MEAN MONTHLY TEMPERATURE (DEGREES FAHRENHEIT)

JAN/JUL     FEB/AUG     MAR/SEP     APR/OCT     MAY/NOV     JUN/DEC
-------     -------     -------     -------     -------     -------
 28.20       29.30       37.40       47.90       57.60       66.80
 72.50       71.10       63.50       53.20       43.40       32.20


   NOTE:  SOLAR RADIATION DATA WAS SYNTHETICALLY GENERATED USING
            COEFFICIENTS FOR     PROVIDENCE          RHODE ISLAND

                STATION LATITUDE  = 41.73 DEGREES
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ANNUAL TOTALS FOR YEAR 1974

	INCHES	CU. FEET	PERCENT
PRECIPITATION	40.66	1092209.000	100.00
RUNOFF	3.990	107176.828	9.81
EVAPOTRANSPIRATION	26.165	702851.812	64.35
PERC./LEAKAGE THROUGH LAYER 2	10.508725	282285.375	25.85
AVG. HEAD ON TOP OF LAYER 2	0.0151		
PERC./LEAKAGE THROUGH LAYER 3	10.120623	271860.156	24.89
CHANGE IN WATER STORAGE	0.384	10319.999	0.94
SOIL WATER AT START OF YEAR	52.482	1409767.000	
SOIL WATER AT END OF YEAR	52.866	1420087.000	
SNOW WATER AT START OF YEAR	0.000	0.000	0.00
SNOW WATER AT END OF YEAR	0.000	0.000	0.00
ANNUAL WATER BUDGET BALANCE	0.0000	0.231	0.00

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ANNUAL TOTALS FOR YEAR 1975

	INCHES	CU. FEET	PERCENT
PRECIPITATION	50.83	1365395.870	100.00
RUNOFF	8.243	221427.906	16.22
EVAPOTRANSPIRATION	26.404	709270.000	51.95
PERC./LEAKAGE THROUGH LAYER 2	14.703395	394962.594	28.93
AVG. HEAD ON TOP OF LAYER 2	0.0189		
PERC./LEAKAGE THROUGH LAYER 3	9.638134	258899.562	18.96
CHANGE IN WATER STORAGE	6.544	175798.016	12.88
SOIL WATER AT START OF YEAR	52.866	1420087.000	
SOIL WATER AT END OF YEAR	59.411	1595885.120	
SNOW WATER AT START OF YEAR	0.000	0.000	0.00
SNOW WATER AT END OF YEAR	0.000	0.000	0.00
ANNUAL WATER BUDGET BALANCE	0.0000	0.435	0.00

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ANNUAL TOTALS FOR YEAR 1976

	INCHES	CU. FEET	PERCENT
PRECIPITATION	46.31	1243979.250	100.00
RUNOFF	8.825	237067.750	19.06
EVAPOTRANSPIRATION	26.067	700220.312	56.29
PERC./LEAKAGE THROUGH LAYER 2	11.360231	305158.531	24.53
AVG. HEAD ON TOP OF LAYER 2	0.0141		
PERC./LEAKAGE THROUGH LAYER 3	15.582978	418589.969	33.65
CHANGE IN WATER STORAGE	-4.166	-111899.164	-9.00
SOIL WATER AT START OF YEAR	59.411	1595885.120	
SOIL WATER AT END OF YEAR	54.474	1463293.750	
SNOW WATER AT START OF YEAR	0.000	0.000	0.00
SNOW WATER AT END OF YEAR	0.770	20692.207	1.66
ANNUAL WATER BUDGET BALANCE	0.0000	0.410	0.00

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ANNUAL TOTALS FOR YEAR 1977

	INCHES	CU. FEET	PERCENT
PRECIPITATION	48.81	1311134.120	100.00
RUNOFF	9.922	266526.344	20.33
EVAPOTRANSPIRATION	26.426	709866.000	54.14
PERC./LEAKAGE THROUGH LAYER 2	12.900718	346539.094	26.43
AVG. HEAD ON TOP OF LAYER 2	0.0193		
PERC./LEAKAGE THROUGH LAYER 3	9.937411	266938.750	20.36
CHANGE IN WATER STORAGE	2.524	67802.969	5.17
SOIL WATER AT START OF YEAR	54.474	1463293.750	
SOIL WATER AT END OF YEAR	57.769	1551788.870	
SNOW WATER AT START OF YEAR	0.770	20692.207	1.58
SNOW WATER AT END OF YEAR	0.000	0.000	0.00
ANNUAL WATER BUDGET BALANCE	0.0000	0.000	0.00

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ANNUAL TOTALS FOR YEAR 1978

	INCHES	CU. FEET	PERCENT

PRECIPITATION	47.00	1262514.000	100.00
RUNOFF	10.217	274454.187	21.74
EVAPOTRANSPIRATION	28.827	774342.937	61.33
PERC./LEAKAGE THROUGH LAYER 2	8.790268	236124.187	18.70
AVG. HEAD ON TOP OF LAYER 2	0.0117		
PERC./LEAKAGE THROUGH LAYER 3	12.202807	327791.812	25.96
CHANGE IN WATER STORAGE	-4.247	-114074.555	-9.04
SOIL WATER AT START OF YEAR	57.769	1551788.870	
SOIL WATER AT END OF YEAR	53.522	1437714.370	
SNOW WATER AT START OF YEAR	0.000	0.000	0.00
SNOW WATER AT END OF YEAR	0.000	0.000	0.00
ANNUAL WATER BUDGET BALANCE	0.0000	-0.359	0.00

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AVERAGE MONTHLY VALUES IN INCHES FOR YEARS 1974 THROUGH 1978

	JAN/JUL	FEB/AUG	MAR/SEP	APR/OCT	MAY/NOV	JUN/DEC
PRECIPITATION						
TOTALS	6.19	2.98	3.95	2.75	3.21	3.10
	3.56	4.08	4.37	4.82	2.78	4.93
STD. DEVIATIONS	2.07	0.30	1.11	0.52	1.25	1.31
	2.62	2.27	2.21	1.87	2.13	0.98
RUNOFF						
TOTALS	3.271	1.991	1.856	0.438	0.000	0.000
	0.000	0.000	0.000	0.000	0.000	0.685
STD. DEVIATIONS	2.831	1.566	0.903	0.675	0.000	0.000
	0.000	0.000	0.000	0.000	0.000	0.894
EVAPOTRANSPIRATION						
TOTALS	1.011	1.268	2.170	2.904	3.097	3.509
	2.693	2.744	2.819	2.286	1.422	0.854
STD. DEVIATIONS	0.147	0.162	0.362	0.573	1.058	1.181
	1.030	1.807	0.751	0.439	0.114	0.173
PERCOLATION/LEAKAGE THROUGH LAYER 2						
TOTALS	0.1441	0.7722	0.8609	1.5586	0.2235	0.1772
	0.3639	1.0558	1.1613	1.7366	1.3169	2.2817
STD. DEVIATIONS	0.2404	1.0731	0.8260	0.5521	0.2011	0.2534
	0.8138	1.7329	1.2322	1.9034	2.0417	1.5109
PERCOLATION/LEAKAGE THROUGH LAYER 3						
TOTALS	1.2383	1.3509	1.0889	0.7547	0.6462	1.1781

	1.1533	0.9603	0.8084	0.7763	0.5874	0.9535
STD. DEVIATIONS	1.0038	0.5983	0.5499	0.2218	0.1725	0.3044
	0.2091	0.1409	0.3778	0.6498	0.3626	0.2920

AVERAGES OF MONTHLY AVERAGED DAILY HEADS (INCHES)

DAILY AVERAGE HEAD ACROSS LAYER 2

AVERAGES	0.0014	0.0158	0.0153	0.0244	0.0034	0.0025
	0.0017	0.0176	0.0193	0.0299	0.0212	0.0372
STD. DEVIATIONS	0.0021	0.0222	0.0158	0.0090	0.0031	0.0037
	0.0039	0.0297	0.0205	0.0312	0.0308	0.0238

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AVERAGE ANNUAL TOTALS & (STD. DEVIATIONS) FOR YEARS 1974 THROUGH 1978

	INCHES		CU. FEET	PERCENT
PRECIPITATION	46.72	(3.815)	1255046.5	100.00
RUNOFF	8.240	(2.5072)	221330.58	17.635
EVAPOTRANSPIRATION	26.778	(1.1556)	719310.12	57.313
PERCOLATION/LEAKAGE THROUGH FROM LAYER 2	11.65267	(2.26120)	313013.937	24.94043
AVERAGE HEAD ACROSS TOP OF LAYER 2	0.016	(0.003)		
PERCOLATION/LEAKAGE THROUGH FROM LAYER 3	11.49639	(2.49877)	308816.062	24.60595
CHANGE IN WATER STORAGE	0.208	(4.5967)	5589.45	0.445

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PEAK DAILY VALUES FOR YEARS 1974 THROUGH 1978

	(INCHES)	(CU. FT.)
PRECIPITATION	4.78	128400.367
RUNOFF	3.215	86358.8906
PERCOLATION/LEAKAGE THROUGH LAYER 2	2.096555	56317.66020
AVERAGE HEAD ACROSS LAYER 2	0.942	
PERCOLATION/LEAKAGE THROUGH LAYER 3	0.153927	4134.80029
SNOW WATER	6.35	170673.0310

MAXIMUM VEG. SOIL WATER (VOL/VOL)	0.3919
MINIMUM VEG. SOIL WATER (VOL/VOL)	0.0870

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FINAL WATER STORAGE AT END OF YEAR 1978

LAYER	(INCHES)	(VOL/VOL)
1	4.3125	0.2537
2	8.0410	0.4730
3	41.1688	0.3431
SNOW WATER	0.000	

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	Further HELP3 Descriptions	Texture #
Vegetative Support Layer Loam & Native Soil Thickness = 12 in.	Vertical Percolation Layer	4
Drainage Layer Sand Thickness = 12 in.	Lateral Drainage Layer Slope =7.5%	1
Geomembrane Layer HDPE Thickness = 0.04 in.	Flexible Membrane Liner	35
Gas Vent Layer Sand Thickness = 12 in.	Vertical Percolation Layer	1
Existing Cover Layer Hydr. Conductivity = 9.2×10^{-4} cm/s Thickness = 34 in.	Vertical Percolation Layer	7
Waste Layer Hydr. Conductivity = 1.4×10^{-4} cm/s Thickness = 120 in.	Vertical Percolation Layer	18

BULKY WASTE AREA
SINGLE BARRIER CAP

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**                                                                          **
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**              HYDROLOGIC EVALUATION OF LANDFILL PERFORMANCE               **
**               HELP MODEL VERSION 3.01   (14 OCTOBER 1994)                **
**                  DEVELOPED BY ENVIRONMENTAL LABORATORY                   **
**                    USAE WATERWAYS EXPERIMENT STATION                     **
**             FOR USEPA RISK REDUCTION ENGINEERING LABORATORY              **
**                                                                          **
**                                                                          **
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PRECIPITATION DATA FILE:     C:\RH\HELP\HELP3\RHPRECIP.D4
TEMPERATURE DATA FILE:       C:\RH\HELP\HELP3\RHTEMP.D7
SOLAR RADIATION DATA FILE:   C:\RH\HELP\HELP3\RHSOLAR.D13
EVAPOTRANSPIRATION DATA:     C:\RH\HELP\HELP3\RHEVAP.D11
SOIL AND DESIGN DATA FILE:   C:\RH\HELP\HELP3\RHSOIL4.D10
OUTPUT DATA FILE:            C:\RH\HELP\HELP3\RUN22.OUT


TIME:  13:37     DATE:  10/ 6/1997


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     TITLE:  Rose Hill - BW Area Good Single Barrier Cap

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     NOTE:  INITIAL MOISTURE CONTENT OF THE LAYERS AND SNOW WATER WERE
              COMPUTED AS NEARLY STEADY-STATE VALUES BY THE PROGRAM.


                                  LAYER  1
                                  --------

                   TYPE 1 - VERTICAL PERCOLATION LAYER
                       MATERIAL TEXTURE NUMBER   4
          THICKNESS                    =     12.00   INCHES
          POROSITY                     =      0.4370 VOL/VOL
          FIELD CAPACITY               =      0.1050 VOL/VOL
          WILTING POINT                =      0.0470 VOL/VOL
          INITIAL SOIL WATER CONTENT   =      0.1497 VOL/VOL
          EFFECTIVE SAT. HYD. COND.    =  0.170000002000E-02 CM/SEC
        NOTE:  SATURATED HYDRAULIC CONDUCTIVITY IS MULTIPLIED BY  4.48
                 FOR ROOT CHANNELS IN TOP HALF OF EVAPORATIVE ZONE.


                                  LAYER  2
                                  --------

                 TYPE 2 - LATERAL DRAINAGE LAYER
                       MATERIAL TEXTURE NUMBER   1
          THICKNESS                    =     12.00   INCHES
          POROSITY                     =      0.4170 VOL/VOL
          FIELD CAPACITY               =      0.0450 VOL/VOL
          WILTING POINT                =      0.0180 VOL/VOL
          INITIAL SOIL WATER CONTENT   =      0.2063 VOL/VOL
          EFFECTIVE SAT. HYD. COND.    =  0.999999978000E-02 CM/SEC
          SLOPE                        =      7.50   PERCENT
          DRAINAGE LENGTH              =    250.0    FEET
```

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                         LAYER  3
                         --------

              TYPE 4 - FLEXIBLE MEMBRANE LINER
                MATERIAL TEXTURE NUMBER  35
THICKNESS                    =      0.04   INCHES
POROSITY                     =      0.0000 VOL/VOL
FIELD CAPACITY               =      0.0000 VOL/VOL
WILTING POINT                =      0.0000 VOL/VOL
INITIAL SOIL WATER CONTENT   =      0.0000 VOL/VOL
EFFECTIVE SAT. HYD. COND.    =  0.199999996000E-12 CM/SEC
FML PINHOLE DENSITY          =      0.75   HOLES/ACRE
FML INSTALLATION DEFECTS     =      4.00   HOLES/ACRE
FML PLACEMENT QUALITY        =  3 - GOOD


                         LAYER  4
                         --------

             TYPE 1 - VERTICAL PERCOLATION LAYER
                MATERIAL TEXTURE NUMBER   1
THICKNESS                    =     12.00   INCHES
POROSITY                     =      0.4170 VOL/VOL
FIELD CAPACITY               =      0.0450 VOL/VOL
WILTING POINT                =      0.0180 VOL/VOL
INITIAL SOIL WATER CONTENT   =      0.1085 VOL/VOL
EFFECTIVE SAT. HYD. COND.    =  0.999999978000E-02 CM/SEC


                         LAYER  5
                         --------

             TYPE 1 - VERTICAL PERCOLATION LAYER
                MATERIAL TEXTURE NUMBER   0
THICKNESS                    =     34.00   INCHES
POROSITY                     =      0.4730 VOL/VOL
FIELD CAPACITY               =      0.2220 VOL/VOL
WILTING POINT                =      0.1040 VOL/VOL
INITIAL SOIL WATER CONTENT   =      0.2264 VOL/VOL
EFFECTIVE SAT. HYD. COND.    =  0.920000020000E-03 CM/SEC


                         LAYER  6
                         --------

             TYPE 1 - VERTICAL PERCOLATION LAYER
                MATERIAL TEXTURE NUMBER   0
THICKNESS                    =    120.00   INCHES
POROSITY                     =      0.6710 VOL/VOL
FIELD CAPACITY               =      0.2920 VOL/VOL
WILTING POINT                =      0.0770 VOL/VOL
INITIAL SOIL WATER CONTENT   =      0.2861 VOL/VOL
EFFECTIVE SAT. HYD. COND.    =  0.140000004000E-03 CM/SEC


          GENERAL DESIGN AND EVAPORATIVE ZONE DATA
          ----------------------------------------

 NOTE:  SCS RUNOFF CURVE NUMBER WAS USER-SPECIFIED.

SCS RUNOFF CURVE NUMBER              =      61.00
```

FRACTION OF AREA ALLOWING RUNOFF	=	100.0	PERCENT
AREA PROJECTED ON HORIZONTAL PLANE	=	7.400	ACRES
EVAPORATIVE ZONE DEPTH	=	20.0	INCHES
INITIAL WATER IN EVAPORATIVE ZONE	=	2.804	INCHES
UPPER LIMIT OF EVAPORATIVE STORAGE	=	8.580	INCHES
LOWER LIMIT OF EVAPORATIVE STORAGE	=	0.708	INCHES
INITIAL SNOW WATER	=	0.000	INCHES
INITIAL WATER IN LAYER MATERIALS	=	47.607	INCHES
TOTAL INITIAL WATER	=	47.607	INCHES
TOTAL SUBSURFACE INFLOW	=	0.00	INCHES/YEAR

EVAPOTRANSPIRATION AND WEATHER DATA

NOTE: EVAPOTRANSPIRATION DATA WAS OBTAINED FROM
PROVIDENCE RHODE ISLAND

MAXIMUM LEAF AREA INDEX	=	3.30
START OF GROWING SEASON (JULIAN DATE)	=	121
END OF GROWING SEASON (JULIAN DATE)	=	290
AVERAGE ANNUAL WIND SPEED	=	10.60 MPH
AVERAGE 1ST QUARTER RELATIVE HUMIDITY	=	64.00 %
AVERAGE 2ND QUARTER RELATIVE HUMIDITY	=	65.00 %
AVERAGE 3RD QUARTER RELATIVE HUMIDITY	=	72.00 %
AVERAGE 4TH QUARTER RELATIVE HUMIDITY	=	70.00 %

NOTE: PRECIPITATION DATA FOR PROVIDENCE RHODE ISLAND
WAS ENTERED FROM THE DEFAULT DATA FILE.

NOTE: TEMPERATURE DATA WAS SYNTHETICALLY GENERATED USING
COEFFICIENTS FOR PROVIDENCE RHODE ISLAND

NORMAL MEAN MONTHLY TEMPERATURE (DEGREES FAHRENHEIT)

JAN/JUL	FEB/AUG	MAR/SEP	APR/OCT	MAY/NOV	JUN/DEC
28.20	29.30	37.40	47.90	57.60	66.80
72.50	71.10	63.50	53.20	43.40	32.20

NOTE: SOLAR RADIATION DATA WAS SYNTHETICALLY GENERATED USING
COEFFICIENTS FOR PROVIDENCE RHODE ISLAND

STATION LATITUDE = 41.73 DEGREES

****

ANNUAL TOTALS FOR YEAR 1974

	INCHES	CU. FEET	PERCENT
PRECIPITATION	40.66	1092209.000	100.00
RUNOFF	3.715	99803.672	9.14
EVAPOTRANSPIRATION	25.023	672156.500	61.54
DRAINAGE COLLECTED FROM LAYER 2	9.1558	245943.234	22.52
PERC./LEAKAGE THROUGH LAYER 3	2.786125	74840.883	6.85
AVG. HEAD ON TOP OF LAYER 3	1.4871		

PERC./LEAKAGE THROUGH LAYER 6	1.908683	51271.051	4.69
CHANGE IN WATER STORAGE	0.858	23034.424	2.11
SOIL WATER AT START OF YEAR	47.787	1283653.870	
SOIL WATER AT END OF YEAR	48.644	1306688.250	
SNOW WATER AT START OF YEAR	0.000	0.000	0.00
SNOW WATER AT END OF YEAR	0.000	0.000	0.00
ANNUAL WATER BUDGET BALANCE	0.0000	0.179	0.00

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ANNUAL TOTALS FOR YEAR 1975

	INCHES	CU. FEET	PERCENT
PRECIPITATION	50.83	1365395.870	100.00
RUNOFF	7.705	206976.469	15.16
EVAPOTRANSPIRATION	25.555	686453.375	50.28
DRAINAGE COLLECTED FROM LAYER 2	11.7928	316778.156	23.20
PERC./LEAKAGE THROUGH LAYER 3	3.908576	104992.180	7.69
AVG. HEAD ON TOP OF LAYER 3	2.2253		
PERC./LEAKAGE THROUGH LAYER 6	2.541662	68274.125	5.00
CHANGE IN WATER STORAGE	3.236	86913.242	6.37
SOIL WATER AT START OF YEAR	48.644	1306688.250	
SOIL WATER AT END OF YEAR	51.880	1393601.500	
SNOW WATER AT START OF YEAR	0.000	0.000	0.00
SNOW WATER AT END OF YEAR	0.000	0.000	0.00
ANNUAL WATER BUDGET BALANCE	0.0000	0.519	0.00

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ANNUAL TOTALS FOR YEAR 1976

	INCHES	CU. FEET	PERCENT
PRECIPITATION	46.31	1243979.250	100.00
RUNOFF	8.413	226003.328	18.17
EVAPOTRANSPIRATION	24.486	657755.312	52.88
DRAINAGE COLLECTED FROM LAYER 2	11.0282	296239.531	23.81
PERC./LEAKAGE THROUGH LAYER 3	3.779781	101532.477	8.16
AVG. HEAD ON TOP OF LAYER 3	2.1185		

PERC./LEAKAGE THROUGH LAYER 6	2.758798	74106.828	5.96
CHANGE IN WATER STORAGE	-0.377	-10125.868	-0.81
SOIL WATER AT START OF YEAR	51.880	1393601.500	
SOIL WATER AT END OF YEAR	50.733	1362783.500	
SNOW WATER AT START OF YEAR	0.000	0.000	0.00
SNOW WATER AT END OF YEAR	0.770	20692.207	1.66
ANNUAL WATER BUDGET BALANCE	0.0000	0.173	0.00

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ANNUAL TOTALS FOR YEAR 1977

	INCHES	CU. FEET	PERCENT
PRECIPITATION	48.81	1311134.120	100.00
RUNOFF	9.082	243972.047	18.61
EVAPOTRANSPIRATION	24.886	668491.875	50.99
DRAINAGE COLLECTED FROM LAYER 2	11.1955	300733.781	22.94
PERC./LEAKAGE THROUGH LAYER 3	3.498041	93964.367	7.17
AVG. HEAD ON TOP OF LAYER 3	1.9789		
PERC./LEAKAGE THROUGH LAYER 6	4.460102	119807.250	9.14
CHANGE IN WATER STORAGE	-0.814	-21870.514	-1.67
SOIL WATER AT START OF YEAR	50.733	1362783.500	
SOIL WATER AT END OF YEAR	50.689	1361605.120	
SNOW WATER AT START OF YEAR	0.770	20692.207	1.58
SNOW WATER AT END OF YEAR	0.000	0.000	0.00
ANNUAL WATER BUDGET BALANCE	0.0000	-0.397	0.00

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ANNUAL TOTALS FOR YEAR 1978

	INCHES	CU. FEET	PERCENT
PRECIPITATION	47.00	1262514.000	100.00
RUNOFF	9.945	267142.625	21.16
EVAPOTRANSPIRATION	25.589	687372.937	54.44
DRAINAGE COLLECTED FROM LAYER 2	8.4338	226548.328	17.94
PERC./LEAKAGE THROUGH LAYER 3	2.563386	68857.687	5.45
AVG. HEAD ON TOP OF LAYER 3	1.3577		

PERC./LEAKAGE THROUGH LAYER 6	3.043446	81753.039	6.48
CHANGE IN WATER STORAGE	-0.011	-303.107	-0.02
SOIL WATER AT START OF YEAR	50.689	1361605.120	
SOIL WATER AT END OF YEAR	50.678	1361302.000	
SNOW WATER AT START OF YEAR	0.000	0.000	0.00
SNOW WATER AT END OF YEAR	0.000	0.000	0.00
ANNUAL WATER BUDGET BALANCE	0.0000	0.147	0.00

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AVERAGE MONTHLY VALUES IN INCHES FOR YEARS 1974 THROUGH 1978

	JAN/JUL	FEB/AUG	MAR/SEP	APR/OCT	MAY/NOV	JUN/DEC
PRECIPITATION						
TOTALS	6.19	2.98	3.95	2.75	3.21	3.10
	3.56	4.08	4.37	4.82	2.78	4.93
STD. DEVIATIONS	2.07	0.30	1.11	0.52	1.25	1.31
	2.62	2.27	2.21	1.87	2.13	0.98
RUNOFF						
TOTALS	3.030	1.887	1.759	0.419	0.000	0.000
	0.018	0.000	0.000	0.000	0.000	0.659
STD. DEVIATIONS	2.706	1.534	0.755	0.635	0.000	0.000
	0.041	0.000	0.000	0.000	0.000	0.866
EVAPOTRANSPIRATION						
TOTALS	1.012	1.265	1.941	2.079	2.785	3.395
	2.682	2.597	2.809	2.271	1.399	0.873
STD. DEVIATIONS	0.151	0.161	0.267	0.385	0.590	1.080
	1.060	1.396	0.582	0.394	0.134	0.199
LATERAL DRAINAGE COLLECTED FROM LAYER 2						
TOTALS	0.6645	0.2766	0.8349	1.5707	0.8685	0.5698
	0.1924	0.6979	0.8017	1.1663	1.1597	1.5183
STD. DEVIATIONS	0.4073	0.3362	0.5797	0.3685	0.2516	0.2787
	0.0935	1.1532	0.6523	0.8274	1.0568	0.7212
PERCOLATION/LEAKAGE THROUGH LAYER 3						
TOTALS	0.2110	0.0922	0.2390	0.4633	0.2703	0.1885
	0.0782	0.2837	0.2349	0.3869	0.3944	0.4648
STD. DEVIATIONS	0.1137	0.0939	0.1650	0.1216	0.0659	0.0750
	0.0308	0.4886	0.1776	0.3040	0.3701	0.2456
PERCOLATION/LEAKAGE THROUGH LAYER 6						
TOTALS	0.2336	0.1728	0.1663	0.1763	0.2284	0.3357
	0.3218	0.2306	0.1810	0.2492	0.3245	0.3223
STD. DEVIATIONS	0.0750	0.0653	0.1396	0.1858	0.1744	0.1473

0.1270	0.1439	0.0860	0.1332	0.1142	0.1584

AVERAGES OF MONTHLY AVERAGED DAILY HEADS (INCHES)

DAILY AVERAGE HEAD ACROSS LAYER 3

AVERAGES	1.2593	0.5842	1.5925	3.2715	1.6564	1.1230
	0.3670	1.9754	1.5801	2.5976	2.8113	3.1836
STD. DEVIATIONS	0.7767	0.7099	1.1057	0.9850	0.4798	0.5494
	0.1783	3.6107	1.2856	2.2892	2.8313	1.8777

AVERAGE ANNUAL TOTALS & (STD. DEVIATIONS) FOR YEARS 1974 THROUGH 1978

	INCHES		CU. FEET	PERCENT
PRECIPITATION	46.72	(3.815)	1255046.5	100.00
RUNOFF	7.772	(2.4141)	208779.62	16.635
EVAPOTRANSPIRATION	25.108	(0.4675)	674446.00	53.739
LATERAL DRAINAGE COLLECTED FROM LAYER 2	10.32122	(1.44485)	277248.594	22.09070
PERCOLATION/LEAKAGE THROUGH FROM LAYER 3	3.30718	(0.60129)	88837.523	7.07842
AVERAGE HEAD ACROSS TOP OF LAYER 3	1.834	(0.388)		
PERCOLATION/LEAKAGE THROUGH FROM LAYER 6	2.94254	(0.94558)	79042.461	6.29797
CHANGE IN WATER STORAGE	0.578	(1.6076)	15529.64	1.237

PEAK DAILY VALUES FOR YEARS 1974 THROUGH 1978

	(INCHES)	(CU. FT.)
PRECIPITATION	4.78	128400.367
RUNOFF	3.173	85236.1484
DRAINAGE COLLECTED FROM LAYER 2	0.11073	2974.56104
PERCOLATION/LEAKAGE THROUGH LAYER 3	0.059357	1594.44983
AVERAGE HEAD ACROSS LAYER 3	13.496	
PERCOLATION/LEAKAGE THROUGH LAYER 6	0.022726	610.46289
SNOW WATER	6.35	170673.0310

MAXIMUM VEG. SOIL WATER (VOL/VOL) 0.3258

MINIMUM VEG. SOIL WATER (VOL/VOL) 0.0255

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FINAL WATER STORAGE AT END OF YEAR 1978

LAYER	(INCHES)	(VOL/VOL)
1	2.0063	0.1672
2	3.3332	0.2778
3	0.0000	0.0000
4	1.3208	0.1101
5	7.6343	0.2245
6	36.2030	0.3017
SNOW WATER	0.000	

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	Further HELP3 Descriptions	Texture #
Vegetative Support Layer Loam & Native Soil Thickness = 12 in.	Vertical Percolation Layer	4
Drainage Layer Sand Thickness = 12 in.	Lateral Drainage Layer Slope = 7.5%	1
Geomembrane Layer HDPE Thickness = 0.04 in.	Flexible Membrane Liner	35
Geosynthetic Liner Clay Thickness = 0.5 in.	Barrier Soil Liner	16
Gas Vent Layer Sand Thickness = 12 in.	Vertical Percolation Layer	1
Existing Cover Layer Hydr. Conductivity = 9.2×10^{-4} cm/s Thickness = 34 in.	Vertical Percolation Layer	7
Waste Layer Hydr. Conductivity = 1.4×10^{-4} cm/s Thickness = 120 in.	Vertical Percolation Layer	18

BULKY WASTE AREA
COMPOSITE CAP

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******************************************************************************
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**                                                                          **
**                                                                          **
**              HYDROLOGIC EVALUATION OF LANDFILL PERFORMANCE               **
**               HELP MODEL VERSION 3.01   (14 OCTOBER 1994)                **
**                  DEVELOPED BY ENVIRONMENTAL LABORATORY                   **
**                    USAE WATERWAYS EXPERIMENT STATION                     **
**             FOR USEPA RISK REDUCTION ENGINEERING LABORATORY              **
**                                                                          **
**                                                                          **
******************************************************************************
******************************************************************************


PRECIPITATION DATA FILE:     C:\RH\HELP\HELP3\RHPRECIP.D4
TEMPERATURE DATA FILE:       C:\RH\HELP\HELP3\RHTEMP.D7
SOLAR RADIATION DATA FILE:   C:\RH\HELP\HELP3\RHSOLAR.D13
EVAPOTRANSPIRATION DATA:     C:\RH\HELP\HELP3\RHEVAP.D11
SOIL AND DESIGN DATA FILE:   C:\RH\HELP\HELP3\RHSOIL8.D10
OUTPUT DATA FILE:            C:\RH\HELP\HELP3\RUN25.OUT


TIME:  13:40     DATE:  10/ 6/1997


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     TITLE:  Rose Hill - BW Area Good Composite Cap -Good liner

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     NOTE:  INITIAL MOISTURE CONTENT OF THE LAYERS AND SNOW WATER WERE
              COMPUTED AS NEARLY STEADY-STATE VALUES BY THE PROGRAM.


                                  LAYER  1
                                  --------

                     TYPE 1 - VERTICAL PERCOLATION LAYER
                         MATERIAL TEXTURE NUMBER   4
          THICKNESS                    =     12.00   INCHES
          POROSITY                     =      0.4370 VOL/VOL
          FIELD CAPACITY               =      0.1050 VOL/VOL
          WILTING POINT                =      0.0470 VOL/VOL
          INITIAL SOIL WATER CONTENT   =      0.1497 VOL/VOL
          EFFECTIVE SAT. HYD. COND.    =  0.170000002000E-02 CM/SEC
        NOTE:  SATURATED HYDRAULIC CONDUCTIVITY IS MULTIPLIED BY  4.48
                 FOR ROOT CHANNELS IN TOP HALF OF EVAPORATIVE ZONE.


                                  LAYER  2
                                  --------

                    TYPE 2 - LATERAL DRAINAGE LAYER
                      MATERIAL TEXTURE NUMBER   1
          THICKNESS                    =     12.00   INCHES
          POROSITY                     =      0.4170 VOL/VOL
          FIELD CAPACITY               =      0.0450 VOL/VOL
          WILTING POINT                =      0.0180 VOL/VOL
          INITIAL SOIL WATER CONTENT   =      0.2222 VOL/VOL
          EFFECTIVE SAT. HYD. COND.    =  0.999999978000E-02 CM/SEC
          SLOPE                        =      7.50   PERCENT
          DRAINAGE LENGTH              =    250.0    FEET
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                         LAYER  3
                         --------

            TYPE 4 - FLEXIBLE MEMBRANE LINER
              MATERIAL TEXTURE NUMBER  35
THICKNESS                    =      0.04   INCHES
POROSITY                     =      0.0000 VOL/VOL
FIELD CAPACITY               =      0.0000 VOL/VOL
WILTING POINT                =      0.0000 VOL/VOL
INITIAL SOIL WATER CONTENT   =      0.0000 VOL/VOL
EFFECTIVE SAT. HYD. COND.    =  0.199999996000E-12 CM/SEC
FML PINHOLE DENSITY          =      0.75   HOLES/ACRE
FML INSTALLATION DEFECTS     =      4.00   HOLES/ACRE
FML PLACEMENT QUALITY        =  3 - GOOD


                         LAYER  4
                         --------

              TYPE 3 - BARRIER SOIL LINER
              MATERIAL TEXTURE NUMBER  16
THICKNESS                    =      0.50   INCHES
POROSITY                     =      0.4270 VOL/VOL
FIELD CAPACITY               =      0.4180 VOL/VOL
WILTING POINT                =      0.3670 VOL/VOL
INITIAL SOIL WATER CONTENT   =      0.4270 VOL/VOL
EFFECTIVE SAT. HYD. COND.    =  0.100000001000E-06 CM/SEC


                         LAYER  5
                         --------

          TYPE 1 - VERTICAL PERCOLATION LAYER
              MATERIAL TEXTURE NUMBER   1
THICKNESS                    =     12.00   INCHES
POROSITY                     =      0.4170 VOL/VOL
FIELD CAPACITY               =      0.0450 VOL/VOL
WILTING POINT                =      0.0180 VOL/VOL
INITIAL SOIL WATER CONTENT   =      0.0449 VOL/VOL
EFFECTIVE SAT. HYD. COND.    =  0.999999978000E-02 CM/SEC


                         LAYER  6
                         --------

          TYPE 1 - VERTICAL PERCOLATION LAYER
              MATERIAL TEXTURE NUMBER   0
THICKNESS                    =     34.00   INCHES
POROSITY                     =      0.4730 VOL/VOL
FIELD CAPACITY               =      0.2220 VOL/VOL
WILTING POINT                =      0.1040 VOL/VOL
INITIAL SOIL WATER CONTENT   =      0.2156 VOL/VOL
EFFECTIVE SAT. HYD. COND.    =  0.920000020000E-03 CM/SEC


                         LAYER  7
                         --------

          TYPE 1 - VERTICAL PERCOLATION LAYER
              MATERIAL TEXTURE NUMBER   0
THICKNESS                    =    120.00   INCHES
POROSITY                     =      0.6710 VOL/VOL
```

```
FIELD CAPACITY              =      0.2920 VOL/VOL
WILTING POINT               =      0.0770 VOL/VOL
INITIAL SOIL WATER CONTENT  =      0.2768 VOL/VOL
EFFECTIVE SAT. HYD. COND.   =  0.140000004000E-03 CM/SEC
```

GENERAL DESIGN AND EVAPORATIVE ZONE DATA

NOTE: SCS RUNOFF CURVE NUMBER WAS USER-SPECIFIED.

```
SCS RUNOFF CURVE NUMBER             =     61.00
FRACTION OF AREA ALLOWING RUNOFF    =    100.0    PERCENT
AREA PROJECTED ON HORIZONTAL PLANE  =      7.400  ACRES
EVAPORATIVE ZONE DEPTH              =     20.0    INCHES
INITIAL WATER IN EVAPORATIVE ZONE   =      2.805  INCHES
UPPER LIMIT OF EVAPORATIVE STORAGE  =      8.580  INCHES
LOWER LIMIT OF EVAPORATIVE STORAGE  =      0.708  INCHES
INITIAL SNOW WATER                  =      0.000  INCHES
INITIAL WATER IN LAYER MATERIALS    =     45.762  INCHES
TOTAL INITIAL WATER                 =     45.762  INCHES
TOTAL SUBSURFACE INFLOW             =      0.00   INCHES/YEAR
```

EVAPOTRANSPIRATION AND WEATHER DATA

NOTE: EVAPOTRANSPIRATION DATA WAS OBTAINED FROM
PROVIDENCE RHODE ISLAND

```
MAXIMUM LEAF AREA INDEX                =  3.30
START OF GROWING SEASON (JULIAN DATE)  =   121
END OF GROWING SEASON (JULIAN DATE)    =   290
AVERAGE ANNUAL WIND SPEED              = 10.60 MPH
AVERAGE 1ST QUARTER RELATIVE HUMIDITY  = 64.00 %
AVERAGE 2ND QUARTER RELATIVE HUMIDITY  = 65.00 %
AVERAGE 3RD QUARTER RELATIVE HUMIDITY  = 72.00 %
AVERAGE 4TH QUARTER RELATIVE HUMIDITY  = 70.00 %
```

NOTE: PRECIPITATION DATA FOR PROVIDENCE RHODE ISLAND
WAS ENTERED FROM THE DEFAULT DATA FILE.

NOTE: TEMPERATURE DATA WAS SYNTHETICALLY GENERATED USING
COEFFICIENTS FOR PROVIDENCE RHODE ISLAND

NORMAL MEAN MONTHLY TEMPERATURE (DEGREES FAHRENHEIT)

JAN/JUL	FEB/AUG	MAR/SEP	APR/OCT	MAY/NOV	JUN/DEC
28.20	29.30	37.40	47.90	57.60	66.80
72.50	71.10	63.50	53.20	43.40	32.20

NOTE: SOLAR RADIATION DATA WAS SYNTHETICALLY GENERATED USING
COEFFICIENTS FOR PROVIDENCE RHODE ISLAND

STATION LATITUDE = 41.73 DEGREES

****

ANNUAL TOTALS FOR YEAR 1974

	INCHES	CU. FEET	PERCENT
PRECIPITATION	40.66	1092209.000	100.00
RUNOFF	3.715	99803.766	9.14
EVAPOTRANSPIRATION	25.024	672207.937	61.55
DRAINAGE COLLECTED FROM LAYER 2	11.9270	320381.812	29.33
PERC./LEAKAGE THROUGH LAYER 4	0.002719	73.028	0.01
AVG. HEAD ON TOP OF LAYER 4	1.9368		
PERC./LEAKAGE THROUGH LAYER 7	1.402669	37678.504	3.45
CHANGE IN WATER STORAGE	-1.410	-37863.016	-3.47
SOIL WATER AT START OF YEAR	45.762	1229261.370	
SOIL WATER AT END OF YEAR	44.353	1191398.370	
SNOW WATER AT START OF YEAR	0.000	0.000	0.00
SNOW WATER AT END OF YEAR	0.000	0.000	0.00
ANNUAL WATER BUDGET BALANCE	0.0000	0.061	0.00

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ANNUAL TOTALS FOR YEAR 1975

	INCHES	CU. FEET	PERCENT
PRECIPITATION	50.83	1365395.870	100.00
RUNOFF	7.761	208468.781	15.27
EVAPOTRANSPIRATION	25.556	686491.062	50.28
DRAINAGE COLLECTED FROM LAYER 2	14.4865	389135.812	28.50
PERC./LEAKAGE THROUGH LAYER 4	0.005180	139.134	0.01
AVG. HEAD ON TOP OF LAYER 4	2.9509		
PERC./LEAKAGE THROUGH LAYER 7	1.058035	28420.934	2.08
CHANGE IN WATER STORAGE	1.969	52879.336	3.87
SOIL WATER AT START OF YEAR	44.353	1191398.370	
SOIL WATER AT END OF YEAR	46.321	1244277.620	
SNOW WATER AT START OF YEAR	0.000	0.000	0.00
SNOW WATER AT END OF YEAR	0.000	0.000	0.00
ANNUAL WATER BUDGET BALANCE	0.0000	0.000	0.00

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ANNUAL TOTALS FOR YEAR 1976

	INCHES	CU. FEET	PERCENT
PRECIPITATION	46.31	1243979.250	100.00
RUNOFF	8.829	237166.812	19.07
EVAPOTRANSPIRATION	24.475	657442.687	52.85
DRAINAGE COLLECTED FROM LAYER 2	15.6190	419558.187	33.73
PERC./LEAKAGE THROUGH LAYER 4	0.005884	158.052	0.01
AVG. HEAD ON TOP OF LAYER 4	3.2695		
PERC./LEAKAGE THROUGH LAYER 7	0.846186	22730.238	1.83
CHANGE IN WATER STORAGE	-3.459	-92918.773	-7.47
SOIL WATER AT START OF YEAR	46.321	1244277.620	
SOIL WATER AT END OF YEAR	42.092	1130666.620	
SNOW WATER AT START OF YEAR	0.000	0.000	0.00
SNOW WATER AT END OF YEAR	0.770	20692.207	1.66
ANNUAL WATER BUDGET BALANCE	0.0000	0.104	0.00

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ANNUAL TOTALS FOR YEAR 1977

	INCHES	CU. FEET	PERCENT
PRECIPITATION	48.81	1311134.120	100.00
RUNOFF	9.130	245242.922	18.70
EVAPOTRANSPIRATION	24.805	666301.937	50.82
DRAINAGE COLLECTED FROM LAYER 2	13.6049	365455.625	27.87
PERC./LEAKAGE THROUGH LAYER 4	0.004907	131.810	0.01
AVG. HEAD ON TOP OF LAYER 4	2.8280		
PERC./LEAKAGE THROUGH LAYER 7	0.698925	18774.531	1.43
CHANGE IN WATER STORAGE	0.572	15358.930	1.17
SOIL WATER AT START OF YEAR	42.092	1130666.620	
SOIL WATER AT END OF YEAR	43.434	1166717.870	
SNOW WATER AT START OF YEAR	0.770	20692.207	1.58
SNOW WATER AT END OF YEAR	0.000	0.000	0.00
ANNUAL WATER BUDGET BALANCE	0.0000	0.120	0.00

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ANNUAL TOTALS FOR YEAR 1978

	INCHES	CU. FEET	PERCENT
PRECIPITATION	47.00	1262514.000	100.00
RUNOFF	10.079	270729.594	21.44
EVAPOTRANSPIRATION	25.493	684786.187	54.24
DRAINAGE COLLECTED FROM LAYER 2	11.8354	317922.875	25.18
PERC./LEAKAGE THROUGH LAYER 4	0.003388	91.020	0.01
AVG. HEAD ON TOP OF LAYER 4	2.1575		
PERC./LEAKAGE THROUGH LAYER 7	0.594435	15967.711	1.26
CHANGE IN WATER STORAGE	-1.001	-26892.332	-2.13
SOIL WATER AT START OF YEAR	43.434	1166717.870	
SOIL WATER AT END OF YEAR	42.433	1139825.500	
SNOW WATER AT START OF YEAR	0.000	0.000	0.00
SNOW WATER AT END OF YEAR	0.000	0.000	0.00
ANNUAL WATER BUDGET BALANCE	0.0000	-0.056	0.00

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AVERAGE MONTHLY VALUES IN INCHES FOR YEARS 1974 THROUGH 1978

	JAN/JUL	FEB/AUG	MAR/SEP	APR/OCT	MAY/NOV	JUN/DEC
PRECIPITATION						
TOTALS	6.19	2.98	3.95	2.75	3.21	3.10
	3.56	4.08	4.37	4.82	2.78	4.93
STD. DEVIATIONS	2.07	0.30	1.11	0.52	1.25	1.31
	2.62	2.27	2.21	1.87	2.13	0.98
RUNOFF						
TOTALS	3.089	1.905	1.785	0.428	0.000	0.000
	0.018	0.000	0.000	0.000	0.000	0.677
STD. DEVIATIONS	2.760	1.534	0.753	0.641	0.000	0.000
	0.041	0.000	0.000	0.000	0.000	0.889
EVAPOTRANSPIRATION						
TOTALS	1.012	1.265	1.907	2.077	2.785	3.396
	2.684	2.575	2.849	2.264	1.390	0.867
STD. DEVIATIONS	0.150	0.161	0.307	0.390	0.590	1.082
	1.061	1.404	0.533	0.407	0.130	0.193
LATERAL DRAINAGE COLLECTED FROM LAYER 2						
TOTALS	0.8909	0.4166	0.9806	2.0925	1.4007	0.8485
	0.3544	0.8298	1.0474	1.4921	1.3676	1.7735
STD. DEVIATIONS	0.4906	0.4141	0.6756	0.4851	0.5053	0.3466
	0.1258	1.2232	0.8566	0.8734	1.1195	0.7147

PERCOLATION/LEAKAGE THROUGH LAYER 4

TOTALS	0.0002	0.0001	0.0003	0.0008	0.0003	0.0002
	0.0001	0.0004	0.0003	0.0005	0.0006	0.0007
STD. DEVIATIONS	0.0001	0.0001	0.0002	0.0004	0.0001	0.0001
	0.0000	0.0008	0.0003	0.0005	0.0007	0.0006

PERCOLATION/LEAKAGE THROUGH LAYER 7

TOTALS	0.0877	0.0771	0.0836	0.0792	0.0802	0.0760
	0.0770	0.0756	0.0717	0.0727	0.0692	0.0701
STD. DEVIATIONS	0.0332	0.0291	0.0308	0.0287	0.0286	0.0265
	0.0265	0.0255	0.0239	0.0238	0.0221	0.0223

AVERAGES OF MONTHLY AVERAGED DAILY HEADS (INCHES)

DAILY AVERAGE HEAD ACROSS LAYER 4

AVERAGES	1.6889	0.8798	2.1860	5.1784	2.6716	1.6723
	0.6759	2.4746	2.2383	3.3167	4.0022	4.5577
STD. DEVIATIONS	0.9367	0.8744	1.5134	2.2395	0.9638	0.6831
	0.2400	4.2869	1.9868	2.5061	3.8874	2.9351

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AVERAGE ANNUAL TOTALS & (STD. DEVIATIONS) FOR YEARS 1974 THROUGH 1978

	INCHES			CU. FEET	PERCENT
PRECIPITATION	46.72	(	3.815)	1255046.5	100.00
RUNOFF	7.903	(	2.4825)	212282.39	16.914
EVAPOTRANSPIRATION	25.071	(	0.4587)	673445.94	53.659
LATERAL DRAINAGE COLLECTED FROM LAYER 2	13.49456	(	1.63703)	362490.875	28.88267
PERCOLATION/LEAKAGE THROUGH FROM LAYER 4	0.00442	(	0.00131)	118.609	0.00945
AVERAGE HEAD ACROSS TOP OF LAYER 4	2.629	(	0.560)		
PERCOLATION/LEAKAGE THROUGH FROM LAYER 7	0.92005	(	0.32107)	24714.385	1.96920
CHANGE IN WATER STORAGE	-0.666	(	2.0579)	-17887.17	-1.425

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PEAK DAILY VALUES FOR YEARS 1974 THROUGH 1978

	(INCHES)	(CU. FT.)
PRECIPITATION	4.78	128400.367

RUNOFF	3.173	85236.1406
DRAINAGE COLLECTED FROM LAYER 2	0.11264	3025.65942
PERCOLATION/LEAKAGE THROUGH LAYER 4	0.000109	2.91543
AVERAGE HEAD ACROSS LAYER 4	15.133	
PERCOLATION/LEAKAGE THROUGH LAYER 7	0.004600	123.56113
SNOW WATER	6.35	170673.0310

MAXIMUM VEG. SOIL WATER (VOL/VOL) 0.3775

MINIMUM VEG. SOIL WATER (VOL/VOL) 0.0266

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FINAL WATER STORAGE AT END OF YEAR 1978

LAYER	(INCHES)	(VOL/VOL)
1	2.0089	0.1674
2	3.7020	0.3085
3	0.0000	0.0000
4	0.2135	0.4270
5	0.5457	0.0455
6	6.8266	0.2008
7	29.1360	0.2428
SNOW WATER	0.000	

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C-2 MODFLOW Model Simulations

GROUNDWATER FLOW MODELING

1.0 INTRODUCTION

A three-dimensional groundwater flow model was used to simulate groundwater conditions at the Site and to evaluate potential groundwater control remedial actions considered under the feasibility study (FS). The groundwater flow model used in this study is the USGS modular three-dimensional groundwater flow model, MODFLOW (McDonald and Harbaugh, 1988). The MODFLOW code is a finite difference formulation which computes vertical and horizontal groundwater flow between grid cells. This formulation requires that the area to be modeled be discretized using rows, columns and layers which creates the three-dimensional model domain. The discretization creates individual cells with each being assigned representative hydraulic properties such as hydraulic conductivity, and the top and bottom elevations of saturated layers. Each cell of the model is indexed by its associated row, column and layer. The center of each cell is a point called a "node" at which the groundwater elevation (head) for the cell is calculated, based on input to the model.

2.0 MODELGRID AND DATA INPUT

The model domain developed for the Site consists of 24 rows and 24 columns. The minimum grid spacing was 50 feet by 50 feet within the landfilled areas. The grid cell size was increased gradually up to a maximum spacing of 200 feet by 200 feet outwards towards the edges of the model. Figure 1 illustrates the model grid.

Three model layers were used to simulate the groundwater flow regime characterized in the RI investigation. Layer 1 represents the upper overburden groundwater system. Layer 1 is unconfined and consists of the glacial outwash deposits as well as the lower limits of the landfill refuse. The bottom of Layer 1 is generally less than 30 feet deep and was assigned

hydraulic conductivities representative of the outwash and refuse (16 ft/day and 0.5 ft/day repectively) as determined during the RI. Figure 2 shows the bottom elevations for layer 1 used as model input.

Layer 2 represents the lower overburden groundwater flow system which consists of glacial till and lacustrine deposits. Average hydraulic properties of these deposits were assigned to this layer (19 ft/day for the glacial till and 5 ft/day for the lacustrine deposits). Elevations of the top of the bedrock surface represent the bottom of layer 2 and are shown in Figure 2.

Layer 3 of the model represented the upper bedrock flow system (upper 100 feet) and was assigned a transmissivity of 50 ft^2/day. The bottom of Layer 3 is the vertical extent of the modeled area and represents competent bedrock. The model assumes this is an impermeable boundary.

The Saugatucket River, which runs approximately north-south through the eastern portion of the model domain, was simulated and incorporated into the model using MODFLOW's river package.

Initial groundwater elevations (or starting heads) input into the model are shown in Figures 3, 4 and 5.

Areal recharge of 16 inches/year was applied to the model assuming the existence of glacial outwash deposits comprising Layer 1 outside of the landfilled areas. The Hydrologic Evaluation of Landfill Performance (HELP) model was used to calculate the amount of areal recharge to be applied to each of the three landfilled areas assuming existing conditions. Results of the HELP model simulations are presented earlier in this appendix. Areal recharge applied to the landfilled areas was 12.9 inches/year in the solid waste landfill and 11.7 inches per year to both the bulky waste area and the sewage sludge landfill. Areal recharge was uniformly applied to the top of cells in Layer 1.

3.0 PRELIMINARY MODEL CALIBRATION

Model simulated steady-state groundwater elevation contours are shown in Figures 7, 8 and 9. These contours were compared to the contours generated from the May 1992 water level data collected during the RI. The steady-state heads calculated in cells corresponding to the locations of monitoring wells were compared with groundwater elevations measured in the wells in January 1992. The results of this comparison are shown in Table 1. The difference between the model output data and the field data ranged between -2.77 and +5.87 feet. This match is believed to represent a reasonable steady-state calibration and will allow the model to reasonably predict site groundwater conditions for the feasibility study such as groundwater control options and associated required groundwater withdrawal volumes ranges. Table 2 is the net water balance for the steady-state model simulation.

4.0 POTENTIAL GROUNDWATER CONTROL SIMULATIONS

Several groundwater control options were simulated using the model. These included:

- capping the landfills using single barrier and/or composite caps
- seepage control along the eastern edge of the Bulky Waste Area, and
- dewatering of the Solid Waste Area

4.1 Landfill Capping (Alternative 3)

The effects of several landfill capping options on the groundwater system were assessed by varying the amount of recharge over the landfilled areas with rates calculated using the HELP model. For FS alternative #3, three possible combinations of landfill capping options were considered: 1) capping both the Solid Waste Area and the Bulky Waste Area with composite caps; 2) capping the Solid Waste Area with a composite cap and the Bulky Waste Area with a

single barrier cap; and 3) capping both landfills with single barrier caps. These simulations provided a comparison of the effects of the two types of capping options and evaluated the potential impacts of the caps such as the ability to dewater the Solid Waste Area below the depth of the refuse. The contoured model output in Layer 1 for each of the three capping options are shown in Figures 10, 11, and 12. A comparison of Figures 10, 11 and 12 with Figure 7 suggests that the greatest decreases in water levels (0.5 to 1.0 foot) in the shallow overburden would occur in the Solid Waste Area with a composite cap. With a composite cap, water levels in the Bulky Waste Area appear to decrease less than 0.5 feet. Groundwater contours for the deep overburden and bedrock (Layers 2 and 3) indicate water level decreases similar to Layer 1 for the three capping simulations.

As a result of these simulations, few regional groundwater effects would be expected to occur as a result of landfill capping due to the interconnection of groundwater flow systems and the regional effects of surface water flow on groundwater flow.

Table 3 is a comparison between model-computed heads in cells with monitoring wells for both pre-capping (existing) and after capping conditions. The greatest decrease in overburden groundwater levels is noted in monitoring wells within the landfilled areas with composite caps simulated. This decrease is considered sufficient to lower the water table in the Solid Waste Area approximately 0.5 feet. A comparison of groundwater contours with Solid Waste Area bottom of refuse contours indicates that groundwater levels would still exceed bottom of refuse levels. As such, additional dewatering actions for the Solid Waste Area were also considered as a contingency to assure that groundwater levels can be lowered further below the waste to allow for seasonal fluctuations. The simulations performed with these dewatering actions are discussed below in Section 4.3.

Refuse in the Bulky Waste and Sewage Sludge Areas were above the water table prior to capping and therefore dewatering impacts in these areas were not as significant in considerations for this model simulation.

4.2 Capping Combined with Bulky Waste Area Leachate Control (Alternative 4)

Evaluation of a combination of landfill capping and leachate/groundwater outbreak control along the eastern edge of the Bulky Waste Area was performed with MODFLOW using the drain package option. Drains were placed along the eastern edge of the Bulky Waste Area, as shown in Figure 13, to intercept the upper water table surface. Drains were placed approximately 1.0 foot below the water table (as determined from existing simulations) to provide a simulated low-yield removal system. The model was then run using the three capping combinations introduced in Section 4.1. The resulting groundwater elevation contours in the shallow overburden are shown in Figures 13, 14 and 15. The estimated rates of groundwater that would be removed removed via the drains for each capping option is presented in Table 4.

Groundwater contours at the eastern edge of the Bulky Waste Area in Figures 13, 14 and 15 indicate that the drains locally influence shallow groundwater flow. A comparison of Figures 13, 14 and 15 with Figures 10, 11 and 12 suggests that the drains do not further lower groundwater levels in the Bulky Waste Area.

Simulations were also run to estimate the rate of groundwater flow to the drains during seasonal water table highs by lowering the drain elevations to 2 feet below the water table. Model output from the three simulations suggested that the rate would increase 1.5 times under this condition.

4.3 Landfill Capping Combined with Solid Waste Area Dewatering and Bulky Waste Area Leachate Control (Alternative 5)

A Solid Waste Area dewatering contingency to supplement the capping of the disposal areas and Bulky Waste Area leachate control was also simulated using the flow model. The

dewatering option was considered to assure that groundwater levels could be lowered below the depth of the refuse in the Solid Waste Area in combination with the previously considered options. For these simulations, drains were placed along the northern edge of the Solid Waste Area, as shown in Figure 16. Three simulations were run using the three capping combinations described above. The resulting groundwater elevation contours and locations of drains are shown in Figures 16, 17 and 18. The rates of groundwater removal with the two drain systems in operation for the three capping options are provided in Table 4.

A comparison of groundwater contours in Figures 16, 17 and 18 with bottom of refuse contours in the Solid Waste Area indicate that groundwater levels would be lowered a maximum of approximately 5 feet below the bottom of the waste. Groundwater contours in the three figures suggest that groundwater would not be in contact with the waste in the Solid Waste Area.

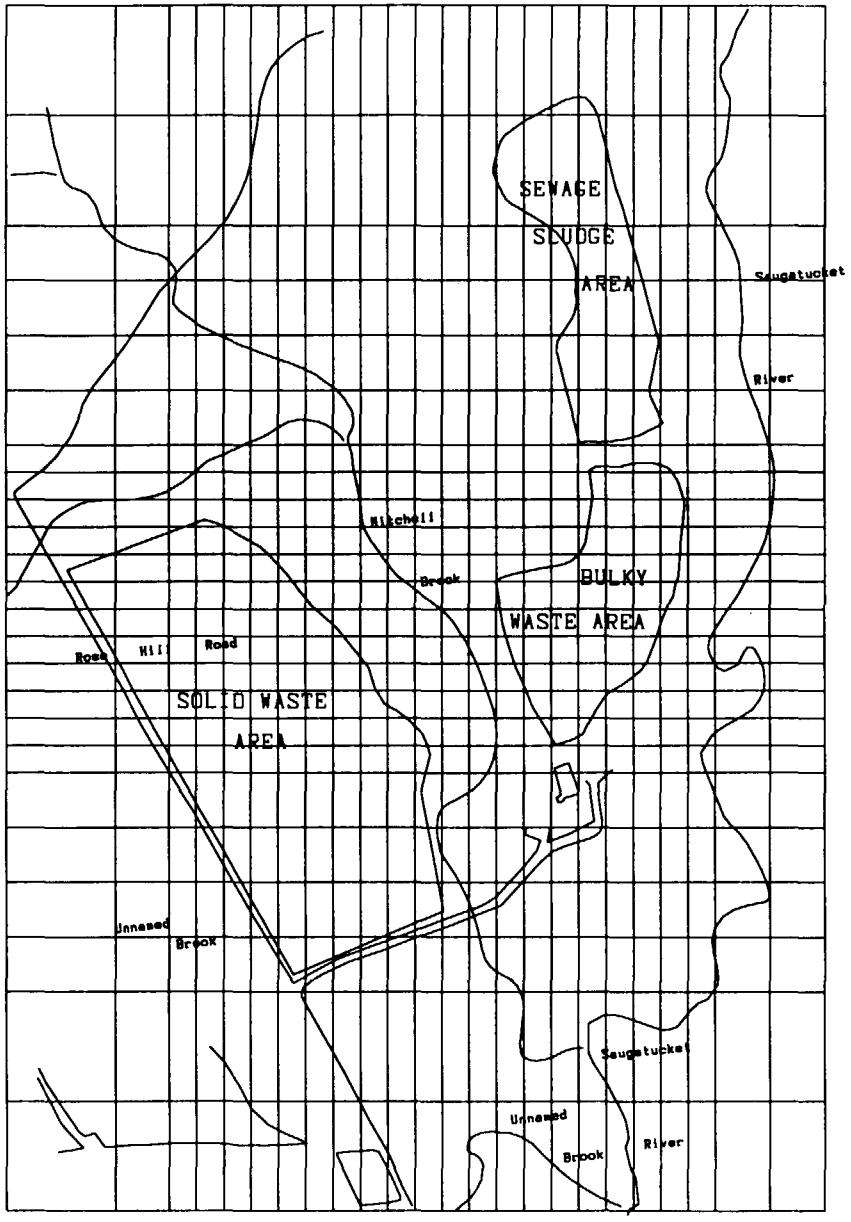
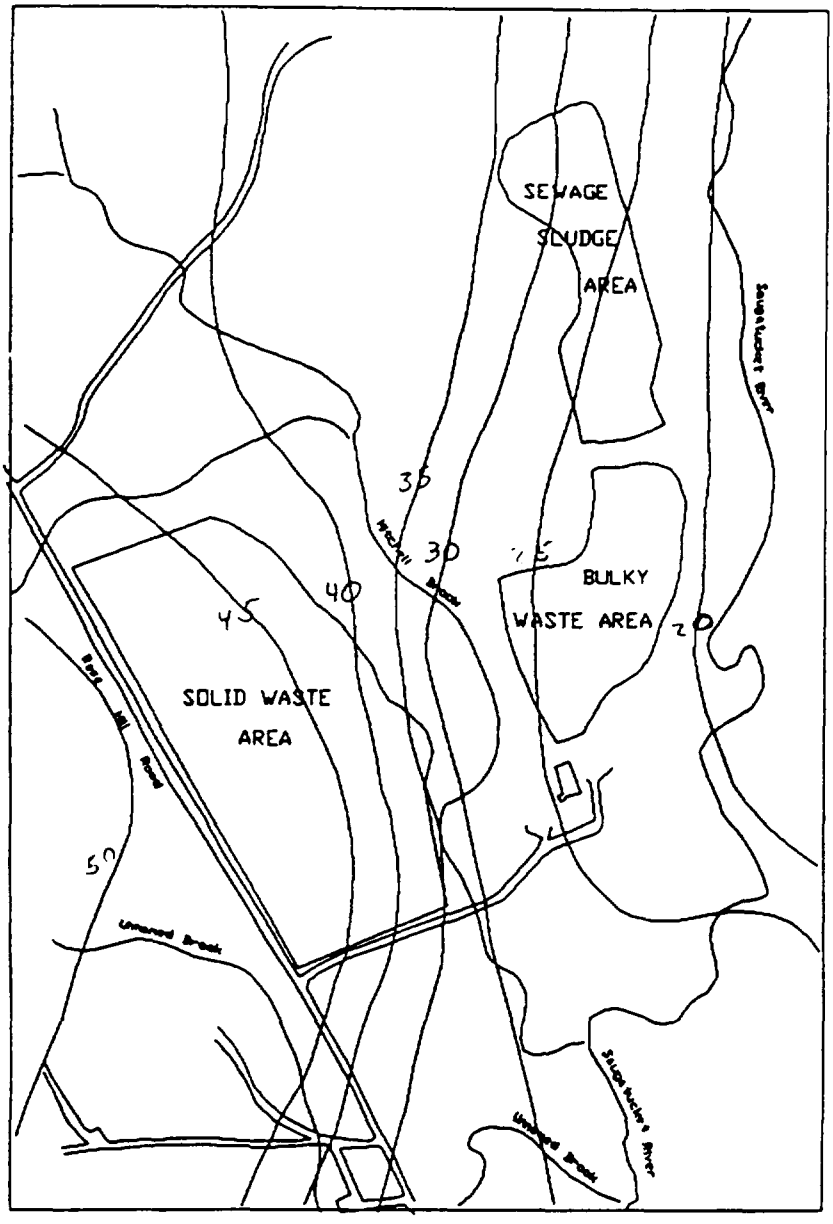


Figure 1. Model Grid



ROSE HILL FS STUDY

700 0 700

SCALE IN FEET

FIGURE 2. BOTTOM ELEVATION CONTOURS OF LAYER 1

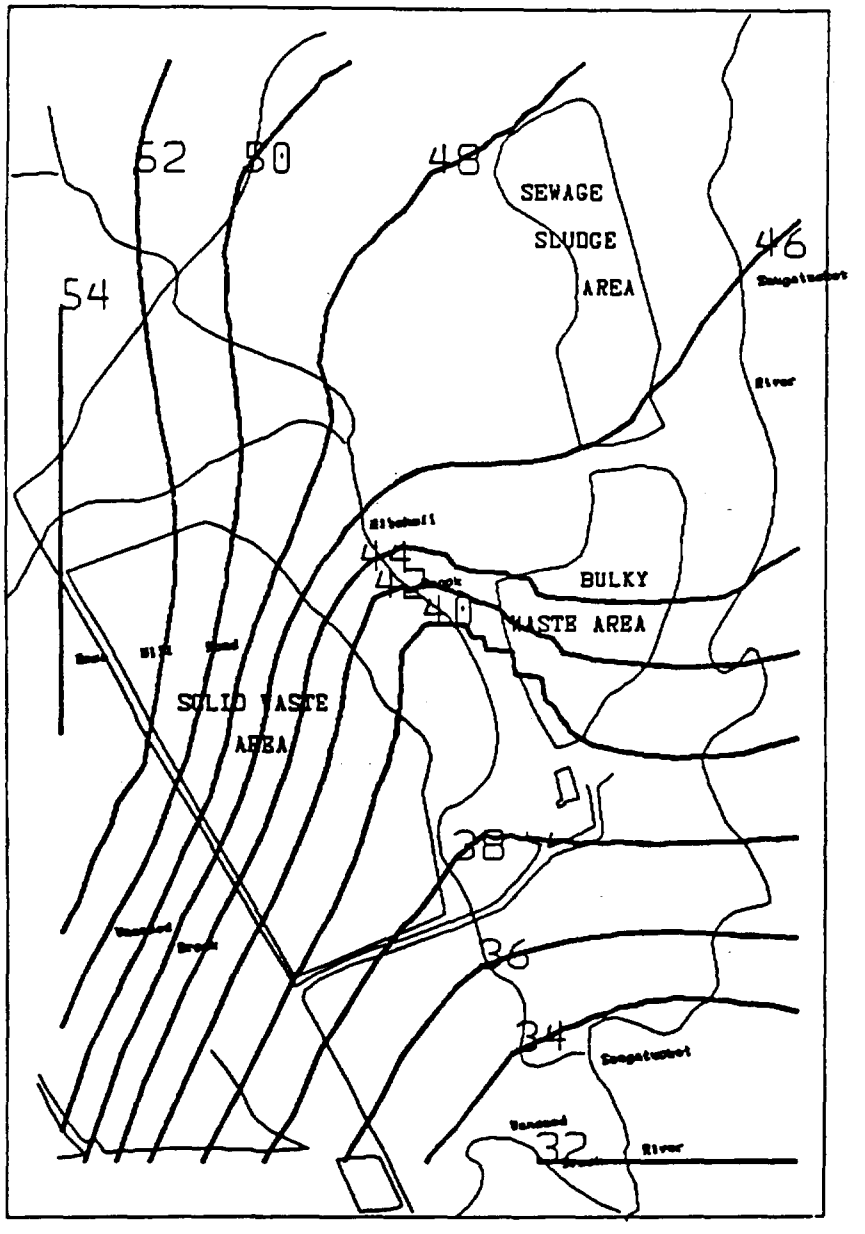
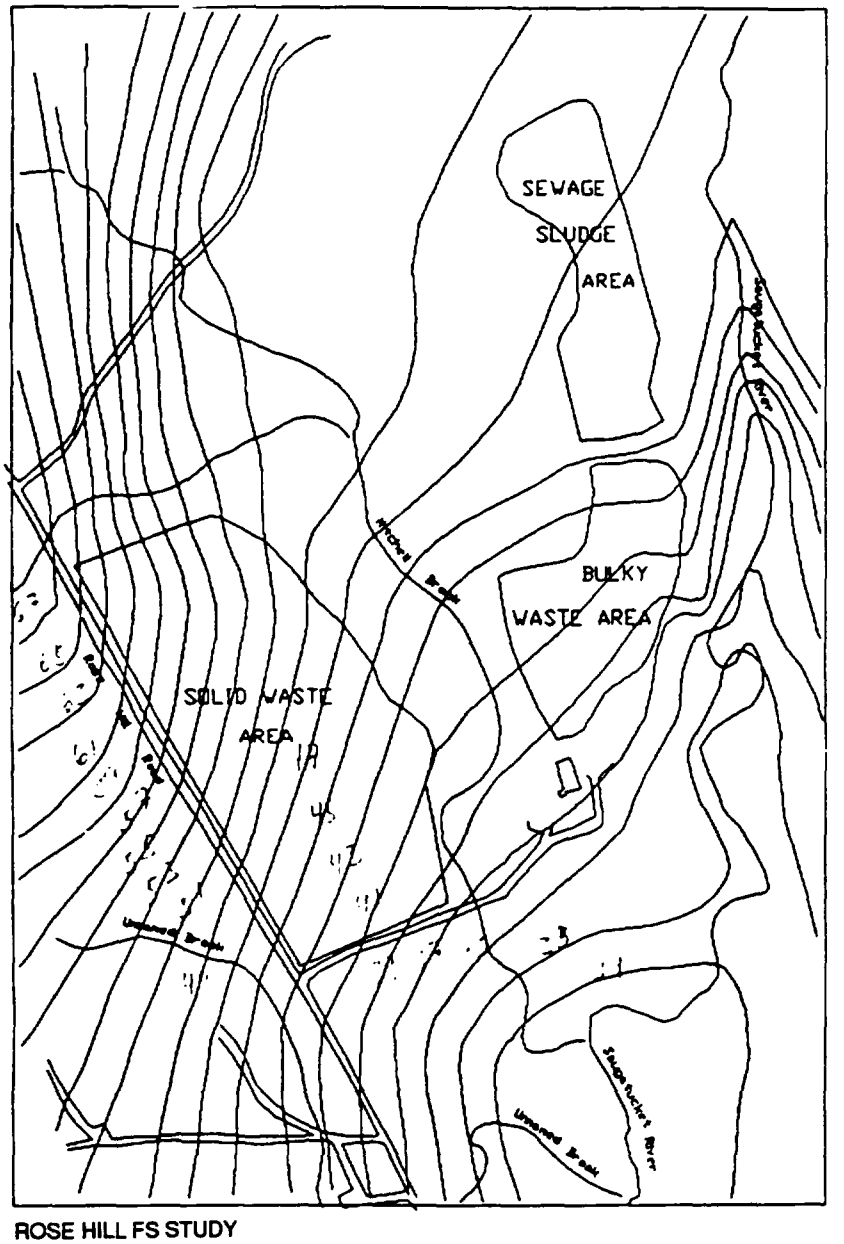


FIGURE 3. BOTTOM ELEVATION CONTOURS OF LAYER 2 (TOP OF BEDROCK)

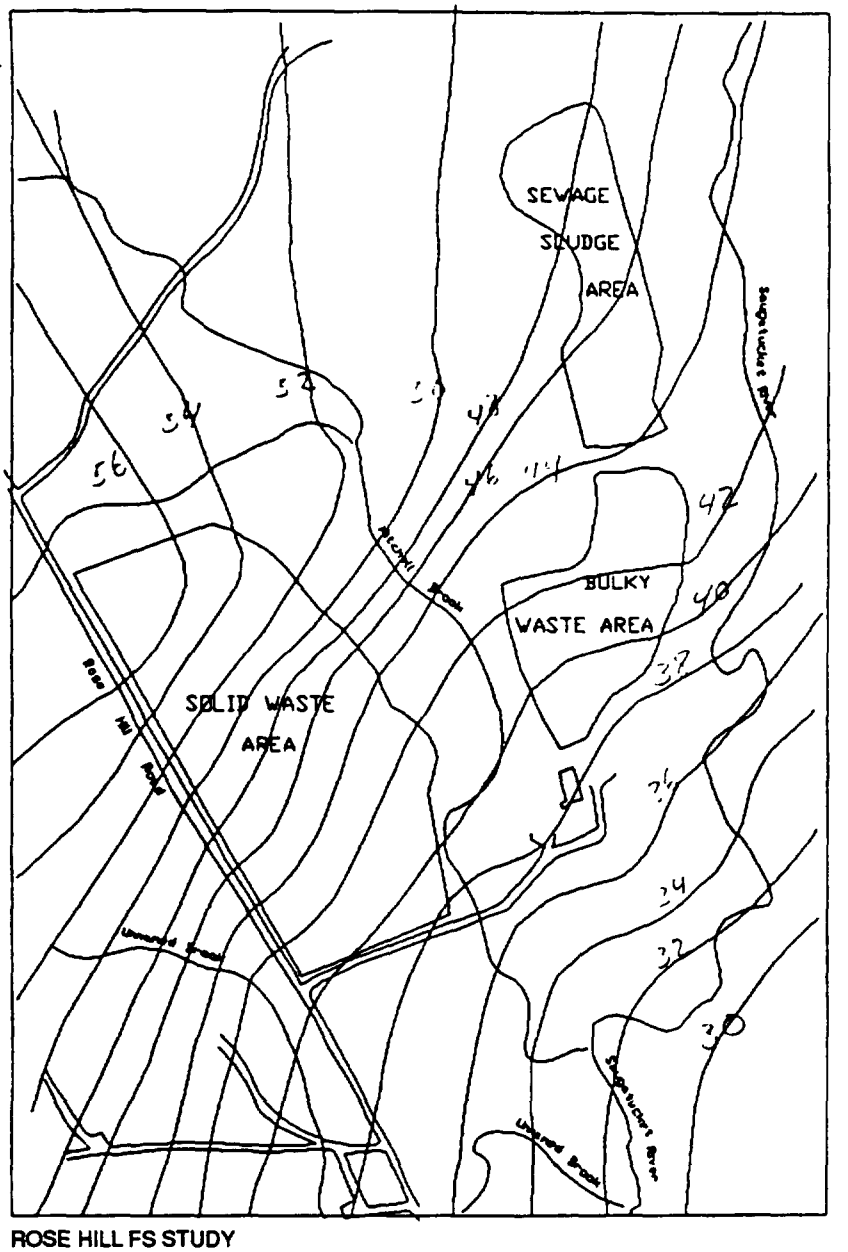


ROSE HILL FS STUDY

700 0 700

SCALE IN FEET

FIGURE 4. UPPER OVERBURDEN INITIAL GROUNDWATER ELEVATION CONTOURS USED N THE MODEL

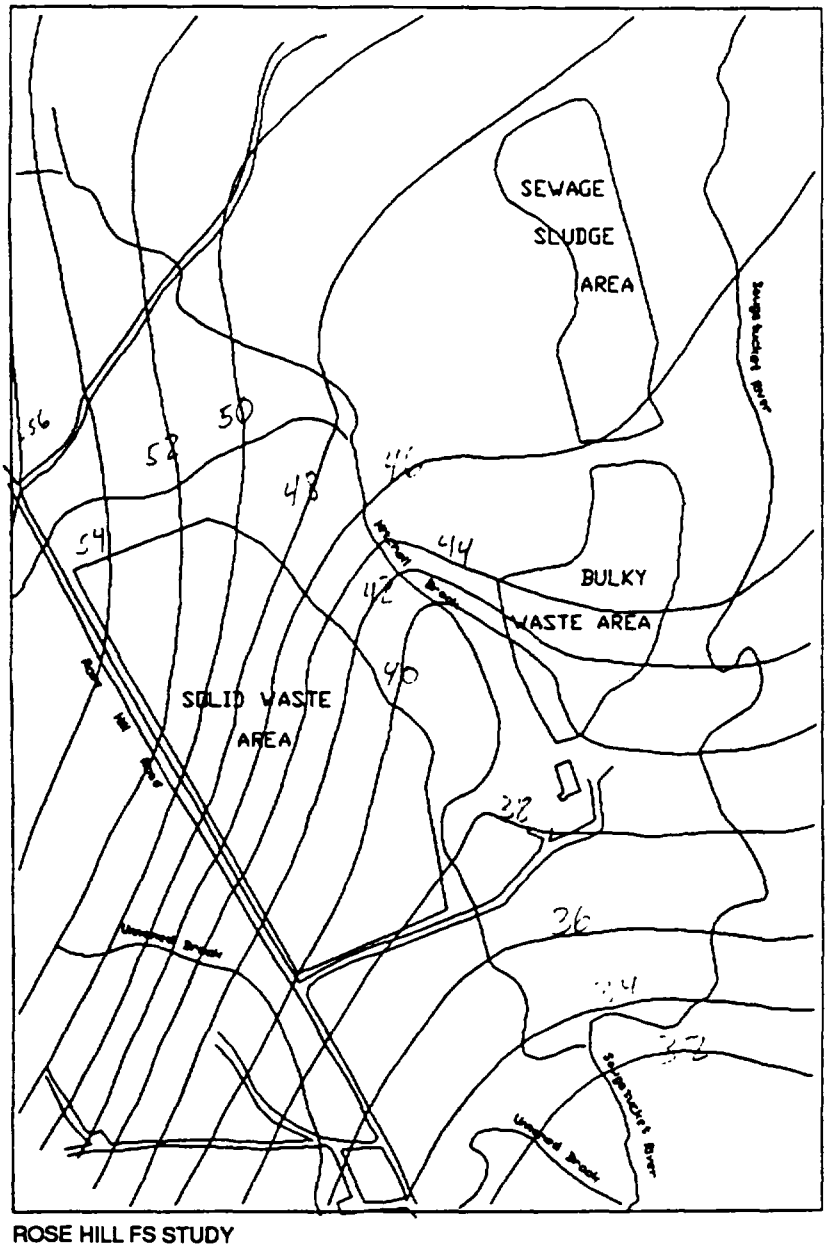


ROSE HILL FS STUDY

700 0 700

SCALE IN FEET

FIGURE 5. LOWER OVERBURDEN INITIAL GROUNDWATER ELEVATION CONTOURS USED IN THE MODEL

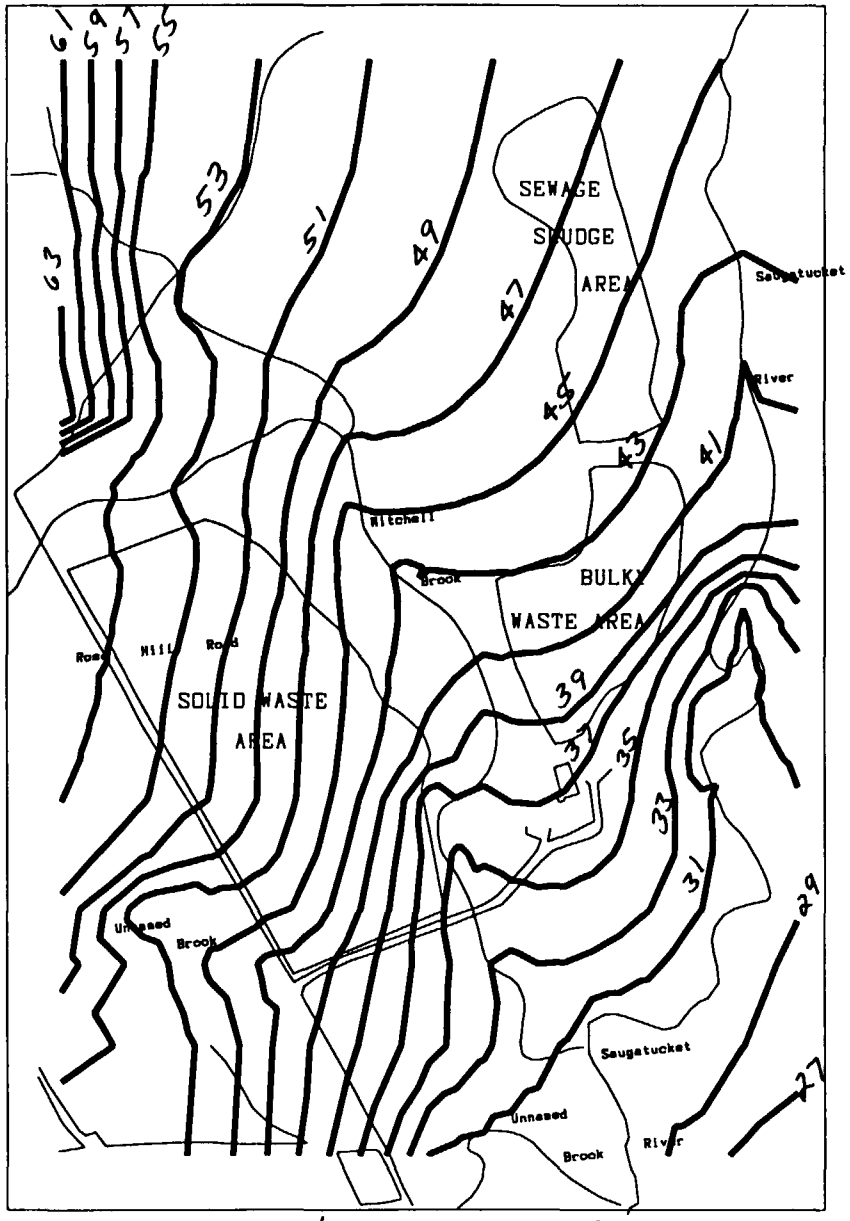


ROSE HILL FS STUDY

700 0 700

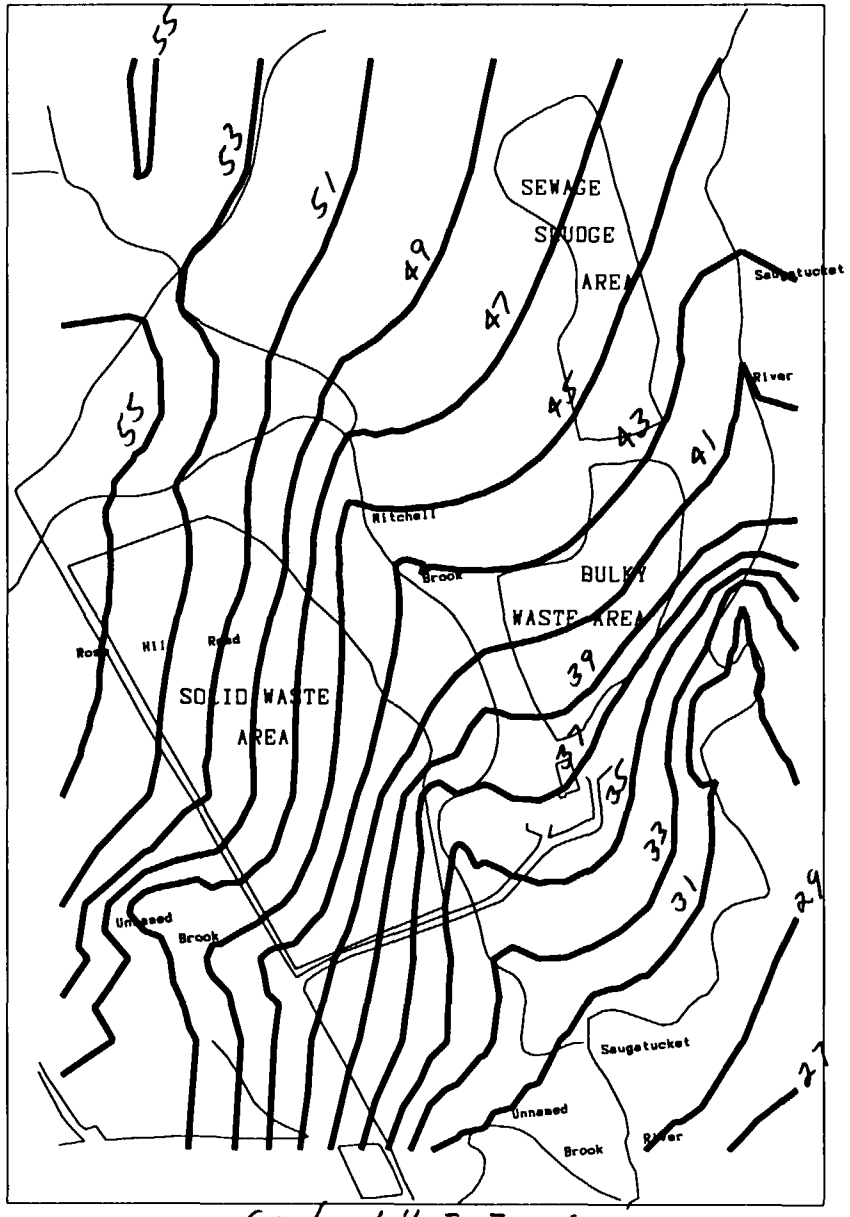
SCALE IN FEET

FIGURE 6. BEDROCK INITIAL GROUNDWATER ELEVATION CONTOURS USED IN THE MODEL



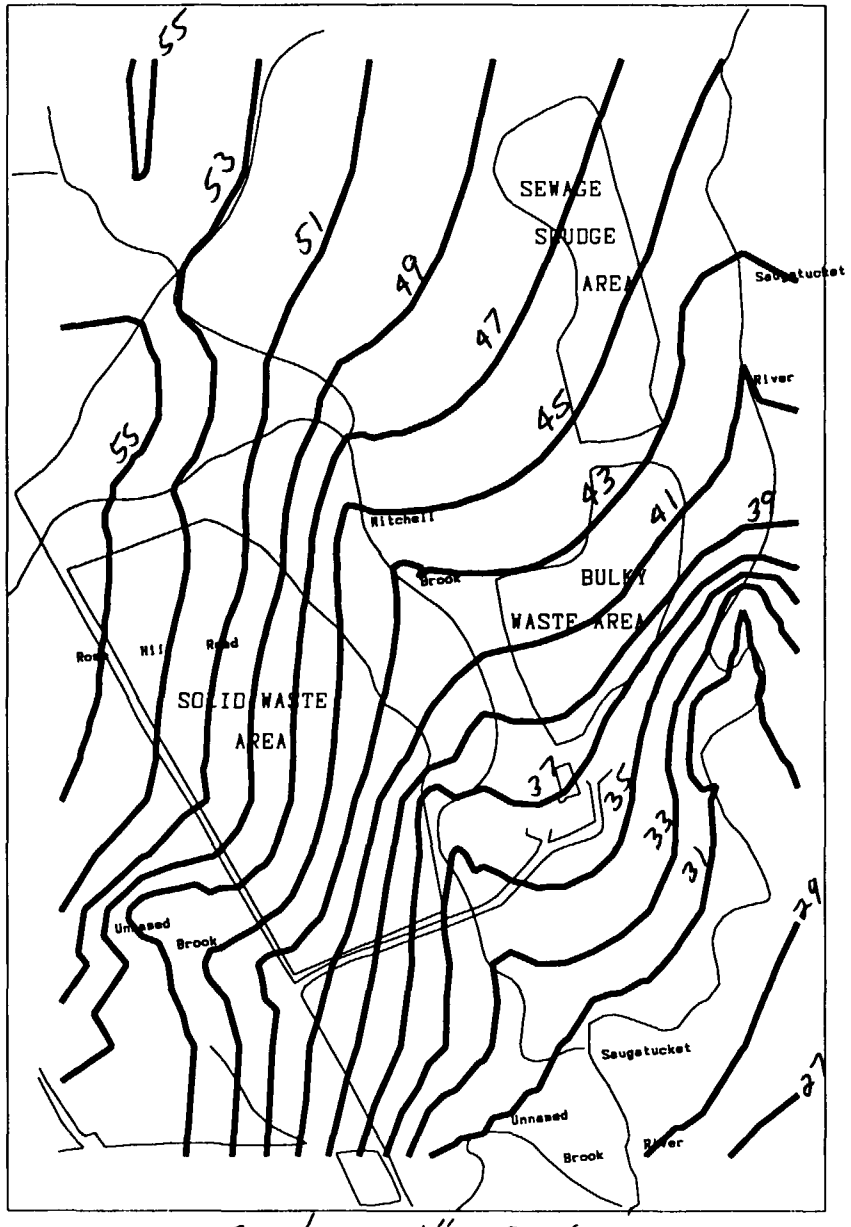
Scale: 1"=700'

Figure 7. Shal. OB - Existing Conditions



Scale 1" = 700'

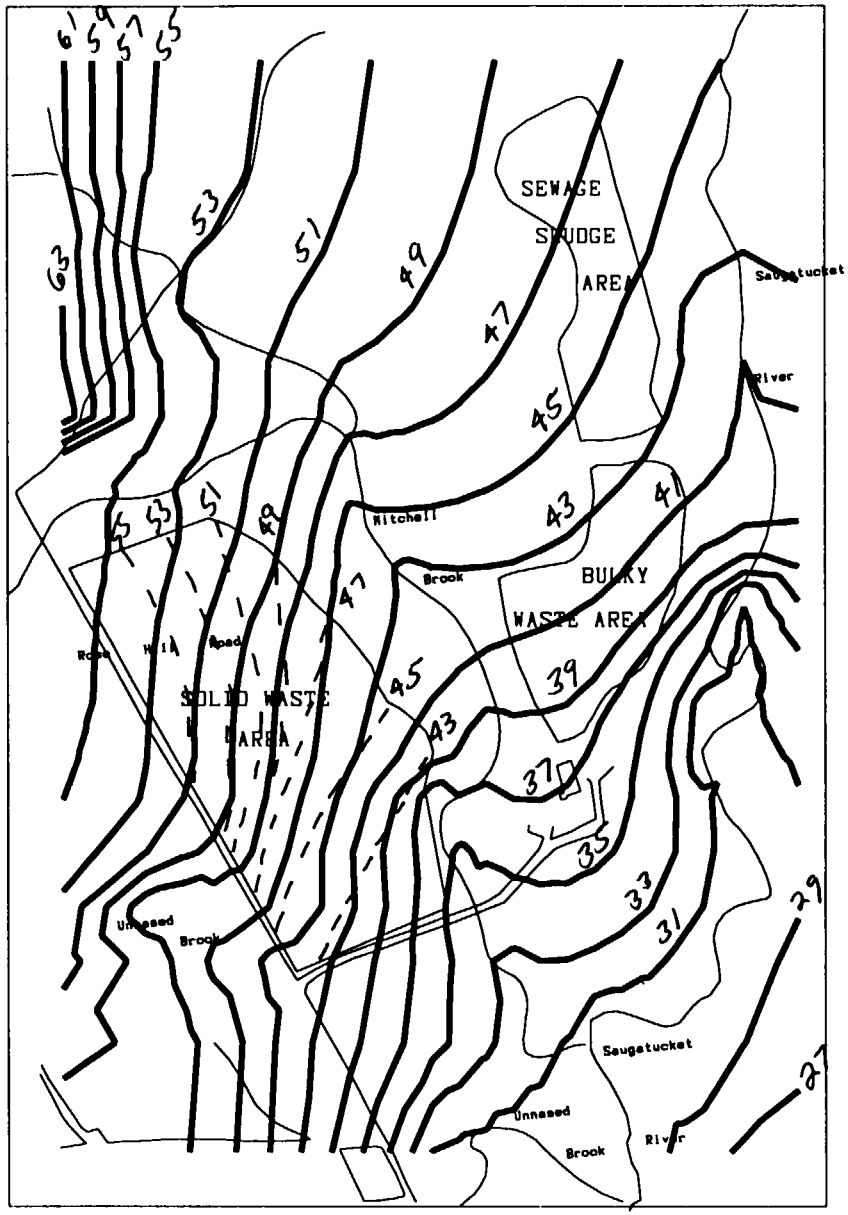
Figure 8. Deep. OB - Existing Conditions



Scale: 1" = 700'

Figure 9. Bedrock - Existing Conditions

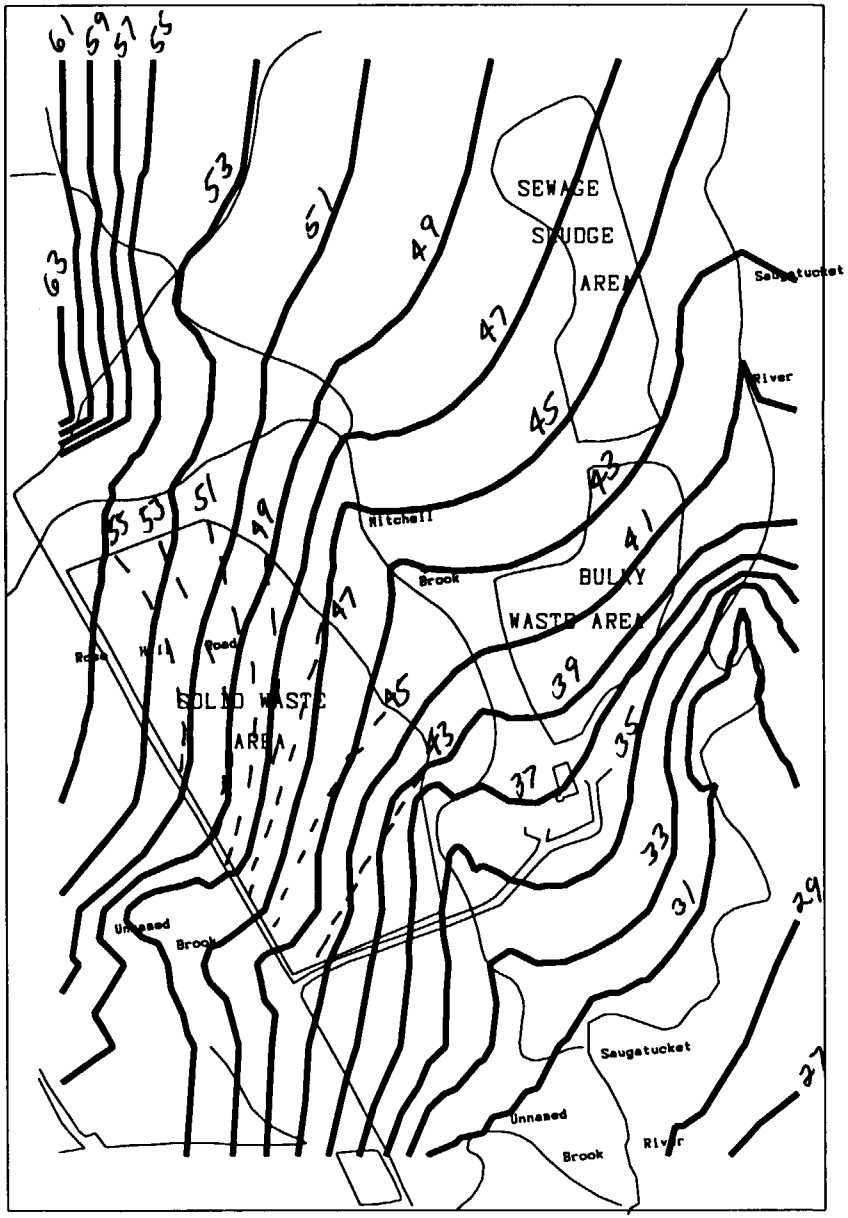
--- Bottom of Refuse Contours



Scale: 1" = 700'

Figure 10.

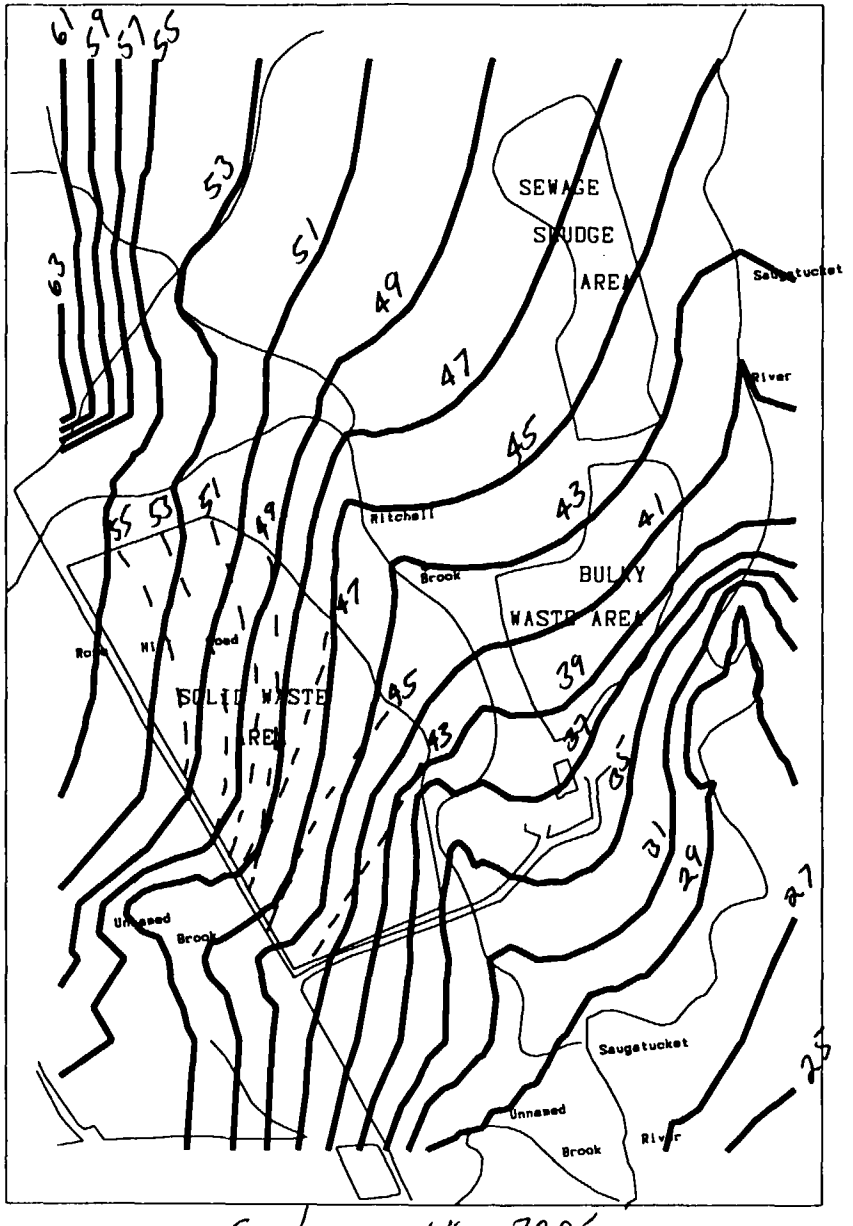
--- Bottom of Refuse Contours



Scale: 1" = 700'

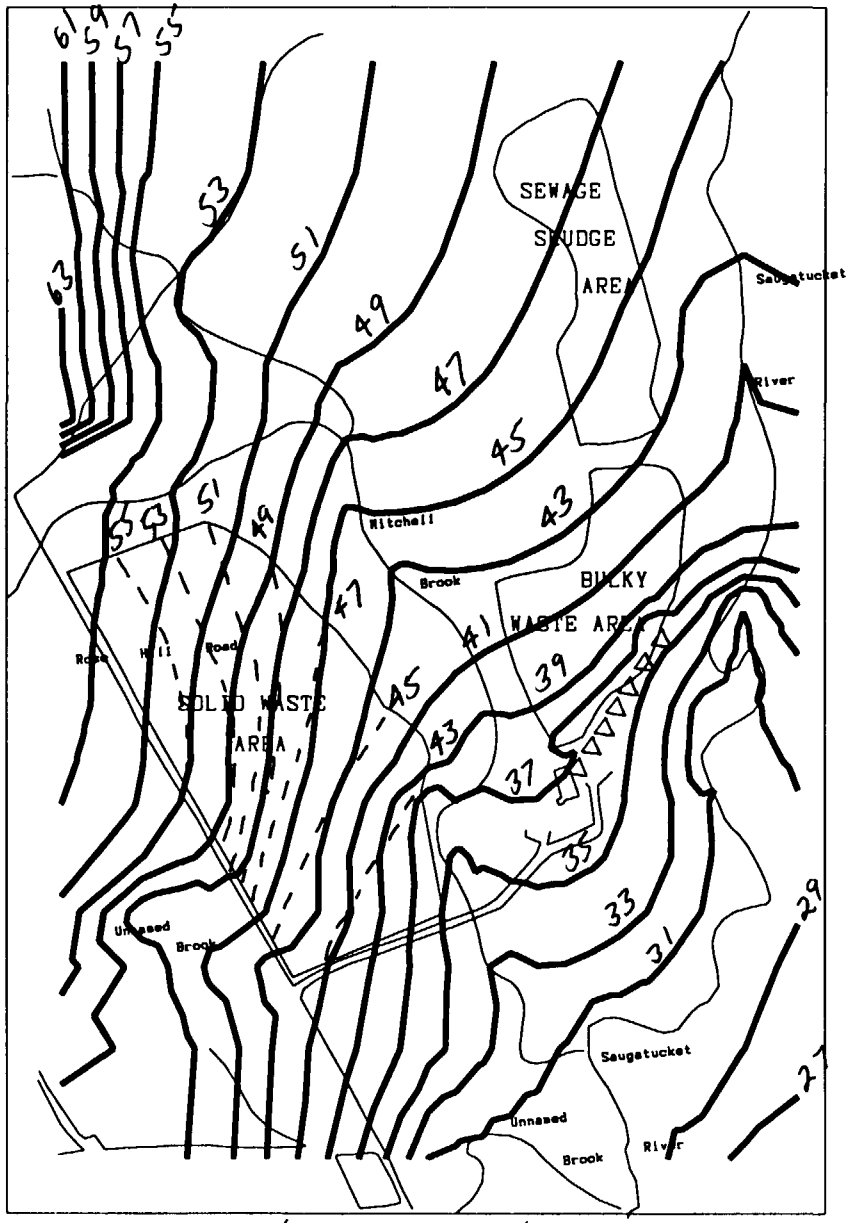
Figure 11.

--- Bottom of Refuse Contours



Scale: 1" = 700'

Figure 12.



--- Bottom of Refuse Contours

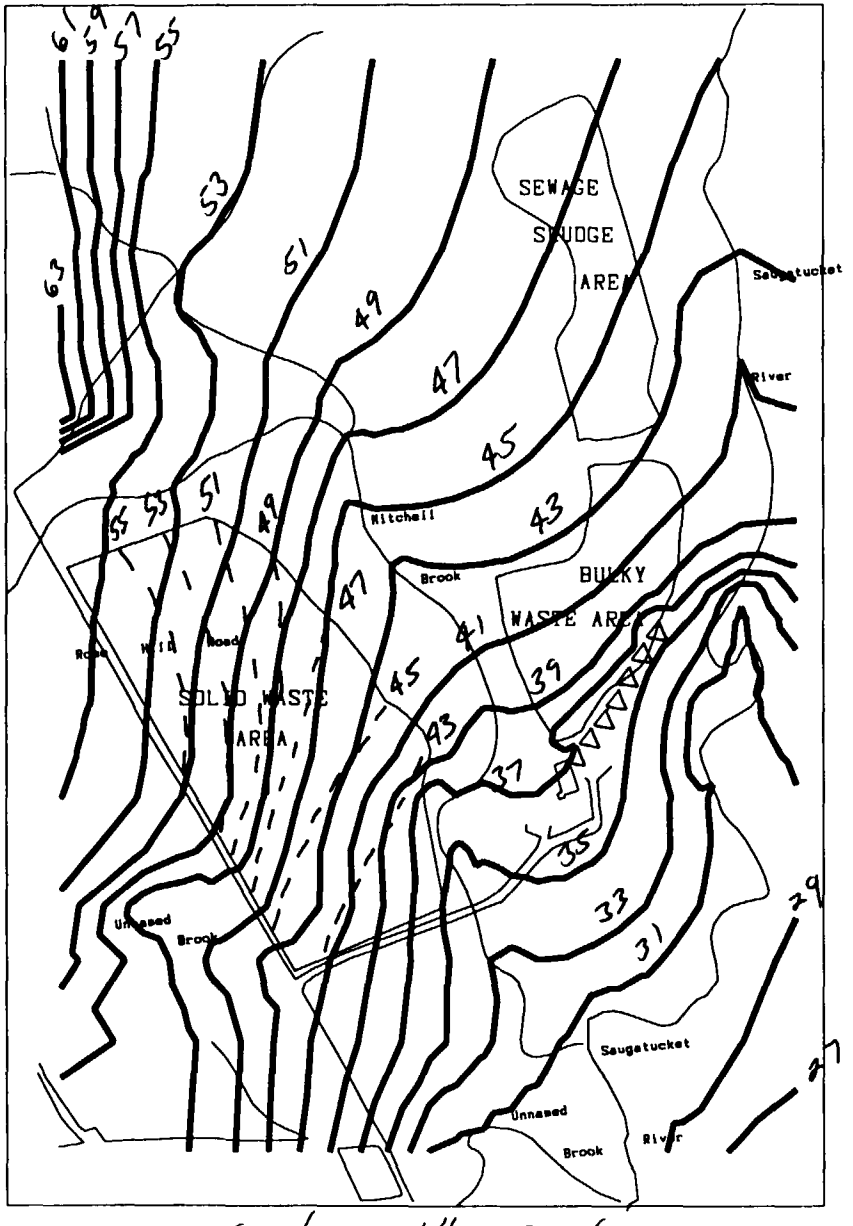
▽ Bulky Waste Drains

Scale: 1" = 700'

Figure 13.

--- Bottom of Refuse Contours

▽ Bulky Waste Drains

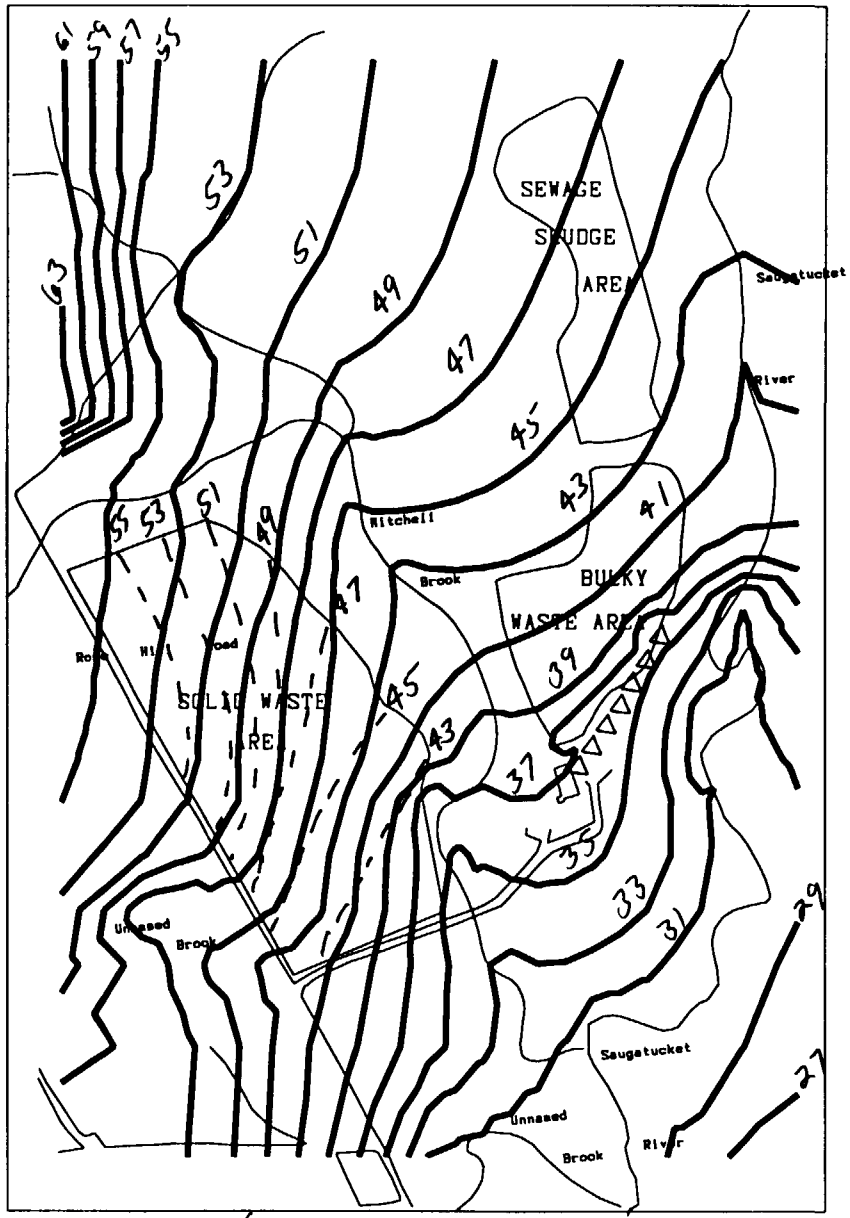


Scale: 1" = 700'

Figure 14.

--- Bottom of Refuse Contours

▽ Bulky Waste Drains



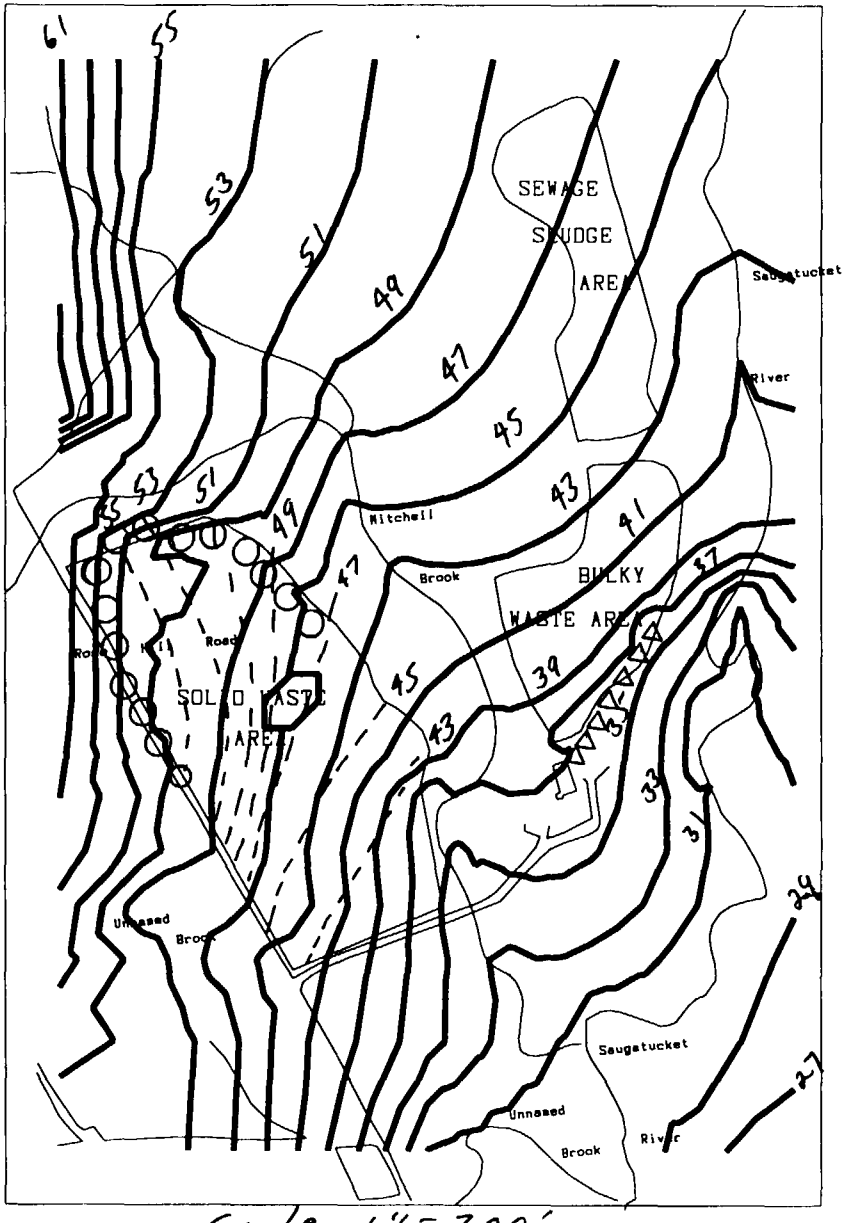
Scale: 1" = 700'

Figure 15.

--- Bottom of Refuse Contours

○ Solid Waste Drains

▽ Bulky Waste Drains



Scale 1"=700'

Figure 16.

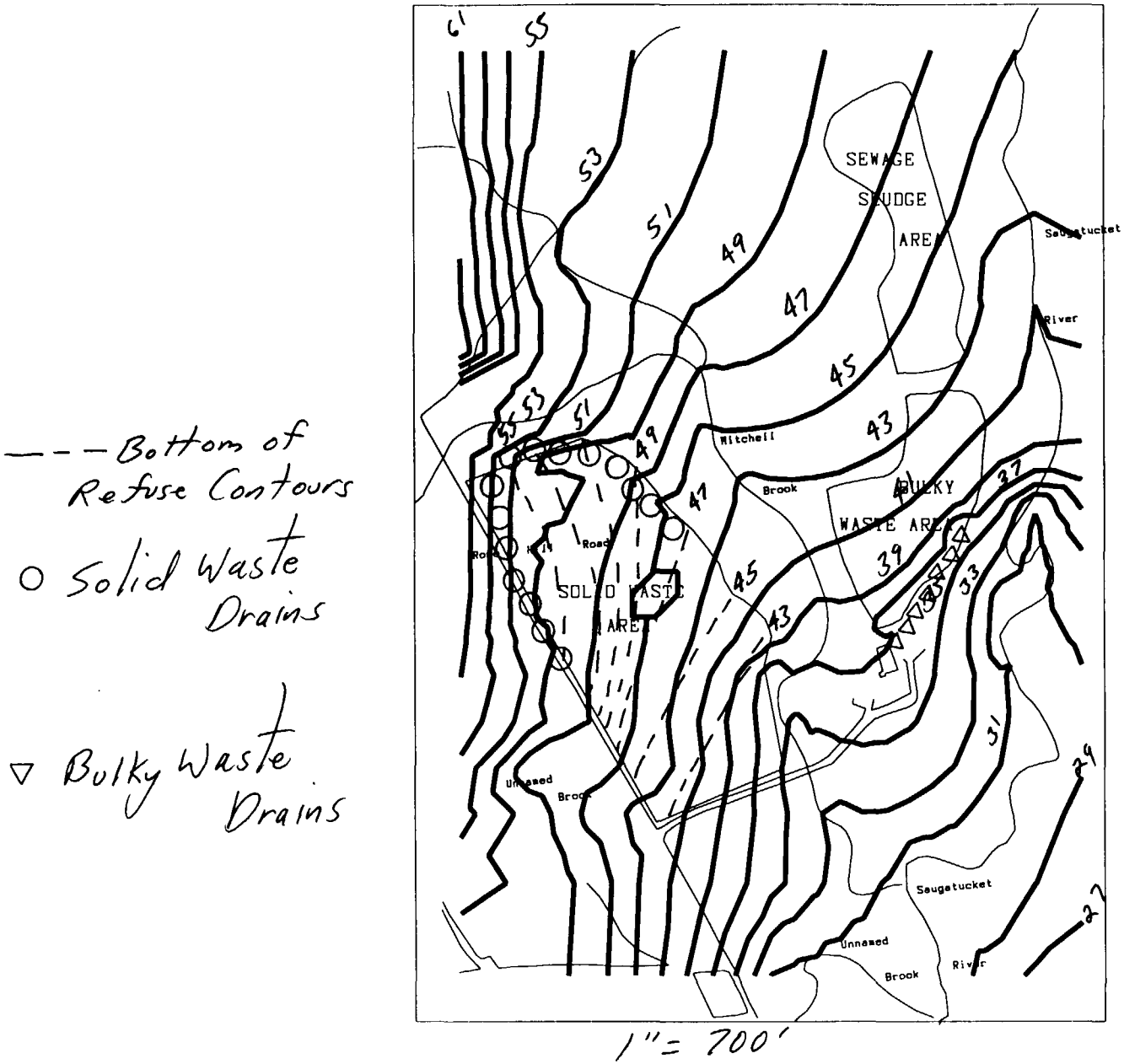
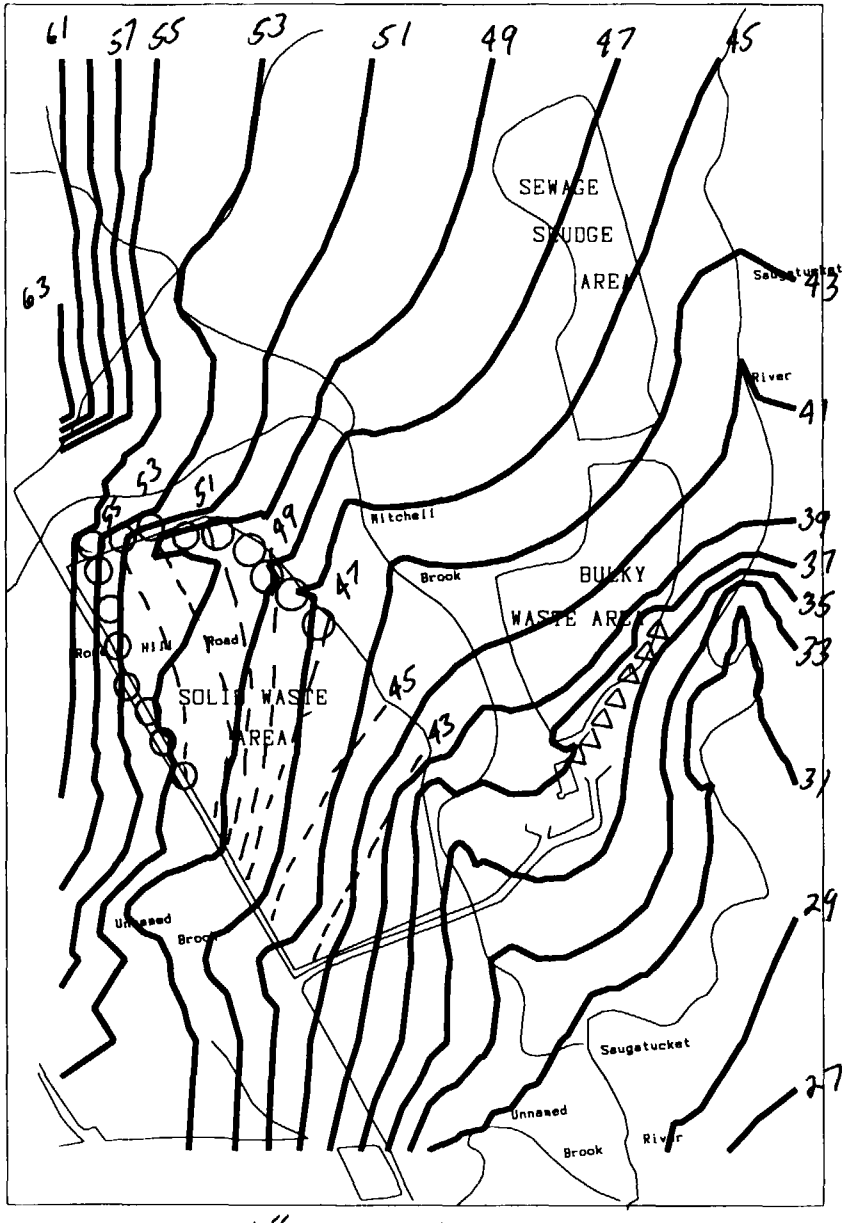

--- Bottom of Refuse Contours
○ Solid Waste Drains
▽ Bulky Waste Drains
SEWAGE SLUDGE AREA
BULKY WASTE AREA
SOLID WASTE AREA
Mitchell Brook
Road
Unnamed Brook
Saugatucket River
1" = 700'

Figure 17.



——— Bottom of Refuse Contours

○ Solid Waste Drains

△ Bulky Waste Drains

1" = 700'

Figure 18.

Table 1. Comparison of Measured Vs. Modeled Heads, Existing Conditions

Monitoring Well No.	Location	Layer	Row	Column	Measured Head (5/92)	Modeled Head (1)	Error
MW-01-1	Upgradient	1	3	3	50.44	53.09	-2.65
MW-01-2	Upgradient	3	3	3	50.41	53.10	-2.69
MW-02-1	In SSA	1	3	18	46.81	46.18	0.63
MW-02-2	In SSA	2	3	18	46.97	46.18	0.79
MW-03-1	150' SE of BWA	1	16	20	36.75	35.16	1.59
MW-03-2	150' SE of BWA	2	16	20	37.54	35.16	2.38
MW-03-3	150' SE of BWA	3	16	20	41.03	35.16	5.87
MW-04-1	250' E of SWA	1	14	12	42.94	42.01	0.93
MW-04-2	250' E of SWA	2	14	12	42.84	42.01	0.83
MW-04-3	250' E of SWA	3	14	12	39.38	42.01	-2.63
MW-05-1	Downgradient	1	21	22	33.76	31.00	2.76
MW-05-2	Downgradient	2	21	22	34.04	31.00	3.04
MW-06-1	250' SE of SWA	1	19	14	38.81	36.62	2.19
MW-06-2	250' SE of SWA	2	19	14	39.38	36.65	2.73
MW-07-1	In SWA	2	17	2	53.82	53.55	0.27
MW-07-2	In SWA	3	17	2	53.22	53.55	-0.33
MW-08-1	200' W of SWA	2	22	5	41.25	44.02	-2.77
MW-08-2	200' W of SWA	3	22	5	41.75	44.02	-2.27
MW-11-1	250' SE of SWA	1	21	14	36.07	33.64	2.43
MW-11-2	250' SE of SWA	2	21	14	36.60	33.68	2.92
MW-11-3	250' SE of SWA	2	21	14	36.72	33.68	3.04
MW-12-1	100' E of BWA	1	11	21	39.01	39.89	-0.88
MW-12-2	100' E of BWA	2	11	21	41.14	39.80	1.34
MW-13-1	200' N of SWA	1	7	3	53.89	53.39	0.50
MW-14-1	In SWA	2	22	9	39.96	40.38	-0.42

1. Model output generated using existing conditions
SWA = Solid Waste Area
BWA = Bulky Waste Area
SSA = Sewage Sludge Area

Table 2. MODFLOW Water Balance using Existing Conditions

```
ALTERNATIVE 1

                                VOLUMETRIC BUDGET FOR ENTIRE MODEL AT END OF TIME
                                --------------------------------------------------
0                     CUMULATIVE VOLUMES      L**3
                      ------------------

                            IN:
                            ---
                              STORAGE =   0.00000
                       CONSTANT HEAD =    57739.
                            RECHARGE =    42478.
                       RIVER LEAKAGE =    32153.
0                           TOTAL IN =   0.13237E+06
0                          OUT:
                           ----
                              STORAGE =   0.00000
                       CONSTANT HEAD =    61148.
                            RECHARGE =   0.00000
                       RIVER LEAKAGE =    72464.
0                          TOTAL OUT =   0.13361E+06
0                           IN - OUT =   -1241.1
0                 PERCENT DISCREPANCY =               -0.93


0

          TIME SUMMARY AT END OF TIME STEP  1 IN STRESS PERIOD  1
                                 SECONDS        MINUTES         HOURS          DAY
                              ---------------------------------------------------
      TIME STEP LENGTH          86400.0        1440.00        24.0000        1.00
    STRESS PERIOD TIME          86400.0        1440.00        24.0000        1.00
 TOTAL SIMULATION TIME          86400.0        1440.00        24.0000        1.00
1
```

Table 3. Comparison of Modeled Heads (FS Alternative 3, Capping Options) with Existing Conditions

Monitoring Well No.	Location	Layer	Row	Column	Modeled Head (1)	Modeled Head (2)	Difference from existing	Modeled Head (3)	Difference from existing	Modeled Head (4)	Difference from existing
MW-01-1	Upgradient	1	3	3	53.09	53.09	0.00	53.09	0.00	53.09	0.00
MW-01-2	Upgradient	3	3	3	53.10	53.10	0.00	53.10	0.00	53.10	0.00
MW-02-1	In SSA	1	3	18	46.18	46.17	0.01	46.18	0.00	46.18	0.00
MW-02-2	In SSA	2	3	18	46.18	46.17	0.01	46.17	0.01	46.17	0.01
MW-03-1	150' SE of BWA	1	16	20	35.16	35.03	0.13	35.07	0.09	35.07	0.09
MW-03-2	150' SE of BWA	2	16	20	35.16	35.03	0.13	35.07	0.09	35.07	0.09
MW-03-3	150' SE of BWA	3	16	20	35.16	35.03	0.13	35.07	0.09	35.07	0.09
MW-04-1	250' E of SWA	1	14	12	42.01	41.87	0.14	41.87	0.14	41.92	0.09
MW-04-2	250' E of SWA	2	14	12	42.01	41.87	0.14	41.87	0.14	41.92	0.09
MW-04-3	250' E of SWA	3	14	12	42.01	41.87	0.14	41.87	0.14	41.92	0.09
MW-05-1	Downgradient	1	21	22	31.00	31.00	0.00	31.00	0.00	31.00	0.00
MW-05-2	Downgradient	2	21	22	31.00	30.99	0.01	30.99	0.01	30.99	0.01
MW-06-1	250' SE of SWA	1	19	14	36.62	36.62	0.00	36.62	0.00	36.62	0.00
MW-06-2	250' SE of SWA	2	19	14	36.65	36.64	0.01	36.64	0.01	36.64	0.01
MW-07-1	In SWA	2	17	2	53.55	53.12	0.43	53.12	0.43	53.29	0.26
MW-07-2	In SWA	3	17	2	53.55	53.12	0.43	53.12	0.43	53.29	0.26
MW-08-1	200' W of SWA	2	22	5	44.02	44.01	0.01	44.01	0.01	44.01	0.01
MW-08-2	200' W of SWA	3	22	5	44.02	44.01	0.01	44.01	0.01	44.01	0.01
MW-11-1	250' SE of SWA	1	21	14	33.64	33.64	0.00	33.64	0.00	33.64	0.00
MW-11-2	250' SE of SWA	2	21	14	33.68	33.67	0.01	33.67	0.01	33.67	0.01
MW-11-3	250' SE of SWA	2	21	14	33.68	33.67	0.01	33.67	0.01	33.67	0.01
MW-12-1	100' E of BWA	1	11	21	39.89	39.44	0.45	39.58	0.31	39.58	0.31
MW-12-2	100' E of BWA	2	11	21	39.80	39.54	0.26	39.62	0.18	39.62	0.18

Table 3. Comparison of Modeled Heads (FS Alternative 3, Capping Options) with Existing Conditions, Continued

Monitoring Well No.	Location	Layer	Row	Column	Modeled Head (1)	Modeled Head (2)	Difference from existing	Modeled Head (3)	Difference from existing	Modeled Head (4)	Difference from existing
MW-13-1	200' N of SWA	1	7	3	53.39	53.38	0.01	53.38	0.01	53.38	0.01
MW-14-1	In SWA	2	22	9	40.38	40.20	0.18	40.20	0.18	40.27	0.11

1. Model output from runs using existing conditions.
2. Model output from runs simulating composite caps in the SWA and BWA.
3. Model output from runs simulating a composite cap in the SWA and a single barrier cap in the BWA.
4. Model output from runs simulating single barrier caps in the SWA and BWA.

SWA = Solid Waste Area
BWA = Bulky Waste Area
SSA = Sewage Sludge Area

Table 4. Estimated Rates of Groundwater Flow to Drains Using MODFLOW

Capping Option	Bulky Waste Seepage Control	Bulky Waste Seepage Control & Solid Waste Dewatering
SWA – composite cap BWA – composite cap	4.25 gpm	41.4 gpm
SWA – composite cap BWA – single barrier cap	4.58 gpm	41.7 gpm
SWA – single barrier cap BWA – single barrier cap	4.58 gpm	43.7 gpm

SWA = Solid Waste Area
BWA = Bulky Waste Area

#9138

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4.6
#9138

Appendix D

Rose Hill
4.6
7138

D. GROUNDWATER TREATMENT

D-1 Precipitation Holding/Equalization Tank Sizing
D-2 Evaluation of Scaling Factor
D-3 Groundwater Treatment Systems - Summary Tables for Groundwater Conditions
D-4 Capital and Operating Cost Quotes
- Metals Treatment Quotation: Lancy/US Filter
- Metals Treatment Quotation: Koch Membrane Systems
- Metals Treatment Quotation: Osmonics
- UV/Chemical Oxidation Quotation: Solarchem
- UV/Chemical Oxidation Quotation: Peroxidation Systems
- UV/Chemical Oxidation Quotation: Ultrox

D-5 Sludge Volume Evaluation
D-6 Development of Disposal Costs
D-7 Development of Chemical Requirements for Precipitation

D-1 Precipitation Holding/Equalization Tank Sizing

Leachate/groundwater treatment systems were originally sized based on 50 and 200 gpm flow rates in the Draft FS. Sizing for the current Alternative #4 treatment system (5 gpm) will be revised as follows.

Assumed scaling factor for 5 gpm system from the 50 gpm system - 0.4

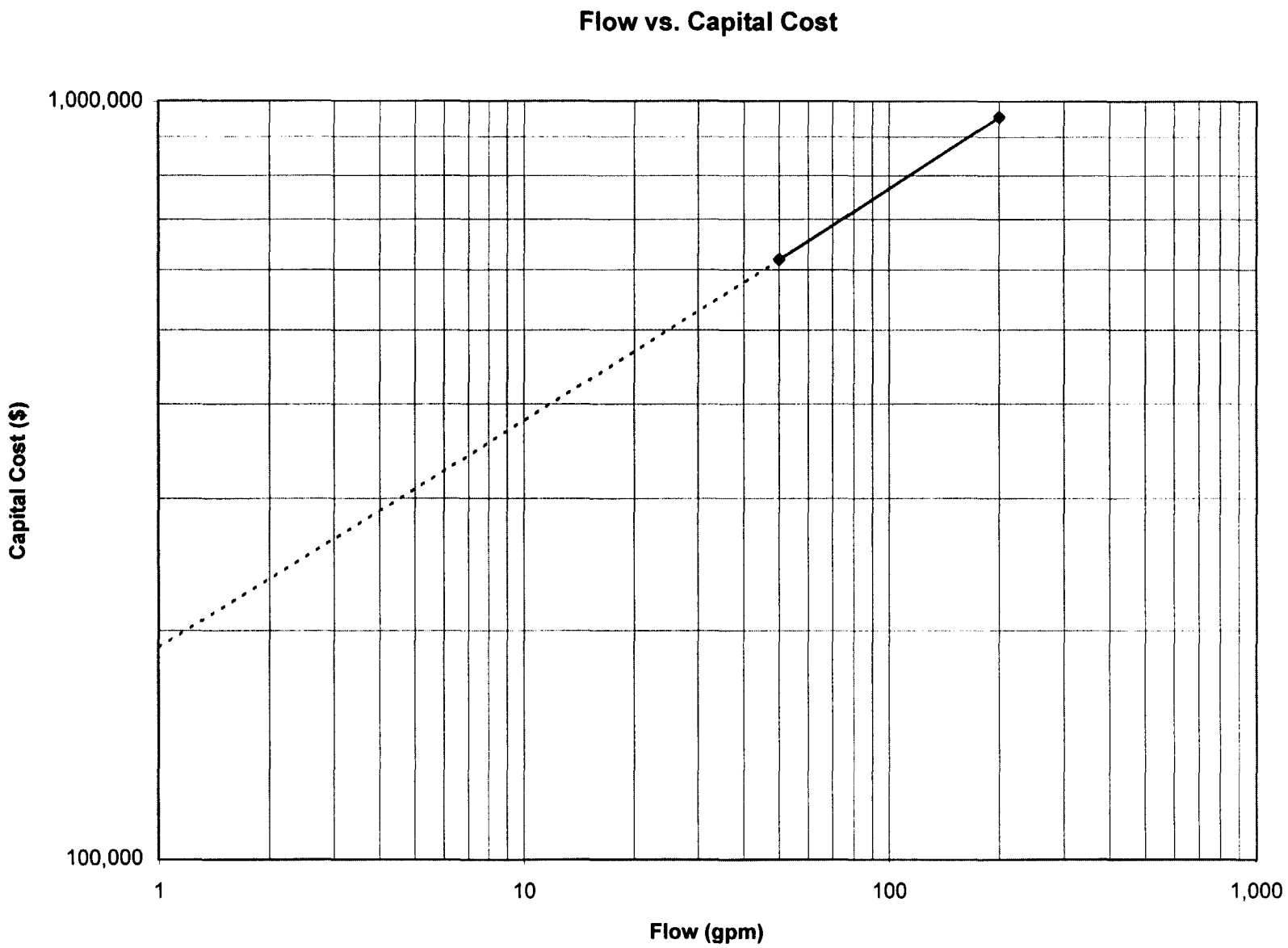
As knowledge of system retention time is usually desired, the initial holding tank size will be calculated.

	50 gpm		5 gpm
Precipitation Holding/Equalization Tank	12,000 gal		4,800 gal
		Selected tank size:	5,000 gal
		This results in a holding time of	17 hrs

All other pieces of equipment will be scaled from respective vendor quotations.

Metcalf & Eddy, Inc.

D-2 Evaluation of Scaling Factor


Flow vs. Capital Cost
1,000,000
100,000
Capital Cost ($)
1
10
100
1,000
Flow (gpm)

D-3 Groundwater Treatment Systems - Summary Tables for Groundwater Conditions

TABLE D-1: GROUNDWATER CONDITIONS FOR THE 5 GPM SYSTEM

ANALYTE (a)	GROUNDWATER CONCENTRATIONS (b) Average	Maximum	PRELIMINARY REMEDIATION GOAL	
	all in (µg/L) except where noted at left			
Ammonia (mg/L)	13	22		
Sulfide (mg/L)	0	0		
Aluminum	2,100	9,220	*	
Antimony	0	0	*	6
Arsenic	0	0	*	
Barium	510	2,120	*	
Beryllium	2	9	*	4
Cadmium	2	5	*	5
Chromium	0	0	*	100
Cobalt	63	295	*	
Copper	0	0	*	
Iron	286,675	1,370,000	*	
Lead	37	174	*	15
Manganese	8,200	14,700	*	840
Mercury	0.11	0.20	*	
Nickel	5	14	*	100
Vanadium	15	65	*	
Zinc	210	133	*	
Dieldrin	0.000	0.000		
2-Methylnaphthalene	0	0		
4-Chloro-3-methylphenol	0	0		
4-Methylphenol	0	0		
Pentachlorophenol	0	0		1
bis(2-Ethylhexyl)phthalate	50	230		6
1,1-Dichloroethane	3	2		
1,1-Dichloroethene	0	0		
1,2-Dichloroethene(total)	3	1		70
4-Methyl-2-pentanone	0	0		
Acetone	0	0		
Benzene	0	0		5
Carbon Disulfide	3	3		
Chloroethane	6	8		
Ethylbenzene	2	2		
Toluene	19	50		
Trichloroethene	0	0		
Vinyl Chloride	0	0		2
Acrylamide	0	0		0.02 (c)
N,N-DMF	0	0		
Hardness (mg/L)	79	214		
pH	6.5	7.1		
Total Organic Carbon (mg/L)	26	50		
Biochemical Oxygen Demand (mg/L)	9	51		

Notes:

(a). Asterisk denotes compounds that will be handled by the metals treatment system.

(b). Concentrations for metals are "total" and not dissolved values.

(c). Goal is significantly below normal analytical detection limits; evaluate potential to meet 2 µg/L standard assuming that this is the detection limit.

TABLE D-2: GROUNDWATER CONDITIONS FOR THE 50 GPM SYSTEM

ANALYTE (a)	GROUNDWATER CONCENTRATIONS (b) Average	Maximum		PRELIMINARY REMEDIATION GOAL
	all in (μg/L) except where noted at left			
Ammonia (mg/L)	9	48		
Sulfide (mg/L)	1	4		
Aluminum	12,616	98,281	*	
Antimony	0	0	*	6
Arsenic	2	9	*	
Barium	210	695	*	
Beryllium	2	13	*	4
Cadmium	4	36	*	5
Chromium	21	136	*	100
Cobalt	21	82	*	
Copper	37	324	*	
Iron	91,571	396,140	*	
Lead	40	180	*	15
Manganese	2,633	10,361	*	840
Mercury	0.11	0.29	*	
Nickel	24	112	*	100
Vanadium	20	133	*	
Zinc	625	6,520	*	
Dieldrin	0.043	0.003		
2-Methylnaphthalene	4	4		
4-Chloro-3-methylphenol	4	4		
4-Methylphenol	8	64		
Pentachlorophenol	12	3		1
bis(2-Ethylhexyl)phthalate	11	59		6
1,1-Dichloroethane	13	195		
1,1-Dichloroethene	4	2		
1,2-Dichloroethene(total)	30	645		70
4-Methyl-2-pentanone	5	27		
Acetone	20	415		
Benzene	10	27		5
Carbon Disulfide	13	77		
Chloroethane	16	77		
Ethylbenzene	14	64		
Toluene	31	156		
Trichloroethene	4	4		
Vinyl Chloride	30	610		2
Acrylamide	141	202		0.02 (c)
N,N-DMF	177	1,273		
Hardness (mg/L)	151	621		
pH	7.1	11.9		
Total Organic Carbon (mg/L)	44	200		
Biochemical Oxygen Demand (mg/L)	12	112		

Notes:

(a). Asterisk denotes compounds that will be handled by the metals treatment system.

(b). Concentrations for metals are "total" and not dissolved values.

(c). Goal is significantly below normal analytical detection limits; evaluate potential to meet 2 μg/L standard assuming that this is the detection limit.

TABLE D-3
SUMMARY OF CAPITAL AND OPERATING COSTS BASED ON QUOTES PROVIDED BY VENDORS

Treatment/Vendor	Flow Rate (gpm)	Capital Cost	Operating Cost ($ / 1K gal)[A]
Inorganic Precipitation/	50	$500,000	–
US Filter	200	$800,000	–
Inorganic Removal via	5	$254,000	–
UF and RO/	50	$643,000	–
Koch Membrane	200	$1,681,000	–
Inorganic Removal via RO/	50	$175,000	–
Osmonics	200	$470,000	–
Organics Removal via	50	$80,000	$0.90
UV-Oxidation/	200	$175,000	$0.90
Solarchem			
Organics Removal via	50	$250,000	$101,200 [B]
UV-Oxidation/	200	$675,000	$366,000 [B]
Peroxidation Systems			
Organics Removal via	50	$218,000	$0.75
UV-Oxidation/	200	$333,000	$0.34
Ultrox			

Notes:

A – Operating cost data not included in US Filter, Koch, or Osmonics quotes.

B – Value given is annual operating cost ($ / yr).

D-4 Capital and Operating Cost Quotes

- Metals Treatment Quotation: Lancy/US Filter
- Metals Treatment Quotation: Koch Membrane Systems
- Metals Treatment Quotation: Osmonics
- UV/Chemical Oxidation Quotation: Solarchem
- UV/Chemical Oxidation Quotation: Peroxidation Systems
- UV/Chemical Oxidation Quotation: Ultrox

- Metals Treatment Quotation: Lancy/US Filter
  Design Basis: 50 gpm System
  Process Description
  Equipment List: 50 gpm System
  Design Basis: 200 gpm System
  Equipment List: 200 gpm System
  Operating Requirements
  Budgetary Prices and Delivery Schedule
  Terms and Conditions
  System Drawings
  Sludge Calculations
  Price Breakout by Equipment
  M&E Quotation Request

U.S. FILTER
UNITED STATES FILTER CORPORATION

June 3, 1993

METCALF & EDDY, INC.
JUN 4
RECEIVED

LANCY
181 THORN HILL ROAD
WARRENDALE, PA 15086-7527
TEL 412-772-0044
FAX 412-772-1360

Metcalf and Eddy
30 Harvard Mill Square
Wakefield, Massachusetts 01880
(617) 246-5200

Attention: Mr. Sean Czarniecki

Reference: Rose Hill, Rhode Island Groundwater/Leachate Project

Subject: Budgetary Proposal to Provide Groundwater Treatment Equipment

Dear Mr. Czarniecki:

United States Filter Corporation is pleased to supply this budgetary proposal regarding the above-referenced project.

We are providing unit process descriptions for a groundwater treatment system to address metals treatment. We have also included an overall conceptual flow diagram which depicts our treatment concept. We feel very confident that the treatment levels required for metals can be achieved with the proposed unit operations. Ultraviolet/oxidation equipment shall also be incorporated into the system and shall be supplied by others. The following design information is being provided for two system alternatives.

With the equalization tank with level controls provided in this system, we feel confident that the system can perform effectively with incoming flow rates as low as 5 gpm.

ALTERNATE NO. 1 - 50 GPM SYSTEM

- ***Design Basis***

Parameter	*Average Influent*	*Effluent Requirements*
Ammonia, mg/l	9	
Sulfide, mg/l	1	
Aluminum, µg/l	12,616	
Antimony, µg/l	0	
Arsenic, µg/l	2	
Barium, µg/l	210	
Beryllium, µg/l	2	1
Cadmium, µg/l	4	5
Chromium, µg/l	21	100

ALTERNATE NO. 1 - 50 GPM SYSTEM

Design Basis (Continued)

Parameter	*Average Influent*	*Effluent Requirements*
Cobalt, µg/l	21	
Copper, µg/l	37	
Iron, µg/l	91,571	
Lead, µg/l	40	15
Manganese, µg/l	2,633	3,650
Mercury, µg/l	0.11	
Nickel, µg/l	24	100
Vanadium, µg/l	20	
Zinc, µg/l	625	
Dieldrin, µg/l	0.043	
2-Methylnaphthalene, µg/l	4	
4-Chloro-3-methylphenol, µg/l	4	
4-Methylphenol, µg/l	8	
Pentachlorophenol, µg/l	12	
bis(2-Ethylhexyl)phthalate, µg/l	11	
1,1-Dichloroethane, µg/l	13	
1,1-Dichloroethene, µg/l	4	
1,2-Dichloroethene (total), µg/l	30	
4-Methyl-2-pentanone, µg/l	5	
Acetone, µg/l	20	
Benzene, µg/l	10	
Carbon Disulfide, µg/l	13	
Chloroethane, µg/l	16	
Ethylbenzene, µg/l	14	
Toluene, µg/l	31	
Trichloroethene, µg/l	4	
Vinyl Chloride, µg/l	30	
Acrylamide, µg/l	141	
N,N-DMP, µg/l	177	
Hardness, mg/l	151	
pH, standard units	7.1	
Total Organic Carbon, mg/l	44	
BOD, mg/l	12	

- ***Process Description***

Equalization

The 50 gpm groundwater shall be transferred (by others) to a 12,000-gallon holding/equalization tank. The holding tank shall have a cover and shall be exhausted to a vapor phase carbon adsorber. This tank shall provide approximately 4 hours retention time. This tank shall serve as a reservoir to provide a continuous feed to the groundwater treatment system. Additionally, this tank shall help to minimize variations of influent groundwater characteristics. Design flow of the system shall be 50 gpm. Should the influent flow rate be less (down to 5 gpm expected), the equalization tank and transfer pumping shall serve to cycle flow through the system on a high level tank demand. The unit operations employed in this system can be idle or automatic recirculation when no flow conditions exist.

Metals Precipitation

The proposed groundwater treatment system maximizes the use of gravity to transfer the wastewater from one reactor to the next. Due to the logistics of the system, lift stations will be necessary to transfer the groundwater to the system. Pumping is also utilized to facilitate the transfer of sludge within the sludge handling system.

The groundwater flows into each reactor where the agitator used produces a mixing pattern that ensures rapid blending of the treatment chemicals and wastewater. The wastewater exits each reactor through a specially designed outlet box which directs the flow from the tank bottom up to the outlet and prevents short-circuiting of untreated wastewater through the reactor.

The proposed system utilizes solid-state instrumentation which is capable of reliably automating the addition of treatment chemicals. The models used have a meter display, proportional chemical feed capabilities, and are housed in a NEMA-12 enclosure.

Metals Precipitation (Continued)

The groundwater shall be transferred from the equalization tank to the first reaction compartment of the Lancy™ Econo-Treat. This compartment shall be lined with 3/16-inch PVC to protect the steel from the acidic groundwater. Transfers shall be accomplished by duplex centrifugal pumps operated by level controls mounted in the equalization tank. (Pumps and level controls supplied by U.S. Filter.) After entering the treatment system, the groundwater will be pH adjusted to acidic conditions (~4) in the first-stage reactor. Sulfuric acid will be used to maintain the pH at approximately 3 to 4 and a coagulant of ferrous sulfate shall be added. Chemical additions will be controlled by solid-state instrumentation to optimize chemical additions/consumption.

The sulfuric acid feed system shall be a metering pump which feeds acid directly from the day tank. The coagulant feed system shall consist of a FRP tank, mixing agitator and metering pump.

The groundwater in the first reaction compartment shall flow by gravity to the second reaction compartment where it will be neutralized to a pH of 9.5 to 10 with caustic in the second-stage reaction compartment. Caustic additions will be controlled by solid-state instrumentation.

The neutralized groundwaters shall continue to flow by gravity into the flocculation compartment and then into the solids separator compartment. A liquid polymer will be added in the floc compartment to aid the settling of the precipitated solids in the solids separator. Both the caustic and polymer feed systems shall be a metering pump which feeds chemicals directly from dedicated day tanks.

After the solid/liquid phases have been separated in the solids separator compartment, the clarified supernatant shall flow by gravity to a lift station for transfer to the sand filter.

Note: The metals precipitation unit shall be covered and exhausted to the vapor phase carbon adsorber.

The accumulated sludge in the solids separator will be periodically transferred to a sludge thickener for further dewatering.

The thickened sludge will undergo a final dewatering in a plate and frame type of filter press where the solids content is expected to reach approximately 25 to 30 percent by weight. The pressed sludge will then be discharged for proper disposal.

Sand Filtration

The liquid phase of the groundwater shall then be directed to a continuous backwash, upflow sand filter for further removal of suspended matter. It is anticipated that particles greater than 11 μm shall be removed to <10 mg/l.

UV / Oxidation / Carbon Adsorption

We believe reduction of the organic compounds would be addressed in this scope of work. If Metcalf and Eddy feels carbon adsorption polishing is required to meet the organic limits after UV oxidation, then we suggest placement of carbon adsorption units after UV/oxidation. pH adjustments for both UV/oxidation and carbon adsorption should also be addressed. These unit operations are not included in our quotation.

Sorption Filter System

To address the polishing of metals to discharge limits, U.S. Filter proposes placement of a Lancy™ Sorption Filter after organics treatment.

Groundwater to be processed by the sorption filter is first collected in the integral reaction module where the pH is elevated and a sulfide reagent is added. This addition ensures that a small amount of free soluble sulfide will be maintained.

The waste will then gravity flow to the sorption filter retention tank. This tank permits continuous operation of the system while obtaining the maximum use of media, as described below.

From the retention tank, the wastewater is pumped to the filter bodies where it is filtered through a proprietary reactive media which performs two functions. First, it filters out the fine, colloidal metal sulfide precipitates formed in the reaction module and secondly, it adsorbs any residual soluble metals and unreacted sulfides remaining in solution. These two features conspire to produce an extremely high effluent quality.

This unit maximizes media use in a unique way. As the soluble particulate metal sulfides are filtered out, the pressure drop increases across the filter. When this pressure differential reaches a predetermined level, the media is automatically bumped off the filter fingers and recoated thereby exposing new open filtration sites. This bump/recoat cycle is not started until the retention tank reaches a low level at which time automatic valves are activated which shut off the feed of waste to the filter. At this time, the solution in the filter system is recycled back through a separate precoat tank until the media is recoated on the filter fingers.

While the filter precoats, the incoming waste is accumulated in the retention tank. After the precoat cycle is completed, the automatic valves are actuated again to permit the processing of the accumulated wastewater.

After exiting the filter, the wastewater is directed to a final pH adjustment module prior to discharging due to the elevated operating pH of the sorption filtration process.

The treated groundwater shall then be routed, via a lift station, to an effluent hold tank. The effluent hold tank may be used as a chemical make-up water supply, and, if necessary, the effluent may be reprocessed back through the system should effluent quality not be met. (This event may occur during start-up and shut-down operations.)

Effluent Monitoring System

The treated groundwater shall pass through a flow monitor/totalizer prior to discharge.

- ***Equipment List - 50 GPM System***

Item No.	*Description*
1-1	EQUALIZATION TANK Lancy Model No. 50-49120-1 * 12,000-gallon capacity, vertical, cylindrical FRP tank * Flanged drain connection * Dip tube * Tie-down lugs TRANSFER PUMP Lancy Model No. 50-2224-050/50-11 * Duplex, FRP constructed horizontal, centrifugal pumps * 50 gpm capacity * 210-gallon capacity, vertical, cylindrical FRP tank * Pump level controls * High level alarm * 230/460-VAC, 3-Phase, TEFC motors FLOW METER AND RECORDER VAPOR PHASE CARBON ADSORBER
1-2	LANCY™ ECONO-TREAT UNIT Lancy Model No. ET120-B-L * Carbon steel fabricated unit * First-stage PVC sheet lined pH adjustment compartment * Second-stage neutralization compartment * Third-stage flocculation compartment * Solids separator compartment with integral corrugated plate interceptor pack(s) and solids collection hopper * Access ladder and platform * Exterior coat of chemically-resistant paint * Reaction compartment agitators * Automatically controlled sludge withdrawal pump * Flanged sludge withdrawal connection * Adjustable effluent trough and flanged effluent nozzles

- ***Equipment List - 50 GPM System (Continued)***

Item No.	***Description***
1-2	LANCY™ ECONO-TREAT UNIT (Continued)

* Chemical supply tanks
* Chemical supply tank agitators
* Chemical feed pumps
* Electrical control system--to control electrically-operated components that are included with the Econo-Treat such as metering pumps, process controllers, agitators and the sludge withdrawal timers and pump
* The unit and the chemical support equipment will be prewired and prepiped at our plant. However, due to shipping limitations, some re-assembly will be required.

ADDITIONAL ACID FEED PUMP
Lancy Model No. 50-5111-000

* One positive displacement metering pump
* 0-18 gph output capacity
* Polypropylene head, check valves and diaphragm
* Suction hose and strainer
* Totally enclosed drive
* Anti-syphon valve
* Dial-knob capacity adjustment

1-3 LIFT STATION
Lancy Model No. 50-2224-050/50-11

* Duplex, FRP constructed horizontal, centrifugal pumps
* 50 gpm capacity
* 210-gallon capacity, vertical, cylindrical FRP tank
* Pump level controls
* High level alarm
* 230/460-VAC, 3-Phase, TEFC motors

- ***Equipment List - 50 GPM System (Continued)***

Item No.	*Description*
1-4	SAND FILTER

* 42-gallon per minute capacity wastewater filter at less than 50 ppm solids
* FRP constructed vertical cylindrical unit
* Inlet connection and riser tubes
* Distribution hood
* Self-cleansing sand bed
* Overflow weir
* Airlift pipe
* Central reject compartment
* Gravity washer/separator
* Reject effluent/filtrate weir
* Continuous upflow/backwash design

1-5 LANCY™ SORPTION FILTER SYSTEM

* 80 gpm maximum capacity
* Skidded modular unit
* ~10 ft-6 in. long by 7 ft wide by 12 ft-6 in. high
* 1,100-gallon reactor tank with agitator
* Sulfide and pH controller
* Sample center
* 1,200-gallon retention tank
* 350-gallon precoat tank with agitator
* Duplex filter feed pumps
* One stainless steel filter body
* Stainless steel filter fingers
* Valves and level controls
* Electrical control panel
* 200-gallon caustic tank with agitator and feed pump
* 150-gallon sulfide tank with agitator and feed pump
* Prewired and prepiped unit
* Operator platform and ladder

- ***Equipment List - 50 GPM System (Continued)***

Item No.	*Description*
1-6	pH ADJUSTMENT MODULE Lancy Model No. 50-4406-1 * 600-gallon capacity, vertical, cylindrical FRP tank * Outlet box * Flanged nozzles * Agitator * Agitator mounting bracket * pH controller, cables, electrode, electrode holder and holder mounting bracket
1-7	LIFT STATION Lancy Model No. 50-2221-050/50-11 * Duplex, cast iron constructed horizontal, centrifugal pumps * 50 gpm capacity * 210-gallon capacity, vertical, cylindrical FRP tank * Pump level controls * High level alarm * 230/460-VAC, 3-Phase, TEFC motors
1-8	EFFLUENT HOLD TANK Lancy Model No. 50-49120-1 * 12,000-gallon capacity, vertical, cylindrical FRP tank * Flanged drain connection * Dip tube * Tie-down lugs TRANSFER PUMPS Lancy Model No. 50-2221-050/50-10 * Duplex, cast iron constructed horizontal centrifugal pumps * 50 gpm capacity * Pump level controls * High level alarm * 230/460-VAC, 3-Phase, TEFC motors

- ***Equipment List - 50 GPM System (Continued)***

Item No.	*Description*
1-9	LANCY™ EFFLUENT MONITOR Lancy Model No. 75-9712-01120

The unit includes:

* Open channel flow measuring device with analog flow percentage meter, digital display totalizer and strip chart recorder.

* pH control with analog display meter, recorder, electrode and electrode holder, pH control selector switches for acid/alkaline adjustment complete with dry contacts to operate chemical feed pumps and agitators. (Pumps and agitators not provided.)

* Pneumatically operated composite sampler and a digital display sample counter. The sampler can be activated manually, on a timed basis or flow proportionally.

* An indoor/outdoor 12-gauge steel epoxy coated insulated enclosure with lifting lugs.

* Thermostatically controlled heating and ventilation.

* Instrument panel lighting.

* 117-VAC duplex convenience outlets mounted above the front and rear panels.

* Full sized front and rear lockable access doors.

* Refrigerator with a 5-gallon composite sample bottle which will contain up to 378 50-ml samples.

- ***Equipment List - 50 GPM System (Continued)***

Item No.	*Description*
	EFFLUENT MONITORING TANK Lancy Model No. EMT-50 * 50 gpm capacity tank * V-notch weir box * Polypropylene construction * Stilling well/transducer mounting bracket * Influent baffle * Flanged effluent nozzle
1-10	SLUDGE THICKENER Lancy Model No. 50-7135-30 * 3,500-gallon capacity, vertical, cylindrical FRP tank * Conical bottom * Internal baffles * Overflow nozzle * Flanged bottom nozzle SLUDGE WITHDRAWAL PUMP Lancy Model No. 50-6211-08-10 * One air-operated diaphragm pump * Cast iron construction * Neoprene elastomers * 110 gpm capacity at 100 psi * 2-inch NPT suction connection * 2-inch NPT discharge connection

- ***Equipment List - 50 GPM System (Continued)***

Item No.	*Description*
1-11	FILTER PRESS

* 5 cu ft filter cake capacity
* 1.26-inch cake thickness
* 100 psi filtration capacity
* Center feed
* Four corner filtrate discharge connection
* Painted steel skeleton
* Woven polypropylene filter cloth
* Automatically operated closure
* Plate shifter

TWO DUMP CARTS

1-12 FILTRATE LIFT STATION
Lancy Model No. 50-2221-110/50-11

* Duplex, cast iron constructed horizontal, centrifugal pumps
* 110 gpm capacity
* 550-gallon capacity, vertical, cylindrical FRP tank
* Pump level controls
* High level alarm
* 230/460-VAC, 3-Phase, TEFC motors

- ***Equipment List - 50 GPM System (Continued)***

Item No.	***Description***
1-13	ELECTRICAL CONTROL PANEL An electrical control panel (ECP) shall be provided to house the circuitry for the equipment items described in this proposal necessary for a complete and operable system and shall consist of the following: * NEMA-12 enclosure * Motors less than 1/2 HP--designed for 115-VAC, 60-Hertz service * Motors 1/2 HP or greater--designed for 230/460, 3-Phase, 60-Hertz service * Single-phase transformer * Main panel disconnect switch (for complete system shutdown) * Numbered terminal strips * Fuse protection (all circuits) * Motor starters with overload heaters (all 3-Phase) Note: Motor disconnects for each piece of equipment or motor to be provided by the installer.

ALTERNATE NO. 2 - 200 GPM SYSTEM

- ***Design Basis***

Parameter	*Average Influent*	*Effluent Requirements*
Ammonia, mg/l	11	
Sulfide, mg/l	1	
Aluminum, µg/l	14,277	
Antimony, µg/l	10	
Arsenic, µg/l	2	
Barium, µg/l	136	
Beryllium, µg/l	2	1
Cadmium, µg/l	3	5
Chromium, µg/l	17	100
Cobalt, µg/l	18	
Copper, µg/l	47	
Iron, µg/l	60,644	
Lead, µg/l	32	15
Manganese, µg/l	2,305	3,650
Mercury, µg/l	0.10	
Nickel, µg/l	27	100
Vanadium, µg/l	20	
Zinc, µg/l	348	
Dieldrin, µg/l	0.020	
2-Methylnaphthalene, µg/l	3	
4-Chloro-3-methylphenol, µg/l	2	
4-Methylphenol, µg/l	8	
Pentachlorophenol, µg/l	6	
bis(2-Ethylhexyl)phthalate, µg/l	4	
1,1-Dichloroethane, µg/l	7	
1,1-Dichloroethene, µg/l	3	
1,2-Dichloroethene (total), µg/l	14	
4-Methyl-2-pentanone, µg/l	2	
Acetone, µg/l	21	
Benzene, µg/l	5	
Carbon Disulfide, µg/l	11	
Chloroethane, µg/l	8	
Ethylbenzene, µg/l	7	

ALTERNATE NO. 2 - 200 GPM SYSTEM

Design Basis (Continued)

Parameter	*Average Influent*	*Effluent Requirements*
Toluene, µg/l	21	
Trichloroethene, µg/l	2	
Vinyl Chloride, µg/l	14	
Acrylamide, µg/l	64	
N,N-DMP, µg/l	84	
Hardness, mg/l	86	
pH, standard units	6.9	
Total Organic Carbon, mg/l	28	
BOD, mg/l	7	

- ***Process Description***

  The unit operations for the 200 gpm alternative are similar to those described in Alternate No. 1 with the exception of modular pH adjustment and flocculation units to accommodate the higher flow rates instead of a Lancy™ Econo-Treat Unit.

- ***Equipment List - 200 GPM System***

Item No.	*Description*
2-1	EQUALIZATION TANK

* SuperBlue® glass-fused-to-steel tank
* 50,000-gallon capacity

TRANSFER PUMP
Lancy Model No. 50-2224-200/50-10

* Duplex, FRP constructed horizontal centrifugal pumps
* 200 gpm capacity
* Pump level controls
* High level alarm
* 230/460-VAC, 3-Phase, TEFC motors

FLOW METER AND RECORDER

2-2 pH ADJUSTMENT MODULES (2 Required)
Lancy Model No. 50-4424-1

* 2,400-gallon capacity, vertical, cylindrical FRP tank
* Outlet box
* Flanged nozzles
* Agitator
* Agitator mounting bracket
* pH controller, cables, electrode, electrode holder and holder mounting bracket

2-3 FLOCCULATION MODULE
Lancy Model No. 50-4506-3

* 600-gallon capacity, vertical, cylindrical FRP tank
* Outlet box
* Flanged nozzles
* Agitator
* Agitator mounting bracket

- ***Equipment List - 200 GPM System (Continued)***

Item No.	***Description***
2-4	CHEMICAL DAY TANKS (4 Required) Lancy Model No. 50-5463-100 * 960-gallon capacity, vertical, cylindrical, FRP tank * Agitator * Agitator mounting bracket * Partial cover and exhaust collar * Dip tube for metering pump CHEMICAL FEED PUMPS Lancy Model No. 50-5151-000 * Five positive displacement metering pumps * 0-18 gph output capacity * Polypropylene head, check valves and diaphragm * Suction hose and strainer * Totally enclosed drive * Anti-syphon valve * Dial-knob capacity adjustment
2-5	SOLIDS SEPARATOR Lancy Model No. 6112-240-2 * 240 gpm flow rate * Twelve CPI packs (proprietary design--FRP construction) * 1/4-inch carbon steel fabrication * Chemical-resistant paint (exterior) * 103 sq ft of settling surface area (Per 60-degree pack) * Flanged sludge withdrawal connection * Flanged effluent connection * Adjustable weir trough

- ***Equipment List - 200 GPM System (Continued)***

Item No.	*Description*
	SLUDGE WITHDRAWAL PUMPS (2 Required) Lancy Model No. 50-6211-04-10 * Air-operated diaphragm pumps * Cast iron construction * Neoprene elastomers * 55 gpm capacity at 100 psi * 1-1/2-inch NPT suction connection * 1-1/4-inch NPT discharge connection
2-6	LIFT STATION Lancy Model No. 50-2224-200/50-11 * Duplex, FRP constructed horizontal, centrifugal pumps * 200 gpm capacity * 1,000-gallon capacity, vertical, cylindrical FRP tank * Pump level controls * High level alarm * 230/460-VAC, 3-Phase, TEFC motors
2-7	SAND FILTER * 228-gallon per minute capacity wastewater filter at less than 50 ppm solids * Steel constructed vertical cylindrical unit * Inlet connection and riser tubes * Distribution hood * Self-cleansing sand bed * Overflow weir * Airlift pipe * Central reject compartment * Gravity washer/separator * Reject effluent/filtrate weir * Continuous upflow/backwash design

- ***Equipment List - 200 GPM System (Continued)***

Item No.	***Description***
2-8	SORPTION FILTER SYSTEM

* 240 gpm capacity
* Skidded modular units
* 31.5 ft long by 21 ft wide by 12.5 ft high
* 3,300-gallon reactor tank with agitator
* Sulfide and pH controller
* Sample center
* 3,600-gallon retention tank
* 1,050-gallon precoat tank with agitator
* Duplex filter feed pumps
* One stainless steel filter body
* Stainless steel filter fingers
* Valves and level controls
* Electrical control panel
* 600-gallon caustic tank with agitator and feed pump
* 450-gallon sulfide tank with agitator and feed pump
* Prewired and prepiped unit
* Operator platform and ladder

2-9 pH ADJUSTMENT MODULE
Lancy Model No. 50-4424-1

* 2,400-gallon capacity, vertical, cylindrical FRP tank
* Outlet box
* Flanged nozzles
* Agitator
* Agitator mounting bracket
* pH controller, cables, electrode, electrode holder and holder mounting bracket

- ***Equipment List - 200 GPM System (Continued)***

Item No.	***Description***
2-10	LIFT STATION Lancy Model No. 50-2224-200/50-11 * Duplex, FRP constructed horizontal, centrifugal pumps * 200 gpm capacity * 1,000-gallon capacity, vertical, cylindrical FRP tank * Pump level controls * High level alarm * 230/460-VAC, 3-Phase, TEFC motors
2-11	EFFLUENT HOLD TANK * SuperBlue® glass-fused-to-steel tank * 50,000-gallon capacity TRANSFER PUMPS Lancy Model No. 50-2221-200/50-10 * Duplex, cast iron constructed horizontal centrifugal pumps * 200 gpm capacity * Pump level controls * High level alarm * 230/460-VAC, 3-Phase, TEFC motors

- ***Equipment List - 200 GPM System (Continued)***

Item No.	***Description***
2-12	LANCY EFFLUENT MONITOR Lancy Model No. 75-9712-01120

The unit includes:

* Open channel flow measuring device with analog flow percentage meter, digital display totalizer and strip chart recorder.

* pH control with analog display meter, recorder, electrode and electrode holder, pH control selector switches for acid/alkaline adjustment complete with dry contacts to operate chemical feed pumps and agitators. (Pumps and agitators not provided.)

* Pneumatically operated composite sampler and a digital display sample counter. The sampler can be activated manually, on a timed basis or flow proportionally.

* An indoor/outdoor 12-gauge steel epoxy coated insulated enclosure with lifting lugs.

* Thermostatically controlled heating and ventilation.

* Instrument panel lighting.

* 117-VAC duplex convenience outlets mounted above the front and rear panels.

* Full sized front and rear lockable access doors.

* Refrigerator with a 5-gallon composite sample bottle which will contain up to 378 50-ml samples.

- ***Equipment List - 200 GPM System (Continued)***

Item No.	***Description***
	EFFLUENT MONITOR TANK Lancy Model No. EMT-200 * 200 gpm capacity tank * V-notch weir box * Polypropylene construction * Stilling well/transducer mounting bracket * Influent baffle * Flanged effluent nozzle
2-13	SLUDGE THICKENERS (2 Required) Lancy Model No. 50-7150-30 * 5,000-gallon capacity, vertical, cylindrical FRP tank * Conical bottom * Internal baffles * Overflow nozzle * Flanged bottom nozzle
	SLUDGE WITHDRAWAL PUMPS (2 Required) Lancy Model No. 50-6211-15-10 * Air-operated diaphragm pumps * Cast iron construction * Neoprene elastomers * 200 gpm capacity at 100 psi * 3-inch NPT suction connection * 3-inch NPT discharge connection

- ***Equipment List - 200 GPM System (Continued)***

Item No.	*Description*
2-14	FILTER PRESS

* 20 cu ft filter cake capacity
* 1.26-inch cake thickness
* 100 psi filtration capacity
* Center feed
* Four corner filtrate discharge connection
* Painted steel skeleton
* Woven polypropylene filter cloth
* Automatically operated closure
* Plate shifter

2-15 FILTRATE LIFT STATION
Lancy Model No. 50-2221-230/50-11

* Duplex, cast iron constructed horizontal, centrifugal pumps
* 230 gpm capacity
* 1,000-gallon capacity, vertical, cylindrical FRP tank
* Pump level controls
* High level alarm
* 230/460-VAC, 3-Phase, TEFC motors

- ***Equipment List - 200 GPM System (Continued)***

Item No.	***Description***
2-16	ELECTRICAL CONTROL PANEL An electrical control panel (ECP) shall be provided to house the circuitry for the equipment items described in this proposal necessary for a complete and operable system and shall consist of the following: * NEMA-12 enclosure * Motors less than 1/2 HP--designed for 115-VAC, 60-Hertz service * Motors 1/2 HP or greater--designed for 230/460, 3-Phase, 60-Hertz service * Single-phase transformer * Main panel disconnect switch (for complete system shutdown) * Numbered terminal strips * Fuse protection (all circuits) * Motor starters with overload heaters (all 3-Phase) Note: Motor disconnects for each piece of equipment or motor to be provided by the installer.

Note: Unless otherwise specified herein, ventilation, interconnecting piping, wiring, conduit, supports, fittings, valves, etc. between U.S. Filter equipment items and/or customer equipment is to be provided by others.

If you require installation prices for the above listed equipment, we would be happy to submit a proposal for the complete installation of this equipment.

ESTIMATED OPERATING REQUIREMENTS

The following are rough estimates of chemical usage and must be confirmed by conducting a treatability study. These estimates are for equipment quoted only and does not include options or equipment supplied by others.

- ***Chemical Usage***

	50 gpm System	200 gpm System	Unit Cost
Caustic	~300 lbs/day	~1,200 lbs/day	~$300/2,000 lbs
Sulfuric Acid	~480 lbs/day	~1,900 lbs/day	~$75/2,000 lbs
Ferrous Sulfate	~315 lbs/day	~1,260 lbs/day	~$160/2,000 lbs
Polymer	~.6 lbs/day	~2.5 lbs/day	~$5.75/lb
Sodium Sulfide	~7.5 lbs/day	~30 lbs/day	$29/100 lbs
Sorption Filter Media	~6 lbs/day	~25 lbs/day	$3.50/lb
Make-Up Water	1,000 gals/day	4,000 gals/day	~$.002/gal
Sludge	14 cu ft/day at 25% dry solids	~50 cu ft/day at 25% dry solids	~$200/ton

- ***Electrical Requirements*** - 480-VAC, 3-Phase power.

  Electrical usage estimate: Alternate No. 1 - 40 Kw-Hr
  Alternate No. 2 - 100 Kw-Hr

  Note: These are theoretical estimates which do not account for mechanical efficiencies.

- ***Manpower*** - Assume 2 operators, 8 hours/day (including UV/oxidation)

- ***Maintenance*** - Assume 1% of facility price/yr

- ***Space Requirements***

  Alternate No. 1 - 50 gpm System — 50 ft long by 50 ft wide by 20 ft high
  Alternate No. 2 - 200 gpm System — 60 ft long by 50 ft wide by 20 ft high

Note: Sludge estimate is based upon assumption of 100 ppm TSS (assumes all metals are soluble) and iron additions of 60 ppm $FeSO_4$ as Fe.

TREATABILITY STUDIES

As you know, we have not had the opportunity to analyze and process representative samples of your waste in our treatability laboratory. While we have ample reason to believe that the proposed system will provide satisfactory treatment, U.S. Filter reserves the right to perform such tests prior to formal acceptance of your order. If you wish, we can perform the treatability work immediately for a fee of $7,500, which would be credited against your purchase order for the proposed system.

ENGINEERING SERVICES

U.S. Filter would provide the following engineering services for the proposed groundwater treatment system:

- Piping and instrumentation diagram(s)
- Electrical drawing(s)
- Equipment layout drawing(s)
- Operating manual consisting of operating instructions, equipment specifications and process descriptions for the major subsystems
- Equipment maintenance manual which includes itemized data sheets for all equipment components
- Visit by a U.S. Filter engineer to client's facility during engineering phase

Note: All copies described above are in triplicate.
Additional copies may be obtained at cost.

START-UP SERVICES

U.S. Filter would provide 5 man-days of start-up services on a portal-to-portal basis. These services normally include the following:

- Pre-start-up checkout/troubleshooting for all equipment
- Supervision of system start-up
- Instruction of operating personnel in system maintenance and operation

Additional days of start-up requested by the client would be charged at our standard per diem rate of $550 per 8-hour working day, on a portal-to-portal basis, plus all out-of-pocket travel and living expenses which would be invoiced as a separate item at net cost.

BUDGETARY PRICES

- ***Alternate No. 1 - 50 gpm System***

  U.S. Filter would supply equipment item Nos. 1-1 through 1-13, engineering and start-up services as described herein for approximately
  FIVE HUNDRED THOUSAND DOLLARS.....$500,000.00.

- ***Alternate No. 2- 200 gpm System***

  U.S. Filter would supply equipment item Nos. 2-1 through 2-16, engineering and start-up services as described herein for approximately
  EIGHT HUNDRED THOUSAND DOLLARS.....$800,000.00.

EQUIPMENT WARRANTY

U.S. Filter would warrant all equipment for a maximum period of 12 months from date of shipment. This warranty would cover all defects in materials or workmanship.

The pH/ORP electrodes are warranted for 30 days from the start-up date, or 6 months from the shipping date, whichever occurs first.

SHIPPING SCHEDULE

Shipment of equipment is quoted F.O.B. shipping point and is anticipated to be ready for shipment 12 to 14 weeks following return of approval drawings. Approval drawings would be issued approximately 4 weeks after acceptance of a purchase order.

Freight would be prepaid and invoiced at time of equipment shipment.

APPENDIX

- Drawing No. A-1
- Literature

CONFIDENTIALITY AGREEMENT

This information is confidential and contains proprietary information. It is not to be disclosed to a third party without the consent of United States Filter Corporation.

U.S. Filter shall be most interested in providing further information to you as needed, and ultimately, we hope that we can work with you on this project. Please do not hesitate to call if we can be of further service to you.

Sincerely,

UNITED STATES FILTER CORPORATION

Deborah M. Buckley

Deborah M. Buckley
Groundwater Market Manager

cc:

Authorized Representative
Global Technologies, Inc.
2 Gordon Street
Simsbury, Connecticut 06070
(203) 651-0255

U.S. FILTER, INC. WARRENDALE, PENNSYLVANIA

TERMS AND CONDITIONS OF SALE
(Systems)

ACCEPTANCE BY U.S. FILTER, INC. WARRENDALE, PENNSYLVANIA (HEREINAFTER "SELLER") OF THE PURCHASER'S PURCHASE ORDER OR OTHER OFFER TO PURCHASE IS EXPRESSLY MADE CONDITIONAL UPON THE PURCHASER'S ASSENT TO ANY TERMS AND CONDITIONS HEREIN WHICH DIFFER FROM, OR ARE ADDITIONAL TO, THOSE IN PURCHASER'S OFFER. THE TERMS AND CONDITIONS HEREIN ARE AN INTEGRAL PART OF ANY OFFER TO SELL BY SELLER, AND THE PURCHASER'S ACCEPTANCE OF SUCH OFFER IS EXPRESSLY LIMITED TO AND CONDITIONED UPON THE EXCLUSIVE APPLICABILITY THERETO OF THESE TERMS AND CONDITIONS.

Terms. Unless otherwise stated herein, prices are F.O.B. point of shipment and payment terms are net thirty (30) days from date of Seller's invoice. Each incremental shipment of equipment and/or materials shall be invoiced at time of shipment in an amount proportional to that of the total contract price. Purchaser shall incur interest at the rate of one and one-half percent (1.5%) per month or the highest rate permitted by applicable law, whichever is less, on amounts not paid in accordance with terms of sale. The price offered is based on shipment of the equipment as stipulated in the proposal. If the shipment schedule is delayed as a result of Purchaser's activities, such as delay in return of approval drawings, inspection, etc., a price adjustment of 2% of the purchase price for each month of delay will be added to the purchase price.

Extra Charges. Unless specified otherwise on the face of Seller's Sales Order Acknowledgement Form, the price to Purchaser does not include installation, erection or service, or any accessory, supportive or associated materials. Seller shall make such reasonable additional charges as it determines in the event it agrees to changes or modifications in said specifications.

Credit. All contracts and orders are subject to credit approval by Seller. If Seller, in its sole judgment, has reasonable grounds for insecurity with respect to due performance by Purchaser, Seller may demand different terms of payment from those specified herein and may demand assurance of Purchaser's due performance. Any such demand may be oral or in writing and Seller may, upon the making of such demand, stop production and suspend shipments hereunder. If within the period stated in such demand Purchaser fails or refuses to agree to such different terms of payment or fails or refuses to give adequate assurance of due performance, Seller may, at its option, treat such failure or refusal as a repudiation of the portion of this order which has not been fully performed or may resume production and may make shipment under reservation of possession or of a security interest and may demand payment against tender of documents of title.

Delivery Delays. Unless a firm delivery date is stated on the face of Seller's Sales Order Acknowledgement Form, shipment dates are approximate, and delivery made within a reasonable time thereof shall be deemed full performance of this aspect of Seller's obligations hereunder. Seller shall not be liable for any delays in performance due to causes beyond Seller's reasonable control or beyond the control of its suppliers which prevents or impedes manufacture, supply or delivery by Seller or such suppliers, including without limitation acts of God, accidents to machinery, differences with workmen, strikes, labor shortages, fires, floods, inadequate or reduced supply or excessive cost of suitable raw materials, delays in transportation or lack of transportation facilities, priorities required or requested by the Federal or any State government or any subdivision or agency thereof or granted for the benefit, directly or indirectly, of any of them, delays in transportation or lack of transportation facilities, restrictions imposed by Federal or State laws or rules or regulations thereunder.

Warranty. Seller warrants that the goods to be supplied hereunder will conform to the description on the face of the Sale Order Acknowledgement Form or applicable document there referenced; that it will convey good title thereto; that such goods will be delivered free from any lawful security interest or other lien or encumbrance unknown to Purchaser; and that such goods will be free from defects in material and workmanship provided that such warranty of freedom from defects in material and workmanship shall extend only for a period of twelve months from the date of installation or for a period of eighteen months from the date of shipment, whichever is shorter, and that Purchaser gives Seller notice of any such defect within thirty (30) days after Purchaser discovers or should have discovered such defect. *Seller makes no warranty that the goods shall be merchantable or fit for any particular purpose. Seller makes no warranty, express or implied, except such as is expressly set forth herein.* Seller shall not be liable for any incidental or consequential damages for any breach of warranty, Seller's liability and Purchaser's exclusive remedy being expressly limited to Seller's choice of (a) the repair of defective goods; (b) the replacement thereof with conforming goods at F.O.B. Purchaser's plant; or (c) the repayment of the purchase price. Replacement of defective goods or repayment of the purchase price therefor will be made only upon return of the defective goods which may be returned at the cost of Seller only after inspection by Seller and receipt by Purchaser of definite shipping instructions from Seller.

Seller makes no warranty whatsoever with respect to goods manufactured by third parties. Warranties with respect to such goods are limited to those offered by such suppliers which are transferable.

A warranty of performance when given by Seller shall be in addition to the warranties provided in the preceding paragraphs hereof. Purchaser's exclusive remedies with respect to any failure of the goods to meet any performance guarantees shall be limited, at Seller's option, to (i) acquiring full ownership of the goods upon payment of ninety percent (90%) of the purchase price, if agreed to by Seller, or (ii) relinquishing ownership and possession of the goods and having Seller refund any payment already made by Purchaser toward the purchase price. In the latter case, the expense for removing the goods from the premises of the Purchaser shall be negotiated by the parties.

Patents. Seller agrees to indemnify Purchaser, its successors and assigns, against all judgments, decrees and reasonable costs (except where the goods sold hereunder are machines, in which event, against court assessed damages and costs) resulting from infringement of any United States Letters Patent covering (a) standard commercial compositions offered for sale generally by Seller at the time of acceptance by it of this order; or (b) standard commercial forms, shapes or constructions offered for sale generally by Seller at the time of acceptance by it of this order, to the extent that such compositions, forms, shapes or constructions are supplied hereunder. Purchaser agrees, for goods delivered under this order, to indemnify Seller, its successors and assigns, against all judgments, decrees and costs resulting from infringement of any United States Letters Patent to the extent that such infringement arises from designs, specifications or instructions furnished or expressly or implicitly required by Purchaser and different from the matters embraced by (a) and (b) of the preceding sentence. Neither party shall be entitled to indemnification under this clause as to any claim of infringement concerning which it does not give to the other party prompt notice in writing upon learning thereof and full opportunity, at the expense of such other party, to defend and dispose of such claim of infringement. The sale of the goods covered by this order shall not grant to Purchaser any right or license of any kind under any patent owned or controlled by Seller or under which Seller is licensed, but the foregoing shall not be understood to limit in any way the right of Purchaser to use and sell such goods, in the event that such goods as sold hereunder are covered by any such patent.

Subsidiaries and Affiliates. This order may be performed and all rights hereunder against Purchaser may be enforced, in whole or in part, by Seller or by its parent corporation or any one or more of the corporations subsidiary to or affiliated with Seller.

Waiver. No provision hereof and no breach of any provision shall be deemed waived by reason of any previous waiver of such provision or of any breach thereof.

Cancellation by Purchaser. If an order is cancelled before engineering and/or production has begun, and before Seller has incurred obligations for items such as materials or components, Purchaser shall pay a cancellation charge equal to 15% of the total purchase price as liquidated damages and not as a penalty; for any order that is cancelled subsequent to that time, Purchaser shall pay a cancellation charge equal to Seller's costs for materials, labor, engineering, shop overhead, and charges made by its suppliers, plus 25% of the total purchase price as liquidated damages and not as a penalty.

Indemnity. Purchaser shall release, hold harmless, indemnify and defend Seller from and against any loss, liability, claims, suits and costs caused by, arising out of, or relating to the design of goods supplied hereunder or the design of the packages or containers in which they are shipped, if such goods, packages or containers are made in compliance with Purchaser's design or specifications.

Taxes. Purchaser shall pay to Seller, in addition to the purchase price of the goods, any other tax, however denominated or measured, imposed on property, or upon its construction, inventory, or upon the manufacture, storage, sale, transportation, importation, delivery, use, or consumption of goods sold to Purchaser.

Insurance. Risk of loss for all goods sold pursuant hereto passes to Purchaser upon shipment. Claims for loss or damage in transit shall be made by Purchaser directly with the carrier. Purchaser shall make all claims for factory shortage within five (5) days of receipt of goods, and failure to do so shall constitute a waiver of Purchaser's right to make any such claims. Purchaser shall furnish at its own expense adequate insurance protecting goods sold pursuant hereto against loss or damage by fire or other causes from time of shipment until full and complete payment has been made.

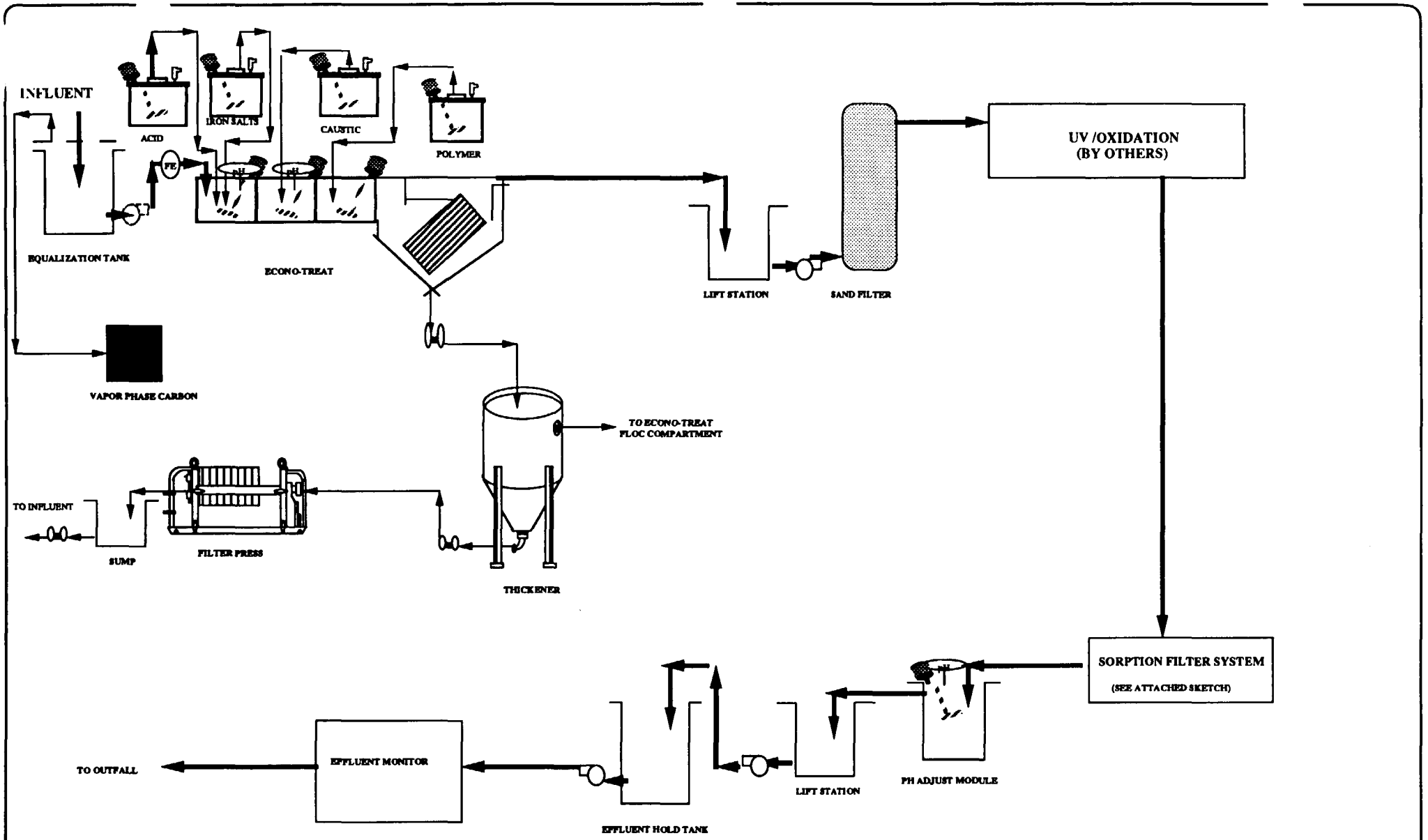
Security Interest. Until such time as Seller has received payment in full for equipment sold pursuant hereto, Seller shall have a security interest herein. Purchaser agrees to extend such reasonable cooperation as Seller may require, including the execution of financing statements or other documents, in order for said security interest to be perfected as against third parties. In the event of default by Purchaser, Seller shall have available all rights at law or equity to a secured seller, including the right to enter upon the premises where such equipment shall be located for purposes of removing same, or rendering it inoperative, and all such rights shall be cumulative.

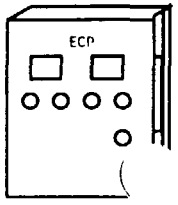
Miscellaneous. When ASME code vessels are supplied, certification by an inspector commissioned by the National Board of Boiler and Pressure Vessel Inspectors shall irrefutably establish conformance of the vessel to the applicable section of the ASME Boiler and Pressure Vessel Code, Latest Edition. Seller will not be responsible for meeting state and local codes or ordinances or other special codes unless the details of these codes are specified in the specifications and are specifically accepted by Seller. All illustrations, drawings, etc., accompanying Seller's proposal show approximate dimensions only and are not binding in detail unless stated to be by Seller. All drawings pertaining to the goods are supplied to Purchaser solely for the limited purpose of permitting Purchaser to install, operate and maintain the goods. They are confidential and except for the purpose above specified, shall not be copied, exhibited or furnished to others without the prior written consent of Seller.

Entirety of Agreement. The terms and conditions contained herein constitute the entire agreement of the parties, and neither party shall be bound by any oral or written understanding not expressly included herein. No valid and binding contract shall exist until such time as the Sale Order Acknowledgement Form is accepted by the Purchaser. No modification or alteration in these terms and conditions shall be effective except by means of a writing duly executed on behalf of both parties, and expressly purporting to amend the terms and conditions.

Governing Law. These terms and conditions shall be governed by and construed in accordance with the laws of the Commonwealth of Pennsylvania, excluding rules relating to choice or conflicts of law.

APPENDIX





This drawing or print is the property of US FILTER, and is subject to return on request. The design concepts and information contained herein are proprietary to this company and are submitted in confidence. They are not transferable and must be used only for the purpose for which the print is expressly loaned. They must not be disclosed, reproduced, or otherwise used in any manner detrimental to th[illegible] of US FILTER. All patent rights are reserved un[illegible] specifically assigned in writing.

Drawn DMB	Date 6/3/93	
Checked		
Approved		
Scale	NONE	

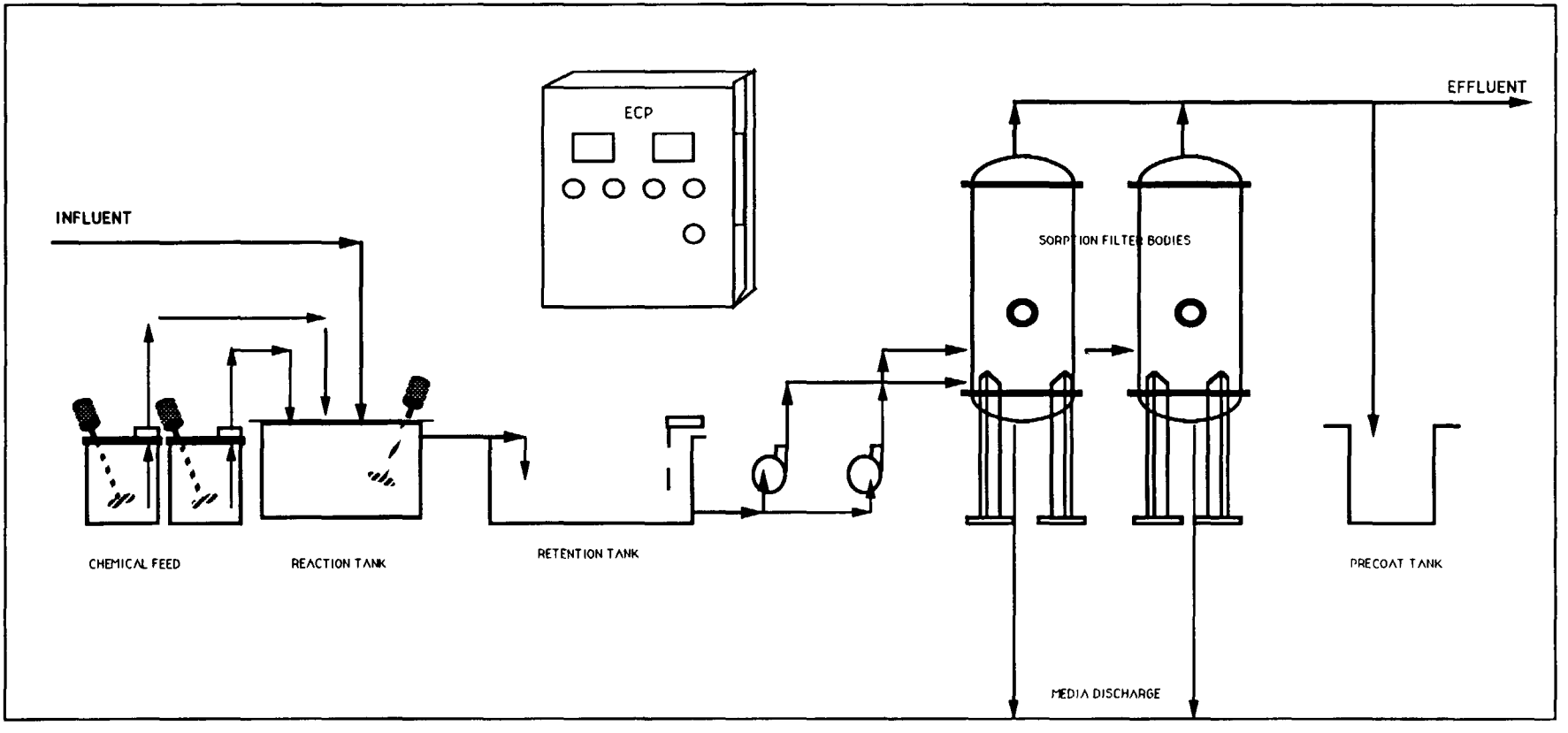
USF

Title: GROUNDWATER TREATMENT SYSTEM- CONCEPTUAL FLOW DIAGRAM

Client: METCALF& EDDY - ROSE HILL LANDFILL SUPERFUND SITE

US FILTER CORPOR[illegible]TION, INC.

Sheet 1 of 1 | Project No. 5040-21 | Dr[illegible] | A-1 | Rev 0


ECP
INFLUENT
EFFLUENT
SORPTION FILTER BODIES
CHEMICAL FEED
REACTION TANK
RETENTION TANK
PRECOAT TANK
MEDIA DISCHARGE

PREPARED BY: DM Barkley	CLIENT: METCALF & EDDY	**U.S. FILTER/ WARRENDALE**
CHECKED BY:	PROJECT NO.: 5040-21	
DATE: 5/5/93 REV.:	SHEET: 1 OF 1	DRAWING NO.:
SUBJECT: SLUDGE CALCULATIONS		

GIVEN FLOW: 200 gpm

Al = 142 mg/L

Fe = 60.6 mg/L

Mn = 2.3 mg/L

ASSUME TSS = .5 (Fe) + 100 mg/L

∴ TSS = 130 mg/L

$$\left[\left(\frac{142\text{ mg}}{L}\text{ Al} \times \frac{78}{27\text{ mg Al}}\text{Al(OH)}_3\right) + \left(\frac{606\text{ mg}}{L}\text{ Fe} \times \frac{1.93\text{ mg}}{1\text{ mg}}\text{Fe(OH)}_3\right) + \left(2.3\text{ mg Mn} \times \frac{2.32\text{ mg}}{1\text{ mg Mn}}\text{Mn(OH)}_2\right) + \left(\frac{130\text{ mg}}{L}\text{ TSS}\right)\right] \times 200\text{ gpm} \times .012 = 1590\ \#/\text{DAY SOLIDS}$$

(410) (1169) (5.336)

THICKENER

$$\frac{1590\ \#}{\text{DAY}} \times \frac{}{.03 \times 8.59} = 6168\ \text{GAL/DAY} \text{ @ } 3\%\text{ DRY SOLIDS}$$

∴ use (1) 10,000 GAL THICKENER

FILTER PRESS

$$\frac{1590}{\text{DAY}} \times \frac{}{.30 \times 81.1} = 65.35\ \text{FT}^3/\text{DAY} \text{ @ } 30\%\text{ DRYNESS} \Big/ 4\ \text{PRESSES/DAY} = 16.3\ \text{FT}^3/\text{PRESS}$$

∴ USE 20 FT³ PRESS

FOR 50 GPM ⇒ ROUGH ESTIMATE WILL BE 1/4 SIZE OF 200 GPM SYSTEM

∴ USE 3000 THICKENER

5 FT³ PRESS

The design concepts and information contained herein are proprietary to U.S. Filter/Warrendale, and are submitted in confidence. They are not to be transferred and must be used only for the project for which the information was prepared. They must not be disclosed, reproduced, or otherwise used in any manner detrimental to the interest of U.S. Filter/Warrendale. All rights are reserved unless specifically assigned in writing

METCALF & EDDY, INC.

TELECON MEMORANDUM

JOB NO. 4609-18-10-10

DATE: 6/22/93

SUBJECT: Rose Hill FS - GW treatment by precipitation.

M&E ENGINEER: S. Czarniecki

OUTSIDE PARTY: Debbie Buckley - U.S. Filter 412 772-1298

MADE CALL (X)

REC'D CALL ( )

COMMENTS

SUMMARY OF CONVERSATION:

She will fax me by end-of-day Thursday breakout of costs for individual components - even though prices change if a component is replaced.

CC:

M&E FORM NO. 196 (9/78)

U.S. FILTER
UNITED STATES FILTER CORPORATION

LANCY™ SYSTEMS AND EQUIPMENT
181 THORN HILL ROAD
WARRENDALE, PA 15086
TEL. 412-772-0044
FAX 412-772-1360

FAX TRANSMITTAL

Date: 6/23/93 Page 1 of 1

To: MR. SEAN CZARNIECKI Company: METCALF & EDDY

Location: WAKEFIELD, MASS

Fax: 617/245-6293 Telephone: 617/246-5200

From: DEBBIE BUCKLEY

cc: TOM WHALEN

DEAR SEAN:

PER YOUR REQUEST, US FILTER IS PROVIDING BREAKOUT PRICES FOR EQUIPMENT ITEMS AS PRESENTED IN OUR JUNE 3, 1993 PROPOSAL FOR THE ROSE HILL, RI GW/LEACHATE PROJECT. AS I ELUDED TO ON THE TELEPHONE, THESE PRICES WOULD NOT INCLUDE THE SERVICES REQUIRED TO DEVELOP THESE EQUIPMENT ITEMS INTO A SYSTEM; SUCH AS: SITE VISIT, START UP, TREATABILITY, MASTER CONTROL PANEL, SYSTEM ENGINEERING, PROJECT MANAGEMENT, ETC. PRICES PRESENTED ARE FOR EQUIPMENT SUPPLY ONLY. THESE ARE, AGAIN, BUDGET PRICES.

ALT 1	SORPTION FILTER SYSTEM	$ 135,000
	ET, THICKENER, FILTER PRESS	$ 162,000
	SAND FILTER	$ 25,000
ALT 2	SORPTION FILTER SYSTEM	$ 225,000
	ET, THICKENER, FILTER PRESS	$ 210,000
	SAND FILTER	$ 55,000

SINCERELY, DMBuckley

Metcalf & Eddy
An Air & Water Technologies Company

004609-0018-010-001

May 24, 1993

Ms. Deborah M. Buckley
Groundwater Market Manager
U.S. Filter, Inc.
181 Thorn Hill Road
Warrendale, PA 15086-7527

Subject: **Contract No. 68-W9-0036**
Work Assignment No. 18-1LA5
Rose Hill Regional Landfill Superfund Site,
South Kingstown, Rhode Island
Request for Quotation on Equipment, Services and Budgetary Costs - Treatment of Contaminated Groundwater

Dear Ms. Buckley:

Metcalf & Eddy (M&E) is currently finalizing the Feasibility Study (FS) for treatment of contaminated groundwater at the Rose Hill Landfill site. As previously discussed, this groundwater is contaminated with weak, municipal landfill leachate. M&E has identified precipitation as an appropriate method for removing the inorganic compounds-of-concern (COCs).

As you have already supplied me with a conceptual process design, an updated quotation describing suggested equipment, services and budgetary costs should be based on the following assumptions:

1) quotations are needed for two different systems; groundwater concentrations are shown in Attachment A for the 50 gpm system (Alternative 4) and Attachment B for the 200 gpm system (Alternative 5).
2) treatment goals are listed in each attachment by compound; for the inorganic compounds, please identify any compounds that <u>may not meet goals</u>.
3) organics will be treated by a UV/Chemical oxidation system after inorganics removal.
4) assume a water temperature of 55 degrees F.
5) 50 gpm flowrate may be as low as 5 gpm (conditions shown in Attachment C); will your system still operate effectively ?
6) treated water discharges to recharge wells or to river.
7) identify operations and maintenance services necessary for your proposed system.
8) identify the make & model of your proposed system; please include copies of brochures, drawings and specifications that you may not have already provided to me.
9) assume budgetary costs accuracy for equipment, f.o.b.

30 Harvard Mill Square Wakefield, MA 01880
Mailing Address PO Box 4043 Woburn, MA 01888-4043
617-246-5200 FAX 617-245-6293

10) identify any other potential pretreatment or special conditions that you feel may be necessary for proper operation.

Your quotations are needed by the end-of-day Friday, June 4, 1993. Thank you for your assistance with this project. If you have any questions, please do not hesitate to contact me at TEL (617) 246-5200, extension 4811 or by FAX at (617) 245-6293.

Very truly yours,

METCALF & EDDY, INC.

Sean Czarniecki

Sean Czarniecki
Engineer II,
Industrial & Hazardous Waste Division

Attachments
cc: D. Peters
WA#18-1LA5
Contract File

ATTACHMENT A: GROUNDWATER CONDITIONS FOR THE 50 GPM SYSTEM

ANALYTE (a)	GROUNDWATER CONCENTRATIONS (b) Average	Maximum		PRELIMINARY REMEDIATION GOAL
	all in (μg/L) except where noted at left			
Ammonia (mg/L)	9	48		
Sulfide (mg/L)	1	4		
Aluminum	12,616	98,281	*	
Antimony	0	0	*	6
Arsenic	2	9	*	
Barium	210	695	*	
Beryllium	2	13	*	1
Cadmium	4	36	*	5
Chromium	21	136	*	100
Cobalt	21	82	*	
Copper	37	324	*	
Iron	91,571	396,140	*	
Lead	40	180	*	15
Manganese	2,633	10,361	*	3,650
Mercury	0.11	0.29	*	
Nickel	24	112	*	100
Vanadium	20	133	*	
Zinc	625	6,520	*	7,300
Dieldrin	0.043	0.003		
2-Methylnaphthalene	4	4		
4-Chloro-3-methylphenol	4	4		
4-Methylphenol	8	64		
Pentachlorophenol	12	3		1
bis(2-Ethylhexyl)phthalate	11	59		4
1,1-Dichloroethane	13	195		
1,1-Dichloroethene	4	2		
1,2-Dichloroethene(total)	30	645		70
4-Methyl-2-pentanone	5	27		
Acetone	20	415		
Benzene	10	27		5
Carbon Disulfide	13	77		
Chloroethane	16	77		
Ethylbenzene	14	64		
Toluene	31	156		
Trichloroethene	4	4		
Vinyl Chloride	30	610		2
Acrylamide	141	202		0.02 (c)
N,N-DMF	177	1,273		
Hardness (mg/L)	151	621		
pH	7.1	11.9		
Total Organic Carbon (mg/L)	44	200		
Biochemical Oxygen Demand (mg/L)	12	112		

Notes:

(a). Asterisk denotes compounds that will be handled by the metals treatment system.

(b). Concentrations for metals are "total" and not dissolved values.

(c). Goal is significantly below normal analytical detection limits; evaluate potential to meet 2 μg/L standard assuming that this is the detection limit.

ATTACHMENT B: GROUNDWATER CONDITIONS FOR THE 200 GPM SYSTEM

ANALYTE (a)	GROUNDWATER CONCENTRATIONS (b) Average	Maximum		PRELIMINARY REMEDIATION GOAL
	all in (μg/L) except where noted at left			
Ammonia (mg/L)	11	30		
Sulfide (mg/L)	1	7		
Aluminum	14,277	76,745	*	
Antimony	10	46	*	6
Arsenic	2	7	*	
Barium	136	445	*	
Beryllium	2	9	*	1
Cadmium	3	25	*	5
Chromium	17	94	*	100
Cobalt	18	53	*	
Copper	47	215	*	
Iron	60,644	218,437	*	
Lead	32	154	*	15
Manganese	2,305	8,391	*	3,650
Mercury	0.10	0.22	*	
Nickel	27	93	*	100
Vanadium	20	115	*	
Zinc	348	3,135	*	7,300
Dieldrin	0.020	0.001		
2-Methylnaphthalene	3	2		
4-Chloro-3-methylphenol	2	2		
4-Methylphenol	8	56		
Pentachlorophenol	6	1		1
bis(2-Ethylhexyl)phthalate	4	21		4
1,1-Dichloroethane	7	89		
1,1-Dichloroethene	3	1		
1,2-Dichloroethene(total)	14	293		70
4-Methyl-2-pentanone	2	12		
Acetone	21	329		
Benzene	5	13		5
Carbon Disulfide	11	57		
Chloroethane	8	37		
Ethylbenzene	7	29		
Toluene	21	121		
Trichloroethene	2	2		
Vinyl Chloride	14	276		2
Acrylamide	64	92		0.02 (c)
N,N-DMF	84	600		
Hardness (mg/L)	86	330		
pH	6.9	9.8		
Total Organic Carbon (mg/L)	28	125		
Biochemical Oxygen Demand (mg/L)	7	58		

Notes:

(a). Asterisk denotes compounds that will be handled by the metals treatment system.

(b). Concentrations for metals are "total" and not dissolved values.

(c). Goal is significantly below normal analytical detection limits; evaluate potential to meet 2 μg/L standard assuming that this is the detection limit.

ATTACHMENT C: GROUNDWATER CONDITIONS FOR 5 GPM FLOW RATES

ANALYTE (a)	GROUNDWATER CONCENTRATIONS (b) Average	Maximum		PRELIMINARY REMEDIATION GOAL
	all in (μg/L) except where noted at left			
Ammonia (mg/L)	13	22		
Sulfide (mg/L)	0	0		
Aluminum	2,100	9,220	*	
Antimony	0	0	*	6
Arsenic	0	0	*	
Barium	510	2,120	*	
Beryllium	2	9	*	1
Cadmium	2	5	*	5
Chromium	0	0	*	100
Cobalt	63	295	*	
Copper	0	0	*	
Iron	286,675	1,370,000	*	
Lead	37	174	*	15
Manganese	8,200	14,700	*	3,650
Mercury	0.11	0.20	*	
Nickel	5	14	*	100
Vanadium	15	65	*	
Zinc	210	133	*	7,300
Dieldrin	0.000	0.000		
2-Methylnaphthalene	0	0		
4-Chloro-3-methylphenol	0	0		
4-Methylphenol	0	0		
Pentachlorophenol	0	0		1
bis(2-Ethylhexyl)phthalate	50	230		4
1,1-Dichloroethane	3	2		
1,1-Dichloroethene	0	0		
1,2-Dichloroethene(total)	3	1		70
4-Methyl-2-pentanone	0	0		
Acetone	0	0		
Benzene	0	0		5
Carbon Disulfide	3	3		
Chloroethane	6	8		
Ethylbenzene	2	2		
Toluene	19	50		
Trichloroethene	0	0		
Vinyl Chloride	0	0		2
Acrylamide	0	0		0.02 (c)
N,N-DMF	0	0		
Hardness (mg/L)	79	214		
pH	6.5	7.1		
Total Organic Carbon (mg/L)	26	50		
Biochemical Oxygen Demand (mg/L)	9	51		

Notes:

(a). Asterisk denotes compounds that will be handled by the metals treatment system.

(b). Concentrations for metals are "total" and not dissolved values.

(c). Goal is significantly below normal analytical detection limits; evaluate potential to meet 2 μg/L standard assuming that this is the detection limit.

- Metals Treatment Quotation: Koch Membrane Systems
  System Drawings and Specifications
  M&E Quotation Request

METCALF & EDDY

JUN 29 1993

RECEIVED

KOCH

KOCH MEMBRANE SYSTEMS INC

Abcor

25 June 1993

Sean Czarniecki,
Engineer
METCALF & EDDY
30 Harvard Mill Square
Wakefield, MA 01880

Subject: South Kingston, Rhode Island

Dear Mr. Czarniecki:

To confirm our telephone conversation yesterday, we are pleased to submit budgetary estimates for the three applications you are considering for feasibility studies. All systems are based on standard KSM design and include:

UF Systems (Except UF 158 which is standard except for piping). 304 SS retentate piping, PVC permeate piping. Feed pump, rack with circ. pump piping and controls. CIP station with dual tanks. NEMA 12 steel control panel with manual controls.

RO Systems (Except once-through which has manual controls). 316 SS retentate piping, PVC permeate piping. Feed and booster pumps, rack with circ. pump piping and controls. Feed/CIP station with single tank. NEMA 12 steel control panel with semi-auto controls.

5 GPM Capacity

UF 1622 S/S once-through, mod-batch w/72 1" FEG tubes	$ 72,000.00
RO 1/6 8" SW once-through, mod-batch w/6 BW modules	$182,000.00
Total:	$254,000.00

50 GPM Capacity

UF 1622RM S/S F&B mod-batch w/736 1" FEG tubes	$260,000.00
RO 2x4/6 SIS 8" SW continuous w/48 BW modules	$383,000.00
Total:	$643,000.00

200 GPM Capacity

4 - UF 1622RM S/S F&B mod-batch w/2640 1" FEG tubes	$827,000.00
RO 4x8/6 SIS 8" SW continuous w/192 BW modules	$854,000.00
Total:	$1,681,000.00

850 Main Street ☐ Wilmington, MA 01887-3388 U.S.A. ☐ TEL. (508) 657-4250 ☐ FAX (508) 657-5208 ☐ TWX 710 347 6537

ABCOR Division of KOCH International (UK) Ltd., Stafford England ☐ ABCOR Division of KOCH International GmbH, Düsseldorf, West Germany
☐ ABCOR Division of KOCH International S.A.R.L., Paris, France
Agents and Associates in more than 20 Countries

Sean, I have included some info on our standard UF systems. The R/O information is unavailable at this time. Please refer to the attached Process and Operating Summary for a description of a modified batch cycle. Thank you for your interest in KOCH MEMBRANE SYSTEMS. If you have any questions, or require any additional information, please do not hesitate to call me.

Very Truly Yours,

Tony

Anthony J. MacDonald
KOCH MEMBRANE SYSTEMS, INC.
Northeast Regional Sales Engineer

AJMd:bal
Enclosures

KOCH
KOCH MEMBRANE SYSTEMS INC
850 Main Street □ Wilmington MA 01887-3388 U.S.A. □ TEL. (508) 657-4250 □ TWX 710 347 6537 □ FAX (508) 657-5208
Abcor

KOCH

KOCH MEMBRANE SYSTEMS INC

Terms and Conditions

Abcor

1. TIME LIMIT. All quotations are valid for a period of sixty (60) calendar days.

2. FOB POINT. Prices included herein are FOB point of manufacture. Transportation and insurance charges, if required, to be prepaid by Koch Membrane Systems, Inc., (hereinafter referred to as "KMS"), will be invoiced at actual cost to the Purchaser. Claims for shortages in shipment shall be deemed waived unless made in writing to KMS within ten (10) days after delivery.

3. PAYMENT TERMS. Payments will be made in accordance with the specified payment schedule. All payments are due net thirty (30) days from date of invoice. If in the judgement of KMS, the financial position of the purchaser does not justify the terms of payment specified, KMS may require full or partial payment prior to shipment of the goods. Purchaser agrees to furnish KMS with the required credit information. Payments for all export shipments will be in accordance with the specified payment schedule included herein by way of a confirmed, irrevocable letter of credit established in favor of KMS on a USA bank to be designated by KMS. This letter of credit is to be established at the time of award of an order. All costs associated with the letter of credit will be for the Purchaser's account.

4. TAXES. Federal, state or local sales and/or use taxes are not included in the price set forth herein.

5. WARRANTY. KMS warrants that all goods manufactured by KMS, except membranes, shall be free from defects in material and workmanship; provided, however, that this warranty shall be limited to goods found to be defective within a period of one (1) year from initial use or fifteen (15) months from the date of shipment, whichever expires first. Except as may otherwise be provided, MEMBRANES ARE SOLD AS IS. This warranty does not cover Purchaser furnished/specified equipment and/or Purchaser furnished materials. Resale products shall carry only the warranty offered by the original manufacturer.

The sole and exclusive remedy of the Purchaser for any liability of KMS of any kind, including (a) warranty, express or implied whether contained in the terms and conditions hereof or in any terms additional or supplemental hereto, (b) contract, (c) negligence, (d) tort, or (e) otherwise, is limited to the repair or replacement, FOB point of manufacture, by KMS of those goods which an examination reveals to be defective during the warranty period, or at KMS' option to refund to purchaser the money paid to KMS for such goods. Purchaser and KMS may mutually agree to acceptance of the goods "as is" with an agreed upon reduction in price. Before KMS undertakes any obligation to remedy defects, the Purchaser must give KMS written notice of its claim and return the defective goods after receipt of shipping instructions from KMS to return such goods. Purchaser will ship the goods to KMS, freight prepaid, and KMS will return the goods to Purchaser, freight collect. All goods returned for repair or replacement pursuant to this section are to be packaged in accordance with the instructions received.

In no event, shall KMS incur any obligation to repair or replace goods which are determined by KMS to be defective due to customer misuse, or due to use not in accordance with specified operating conditions, and operating and maintenance instructions. KMS retains the option to witness the operation of the goods to verify operating conditions. KMS shall not incur any obligation hereunder with respect to goods, which are repaired or modified in any way by the Purchaser without KMS prior written approval. Installation by the Purchaser during regular intervals of normal maintenance of parts supplied by KMS shall not constitute such modification.

EXCEPT FOR THE EXPRESS WARRANTY STATED HEREIN, KMS DISCLAIMS ALL WARRANTIES WITH RESPECT TO THE GOODS, INCLUDING ANY AND ALL IMPLIED WARRANTIES OF MERCHANTABILITY OR FITNESS FOR PARTICULAR PURPOSE.

6. CONFIDENTIAL INFORMATION. The information, drawings, plans and specifications being furnished by KMS have been developed at KMS' expense and shall not be used or disclosed by Purchaser for any purpose other than to install, operate, and maintain the goods supplied hereunder.

7. DELIVERIES. The delivery date(s) quoted are based on KMS' best estimate of a realistic time when delivery to the carrier will be made, and are subject to confirmation at time of acceptance of any resulting order. KMS reserves the right to make either early shipment or partial shipments and invoice Purchaser accordingly.

8. EXCUSABLE DELAYS. KMS shall not be liable for loss, damages, detention or delays resulting from causes beyond its reasonable control or caused by but not limited to strikes, restrictions of the United States Government, or other governments having jurisdiction, delays in transportation, inability to obtain necessary labor, materials, or manufacturing facilities.

9. PATENTS. The Purchaser shall indemnify and hold KMS harmless against any expense or loss or other damage resulting from infringement of patents or trademarks arising from KMS' compliance with any designs, specifications or instructions of the Purchaser.

10. TITLE AND RISK OF LOSS OR DAMAGE. Risk of loss and/or damage shall pass to the Purchaser upon delivery of the goods to the F.O.B. point. Title shall pass to the Purchaser upon receipt of final payment by KMS.

11. INSTALLATION/FIELD SERVICE. Installation of goods furnished hereunder shall be by the Purchaser, unless otherwise agreed to in writing.

Field service will be provided on a per diem basis upon written authorization by the Purchaser and will be at the rates in effect at the time such services are provided unless otherwise agreed to in writing. Field service at the jobsite to diagnose equipment problems will be provided on a per diem basis at the then current rates.

12. CANCELLATION. Cancellation of any order must be by written notice to KMS and will be subject to cancellation charges.

13. LAWS, CODES, AND STANDARDS. Except as expressly stated herein, the price and schedule included herein are based on United States laws, codes, and standards in effect as of the date of this order. Should such laws, codes, and standards change and increase or decrease the cost of performing the work or impact the schedule, KMS will advise Purchaser of such. Purchaser and KMS shall mutually agree to any modification to the order resulting from such change.

14. CONSEQUENTIAL DAMAGES/LIMIT OF LIABILITY. KMS shall not in any case whatsoever be liable for special, incidental, indirect or consequential damages of any kind. In no case shall KMS' liability exceed the amount paid to KMS by the Purchaser for the specific goods giving rise to such liability. Purchaser agrees to indemnify and hold KMS harmless from and against all liabilities, claims and demands of third parties of any kind relating to the goods and their use arising after shipment of the goods.

15. MODIFICATION. No modification or waiver of any part of this agreement shall be valid unless it is in writing and signed by an authorized representative of the Purchaser and KMS.

16. ASSIGNMENT. This agreement may not be transferred or assigned by operation of law or otherwise, without the prior express written consent of KMS. Any transfer or assignment of any rights, duties or obligations hereunder without such consent shall be void.

17. EXPORT SALES. No provision of this agreement shall be construed to require KMS to export or deliver any technical information, data and/or equipment if such export or delivery is then prohibited or restricted by any law or regulation of the U.S. Government.

18. INSURANCE. Upon the request by Purchaser, KMS will provide a Certificate of Insurance evidencing the following types of insurance:

Workers' Compensation	Statutory	
Employer Liability	$100,000.00	
Comprehensive General Liability	$1,000,000.00 Combined Single Limit for BI & PD	$1,000,000 00 Aggregate
Comprehensive Auto Liability & Physical Damage	$1,000,000.00 Combined Single Limit for BI & PD	$1,000,000.00 Aggregate

19. GOVERNING LAW. All matters involving the validity, interpretation and application to this agreement shall be controlled by the laws of the Commonwealth of Massachusetts, United States of America.

20. HEADINGS. The headings used throughout are for administrative convenience only and shall be disregarded for the purpose of construing and enforcing this agreement.

21. ENTIRE AGREEMENT. Purchaser by acceptance of KMS' offer does acknowledge and agree to the terms and conditions contained herein. Only representations, promises, conditions or understandings subsequently reduced to writing and signed by an authorized representative of each party shall be binding upon either party.

SECTION II. PROCESS AND OPERATING SUMMARY

The soluble oil or water waste treatment process begins with waste collection in an equalization tank (figure II.1). The equalization tank should have a minimum capacity of one working day unless the waste flow is highly variable, in which case a larger tank will be required. The equalization tank is to be equipped to remove, essentially completely, free oil and settleable solids. A skimming device for surface oil and sophisticated separator (e.g. API, coalescing, etc.), may be employed to remove free oil and/or suspended solids.

The waste is then transferred to a process tank (volume usually equal to 1/2 to 1 day's capacity). The withdrawal line from the equalization tank should be at least two feet off the bottom so that the settled solids will not be transferred into the process tank. The transfer pump will depend on the type of operation employed, i.e. "batch" concentration or "modified batch" concentration.

BATCH CONCENTRATION

For this operation the process tank is filled and the wastewater is circulated between the process tank and the KOCH ultrafilter. The soluble oil or water will slowly be concentrated as the clear water discharges to the sewer during the ultrafiltration cycle. Cleaning is performed between cycles or at the end of several cycles, depending on need. Two process tanks can be used to facilitate the continual processing of batches and waste collection.

MODIFIED-BATCH CONCENTRATION CYCLE

The modified-batch cycle is similar to a batch cycle except during the initial phase of the cycle (4-5 days) the process tank is kept full with fresh feed to minimize the oil concentrate of its contents. This is accomplished by using level controls to activate the transfer pump.

Following this phase, flow to the process tank is stopped by overriding the level controls. The wastewater remaining in the process tank is "batch" concentrated to the maximum oil content achievable. The final concentrate is then discharged to a holding tank for ultimate disposal and the system is cleaned for the subsequent week's operation. This phase of the cycle, i.e. batch concentration and cleaning, is normally performed in a single day.

PROCESS TANK HEATING:

The normal operating temperature range for ultrafiltration is 80°F-120°. If the influent waste temperature is significantly below 80°F, heating may be required.

Koch Membrane Systems, Inc., 850 Main Street, Wilmington, Massachusetts 01887-3388 ■ Tel. (508) 657-4250 ■ TWX 710 347 6537 ■ FAX (508) 657-5208

KOCH

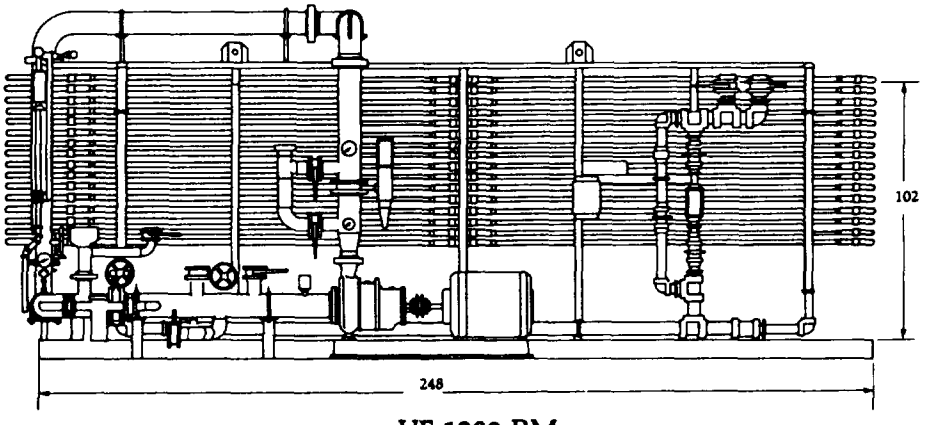
KOCH MEMBRANE SYSTEMS INC

Abcor

UF-1200 RM SYSTEM FOR TREATING INDUSTRIAL WASTEWATER

Koch Membrane Systems' UF-1200 RM (rack mount) ultrafiltration wastewater treatment system is designed for treating a variety of liquid wastes.

The system is capable of treating volumes from 34,000 gallons per day (128,700 liters per day) to 176,800 gallons per day (669,260 liters), depending on the stream:



UF-1200 RM Daily Capacity		
Typical coolant oily waste, high parts per million (i.e. 5,000-50,000 PPM initial oil and grease concentration)	Chemical and low parts per million waste (i.e. less than 5,000 PPM solids concentration	Fine particle separation (metal hydroxides, pigments)
34,000 gallons per day (128,700 liters per day)	81,600 gallons per day (308,890 liters per day)	176,800 gallons per day (669,260 liters per day)

BENEFITS	SPECIAL FEATURES
• Simple, one-step operation saves labor costs	System operation is semi-automatic requiring virtually no operator attention
• Eliminates cost of pretreatment	No pretreatment necessary. No chemicals to store or mix
• Lowers hauling costs	System reduces spent coolant and other waste volume by as much as 98%, minimizing amount to be disposed of. Plus, system generates no additional sludge
• Saves Energy	System operates at low pressure
• Rugged, versatile, easily serviced and replaced	Standard NEMA frame and TEFC motors

KOCH

KOCH MEMBRANE SYSTEMS INC

850 Main Street ☐ Wilmington, MA 01887-3388 U.S.A. ☐ TEL. (508) 657-4250 ☐ FAX (508) 657-5208

ABCOR Division of KOCH International (UK) Ltd., Stafford, England ☐ ABCOR Division of KOCH International GmbH, Düsseldorf, West Germany ☐ ABCOR Division of KOCH International S.A.R.L., Paris, France

Agents and Associates in more than 20 Countries

Standard Equipment

- 544 Abcor® tubular membranes, with 1200 square feet (111.5M²) of membrane area
- One ultrafiltration stage with:
  - One circulation pump and motor - 100 HP, 1020 gpm (3860 lpm)
  - Pressure gauges for manifold inlet/outlet
  - Pressure switches with audible-visual alarm and automatic shutdown for low pressure at circulation pump suction and high pressure at membrane module inlet
  - High temperature switch with audible-visual alarm and automatic shutdown of circulation pump
  - Temperature indicator
  - Permeate glass-tube rotameter
  - Entrance piping Y-connection and screens for convenient manual insertion and removal of spongeballs for mechanical cleaning during chemical cleaning
  - Air vent and vacuum breaker assembly
- One Cleaning Tankage Sub-assembly, including:
  - 600 gallon (2270 liter) tank
  - Temperature indicator in tank
  - Steam sparger system with a temperature control valve
- One Cleaning Pump Package Sub-assembly, including:
  - One cleaning pump and motor - 15 HP, 300 gpm (1135 lpm)
  - Pressure gauge for cleaning pump discharge
  - Pressure switch with audible-visual alarm and automatic shutdown for low pressure at cleaning pump discharge
  - High temperature switch with audible-visual alarm and automatic shutdown on cleaning pump suction
- All valves, piping, and wiring
- One free standing local control panel

DIMENSIONS

Length:	21 feet	(6.4M)
Width:	10 feet	(3M)
Height:	9 feet	(2.7M)
Oper. Wt.:	13,250 lbs.	(6,010Kg)
Ship Wt.:	10,525 lbs.	(4,775Kg)

ULTRAFILTRATION

Ultrafiltration (UF) is a low pressure (10-150 PSI [1.4 -21.7 KPA]) membrane process for separating suspended solids and high molecular weight dissolved materials from liquids.

Fluid flows across the membrane surface at high velocity. This cross-flow characteristic differs from the perpendicular flow of ordinary filtration, where a "cake" builds up on the filter surface requiring frequent filter replacement or cleaning. Cross-flow prevents filter-cake buildup, resulting in high filtration rates that can be maintained continuously.

Ultrafiltration is a proven, reliable, simple (one-step), treatment process that requires minimum energy and minimum operator attention.

MEMBRANES

Koch manufactures Abcor® membranes, the most rugged reliable available for industrial wastewater treatment. Membranes are available in a broad range of molecular weight cutoffs. Koch engineers will study your stream then recommend the best membrane for treating your system.

The UF-1200 RM comes equipped with membranes in tubular form. The benefits are as follows:

- They are easy to clean and require no flow reversal, which weakens membranes.
- Superior, more chemically resistant polymer selection and rugged design means these membranes will last two to three times longer than others.

START-UP, TRAINING AND SERVICE

Koch's Technical Service Department will start up your system and train operators in how to run the system. You will receive an in-depth operating manual, in addition to training. Service engineers are available to help you with system operation at any time during the life of the equipment.

Koch's Technical Service Department is committed to making sure your system operates efficiently day after day. Simply call, and one of our Tech Service engineers will help you optimize performance of your system.

THE KOCH DIFFERENCE

Koch doesn't just sell you membranes and systems. Our technical staff studies your specific wastewater problem, conducts feasibility tests if necessary, specifies and designs the right membrane and system for your needs, then works with you to ensure that our products perform as promised.

Find out more by calling o. writing today. Let Koch show you how you too can take advantage of the simplest, most economical approach to treating wastewater.

KOCH

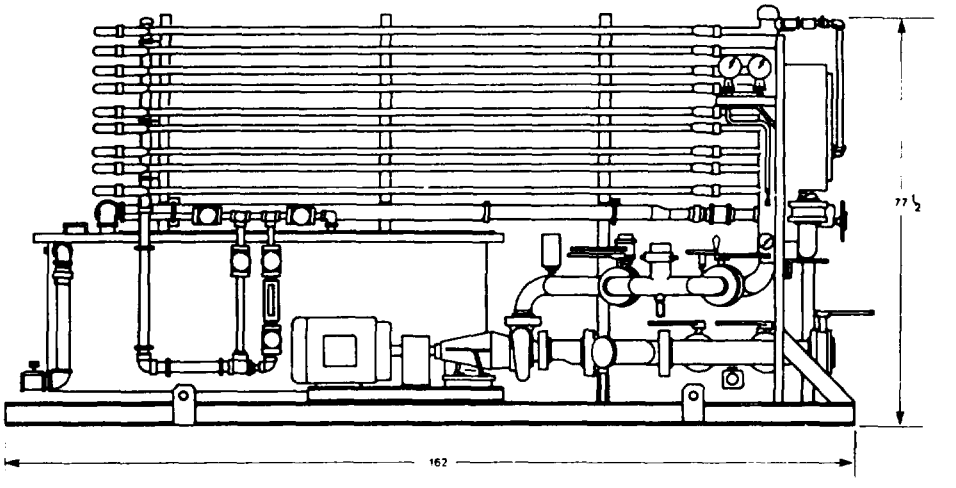
KOCH MEMBRANE SYSTEMS INC

Abcor

UF-158 SYSTEM FOR TREATING INDUSTRIAL WASTEWATER

Koch Membrane Systems' UF-158 ultrafiltration wastewater treatment system is designed for both pilot and demonstration applications and for use as a fully operational system for treating a variety of liquid wastes.

The system is capable of treating volumes from 4,500 gallons per day (17,035 liters per day) to 23,400 gallons per day (88,580 liters), depending on the stream:



UF-158 Daily Capacity		
Typical coolant oily waste, high parts per million (i.e. 5,000-50,000 PPM initial oil and grease concentration)	Chemical and low parts per million waste (i.e. less than 5,000 PPM solids concentration	Fine particle separation (metal hydroxides, pigments)
4,500 gallons per day (17,035 liters per day)	10,800 gallons (40,880 liters per day)	23,400 gallons per day (88,580 liters per day)

BENEFITS	SPECIAL FEATURES
• Simple, one-step operation saves labor costs	System operation is semi-automatic requiring virtually no operator attention
• Eliminates cost of pretreatment	No pretreatment necessary. No chemicals to store or mix
• Lowers hauling costs	System reduces spent coolant and other waste volume by as much as 98%, minimizing amount to be disposed of. Plus, system generates no additional sludge
• Saves Energy	System operates at low pressure
• Rugged, versatile, easily serviced and replaced	Standard NEMA frame and TEFC motors

KOCH

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850 Main Street ☐ Wilmington, MA 01887-3388 U.S.A. ☐ TEL. (508) 657-4250 ☐ FAX (508) 657-5208

ABCOR Division of KOCH International (UK) Ltd., Stafford, England ☐ ABCOR Division of KOCH International GmbH, Düsseldorf, West Germany ☐ ABCOR Division of KOCH International S.A.R.L., Paris, France

Agents and Associates in more than 20 Countries

Standard Equipment

- 72 Abcor® tubular membranes with 158 square feet (14.6M²) of membrane area
- Centrifugal circulation pumping system, 15 HP, 270 gpm (1025 lpm)
- Feed temperature gauge
- Two pressure gauges
- High temperature switch interlocked to circulation pump
- Low pressure switch interlocked to circulation pump
- Audible-visual alarms for high temperature and low pressure switches
- Permeate line direct reading flowmeter
- All valves, piping and internal wiring
- Cleaning tank and associated piping
- Control panel
- Spongeballs (1 dozen) for mechanical cleaning. Semi-automatic operation
- Koch liquid detergent (5 gallons [19 liters])

DIMENSIONS

Length:	14 feet (4.2M)
Width:	4 feet (1.2M)
Height:	7 feet (2.1M)
Oper. Wt.:	5,125 lbs. (2,325Kg)
Ship. Wt.:	4,825 lbs. (2,190Kg)
Voltage:	230/460 VAC, 3 phase, 60 Hz

ULTRAFILTRATION

Ultrafiltration (UF) is a low pressure (10-150 PSI [1.4 -21.7 KPA]) membrane process for separating suspended solids and high molecular weight dissolved materials from liquids.

Fluid flows across the membrane surface at high velocity. This cross-flow characteristic differs from the perpendicular flow of ordinary filtration, where a "cake" builds up on the filter surface requiring frequent filter replacement or cleaning. Cross-flow prevents filter-cake buildup, resulting in high filtration rates that can be maintained continuously.

Ultrafiltration is a proven, reliable, simple (one-step), treatment process that requires minimum energy and minimum operator attention.

MEMBRANES

Koch manufactures Abcor® membranes, the most rugged and reliable available for industrial wastewater treatment. Membranes are available in a broad range of molecular weight cutoffs. Koch engineers will study your stream then recommend the best membrane for treating your system.

The UF-158 comes equipped with membranes in tubular form. The benefits are as follows:

- They are easy to clean and require no flow reversal, which weakens membranes.
- Superior, more chemically resistant polymer selection and rugged design means these membranes will last two to three times longer than others.

START-UP, TRAINING AND SERVICE

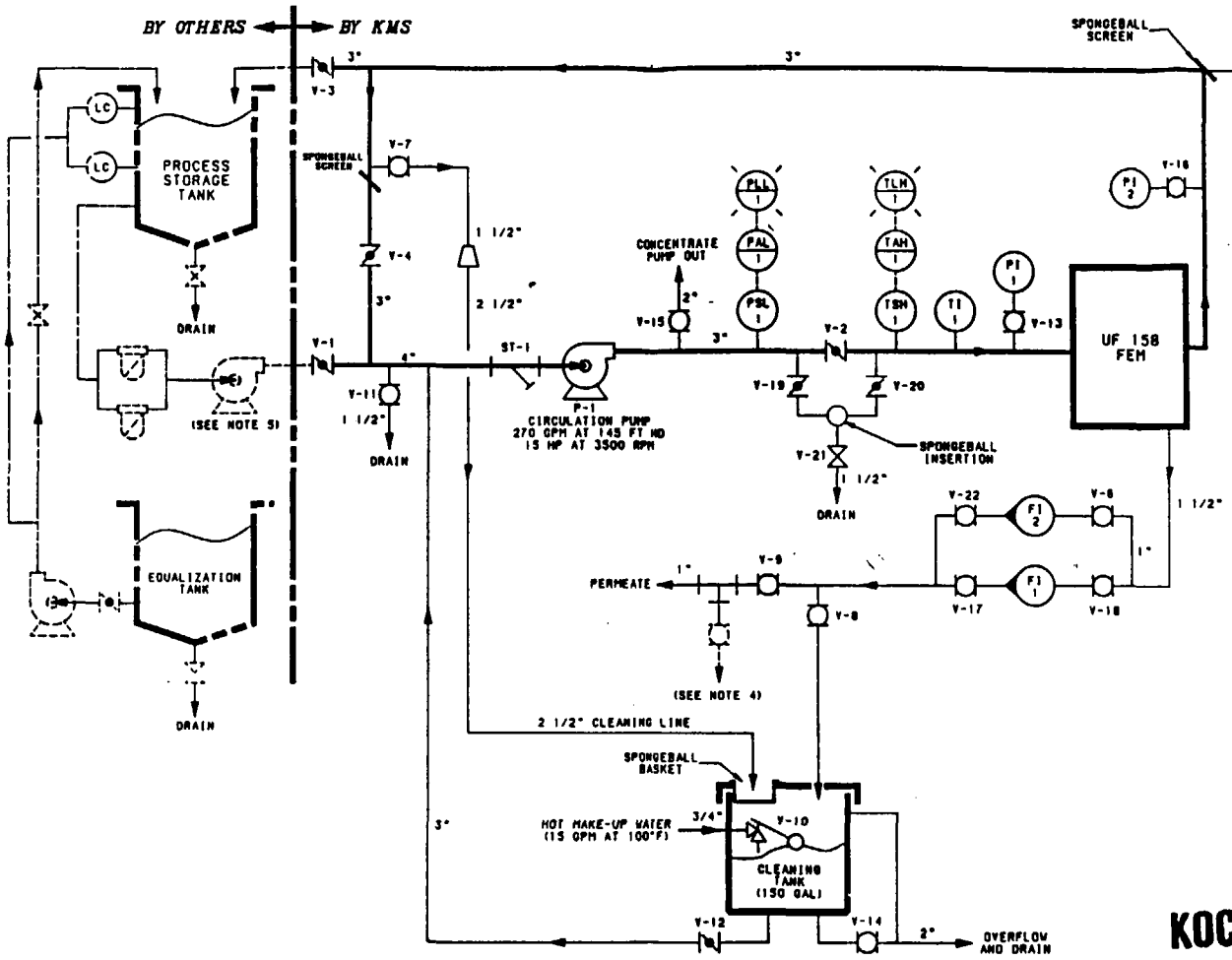
Koch's Technical Service Department will start up your system and train operators in how to run the system. You will receive an in-depth operating manual, in addition to training. Service engineers are available to help you with system operation at any time during the life of the equipment.

Koch's Technical Service Department is committed to making sure your system operates efficiently day after day. Simply call, and one of our Tech Service engineers will help you optimize performance of your system.

THE KOCH DIFFERENCE

Koch doesn't just sell you membranes and systems. Our technical staff studies your specific wastewater problem, conducts feasibility tests if necessary, specifies and designs the right membrane and system for your needs, then works with you to ensure that our products perform as promised.

Find out more by calling or writing today. Let Koch show you how you too can take advantage of the simplest, most economical approach to treating wastewater.



NOTES:

1. SYMBOLS PER ISA STANDARD S5.1
2. UNIT DESIGN PARAMETERS:
   A) UF 158 FE-M
      9 PARALLEL PASSES OF 8 IN SERIES
   B) FLOW PER TUBE: 30GPM
   C) INLET PRESSURE: 50 PSIG
   D) OUTLET PRESSURE: 18 PSIG
   E) OPERATING TEMPERATURE: 100°F (NORMAL)
      125°F (MAXIMUM)
   F) MAXIMUM ALLOWABLE PERMEATE BACK PRESSURE: 5 PSIG
3. LAST VALVE NO. USED 24
4. 1" BALL VALVE BY OTHERS
5. SYSTEM IS DESIGNED FOR STRAIGHT BATCH OPERATION WITH PROCESS TANK ON SAME FLOOR LEVEL AS UF SYSTEM. FEED PUMP WILL BE REQUIRED IF PROCESS TANK IS BELOW UF SYSTEM.

KOCH CONFIDENTIAL

REVISIONS			
SYM	DESCRIPTION	APPROVAL	DATE
A	APPROVED & RELEASED		
D	REDRAWN ON CAD	A.M.P.	4-14-89
E	RELOCATED TSH-1 PER ECO F649	[illegible]	7-10-90

SEPARATE PARTS LIST

YES ☐ NO ☒

APPLICATION

USED ON

UNLESS OTHERWISE SPECIFIED DIMENSIONS ARE IN INCHES
TOLERANCES ON:
ANGLES, ±
FRACTIONS, ±
DECIMALS, .XX ±
.XXX ±

MATERIAL:

FINISH:

	NAME	DATE
DRAWN	R. J.	4-14-89
CHECKED	A.M.P.	4-14-89
ENGINEER		
PROJ APP		
MICROFILM		
PROJ NO.		

KOCH
KOCH MEMBRANE SYSTEMS INC
850 Main Street Wilmington, Ma. 01887

Abcor MEMBRANES

TITLE UF-158 FE-M O/W SYSTEM
FLOW SCHEMATIC
(15 HP 3500 RPM)

KMS PART NO.	SIZE		REV.
	C	5388-5017	E

Metcalf & Eddy
An Air & Water Technologies Company

004609-0018-010-001

June 17, 1993

Mr. Anthony J. MacDonald
Sales Engineer
Northeast Region
Koch Membrane Systems, Inc.
850 Main Street
Wilmington, Massachusetts 01887-3388

Subject: **Contract No. 68-W9-0036**
Work Assignment No. 18-1LA5
Rose Hill Regional Landfill Superfund Site,
South Kingstown, Rhode Island
Request for Quotation on Equipment, Services and Budgetary Costs - Treatment of Contaminated Groundwater using Membrane Filtration

Dear Mr. MacDonald:

Metcalf & Eddy (M&E) is currently finalizing the Feasibility Study (FS) for treatment of contaminated groundwater at the Rose Hill Landfill site. This groundwater is contaminated with weak, municipal landfill leachate. M&E has identified reverse osmosis as an appropriate method for removing th inorganic compounds-of-concern (COCs). I attended your seminar in Newton this morning and feel that your company has the perfect background to assist us on this project.

I am requesting a quotation describing suggested equipment, services and budgetary costs should be based on the following assumptions:

1) quotations are needed for two different systems; groundwater concentrations are shown in Attachment A for the 50 gpm system (Alternative 4) and Attachment B for the 200 gpm system (Alternative 5).
2) treatment goals are listed in each attachment by compound; for the inorganic compounds, please identify any compounds that <u>may not meet goals</u>.
3) organics will be treated by a UV/Chemical oxidation system after inorganics removal; if you feel this should be placed prior to reverse osmosis due to organics affecting the membrane, please state this.
4) assume a water temperature of 55 degrees F.
5) 50 gpm flowrate may be as low as 5 gpm; will your system still operate effectively? This will probably require semi-batch processing.
6) treated water discharges to recharge wells or to river.
7) identify operations and maintenance services necessary for your proposed system.
8) identify the make & model of your proposed system; please include copies of brochures, drawings and specifications.
9) assume budgetary costs accuracy for equipment, f.o.b.

30 Harvard Mill Square, Wakefield, MA 01880
Mailing Address: PO Box 4043, Woburn, MA 01888-4043

10) identify any other potential pretreatment or special conditions that you feel may be necessary for proper operation.

Based on my understanding of today's seminar, I am assuming that you would perform a precipitation followed by ultrafiltration, and then polish the stream using reverse osmosis. It would be appreciated if costs for the system were broken down into those three steps. I would also assume that you would employ modified batch processing to reduce the volume of waste to be disposed of. An approximate volume of this waste generated would be helpful. As this is a closed landfill, there is currently no equipment (i.e. tanks) available for use. These would need to be included in the system. I understand that without a pilot test, the membrane costs will be very rough, but since this is a feasibility study, we cannot perform such a test.

Your quotations are needed by the end-of-day Thursday, June 24, 1993. Thank you for your assistance with this project. If you have any questions, please do not hesitate to contact me at TEL (617) 246-5200, extension 4811 or by FAX at (617) 245-6293.

Very truly yours,

METCALF & EDDY, INC.

Sean Czarniecki

Sean Czarniecki
Engineer II,
Industrial & Hazardous Waste Division

Attachments
cc: D. Peters
WA#18-1LA5

ATTACHMENT A: GROUNDWATER CONDITIONS FOR THE 50 GPM SYSTEM

ANALYTE (a)	GROUNDWATER CONCENTRATIONS (b) Average	Maximum		PRELIMINARY REMEDIATION GOAL
	all in (μg/L) except where noted at left			
Ammonia (mg/L)	9	48		
Sulfide (mg/L)	1	4		
Aluminum	12,616	98,281	*	87
Antimony	0	0	*	6
Arsenic	2	9	*	
Barium	210	695	*	
Beryllium	2	13	*	1
Cadmium	4	36	*	5
Chromium	21	136	*	100
Cobalt	21	82	*	
Copper	37	324	*	
Iron	91,571	396,140	*	1,000
Lead	40	180	*	15
Manganese	2,633	10,361	*	45
Mercury	0.11	0.29	*	
Nickel	24	112	*	100
Vanadium	20	133	*	
Zinc	625	6,520	*	7,300
Dieldrin	0.043	0.003		
2-Methylnaphthalene	4	4		
4-Chloro-3-methylphenol	4	4		
4-Methylphenol	8	64		
Pentachlorophenol	12	3		1
bis(2-Ethylhexyl)phthalate	11	59		4
1,1-Dichloroethane	13	195		
1,1-Dichloroethene	4	2		
1,2-Dichloroethene(total)	30	645		70
4-Methyl-2-pentanone	5	27		
Acetone	20	415		
Benzene	10	27		5
Carbon Disulfide	13	77		
Chloroethane	16	77		
Ethylbenzene	14	64		
Toluene	31	156		
Trichloroethene	4	4		
Vinyl Chloride	30	610		2
Acrylamide	141	202		0.02 (c)
N,N-DMF	177	1,273		
Hardness (mg/L)	151	621		
pH	7.1	11.9		
Total Organic Carbon (mg/L)	44	200		
Biochemical Oxygen Demand (mg/L)	12	112		

Notes:

(a). Asterisk denotes compounds that will be handled by the metals treatment system.

(b). Concentrations for metals are "total" and not dissolved values.

(c). Goal is significantly below normal analytical detection limits; evaluate potential to meet 2 μg/L standard assuming that this is the detection limit.

ATTACHMENT B: GROUNDWATER CONDITIONS FOR THE 200 GPM SYSTEM

ANALYTE (a)	GROUNDWATER CONCENTRATIONS (b) Average	Maximum		PRELIMINARY REMEDIATION GOAL
	all in (μg/L) except where noted at left			
Ammonia (mg/L)	11	30		
Sulfide (mg/L)	1	7		
Aluminum	14,277	76,745	*	87
Antimony	10	46	*	6
Arsenic	2	7	*	
Barium	136	445	*	
Beryllium	2	9	*	1
Cadmium	3	25	*	5
Chromium	17	94	*	100
Cobalt	18	53	*	
Copper	47	215	*	
Iron	60,644	218,437	*	1,000
Lead	32	154	*	15
Manganese	2,305	8,391	*	45
Mercury	0.10	0.22	*	
Nickel	27	93	*	100
Vanadium	20	115	*	
Zinc	348	3,135	*	7,300
Dieldrin	0.020	0.001		
2-Methylnaphthalene	3	2		
4-Chloro-3-methylphenol	2	2		
4-Methylphenol	8	56		
Pentachlorophenol	6	1		1
bis(2-Ethylhexyl)phthalate	4	21		4
1,1-Dichloroethane	7	89		
1,1-Dichloroethene	3	1		
1,2-Dichloroethene(total)	14	293		70
4-Methyl-2-pentanone	2	12		
Acetone	21	329		
Benzene	5	13		5
Carbon Disulfide	11	57		
Chloroethane	8	37		
Ethylbenzene	7	29		
Toluene	21	121		
Trichloroethene	2	2		
Vinyl Chloride	14	276		2
Acrylamide	64	92		0.02 (c)
N,N-DMF	84	600		
Hardness (mg/L)	86	330		
pH	6.9	9.8		
Total Organic Carbon (mg/L)	28	125		
Biochemical Oxygen Demand (mg/L)	7	58		

Notes:

(a). Asterisk denotes compounds that will be handled by the metals treatment system.

(b). Concentrations for metals are "total" and not dissolved values.

(c). Goal is significantly below normal analytical detection limits; evaluate potential to meet 2 μg/L standard assuming that this is the detection limit.

ATTACHMENT C: GROUNDWATER CONDITIONS FOR 5 GPM FLOW RATES

ANALYTE (a)	GROUNDWATER CONCENTRATIONS (b) Average	Maximum		PRELIMINARY REMEDIATION GOAL
	all in (μg/L) except where noted at left			
Ammonia (mg/L)	13	22		
Sulfide (mg/L)	0	0		
Aluminum	2,100	9,220	*	87
Antimony	0	0	*	6
Arsenic	0	0	*	
Barium	510	2,120	*	
Beryllium	2	9	*	1
Cadmium	2	5	*	5
Chromium	0	0	*	100
Cobalt	63	295	*	
Copper	0	0	*	
Iron	286,675	1,370,000	*	1,000
Lead	37	174	*	15
Manganese	8,200	14,700	*	45
Mercury	0.11	0.20	*	
Nickel	5	14	*	100
Vanadium	15	65	*	
Zinc	210	133	*	7,300
Dieldrin	0.000	0.000		
2-Methylnaphthalene	0	0		
4-Chloro-3-methylphenol	0	0		
4-Methylphenol	0	0		
Pentachlorophenol	0	0		1
bis(2-Ethylhexyl)phthalate	50	230		4
1,1-Dichloroethane	3	2		
1,1-Dichloroethene	0	0		
1,2-Dichloroethene(total)	3	1		70
4-Methyl-2-pentanone	0	0		
Acetone	0	0		
Benzene	0	0		5
Carbon Disulfide	3	3		
Chloroethane	6	8		
Ethylbenzene	2	2		
Toluene	19	50		
Trichloroethene	0	0		
Vinyl Chloride	0	0		2
Acrylamide	0	0		0.02 (c)
N,N-DMF	0	0		
Hardness (mg/L)	79	214		
pH	6.5	7.1		
Total Organic Carbon (mg/L)	26	50		
Biochemical Oxygen Demand (mg/L)	9	51		

Notes:

(a). Asterisk denotes compounds that will be handled by the metals treatment system.

(b). Concentrations for metals are "total" and not dissolved values.

(c). Goal is significantly below normal analytical detection limits; evaluate potential to meet 2 μg/L standard assuming that this is the detection limit.

- Metals Treatment Quotation: Osmonics M&E Quotation Request

OSMONICS, INC.

5951 Clearwater Drive
Minnetonka, Minnesota 55343-8990 USA
(15 miles west of Minneapolis airport)
Phone: 612/933-2277
Fax: 612/933-0141 • Telex: 29-0847

WATER PURIFICATION, FLUID HANDLING, FILTRATION AND SEPARATION SPECIALISTS SINCE 1969

June 16, 1993

Mr. Sean Czarniecki
METCALF & EDDY
30 Harvard Mill Square
Wakefield, MA 01880

Re: Budgetary Information on MPE Contract Number 68-W9-0036

Dear Sean:

Thank you for your interest in Osmonics and our products. We are pleased to provide information on reverse osmosis (RO).

Based on the water analyses provided, it appears that reverse osmosis could be viable in conjunction with other technologies. To make membrane technology feasible, extensive pretreatment would be required to precipitate many of the constituents prior to further concentration by the RO. Liquids with low osmotic pressure and Langelier Saturation Index (LSI) less than zero may allow an RO to operate with recoveries as high as 75%. For your applications, this could provide concentrate flows as low as 12.5 gpm and 50 gpm. This reduced volume could then be sent to an evaporator for further treatment.

A budget number for RO's for these systems would be 145,000-175,000 for a 50-gpm feed and 350,000-470,000 for the 200-gpm feed. Osmonics is also involved with media filters and ozone among other equipment. Ozone could be used as an oxidant to assist precipitation as well as destruction of bacteria.

Typical equipment for an RO includes:

<u>CHF DELUXE RO MACHINE</u>

SEPA® Membrane
OSMO® Sepralators
PVC or 304SS Sepralator Housings
Variable Recovery
Thermal Cut-Out Switch (set at 105°F)
Concentrate Flow Meter
Permeate Flow Meter
Primary/Final Pressure Gauges
5-Micron HYTREX® Prefilter Cartridge and Housing
TONKAFLO® Multi-Stage Centrifugal Pump
UNI pH Monitor
Conductivity Meter
PVC, 304SS or 316SS Piping. "L" grades would also be available.

cont...

Enclosed are pages detailing RO as well as an Osmonics Family Product Binder which contains information on the various product lines we offer. Please call us at 612/933-2277 if there are any questions.

Sincerely,

OSMONICS, INC.

Alan T. Rivers

Alan T. Rivers
Application Engineer
Engineered Products & Systems

ATR/pc

Encl: Family Product Binder
A Historical Perspective of UF and RO Membrane Development
Engineering Memo #13

cc: Mr. Harold S. Gooding, Sales Engineer, Engineered Products & Systems, OSMONICS, INC.

Metcalf & Eddy
An Air & Water Technologies Company

004609-0018-010-001

May 24, 1993

Mr. Harold S. Gooding
Sales Engineer
Engineered Products & Systems
Osmonics
5951 Clearwater Drive
Minnetonka, Minnesota 55343

Subject: **Contract No. 68-W9-0036**
Work Assignment No. 18-1LA5
Rose Hill Regional Landfill Superfund Site
South Kingston, Rhode Island
Request for Quotation on Equipment, Services and Budgetary Costs - Treatment of Contaminated Groundwater using Reverse Osmosis

Dear Mr Gooding:

Metcalf & Eddy (M&E) is currently finalizing the Feasibility Study (FS) for treatment of contaminated groundwater at the Rose Hill Landfill site. As previously discussed, this groundwater is contaminated with weak, municipal landfill leachate. M&E has identified reverse osmosis as an appropriate method for removing the inorganic compounds-of-concern (COCs).

A quotation describing suggested equipment, services and budgetary costs should be based on the following assumptions:

1) quotations are needed for two different systems; groundwater concentrations are shown in Attachment A for the 50 gpm system (Alternative 4) and Attachment B for the 200 gpm system (Alternative 5).
2) treatment goals are listed in each attachment by compound; for the inorganic compounds, please identify any compounds that <u>may not meet goals</u>.
3) organics will be treated by a UV/Chemical oxidation system after inorganics removal.
4) assume a water temperature of 55 degrees F.
5) 50 gpm flowrate may be as low as 5 gpm (conditions shown in Attachment C); will your system still operate effectively ?
6) treated water discharges to recharge wells or to river.
7) identify operations and maintenance services necessary for your proposed system.
8) identify the make & model of your proposed system; please include copies of brochures, drawings and specifications that you may not have already provided to me.
9) assume budgetary costs accuracy for equipment, f.o.b.

30 Harvard Mill Square, Wakefield MA 01880
Mailing Address PO Box 4043 Woburn MA 01888-4043
617-246-5300 FAX 617-245-6293

10) identify any other potential pretreatment or special conditions that you feel may be necessary for proper operation.

Your quotations are needed by the end-of-day Friday, June 4, 1993. While looking at your sizing calculations, I noticed that the aluminum concentration you used was an order of magnitude too high. I was also wondering if the ratio of $Mn(OH)_2$ to Mn is actually 2.32. These items may affect the size of equipment you have selected for us and I would appreciate it if you could take a quick look at them again.

Thank you for your assistance with this project. If you have any questions, please do not hesitate to contact me at TEL (617) 246-5200, extension 4811 or by FAX at (617) 245-6293.

Very truly yours,

METCALF & EDDY, INC.

Sean Czarniecki

Sean Czarniecki
Engineer II,
Industrial & Hazardous Waste Division

Attachments
cc: D. Peters
WA#18-1LA5

Mr. Frank Estill
Global Technologies, Inc.
2 Gordon Street
Simsbury, CT 06070

ATTACHMENT A: GROUNDWATER CONDITIONS FOR THE 50 GPM SYSTEM

ANALYTE (a)	GROUNDWATER CONCENTRATIONS (b) Average	Maximum		PRELIMINARY REMEDIATION GOAL
	all in (μg/L) except where noted at left			
Ammonia (mg/L)	9	48		
Sulfide (mg/L)	1	4		
Aluminum	12,616	98,281	*	← 87
Antimony	0	0	*	6
Arsenic	2	9	*	
Barium	210	695	*	
Beryllium	2	13	*	1
Cadmium	4	36	*	5
Chromium	21	136	*	100
Cobalt	21	82	*	
Copper	37	324	*	
Iron	91,571	396,140	*	1,000
Lead	40	180	*	15
Manganese	2,633	10,361	*	~~3,650~~ 45
Mercury	0.11	0.29	*	
Nickel	24	112	*	100
Vanadium	20	133	*	
Zinc	625	6,520	*	7,300
Dieldrin	0.043	0.003		
2-Methylnaphthalene	4	4		
4-Chloro-3-methylphenol	4	4		
4-Methylphenol	8	64		
Pentachlorophenol	12	3		1
bis(2-Ethylhexyl)phthalate	11	59		4
1,1-Dichloroethane	13	195		
1,1-Dichloroethene	4	2		
1,2-Dichloroethene(total)	30	645		70
4-Methyl-2-pentanone	5	27		
Acetone	20	415		
Benzene	10	27		5
Carbon Disulfide	13	77		
Chloroethane	16	77		
Ethylbenzene	14	64		
Toluene	31	156		
Trichloroethene	4	4		
Vinyl Chloride	30	610		2
Acrylamide	141	202		0.02 (c)
N,N-DMF	177	1,273		
Hardness (mg/L)	151	621		
pH	7.1	11.9		
Total Organic Carbon (mg/L)	44	200		
Biochemical Oxygen Demand (mg/L)	12	112		

Notes:

(a). Asterisk denotes compounds that will be handled by the metals treatment system.

(b). Concentrations for metals are "total" and not dissolved values.

(c). Goal is significantly below normal analytical detection limits; evaluate potential to meet 2 μg/L standard assuming that this is the detection limit.

ATTACHMENT B: GROUNDWATER CONDITIONS FOR THE 200 GPM SYSTEM

ANALYTE (a)	GROUNDWATER CONCENTRATIONS (b) Average	Maximum	PRELIMINARY REMEDIATION GOAL	
	all in (μg/L) except where noted at left			
Ammonia (mg/L)	11	30		
Sulfide (mg/L)	1	7		
Aluminum	14,277	76,745	*	87
Antimony	10	46	*	6
Arsenic	2	7	*	
Barium	136	445	*	
Beryllium	2	9	*	1
Cadmium	3	25	*	5
Chromium	17	94	*	100
Cobalt	18	53	*	
Copper	47	215	*	
Iron	60,644	218,437	*	1,000
Lead	32	154	*	15
Manganese	2,305	8,391	*	~~3,650~~ 45
Mercury	0.10	0.22	*	
Nickel	27	93	*	100
Vanadium	20	115	*	
Zinc	348	3,135	*	7,300
Dieldrin	0.020	0.001		
2-Methylnaphthalene	3	2		
4-Chloro-3-methylphenol	2	2		
4-Methylphenol	8	56		
Pentachlorophenol	6	1		1
bis(2-Ethylhexyl)phthalate	4	21		4
1,1-Dichloroethane	7	89		
1,1-Dichloroethene	3	1		
1,2-Dichloroethene(total)	14	293		70
4-Methyl-2-pentanone	2	12		
Acetone	21	329		
Benzene	5	13		5
Carbon Disulfide	11	57		
Chloroethane	8	37		
Ethylbenzene	7	29		
Toluene	21	121		
Trichloroethene	2	2		
Vinyl Chloride	14	276		2
Acrylamide	64	92		0.02 (c)
N,N-DMF	84	600		
Hardness (mg/L)	86	330		
pH	6.9	9.8		
Total Organic Carbon (mg/L)	28	125		
Biochemical Oxygen Demand (mg/L)	7	58		

Notes:

(a). Asterisk denotes compounds that will be handled by the metals treatment system.

(b). Concentrations for metals are "total" and not dissolved values.

(c). Goal is significantly below normal analytical detection limits; evaluate potential to meet 2 μg/L standard assuming that this is the detection limit.

ATTACHMENT C: GROUNDWATER CONDITIONS FOR 5 GPM FLOW RATES

ANALYTE (a)	GROUNDWATER CONCENTRATIONS (b) Average	Maximum		PRELIMINARY REMEDIATION GOAL
	all in (μg/L) except where noted at left			
Ammonia (mg/L)	13	22		
Sulfide (mg/L)	0	0		
Aluminum	2,100	9,220	*	87
Antimony	0	0	*	6
Arsenic	0	0	*	
Barium	510	2,120	*	
Beryllium	2	9	*	1
Cadmium	2	5	*	5
Chromium	0	0	*	100
Cobalt	63	295	*	
Copper	0	0	*	
Iron	286,675	1,370,000	*	1,000
Lead	37	174	*	15
Manganese	8,200	14,700	*	~~3,650~~ 45
Mercury	0.11	0.20	*	
Nickel	5	14	*	100
Vanadium	15	65	*	
Zinc	210	133	*	7,300
Dieldrin	0.000	0.000		
2-Methylnaphthalene	0	0		
4-Chloro-3-methylphenol	0	0		
4-Methylphenol	0	0		
Pentachlorophenol	0	0		1
bis(2-Ethylhexyl)phthalate	50	230		4
1,1-Dichloroethane	3	2		
1,1-Dichloroethene	0	0		
1,2-Dichloroethene(total)	3	1		70
4-Methyl-2-pentanone	0	0		
Acetone	0	0		
Benzene	0	0		5
Carbon Disulfide	3	3		
Chloroethane	6	8		
Ethylbenzene	2	2		
Toluene	19	50		
Trichloroethene	0	0		
Vinyl Chloride	0	0		2
Acrylamide	0	0		0.02 (c)
N,N-DMF	0	0		
Hardness (mg/L)	79	214		
pH	6.5	7.1		
Total Organic Carbon (mg/L)	26	50		
Biochemical Oxygen Demand (mg/L)	9	51		

Notes:

(a). Asterisk denotes compounds that will be handled by the metals treatment system.

(b). Concentrations for metals are "total" and not dissolved values.

(c). Goal is significantly below normal analytical detection limits; evaluate potential to meet 2 μg/L standard assuming that this is the detection limit.

- UV/Chemical Oxidation Quotation: Solarchem
  Cost Estimates
  Performance Specification
  System Drawings
  M&E Quotation Request

Solarchem

May 25, 1993

METCALF & EDDY, INC.
JUN 1 1993
RECEIVED

Mr. Dan Peters
Metcalf and Eddy, Inc.
P O Box 4043
Woburn, MA
01888-4043

As a follow up to our recent telephone conversation, I am writing to provide a cost estimate to treat your groundwater with our **Rayox**® UV/Oxidation system.

Solarchem has a strong experience base in the treatment of contaminated wastewater and groundwater, with commercial **Rayox**® installations treating between 2 gpm and 600 gpm of water with the following contaminants:

- BTEX, MTBE for the oil and gas industry
- PCP, Phenols, PAH's for the wood treating industry
- Chlorinated Solvents (TCE, PCE) for the chemical industry
- NG, TNT, DNT for the explosives industry

Details on the treatment of these and other contaminants are given in the enclosed brochure and technical papers. Of particular interest to you may be the technical papers, where our experience treating various VOCs is outlined.

Features and advantages of the **Rayox**® Second Generation UV/Oxidation process include:

- *Destruction of up to 99.999+% of contaminants* - no transfer of toxic material from one medium to another.
- *Proprietary Solarchem UV lamps* - significantly enhanced output in the region of the UV spectrum where virtually all organic contaminants are most photochemically active gives inherently lower operating costs from simultaneous oxidation/photolysis of organics.
- *Transmittance Controller* - a proven and effective wiper mechanism prevents fouling of the UV lamp, which increases system efficiency and eliminates the need for a metals pretreatment system or shutdown for cleaning.
- *ENOX catalysts* - proprietary reagents and processes can reduce capital costs and enhance performance.
- *Programmable Logic Controller (PLC)* - maintains automatic, failsafe, unattended operation, reduces operator time and costs, and adds flexibility for variable flow rates or future additions. A PLC also allows use of a message window for easy diagnostics, and a modem and telephone dialer for easy servicing and remote monitoring.

130 Royal Crest Court
Markham, Ontario
Canada, L3R 0A1
Telephone: (416) 477 - 9242
Facsimile: (416) 477 - 4511

7320 Smoke Ranch Road
Las Vegas, Nevada 89128
USA
Telephone: (702) 255 - 7055
Facsimile: (702) 255 - 7280

Solarchem

Cost Estimate:

Based on our extensive experience treating organics in groundwater we estimate that to treat to the performance specifications attached as Table 1, the following system will be required:

Alternative 4 (50 gpm)

1 x 30 kW **Rayox**® UV/Oxidation System

Capital Investment $ 80,000

Alternative 5 (200 gpm)

4 x 30 kW **Rayox**® UV/Oxidation System

Capital Investment $ 175,00

Including:

- **Rayox**® reactors and power supplies
- Peroxide Delivery System
- Catalyst Delivery System
- System Controller (PLC)
- Operation Manual
- Heat Exchanger

For your reference, I have attached drawings showing dimensions of a 1 x 30 kW and a 4 x 30 kW **Rayox**® skid and the peroxide delivery system.

Based on $0.05 per kWh for electrical power in your area, and market rates for H_2O_2, the following are typical operating costs:

	$/1000USG
Electrical Power	$ 0.50
Replacement UV Lamps	0.25
Hydrogen Peroxide	0.15
Total Operating Costs	$ 0.90

Other information pertinent to this estimate is as follows:

- Normal delivery is 12-16 weeks.
- Leasing terms can be arranged.
- Solarchem warrants the performance of the system indefinitely, as well as the materials and workmanship of its equipment for a period of one year after installation date.
- Periodic maintenance contracts are available. Normal maintenance includes daily logging of system parameters and approximately 4 hours/month of maintenance.
- Solarchem offers 48 hour emergency service to any point in North America.
- Delivery, site preparation and installation are not included.
- If the flow is decreased to 5 gpm, a temperature rise of 40F would occur through a 30 kw reactor. This will not effect the treatment by our system but may require a heat exchanger to cool the water prior to open water discharge.

Design Test - The Next Practical Step

Due to the potential variability of groundwater streams, your stream should be tested by Solarchem engineers in order to design the optimum utilization of UV reactors, H_2O_2, catalysts and pH, and in order to confirm our budget estimate.

To perform a Design Test, we require 1 x 55 gallon drum of representative water along with recent analysis of the water and your discharge requirements. This large volume of water means we can do tests on batches of 7 gallons each, allowing a more reliable scale-up to a commercial system.

You will receive a Design Test report which summarizes:

- our assessment of the **Rayox®** treatment alternatives evaluated
- a confirmation of the capital investment and operating costs to meet the treatment specification
- a process flow schematic of the proposed least cost system
- a firm delivery schedule for a commercial system, subject to confirmation at time of order
- a warranty statement of system performance to the agreed specifications

Solarchem

The cost for a design test is $5,000 not including outside analyses, if necessary. Please note that the $5,000 fee will be applied as a credit towards the purchase of a full-scale system. Solarchem offers assistance for the transportation of water from the client's facilities to our Markham laboratories.

I trust that this letter has provided the information you were looking for. Please call me if you have any questions or wish to arrange for a design test.

Yours sincerely,

SOLARCHEM ENVIRONMENTAL SYSTEMS
per:

Rob Abernethy, P.Eng.
Technical Sales Representative

RA/ps
60.M.

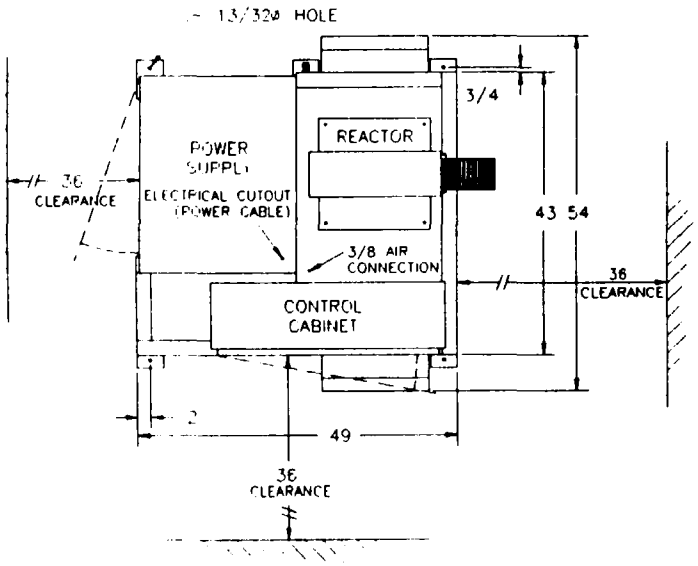
Solarchem

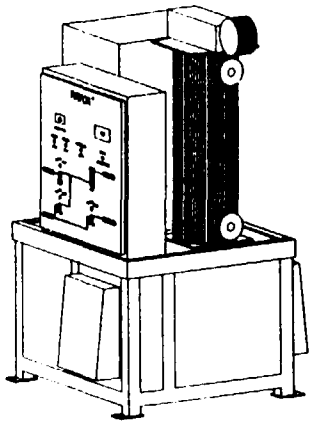
TABLE 1

Rose Hill Groundwater
Treatment Performance Specification

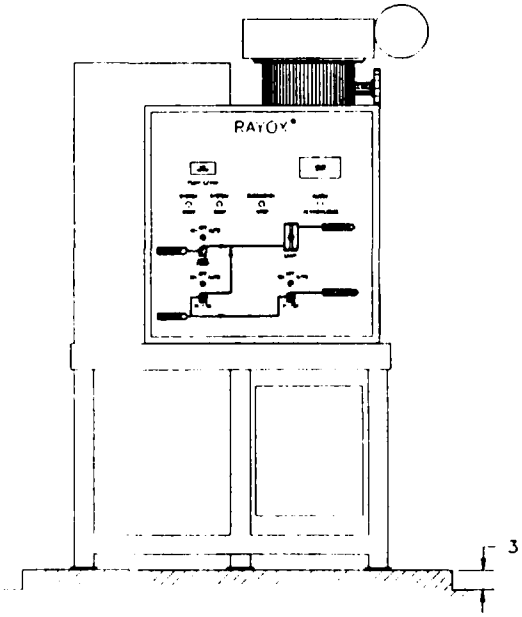
	Contaminant	Influent (ppb)	Effluent (ppb)	Flow Rate (gpm)
Alternative 4	Acrylamide	202	2	50
Alternative 5	Acrylamide	92	2	200

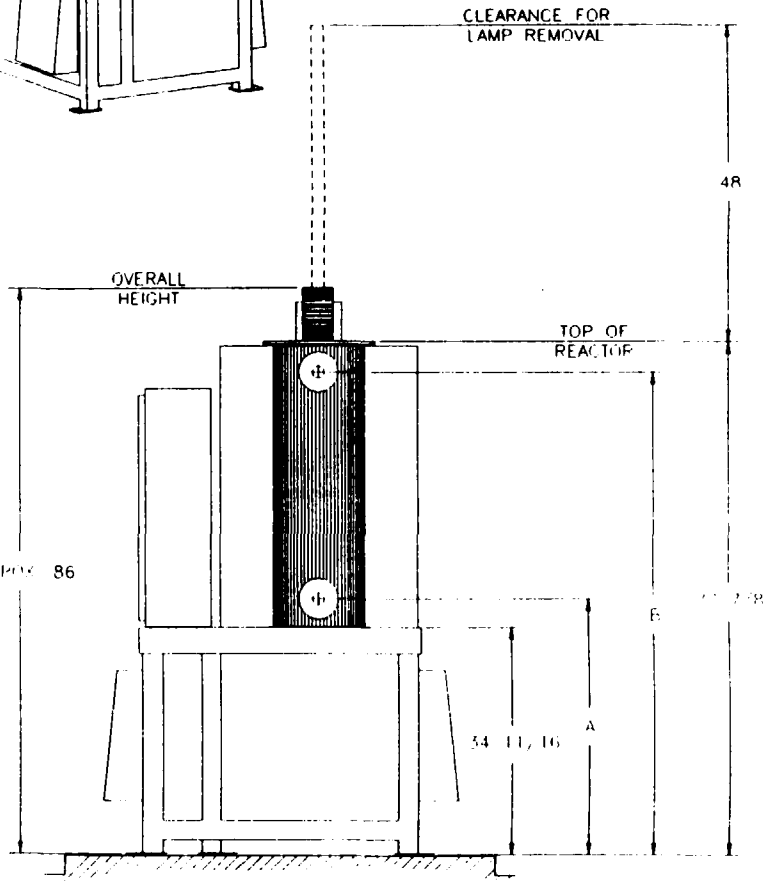
* Acrylamide is the rate limiting contaminant. All of the other organic contaminants will be well below their remediation goals when acrylamide reaches it's remediation good.





PORT SIZE	APPROX A	B
1	38 1/4	74
1 1/2	39	73 1/4
2	39	73 1/4
3	39	73 1/4





THESE DRAWINGS, SPECIFICATIONS AND TECHNICAL DATA ARE THE PROPERTY OF SOLAR NEW ENVIRONMENTAL SYSTEMS INC. ARE SUBJECT TO RETURN UPON REQUEST. THEY ARE SUBMITTED ON THE CONDITION THAT THEY WILL NOT BE USED OR REPRODUCED IN ANY WAY WITHOUT OUR WRITTEN APPROVAL.

REVISIONS

REV	DESCRIPTION	DATE	APPVD
A	ECO [illegible]	[illegible]	
B			
C			
D			
E			

NOTES

1. APPROX WEIGHT 1600 LBS
2. REFER TO PIPING DRAWING FOR REACTOR NOZZLE ORIENTATION AND PIPING.
3. MINIMUM 36" CLEARANCE REQUIRED FOR MAINTENANCE ACCESS AS SHOWN
4. UNIT TO BE MOUNTED ON 3" RAISED CONCRETE SLAB

FINISH

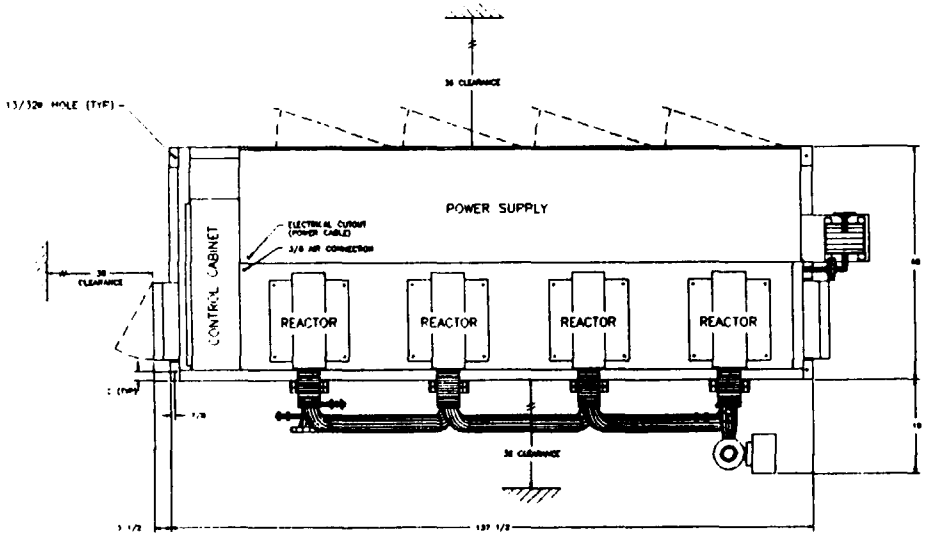
MATERIAL

ANGULAR ±1/2° DECIMAL 1 PLACE ±.01"
FRACTIONAL ±1/32 DECIMAL 2 PLACES ±.005"
DECIMAL 3 PLACES ±.001" DECIMAL 4 PLACES ±.0005"

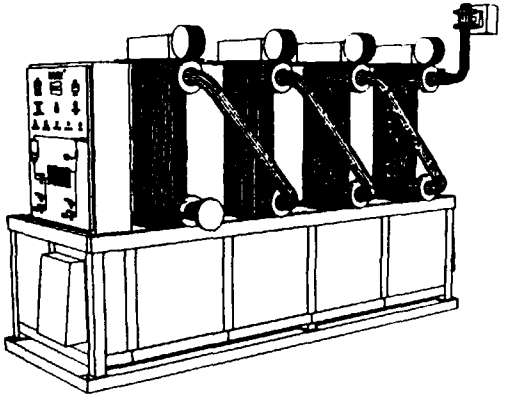
	NAME	DATE
DRAWN		
DESIGN		
CHECK		
APPVD		

RAYOX 30 kW REACTOR [illegible]

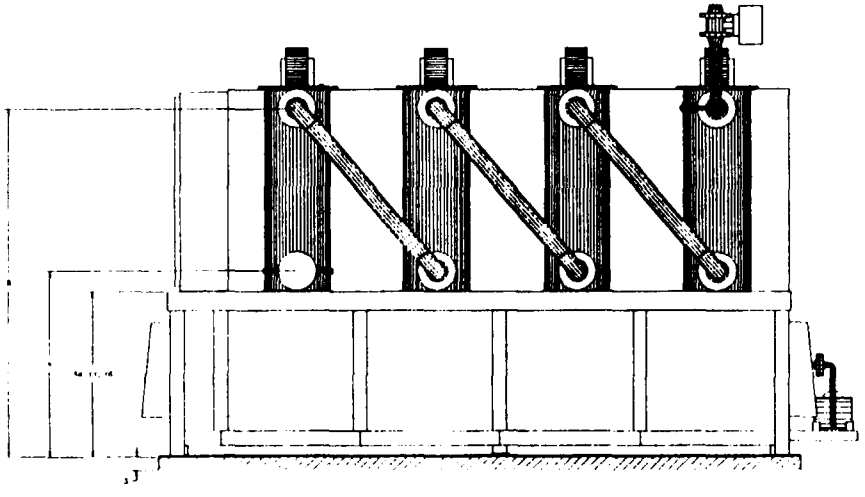
SCALE NONE | SIZE | DWG NO. [illegible] | REV A



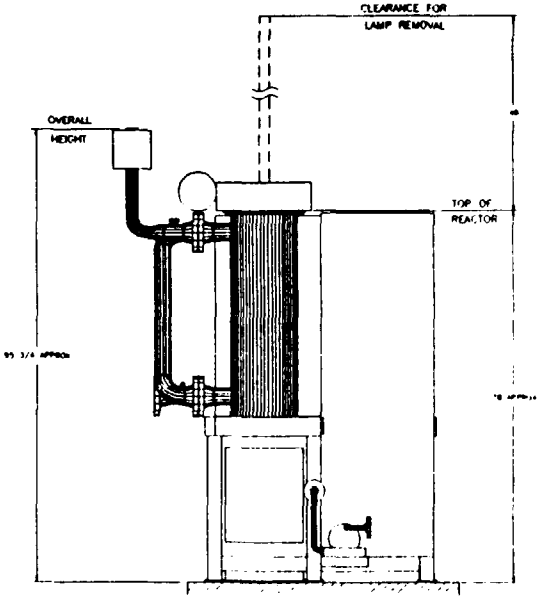
PLAN



ISOMETRIC VIEW



FRONT ELEVATION



SIDE ELEVATION

THESE DRAWINGS, SPECIFICATIONS AND DESIGNS ARE THE PROPERTY OF SOLARCHEM ENVIRONMENTAL SYSTEMS AND ARE SUBJECT TO RETURN UPON REQUEST. THEY ARE SUBMITTED ON THE CONDITION THAT THEY WILL NOT BE USED OR REPRODUCED IN ANY WAY WITHOUT OUR WRITTEN APPROVAL.

REVISIONS

REV	DESCRIPTION	DATE	APPVD
A			
B			
C			
D			
E			

NOTES

1. APPROX WT = 2800 lbs REFER TO PIPING DRAWING FOR REACTOR NOZZLE ORIENTATION AND PIPING
2. MINIMUM 36" CLEARANCE REQUIRED FOR MAINTENANCE ACCESS AS SHOWN
3. UNIT TO BE MOUNTED ON 3" CONCRETE SLAB

PORT SIZE	APPROX A	APPROX B
1	38 1/4	76
1 1/2	39	73 1/4
2	39	73 1/4
3	39	73 1/4

FINISH

MATERIAL

DIMENSIONS IN INCHES UNLESS OTHERWISE SPECIFIED
TOLERANCES UNLESS OTHERWISE SPECIFIED

ANGULAR	± 0°30'	DECIMAL 2 PLACE	± .01
FRACTIONAL	± 1/32	DECIMAL 3 PLACE	± .005
DECIMAL 1 PLACE	± .1"	DECIMAL 4 PLACE	± .0001

	NAME	DATE
DRAWN		
DESIGN		
CHECK		
APPR		

Solarchem

40 WEST [illegible]
RICHMOND HILL
ONTARIO
L4B [illegible]

TITLE: RAYOX 4x36kW REACTOR OUTLINE DETAIL

SCALE: NONE | DWG No: 0001-RD-[illegible] | REVISION

WA # 18-1 LAS
File Copy

Metcalf & Eddy
An Air & Water Technologies Company

May 19, 1993

Mr. Robert Abernethy
Sales Engineer
Solarchem Environmental Systems
130 Royal Crest Court
Markham, Ontario, Canada L3R 0A1

Subject: **Request for Quotation on Equipment, Services and Budgetary Costs - Treatment of Contaminated Groundwater using UV/Chemical Oxidation, Rose Hill Regional Landfill Superfund Site, South Kingstown, Rhode Island**

Dear Mr. Abernethy:

Metcalf & Eddy (M&E) is currently finalizing the Feasibility Study (FS) for treatment of contaminated groundwater at the Rose Hill Landfill site. This groundwater is contaminated with weak, municip landfill leachate. M&E has identified treatment using ultra-violet/chemical oxidation technology as the most appropriate method for removing the organic compounds-of-concern (COCs).

A quotation describing suggested equipment, services and budgetary costs should be based on the following assumptions:

1) quotations are needed for two different systems; groundwater concentrations are shown in Attachment A for the 50 gpm system (Alternative 4) and Attachment B for the 200 gpm system (Alternative 5).
2) treatment goals are listed in each attachment by compound; for the organic compounds, please identify any compounds that <u>may not meet goals</u>.
3) suspended solids and metals pretreatment system will have removed the compounds noted by asterisk prior to entering the UV/Chemical oxidation system.
4) assume a water temperature of 55 degrees F.
5) 50 gpm flowrate may be as low as 5 gpm; will your system still operate effectively ?
6) treated water discharges to recharge wells or to river.
7) identify operations and maintenance services necessary for your proposed system.
8) identify the make & model of your proposed system; please include copies of brochures, drawings and specifications.
9) assume budgetary costs accuracy for equipment, f.o.b.
10) identify any other potential pretreatment or special conditions that you feel may be necessary for proper operation.

30 Harvard Mill Square Wakefield, MA 01880
Mailing Address PO Box 4043 Woburn MA 01888-4043
617-246-5600 FAX 617-245-6293

Your quotations are needed by the end-of-day Wednesday, May 26, 1993. Thank you for your assistance with this project. If you have any questions, please do not hesitate to contact me at TEL (617) 246-5200, extension 4272 or by FAX at (617) 245-6293.

Very truly yours,

METCALF & EDDY, INC.

Daniel P. Peters

Daniel P. Peters, P.E., ChE
Project Engineer,
Industrial & Hazardous Waste Division

Attachments
cc: S. Czarniecki
WA#18-1LA5

ATTACHMENT A: GROUNDWATER CONDITIONS FOR THE 50 GPM SYSTEM

ANALYTE (a)	GROUNDWATER CONCENTRATIONS (b) Average	Maximum		PRELIMINARY REMEDIATION GOAL
	all in (μg/L) except where noted at left			
Ammonia (mg/L)	9	48		
Sulfide (mg/L)	1	4		
Aluminum	12,616	98,281	*	
Antimony	0	0	*	6
Arsenic	2	9	*	
Barium	210	695	*	
Beryllium	2	13	*	1
Cadmium	4	36	*	5
Chromium	21	136	*	100
Cobalt	21	82	*	
Copper	37	324	*	
Iron	91,571	396,140	*	
Lead	40	180	*	15
Manganese	2,633	10,361	*	3,650
Mercury	0.11	0.29	*	
Nickel	24	112	*	100
Vanadium	20	133	*	
Zinc	625	6,520	*	7,300
Dieldrin	0.043	0.003		
2-Methylnaphthalene	4	4		
4-Chloro-3-methylphenol	4	4		
4-Methylphenol	8	64		
Pentachlorophenol	12	3		1
bis(2-Ethylhexyl)phthalate	11	59		4
1,1-Dichloroethane	13	195		
1,1-Dichloroethene	4	2		
1,2-Dichloroethene(total)	30	645		70
4-Methyl-2-pentanone	5	27		
Acetone	20	415		
Benzene	10	27		5
Carbon Disulfide	13	77		
Chloroethane	16	77		
Ethylbenzene	14	64		
Toluene	31	156		
Trichloroethene	4	4		
Vinyl Chloride	30	610		2
Acrylamide	141	202		0.02 (c)
N,N-DMF	177	1,273		
Hardness (mg/L)	151	621		
pH	7.1	11.9		
Total Organic Carbon (mg/L)	44	200		
Biochemical Oxygen Demand (mg/L)	12	112		

Notes:

(a). Asterisk denotes compounds that will be handled by the metals treatment system.

(b). Concentrations for metals are "total" and not dissolved values.

(c). Goal is significantly below normal analytical detection limits; evaluate potential to meet 2 μg/L standard assuming that this is the detection limit.

ATTACHMENT B: GROUNDWATER CONDITIONS FOR THE 200 GPM SYSTEM

ANALYTE (a)	GROUNDWATER CONCENTRATIONS (b) Average	Maximum		PRELIMINARY REMEDIATION GOAL
	all in (μg/L) except where noted at left			
Ammonia (mg/L)	11	30		
Sulfide (mg/L)	1	7		
Aluminum	14,277	76,745	*	
Antimony	10	46	*	6
Arsenic	2	7	*	
Barium	136	445	*	
Beryllium	2	9	*	1
Cadmium	3	25	*	5
Chromium	17	94	*	100
Cobalt	18	53	*	
Copper	47	215	*	
Iron	60,644	218,437	*	
Lead	32	154	*	15
Manganese	2,305	8,391	*	3,650
Mercury	0.10	0.22	*	
Nickel	27	93	*	100
Vanadium	20	115	*	
Zinc	348	3,135	*	7,300
Dieldrin	0.020	0.001		
2-Methylnaphthalene	3	2		
4-Chloro-3-methylphenol	2	2		
4-Methylphenol	8	56		
Pentachlorophenol	6	1		1
bis(2-Ethylhexyl)phthalate	4	21		4
1,1-Dichloroethane	7	89		
1,1-Dichloroethene	3	1		
1,2-Dichloroethene(total)	14	293		70
4-Methyl-2-pentanone	2	12		
Acetone	21	329		
Benzene	5	13		5
Carbon Disulfide	11	57		
Chloroethane	8	37		
Ethylbenzene	7	29		
Toluene	21	121		
Trichloroethene	2	2		
Vinyl Chloride	14	276		2
Acrylamide	64	92		0.02 (c)
N,N-DMF	84	600		
Hardness (mg/L)	86	330		
pH	6.9	9.8		
Total Organic Carbon (mg/L)	28	125		
Biochemical Oxygen Demand (mg/L)	7	58		

Notes:

(a). Asterisk denotes compounds that will be handled by the metals treatment system.

(b). Concentrations for metals are "total" and not dissolved values.

(c). Goal is significantly below normal analytical detection limits; evaluate potential to meet 2 μg/L standard assuming that this is the detection limit.

- UV/Chemical Oxidation Quotation: Peroxidation Systems
  50 gpm System
  200 gpm System
  M&E Quotation Request

May 26, 1993

METCALF & EDDY, INC.
JUN 1 1993
RECEIVED

Mr. Daniel P. Peters, P.E., ChE
Metcalf & Eddy
30 Harvard Mill Square, Box 4043
Woburn, MA 01888-4043

RE: **perox-pure™** Treatment Estimate for Contaminated Groundwater from the Rose Hill Regional Landfill Superfund Site in South Kingston, Rhode Island
Proposal #NAO-93071-16484-PN01

Dear Mr. Peters:

Thank you for your interest in the **perox-pure™** Process. As requested, we have prepared this preliminary estimate for **perox-pure™** Process treatment of the water described in Attachments A & B. The figures quoted are preliminary only and are subject to change.

perox-pure™ SYSTEM

Peroxidation System Inc's **perox-pure™** system is a complete skid mounted ultraviolet (UV), hydrogen peroxide (H_2O_2) system with all required controls. Only a minimal foundation with containment dike, electrical and plumbing connections are necessary. Over 80 systems are in use in North America and Europe. Many of our customers use the **perox-pure™** Process at multiple plant locations.

The unique difference between the **perox-pure™** organic destruction process and other systems is its ability to actually destroy organics to non-detectable levels, thus eliminating the generation of by-product wastes or air discharges to handle or treat.

In contrast to treatment by liquid phase activated carbon, **perox-pure™** doesn't require solids handling, transport and potential liability. Compared to the complexities of air stripping with vapor phase treatment **perox-pure™** is simple, straight forward and doesn't require an air permit or vapor monitoring.

If circumstances dictate the desirability of using the **perox-pure™** Process along with other technologies, we are prepared to offer the total system.

INVESTMENT AND OPERATING COSTS

The **perox-pure™** treatment system estimated to treat the anticipated flow and organic loading is presented below.

	Case A	Case B
Equipment Capital Investment	$200-250,000	$600-675,000
Installation/Start-up	$8,500	$12,500
Maintenance Parts (est. @ 8% of Capital)	$18,000/yr.	$51,000/yr.
Hydrogen Peroxide (est. @ $0.65/lb. 50%)	$12,300/yr.	$31,300/yr.
Power (est. @ $0.06/kWh)	$70,900/yr.	$283,600/yr.

Peroxidation Systems Inc.
5151 E. Broadway, Suite 600 Tucson, Arizona 85711 602-790-8383 FAX 602-790-8008

Please note this preliminary estimate does not include site preparation, pretreatment or post-treatment equipment, if any, freight, taxes, special permits or on-site equipment handling. Normal delivery is 12-16 weeks after receipt of order.

PROCESS ASSESSMENT

Due to the variability of treatment costs depending on the physical and chemical characteristics of the water, a more definitive estimate will require a process feasibility evaluation in our Tucson facility. For this evaluation we would need 15 gallons of water, depending on pretreatment requirements, if any. These test results would enable us to more accurately select the appropriate unit size and "firm up" our estimate. The cost for this testing is $3,500, plus analytical.

SUMMARY

The **perox-pure™** Process offers the advantages of a proven, cost-effective treatment system that creates no air emissions or generation of secondary waste products.

Your Area Sales Manager, Mr. Mike Donaway of PSI's Cranford, New Jersey office, would be happy to discuss any questions you have, as well as how to take the next step in your evaluation of **perox-pure™** technology, and can be reached at (908) 276-0044.

Thank you very much for your continued interest in our products and services!

Sincerely yours,

Norman Olson

Norman A. Olson
Applications Specialist

NAO:cw
Enclosures

cc: Mike Donaway, PSI

ATTACHMENT A: GROUNDWATER CONDITIONS FOR THE 50 GPM SYSTEM

ANALYTE (a)	GROUNDWATER CONCENTRATIONS (b) Average	Maximum		PRELIMINARY REMEDIATION GOAL
	all in (μg/L) except where noted at left			
Ammonia (mg/L)	9	48		
Sulfide (mg/L)	1	4		
Aluminum	12,616	98,281	*	
Antimony	0	0	*	6
Arsenic	2	9	*	
Barium	210	695	*	
Beryllium	2	13	*	1
Cadmium	4	36	*	5
Chromium	21	136	*	100
Cobalt	21	82	*	
Copper	37	324	*	
Iron	91,571	396,140	*	
Lead	40	180	*	15
Manganese	2,633	10,361	*	3,650
Mercury	0.11	0.29	*	
Nickel	24	112	*	100
Vanadium	20	133	*	
Zinc	625	6,520	*	7,300
Dieldrin	0.043	0.003		
2-Methylnaphthalene	4	4		
4-Chloro-3-methylphenol	4	4		
4-Methylphenol	8	64		
Pentachlorophenol	12	3		1
bis(2-Ethylhexyl)phthalate	11	59		4
1,1-Dichloroethane	13	195		
1,1-Dichloroethene	4	2		
1,2-Dichloroethene(total)	30	645		70
4-Methyl-2-pentanone	5	27		
Acetone	20	415		
Benzene	10	27		5
Carbon Disulfide	13	77		
Chloroethane	16	77		
Ethylbenzene	14	64		
Toluene	31	156		
Trichloroethene	4	4		
Vinyl Chloride	30	610		2
Acrylamide	141	202		0.02 (c)
N,N-DMF	177	1,273		
Hardness (mg/L)	151	621		
pH	7.1	11.9		
Total Organic Carbon (mg/L)	44	200		
Biochemical Oxygen Demand (mg/L)	12	112		

Notes:

(a). Asterisk denotes compounds that will be handled by the metals treatment system.

(b). Concentrations for metals are "total" and not dissolved values.

(c). Goal is significantly below normal analytical detection limits; evaluate potential to meet 2 μg/L standard assuming that this is the detection limit.

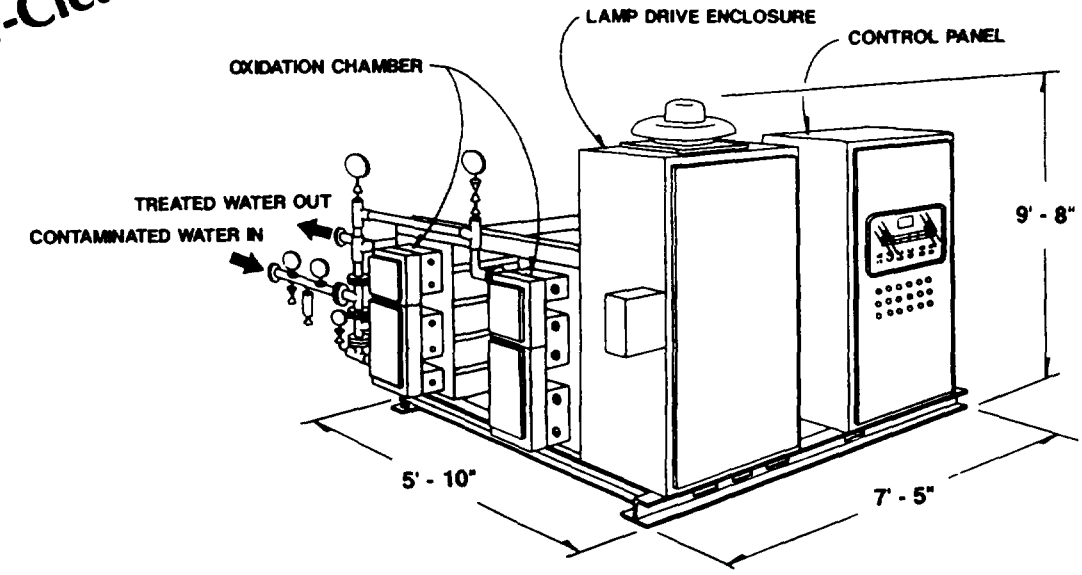
perox-pure™

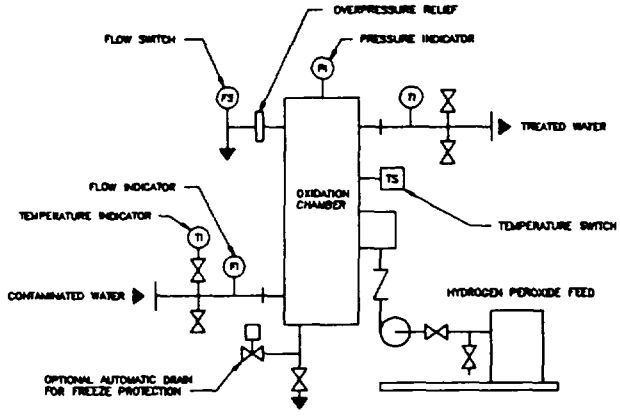
ORGANIC DESTRUCTION PROCESS

MODULAR TREATMENT SYSTEM

Now Self-Cleaning

MODEL S-135





SPECIFICATIONS	Model S-135	
Flow Rate:		
Maximum	200 gpm	350 gpm
Connections:	150# Flange	15[illegible] [illegible]ange
Inlet:	3"	4"
Outlet:	3"	4"
Power Supply:	3 pH/60Hz/480V, 135KW	
Electrical Encl.:	NEMA 3R	
Material -		
Wetted Parts:	Quartz, Fluorpolymers	
External Parts:	Enameled Steel	
Weight -		
Shipping:	5400 lbs.	
Operating:	6300 lbs.	

The perox-pure™ chemical oxidation system consists of modular, skid-mounted equipment designed to treat water contaminated by dissolved organic compounds. Bench-scale process evaluations will determine pretreatment requirements (if any) and the oxidation time necessary for the desired treatment level. Full-scale oxidation chamber volume, UV requirements and oxidant dosage are then selected.

The perox-pure™ system incorporates corrosion resistant fluorocarbon-lined oxidation chambers and horizontally mounted medium pressure UV lamps. Indicators are provided to monitor performance of each lamp. A sequential hydrogen peroxide addition feature provides easy process optimization for maximum economy. In addition, a patented tube cleaning device maximizes performance and minimizes maintenance time. The cleaning device is automatic and self propelled, requiring no external actuating mechanism or sliding shaft seals. Other design features include shop-wired and tested control panels interlocked with personnel and process safety features to shut-off power and display the cause at preset conditions. Installation is quick and easy.

The perox-pure™ system and its components are covered by numerous issued and pending patents.

Peroxidation Systems Inc.

5151 E. Broadway, Suite 600 Tucson, Arizona 85711 602-294-[illegible] [illegible]

ATTACHMENT B: GROUNDWATER CONDITIONS FOR THE 200 GPM SYSTEM

ANALYTE (a)	GROUNDWATER CONCENTRATIONS (b) Average	Maximum		PRELIMINARY REMEDIATION GOAL
	all in (μg/L) except where noted at left			
Ammonia (mg/L)	11	30		
Sulfide (mg/L)	1	7		
Aluminum	14,277	76,745	*	
Antimony	10	46	*	6
Arsenic	2	7	*	
Barium	136	445	*	
Beryllium	2	9	*	1
Cadmium	3	25	*	5
Chromium	17	94	*	100
Cobalt	18	53	*	
Copper	47	215	*	
Iron	60,644	218,437	*	
Lead	32	154	*	15
Manganese	2,305	8,391	*	3,650
Mercury	0.10	0.22	*	
Nickel	27	93	*	100
Vanadium	20	115	*	
Zinc	348	3,135	*	7,300
Dieldrin	0.020	0.001		
2-Methylnaphthalene	3	2		
4-Chloro-3-methylphenol	2	2		
4-Methylphenol	8	56		
Pentachlorophenol	6	1		1
bis(2-Ethylhexyl)phthalate	4	21		4
1,1-Dichloroethane	7	89		
1,1-Dichloroethene	3	1		
1,2-Dichloroethene(total)	14	293		70
4-Methyl-2-pentanone	2	12		
Acetone	21	329		
Benzene	5	13		5
Carbon Disulfide	11	57		
Chloroethane	8	37		
Ethylbenzene	7	29		
Toluene	21	121		
Trichloroethene	2	2		
Vinyl Chloride	14	276		2
Acrylamide	64	92		0.02 (c)
N,N-DMF	84	600		
Hardness (mg/L)	86	330		
pH	6.9	9.8		
Total Organic Carbon (mg/L)	28	125		
Biochemical Oxygen Demand (mg/L)	7	58		

Notes:

(a). Asterisk denotes compounds that will be handled by the metals treatment system.

(b). Concentrations for metals are "total" and not dissolved values.

(c). Goal is significantly below normal analytical detection limits; evaluate potential to meet 2 μg/L standard assuming that this is the detection limit.

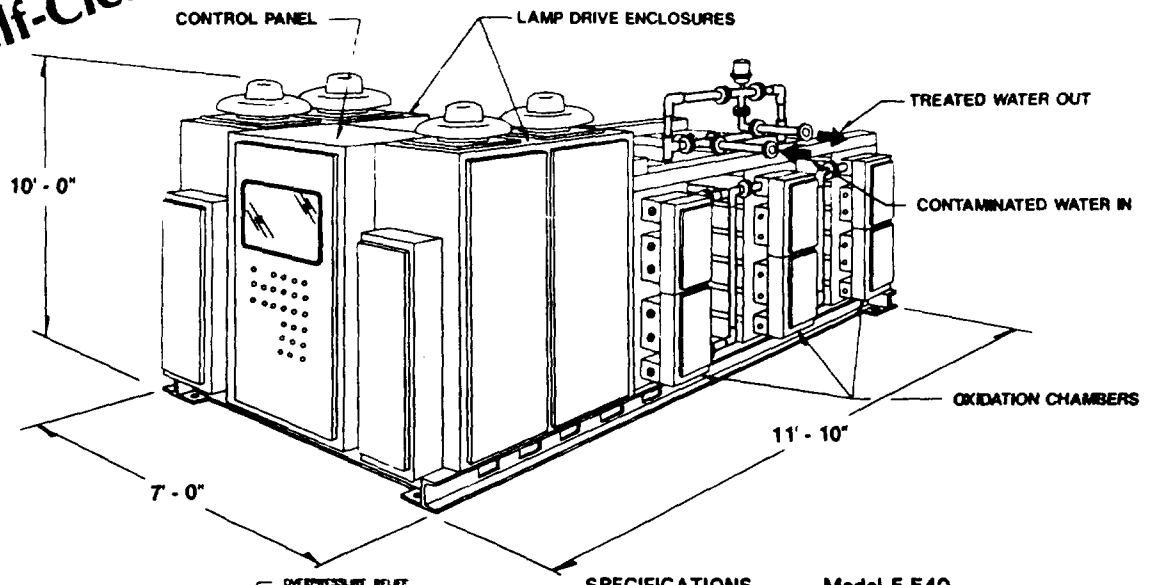
perox-pure™

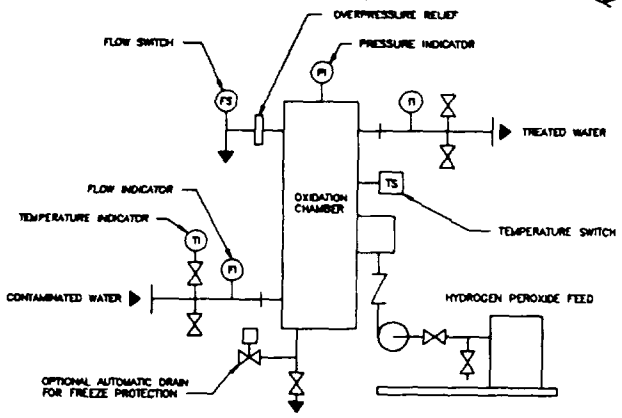
ORGANIC DESTRUCTION PROCESS

MODULAR TREATMENT SYSTEM

MODEL E-540

Now Self-Cleaning





SPECIFICATIONS	Model E-540	
Flow Rate:		
Maximum	200 gpm	1500 gpm
Connections:	150# Flange	150# Flang
Inlet:	3"	8'
Outlet:	3"	8"
Power Supply:	3 pH/60Hz/480V, 540KW (2 @ 270 KV	
Electrical Encl.:	NEMA 3R	
Material -		
Wetted Parts:	Quartz, Fluoropolymers	
External Parts:	Enameled Steel	
Weight -		
Shipping:	21000 lbs.	
Operating:	23800 lbs.	

The perox-pure™ chemical oxidation system consists of modular, skid-mounted equipment designed to treat water contaminated by dissolved organic compounds. Bench-scale process evaluations will determine pretreatment requirements (if any) and the oxidation time necessary for the desired treatment level. Full-scale oxidation chamber volume, UV requirements and oxidant dosage are then selected.

The perox-pure™ system incorporates corrosion resistant fluorocarbon-lined oxidation chambers and horizontally mounted medium pressure UV lamps. Indicators are provided to monitor performance of each lamp. A sequential hydrogen peroxide addition feature provides easy process optimization for maximum economy. In addition, a patented tube cleaning device maximizes performance and minimizes maintenance time. The cleaning device is automatic and self propelled, requiring no external actuating mechanism or sliding shaft seals. Other design features include shop-wired and tested control panels interlocked with personnel and process safety features to shut-off power and display the cause at preset conditions. Installation is quick and easy.

The perox-pure™ system and its components are covered by numerous issued and pending patents.

Peroxidation Systems Inc.

[illegible] 602-790-9383 FAX 602-790-8008

WA # 18 - 1LAS
File Copy

Metcalf & Eddy
An Air & Water Technologies Company

May 19, 1993

Mr. Norman A. Olson
Application Specialist
Peroxidation Systems, Inc.
5151 East Broadway, Suite 600
Tucson, AZ 85711

Subject: **Request for Quotation on Equipment, Services and Budgetary Costs - Treatment of Contaminated Groundwater using UV/Chemical Oxidation, Rose Hill Regional Landfill Superfund Site, South Kingstown, Rhode Island**

Dear Mr. Olson:

Metcalf & Eddy (M&E) is currently finalizing the Feasibility Study (FS) for treatment of contaminated groundwater at the Rose Hill Landfill site. This groundwater is contaminated with weak, municipal landfill leachate. M&E has identified treatment using ultra-violet/chemical oxidation technology as the most appropriate method for removing the organic compounds-of-concern (COCs).

A quotation describing suggested equipment, services and budgetary costs should be based on the following assumptions:

1) quotations are needed for two different systems; groundwater concentrations are shown in Attachment A for the 50 gpm system (Alternative 4) and Attachment B for the 200 gpm system (Alternative 5).
2) treatment goals are listed in each attachment by compound; for the organic compounds, please identify any compounds that <u>may not meet goals</u>.
3) suspended solids and metals pretreatment system will have removed the compounds noted by asterisk prior to entering the UV/Chemical oxidation system.
4) assume a water temperature of 55 degrees F.
5) 50 gpm flowrate may be as low as 5 gpm; will your system still operate effectively ?
6) treated water discharges to recharge wells or to river.
7) identify operations and maintenance services necessary for your proposed system.
8) identify the make & model of your proposed system; please include copies of brochures, drawings and specifications.
9) assume budgetary costs accuracy for equipment, f.o.b.
10) identify any other potential pretreatment or special conditions that you feel may be necessary for proper operation.

30 Harvard Mill Square, Wakefield, MA 01880
Mailing Address PO Box 4043 Woburn, MA 01888-4043
617-246-5200 FAX 617-245-6293

Your quotations are needed by the end-of-day Wednesday, May 26, 1993. Thank you for your assistance with this project. If you have any questions, please do not hesitate to contact me at TEL (617) 246-5200, extension 4272 or by FAX at (617) 245-6293.

Very truly yours,

METCALF & EDDY, INC.

Daniel P. Peters

Daniel P. Peters, P.E., ChE
Project Engineer,
Industrial & Hazardous Waste Division

Attachments
cc: S. Czarniecki
WA#18-1LA5

ATTACHMENT A: GROUNDWATER CONDITIONS FOR THE 50 GPM SYSTEM

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bis(2-Ethylhexyl)phthalate	11	59		4
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1,1-Dichloroethene	4	2		
1,2-Dichloroethene(total)	30	645		70
4-Methyl-2-pentanone	5	27		
Acetone	20	415		
Benzene	10	27		5
Carbon Disulfide	13	77		
Chloroethane	16	77		
Ethylbenzene	14	64		
Toluene	31	156		
Trichloroethene	4	4		
Vinyl Chloride	30	610		2
Acrylamide	141	202		0.02 (c)
N,N-DMF	177	1,273		
Hardness (mg/L)	151	621		
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Total Organic Carbon (mg/L)	44	200		
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Notes:

(a). Asterisk denotes compounds that will be handled by the metals treatment system.

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Chromium	17	94	*	100
Cobalt	18	53	*	
Copper	47	215	*	
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Manganese	2,305	8,391	*	3,650
Mercury	0.10	0.22	*	
Nickel	27	93	*	100
Vanadium	20	115	*	
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Dieldrin	0.020	0.001		
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4-Chloro-3-methylphenol	2	2		
4-Methylphenol	8	56		
Pentachlorophenol	6	1		1
bis(2-Ethylhexyl)phthalate	4	21		4
1,1-Dichloroethane	7	89		
1,1-Dichloroethene	3	1		
1,2-Dichloroethene(total)	14	293		70
4-Methyl-2-pentanone	2	12		
Acetone	21	329		
Benzene	5	13		5
Carbon Disulfide	11	57		
Chloroethane	8	37		
Ethylbenzene	7	29		
Toluene	21	121		
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Acrylamide	64	92		0.02 (c)
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- UV/Chemical Oxidation Quotation: Ultrox
  Parameters Basis
  System Components: 50 and 200 gpm
  Costs and Assumptions
  M&E Quotation Request

ULTROX

A Division of Resources Conservation Company

2435 South Anne Street
Santa Ana, CA 92704-5308
Phone: 714 545-5557
Fax: 714 557-5396

May 26, 1993

METCALF & EDDY, INC.
JUN 1 1993
RECEIVED

Mr. Daniel P. Peters, P.E., ChE
Metcalf & Eddy
30 Harvard Mill Square
Wakefield, MA 01880

Dear Mr. Peters:

Please find attached budget capital and O&M costs for the ULTROX® UV/Oxidation system estimated to meet your groundwater treatment requirements at the Rose Hill Regional Landfill Superfund Site in South Kingston, Rhode Island. Because UV/Oxidation destroys different compounds with different levels of efficiency, we are basing our estimates on experiences with similar contaminants.

With respect to your questions, I have itemized responses below:

1. Budget quotations are attached.

2. Ultrox equipment is expected to meet treatment objectives for all organic compounds where Preliminary Remediation Goals are provided.

3. Budget quotation assumes pretreatment for solids and metals are provided by others.

4. Water temperature of 55°F is assumed.

5. The Ultrox® systems quoted are capable of operation at lower flow rates. Individual banks of lamps can be turned off and ozone generators can be turned down to save on operating costs when flows are lower.

6. Systems can accommodate any discharge requirements

7. UV lamps must be replaced after one year of continuous operation. Oxidant dosage settings are checked once per day (2 minutes).

8. Makes and models of equipment are listed in attached budget quotation. Brochures are sent by mail with original. Ultrox systems are not "off the shelf" systems. Each set of drawings is a portion of a complete documentation package provided with each system. A sketch is provided as an example of a layout. A set of specifications is prepared for a full scale system proposal, but not as part of budgetary quotations.

9. Budgetary cost estimates are expected to be +/- 25%. Estimates are based on FOB Santa Ana, CA.

10. No other pretreatment is required for the Ultrox® systems.

To provide more complete data and a firm price quotation, we recommend a laboratory treatability study. This would allow us to subject the targeted compounds to a variety of oxidation variables and determine the optimum, cost effective dosing needed to reach your required target concentrations. I have enclosed our laboratory fee schedule for your consideration.

Should you require any further information or clarification, please give me a call.

Sincerely,
ULTROX

William S. Himebaugh
National Sales Manager

WSH/gkr
enc: Budget Quote & Fee Schedule

BUDGET CAPITAL AND O&M COSTS
FOR THE ULTROX® UV/OXIDATION SYSTEM

I. PARAMETERS

50 GPM System

PARAMETERS	CONCENTRATION (ug/l)	GOAL (ug/l)
PCP	12	1
bis(2-ethylhexyl)phthalate	11	4
1,2-DCE	30	70
Benzene	10	5
Vinyl Chloride	30	2
Acrylamide	141	0.02

200 GPM SYSTEM

PARAMETERS	CONCENTRATION (ug/l)	GOAL (ug/l)
PCP	6	1
bis(2-ethylhexyl)phthalate	4	4
1,2-DCE	14	70
Benzene	5	5
Vinyl Chloride	14	2
Acrylamide	64	0.02

II. UV/OXIDATION SYSTEM COMPONENTS

50 GPM SYSTEM

A. OXIDATION REACTOR
   1. F-1300

B. OZONE GENERATOR
   1. 21 LB/DAY OZONE GENERATOR

C. OZONE GENERATOR AIR PREPARATION SYSTEM
   1. COMPRESSOR
   2. AIR DRYER (-70°F DEWPOINT)
   3. AIR FILTER

D. HYDROGEN PEROXIDE FEED SYSTEM
   1. CHEMICAL METERING PUMP (0.5 GPH)
   2. CALIBRATION CYLINDER
   3. PUMP STAND

E. VAPOR TREATMENT
   1. D-TOX™/DECOMPOZON™ CATALYTIC OZONE/VOC DESTRUCTION UNIT

F. POWER CONTROL UNIT
   1. PROGRAMMABLE LOGIC AUTOMATIC CONTROL UNIT

50 GPM SYSTEM

A. OXIDATION REACTOR
   1. F-1300
   2. C-5000

B. OZONE GENERATOR
   1. 50 LB/DAY OZONE GENERATOR

C. OZONE GENERATOR AIR PREPARATION SYSTEM
   1. COMPRESSOR
   2. AIR DRYER (-70°F DEWPOINT)
   3. AIR FILTER

D. HYDROGEN PEROXIDE FEED SYSTEM
   1. CHEMICAL METERING PUMP (0.5 GPH)
   2. CALIBRATION CYLINDER
   3. PUMP STAND

E. VAPOR TREATMENT
   1. D-TOX™/DECOMPOZON™ CATALYTIC OZONE/VOC DESTRUCTION UNIT

F. POWER CONTROL UNIT
   1. PROGRAMMABLE LOGIC AUTOMATIC CONTROL UNIT

III. ASSUMPTIONS

A. ELECTRICAL COSTS = $0.06/KWH

B. H_2O_2 COSTS = $0.70/LB

C. REPLACEMENT COSTS PER LAMP = $60 (lamp life = 1.2 yrs.)

IV. COSTS

<u>50 GPM SYSTEM</u>

A.	TOTAL BUDGET CAPITAL COST*:	$ 218,000
B.	TOTAL BUDGET O&M COSTS**:	$0.75/1000 GALLONS

<u>200 GPM SYSTEM</u>

A.	TOTAL BUDGET CAPITAL COST*:	$ 333,000
B.	TOTAL BUDGET O&M COSTS**:	$0.34/1000 GALLONS

* Capital costs are estimated FOB Santa Ana, CA and do not include installation, start up or training. These cost calculation require detailed requirements for integrating into the remediation program.

** O&M costs include electrical power costs, H_2O_2 costs, and amortized UV lamp replacement costs.

ULTROX

STANDARD TERMS AND FEE SCHEDULE FOR LABORATORY TREATABILITY AND PILOT PLANT STUDIES

LABORATORY TREATABILITY STUDIES (Santa Ana, CA)

$700/day with a five day minimum

Analytical work at an independent laboratory will be billed at cost plus 20%

FIELD PILOT PLANT STUDIES

Models P-75

$2,650/week, with a one week minimum

Models P-325, P-650, P-675

$3,100/week, with a one week minimum

D-TOX CF-1 with G-14 lb/day ozone generator	$2,500/week
D-TOX CF-1 with G-28 lb/day ozone generator	$2,800/week

An Ultrox field engineer will be provided at a charge of $2,400 (plus travel and living expenses) for the first five working days on site. A per diem charge of $575.00 (plus travel and living expenses) will be invoiced for each additional day an Ultrox field engineer is required. Rates for extended rental periods, i.e. greater than four weeks, will be quoted upon request.

A credit of 50% on up to 4 weeks laboratory work and pilot plant work will be given for purchase of an ULTROX® system purchased within six months of test completion. The credit does not apply to charges for living, travel and freight expenses or field engineer's time, or for analytical charges at an independent laboratory.

TERMS

- Payable upon receipt of invoice
- Invoices for laboratory tests are issued upon completion of tests or on a monthly basis for extended laboratory studies.
- Freight charges for shipment of samples and/or pilot plant units to and from Santa Ana, CA, are the customer's responsibility.
- Invoices for pilot plant rentals are issued on a monthly basis.
- First week's pilot plant rental due with purchase order.
- One third (1/3) payment due with purchase order on laboratory studies.
- Charges commence on the day the unit arrives at client's facility until it is returned to Santa Ana, CA. Federal holidays, Saturdays and Sundays that the unit is in transit are not billed to our clients.
- Any damage to the unit above normal operating wear is the responsibility of the customer.
- Actual travel and daily living expenses for Ultrox field engineers are billed to the customer.
- Prices are subject to change without notice.
- All samples will be returned to client after testing is completed.

Prices effective 4/1/91

WA # 16-1LA5
File Copy

Metcalf & Eddy
An Air & Water Technologies Company

May 19, 1993

Mr. William Heimbaugh
Manager of Marketing & Sales
Ultrox International
2435 South Ann Street
Santa Anna, CA 92714

Subject: **Request for Quotation on Equipment, Services and Budgetary Costs - Treatment of Contaminated Groundwater using UV/Chemical Oxidation, Rose Hill Regional Landfill Superfund Site, South Kingstown, Rhode Island**

Dear Mr. Heimbaugh:

Metcalf & Eddy (M&E) is currently finalizing the Feasibility Study (FS) for treatment of contaminated groundwater at the Rose Hill Landfill site. This groundwater is contaminated with weak, municipal landfill leachate. M&E has identified treatment using ultra-violet/chemical oxidation technology as the most appropriate method for removing the organic compounds-of-concern (COCs).

A quotation describing suggested equipment, services and budgetary costs should be based on the following assumptions:

1) quotations are needed for two different systems; groundwater concentrations are shown in Attachment A for the 50 gpm system (Alternative 4) and Attachment B for the 200 gpm system (Alternative 5).
2) treatment goals are listed in each attachment by compound; for the organic compounds, please identify any compounds that <u>may not meet goals</u>.
3) suspended solids and metals pretreatment system will have removed the compounds noted by asterisk prior to entering the UV/Chemical oxidation system.
4) assume a water temperature of 55 degrees F.
5) 50 gpm flowrate may be as low as 5 gpm; will your system still operate effectively ?
6) treated water discharges to recharge wells or to river.
7) identify operations and maintenance services necessary for your proposed system.
8) identify the make & model of your proposed system; please include copies of brochures, drawings and specifications.
9) assume budgetary costs accuracy for equipment, f.o.b.
10) identify any other potential pretreatment or special conditions that you feel may be necessary for proper operation.

30 Harvard Mill Square, Wakefield MA 01880
Mailing Address PO Box 4043 Woburn MA 01888-4043
617-246-5200 FAX 617-245-6293

Your quotations are needed by the end-of-day Wednesday, May 26, 1993. Thank you for your assistance with this project. If you have any questions, please do not hesitate to contact me at TEL (617) 246-5200, extension 4272 or by FAX at (617) 245-6293.

Very truly yours,

METCALF & EDDY, INC.

Daniel P. Peters

Daniel P. Peters, P.E., ChE
Project Engineer,
Industrial & Hazardous Waste Division

Attachments
cc: S. Czarniecki
WA#18-1LA5

ATTACHMENT A: GROUNDWATER CONDITIONS FOR THE 50 GPM SYSTEM

ANALYTE (a)	GROUNDWATER CONCENTRATIONS (b) Average	Maximum		PRELIMINARY REMEDIATION GOAL
	all in (μg/L) except where noted at left			
Ammonia (mg/L)	9	48		
Sulfide (mg/L)	1	4		
Aluminum	12,616	98,281	*	
Antimony	0	0	*	6
Arsenic	2	9	*	
Barium	210	695	*	
Beryllium	2	13	*	1
Cadmium	4	36	*	5
Chromium	21	136	*	100
Cobalt	21	82	*	
Copper	37	324	*	
Iron	91,571	396,140	*	
Lead	40	180	*	15
Manganese	2,633	10,361	*	3,650
Mercury	0.11	0.29	*	
Nickel	24	112	*	100
Vanadium	20	133	*	
Zinc	625	6,520	*	7,300
Dieldrin	0.043	0.003		
2-Methylnaphthalene	4	4		
4-Chloro-3-methylphenol	4	4		
4-Methylphenol	8	64		
Pentachlorophenol	12	3		1
bis(2-Ethylhexyl)phthalate	11	59		4
1,1-Dichloroethane	13	195		
1,1-Dichloroethene	4	2		
1,2-Dichloroethene(total)	30	645		70
4-Methyl-2-pentanone	5	27		
Acetone	20	415		
Benzene	10	27		5
Carbon Disulfide	13	77		
Chloroethane	16	77		
Ethylbenzene	14	64		
Toluene	31	156		
Trichloroethene	4	4		
Vinyl Chloride	30	610		2
Acrylamide	141	202		0.02 (c)
N,N-DMF	177	1,273		
Hardness (mg/L)	151	621		
pH	7.1	11.9		
Total Organic Carbon (mg/L)	44	200		
Biochemical Oxygen Demand (mg/L)	12	112		

Notes:

(a). Asterisk denotes compounds that will be handled by the metals treatment system.

(b). Concentrations for metals are "total" and not dissolved values.

(c). Goal is significantly below normal analytical detection limits; evaluate potential to meet 2 μg/L standard assuming that this is the detection limit.

ATTACHMENT B: GROUNDWATER CONDITIONS FOR THE 200 GPM SYSTEM

ANALYTE (a)	GROUNDWATER CONCENTRATIONS (b) Average	Maximum		PRELIMINARY REMEDIATION GOAL
	all in (μg/L) except where noted at left			
Ammonia (mg/L)	11	30		
Sulfide (mg/L)	1	7		
Aluminum	14,277	76,745	*	
Antimony	10	46	*	6
Arsenic	2	7	*	
Barium	136	445	*	
Beryllium	2	9	*	1
Cadmium	3	25	*	5
Chromium	17	94	*	100
Cobalt	18	53	*	
Copper	47	215	*	
Iron	60,644	218,437	*	
Lead	32	154	*	15
Manganese	2,305	8,391	*	3,650
Mercury	0.10	0.22	*	
Nickel	27	93	*	100
Vanadium	20	115	*	
Zinc	348	3,135	*	7,300
Dieldrin	0.020	0.001		
2-Methylnaphthalene	3	2		
4-Chloro-3-methylphenol	2	2		
4-Methylphenol	8	56		
Pentachlorophenol	6	1		1
bis(2-Ethylhexyl)phthalate	4	21		4
1,1-Dichloroethane	7	89		
1,1-Dichloroethene	3	1		
1,2-Dichloroethene(total)	14	293		70
4-Methyl-2-pentanone	2	12		
Acetone	21	329		
Benzene	5	13		5
Carbon Disulfide	11	57		
Chloroethane	8	37		
Ethylbenzene	7	29		
Toluene	21	121		
Trichloroethene	2	2		
Vinyl Chloride	14	276		2
Acrylamide	64	92		0.02 (c)
N,N-DMF	84	600		
Hardness (mg/L)	86	330		
pH	6.9	9.8		
Total Organic Carbon (mg/L)	28	125		
Biochemical Oxygen Demand (mg/L)	7	58		

Notes:

(a). Asterisk denotes compounds that will be handled by the metals treatment system.

(b). Concentrations for metals are "total" and not dissolved values.

(c). Goal is significantly below normal analytical detection limits; evaluate potential to meet 2 μg/L standard assuming that this is the detection limit.

D-5 Sludge Volume Evaluation

TABLE D-5: SLUDGE VOLUME FROM PRECIPITATION - 5 gpm

ITEM	DESCRIPTION/ EQUATION	VALUE	SI UNITS	EQUIVALENT VALUE	U.S. UNITS
PURPOSE:	Worksheet calculates hydroxide sludge production for selected metals. Thickener and filter press sizing are also included.		Developed by:	S. Czarniecki	*Version:* *Jun-16-93*
			Checked by:	N. Bergeron	*Sep-6-96*
REFERENCES:	Metcalf & Eddy, Inc., Wastewater Engineering - Treatment, Disposal, and Reuse, 3rd Edition, McGraw-Hill, Inc., New York, NY, 1991.	U.S. Filter, Inc., Warrendale, PA; Conceptual Process Design for Metals Treatment, May 10, 1993.			
PROCEDURE FOR USE:	1)Input metals, hydroxides and their respective molar masses. 2)Input feed concentrations. 3)If necessary, change assumed specific gravities for sludge and solids for the thickener and filter press, respectively.	4) If necessary, change assumed solids percentages for the thickener and filter press.			
ASSUMPTIONS:	1)Excess waters are not attached to hydroxides unless the user includes them both in formula and molar mass.	2) Various assumptions stated below.			

TABLE D-5: SLUDGE VOLUME FROM PRECIPITATION – 5 gpm

ITEM	DESCRIPTION/ EQUATION	VALUE	SI UNITS	EQUIVALENT VALUE	U.S. UNITS
A. INPUT VARIABLES:					
1. Molar Mass of Metals in Feed Stream					
MET1	Major metal ions which will be removed by precipitation, plus TSS, which creates conservative value.	Al	27 mg/mol	27	lb/lbmol
MET2		Fe	56 mg/mol	56	lb/lbmol
MET3		Mn	55 mg/mol	55	lb/lbmol
MET4		TSS	-- mg/mol	--	lb/lbmol
2. Molar Mass of Hydroxides Formed					
HYD1	Hydroxides formed in precipitation process. TSS does not form hydroxide.	Al(OH)3	78 mg/mol	78	lb/lbmol
HYD2		Fe(OH)3	107 mg/mol	107	lb/lbmol
HYD3		Mn(OH)2	89 mg/mol	89	lb/lbmol
HYD4		TSS	-- mg/mol	--	lb/lbmol
3. Concentrations of Metals in Feed Stream					
CONC1	For MET1		2.1 mg/L	1.75E-05	lb/gal
CONC2	For MET2		287 mg/L	2.40E-03	lb/gal
CONC3	For MET3		8.2 mg/L	6.84E-05	lb/gal
CONC4	For MET4: TSS value assumed in this case since it was not analyzed for. Assumed 100 mg/L plus half of Fe concentration (U.S. Filter).		244 mg/L	2.04E-03	lb/gal
4. Feed Stream Flow Rate					
FLOW	Input flow rate of feed stream.		18.93 L/min	5	gal/min

TABLE D-5: SLUDGE VOLUME FROM PRECIPITATION – 5 gpm

ITEM	DESCRIPTION/ EQUATION	VALUE	SI UNITS	EQUIVALENT VALUE	U.S. UNITS
B. OUTPUT QUANTITIES: 1. Sludge Mass: SM	= [CONC1 * (HYD1/MET1)]+[CONC2 * (HYD2/MET2)]+...+[CONCn] where CONCn is the TSS concentration	811.71	mg/L solids	6.77E-03	lb/gal solids
2. Sludge Mass Per Day: SMPD	= SM * FLOW * 60 min/hr * 24 hr/day	2.21E+07	mg/day solids	48.77	lb/day solids
C. THICKENER SIZING: 1. Sludge sp. gr. SLSG	Assumed value from M&E, 1991, p773 – range 1.005–1.05 – and assumption from U.S. Filter	1.03		1.03	
2. Sludge Dry Solids Fraction SLDSF	Percentage assumed – U.S. Filter	3.00%		3.00%	
3. Sludge Volume Per Day SLVPD	= SMPD / SLDSF / (SLSG * refden) where refden is either 8.34 lbs/gal or 1E+6 mg/L	715.99	L/day @ SLDSF dry solids	189.26	gal/day @ SLDSF dry solids

TABLE D-5: SLUDGE VOLUME FROM PRECIPITATION – 5 gpm

ITEM	DESCRIPTION/ EQUATION	VALUE	SI UNITS	EQUIVALENT VALUE	U.S. UNITS
D. FILTER PRESS SIZING:					
1. Sludge Solids sp. gr. SLSSG	Assumed value from M&E, 1991, p868 – range 1.2–2.2 – and assumption from U.S. Filter	1.3		1.3	
2. Filter Cake Solids Fraction FCSF	Percentage assumed – U.S. Filter	30.00%		30.00%	
3. Filter Cake Volume Per Day FCVPD	= SMPD / FCSF / (SLSSG * refden2) where refden2 is either 62.43 lbs/ft ^3 or 1E+9 mg/m ^3	0.06 m ^3/day @ FCSF solids		2.00 ft ^3/day @ FCSF solids	

TABLE D-6: SLUDGE VOLUME FROM PRECIPITATION – 50 gpm

ITEM	DESCRIPTION/ EQUATION	VALUE	SI UNITS	EQUIVALENT VALUE	U.S. UNITS
PURPOSE:	Worksheet calculates hydroxide sludge production for selected metals. Thickener and filter press sizing are also included.		Developed by: Checked by:	S. Czarniecki C. McLane	*Version:* *Jun-16-93* *July-13-93*
REFERENCES:	Metcalf & Eddy, Inc., Wastewater Engineering – Treatment, Disposal, and Reuse, 3rd Edition, McGraw-Hill, Inc., New York, NY, 1991.	U.S. Filter, Inc., Warrendale, PA; Conceptual Process Design for Metals Treatment, May 10, 1993.			
PROCEDURE FOR USE:	1)Input metals, hydroxides and their respective molar masses. 2)Input feed concentrations. 3)If necessary, change assumed specific gravities for sludge and solids for the thickener and filter press, respectively. 4) If necessary, change assumed solids percentages for the thickener and filter press.				
ASSUMPTIONS:	1)Excess waters are not attached to hydroxides unless the user includes them both in formula and molar mass. 2) Various assumptions stated below.				

TABLE D-6: SLUDGE VOLUME FROM PRECIPITATION – 50 gpm

ITEM	DESCRIPTION/ EQUATION	VALUE	SI UNITS	EQUIVALENT VALUE	U.S. UNITS
A. INPUT VARIABLES:					
1. Molar Mass of Metals in Feed Stream					
MET1	Major metal ions which will be removed by precipitation, plus TSS, which creates conservative value.	Al	27 mg/mol	27	lb/lbmol
MET2		Fe	56 mg/mol	56	lb/lbmol
MET3		Mn	55 mg/mol	55	lb/lbmol
MET4		TSS	-- mg/mol	--	lb/lbmol
2. Molar Mass of Hydroxides Formed					
HYD1	Hydroxides formed in precipitation process. TSS does not form hydroxide.	Al(OH)3	78 mg/mol	78	lb/lbmol
HYD2		Fe(OH)3	107 mg/mol	107	lb/lbmol
HYD3		Mn(OH)2	89 mg/mol	89	lb/lbmol
HYD4		TSS	-- mg/mol	--	lb/lbmol
3. Concentrations of Metals in Feed Stream					
CONC1	For MET1		12.6 mg/L	1.05E-04	lb/gal
CONC2	For MET2		91.6 mg/L	7.64E-04	lb/gal
CONC3	For MET3		2.6 mg/L	2.17E-05	lb/gal
CONC4	For MET4: TSS value assumed in this case since it was not analyzed for. Assumed 100 mg/L plus half of Fe concentration (U.S. Filter).		146 mg/L	1.22E-03	lb/gal
4. Feed Stream Flow Rate					
FLOW	Input flow rate of feed stream.		189.28 L/min	50	gal/min

TABLE D-6: SLUDGE VOLUME FROM PRECIPITATION - 50 gpm

ITEM	DESCRIPTION/ EQUATION	VALUE	SI UNITS	EQUIVALENT VALUE	U.S. UNITS
B. OUTPUT QUANTITIES: 1. Sludge Mass: SM	= [CONC1 * (HYD1/MET1)]+[CONC2 * (HYD2/MET2)]+...+[CONCn] where CONCn is the TSS concentration	361.63	mg/L solids	3.02E-03	lb/gal solids
2. Sludge Mass Per Day: SMPD	= SM * FLOW * 60 min/hr * 24 hr/day	9.86E+07	mg/day solids	217.30	lb/day solids
C. THICKENER SIZING: 1. Sludge sp. gr. SLSG	Assumed value from M&E, 1991, p773 - range 1.005-1.05 - and assumption from U.S. Filter	1.03		1.03	
2. Sludge Dry Solids Fraction SLDSF	Percentage assumed - U.S. Filter	3.00%		3.00%	
3. Sludge Volume Per Day SLVPD	= SMPD / SLDSF / (SLSG * refden) where refden is either 8.34 lbs/gal or 1E+6 mg/L	3189.85	L/day @ SLDSF dry solids	843.20	gal/day @ SLDSF dry solids

TABLE D-6: SLUDGE VOLUME FROM PRECIPITATION – 50 gpm

ITEM	DESCRIPTION/ EQUATION	VALUE	SI UNITS	EQUIVALENT VALUE	U.S. UNITS
D. FILTER PRESS SIZING: 1. Sludge Solids sp. gr. SLSSG	Assumed value from M&E, 1991, p868 – range 1.2–2.2 – and assumption from U.S. Filter	1.3		1.3	
2. Filter Cake Solids Fraction FCSF	Percentage assumed – U.S. Filter	30.00%		30.00%	
3. Filter Cake Volume Per Day FCVPD	= SMPD / FCSF / (SLSSG * refden2) where refden2 is either 62.43 lbs/ft ^3 or 1E+9 mg/m ^3	0.25 m ^3/day @ FCSF solids		8.92 ft ^3/day @ FCSF solids	

D-6 Development of Disposal Costs

Project: Rose Hill FS | Acct. No. 4609-18-10-10 | Page 1 of 1
Subject: Sludge Calcs | Comptd. By S. Czarniecki | Date 6/15/93
Detail: Disposal Costs | Ck'd. By C. McLane | Date 7/13/93

200 gpm

28.7 ft³/day filter cake - say 30 ft³/day

solids sp. gr. = 1.3

30 ft³/day (1.3)(62.43 lb/ft³) = 2435 lb/day

50 gpm

8.9 ft³/day filter cake - say 9 ft³/day

9 (1.3)(62.43) = 730 lb/day

Assuming $200/ton (See U.S. Filter Proposal)

200 gpm $200/2000 lb × 2435 lb/day = $243.50/day × day/288(1000 gal) = $0.84/1000 gal

50 gpm " × 730 lb/day = $73/day × day/72(1000 gal) = $1.01/1000 gal

NONREPRODUCIBLE GRID FORM 145

METCALF & EDDY, ENGINEERS

D-7 Development of Chemical Requirements for Precipitation

Project: Rose Hill FC | Acct. No. 460T-18-10-10 | Page 1 of 1
Subject: GW/Leachate Treatment | Comptd. By: S. Czarnieckt | Date: 6/15/93
Detail: Chemical Requirements/Elec. | Ck'd. By: C. McLane | Date: 7/13/93

50 gpm - 72000 gal/day 200 gpm - 288000 gal/day

From U.S. Filter Proposal:

50gpm Caustic: $300/2000 lbs × 300 lbs/day = $45/day × day/72(1000gal) = $0.63/1000 gal

200gpm (Useas check): $300/2000 lbs × 1200 lbs/day = $180/day × day/288(1000gal) = $0.63/1000gal

Sulfuric Acid

50gpm: $75/2000 lbs × 480 lbs/day = $18/day × day/72(1000gal) = $0.25/1000gal

Ferrous Sulfate

50gpm: $160/2000 lbs × 315 lbs/day = $25.20/day × day/72(1000gal) = $0.35/1000gal

Polymer

50gpm: $5.75/lb × 0.6 lbs/day = $3.45/day × day/72(1000gal) = $0.05/1000 gal

Sodium Sulfide

50gpm: $29/100 lbs × 7.5 lbs/day = $2.18/day × day/72(1000gal) = $0.03/1000 gal

Sorption Filter Media

50 gpm: $3.50/lb × 6 lbs/day = $21/day × day/72(1000gal) = $0.29/1000 gal

Total = $1.60/1000 gal

Electricity assume usage is per day

50gpm - 40 Kw-Hr/day × $0.07/Kwhr (assumed) = $2.80/day × day/72(1000gal) = $0.04/1000 gal

200gpm: 100 Kw-Hr/day × $0.07/Kwhr = $7/day × day/288(1000gal) = $0.02/1000 gal

NONREPRODUCIBLE GRID FORM 145
METCALF & EDDY, ENGINEERS

E. LANDFILL GAS COLLECTION AND TREATMENT

E-1 Landfill Gas Generation Rate Calculation: Scholl Canyon Model
E-2 Perimeter Gas Flowrate Calculations: Johnson Equation
E-3 Gas Composition Calculations
E-4 Enclosed Landfill Gas Flare Calculations
- Vendor Quotation: John Zink Company
- Auxiliary Fuel Requirements

E-5 Additional Landfill Gas Collection System Calculations - Draft FS
E-6 Photocatalytic Oxidation Calculations
E-7 Regulatory Analyses/Clarifications

E-1 Landfill Gas Generation Rate Calculation: Scholl Canyon Model

ROSE HILL SOLID WASTE AREA *VERSION: SEP-08-98*
GAS GENERATION RATE CALCULATION Checked by: Sean Czarniecki 08/26/96
METHOD 1: SCHOLL CANYON FIRST ORDER KINETIC MODEL

FORMULA:

$$Q = 2 \cdot [k \cdot L \cdot R\,[\exp(-k \cdot (t-lag))]]$$

[Source: Methane Generation & Recovery from Landfills, Emcon Associates, 1982]

Incorporates: New Stationary Source Performance Standards for Municipal Solid Waste LFs FR 9905, Vol. 61, No. 49, March 12, 1996 *(Formula is multiplied by 2 since it is for methane generation and CH_4 is assumed to be 50% of LFG)*

WHERE:

Q = landfill gas generation rate @ time t (ft^3 LFG / yr)
L = potential methane gas generation capacity of refuse (ft^3 CH_4 / ton)
R = annual refuse acceptance rate in landfill (tons)
k = methane production rate (1 / yr)
t = time since refuse placement (yr)
lag = time to reach conditions suitable for methane production (yr)

INPUT PARAMETERS:

					tons MSW
L =	3,204	Year closed =	1982	Avg. refuse 1967-1970:	18,667
k =	0.04	Current year =	1997	Avg. refuse 1971-1975:	10,889
lag =	2	Time since closure =	15	Avg. refuse 1976-1977:	24,000
				Avg. refuse 1978-1982:	20,400

L and k are EPA AP-42 default values (9/97).

YEAR	TIME SINCE REFUSE PLACEMENT	GENERATION RATE 1997
1968	29	1.62E+06
1969	28	1.69E+06
1970	27	1.76E+06
1971	26	1.07E+06
1972	25	1.11E+06
1973	24	1.16E+06
1974	23	1.21E+06
1975	22	1.25E+06
1976	21	2.88E+06
1977	20	2.99E+06
1978	19	2.65E+06
1979	18	2.76E+06
1980	17	2.87E+06
1981	16	2.99E+06
1982	15	3.11E+06
1983	-	0.00E+00
1984	-	0.00E+00
1985	-	0.00E+00
1986	-	0.00E+00
1987	-	0.00E+00
1988	-	0.00E+00
1989	-	0.00E+00
1990	-	0.00E+00
1991	-	0.00E+00
1992	-	0.00E+00
1993	-	0.00E+00
TOTAL 1997	**LF GAS PRODUCTION**	3.11E+07 ft^3 LFG / yr
		2.79E+04 cm^3 LFG / s

Total MSW disposed (tons)	279,113
Total MSW disposed (Mg)	253,164

This area determines the contribution towards the 1997 LFG generation rate. No refuse was placed after 1982, so there is no contribution from waste placed after that date.

ROSE HILL SOLID WASTE AREA
GAS GENERATION RATE CALCULATION
METHOD 1: SCHOLL CANYON FIRST ORDER KINETIC MODEL (continued)

TOTAL ANNUAL LFG PRODUCTION OVER TIME: ESTIMATED PROJECTIONS

Year	Estimated Annual LFG Production (ft^3 / yr)	Time Since Landfill Closure (years)
1997	3.11E+07	15
1998	2.99E+07	16
1999	2.87E+07	17
2000	2.76E+07	18
2001	2.65E+07	19
2002	2.55E+07	20
2003	2.45E+07	21
2004	2.35E+07	22
2005	2.26E+07	23
2006	2.17E+07	24
2007	2.09E+07	25
2008	2.00E+07	26
2009	1.93E+07	27
2010	1.85E+07	28
2011	1.78E+07	29
2012	1.71E+07	30

Confirmation modeling utilizing EPA's Landfill Air Emission Estimation model is attached. Note that the model printout is for methane only, which is assumed to be 50% of the LFG flow.

The model output shows		4.444E+05	m^3 CH_4 / yr
	=	888,800	m^3 LFG / yr
	=	0.0282	m^3 LFG / s
	=	60	ft^3 / min

Source: C:\RH\AIR\RH_NEW.PRM

Model Parameters

Lo : 100.00 m^3 / Mg
k : 0.0400 1/yr
NMOC : 595.00 ppmv
Methane : 50.0000 % volume
Carbon Dioxide : 50.0000 % volume

Landfill Parameters

Landfill type : No Co-Disposal
Year Opened : 1967 Current Year : 1997 Closure Year: 1997
Capacity : 253164 Mg
Average Acceptance Rate Required from
Current Year to Closure Year : 0.00 Mg/year

Model Results

Year	Refuse In Place (Mg)	Methane Emission Rate (Mg/yr)	Methane Emission Rate (Cubic m/yr)
1968	1.693E+04	4.519E+01	6.774E+04
1969	3.387E+04	8.861E+01	1.328E+05
1970	5.080E+04	1.303E+02	1.953E+05
1971	6.774E+04	1.704E+02	2.554E+05
1972	7.761E+04	1.901E+02	2.849E+05
1973	8.749E+04	2.090E+02	3.133E+05
1974	9.737E+04	2.272E+02	3.405E+05
1975	1.072E+05	2.446E+02	3.666E+05
1976	1.171E+05	2.614E+02	3.918E+05
1977	1.389E+05	3.092E+02	4.635E+05
1978	1.607E+05	3.552E+02	5.324E+05
1979	1.792E+05	3.907E+02	5.856E+05
1980	1.977E+05	4.247E+02	6.366E+05
1981	2.162E+05	4.575E+02	6.857E+05
1982	2.347E+05	4.889E+02	7.328E+05
1983	2.532E+05	5.190E+02	7.780E+05
1984	2.532E+05	4.987E+02	7.475E+05
1985	2.532E+05	4.791E+02	7.182E+05
1986	2.532E+05	4.603E+02	6.900E+05
1987	2.532E+05	4.423E+02	6.629E+05
1988	2.532E+05	4.249E+02	6.370E+05
1989	2.532E+05	4.083E+02	6.120E+05
1990	2.532E+05	3.923E+02	5.880E+05
1991	2.532E+05	3.769E+02	5.649E+05
1992	2.532E+05	3.621E+02	5.428E+05
1993	2.532E+05	3.479E+02	5.215E+05
1994	2.532E+05	3.343E+02	5.010E+05
1995	2.532E+05	3.212E+02	4.814E+05
1996	2.532E+05	3.086E+02	4.625E+05
1997	2.532E+05	2.965E+02	4.444E+05
1998	2.532E+05	2.848E+02	4.270E+05
1999	2.532E+05	2.737E+02	4.102E+05
2000	2.532E+05	2.629E+02	3.941E+05
2001	2.532E+05	2.526E+02	3.787E+05
2002	2.532E+05	2.427E+02	3.638E+05
2003	2.532E+05	2.332E+02	3.496E+05
2004	2.532E+05	2.241E+02	3.359E+05
2005	2.532E+05	2.153E+02	3.227E+05
2006	2.532E+05	2.068E+02	3.100E+05
2007	2.532E+05	1.987E+02	2.979E+05
2008	2.532E+05	1.909E+02	2.862E+05
2009	2.532E+05	1.835E+02	2.750E+05
2010	2.532E+05	1.763E+02	2.642E+05
2011	2.532E+05	1.693E+02	2.538E+05
2012	2.532E+05	1.627E+02	2.439E+05

Updated LFG production rates for the Bulky Waste Area are being calculated for consistency during risk calculations. Time and new AP-42 default generation coefficients will produce lower emission rates, similar to the Solid Waste Area.

Information from Appendix E in the RI (May 1994) was used as a basis to run EPA's Landfill Air Emission Estimation model.

The model output is attached. Note that the model printout is for methane only, which is assumed to be 50% of the LFG flow.

The model output shows		6.134E+04	m^3 CH_4 / yr
	=	1.23E+05	m^3 LFG / yr
	=	0.0039	m^3 LFG / s
	=	8.2	ft^3 LFG / min

METCALF & EDDY

Source: C:\RH\AIR\RHBWANEW.PRM

Model Parameters

Lo : 100.00 m^3 / Mg
0.0400 1/yr
C : 595.00 ppmv
Methane : 50.0000 % volume
Carbon Dioxide : 50.0000 % volume

Landfill Parameters

Landfill type : No Co-Disposal
Year Opened : 1982 Current Year : 1998 Closure Year: 1998
Capacity : 26218 Mg
Average Acceptance Rate Required from
Current Year to Closure Year : 0.00 Mg/year

Model Results

Year	Refuse In Place (Mg)	Methane Emission Rate (Mg/yr)	(Cubic m/yr)
1983	1.080E+04	2.881E+01	4.318E+04
1984	2.622E+04	6.884E+01	1.032E+05
1985	2.622E+04	6.614E+01	9.913E+04
1986	2.622E+04	6.354E+01	9.525E+04
1987	2.622E+04	6.105E+01	9.151E+04
1988	2.622E+04	5.866E+01	8.792E+04
1989	2.622E+04	5.636E+01	8.448E+04
1990	2.622E+04	5.415E+01	8.116E+04
1991	2.622E+04	5.202E+01	7.798E+04
1992	2.622E+04	4.998E+01	7.492E+04
1993	2.622E+04	4.802E+01	7.199E+04
1994	2.622E+04	4.614E+01	6.916E+04
1995	2.622E+04	4.433E+01	6.645E+04
1996	2.622E+04	4.259E+01	6.385E+04
1997	2.622E+04	4.092E+01	6.134E+04
1998	2.622E+04	3.932E+01	5.894E+04
1999	2.622E+04	3.778E+01	5.663E+04
2000	2.622E+04	3.630E+01	5.441E+04
2001	2.622E+04	3.487E+01	5.227E+04
2002	2.622E+04	3.351E+01	5.022E+04
2003	2.622E+04	3.219E+01	4.825E+04
2004	2.622E+04	3.093E+01	4.636E+04
2005	2.622E+04	2.972E+01	4.454E+04
2006	2.622E+04	2.855E+01	4.280E+04
2007	2.622E+04	2.743E+01	4.112E+04
2008	2.622E+04	2.636E+01	3.951E+04
2009	2.622E+04	2.532E+01	3.796E+04
2010	2.622E+04	2.433E+01	3.647E+04
2011	2.622E+04	2.338E+01	3.504E+04
2012	2.622E+04	2.246E+01	3.367E+04
2013	2.622E+04	2.158E+01	3.235E+04
2014	2.622E+04	2.073E+01	3.108E+04
2015	2.622E+04	1.992E+01	2.986E+04
2016	2.622E+04	1.914E+01	2.869E+04
2017	2.622E+04	1.839E+01	2.756E+04
2018	2.622E+04	1.767E+01	2.648E+04
2019	2.622E+04	1.697E+01	2.544E+04
2020	2.622E+04	1.631E+01	2.445E+04
2021	2.622E+04	1.567E+01	2.349E+04
2022	2.622E+04	1.506E+01	2.257E+04
2023	2.622E+04	1.446E+01	2.168E+04
2024	2.622E+04	1.390E+01	2.083E+04
2025	2.622E+04	1.335E+01	2.001E+04
2026	2.622E+04	1.283E+01	1.923E+04
2027	2.622E+04	1.233E+01	1.848E+04

E-2 Perimeter Gas Flowrate Calculations: Johnson Equation

ROSE HILL SOLID WASTE AREA
LANDFILL GAS VOLUMETRIC FLOWRATE CALCULATION

Purpose:	This spreadsheet calculates landfill gas flowrates collected from extraction wells under vacuum using the Johnson equation for steady flow in a confined vadose zone.	Developed by:	K. Campbell	Run Date:	08/16/96
		Checked by:	S. Czarniecki	Date:	08/23/96

The Johnson equation is shown below and in Attachment A, copied from *A Practical Approach to the Design, Operation, and Monitoring of In Situ Soil–Venting Systems*, Groundwater Monitoring Review, Johnson et al., Spring 1990.

$$\text{Flowrate } (cm^3/s) = \pi * K_g/\mu_g * P_w * [(1-(P_{atm}/P_w)^2)/\ln(R_w/R_I)]$$

INPUT PARAMETERS:

Air Viscosity, μ_a =	1.75E−04 g/cm•s	0°C [Bennett & Meyers, 1982, App. 9 – Attached]
Landfill Gas Viscosity, μ_{lfg} =	1.18E−04 g/cm•s	0°C Avg. of CH_4 & CO_2 [Bennett & Meyers, 1982]
Mix Fraction Air, X_a =	0.8	Assumed
Mix Fraction Landfill Gas, X_{lfg} =	0.2	$1 - X_a$
Mixed Gas Viscosity, μ_g =	1.63E−04 g/cm•s	$\mu_a * X_a + \mu_{lfg} * X_{lfg}$
Soil Hydraulic Conductivity, K =	5.80E−03 cm/s	Sand [USEPA, 1994, p.30]
Water Viscosity, μ_w =	1.307E−02 g/cm•s	@ 10°C [CRC 68th, p. F−39]
Water Density, rho_w =	9.997E−01 g/cm^3	@ 10°C [CRC 68th, p. F−10]
Gravitational Acceleration, Ag =	9.81E+02 cm/s^2	
Vent Well Diameter, d =	15.24 cm	6 in. diameter
Depth to Confining Layer, b =	661 cm	22 ft. avg. well depth (btw. 20−25 ft.)
Atmospheric Pressure, P_{atm} =	1.01E+06 g/cm•s^2	
Linear Distance Along rose Hill Road, m =	540 m	Estimate from maps

CALCULATION:

Hydraulic Intrinsic Permeability, K_i = (Soil Gas Permeability, K_g)	7.733E−08 cm^2	$K \bullet \mu_w/rho_w \bullet Ag$ [Fetter, 1988, p.78]

INDIVIDUAL WELL FLOWRATE TO ESTABLISH RADIUS OF INFLUENCE

VACUUM APPLIED AT WELL		RADIUS OF INFLUENCE, R						
		304 cm	608 cm	912 cm	1,216 cm	1,520 cm	1,824 cm	3,048 cm
(in. water)	(cm water)	10 ft	20 ft	30 ft	40 ft	50 ft	60 ft	100 ft
		(cm^3/s)						
4	10.2	5,357	4,509	4,127	3,893	3,729	3,605	3,296
5	12.7	6,678	5,621	5,145	4,853	4,648	4,494	4,108
10	25.4	13,440	11,313	10,354	9,767	9,356	9,044	8,269
15	38.1	20,291	17,080	15,632	14,746	14,124	13,654	12,484
17	44.0	23,505	19,785	18,108	17,081	16,361	15,817	14,461
20	50.8	27,233	22,923	20,981	19,791	18,957	18,326	16,755
25	63.5	34,271	28,847	26,402	24,905	23,856	23,062	21,085

FLOWRATE OF SYSTEM

VACUUM APPLIED AT WELL		TOTAL NUMBER OF WELLS BASED ON RADIUS OF INFLUENCE ABOVE						
(in. water)	(cm water)	103	52	35	26	21	18	11
		(cm^3/s)						
5	12.7	6.88E+05	2.92E+05	1.80E+05	1.26E+05	9.76E+04	8.09E+04	4.52E+04
10	25.4	1.38E+06	5.88E+05	3.62E+05	2.54E+05	1.96E+05	1.63E+05	9.10E+04
15	38.1	2.09E+06	8.88E+05	5.47E+05	3.83E+05	2.97E+05	2.46E+05	1.37E+05
17	44.0	2.42E+06	1.03E+06	6.34E+05	4.44E+05	3.44E+05	2.85E+05	1.59E+05
20	50.8	2.81E+06	1.19E+06	7.34E+05	5.15E+05	3.98E+05	3.30E+05	1.84E+05
25	63.5	3.53E+06	1.50E+06	9.24E+05	6.48E+05	5.01E+05	4.15E+05	2.32E+05

Notes:

Flowrate of 3.83E+05 chosen because a 40 ft radius of influence and 38.1 cm (15 in) water vacuum is sufficient to prevent landfill gas migration beyon collection system. A total of 26 perimeter extraction wells would be required for a 40 ft radius of influence.

tures accidentally released to the environment. There are more sophisticated equations for predicting vapor concentrations in soil systems based on equilibrium partitioning arguments, but these require more detailed information (organic carbon content, soil moisture) than is normally available. If a site is chosen for remediation, the residual total hydrocarbons in soil typically exceed 500 mg/kg. In this residual concentration range most of the hydrocarbons will be present as a separate or "free" phase, the contaminant vapor concentrations become independent of residual concentration (but still depend on composition), and Equation 1 is applicable (Johnson et al. 1988). In any case, it should be noted that these are estimates only for vapor concentrations at the start of venting, which is when the removal rates are generally greatest. Contaminant concentrations in the extracted vapors will decline with time due to changes in composition, residual levels, or increased diffusional resistances. These topics will be discussed in more detail.

Under Ideal Vapor Flow Conditions (i.e., 100 – 1000 scfm Vapor Flow Rates), Is This Concentration Great Enough to Yield Acceptable Removal Rates?

Question 2 is answered by multiplying the concentration estimate C_{est}, by a range of reasonable flow rates, Q:

$$R_{est} = C_{est}\ Q \qquad (2)$$

Here R_{est} denotes the estimated removal rate, and C_{est} and Q must be expressed in consistent units. For reference, documented venting operations at service station sites typically report vapor flow rates in the 10 – 100 scfm range (Hutzler et al. 1988), although 100 – 1000 scfm flow rates are achievable for sandy soils or large numbers of extraction wells. At this point in the decision process what is still being neglected is that vapor concentrations decrease during venting due to compositional changes and mass transfer resistances. Figure 4 presents calculated removal rates R_{est} [kg/d] for a range of C_{est} and Q values. C_{est} values are presented in [mg/L] and [ppm_{CH4}] units, where [ppm_{CH4}] represents methane-equivalent parts-per-million volume/volume (ppm_v) units. The [ppm_{CH4}] units are used because field analytical tools that report [ppm_v] values are often calibrated with methane. The [mg/L] and [ppm_{CH4}] units are related by:

$$[mg/L] = \frac{[ppm_{CH4}] * 16000\ mg\text{-}CH_4/mole\text{-}CH_4 * 10^{-6}}{(0.0821\ l\text{-}atm/^oK\text{-}mole) * (298\ K)} \qquad (3)$$

For field instruments calibrated with other compounds (i.e., butane, propane), [ppm_v] values are converted to [mg/L] by replacing the molecular weight of CH_4 in Equation 3 by the molecular weight [mg/mole] of the calibration compound.

Acceptable or desirable removal rates $R_{acceptable}$, can be determined by dividing the estimated spill mass M_{spill}, by the maximum acceptable cleanup time τ:

$$R_{acceptable} = M_{spill}/\tau \qquad (4)$$

For example, if 1500kg (≈ 500 gal) of gasoline had been spilled at a service station and it was wished to

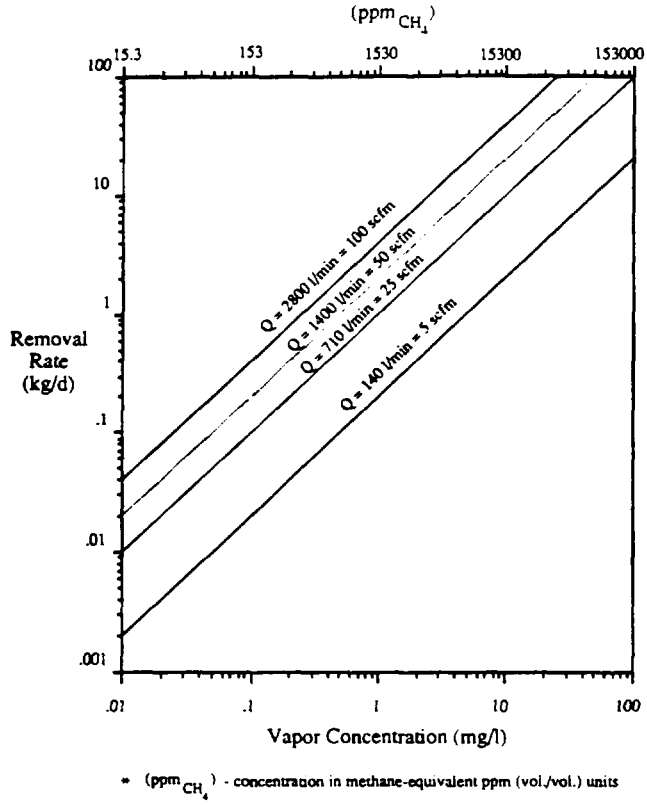


Figure 4. In situ soil-venting removal rate dependence on vapor extraction rate and vapor concentration.

complete the cleanup within eight months, then $R_{acceptable}$ = 6.3 kg/d. Based on Figure 4, therefore, C_{est} would have to average >1.5 mg/L (2400 ppm_{CH4}) for Q=2800 l/min (100 cfm) if venting is to be an acceptable option. Generally, removal rates <1 kg/d will be unacceptable for most releases, so soils contaminated with compounds (mixtures) having saturated vapor concentrations less than 0.3 mg/L (450 ppm_{CH4}) will not be good candidates for venting, unless vapor flow rates exceed 100 scfm. Judging from the compounds listed in Table 1, this corresponds to compounds with boiling points (T_b)>150 C, or pure component vapor pressures <0.0001 atm evaluated at the subsurface temperature.

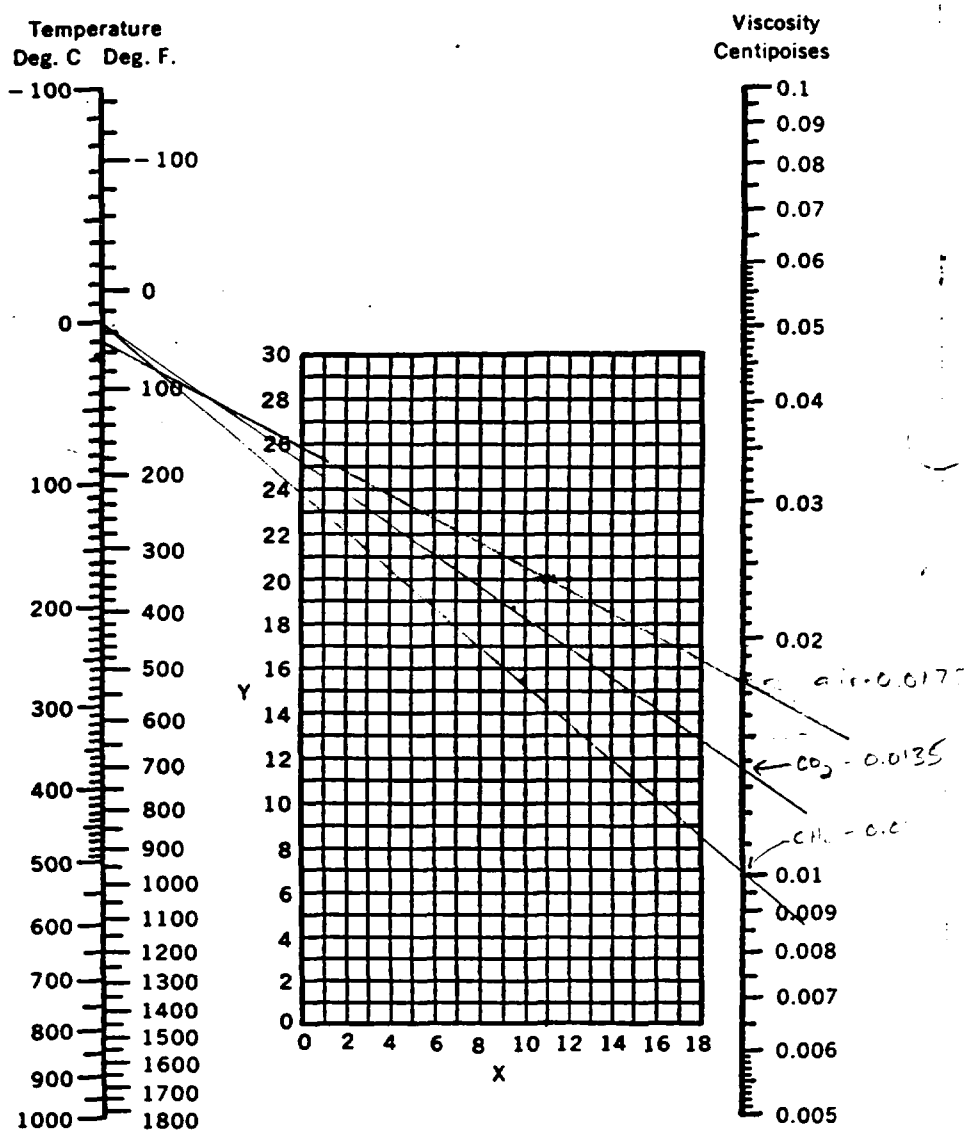
What Range of Vapor Flow Rates Can Realistically Be Achieved?

Question 3 requires that realistic vapor flow rates for the site-specific conditions be estimated. Equation 5, which predicts the flow rate per unit thickness of well screen Q/H [cm^2/s], can be used for this purpose:

$$\frac{Q}{H} = \pi \frac{k}{\mu} p_w \frac{[1 - (P_{Atm}/P_w)^2]}{\ln(R_w/R_I)} \qquad (5)$$

where:

k = soil permeability to air flow [cm^2] or [darcy]
μ = viscosity of air = 1.8 x 10^{-4} g/cm-s or 0.018 cp
P_w = absolute pressure at extraction well [g/cm-s^2] or [atm]
P_{Atm} = absolute ambient pressure ≈ 1.01 x 10^6 g/cm-s^2 or 1 atm
R_w = radius of vapor extraction well [cm]
R_I = radius of influence of vapor extraction well [cm].



Viscosities of gases and vapors at 1 atm; for coordinates, see table on previous page.

M

...py, Btu/lb	
Vaporization λ	Sat. vapor H_y
1075.8	1075.8
1074.1	1077.1
1071.3	1079.3
1068.4	1081.5
1065.6	1083.7
1062.7	1085.8
1059.9	1088.0
1057.1	1090.2
1054.3	1092.3
1051.5	1094.5
1048.6	1096.6
1045.8	1098.8
1042.9	1100.9
1040.1	1103.1
1037.2	1105.2
1031.6	1109.5
1025.8	1113.7
1020.0	1117.9
1014.1	1122.0
1008.2	1126.1
1002.3	1130.2
996.3	1134.2
990.2	1138.1
984.1	1142.0
977.9	1145.9
971.6	1149.7
970.3	1150.4
965.2	1153.4
958.8	1157.0
952.2	1160.5
945.5	1164.0
938.7	1167.3
931.8	1170.6
924.7	1173.8
917.5	1176.8
910.1	1179.7
902.6	1182.5
894.9	1185.2
887.0	1187.7
879.0	1190.1
870.7	1192.3
862.2	1194.4
853.5	1196.3
844.6	1198.1
835.4	1199.6
826.0	1201.0
816.3	1202.1
806.3	1203.1
796.0	1203.8
785.4	1204.3
774.5	1204.6

Steam," by Joseph H. Keenan and
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APPENDIX 9

VISCOSITIES OF GASES†

No.	Gas	X	Y	No.	Gas	X	Y
1	Acetic acid	7.7	14.3	29	Freon-113	11.3	14.0
2	Acetone	8.9	13.0	30	Helium	10.9	20.5
3	Acetylene	9.8	14.9	31	Hexane	8.6	11.8
4	Air	11.0	20.0	32	Hydrogen	11.2	12.4
5	Ammonia	8.4	16.0	33	$3H_2 + N_2$	11.2	17.2
6	Argon	10.5	22.4	34	Hydrogen bromide	8.8	20.9
7	Benzene	8.5	13.2	35	Hydrogen chloride	8.8	18.7
8	Bromine	8.9	19.2	36	Hydrogen cyanide	9.8	14.9
9	Butene	9.2	13.7	37	Hydrogen iodide	9.0	21.3
10	Butylene	8.9	13.0	38	Hydrogen sulfide	8.6	18.0
11	Carbon dioxide	9.5	18.7	39	Iodine	9.0	18.4
12	Carbon disulfide	8.0	16.0	40	Mercury	5.3	22.9
13	Carbon monoxide	11.0	20.0	41	Methane	9.9	15.5
14	Chlorine	9.0	18.4	42	Methyl alcohol	8.5	15.6
15	Chloroform	8.9	15.7	43	Nitric oxide	10.9	20.5
16	Cyanogen	9.2	15.2	44	Nitrogen	10.6	20.0
17	Cyclohexane	9.2	12.0	45	Nitrosyl chloride	8.0	17.6
18	Ethane	9.1	14.5	46	Nitrous oxide	8.8	19.0
19	Ethyl acetate	8.5	13.2	47	Oxygen	11.0	21.3
20	Ethyl alcohol	9.2	14.2	48	Pentane	7.0	12.8
21	Ethyl chloride	8.5	15.6	49	Propane	9.7	12.9
22	Ethyl ether	8.9	13.0	50	Propyl alcohol	8.4	13.4
23	Ethylene	9.5	15.1	51	Propylene	9.0	13.8
24	Fluorine	7.3	23.8	52	Sulfur dioxide	9.6	17.0
25	Freon-11	10.6	15.1	53	Toleune	8.6	12.4
26	Freon-12	11.1	16.0	54	2,3,3-Trimethylbutane	9.5	10.5
27	Freon-21	10.8	15.3	55	Water	8.0	16.0
28	Freon-22	10.1	17.0	56	Xenon	9.3	23.0

Coordinates for use with figure overleaf.

† By permission, from J. H. Perry (ed.), "Chemical Engineers' Handbook," 5th ed., pp. 3-210 and 3-211. Copyright, 1973, ©, McGraw-Hill Book Company.

METCALF & EDDY, INC.

TELECON MEMORANDUM

JOB NO. 020617-0011

DATE: Aug. 15, 199-

SUBJECT: Rose Hill Landfill FS - Perimeter & Internal LFG Control Systems : Solid Waste Area

M&E ENGINEER: Daniel Peters

MADE CALL (✓) 8:30, 13:00

REC'D CALL (✓) 12:30

OUTSIDE PARTY: Fred Rice, Pres. F.C. Rice & Co., Inc., 15 Heather Lane, Hampton, NH & TEL (603) 929-1771 FAX

COMMENTS

Fred concerned that we may use more propane than we expect (Fred not aware of the alternate flare design)

SUMMARY OF CONVERSATION:

8:30 Called & left message for Fred re: Rose Hill Landfill — key issue internal vs. perimeter landfill gas collection system

12:30, 13:00 Called Fred back

- Fred's primary concern is the potential for over-estimation of the gas generation rate using the EPA default coefficients; this may cause an O&M impact for combusting the perimeter gas stream in the flare
- Fred recommended eliminating the perimeter extraction well system and ~~ee~~ replacing it with an upgraded internal system as follows:
  - change well spacing from 200-ft (center to center) to 100-ft (center to center)
  - locate internal well system ~50 ft in from refuse limit along perimeter areas w/migration problems
  - internal well layout should be in a uniform, checkerboard pattern

CC: [redacted] J. Osborn

Barb Weir

Deb Simone

RAC WA# 007-RICO-01A5

METCALF & EDDY, INC.

TELECON MEMORANDUM

JOB NO. _____ DATE: Aug. 15, 1997

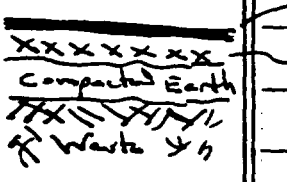
SUBJECT: _____

M&E ENGINEER: _____ OUTSIDE PARTY: Fred Rice

MADE CALL ( )

REC'D CALL ( )

COMMENTS	SUMMARY OF CONVERSATION:
	• I discussed w/ Fred that residences along Rose Hill Road were very close to the Solid Waste Area fill ... did he think an internal system alone would be sufficient to prevent migration? Fred felt it would
	• Fred suggested some additional design features which should be added to the internal LFG collection system:
	– add a liner to act as a barrier along Rose Hill Road in conjuction w/ internal system
	– do not have a sand vent layer under the L.F. cap (will short-circuit LFG wells); instead use a geotextile to avoid damaging liner & add compacted earth onto waste
	– add a ring main system w/ branches of 4 to 5 wells on each branch to allow partial shutdown of collection system
	– header pipe should be placed above the liner w/ 18" minimum cover to prevent freezing of LFG condensate



above liner
To ~~prevent~~ monitor pipe settlement

CC:

M&E FORM NO. 196 (9/78)

E-3 Gas Composition Calculations

The feed gas streams which will be collected for treatment have different compositions based on the location and type of collection system utilized. Each process technology evaluated requires knowledge of the feed stream(s) methane composition for permitting and combustion purposes.

Internal LFG Stream

The total landfill gas generated [from SCHOLLRE.xls] is 2.79E+04 cm^3/s or 59 cfm
Assuming 70% of this amount is collected by the Internal system, 1.96E+04 cm^3/s or **41 cfm**
would have been collected in 1997.

The composition of this stream is assumed to be 50% Methane and
50% Carbon Dioxide

Perimeter Gas Stream

The total gas collected from the Perimeter system [from JOHNSON.wk1] is 3.83E+05 cm^3/s or **812 cfm**
This includes air and LFG generated by the landfill.
Assuming 30% of the total landfill gas generated is collected by the perimeter system, this value is
8.38E+03 cm^3/s or 18 cfm
This amounts to 2% of the perimeter gas stream.

The composition of this portion of the stream is assumed to be 50% Methane and
50% Carbon Dioxide

The remaining 98% of the stream is assumed to be air at a composition of 21% Oxygen and
79% Nitrogen

Therefore, the composition of the perimeter gas stream is calculated to be 1% Methane
1% Carbon Dioxide
21% Oxygen
77% Nitrogen

Compositions for the blending of the two streams are calculated in COMPOSIT.xls.

METCALF & EDDY

ROSE HILL SOLID WASTE AREA *VERSION: SEP-03-98*

GAS COMPOSITIONS *Checked by: Sean Czarniecki* 08/26/96

file: COMPOSIT.xls

Input Values:

Qair - from worksheet for Johnson Equation

Qgas - from worksheet from the Scholl Canyon Model; for a conservative estimate - see also Gamma model

Qair =	3.83E+05	cm^3/s	Total gas (air & LFG) collected from perimeter system [from JOHNSON.wk1]
Qgas =	2.79E+04	cm^3/s	Total landfill gas generated [from SCHOLLRE.xls]
Assume	70%	of Qgas is collected by the internal system	
Therefore,	30%	of Qgas is collected by the perimeter system	
This equals	8.38E+03	cm^3/s	
and is	2%	of Qair	
Therefore,	3.75E+05	cm^3/s	is assumed to be air without landfill gas (Q_a)

$Vlfg = Q_a + Qgas$ =	4.03E+05	cm^3/s	
	0.4026	m^3/s	

Composition of gas:

Assuming:	Q_a is	21%	Oxygen and
		79%	Nitrogen
	Qgas is	50%	Methane and
		50%	Carbon Dioxide

$Q\ CH_4$ =	Qgas *	50%	=	1.40E+04	cm^3/s	0.0140	m^3/s
$Q\ CO_2$ =	Qgas *	50%	=	1.40E+04	cm^3/s	0.0140	m^3/s
$Q\ N_2$ =	Q_a *	79%	=	2.96E+05	cm^3/s	0.2959	m^3/s
$Q\ O_2$ =	Q_a *	21%	=	7.87E+04	cm^3/s	0.0787	m^3/s
Check:			Total	4.03E+05	cm^3/s	0.4026	m^3/s

$YlfgCH_4$ =	$Q\ CH_4/Vlfg$	=	0.0347
$YlfgCO_2$ =	$Q\ CO_2/Vlfg$	=	0.0347
$YlfgN_2$ =	$Q\ N_2/Vlfg$	=	0.7352
$YlfgO_2$ =	$Q\ O_2/Vlfg$	=	0.1954

Check: 1.0000

Non-combustion LFG treatment processes (such as photocatalytic oxidation) which do not treat methane will produce the following amounts of methane:

Feed Gas

Total landfill gas (1997) [from SCHOLLRE.xls] = 59 cfm = 0.987 cfs = 0.028 m^3/s

Assume all methane will be captured by either the internal system or the perimeter system.

The landfill gas composition is assumed to be

50% methane

50% carbon dioxide

Therefore, the flow of methane through a non-combustion treatment process is approximately

CH4FLOW = 30 cfm = 0.493 cfs = 0.014 m^3/s

Density of 20°C air: 0.001205 g/cm^3 = 0.075 lb/ft^3 [ref: CRC, 1987]

Density of 0°C methane: 0.000717 g/cm^3 = 0.045 lb/ft^3 = CH4DENSITY [ref: Perry & Green, 1984]

Assume that temperature will not greatly impact density.

The colder temperature methane density provides a more conservative mass value.

Amount of methane out of treatment process:

CH4FLOW x CH4DENSITY = 1.325 lb/min = 79.48 lb/hr = 1,907 lb/day

LEL calculations

From COMPOSIT.xls gas composition calculations, the combination of the internal & perimeter gas streams will result in an approximate methane concentration of 3.47%

The LEL of methane is 5% by volume.

Therefore, additional dilution air will probably not be necessary.

METCALF & EDDY

E-4 Enclosed Landfill Gas Flare Calculations

- Vendor Quotation: John Zink Company
- Auxiliary Fuel Requirements

- Vendor Quotation: John Zink Company

JOHN ZINK
A KOCH INDUSTRIES COMPANY

International Headquarters
PO Box 21220
Tulsa Oklahoma 74121-1220
918/234-1900

July 17, 1997

Metcalf & Eddy
30 Harvard Mill Square
Wakefield, MA 01880

Attention: Sean Czarniecki

Subject: Landfill Gas Flare System for the Rose Hill Regional Landfill
John Zink Proposal Number BF 3746

Dear Mr. Czarnieki,

Thank you for your recent inquiry into John Zink Biogas Flare products. We appreciate the opportunity to assist you with the flare portion of your project. As the leading supplier of landfill gas flare equipment throughout the world, John Zink Company is pleased to offer our field proven **ZTOF** Enclosed Flare System for your application.

With over 300 installations nationwide, John Zink has the expertise and resources to ensure your flare project is successful. We can provide skid packages for your system that will result in a lower installed cost while limiting the installation time and hassle.

We have offered a number of options in our proposal to allow you to customize your system to meet your particular needs. After you have reviewed this proposal, please let us know if there are any additional options you would like to pursue.

Emission compliance (present or future) is another benefit of John Zink enclosed flares. With high destruction of the waste hydrocarbons, John Zink Enclosed Flares are also low in NOx and CO emissions. John Zink flares have consistently passed local and federal emissions tests.

We look forward to working with you on this project, and if you require any additional information please do not hesitate to contact me at (918) 234-1884.

Best Regards,

JOHN ZINK COMPANY

Tim Locke
Business Team Leader
Biogas Flare Group

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I. TECHNICAL SUMMARY

A. DESIGN CRITERIA

Flare Gas Stream

Type:	Internal LF Gas	Perimeter LF Gas
Composition:	50 % CH_4 (maximum) 50 % CO_2, air, inerts	2% CH4; 2% CO2 Remainder Air
Lower Heating Value:	455 BTU/SCF	18 BTU/SCF
Temperature:	100 °F	100°F
Flow Rate:	80 SCFM	810 SCFM
Waste Heat Release:	2.2 MMBtu/hr (maximum)	

NOTE: *Assist gas is not required for the above flow rates and compositions. However, if these vary, then natural gas assist may be required.*

Mechanical

Design Wind Speed:	100 mph
Ambient Temperature:	-20 °F to 120 °F
Electrical Area:	non-hazardous
Elevation:	sea level (14.7 psia)

Unit Design

Smokeless Capacity:	100%
Pressure Drop:	< 8" w.c. through flare and flame arrestor
Operating Temperature:	1400 °F - 1800 °F (2000 °F shutdown)
Retention Time:	0.7 seconds at 1800 °F (minimum)

NOTE: *Low methane concentrations may require auxiliary fuel to initiate combustion and maintain temperature.*

Utilities

Pilot Gas (Intermittent):	22 SCFH propane at 7-10 psig
Compressed Air:	Required for Condensate Injection System (optional)
Electricity:	460 V, 3 ph, 60 Hz for blower control (including step-down transformer for control system components) 110 V, 1 ph, 60 Hz for control system components
Fired (Auxiliary) Fuel:	None based on the flows given above. However, if the methane concentration or flow rates vary, natural gas assist may be required.

Expected Flue Gas

Operating Temperature	1600°F	1800°F
CO_2 Volume %	7.0	8.1
H_2O Volume %	8.2	9.2
N_2 Volume %	72.6	71.8
O_2 Volume %	12.2	10.9

Emission Range (Design Flow)[1]

Operating Temperature	1600°F	1800°F
Overall Destruction Efficiency[2]	98%	99%
NOx, lb / MMBtu[3]	0.06	0.08
CO, lb / MMBtu[4]	0.20	0.15

[1] Expected emission rates at lower operating temperatures are available upon request.

[2] Typical sulfur containing compounds are expected to have greater than 98% oxidation efficiency.

[3] Excludes NOx from fixed nitrogen.

[4] Excludes CO contribution present in landfill gas.

NOTE: *Projected emissions are based on field tests of operating units and the HHV of the landfill gas. Destruction efficiency, NOx, and CO emissions shown are valid for combustion of landfill gas only. These expected emissions are the same for the simultaneous combustion of landfill gas and condensate injection within the specified design range for typical MSW condensate. A condensate composition analysis is required to verify specific expected emissions.*

B. EQUIPMENT DESCRIPTION

Item 1, ZTOF Enclosed Flare Assembly

- 3'-6" diameter x 30' overall height, 1/4" A-36 carbon steel vessel.
- 2" layer of A.P. Green (or equal) ceramic fiber refractory mounted on Inconel pins and keepers. (2400 °F hot face refractory). The surface layer of 1" 8# refractory is overlapped both horizontally and vertically for additional protection.
- Burner Management System for landfill gas application.
  - Burner manifold assembly with flanged inlet connection. Individually flanged burner connections allow easy servicing.
  - **V-Mix™** biogas burner with stainless steel anti-flashback tips for high temperature corrosion resistance and maximum flame stability through the full range of design flow rates.
  - Perimeter gas distribution manifold for direct injection into the base of the enclosed flare.
  - **Tru-Lite™** ignitor assembly for use during start-up cycles. This externally mounted pilot provides easy operation and can be removed for maintenance without entering the vessel.
- Bolted blade combustion air damper(s). Opposed blade design provides 5:1 air turndown control. Galvanized finish and stainless steel press-fit bearings ensure smooth, long term operation. A special proprietary lower burner chamber design minimizes direct radiation on the damper for maximum service life.

  NOTE: *Removal of these bolted blades allows access to the lower flare burner chamber and eliminates the need for a separate manway.*

- Four (4) 4" NPT sample ports at 90° apart located 1/2 stack diameter from the flare top for accurate emission testing.

  NOTE: *These ports can be accessed by use of a temporary device such as power-lift vehicle or permanent ladder and platform equipment. Refer to the options sections for ladder and platform selection.*

- Three (3) thermocouple connections at various elevations for temperature monitoring.
- Exterior protection using SSPC-SP-6 sandblast and Sherwin Williams Zinc Clad I coating system, gray-green color, 2 1/2 - 3 mils DFT for superior corrosion protection at shell temperatures to 750 °F.
- AISC designed continuous base plate for high wind stability.
- Lifting lugs to assist in erection.

- Thermocouple conduit mounting brackets.
- Galvanized personnel protection screen located on lower portion of stack to prevent contact with the vessel surface. Additional screenings is available for upper stack instrument locations. See Ladder and Platform options for details.

Item 2, <u>Control System</u>

Control Station Assembly

- Self-Supporting Steel Rack
- Flare Control Panel with 110V items enclosed in a separate panel for electrical safety including:
  - Allen Bradley SLC-500 programmable logic controller.
  - Honeywell UDC 3000 temperature controller for automatic temperature control.
  - Honeywell UDC 2000 temperature indicator for stack mounted high temperature shutdown thermocouple.
  - One (1) flame scanner relay.
  - Four (4) ammeter(s) for landfill gas blower motors (200% scale).
  - Four (4) hourmeter(s) for landfill gas blower motors.
  - Two (2) "manual-off-automatic" blower selector switch(es).
  - Indicating lights:

a.	Panel power ON	c.	Flame proved
b.	Purging	f.	Low stack temperature (shutdown)
c.	Purge complete	g.	High stack temperature (shutdown)
d.	Pilot gas ON	h.	Flame failure (shutdown)

- Main power supply disconnect.
- Power transformer to step-down 460V, 3 ph, 60 Hz service to 110 V, 1 ph, 60 Hz for use as required by control components.
- Motor Starter Panel.
  - Four (4) landfill gas blower motor starter(s).
  - One (1) stack mounted purge blower motor starter.
- Other Rack Mounted Components.
  - Pilot gas train including pressure regulator, fail-closed shutdown valves, manual block valve and pressure indicator.
  - 15A convenience outlet (duplex) with weatherproof cover.
  - 100W high pressure sodium security light with manual switch and photocell.

- Appropriate items will be enclosed in weatherproof (NEMA 4) panels.
- The control station assembly will be pre-piped and wired in our UL approved shop and function tested simulating actual operations.

Stack Mounted Controls

- One (1) combustion air damper to control the operating temperature Damper with automatically controlled louvers are provided with the automatic temperature control feature.
- Ignition panel assembly including transformer, pilot spark electrode ignition timer and ignition wire. Enclosure is stack mounted for easy access to the pilot assembly.
- One (1) self-checking flame scanner.
- One (1) purge air blower.
- One (1) high temperature shutdown thermocouple.
- Two (2) temperature monitoring thermocouples with location based on specific flow conditions.

Automatic Temperature Control

- Flue gas temperature is automatically controlled by adjusting the air flow into the unit. Lower waste gas flows or lower methane concentrations will automatically close the inlet air louvers. The control loop consists of a thermocouple and temperature indicator/controller and electrically operated actuator(s) on the air louvers. Included with this option is the enhanced automatic start-up feature which includes additional timers, relays, and controls to allow the air damper to open to a preset position, for a flare warm-up, before returning to modulating temperature control. This feature allows more air into the stack during start-up when a stack is cold and lacking draft, thereby minimizing any smoke at start-up.

Miscellaneous Accessories

- Three (3) operating manuals with essential operating instructions, appropriate vendor literature on instrumentation, and drawings combined in a three ring binder.

Item 3, <u>Flare System Accessories</u>

- 400 ft of thermocouple extension wire.
- One (1) gallon of field touch-up paint.

C. OPTIONAL EQUIPMENT

Item 4, Inlet Flame Arrester

- Two (2) 3" Varec Model 5010 Flame Arrester with aluminum housing and aluminum internals. Internal elements can be cleaned without removing the flame arrester body from the pipe.

Item 5, ZMS Moisture Separator

- Two (2) 3'-0" O.D. x 6' Tall moisture separator with flanged inlet and outlet, drain connection, level gauge, stainless steel mesh pad for moisture collection, and a flanged top for accessibility and maintenance. The vessel will be constructed of carbon steel and coated internally with a phenolic painting system to protect the vessel from the corrosive landfill gas. The exterior of the vessel will be prepared with an SSPC-SP-6 sandblast, primed with an epoxy primer, and coated with enamel.

Item 6, Automatic Inlet Valve With Pneumatic Actuator

- Two (2) 3 " Xomox Pliaxseal High Performance Butterfly Valve, ANSI 150 lb with carbon steel body, 316 stainless steel disk, PTFE seat with Bettis pneumatic fail-closed actuator, three-way solenoid valve, speed control valve and auxiliary switches. This valve can be actuated by nitrogen cylinders (not included) or by 100 psig compressed air if available.

Item 7, Flow Meter

- Two (2) FCI Thermal Mass Flow Meter Assembly with 316 stainless steel probe for 3/4" NPT mounting. The output of this meter can be wired to Optional Item 8 to provide for continuous flow monitoring.

Item 8, Chart Recorder

- One (1) Honeywell model DR4500T Digital Circular Chart Recorder. The circular chart recorder is a microprocessor based recorder which draws its own chart as it records data. User can design the chart to match specific applications. The recorder will have two (2) inputs with options for up to four (4) inputs. All inputs are 4-20 mA. With this option the Honeywell controller will be provided with an optional output signal allowing the recorder and controller to read the same temperature from the thermocouple. Additionally, the recorder is capable of totalizing the system flow.

Item 9, Autodialer

- One (1) Raco Verbatim automatic dialer with four (4) digital inputs. This unit is voice programmable and capable of dialing up to 16 telephone numbers in the event of an alarm condition (e.g., flame failure, high-temperature shutdown, etc.). At an additional cost, this unit can also process analog signals (e.g., flare operating temperature, system flow rate, etc.) and provide this information when accessed remotely via telephone.

Item 10, *Underwriters Laboratories* Classification

- John Zink Company is dedicated to ensuring the highest level of quality and safety standards in its products. This performance level is reflected in all products and provides the capability to apply the UL listing symbol for Industrial Control Panels on motor starters and a UL classification symbol on Flare Control Panels. This option is provided for applications requiring Underwriters Laboratories Certification.

Item 11, Ladder

- Galvanized ladder for access to thermocouples. Equipment includes ladder, rails, two (2) safety belts, and personnel protection screening behind the ladder and around the thermocouple ports. A lockable gate, for preventing unauthorized access, can be added for an additional price.

Item 12, Service Platform

- Galvanized 360° service platform for accessing the stack sample connections, designed per OSHA requirements. A continuous band of personnel protection screening around the sample ports is included with this option.

Item 13, Hinged Damper

- One of the manual dampers may be hinged in order to provide easy access to the bottom of the flare stack for inspection and maintenance of the burners.

Item 14, Control Panel Weather Hood

- This fabricated steel hood is designed to limit the panel's exposure to the elements. It provides approximately 4' of overhang to the front and 2' to the rear. The hood is painted to match the rest of the control panel rack and comes with a fluorescent light assembly for enhanced visibility of the panel components at night. This hood is painted to match the control panel rack.

Item 15, Top-Coat Finish

- Sherwin Williams Kem High Temperature 881A001 Gray with 700C418 catalyst coated 1-2 mils DFT. This coat is applied over the standard Sherwin Williams Zinc Clad I primer to provide an enhanced finish with superior corrosion protection up to 500 °F.

Item 16, Flare Base Ring Template

- One (1) enclosed flare base ring template constructed of 1/4" carbon steel plate to assist in setting and installing the anchor bolts in the field. The template is match-drilled with the actual baseplate and shipped in 1 to 4 marked pieces, depending on the size of the flare stack.

Item 17, Landfill Gas Blower

- Two (2) Lamson or Hoffman landfill gas blowers sized for the interior gas stream of 80 scfm.
- Two (2) Lamson or Hoffman landfill gas blowers sized for the perimeter gas stream of 810 scfm.

Item 18, Condensate Injection System

- ? (?) stack-mounted condensate injection guns. Each gun is capable of disposing of up to 1 GPM of condensate. Each gun can be removed from service for maintenance purposes or to minimize air consumption without removing the compressed air or condensate piping.
- A flare stack condensate injection gun port for each condensate injection nozzle.
- AISC designed skid with galvanized grating.
- One (1) air compressor complete with particulate filters.
- Two (2) pneumatic condensate pumps.
- One (1) 550 gallon high-density cross-linked polyethylene condensate storage tank with level control.
- Controls (mounted in control station panel, see Item 2) complete with lights, switches, and PLC logic for safe operation of the condensate injection system.
- All components fully piped and assembled within the skid boundaries

Item 19, Blower Skid Assembly

- One heavy duty AISC designed skid with galvanized grating.
- ??? (?) ?? HP landfill gas blower(s).
- Fully supported 304 stainless steel waste gas piping.
- ??? (?) manual butterfly valves for blower inlet and outlet.
- ??? (?) flexible expansion joints for blower inlet and outlet.
- ??? (?) check valve for blower outlet.
- Two (2) five gallon propane tanks for intermittent ignition fuel supply
- All piping, wiring, and conduit within the skid boundaries will be factory installed.

D. OPERATION

The following is a brief outline of the system start-up and operating sequence.

System start-up begins with a timed air purge cycle to evacuate any fugitive hydrocarbons from the flare enclosure. After purge is completed, the pilot is lit. Upon proving the pilot flame with the flame scanner, the waste gas valve is opened and the waste gas blower is started allowing flow to the flare enclosure. This allows use of the waste gas for system warm-up.

After the waste gas valve is opened, the pilot gas shuts off after a timed delay to limit utility gas usage. If a flame is still sensed on the main burner the system will continue operation, if not, it will shutdown on flame failure.

In the automatic mode, the above sequence automatically starts when power is supplied. If the unit shuts down for any reason except high stack temperature, the automatic mode will allow the unit to attempt to purge and restart for a specified time period. A remote signal is sent if the unit fails to restart. Units can be operated in the manual mode which requires an operator at the flare to start and restart the system using a push-button sequence. If the unit shuts down for any reason, operator assisted restart is required.

The unit temperature is set by adjusting the air dampers (manually or automatically). Opening the dampers reduces the flue gas temperature by adding quench air

Due to the presence of an open flame, the flare assembly should be located in a "non-hazardous" electrical area.

II. COMMERCIAL

A. BUDGET PRICING

Item	*Description*	*Total*
1	One (1) ZTOF Enclosed Flare System	
2	Control System	
3	Accessories	$90,000
	OPTIONS	
4	Two (2) Inlet Flame Arrester	Included
5	Two (2) Moisture Separator	$18,000
6	Two (2) Automatic Inlet Valve	$3,000
7	Two (2) Flow Meter	$ 7,000
8	One (1) Digital Circular Chart Recorder	$ 3,300
9	One (1) Autodialer	$ 3,300
10	*Underwriters Laboratories* Classification	$ 1,500
11	One (1) Ladder	$ 3,500
12	One (1) Service Platform	Upon Request
13	One (1) Hinged Damper	$ 800
14	Control Panel Weather Hood	$ 2,000
15	Top-Coat Finish	$ 3,000
16	One (1) Flare Base Ring Template	$ 900
17	Four (4) Landfill Gas Blowers	$60,000
18	One (1) Condensate Injection Skid	Upon Request
19	One (1) Blower Skid Assembly	Upon Request
20	(2) Consecutive Days of Field Start-up and Training	$ 3,500
21	Estimated Freight	$5,000

B. TERMS AND CONDITIONS

Prices are F.O.B. point of manufacture Skiatook, Oklahoma and do not include foreign, federal, state, local sales, excise or other use taxes. Freight charges are not included in the pricing unless specifically noted otherwise.

All pricing contained herein is based on and contingent upon John Zink Standard Terms and Conditions of Sale attached and made part of this offering.

Prices are firm for acceptance for thirty (30) days and for the quoted delivery. Should shipment be delayed past the quoted delivery by acts of Buyer or its agents, the quoted price will be subject to escalation based upon appropriate material and labor indexes.

Should delivery be delayed past the quoted delivery by acts of Buyer or its agents, vendor shall have the right to invoice and be paid for materials on hand, fabrication performed and services rendered.

PAYMENT TERMS: Terms of payment will be 100% net thirty (30) days after invoicing as follows:

25% Upon issuance of drawings
25% Upon receipt of major materials
25% Upon completion of one-half the fabrication
25% Upon notification of readiness for shipment

A guaranteed form of payment acceptable to John Zink, such as an irrevocable letter of credit on a major United States bank may be required.

C. WARRANTY

John Zink Company warrants only new products manufactured by John Zink against workmanship and/or materials under normal and proper use. Please refer to John Zink Standard Terms and Conditions of Sale (attached) for conditions and limitations.

D. DELIVERY SCHEDULE

Based on a release to purchase major materials at the time a purchase order number is issued, John Zink Company will maintain the following delivery schedule:

Submittals for Approval:	4 - 6 weeks after receipt of order
Fabrication:	10 - 12 weeks after receipt of approved drawings

Overall schedule will be based on time required for drawing approval. Improved schedules may be arranged to meet specific project requirements.

E. OTHER CONDITIONS

Shipping

Shipping will be via common carrier. Portions of the unit will be shipped loose to reduce shipping costs and damage to the unit.

Spare Parts

Due to the custom designed nature of this package, a spare parts price listing is to be submitted with the certified drawing package. Partial lists for equipment parts can be made available on request.

Change Orders

John Zink Company has based pricing on the inquiry design information. In the event of process changes, we reserve the right to alter our equipment design in order to maintain safe engineering practices.

If additions or deletions are required after an order is received, a price summary will be submitted to the customer's office for approval. The Engineering Change Order (ECO) will include charges for drafting and engineering changes, material and labor changes, freight and administration costs. Change orders must be approved by the client and returned to John Zink prior to beginning additional work.

Equipment dimensions, sizes and subvendor selections offered in this proposal are subject to change after the design is finalized.

Field Service

Start-up and training services are included as listed above. Additional services are offered according to attached John Zink Company Technical Assistance Agreement.

F. GENERAL SCOPE OF WORK

John Zink Company will furnish the labor, materials, equipment and tools necessary to fabricate the proposed system.

General construction bolts, nuts, washers, gaskets and other bolts/fixings associated with the connecting and assembly of equipment supplied by John Zink are included.

The following items are not included in this proposal:

- Detailed fabrication drawings are the proprietary property of John Zink Company. Customer drawings include the necessary dimensions, nozzle placements, structural details, and other data required to assemble the equipment.
- All civil works. John Zink will supply the data necessary to design such civil works by providing loadings for equipment.
- Erection of equipment or installation of piping or instruments. John Zink can supply turnkey installations on many projects.
- The supply or installation of fireproofing materials, personnel protection, heat tracing, external insulation, electrical/thermocouple wire, conduit, piping, bolts, gaskets, and finish paint unless specifically noted.
- Obtainment of permits, licenses, and approval by and from authorities to install and operate this equipment.
- Any additional cost incurred for fees and/or the preparation of drawings, forms and/or data for approval by state or local agencies of the design of the system.
- Automatic compliance with state, local or municipal codes unless specifically reviewed. All equipment is designed to applicable national codes and standards.
- Please note that John Zink Company has numerous units operating in many states and is knowledgeable in dealing with various regulatory authorities.

III. ATTACHMENTS

A. Standard Terms and Conditions

B. Technical Assistance Agreement

KOCH ENGINEERING COMPANY, INC.
JOHN ZINK COMPANY.

International Headquarters
11920 East Apache
Tulsa, Oklahoma 74121-1220
Phone: 918/234-2783
Facsimile: 918-234-1986

Tim Locke
Business Team Leader
Biogas Flare Group

TELEFAX TRANSMITTAL MESSAGE

DATE:	July 22, 1997
TO:	Sean Czamiecki
COMPANY:	Metcalf & Eddy, Inc.
FAX NUMBER:	(617)245-6293
TOTAL PAGES:	2
REFERENCE:	***Quotation Clarifications***
COPIES:	D. Ryan (610-252-6161)

IF MISSENT PLEASE TELEPHONE 918 234-2783. THIS MESSAGE IS BEING SENT FROM 918 234-1986.

In response to your recent questions on our previously submitted proposal, please find the following:

1. A lower temperature on the perimeter gas will have no impact on the proposed flare system or utility consumption.
2. Yes, 100% of the oxygen in the perimeter gas is being utilized for combustion. However, in addition to the perimeter gas, quench air will be required at a rate of approximately 450 scfm at 1600°F and approximately 560 scfm at 1500°F stack temperature. Based on a 3'-6" O.D. stack with 2" of insulation and ¼" wall thickness, the velocity at 1600°F will be 11.5 fps and at 1500°F will be 11.9 fps (these values are plus or minus 15% due to the stack heat losses).
3. Basically, the industry standard is to guarantee a 98% DRE for NMOC's in landfill gas when measured as a common compound, such as Hexane. This is due to the difficulty of measuring a number of different compounds on the inlet and outlet, which are typically in the very small ppm range. This analysis may not show a 98% DRE of each and every compound, but when averaged, the 98% DRE will be met.
4. Generally on a 3.5' diameter flare, it will take approximately 1.5 MMBtu/Hr to maintain an operating temperature of 1500° to 1600°F. It does not matter if this heat duty is the result of the landfill gas or an assist gas.
   - 4a. Natural gas heating value - 1000 Btu/Scf
     Propane heating value - 2316 Btu/Scf

4b. As stated above, we will need approximately 1.5 MMBtu/Hr to maintain an operating temperature of 1500°F to 1600°F, either from the landfill gas or from an assist gas. Based on 50% methane, 1.5 MMBtu/Hr equates to 55 scfm of landfill gas. However, as the landfill gas flow rate decreases, typically so does the methane concentration. Therefore, higher flow rates will be required to maintain temperature as the methane decreases. One way to minimize assist gas consumption in the future would be to operate the flare on a timer, set for several hours a day or several days a week. This way, while the flare was down, the landfill gas would build up allowing larger flows to the flare while is was in operation and could minimize or possibly eliminate the need for assist gas.

I hope that this has addressed you questions. If you would like further information, please feel free to call our local representative, David Ryan at (610)252-6160 or myself at (918)234-2783.

Regards,

JOHN ZINK COMPANY,
a division of Koch Engineering Company, Inc.

Tim Locke
Business Team Leader
Biogas Flare Group

KOCH ENGINEERING COMPANY, INC.
JOHN ZINK COMPANY.

International Headquarters
11920 East Apache
Tulsa, Oklahoma 74121-1220
Phone: 918/234-2783
Facsimile: 918-234-1986

Tim Locke
Business Team Leader
Biogas Flare Group

TELEFAX TRANSMITTAL MESSAGE

DATE:	August 4, 1997
TO:	Sean Czamiecki
COMPANY:	Metcalf & Eddy
FAX NUMBER:	(617)245-6293
TOTAL PAGES:	1
REFERENCE:	***Pilot Gas Consumption***
COPIES:	D. Ryan

IF MISSENT, PLEASE TELEPHONE 918 234-2783. THIS MESSAGE IS BEING SENT FROM 918 234-1986.

In response to your pilot gas usage question, I would guess that a flare system in normal operation will be started and stopped once or twice a month, with the pilot going through the following sequence:

The pilot will initially try to light for 10 seconds, if at this point the pilot is not lit, the system will shut down. If the pilot does light, then the system allows 5 seconds for a blower to start, then the inlet block valve starts opening and can take up to 30 seconds to open fully. Once the valve has been proven fully open by the valve open limit switch, the pilot will remain on for an additional 15 seconds. After that time, the pilot is shut off. If after the 15 seconds the main flame is lit, the pilot remains off, if the main flame is not proven, the pilot ignition sequence starts over. Therefore, the pilot is on for a maximum of 60 seconds every time the unit starts.

I have attached a pilot gas consumption chart for your convenience. If you have any further questions or comments, please feel free to call David Ryan, our local sales representative, at (610)252-6210 or myself at (918)234-2783.

Regards,

Pilot Usage

Propane Bottle Information

Cylinder Size (gallon)	O.D. (in)	Height (in)	Volume (ft^3)	Fuel Weight (lbs)	Capacity (SCF)	Weight (lbs)
5			0.766	20	108	
100			15.313	400	2167	

Pilot Fuel	Operating Pressure (PSIG)	Pilot Firing Rate (SCFH)	Avg. Pilot Run Time (Sec)	Pilot usage per start-up (SCF)	# of start-ups/ 5 gal.	# of start-ups/ 100 gal.
Propane	10	22.000	60	0.367	295	5910
Natural Gas	15	45.000	60	0.750	144	2889

Metcalf & Eddy
An Air & Water Technologies Company

July 10, 1997

Mr. Tim Locke
Biogas Flare Group
John Zink Company
11920 East Apache
Tulsa, Oklahoma 74116

Subject: **Request for Preliminary Sizing and Budget Quotation - Enclosed Landfill Gas Flare; Rose Hill Regional Landfill Superfund Site, South Kingstown, Rhode Island**

Dear Mr. Locke:

Metcalf & Eddy (M&E) is currently finalizing the Feasibility Study (FS) for the Rose Hill Regional Landfill site in South Kingstown, RI. One of the FS alternatives includes treatment of landfill gas (LFG) utilizing an enclosed flare. Previous contact with your company regarding this project has been made on two occaisions. The first was a similar request made to Mr. David Ryan on February 17, 1993. The second was a phone discussion which you and I had on June 3, 1997. M&E is interested in obtaining a preliminary LFG flare sizing and budgetary equipment cost quotation to use for the lastest version of the FS.

As previously discussed, there are two gas streams anticipated, an Internal LFG stream and a dilute Perimeter Gas stream. Previously, these streams were assumed to be combined prior to combustion. However, due to the anticipated gas stream compositions (see below), the amount of auxiliary fuel required to sustain combustion of the LFG contaminants was found to be quite large. The costs associated with the auxiliary fuel has caused much concern with those that will be paying the O&M costs. Therefore, an alternative design which reduces the O&M costs is desired. As we discussed, by keeping the Perimeter Gas separated from the Internal LFG prior to entering the flare, auxilary fuel costs should be reduced.

Please develop preliminary flare sizing based on the following assumptions:

1) Internal LFG flow rate: 80 cfm, 50% CH_4 by volume, 50% CO_2
2) Perimeter gas flow rate: 810 cfm, 2% CH_4 by volume, 2% CO_2, balance air
3) Flare combustion temperature: 1,500 °F
4) There will not be a building available to place the equipment in

Please include the following items in your quotation:

1) System Requirements:

30 Harvard Mill Square, Wakefield, MA 01880-5371 • Mailing Address: PO Box 4071, Wakefield, MA 01880-5371
TEL: 617-246-5200 FAX: 617-245-6293

- flare dimensions (diameter, height)
- combustion and quench air flowrates required
- stack velocities (if possible)

2) Budgetary equipment costs (+50%, -30% accuracy), including blower costs (2 for each gas stream)

3) Construction Items:
   - estimated lead time for flare delivery
   - utility requirements
   - instrumentation requirements
   - foundation requirements/weight loads

4) Operations & Maintenance items:
   - start-up support needed
   - expected lifetimes of major equipment
   - auxiliary fuel needed*
   - pilot fuel needed*
   - annual O&M labor required
   - maintenance equipment and spare parts

5) Installation cost multipliers (freight, taxes, installation) if known

* Please calculate for both propane and natural gas and present heating value assumptions.

Your quotations are needed by the end-of-day Friday, July 18, 1997. Thank you for your assistance with this project. If you have any questions, please do not hesitate to contact me at TEL (617) 224-6811 or by FAX at (617) 245-6293.

Very truly yours,

METCALF & EDDY, INC.

Sean Czarniecki

Sean Czarniecki, P.E., ChE
Project Engineer

cc: File

Metcalf & Eddy, Inc.

30 Harvard Mill Square
Wakefield, Massachusetts
P.O. Box 4071
01880-5371

FAX Number: 617/245-6293

TELECOPIER TRANSMITTAL SHEET

Date: 7-10-97

PLEASE DELIVER AT ONCE TO:

Name: Mr. Tim Locke

Location: John Zink Company

FAX Number if not M&E: 918-234-1986

From: Sean Czarniecki Ext: 6811

Please make copies and deliver to the following additional people:

Additional Information/Message:

TOTAL Number of pages being transmitted (including this cover): 3

PLEASE TELEPHONE THE MAILROOM
IF YOU DO NOT RECEIVE THE CORRECT NUMBER OF PAGES -
617/224-6296 or 6298

FOR WAKEFIELD USE ONLY:

DO YOU WANT ORIGINAL BACK? YES ☒ NO ☐

JOB NO. 020617-0011 DEPT NO. 2114

Project	Rose Hill	Acct. No.	020617-0011	Page	1 of 2
Subject	Flare Quotation	Comptd. By	S. Czarniecki	Date	7/21/97
Detail		Ck'd. By		Date	

NONREPRODUCIBLE GRID FORM 145

METCALF & EDDY, ENGINEERS

Tim,

Thanks for your quotation. I have a few more questions:

(1) You have the Gas Stream Temperature at 100°F. We can see that for the internal stream, but the perimeter would probably be lower. Does this change anything? We don't think it will, but thought we'd ask.

(2) Is the perimeter gas being used as combustion air? What is the amount of combustion air the flare will be using? These questions need to be answered so that I can calculate the stack discharge velocity - I need to perform dispersion modeling. If you can give me the velocity, my life would also be made easier, although it is not difficult to calculate.

(3) We generally anticipate approximately 98% DRE for our organic contaminants. Based on existing literature, this may vary depending on the compound. Do you have a standard list of compounds that we could compare our list to check our assumptions? Vinyl chloride is our major contaminant and we assume a conservative 95% DRE. Any comments?

(4) Based on the flows I gave you, we don't need aux. fuel. However, the LFG production is decreasing. I've attached the projected flows for Internal Gas (assume Perimeter Gas remains the same). ~~What is your too~~ It appears that approximately 2 MMBtu/hr will be the low point prior to aux. fuel being required. Is this correct?

(4a) What are the heating values you utilize for propane and natural gas?

(4b) How much aux. fuel do you anticipate being required based on the flows presented?

Thank you for you time in this matter. You can either contact me by fax 617-245-6293 or phone 617-224-6811.

Sean Czarniecki

Project Rose Hill | Acct. No. 020617-0011 | Page 2 of 2
Subject Flare Quotation | Comptd. By S. Czarniecki | Date 7/21/97
Detail | Ck'd. By | Date

Projected Internal Gas Stream Flows

	SCFM
1996	80
1997	73
1998	69
1999	66
2000	63
2001	60
2002	57
2003	54
2004	51
2005	49
2006	46
2007	44
2008	42
2009	40
2010	38
2011	36
2012	34

End of Operation

NONREPRODUCIBLE GRID FORM 145
METCALF & EDDY, ENGINEERS

Metcalf & Eddy
An Air & Water Technologies Company

September 3, 1998

Mr. Tim Locke
Biogas Flare Group
John Zink Company
11920 East Apache
Tulsa, Oklahoma 74116

VIA FAX TRANSMITTAL: 918-234-1986

Subject: **Request for Updated Preliminary Sizing and Budget Quotation - Enclosed Landfill Gas Flare; Rose Hill Regional Landfill Superfund Site, South Kingstown, Rhode Island**

Dear Mr. Locke:

Although I have stated this in the past, Metcalf & Eddy (M&E) is truly finalizing the Feasibility Study (FS) for the Rose Hill Regional Landfill site in South Kingstown, RI. Our most recent contact with you regarding this project was in July 1997 (John Zink Proposal Number BF 3746). Since that time, the landfill gas (LFG) flow rate estimate has been reduced, both due to time and updated EPA AP-42 LFG generation coefficients. While we could use the previous quotation for a larger flare and say that it is conservative, the reduced LFG flow rate creates a increased need for auxiliary fuel. To prevent PRP confusion regarding increased numbers, I would prefer to put an updated quotation in the FS for a flare which is sized better for the new flow rate. If this is not possible, I will use the above-noted proposal.

Please provide information as before based on the following assumptions:

1) Internal LFG flow rate: 40 cfm, 50% CH_4 by volume, 50% CO_2 (changed from 80 cfm)
2) Perimeter gas flow rate: 810 cfm, 2% CH_4 by volume, 2% CO_2, balance air (same as before)

To assist in determination of auxiliary fuel needs over time, please include the heat input (MMBtu/hr) required for the proposed flare to maintain a temperature between 1500°F and 1600°F. Previously, this value was 1.5 MMBtu/hr or approximately 55 scfm LFG. As we are now estimating a flow less than this, you can see why this update would be appropriate.

30 Harvard Mill Square, P.O. Box 4071, Wakefield, MA 01880
TEL: 781-246-5200 FAX: 781-245-6293

In order to incorporate this information into the FS, your quotation is needed by the end-of-day Friday, September 18, 1998. Thank you for your assistance with this project. If you have any questions, please do not hesitate to contact me at TEL (781) 224-6811, by FAX at (781) 245-6293, or by Email at Sean_Czarniecki@air-water.com.

Very truly yours,

METCALF & EDDY, INC.

Sean Czarniecki

Sean Czarniecki, P.E., ChE
Project Engineer

cc: File

KOCH ENGINEERING COMPANY, INC.
JOHN ZINK COMPANY®

International Headquarters
11920 East Apache
Tulsa, Oklahoma 74121-1220
Phone: 918/234-2783
Facsimile: 918-234-1986

Tim Locke
Business Team Leader
Biogas Flare Group

TELEFAX TRANSMITTAL MESSAGE

DATE:	September 8, 1998
TO:	Sean Czamiecki
COMPANY:	Metcalf & Eddy
FAX NUMBER:	(781)224-6548
TOTAL PAGES:	1
REFERENCE:	***Rose Hill Enclosed Flare Proposal***
COPIES:	D. Ryan

IF MISSENT, PLEASE TELEPHONE 918 234-2783. THIS MESSAGE IS BEING SENT FROM 918 234-1986.

In response to your recent request for an updated proposal on the Rose Hill Regional Landfill Superfund Site, our previous size of the flare will not change. However, after further review of the perimeter gas stream, I would like to recommend utilizing a detonation arrester in lieu of the flame arrester as originally proposed. This change will require an additional price of approximately $10,000, bringing the total budget price of the offering to $100,000.

The amount of heat input into the flare will not change (1.5 mmbtu/hr). This heat duty can be the result of landfill gas, assist gas, or any combination of the two.

If you have any further questions or need clarifications, please feel free to call me at (918)234-2783.

Regards,

- Auxiliary Fuel Requirements

Using LFG production values from the Scholl-Canyon model results and assumptions listed below, we calculate the future auxiliary fuel needs.

Year	Time Since LF Closure (years)	Annual LFG Production (ft^3 / yr)	Annual LFG Production (cfm)	Internal LFG Production (cfm)	Heating Value (Btu/hr)	Assist Heat (Btu/hr)	Natural Gas (scfm)	Propane (scfm)
1997	15	3.11E+07	59	41	1.13E+06	3.69E+05	6.1	2.7
1998	16	2.99E+07	57	40	1.09E+06	4.13E+05	6.9	3.0
1999	17	2.87E+07	55	38	1.04E+06	4.56E+05	7.6	3.3
2000	18	2.76E+07	53	37	1.00E+06	4.97E+05	8.3	3.6
2001	19	2.65E+07	50	35	9.64E+05	5.36E+05	8.9	3.9
2002	20	2.55E+07	48	34	9.26E+05	5.74E+05	9.6	4.1
2003	21	2.45E+07	47	33	8.90E+05	6.10E+05	10.2	4.4
2004	22	2.35E+07	45	31	8.55E+05	6.45E+05	10.7	4.6
2005	23	2.26E+07	43	30	8.22E+05	6.78E+05	11.3	4.9
2006	24	2.17E+07	41	29	7.89E+05	7.11E+05	11.8	5.1
2007	25	2.09E+07	40	28	7.58E+05	7.42E+05	12.4	5.3
2008	26	2.00E+07	38	27	7.29E+05	7.71E+05	12.9	5.6
2009	27	1.93E+07	37	26	7.00E+05	8.00E+05	13.3	5.8
2010	28	1.85E+07	35	25	6.73E+05	8.27E+05	13.8	6.0
2011	29	1.78E+07	34	24	6.46E+05	8.54E+05	14.2	6.1
2012	30	1.71E+07	32	23	6.21E+05	8.79E+05	14.7	6.3
						Total	172.7	74.55

Assumptions

Flare will operate until 30 years beyond landfill closure, which was 1982.

The Internal LFG stream remains at 50% methane and 50% carbon dioxide and is 70% of the total LFG production.

The Perimeter LFG stream volume and composition remains constant over time.

The Internal LFG stream has a Lower Heating Value of 455 Btu/scf [Ref: John Zink Co., 1997]

1.5 MMBtu/hr are requred to maintain an operating temperature of 1500 to 1600°F [Ref: John Zink Co., 1997]

Natural gas heating value - 1000 Btu/scf Propane heating value - 2316 Btu/scf [Ref: John Zink Co., 1997]

METCALF & EDDY

Worst case total aux. fuel occurs if flare is operated 24 hrs/day. However, intermittent operation utilizing a timer may reduce or eliminate the need for aux. fuel. This would only occur if the perimeter system was found to be unnecessary in the future. Calculations below assume present day costs and 24 hr operation.

Natural Gas

172.7 cfm = 9.08E+07 cf total — Using 1997 as a basis, 15 years of operation gives an annual O&M

$0.79 /cf = $71,694,675 total — cost for natural gas as $4,779,645

[Cost Ref: Providence Gas Telecommunication - Attached]

Propane

74.55 cfm = 3.92E+07 cf total — Using 1997 as a basis, 15 years of operation gives an annual O&M

$0.02 /cf = $783,703 total — cost for propane as $52,247

[Cost Ref: Star Gas Telecommunication - Attached]

Natural Gas Line Installation

M&E reviewed the location of a natural gas line while performing aux. fuel cost calculations. The nearest gas line is located approximately 4,700 ft from the proposed flare location, at the intersection of Broad Rock Road and Saugatucket Road. [Providence Gas Telecommunication - Attached] Providence Gas Co. also provided an approximate cost of $22/ft for connection to a gas main.

This results in an installation cost of approximately $103,400 to install a natural gas line.

Based on the costs provided above, propane appears to be the best fuel for the flare at the Rose Hill site.

METCALF & EDDY

METCALF & EDDY, INC.

TELECON MEMORANDUM

JOB NO. 820617

DATE: 7/23/97

SUBJECT: Rose Hill Landfill
Gas Utility Location

M&E ENGINEER: N. Bergeron

OUTSIDE PARTY: Cindy
Providence Gas - Drafting Dept.
(401) 272-5040 x514

MADE CALL (X)

REC'D CALL ( )

COMMENTS	SUMMARY OF CONVERSATION:
11:00	I asked if Rose Hill Rd. had a gas line. Cindy looked it up and left a message that Rose Hill Rd. had no record of a gas line.
11:30	I called back to find out where the nearest gas line was. Cindy left a message that Moorsfield Road and Broad Rock Road had gas lines.
1:30	I called Cindy back to see if there was a gas line at the intersection of of Broad Rock Road and Saugatucket Road. Cindy verified that there was a gas line at this intersection.

CC:

M&E FORM NO. 196 (9/78)

METCALF & EDDY, INC.

TELECON MEMORANDUM

JOB NO. 020617

DATE: 7/23/97

SUBJECT: Rose Hill Landfill Feasability
Natural Gas Cost

M&E ENGINEER: N. Bergeron

OUTSIDE PARTY: Russ
Providence Gas
(401) 831-8806

MADE CALL (X)

REC'D CALL ( )

COMMENTS

SUMMARY OF CONVERSATION:

Cost for natural gas:
$0.79/ft3

CC:

M&E FORM NO. 196 (9/78)

METCALF & EDDY, INC.

TELECON MEMORANDUM

JOB NO. 0201617

DATE: 7/23/97

SUBJECT: Rose Hill Landfill
Gas Utility Installation Cost

M&E ENGINEER: N. Bergeron

OUTSIDE PARTY: Lynn Moorer
Providence Gas - Marketing
(401) 272-5040 x 528

MADE CALL (X)

REC'D CALL ( )

COMMENTS

SUMMARY OF CONVERSATION:

I called to find a unit cost for gas line installation. Lynn referenced a chart for installation of a 2" main in a paved road. Chart only went up to 500' length:

For 500' → total cost = $11,000.

Using this the unit cost = $22/ft.

CC:

M&E FORM NO. 196 (9/78)

METCALF & EDDY, INC.

TELECON MEMORANDUM

JOB NO. 020617

DATE: 7/25/97

SUBJECT: Rose Hill Landfill
Propane Gas Price

M&E ENGINEER: N. Bergeron

OUTSIDE PARTY: Don
Star Gas
(401) 294-9547

MADE CALL ( )

REC'D CALL (X)

COMMENTS

SUMMARY OF CONVERSATION:

Don called with a propane price. He would charge $0.25/gal over the CELKIRK (sp? - a propane price index) He checked over the last 12 months and came up with an average CELKIRK price of $0.68/gal. He said that this past year was the highest in ten years (so its a conservative est.) This would give a price of $0.81/gal. Dividing by 36.4 ft³/gal yields a propane price of $0.02/ft³.

CC:

M&E FORM NO. 196 (9/78)

METCALF & EDDY, INC.

TELECON MEMORANDUM

JOB NO. 020617-0011

DATE: 7/28/97

SUBJECT: Rose Hill Landfill Flare
Propane Cost

M&E ENGINEER: N. Bergeron

OUTSIDE PARTY: Tom Ames
Suburban Propane

MADE CALL (X)

REC'D CALL ( )

COMMENTS

SUMMARY OF CONVERSATION:

I asked Tom for a unit cost for propane. He said that for large volumes of propane he would be down around $0.12 to $0.15/gallon of propane above the CELKIRK (sp?) price. CELKIRK is an index or cost baseline in the propane industry.

CC:
S. Scarnicchi

M&E FORM NO. 196 (9/78)

METCALF & EDDY, INC.

TELECON MEMORANDUM

JOB NO. 020617-0011 DATE: 8/7/97

SUBJECT: Rose Hill Landfill Flare Propane Tank

M&E ENGINEER: S. Czarnieckí

MADE CALL ( )

REC'D CALL (X)

OUTSIDE PARTY: Don Andreozzi
Star Gas
401-294-9547 Fax 401-294-1465

COMMENTS

SUMMARY OF CONVERSATION:

1:15

I told Don that we are looking for a cost on a propane tank. He said the tank is free with the propane purchase. We just have to determine the best size based on our needs. He asked what our usage will be & I explained that I have it in cfm. He needed gallons, so I said I would fax a graph for him. He thinks ~ 1000 to 2000 gal tan

I asked what codes we will need to follow - he said NFPA 58 will require that the tank is 25 ft from any building or property line.

1:45

Don said he would suggest the 1st 4 years using a single 1000 gal tank and then adding another after that. Peak operation will be ~160 gpd (1120 gal/wk) so he would fill them once a week. If you go over 2000 gal in size, new rules kick in.

The size is 16 ft long & about 60" in diameter. You need 3 ft between tanks. If you use a concrete pad, they will put down patio blocks. If you fence it in, you need two gates so no one gets trapped.

CC:
B. Weir
S. McCarron

M&E FORM NO. 196 (9/78)

E-5 Additional Landfill Gas Collection System Calculations - Draft FS

Project Rose Hill FS Acct. No. 9599-18-16-16 Page 1 of 3
Subject Perimeter Collection System Comptd. By DJC Date 6/1/93
Detail Ck'd. By Date

USE EQUATION DEVELOPED BY JOHNSON TO SIMULATE PERFORMANCE OF PERIMETER GAS EXTRACTION SYSTEM

$$\frac{Q}{H} = \pi \frac{K}{\mu} P_w \frac{1-(P_{atm}/P_w)^2}{\ln(R_w/R_I)} \quad *$$

K = soil PERMEABILITY (cm^2)
μ = VISCOSITY OF AIR g/cm-s
P_w = ABSOLUTE PRESSURE AT EXTRACTION WELL [g/cm-s^2]
P_{atm} = ABSOLUTE AMBIENT PRESSURE
R_w = RADIUS OF VAPOR EXTRACTION WELL
R_I = RADIUS OF INFLUENCE OF VAPOR EXTRACTION WELL

ATTACHED WORKSHEETS 1) INPUT PARAMETERS; 2) SOLUTIONS TO EQUATION AT DIFFERENT RADIUS' OF INFLUENCE AND EXTRACTION. VACUUMS

ASSUME: RADIUS OF INFL. = 40 ft *
EXTRACTION VACUUM = 18 in H_2O

FLOW RATE = 18,800 cm^3/s [FROM 3/3]

= 40 cfm/well

NUMBER OF WELLS ALONG ROSE HILL ROAD:

ASSUME OVERLAP = 1/4 R_I

= 26 WELLS

TOTAL FLOW RATE:

40 cfm/well × 26 wells = 1,040 cfm

SAY 1,000 cfm

* SOURCE: JOHNSON, P.C. A PRACTICAL APPROACH TO THE DESIGN, OPERATION, AND MONITORING OF IN-SITU SOIL VENTING SYSTEMS. GROUNDWATER MONITORING REV. VOL. 10 NO. 2. SPRING 1990.

NONREPRODUCIBLE GRID FORM 145
METCALF & EDDY, ENGINEERS

ROSE HILL SOLID WASTE LANDFILL: PERIMETER GAS EXTRACTION SYSTEM
VOLUMETRIC FLOWRATE CALCULATION
SOLUTION USING JOHNSON EQUATION FOR STEADY FLOW IN CONFINED VADOSE ZONE

INPUT PARAMETERS:

Air Viscosity, ua =	1.71E−04	g/cm•s
Air Density, rhoa =	1.29E−03	g/cm³
Landfill Gas Viscosity, ulfg =	1.21E−04	g/cm•s
Landfill Gas Density, rholfg =	1.35E−03	g/cm³
Mix Fraction Air, Xa =	0.5	
Mix Fraction Landfill Gas, Xlfg =	0.5	
Mixed Gas Viscosity, ug =	1.46E−04	g/cm•s
Mixed Gas Density, rhog =	1.32E−03	g/cm³
Soil Hydraulic Conductivity, K =	5.80E−03	cm/s
Water Viscosity, uw =	1.791E−02	g/cm•s
Water Density, rhow =	9.997E−01	g/cm³
Gravitational Acceleration, Ag =	9.81E+02	cm/s²
Gas Specific Gravity, gamma =	0.001	
Molecular Weight Air, MWa =	29	g/mol
ular Weight Landfill Gas, MWlfg =	30	g/mol
Molecular Weight Mix, MWg =	29	g/mol
Soil Porosity, n =	0.3	
Engineering Gas Constant, R =	8.314E+07	g•cm²/K•mol•s²
Temperature, T =	10	°C
Vent Well Diameter, d =	20.32	cm
Depth to Confining Layer, b =	450	cm
Atmospheric Pressure, Patm =	1.01E+06	g/cm•s²
stance Along Rose Hill Road, m =	540	m
stance Along Entrance Road, m =	194	m
stance Along Northern Road, m =	194	m

CALCULATION:

draulic Intrinsic Permeability, ki =K*uw/rhow*Ag cm²
ki = 1.054E−07 cm²

Soil Gas Conductivity, Kg = K*uw*rhog/rhow cm/s
Kg = 9.342E−04 cm/s

Soil Gas Permeability, kg = Ki cm²
kg = 1.054E−07 cm²

Storage Coefficient, Ss =Ag*MWg/R*T 1/cm
Ss = 3.626E−07 1/cm

Assume Radius of Infl. of 40 ft.

SOLUTION OF JOHNSTON EQUATION–FLOWRATE AT WELL TO ESTABLISH RADIUS OF INFLUENCE, R, AT FIXED VACUUM PRESSURE

APPLIED VACUUM AT W (cm water	(g/cm–s^2)	FLOW AT WELL (cm^3/s)	304 cm 10 ft	608 cm 20 ft	912 cm 30 ft	1216 cm 40 ft	1520 cm 50 ft	1824 cm 60 ft	3048 cm 100 ft
10.2	1.000E+06		6032	5010	4559	4284	4094	3950	3594
12.7	9.978E+05	3925	7520	6246	5683	5341	5103	4924	4481
25.4	9.851E+05	6710	15135	12571	11438	10750	10271	9910	9018
38.1	9.727E+05	10065	22850	18979	17268	16230	15507	14962	13615
44.0	9.669E+05	11623	26469	21985	20003	18800	17962	17331	15771
50.8	9.602E+05	13420	30668	25473	23176	21783	20812	20081	18273
63.5	9.478E+05	16774	38583	32065	29155	27419	26190	25270	22995

Assume Drawdown at Well = 18 in = 44 cm H_2O

(cm water	(g/cm–s^2)	TOTAL FLOW RATE (cm^3/s)						
NUMVER OF WELLS		103	52	35	26	21	18	11
12.7	9.978E+05	7.746E+06	6.403E+06	5.829E+06	5.501E+06	5.269E+06	5.072E+06	4.619E+06
25.4	9.851E+05	1.559E+06	1.295E+06	1.178E+06	1.107E+06	1.058E+06	1.021E+06	9.289E+05
38.1	9.727E+05	2.364E+06	1.956E+06	1.779E+06	1.672E+06	1.597E+06	1.541E+06	1.402E+06
50.8	9.602E+05	3.159E+06	2.624E+06	2.387E+06	2.244E+06	2.144E+06	2.068E+06	1.882E+06
63.5	9.478E+05	3.975E+06	3.302E+06	3.004E+06	2.825E+06	2.698E+06	2.603E+06	2.369E+06

E-6 Photocatalytic Oxidation Calculations

ACIDGAS.XLS

Data from Appendix D in the Remedial Investigation Report (M&E, 1994) was used for contaminant concentrations in the Solid Waste Area. Presented below are conversion calculations for ppbv to mg/m^3, followed by conversion of these concentrations to account for dilution by air that will also be drawn in during gas extraction (the sample data are for "pure" landfill gas, and must be adjusted to account for the air collected by the perimeter and internal collection systems). Contaminants shown were selected by risk assessment personnel.

Locations sampled:
SG-SW(13+300)-12
SG-SW(11+500)-05
SG-SWD(13+300)-12
SG-SW(03+300)-06

Conversion from ppbv to mg/m^3: [from spreadsheet SUMMA.WK1, 8/14/96, prepared by S. Czarniecki]

Based on 760 torr (1 atm.) barometric pressure at 25°C and where 24.45 = molar volume in liters

mg/m^3 = (ppbv * gram molecular weight of substance) / (24.45 * 1000)

Conversion to account for dilution by extracted air:

Assumptions and Calculations:

1. The air does not contain any of the contaminants of concern.
2. The volumetric flow rate of air without landfill gas is 374,616 cm^3/s
   [from calculation dated 9/03/98, spreadsheet COMPOSIT.XLS]
3. The volumetric flow rate of air + landfill gas = total influent to photocatalytic oxidation unit
   = 402,562 cm^3/s
4. Therefore the volumetric flow rate of landfill gas = 402,562 - 374,616
   = 27,946 cm^3/s
5. Concentration of contaminant in influent gas (air + landfill gas) = concentration in landfill gas x [landfill gas flow rate/(air + landfill gas flow rate)] = concentration x 52,000/420,000

ACIDGAS.XLS

Contaminants:	MW	Landfill Gas Concentrations Maximum Detection (ppbv) [1]	(mg/m³)	Photocatalytic Oxidation Unit Influent Concentrations Maximum Detection (ppbv) [1]	(mg/m³)
Benzene	78.1	2,500	8.0	174	0.55
1,1-Dichloroethene	**97**	**8,100**	**32**	**562**	**2.23**
cis-1,2-Dichloroethene	**97**	**5,900,000**	**23,000**	**409,579**	**1,597**
***trans*-1,2-Dichloroethene**	**97**	**6,700**	**27**	**465**	**1.85**
Ethylbenzene	106.2	5,800	25	403	1.75
Methylene Chloride	**84.9**	**19,000**	**66**	**1,319**	**4.58**
Toluene	92.1	62,000	230	4,304	15.97
Trichloroethene	**131.4**	**5,700**	**31**	**396**	**2.13**
Vinyl Chloride	**62.5**	**1,200,000**	**3,100**	**83,304**	**215.20**
m,p-Xylene	106.2	9,400	41	653	2.83
o-Xylene	106.2	2,500	11	174	0.75
Carbon Disulfide	76.1	280	0.87	19	0.06
Dichlorodifluoromethane	**120.9**	**22,000**	**110** [2]	**1,527**	**7.64**
1,1-Dichloroethane	**99**	**34,000**	**140**	**2,360**	**9.72**
4-Methyl-2-pentanone	100.2	1,600	6.6	111	0.46
1,1,2,2-Tetrachloroethane	**167.9**	**0 ***	**0**	**0**	**0**
1,1,1-Trichloroethane	**133.4**	**1,900**	**10**	**132**	**0.72**
1,2,4-Trimethylbenzene	120.2	500	2	35	0.17
1,3,5-Trimethylbenzene	120.2	870	4.3	60	0.30
Acetone	58.1	0 *	0	0	0
1,2,4-Trichlorobenzene	**181.5**	**0 ***	**0**	**0**	**0**

ACIDGAS.XLS

Major Components of Influent Gas to the Photocatalytic Oxidation System are: Methane, Carbon Dioxide, Nitrogen, and Oxygen

The percentages (by volume) of these gases [from spreadsheet COMPOSIT.XLS, dated 9/03/98] are:

Percent by volume Methane (CH_4):	3.47
Percent by volume Carbon Dioxide (CO_2):	3.47
Percent by volume Nitrogen (N_2):	73.52
Percent by volume Oxygen (O_2):	19.54

Relative Humidity and Temperature of Influent Gas to the Photocatalytic Oxidation System:

Given the source of the gas, it is assumed that the relative humidity will approach 100% and the temperature will not drop below 10° C.

DESTRUCTION AND REMOVAL EFFICIENCIES:

For the purpose of estimating acid gas production, 100% destruction of chlorinated VOCs in the influent gas stream is assumed.

It is further assumed that the percentages of HCl and Cl_2 formed will be the same for each chlorinated VOC and will be as follows:

6.7% of the total chlorine atoms formed will go to HCl;

93.3% of the total chlorine atoms formed will go to Cl_2.

These values are based on values provided by KSE, Inc. for the photocatalytic oxidation of vinyl chloride.

Notes:

* Not detected in solid waste area SUMMA canister samples, but were chemicals of concern in RI report (M&E, 1994)

(1) Maximum of four samples. Duplicate samples not averaged prior to identifying maximum.

(2) Shows as 100 mg/m^3 on analytical sheet possibly due to calculation at different temperature.

ACIDGAS.XLS

Chlorinated VOCs:	MW	No. Cl atoms	Influent to Photocatalytic Units: Concentration (ppbv)	Influent to Photocatalytic Units: Flow (gmoles/s)	Effluent from Photocatalytic Units: Cl production assuming 100%DRE (g-atoms/s)
1,1-Dichloroethene	97	2	562	1.01E-05	2.02E-05
cis-1,2-Dichloroethene	97	2	409,579	7.36E-03	1.47E-02
trans-1,2-Dichloroethene	97	2	465	8.36E-06	1.67E-05
Methylene Chloride	84.9	2	1,319	2.37E-05	4.74E-05
Trichloroethene	131.4	3	396	7.11E-06	2.13E-05
Vinyl Chloride	62.5	1	83,304	1.50E-03	1.50E-03
Dichlorodifluoromethane	120.9	2	1,527	2.74E-05	5.49E-05
1,1-Dichloroethane	99	2	2,360	4.24E-05	8.48E-05
1,1,2,2-Tetrachloroethane	167.9	4	0	0.00E+00	0.00E+00
1,1,1-Trichloroethane	133.4	3	132	2.37E-06	7.11E-06
1,2,4-Trichlorobenzene	181.5	3	0	0.00E+00	0.00E+00

CALCULATIONS:

Total influent gas flow rate = 402,562 cm^3/s (STP) x 1 gmole/22,400 cm^3 = 17.97 gmoles/s

VOC Flow (gmoles/s) = VOC concentration (ppbv) x 1 /1,000,000,000 x total influent gas flow rate (gmoles/s)

Cl production (g-atoms/s) = VOC flow (gmoles/s) x no. Cl atoms

ACIDGAS.XLS

Chlorinated VOCs:	Effluent from Photocatalytic Units: HCl @ 6.7% of Cl atoms (gmoles/s)	Effluent from Photocatalytic Units: Cl_2 @ 93.3% of Cl atoms (gmoles/s)	Convert to lb/hr: HCl (lb/hr)	Convert to lb/hr: Cl_2 (lb/hr)
1,1-Dichloroethene	1.35E-06	9.43E-06	3.91E-04	5.30E-03
cis-1,2-Dichloroethene	9.86E-04	6.87E-03	2.85E-01	3.86E+00
trans-1,2-Dichloroethene	1.12E-06	7.80E-06	3.24E-04	4.38E-03
Methylene Chloride	3.18E-06	2.21E-05	9.18E-04	1.24E-02
Trichloroethene	1.43E-06	9.95E-06	4.13E-04	5.60E-03
Vinyl Chloride	1.00E-04	6.98E-04	2.90E-02	3.93E-01
Dichlorodifluoromethane	3.68E-06	2.56E-05	1.06E-03	1.44E-02
1,1-Dichloroethane	5.68E-06	3.96E-05	1.64E-03	2.22E-02
1,1,2,2-Tetrachloroethane	0.00E+00	0.00E+00	0.00E+00	0.00E+00
1,1,1-Trichloroethane	4.76E-07	3.32E-06	1.38E-04	1.87E-03
1,2,4-Trichlorobenzene	0.00E+00	0.00E+00	0.00E+00	0.00E+00
TOTALS:	0.0011	7.68E-03	0.3190	4.320

CALCULATE CONCENTRATIONS OF HCl and Cl_2 IN EXIT GAS (Assumes change in total moles of gas is negligible):

HCl: 0.0011 gmoles/s / 18 gmoles/s total gas flow x 1,000,000 = 61.41 ppmv

Cl_2: 0.00768 gmoles/s / 18 gmoles/s total gas flow x 1,000,000 = 427.55 ppmv

CALCULATIONS:

HCl (gmoles/s) = total Cl atoms (g-atoms/s) x 0.067

Cl_2 (gmoles/s) = total Cl atoms (g-atoms/s) x 0.933 x 1 gmole Cl_2/2 g-atoms Cl

HCl (lb/hr) = HCl (gmoles/s) x 3,600 s/hr x 36.45 g/gmoles x 1 lb/454 g

Cl_2 (lb/hr) = Cl_2 (gmoles/s) x 3,600 s/hr x 70.9 g/gmole x 1 lb/454 g

To determine if the treatment systems will be considered major sources by Rhode Island Air Pollution Control Rule #9, we must estimate the annual emissions of VOCs and NOx.
"Major stationary source" means any stationary source of air pollutants which emits or has the potential to emit 50 tons/yr or more of VOCs or NOx or 100 tons/yr of any other regulated air pollutant.

VOCs

Utilizing data from SUMMA.wk1, we assume that all contaminants detected are VOCs and that worst case treatment would allow 100% emissions. The total LFG concentration would be = 26,845 mg/m^3

From SCHOLLRE.xls, the LFG production is = 0.0282 m^3/s

Therefore, without treatment, the total VOCs leaving the landfill = 757 mg/s
= 52,601 lb/yr
= 26 ton/yr

This shows that any treatment system utilized will not be a major source for VOCs.

NOx

Flare operation is anticipated to produce more NOx than photocatalytic oxidation, since photocatalytic oxidation is a non-thermal treatment. From vendor quotations, NOx production at 1600°F is estimated to be 0.06 lb/MMBtu. The vendor also requires 1.5 MMBtu/hr of heating value for operation from 1500 to 1600°F.

For one year, NOx production is estimated at 788 lb/yr
= 0.4 ton/yr

This shows that the flare will not be a major source for NOx.

Any Other Regulated Pollutant

If Methane is considered a regulated pollutant under the definition of a major source, then any non-combustion treatment system becomes a major source (see GAS_COMP.xls).

METCALF & EDDY

E-7 Regulatory Analyses/Clarifications

METCALF & EDDY, INC.

TELECON MEMORANDUM

JOB NO. 020617-0012

DATE: 9-8-98

SUBJECT: Rose Hill methane generation/permit implications

M&E ENGINEER: S. Czarnieck.

OUTSIDE PARTY: Doug McVay
RIDEM - Air Resources
401-222-2808 x7011

MADE CALL (X)

REC'D CALL ( )

COMMENTS

SUMMARY OF CONVERSATION:

I briefly discussed the reasons for calling. Doug explained that the 100 lb/day and 10 lb/hr are permit thresholds. This does not mean that the discharge would not be allowed or that treatment is needed. In the Rose Hill situation, the landfill is not necessarily a new source, and Doug's only real concern was that by putting in passive vents, will an increase of 10 lb/hr occur (since the gas has a better conduit). I explained how the gas that is currently generated doesn't build up - otherwise, there would be blowouts. However, the cap will contain the gas + the vents will just release the same amount that would have been released without the cap in place. He seemed to accept that and also understood that gas generation will go down from what it is now.

The only other trigger we must look at is VOCs. There are compounds listed both in Rule #9 and #22 (Air toxics) which may require demonstration that thresholds are not exceeded.

Also, even though passive vents are installed, they are not individual sources. The landfill is the source.

CC: D. Simone

File - 020617

M&E FORM NO. 196 (9/78)

Emailed letter
Forwarded by D. Newton

22 September 1998

Mr. David Newton, Remedial Project Manager
Office of Site Remediation and Restoration
USEPA Region I
John F. Kennedy Federal Building, HBO
Boston, MA 02203

RE: Rose Hill Regional Landfill Superfund Site ARARs
Clarification of RIDEM Air Resources Regulations

Dear Mr. Newton:

After reviewing Metcalf & Eddy's memorandum of 14 September 1998, I have further conferred with Doug McVay from our Air Resources Office and can provide you with the following clarification:

Rhode Island Air Pollution Control (APC) Regulation No. 9 and associated document entitled "Sources Required to File Applications for Approval to Construct, Install or Modify", and APC Reg. No. 22 may be considered ARARs.

First of all, there are two types of permits which could be required under the APC Regulations: 1. A Minor or Major Source Permit to construct (Reg. No. 9); 2. An Air Toxics Operating Permit (Reg. No.22).

Reg. No. 9 requires that a facility (such as a landfill) which is constructing, installing or modifying anything (such as a cap) that would result in an increase in air emissions equal to or greater than any of the thresholds listed in Section 9.3.1 a – g, must apply for a permit to construct. In order for the Department to approve a permit to construct the applicant must apply BACT to control the air emissions. Therefore, only if installation of a cap and landfill gas collection system creates an increase in emissions will any of the requirements under Reg. No.9 apply.

The thresholds which may apply to Rose Hill are:

9.3.1 (e) Any stationary source that emits or has the potential to emit, in the aggregate, 10 tons per year or more of a hazardous air pollutant, or 25 tons per year or more of any combination of hazardous air pollutants.

9.3.1 (f) Any stationary source which has the potential to increase emissions of a listed toxic air contaminant by greater than the minimum quantity for that contaminant, as specified in Appendix A of this Regulation.

9.3.1 (g) Any other stationary source or process except for those outlined in Subsection 9.3.1(a) having the potential to emit one hundred pounds or more per day, or ten pounds or more per hour of any air contaminant or combination of air contaminants into the atmosphere, including but not limited to the following categories: (*see list*)

9.3.1. (h) Any air pollution control system and appurtenances.

Under Reg. No. 22 – An air toxics operating permit would be needed if annual emissions from the landfill (not just the increase) exceeds any of the quantities in Table 3 of the regulations.

Based upon the preliminary data Metcalf & Eddy calculated for emissions for the Solid Waste Area (SWA) and Bulky Waste Area (BWA), emission of hazardous air pollutants or VOCs are below the threshold limits, and a permit would only be needed if installation of a cap would increase the methane emissions by 10 lbs/hr or 100 lbs /day. If there is no increase in methane emissions then passive venting or other air pollution control devises which do not destroy methane (photocatalytic oxidation) would be acceptable.

If you require any further clarification or have any questions please feel free to contact me at 401-222-4700 X7126.

Sincerely,

Cynthia M. Gianfrancesco
Sr. Environmental Scientist
Office of Waste Management

cc: Warren Angell, OWM
Doug McVayl, OAR

Rharar.ltr

Metcalf & Eddy

Memorandum

To: D. Simone **Date:** 14 September 1998

Location: Wakefield, MA **Project No.:** 020617-0012

From: S. Czarniecki SC

Subject: **Rose Hill Landfill RIDEM Air Permitting Thresholds**

Following review of the email message sent by Dave Newton on 09/08/98 which forwarded questions by Cynthia Gianfrancesco, I proceeded to determine the significance of RIDEM's air permitting thresholds as they apply to passive venting of landfill gas (LFG) at the Rose Hill Solid Waste and Bulky Waste Landfills.

LFG and Methane Emission Estimates

Flow rate calculations for the Solid Waste Area (SWA) were presented in the Draft Final FS (11/97) and flow rates for the Bulky Waste Area (BWA) were presented in the risk assessment of the Final RI report (5/94). The flow rates for the BWA were not included in the Revised Draft Final FS since the risk assessment determined that there was no risk from LFG at the BWA and it would be passively vented. While updating the risk tables for the SWA using new LFG generation rates, the BWA flow rates have been recalculated and are to be included in the Final FS. A comparison of the old and new flow rates for both areas are attached (Attachment A). The first-order kinetic model used by M&E for previous calculations is the same as that incorporated in EPA's Landfill Gas Emissions Model (LandGEM), which is used for current calculations. Methane emissions are assumed to be 50% of the total LFG emissions.

State Regulations

Rhode Island Air Pollution Control Regulation No. 9 (APCR#9) states that a Minor source permit is required for the construction, installation or modification of any of the following:

[9.3.1(e)] Any stationary source that emits or has the potential to emit, in the aggregate, 10 tons per year or more of any hazardous air pollutant or 25 tons per year or more of any combination of hazardous air pollutants.

[9.3.1(f)] Any stationary source which has the potential to increase emissions of a listed toxic air contaminant by greater than the minimum quantity for that contaminant, as specified in Appendix A of this regulation.

[9.3.1(g)] Any other stationary source or process....having the potential to emit one hundred pounds or more per day, or ten pounds or more per hour of any air contaminant or combination of air contaminants into the atmosphere...

[9.3.1(h)] Any air pollution control system and appurtenances.

Rhode Island APCR#9 also states that a Major source permit is required for the following:

[9.4.1(b)(1)] Any stationary source of air pollutants which emits or has the potential to emit 50 tons per year or more of volatile organic compounds or nitrogen oxides or 100 tons per year of any other regulated air pollutant.

As Dave discussed in his email, under Superfund, if permitting thresholds are exceeded, the substantive requirements of the regulation would be followed even though the permit itself is not required. This still allows RIDEM to state whether or not a specific discharge will be allowed.

Permitting issues were previously reviewed in 1997 when innovative LFG treatment processes were reviewed for the SWA (i.e. photocatalytic oxidation). Mark Dennin of RIDEM noted that uncontrolled methane emissions exiting a process were possibly regulated under APCR#9. M&E confirmed with RIDEM's Doug McVay (Air Bureau) that the State considers methane as being included under "any other air contaminant." At the time, uncontrolled methane exiting the innovative process was estimated above the 100 pounds per day and 10 pounds per hour thresholds, so the Air Bureau would need to review the emissions. However, the methane emission was estimated at greater than 100 pounds per hour. This emission was noted by Doug McVay as being too much to allow as an untreated release. For this reason, an enclosed flare was still selected as the appropriate treatment option at the SWA.

To better understand RIDEM's interpretation of the regulation discussed above, I contacted Doug McVay in RIDEM's Air Bureau. As I understand the regulation following discussion with Doug, the BWA is not really a new source, since it has been emitting LFG for many years. As long as installing a landfill cap with passive vents does not increase the current methane (or other air pollutant) emissions 10 pounds per day, the Minor source permitting requirements do not need to be followed. I explained to Doug that the landfill generates LFG which currently escapes through the existing cover materials. If it were to build up, there would be a blow out at some point, but the existing cover materials are too porous to allow that. Once a liner is placed over the landfill, gases will build up under the liner, until vents are installed through the liner. These vents allow the gases which were previously escaping naturally to exit through the installed cap. Doug stated that if this is the case, then the permitting requirements would not be triggered by a source modification/increase. However, thresholds for VOCs, hazardous air pollutants (HAPs) and toxic compounds must be reviewed

as well, since Operating Permit requirements under Rhode Island Air Pollution Control Regulation No. 22 overlaps with APCR#9.

While an old landfill does not appear to trigger Regulation No. 9, any treatment system used on the LFG triggers the permitting requirements by 9.3.1(h). Currently, treatment of the SWA LFG is required due to risk from specific VOCs. Therefore, the permitting requirements are triggered.

Permitting Threshold Calculations

Emission estimates were calculated for comparison to permitting thresholds for the following: hazardous air pollutants (HAPs), toxic air contaminants, VOCs and methane (other air pollutant). Calculations were performed two ways: (1) SUMMA canister sampling at the SWA resulted in a list of detected VOCs which were then applied to the 1997 LFG flow rate (calculated above using LandGEM); and (2) default concentrations from the contaminant list for EPA's LandGEM were applied to the 1997 LFG flow rate. Attachment E presents calculations using the SUMMA canister date. Attachment F summarizes results using EPA's LandGEM. It should be noted that most of the default values of the model's listed compounds are significantly lower than those measured at Rose Hill and, therefore, result in noticeably lower emissions than those estimated using site-specific sampling data. However, there are a few contaminants in LandGEM with default concentrations higher than those detected on site. There are also contaminants listed in LandGEM which were not included in the SUMMA canister analysis.

Calculations are not attached for the BWA due to significantly lower emissions than the SWA. However, using the default acrylonitrile concentration from LandGEM results in an emission of 0.0008 lb/hr. This will be discussed further in the next section.

Comparison of Calculations to Permitting Thresholds

Each of the permitting thresholds noted earlier are presented below with site-specific information following:

- 9.3.1(e) - Emissions for both the SWA and BWA were below the thresholds for HAPs.

- 9.3.1(f) - Using default LandGEM concentrations for tetrachloroethylene at the SWA and acrylonitrile at both the SWA and BWA, Appendix A thresholds for toxic air contaminants were exceeded. However, emissions from the existing landfill areas at Rose Hill are expected to only decrease over time. Placing a cap with passive vents is not anticipated to increase emissions.

- 9.3.1(g) - Methane emissions from both the SWA and BWA are estimated to be greater than 100 lb/day and 10 lb/hr thresholds for any air contaminant.

- 9.3.1(h) - If the landfill areas are passively vented, there are no air pollution control systems involved.

- 9.4.1(b)(1) - Emissions from both the SWA and BWA are estimated below the threshold for VOCs and NOx. Methane emissions from the BWA are estimated below the 100 try threshold for any other regulated air pollutant. However, SWA methane emissions are estimated above the threshold.

Although thresholds are exceeded, conversation with Doug McVay led me to the conclusion that an existing source without an air pollution control system, such as a passively vented landfill, would not require permitting. However, based on the written regulation, this appears to be a RIDEM interpretation which would need to be clarified in writing.

Conclusions

- Risk to human health as determined in the 1994 risk assessment is driving the need for a flare at the SWA. This air pollution control system would require the substantive requirements of the permitting regulations to be followed.

- While uncontrolled methane emissions from both the SWA and BWA are estimated above permitting thresholds, it is still unclear if passive venting of existing landfills is considered exempt from the regulation.

- A clarification in writing from RIDEM would be appreciated regarding the applicability of these permitting thresholds to existing landfills.

cc: File

LFG rates prior to 1997 AP-42 update:

SWA

1996 (Scholl-Canyon kinetic model) -		5.77E+07	ft^3 LFG / yr	[FS, 1997]
	=	110	cfm	
	=	0.052	m^3 / s	

BWA

1993 (Scholl-Canyon kinetic model) -		1.75E+07	ft^3 LFG / yr	[RI, 1994]
	=	33	cfm	
	=	0.016	m^3 / s	

LFG rates following 1997 AP-42 update:

SWA

1997 (Scholl-Canyon kinetic model) -		3.11E+07	ft^3 LFG / yr	[Attachment B]
	=	59	cfm	
	=	0.028	m^3 / s	

SWA

1997 (EPA Landfill Gas Emissions Model) -		4.44E+05	m^3 CH_4 / yr	[Attachment C]
	=	888,800	m^3 LFG / yr	
	=	0.0282	m^3 LFG / s	
	=	60	cfm	

BWA

1997 (EPA Landfill Gas Emissions Model) -		6.13E+04	m^3 CH_4 / yr	[Attachment D]
	=	122,680	m^3 LFG / yr	
	=	0.0039	m^3 LFG / s	
	=	8.2	cfm	

Methane Emissions following 1997 AP-42 update: 2204.6 lb / Mg

SWA

1997 (EPA Landfill Gas Emissions Model) -		2.97E+02	Mg CH_4 / yr	[Attachment C]
	=	653,664	lb CH_4 / yr	
	=	327	ton CH_4 / yr	
	=	1,791	lb CH_4 / day	
	=	75	lb CH_4 / hr	
	=	1.2	lb CH_4 / min	

BWA

1997 (EPA Landfill Gas Emissions Model) -		4.09E+01	Mg CH_4 / yr	[Attachment D]
	=	90,212	lb CH_4 / yr	
	=	45	ton CH_4 / yr	
	=	247	lb CH_4 / day	
	=	10.3	lb CH_4 / hr	
	=	0.17	lb CH_4 / min	

METCALF & EDDY

Project:	Rose Hill LFG Emissions	Acct. No.	020617-0012	Page:	1 of 2
Subject:	VOCs/HAPs	Prepared by:	S. Czarniecki	Date:	9/11/98
Detail:		Checked by:		Date:	

GAS_VOCS

Data from Appendix D in the Remedial Investigation Report (M&E, 1994) was used for contaminant concentrations in the Solid Waste Area. Presented below are conversion calculations for ppbv to mg/m^3, followed by the calculations of mass exiting with the landfill gas. The landfill gas flow rate utilized is for 1997 using the EPA's Landfill Air Emission Estimation model.

Contaminants shown are those that were detected during SUMMA canister sampling (M&E, RI, 1994).

Locations sampled:
SG-SW(13+300)-12
SG-SW(11+500)-05
SG-SWD(13+300)-12
SG-SW(03+300)-06

Conversion from ppbv to mg/m^3:

Based on 760 torr (1 atm.) barometric pressure at 25°C and where 24.45 = molar volume in liters

mg/m^3 = (ppbv * gram molecular weight of substance) / (24.45 * 1000)

1997 LFG flow rate: 888,800 m^3 / yr

Project:	Rose Hill LFG Emissions	Acct. No.	020617-0012	Page:	2 of 2
Subject:	VOCs/HAPs	Prepared by:	S. Czarniecki	Date:	9/11/98
Detail:		Checked by:		Date:	

GAS_VOCS

Detected Contaminants (Bold are HAPs):	MW	Landfill Gas Concentrations Maximum Detection (ppbv) [1]	(mg/m^3)	(mg/yr)	non-VOCs under APCR 9.1.40	(tpy)	lb/hr	Appx.A Toxics[1]
Benzene	78.1	2,500	8.0	7,097,677		0.0078	0.0018	x
1,1-Dichloroethene	97	8,100	32	28,561,561		0.031	0.0072	
cis-1,2-Dichloroethene	97	5,900,000	23,000	20,442,400,000		23	5.1456	
trans-1,2-Dichloroethene	97	6,700	27	23,624,995		0.026	0.0059	
Ethylbenzene	106.2	5,800	25	22,391,217		0.025	0.0056	
Methylene Chloride	84.9	19,000	66	58,638,989	x	0.065	0.0148	x
Toluene	92.1	62,000	230	204,424,000		0.23	0.0515	x
Trichloroethene	131.4	5,700	31	27,226,725		0.030	0.0069	x
Vinyl Chloride	62.5	1,200,000	3,100	2,755,280,000		3.0	0.6935	
m,p-Xylene	106.2	9,400	41	36,289,213		0.040	0.0091	x
o-Xylene	106.2	2,500	11	9,651,387		0.011	0.0024	x
Carbon Disulfide	76.1	280	0.87	774,583		0.00085	0.0002	
Dichlorodifluoromethane (Freon 12)	120.9	22,000	110	97,768,000	x	0.11	0.0246	
1,1-Dichloroethane	99	34,000	140	124,432,000		0.14	0.0313	
4-Methyl-2-pentanone (MIBK)	100.2	1,600	6.6	5,827,911		0.0064	0.0015	
1,1,1-Trichloroethane	133.4	1,900	10	9,213,712	x	0.010	0.0023	
1,2,4-Trimethylbenzene	120.2	500	2.5	2,184,739		0.0024	0.0005	
1,3,5-Trimethylbenzene	120.2	870	4.3	3,801,447		0.0042	0.0010	
Chloromethane(methyl chloride)	50.5	1,400	2.9	2,570,068		0.0028	0.0006	
Chloroethane(ethyl chloride)	64.5	6,600	17.4	15,474,935		0.017	0.0039	
Trichlorofluoromethane	137.4	250	1.4	1,248,682	x	0.0014	0.0003	
Carbon Tetrachloride	153.8	45	0.28	251,590		0.00028	0.0001	x
Tetrachloroethene	165.8	1,200	8.1	7,232,542		0.0080	0.0018	x
Bromoform	252.8	230	2.4	2,113,635		0.0023	0.0005	
1,4-Dichlorobenzene	147	72	0.43	384,747		0.00042	0.0001	
Freon 114 (1,2-Dichlorotetrafluoroethane)	170.9	280	2.0	1,739,503	x	0.0019	0.0004	
					Total:	26.3		

RI APCR #9.3.1(e) HAP thresholds: Individual - 10 tpy, Total - 25 tpy — HAPs only: 3.7

RI APCR #9.4.1(b) VOC threshold: Total - 50 tpy — Considered VOCs under RI APCR 9.1.40: 26.2

[1] No toxic air contaminants as listed in RI APCR #9 Appx. A were above their respective thresholds.

Project	Rose Hill Feasibility Study	Acct. No.	020617 - 0012	Page	1 of 1
Subject	LandGEM Emissions	Comptd. By	S. Czarniecki	Date	11-Sep-98
Detail	Solid Waste Area	Ck'd By		Date	

P:\NE\ROSEHILL\FS\APPX-E\GAS_VOCS.XLS

	LandGEM Compounds(Bold are HAPs):	MW	ppmv	SUMMA ppmv[1]	mg/m³	mg/yr	tpy	lb/hr	non-VOCs	Appx. A Toxics[2]
	1,1,1-Trichloroethane	133.41	0.48	1.9	2.6	2,327,849	0.0026	6E-04	x	
	1,1,2,2-Tetrachloroethane	167.85	1.11		7.6	6,772,820	0.0075	0.002		
	1,1,2-Trichloroethane	133.41	0.1		0.5	484,969	0.0005	1E-04		x
	1,1-Dichloroethane	98.96	2.35	34	9.5	8,453,815	0.0093	0.002		
	1,1-Dichloroethene	96.94	0.2	8.1	0.8	704,788	0.0008	2E-04		
	1,2-Dichloroethene	98.96	0.41	5,900 (cis)	1.7	1,474,921	0.0016	4E-04		
	1,2-Dichloropropane	112.99	0.17		0.8	698,255	0.0008	2E-04		
	2-Propanol	60.01	50.06		122.9	109,204,279	0.1204	0.027		
	Acetone	58.08	7.01		16.7	14,800,276	0.0163	0.004		
	Acrylonitrile	53.06	11.5		25.0	22,181,467	0.0245	0.006		x
	Benzene (1.91-30)	78.12	1.91	2.5	6.1	5,424,014	0.0060	0.001		x
	Bromodichloromethane	163.83	3.13		21.0	18,640,732	0.0206	0.005		
	Butane	58.12	5.03		12.0	10,627,198	0.0117	0.003		
	Carbon Disulfide	76.14	0.58	**0.28**	1.8	1,605,336	0.0018	4E-04		
	Carbon Tetrachloride	153.84	0.04	0.045	0.3	223,694	0.0002	6E-05		x
	Carbonyl Sulfide	60.07	0.49		1.2	1,069,988	0.0012	3E-04		
	Chlorobenzene	112.56	0.25		1.2	1,022,938	0.0011	3E-04		
	Chlorodifluoromethane	86.47	1.21		4.3	3,803,435	0.0042	1E-03		
	Chloroethane	64.52	1.37	6.6	3.6	3,213,217	0.0035	8E-04		
	Chloroform	119.38	0.02		0.1	86,793	0.0001	2E-05		x
	Chloromethane	50.49	1.21	1.4	2.5	2,220,833	0.0024	6E-04		
x	Dichlorobenzene	147	0.21		1.3	1,122,178	0.0012	3E-04		
	Dichlorodifluoromethane	120.91	15.7	22	77.6	69,006,032	0.0761	0.017	x	
	Dichlorofluoromethane	102.92	4.4		18.5	16,461,812	0.0181	0.004	x	
	Dichloromethane (MeCl)	84.93	14.3	19	49.7	44,149,150	0.0487	0.011	x	x
	Dimethyl Sulfide	62.13	7.82		19.9	17,661,732	0.0195	0.004		
	Ethanol	46.08	27.2		51.3	45,562,396	0.0502	0.011		
	Ethylbenzene	106.17	4.61	5.8	20.0	17,792,129	0.0196	0.004		
	Ethyl Mercaptan	62.13	2.28		5.8	5,149,456	0.0057	0.001		
	Fluorotrichloromethane	137.37	0.76	**0.25**	4.3	3,795,165	0.0042	1E-03	x	
	Hexane	86.18	6.57		23.2	20,582,449	0.0227	0.005		
	Mercury	200	0.11		0.9	799,738	0.0009	2E-04		
	Methyl Ethyl Ketone	72.11	7.09		20.9	18,585,186	0.0205	0.005		
	Methyl Isobutyl Ketone	100.16	1.21	1.6	5.0	4,405,598	0.0049	0.001		
	Methyl Mercaptan	48.11	4.33		8.5	7,572,660	0.0083	0.002		
	Petane	72.15	3.29		9.7	8,628,939	0.0095	0.002		
	Tetrachloroethylene	165.83	3.73	**1.2**	25.3	22,485,219	0.0248	0.006		x
	Propane	44.1	11.1		20.0	17,794,539	0.0196	0.004		
	Toluene (39.3-165)	92.14	39.3	62	148.1	131,633,352	0.1451	0.033		x
	Trichloroethene	131.29	2.82	5.7	15.1	13,458,788	0.0148	0.003		
	trans-1,2-Dichloroethene	96.94	2.84	6.7	11.3	10,007,983	0.0110	0.003		
	Vinyl Chloride	62.5	7.34	1,200	18.8	16,676,360	0.0184	0.004		
	Xylene	106.17	12.1	**11.9**	52.5	46,699,515	0.0515	0.012		x
						Total:	0.8325			
						HAPs only:	0.4341			
						Considered VOCs under RI APCR 9.1.40:	0.6828			

[1] Comparison values. Bold values are lower than LandGEM.

[2] Boxed contaminants are above their respective thresholds listed in RI APCR#9 Appx. A.

METCALF & EDDY

METCALF & EDDY, INC.

TELECON MEMORANDUM

JOB NO. 020617-0012 DATE: 10/2/98

SUBJECT: Rose Hill - Air Regulations Clarification

M&E ENGINEER: S. Czarnieck. OUTSIDE PARTY: Doug McVay

MADE CALL (X) RIDEM - Air Resources

REC'D CALL ( ) 401-222-2808 x 7011

COMMENTS

SUMMARY OF CONVERSATION:

We reviewed the fax I sent. The history he remembers is that if you had to get a permit, BACT had to be applied. You would then compare a flare to photocat. (for example). Cost vs. control effectiveness would then be evaluated. When he heard the quantity of methane, he stated that he would have to go with a process that treated the methane. However, if permitting is not required, this evaluation is not performed and the emissions can occur.

APCR #9 requires a permit for a source when constructing, installing or modifying. An existing landfill doesn't meet the first two. Modification of the source is possible, but there must be a net emissions increase. Therefore, passive venting does not apply. If you modify the source with air pollution control, a permit is needed unless it is exempt. At Rose Hill, the SWA would not be exempt. I asked if BACT would then kick in. He said no, because the BACT requirement is for an increase in emissions. Therefore, the methane which makes the landfill not exempt would also not require control. Doug stated he would try to figure out a federal requirement to treat the methane, but was not hopeful.

Ray said there is nothing which would require the methane treatment

APCR #22 may require treatment/permitting for the two toxics we noted as above limits. I have to review this. The operating permit requirements are for the facility as a whole, not just an emissions increase. I have to review the Ambient Air Limits at the property boundaries to determine the applicability.

CC:
D. Simone
File - 020617

M&E FORM NO. 196 (9/78)

METCALF & EDDY, INC.

TELECON MEMORANDUM

JOB NO. 020617-0012

DATE: 10-14-98

SUBJECT: Rose Hill Air Permitting

M&E ENGINEER: S. Czarnieck

OUTSIDE PARTY: Doug McKay
RIDEM - Air Resources
401-222-2808 x 7011

MADE CALL ( )

REC'D CALL (✓)

COMMENTS

SUMMARY OF CONVERSATION:

I had previously sent an Email to Doug (attached) regarding toxics permitting.

Doug said they would use EPA default emission values for permitting if there were no sample results for a specific compound. The permitee could sample using SUMMA canisters to show that the default value was high for the site.

CC:
D. Simone
File

M&E FORM NO. 196 (9/78)

Lotus cc:Mail for Sean Czarniecki

Author: Sean Czarniecki at awtwak_po
Date: 10/13/98 8:48 AM
Priority: Normal
TO: DMcVay@dem.state.ri.us at AWT_INTERNET_PO
Subject: question I left on voice mail

Doug,

I'm sure that the message I left on your voice mail yesterday was a little confusing, so I'll lay it out a little better here.

This regarding the Rose Hill site and Reg. #22.

The two toxics (acrylonitrile and PCE) which were above emissions thresholds (lb/hr) in the backup I sent were not actually detected at the site at the concentrations which created the threshold exceedence. In the backup I sent, I used two different methods for calculations: summa canister samples (TO-14 analysis) and EPA's LandGEM model. The TO-14 analyte list did not include acrylonitrile, and PCE was detected at a level which would create an emission estimate below the threshold. I used EPA's default concentrations from LandGEM for a comparison since there are a few extra compounds included in the model which were not part of TO-14.

I quickly reviewed ISC impacts for each compound at the property boundaries and found that PCE is below its limit for both the TO-14 and LandGEM concentrations. However, acrylonitrile is above its limit.

The question is - would RIDEM require permitting for passive venting based on the acrylonitrile estimates even though they are EPA default values? Of course, if that were the only compound of concern, I'm sure someone would sample and analyze to show that actual values are below the permitting thresholds, but I just wanted to know RIDEM's stance on contaminants which were not analyzed.

Thank you for your time in this matter.

Sean
Sean_Czarniecki@air-water.com
781-224-6811

Metcalf & Eddy

Memorandum

To: D. Simone **Date:** 14 October 1998

Location: Wakefield, MA **Project No.:** 020617-0012

From: S. Czarniecki SC

Subject: **Rose Hill Landfill RIDEM Air Permitting Clarifications**

Based on review of Cynthia Gianfrancesco's Air Resources Regulations letter dated 09/22/98, I spoke with Doug McVay for final clarification regarding the following issues at Rose Hill.

Since I found that APCR #9 does not specifically state that application for a permit to construct is required only if installation of a cap and landfill gas collection system creates an increase in emissions, I requested RIDEM clarification on this issue. Doug explained to me that APCR #9 should be looked at for sources which are constructed, installed or modified to generate a net emissions increase. Rose Hill's landfills are existing, so the "constructed" and "installed" components do not apply. "Modified" has potential at Rose Hill, but there would not be a net emissions increase for passive venting of the landfill gas (LFG), so APCR #9 would not apply. However, modification of the source by air pollution control equipment such as a flare or photocatalytic oxidation would create applicability of APCR #9 [9.3.1(h)] unless the system qualifies for exemption.

For Rose Hill, the LFG emitted from the Solid Waste Area (SWA) exceeds thresholds in Subsection 9.3.1(g), so any air pollution control system requires a permit. However, Best Available Control Technology (BACT) need not be applied [9.3.3(a)] since there is no net emissions increase. Therefore, it appears that any air pollution control system may be added at the site, even if it does not treat the methane emissions (which drives the permit application).

Based on the information I gave him, Doug also noted that the SWA has two air toxics, tetrachloroethylene and acrylonitrile, which should be reviewed under APCR #22. I have briefly reviewed these and found the following:

- Acrylonitrile is not a standard TO-14 compound, and was therefore not reported for the summa canister results. Therefore, the only concentration data to work with is the default values in EPA's LandGEM model. The estimated emission rate for this compound using this data is above its respective threshold. This would require the source (passive venting of the landfill) to be registered at a minimum.

- Acrylonitrile annual average impacts at property boundaries exceed Ambient Air Levels (AALs) using the LandGEM default concentration. This would require the source to be treated and permitted unless sampling is performed to show that site-specific concentrations are lower than the LandGEM default, thereby reducing property boundary impacts to below AALs.

- Tetrachloroethylene (PCE) was detected at a value for which emissions are below the permitting threshold. However, the default value in EPA's LandGEM model creates an emission estimate above the threshold. With either concentration, the AALs are not exceeded for PCE.

If AALs are not exceeded, APCR #22 would not require permitting for passive venting of the SWA or addition of an air pollution control system since there is no net increase of toxic emissions.

In summary, Cynthia's letter is correct as it applies to Rose Hill except for the statement regarding APCR #9, "In order for the Department to approve a permit to construct the applicant must apply BACT to control the air emissions." This one statement is a minor misinterpretation on the conservative side, so it does not appear that we need to ask for a new clarification letter.

cc: File

F. AMBIENT AIR DISPERSION

F-1 Area Source Modeling - Risk Assessment
F-2 Point Source Modeling - Flare
F-3 PRG Exceedances
F-4 Basement Ambient Air Correlation
F-5 Point Source Modeling: Non-Combustion Technology

F-1 Area Source Modeling - Risk Assessment

Project	Rose Hill FS	Acct. No.	4609-18-10-11	Page	1 of 1
Subject	Air Modeling	Comptd. By	S. Czarniecki	Date	08/14/96
Detail	SUMMA Canister Concentrations	Ck'd. By	J. Young	Date	08/14/96

C:\RH\AIR\ISCST3\SUMMA.WK1

SUMMA.WK1

Data from Appendix D in the Remedial Investigation Report (M&E, 1994) was used for contaminant concentrations in the Solid Waste Area. Attachment A presents these results as well as a map showing sampling locations. Presented below is conversion calculations for ppbv to mg/m^3. Contaminants shown were selected by risk assessment personnel.

Locations sampled: SG-SW(13+300)-12
SG-SW(11+500)-05
SG-SWD(13+300)-12
SG-SW(03+300)-06

Conversion from ppbv to mg/m^3:

Based on 760 torr (1 atm.) barometric pressure at 25°C and where 24.45 = molar volume in liters

mg/m^3 = (ppbv * gram molecular weight of substance) / (24.45 * 1000)

Contaminants:	MW	Maximum Detection (ppbv)[1]	(mg/m^3)
Benzene	78.1	2,500	8.0
1,1-Dichloroethene	97	8,100	32
cis-1,2-Dichloroethene	97	5,900,000	23,000
trans-1,2-Dichloroethene	97	6,700	27
Ethylbenzene	106.2	5,800	25
Methylene Chloride	84.9	19,000	66
Toluene	92.1	62,000	230
Trichloroethene	131.4	5,700	31
Vinyl Chloride	62.5	1,200,000	3,100
m,p-Xylene	106.2	9,400	41
o-Xylene	106.2	2,500	11
Carbon Disulfide	76.1	280	0.87
Dichlorodifluoromethane	120.9	22,000	110 [2]
1,1-Dichloroethane	99	34,000	140
4-Methyl-2-pentanone	100.2	1,600	6.6
1,1,2,2-Tetrachloroethane	167.9	0 *	0
1,1,1-Trichloroethane	133.4	1,900	10
1,2,4-Trimethylbenzene	120.2	500	2
1,3,5-Trimethylbenzene	120.2	870	4.3
Acetone	58.1	0 *	0
1,2,4-Trichlorobenzene	181.5	0 *	0

Notes:

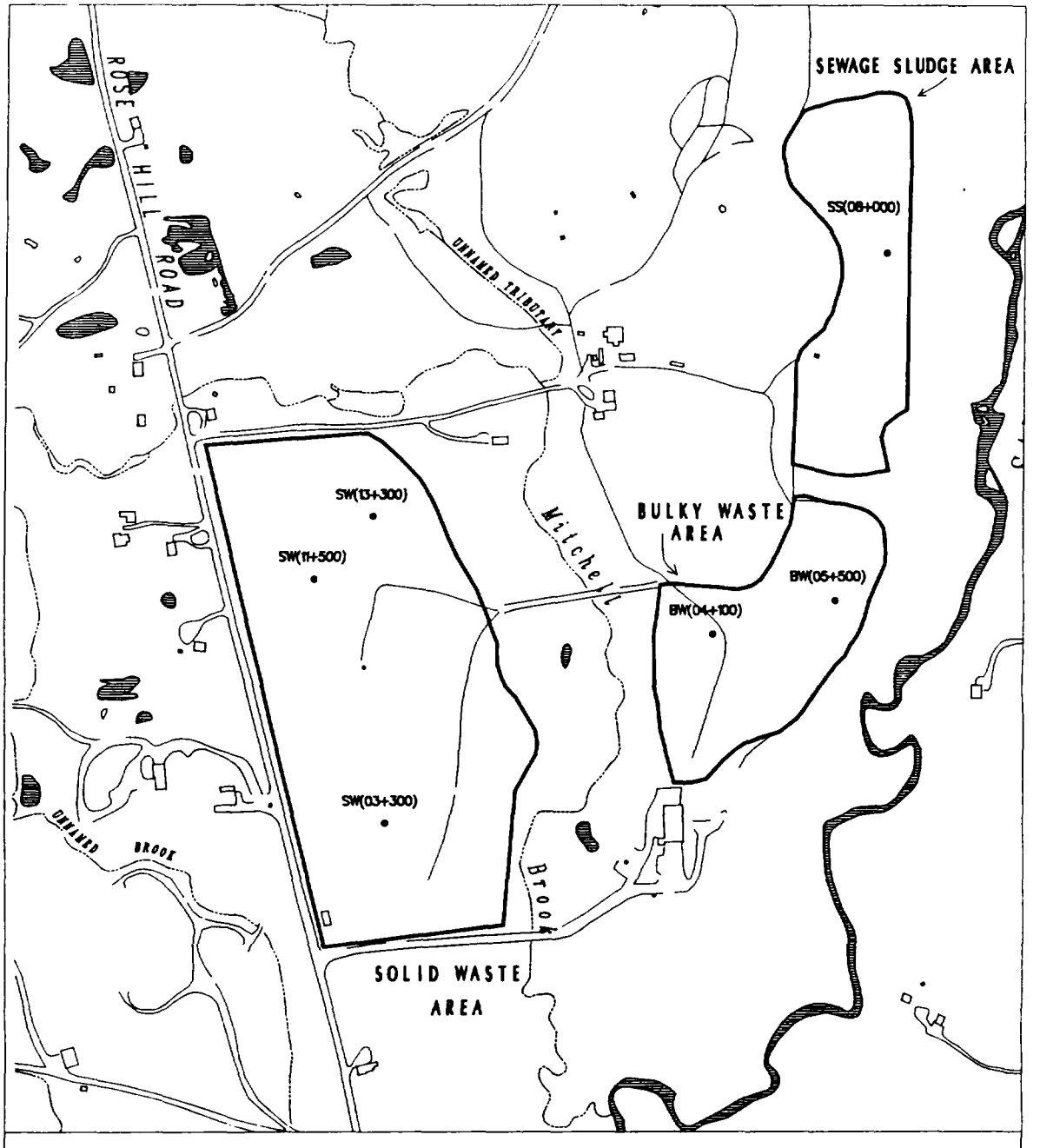
* Not detected in solid waste area SUMMA canister samples, but were chemicals of concern in RI report (M&E, 1994)

[1] Maximum of four samples. Duplicate samples not averaged prior to identifying maximum.

[2] Shows as 100 mg/m^3 on analytical sheet possibly due to calculation at different temperature.

Metcalf & Eddy, Inc.

ATTACHMENT A



Primary Road

Secondary Road

Stream or Brook

Landfill Area

Lake, Pond, or River

Locations of TO-14 and Reduced Sulfur Analysis of Landfill Gas

SCALE IN FEET

350 0 100 350

FIGURE 2-28

TO-14 and Reduced Sulfur Analysis Sampling Locations

ROSE HILL REGIONAL LANDFILL

SOUTH KINGSTOWN, RI

METCALF & EDDY

Volatile Analysis of SUMMA Canisters
(ppbv)

SITE: ROSE HILL REGIONAL LANDFILL
SAS NO.: 7165A SDG NO.: SA1401

TRAFFIC REPORT NUMBER:			SA1401		SA1402		SA1403		SA1404		SA1405		SA1406	
M&E SAMPLE ID:			SG-SS(08+000)-12		SG-BW(04+100)-06		SG-BW(05+500)-12		SG-SW(13+300)-12		SG-SW(11+500)-05		SG-SWD(13+300)-12	
COMPOUND	CRQL	MW		mg/m3		mg/m3		mg/m3		mg/m3		mg/m3		mg/m3
Dichlorodifluromethane	5	120.9	8 U	0.04	282 J	1.39	5200	26	12000 J	59	9200	45	22000 J	100
Freon 114	5	170.9	8 U	0.06	360 U	2.5	330 U	2.3	40000 U	300	280 J	2.0	140000 U	980
Chloromethane	5	50.5	8 U	0.02	360 U	0.74	330 U	0.68	40000 U	80	1400 J	2.9	140000 UJ	290
Vinyl Chloride	5	62.5	8 U	0.02	5500 D	14	470	1.2	490000 A	1300	400000 D	1000	1200000	3100
Bromomethane	5	95	8 U	0.03	360 U	1.4	330 U	1.3	40000 U	200	1800 U	7.0	140000 U	540
Chloroethane	5	64.5	8 U	0.02	740 J	1.9	670	1.8	6600 J	17	1800 U	4.7	140000 U	370
Trichlorofluoromethane	5	137.4	8 U	0.05	230 J	1.3	28 J	0.16	40000 U	200	250 J	1.4	140000 U	790
1,1-Dichloroethene	5	97	8 U	0.03	78 J	0.31	23 J	0.091	5600 J	22	3800	15	8100 J	32
Carbon Disulfide	5	76.1	8 U	0.03	360 U	1.1	330 U	1.0	40000 U	100	280 J	0.87	140000 U	430
Freon 113	5	187.4	8 U	0.06	14 J	0.11	330 U	2.5	40000 U	300	31 J	0.24	140000 U	1100
Acetone	5	58.1	34	0.08	560 J	1.3	330 U	0.78	40000 U	90	1800 U	4.3	140000 U	330
Methylene Chloride	5	84.9	0.6 J	0.002	260 J	0.90	680	2.4	8000 J	30	2400	8.3	19000 J	66
trans-1,2-Dichloroethene	5	97	8 U	0.03	75 J	0.30	28 J	0.11	3600 J	14	1000 J	4	6700 J	27
1,1-Dichloroethane	5	99	8 U	0.03	1700 J	6.9	510	2.1	22000 J	89	3900	16	34000 J	140
cis-1,2-Dichloroethene	5	97	8 U	0.03	4400 A	17	1200	4.8	2300000 A	9100	1800000 D	7100	5900000 J	23000
2-Butanone	5	72.1	8 U	0.02	740 J	2.2	590 A	1.7	40000 U	100	1800 U	5.3	140000 U	410
Chloroform	5	119.4	8 U	0.04	360 U	1.8	330 U	1.6	40000 U	200	1800 U	8.8	140000 U	680
1,1,1-Trichloroethane	5	133.4	8 U	0.04	310 J	1.7	330 U	1.8	1900 J	10	230 J	1.3	140000 U	760
Carbon Tetrachloride	5	153.8	8 U	0.05	360 U	2.3	330 U	2.1	40000 U	300	45 J	0.28	140000 U	880
Benzene	5	78.1	8 U	0.03	920 J	2.9	95 AJ	0.30	2500 J	8.0	620 J	2.0	140000 U	450
1,2-Dichloroethane	5	99	8 U	0.03	360 U	1.5	330 U	1.3	40000 U	160	1800 U	7.3	140000 U	570
Trichloroethene	5	131.4	8 U	0.04	570 J	3.1	700 A	3.8	2700 J	14	5700	31	140000 U	750
1,2-Dichloropropane	5	113	8 U	0.04	360 U	1.7	330 U	1.5	40000 U	200	1800 U	8.3	140000 U	650
Bromodichloromethane	5	163.9	8 U	0.05	360 U	2.4	330 U	2.2	40000 U	300	1800 U	12	140000 U	940
2-Chloroethyl Vinyl Ether	5	106.6	8 U	0.04	360 U	1.6	330 U	1.4	40000 U	200	1800 U	7.8	140000 U	610
cis-1,3-Dichloropropene	5	111	8 U	0.04	360 U	1.6	330 U	1.5	40000 U	200	1800 U	8.2	140000 U	630
4-Methyl-2-pentanone	5	100.2	8 U	0.03	360 U	1.5	330 U	1.3	1600 J	6.5	1800 U	7.4	140000 U	570
Toluene	5	92.1	8 U	0.03	9100 A	34	5700	21	22000 J	83	19000	71	62000 J	230
trans-1,3-Dichloropropene	5	111	8 U	0.04	360 U	1.6	330 U	1.5	40000 U	200	1800 U	8.2	140000 U	630
1,1,2-Trichloroethane	5	133.4	8 U	0.04	360 U	2.0	330 U	1.8	40000 U	200	1800 U	9.8	140000 U	760
Tetrachloroethene	5	165.8	8 U	0.06	130 J	0.88	200 J	1	40000 U	300	1200 J	8.1	140000 U	950
Dibromochloromethane	5	208.3	8 U	0.07	360 U	3.1	330 U	2.8	40000 U	300	1800 U	15	140000 U	1200
1,2-Dibromomethane	5	173.9	8 U	0.06	360 U	2.6	330 U	2.3	40000 U	300	1800 U	13	140000 U	990
2-Hexanone	5	100.2	8 U	0.03	360 U	1.5	330 U	1.3	40000 U	200	1800 U	7.4	140000 U	570
Chlorobenzene	5	112.6	8 U	0.04	360 U	1.7	330 U	1.5	40000 U	200	1800 U	8.3	140000 U	640
Ethylbenzene	5	106.2	2 J	0.01	2800 J	12	1300	5.6	40000 U	200	3000	10	140000 U	610
m,p-Xylene	5	106.2	4 J	0.02	5600 J	24	750	3.3	40000 U	200	5600	24	140000 U	610
o-Xylene	5	106.2	2 J	0.01	1500 J	6.5	160 J	0.69	40000 U	200	1000 J	4	140000 U	610
Styrene	5	104.2	8 U	0.03	1100 J	4.7	250 J	1.1	40000 U	200	1800 U	7.7	140000 U	600
Bromoform	5	252.8	8 U	0.08	360 U	3.7	330 U	3.4	40000 U	400	230 J	2.4	140000 U	1400
1,1,2,2-Tetrachloroethane	5	167.9	8 U	0.06	360 U	2.5	330 U	2.3	40000 U	300	1800 U	12	140000 U	960
1,3,5-Trimethylbenzene	5	120.2	0.6 J	0.003	310 J	1.5	61 AJ	0.30	870 J	4.3	150 J	0.74	140000 U	690
1,2,4-Trimethylbenzene	5	120.2	1 J	0.005	470 J	2.3	160 J	0.78	40000 U	200	220 J	1.1	140000 U	690
1,3-Dichlorobenzene	5	147	8 U	0.05	360 U	2.2	330 U	2.0	40000 U	200	1800 U	11	140000 U	840

Volatile Analysis of SUMMA Canisters
(ppbv)

SITE: ROSE HILL REGIONAL LANDFILL
SAS NO.: 7165A SDG NO.: SA1401

TRAFFIC REPORT NUMBER:			SA1401		SA1402		SA1403		SA1404		SA1405		SA1406	
M&E SAMPLE ID:			SG-SS(08+000)-12		SG-BW(04+100)-06		SG-BW(05+500)-12		SG-SW(13+300)-12		SG-SW(11+500)-05		SG-SWD(13+300)-12	
COMPOUND	CRQL	MW		mg/m3		mg/m3		mg/m3		mg/m3		mg/m3		mg/m3
1,4-Dichlorobenzene	5	147	8 U	0.05	360 U	2.2	330 U	2.0	40000 U	200	1800 U	11	140000 U	840
Benzyl Chloride	5	126.6	8 U	0.04	360 U	1.9	330 U	1.7	40000 U	200	1800 U	9.3	140000 U	720
1,2-Dichlorobenzene	5	147	8 U	0.05	360 U	2.2	330 U	2.0	40000 U	200	1800 U	11	140000 U	840
1,2,4-Trichlorobenzene	5	181.5	8 U	0.06	360 U	2.7	37 J	0.27	40000 U	300	1800 U	13	140000 U	1000
Hexachlorbutadiene	5	260.8	8 U	0.09	360 U	3.8	29 J	0.31	40000 U	400	1800 U	19	140000 U	1500

DILUTION FACTOR:	1.642110	73.12241	66	7887.555	357.7192	28219.79
RECEIPT PRESSURE (in Hg):	5.5	2.5	2	4.5	7.5	1.5
FINAL PRESSURE (psi):	5	5	5	5	5	5
SAMPLE VOLUME:	1000	20	25	0.2	5	0.05
DATE SAMPLED:	05/07/92	05/08/92	05/11/92	05/12/92	05/12/92	05/12/92
DATE ANALYZED:	05/20/92	05/20/92	05/21/92	05/20/92	05/21/92	05/22/92
REMARKS:						

Footnotes:

CRQL - Contract Required Quantitation Limits.
J - Quantitation is approximate due to limitations identified in the quality control review .
U - Value reported is the sample detection limit.
R - Value is rejected.
UJ - Sample detection limit is approximate due to limitations identified in the quality control review.
D - Quantitation is from a diluted sample result.
DJ - Quantitation is from a diluted sample result, but should be considered estimated due to limitations identified in the quality control review.
A - Quantitation is the average of two diluted analysis results.
AJ - Quantitation is the average of two diluted analysis results, but should be considered estimated due to limitations identified in the quality control review.

SITE: ROSE HILL REGIONAL LANDFILL
SAS NO.: 7165A SDG NO.: SA1

TRAFFIC REPORT NUMBER:			SA1407		SA1408	
M&E SAMPLE ID:			SG-SW(03+300)-06		SG-EB(05-011)-0	
COMPOUND	CRQL	MW		mg/m3		mg/m3
Dichlorodifluromethane	5	120.9	210	1.0	0.3 J	0.001
Freon 114	5	170.9	160 U	1.1	6 U	0.04
Chloromethane	5	50.5	160 UJ	0.33	6 U	0.01
Vinyl Chloride	5	62.5	1200	3.1	6 U	0.02
Bromomethane	5	95	160 U	0.62	6 U	0.02
Chloroethane	5	64.5	450	1.2	6 U	0.02
Trichlorofluoromethane	5	137.4	32 J	0.18	0.1 J	0.0006
1,1-Dichloroethene	5	97	10 J	0.04	6 U	0.02
Carbon Disulfide	5	76.1	38 J	0.12	6 U	0.02
Freon 113	5	187.4	160 U	1.2	0.3 J	0.002
Acetone	5	58.1	160 U	0.38	6 U	0.01
Methylene Chloride	5	84.9	200	0.7	6 U	0.02
trans-1,2-Dichloroethene	5	97	22 J	0.087	6 U	0.02
1,1-Dichloroethane	5	99	53 J	0.21	6 U	0.02
cis-1,2-Dichloroethene	5	97	380	1.5	0.4 J	0.002
2-Butanone	5	72.1	160 U	0.47	6 U	0.02
Chloroform	5	119.4	160 U	0.78	6 U	0.03
1,1,1-Trichloroethane	5	133.4	160 U	0.87	0.2 J	0.001
Carbon Tetrachloride	5	153.8	160 U	1.0	6 U	0.04
Benzene	5	78.1	820	2.6	6 U	0.02
1,2-Dichloroethane	5	99	160 U	0.65	6 U	0.02
Trichloroethene	5	131.4	84 J	0.45	6 U	0.03
1,2-Dichloropropane	5	113	160 U	0.74	6 U	0.03
Bromodichloromethane	5	163.9	160 U	1.1	6 U	0.04
2-Chloroethyl Vinyl Ether	5	106.6	160 U	0.70	6 U	0.03
cis-1,3-Dichloropropene	5	111	160 U	0.72	6 U	0.03
4-Methyl-2-pentanone	5	100.2	160 U	0.65	6 U	0.02
Toluene	5	92.1	5500 A	21	0.6 J	0.002
trans-1,3-Dichloropropene	5	111	160 U	0.72	6 U	0.03
1,1,2-Trichloroethane	5	133.4	160 U	0.87	6 U	0.03
Tetrachloroethene	5	165.8	84 J	0.57	0.1 J	0.0007
Dibromochloromethane	5	208.3	160 U	1.4	6 U	0.05
1,2-Dibromomethane	5	173.9	160 U	1.1	6 U	0.04
2-Hexanone	5	100.2	160 U	0.65	6 U	0.02
Chlorobenzene	5	112.6	160 U	0.74	6 U	0.03
Ethylbenzene	5	106.2	5800 A	25	6 U	0.03
m,p-Xylene	5	106.2	9400 A	41	6 U	0.03
o-Xylene	5	106.2	2500 A	11	6 U	0.03
Styrene	5	104.2	160 U	0.68	6 U	0.03
Bromoform	5	252.8	160 U	1.7	6 U	0.06
1,1,2,2-Tetrachloroethane	5	167.9	160 U	1.1	6 U	0.04
1,3,5-Trimethylbenzene	5	120.2	210	1.0	6 U	0.03
1,2,4-Trimethylbenzene	5	120.2	500	2	6 U	0.03
1,3-Dichlorobenzene	5	147	160 U	0.96	6 U	0.04

SITE: ROSE HILL REGIONAL LANDFILL
SAS NO.: 7165A SDG NO.: SA1

TRAFFIC REPORT NUMBER:			SA1407		SA1408	
M&E SAMPLE ID:			SG-SW(03+300)-06		SG-EB(05-011)-0	
COMPOUND	CRQL	MW		mg/m3		mg/m3
1,4-Dichlorobenzene	5	147	72 J	0.43	6 U	0.04
Benzyl Chloride	5	126.6	160 U	0.83	6 U	0.03
1,2-Dichlorobenzene	5	147	160 U	0.96	6 U	0.04
1,2,4-Trichlorobenzene	5	181.5	160 U	1.2	6 U	0.04
Hexachlorbutadiene	5	260.8	160 U	1.7	6 U	0.06

DILUTION FACTOR:	32.18325	1.304736
RECEIPT PRESSURE (in Hg):	5	-0.81442
FINAL PRESSURE (psi):	5	5
SAMPLE VOLUME:	50	1000
DATE SAMPLED:	05/13/92	05/11/92
DATE ANALYZED:	05/22/92	05/20/92
REMARKS:		

Footnotes:

- CRQL - Contract Required Quantitation Limits.
- J - Quantitation is approximate due to limitations identified in the quality control review
- U - Value reported is the sample detection limit.
- R - Value is rejected.
- UJ - Sample detection limit is approximate due to limitations identified in the quality control review.
- D - Quantitation is from a diluted result.
- DJ - Quantitation is from a diluted result, but should be consider estimated due to limitations identified in the quality control review.
- A - Quantitation is the average of diluted analysis results.
- AJ - Quantitation is the average of diluted analysis results, but considered estimated due to li identified in the quality cont

The FS Solid Waste Area was drawn onto the modeling grid from previous efforts (M&E, 1993) and area source squares were drawn to cover the area. See Attachment A for the numbered squares.

Historically, the source-to-receptor distance for area sources was required to be greater than the length of one side of a respective area source square to have valid results. With ISCST3, this is not the case. Attachment B is text from the User's Guide for ISC3 which describes that the only restriction is that sources with side length less than 3 meters should be used with caution near receptors. In the Rose Hill case, the smallest receptor has a length of 15 meters, so this does not apply.

Grid squares on Attachment A are 50 ft on each side = 15.2 m

Input for model (all values in meters)

	Southwest Corner			Values are the X, Y coords. times square length			
Square	X	Y	Length	X	Y	Length	Area (m^2)
1	8	35	7	121.92	533.40	106.68	11,381
2	15	35	6	228.60	533.40	91.44	8,361
3	9	30	5	137.16	457.20	76.20	5,806
4	14	32	3	213.36	487.68	45.72	2,090
5	17	32	3	259.08	487.68	45.72	2,090
6	20	33	2	304.80	502.92	30.48	929
7	20	32	1	304.80	487.68	15.24	232
8	21	32	1	320.04	487.68	15.24	232
9	14	31	1	213.36	472.44	15.24	232
10	14	30	1	213.36	457.20	15.24	232
11	15	25	7	228.60	381.00	106.68	11,381
12	10	25	5	152.40	381.00	76.20	5,806
13	11	22	3	167.64	335.28	45.72	2,090
14	14	22	3	213.36	335.28	45.72	2,090
15	17	23	2	259.08	350.52	30.48	929
16	22	25	2	335.28	381.00	30.48	929
17	19	19	6	289.56	289.56	91.44	8,361
18	17	21	2	259.08	320.04	30.48	929
19	12	17	5	182.88	259.08	76.20	5,806
20	17	19	2	259.08	289.56	30.48	929
21	17	17	2	259.08	259.08	30.48	929
22	19	14	5	289.56	213.36	76.20	5,806
23	13	14	3	198.12	213.36	45.72	2,090
24	16	14	3	243.84	213.36	45.72	2,090
25	14	12	2	213.36	182.88	30.48	929
26	16	9	5	243.84	137.16	76.20	5,806
27	21	11	3	320.04	167.64	45.72	2,090
						Total ->	90,580 m^2

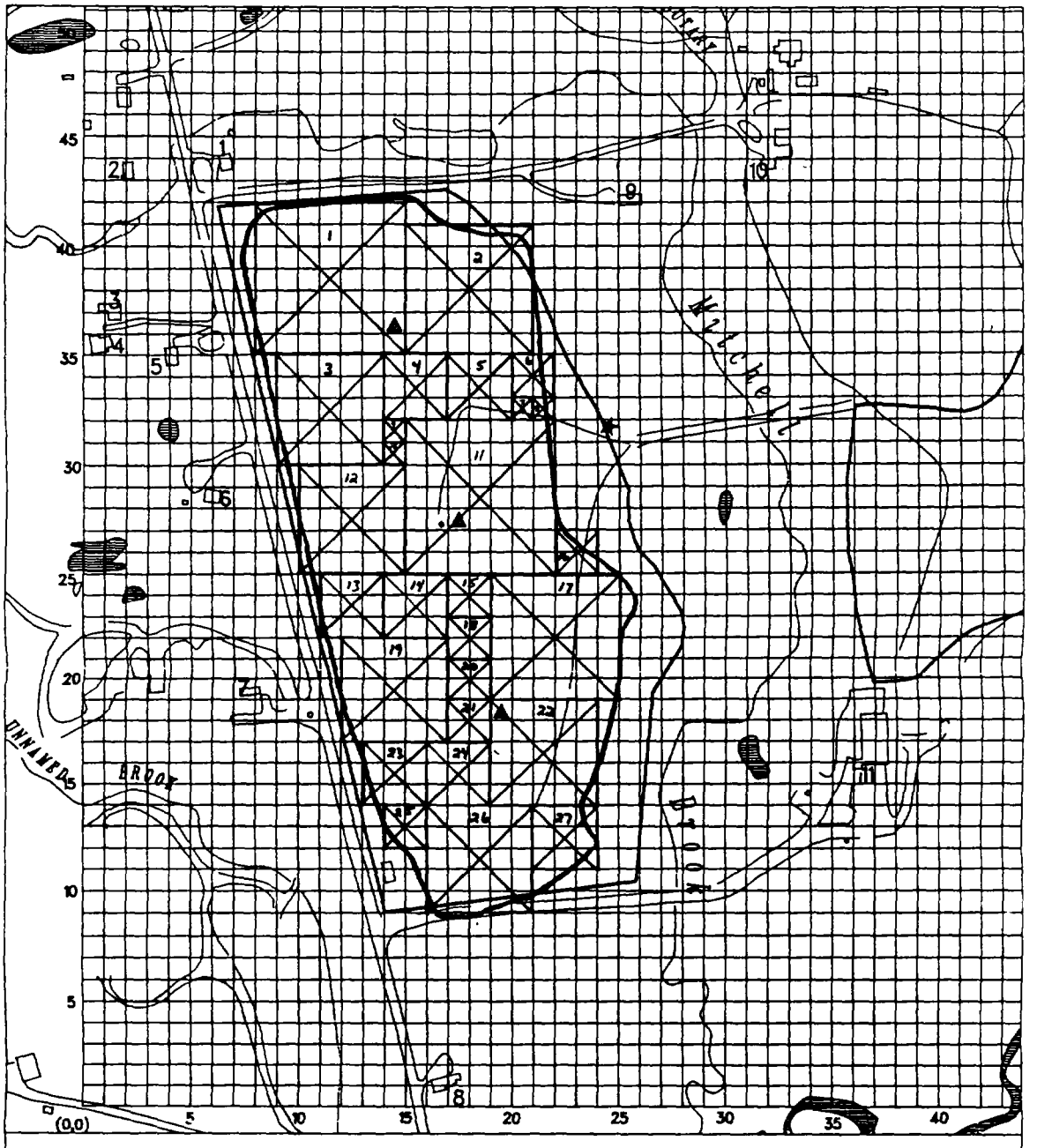
Emission Rate (g / m^2-s) to be used in model

Landfill Gas Production	=	0.0282	m^3 / s	See Attachment C
Landfill Area	=	90,580	m^2	See Total Above

Vinyl chloride is expected to be the most significant contaminant in the air, so modeling will be based on its conc.

Contaminant Concentration		3,100,000	$\mu g / m^3$	From SUMMA.WK1
	=	3	g / m^3	
Contaminant Emission Rate	=	9.65E-07	g / m^2-s	Conc. * Rate / Area

METCALF & EDDY



Primary Road

Secondary Road

Stream or Brook

Landfill Area

Lake, Pond, or River

Stack Location: System 1

Stack Location: Systems 2&3

Residential Receptor

Receptor 11 is Non-Residential: Transfer Station

SCALE IN FEET

250 0 100 250

FIGURE C-1

AIR DISPERSION MODEL GRID AND RESIDENTIAL RECEPTOR LOCATIONS

ROSE HILL LANDFILL

SOUTH KINGSTOWN, RI

METCALF & EDDY

ATTACHMENT A

1 block = 1521 m (50 ft)

Q_A = area source emission rate (mass per unit area per unit time)

K = units scaling coefficient (Equation (1-1))

V = vertical term (see Section 1.1.6)

D = decay term as a function of x (see Section 1.1.7)

The Vertical Term is given by Equation (1-50) or Equation (1-54) with the effective emission height, h_e, being the physical release height assigned by the user. In general, h_e should be set equal to the physical height of the source of emissions above local terrain height. For example, the emission height h_e of a slag dump is the physical height of the slag dump.

Since the ISCST algorithm estimates the integral over the area upwind of the receptor location, receptors may be located within the area itself, downwind of the area, or adjacent to the area. However, since σ_z goes to 0 as the downwind distance goes to 0 (see Section 1.1.5.1), the plume function is infinite for a downwind receptor distance of 0. To avoid this singularity in evaluating the plume function, the model arbitrarily sets the plume function to 0 when the receptor distance is less than 1 meter. As a result, the area source algorithm will not provide reliable results for receptors located within or adjacent to very small areas, with dimensions on the order of a few meters across. In these cases, the receptor should be placed at least 1 meter outside of the area.

SOURCE: "USER'S GUIDE FOR THE INDUSTRIAL SOURCE COMPLEX (ISC3) DISPERSION MODELS, VOLUME II - DESCRIPTION OF MODEL ALGORITHMS," EPA-454/B-95-003b, USEPA, Office of Air Quality Planning and Standards, Emissions, Monitoring, and Analysis Division, Research Triangle Park, North Carolina, September 1995.

ATTACHMENT C

ROSE HILL SOLID WASTE AREA
GAS GENERATION RATE CALCULATION
METHOD 1: SCHOLL CANYON FIRST ORDER KINETIC MODEL

VERSION: SEP-08-98
Checked by: Sean Czarniecki 08/26/96

FORMULA:

$$Q = 2 \cdot [k \cdot L \cdot R \{\exp(-k \cdot (t-lag))\}]$$

[Source: Methane Generation & Recovery from Landfills, Emcon Associates, 1982]

Incorporates: New Stationary Source Performance Standards for Municipal Solid Waste LFs FR 9905, Vol. 61, No. 49, March 12, 1996

(Formula is multiplied by 2 since it is for methane generation and CH_4 is assumed to be 50% of LFG)

WHERE:

Q = landfill gas generation rate @ time t (ft^3 LFG / yr)
L = potential methane gas generation capacity of refuse (ft^3 CH_4 / ton)
R = annual refuse acceptance rate in landfill (tons)
k = methane production rate (1 / yr)
t = time since refuse placement (yr)
lag = time to reach conditions suitable for methane production (yr)

INPUT PARAMETERS:

					tons MSW
L =	3,204	Year closed =	1982	Avg. refuse 1967-1970:	18,667
k =	0.04	Current year =	1997	Avg. refuse 1971-1975:	10,889
lag =	2	Time since closure =	15	Avg. refuse 1976-1977:	24,000
				Avg. refuse 1978-1982:	20,400

L and k are EPA AP-42 default values (9/97).

YEAR	TIME SINCE REFUSE PLACEMENT	GENERATION RATE 1997
1968	29	1.62E+06
1969	28	1.69E+06
1970	27	1.76E+06
1971	26	1.07E+06
1972	25	1.11E+06
1973	24	1.16E+06
1974	23	1.21E+06
1975	22	1.25E+06
1976	21	2.88E+06
1977	20	2.99E+06
1978	19	2.65E+06
1979	18	2.76E+06
1980	17	2.87E+06
1981	16	2.99E+06
1982	15	3.11E+06
1983	-	0.00E+00
1984	-	0.00E+00
1985	-	0.00E+00
1986	-	0.00E+00
1987	-	0.00E+00
1988	-	0.00E+00
1989	-	0.00E+00
1990	-	0.00E+00
1991	-	0.00E+00
1992	-	0.00E+00
1993	-	0.00E+00
TOTAL 1997 LF GAS PRODUCTION		**3.11E+07** ft³ LFG / yr
		2.79E+04 cm³ LFG / s

Total MSW disposed (tons)	279,113
Total MSW disposed (Mg)	253,164

This area determines the contribution towards the 1997 LFG generation rate. No refuse was placed after 1982, so there is no contribution from waste placed after that date.

ROSE HILL SOLID WASTE AREA
GAS GENERATION RATE CALCULATION
METHOD 1: SCHOLL CANYON FIRST ORDER KINETIC MODEL (continued)

TOTAL ANNUAL LFG PRODUCTION OVER TIME: ESTIMATED PROJECTIONS

Year	Estimated Annual LFG Production (ft^3 / yr)	Time Since Landfill Closure (years)
1997	3.11E+07	15
1998	2.99E+07	16
1999	2.87E+07	17
2000	2.76E+07	18
2001	2.65E+07	19
2002	2.55E+07	20
2003	2.45E+07	21
2004	2.35E+07	22
2005	2.26E+07	23
2006	2.17E+07	24
2007	2.09E+07	25
2008	2.00E+07	26
2009	1.93E+07	27
2010	1.85E+07	28
2011	1.78E+07	29
2012	1.71E+07	30

Confirmation modeling utilizing EPA's Landfill Air Emission Estimation model is attached. Note that the model printout is for methane only, which is assumed to be 50% of the LFG flow.

The model output shows		4.444E+05	m^3 CH_4 / yr
	=	888,800	m^3 LFG / yr
	=	0.0282	m^3 LFG / s
	=	60	ft^3 / min

RECEPTOR.WK1

From a previous modeling effort (6/95), residential receptors and road/driveway receptors were designated. See Attachment A for these locations on the modeling grid.

RECEPTOR LOCATIONS:

Grid squares on Attachment A are 50 ft on each side = 15.24 m

Receptor #	X	Y	Input for model (all values in meters) Values are the X, Y coords. times square length X	Y
1	6.5	44	99.06	670.56
2	2	43.5	30.48	662.94
3	1.5	37	22.86	563.88
4	1	35.5	15.24	541.02
5	4	35	60.96	533.40
6	6	28.5	91.44	434.34
7	8	19.5	121.92	297.18
8	17	1	259.08	15.24
9	25.5	42	388.62	640.08
10	32	44	487.68	670.56
11	37	16	563.88	243.84
12	16	43	243.84	655.32
13	11	18	167.64	274.32
14	7.5	42.5	114.30	647.70
15	6	39	91.44	594.36
16	15	8.5	228.60	129.54
17	24	9.5	365.76	144.78

Metcalf & Eddy, Inc.

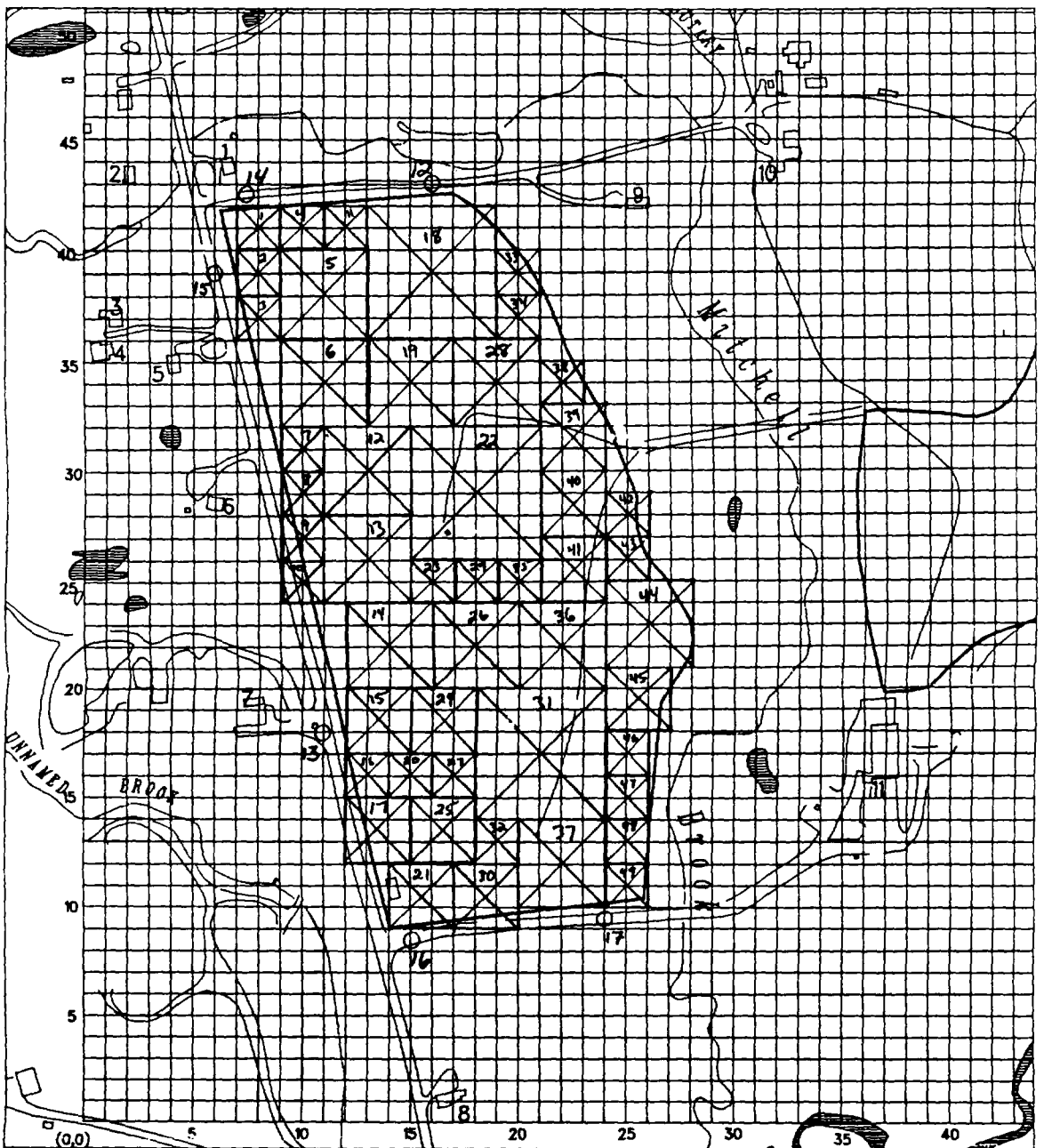


FIGURE 1

AIR DISPERSION MODEL GRID AND RESIDENTIAL RECEPTOR LOCATIONS

ROSE HILL LANDFILL
SOUTH KINGSTOWN, RI

METCALF & EDDY

ATTACHMENT A
(Ignore green Source Squares)

RESULTS.XLS

The most recent meteorological data available on EPA's SCRAM electronic bulletin board for the Rose Hill Regional Landfill area was 1991. Surface data utilized was from the NOAA weather station at T.F. Green Airport in Providence, Rhode Island (#14765). Mixing height data utilized was from the weather station located in Chatham, Massachusetts (#14684), the closest station with mixing height data.

ISCST3 model runs were performed for the years 1987, 1988, 1989, 1990 and 1991 to determine maximum residential receptor concentration impacts resulting from Solid Waste Area landfill gas emissions. All runs were performed with the landfill assumed to be at the same elevation as the receptors (worst case). Runs were previously performed for 1989 and 1991 with the landfill elevation at 5.2 meters above the receptors (average landfill height is approximately 17 feet above the surrounding area as shown on topographic maps) to show the difference between emissions from two different elevations. (Attachment A presents printout of this previous comparison - RESULTS.WK1)

A contaminant emission rate of 9.65E-07 g/m^2-s was used in the model (based on a vinyl chloride concentration of 3,100,000 μg/m^3).

Year ->	1987	1988	1989	1990	1991
Landfill El. (m)	0	0	0	0	0
Receptor #	Modeled Concentration Based on Input of 3,100,000 μg/m^3				
1	1.18274	1.01664	1.11362	1.11036	0.84685
2	0.48215	0.39095	0.47060	0.48857	0.37695
3	0.51002	0.37796	0.52734	0.54254	0.52044
4	0.49541	0.36091	0.51535	0.52779	0.51832
5	0.89999	0.65198	0.91694	0.89877	0.87818
6	1.36069	0.95517	1.37748	1.28185	1.34315
7	1.45974	0.99421	1.47472	1.31336	1.52731
8	0.94580	0.73515	0.92235	0.72892	1.22047
9	1.83921	2.20794	2.32251	2.11477	2.28048
10	0.88957	1.09845	1.17092	1.09215	1.20564
11	1.28599	1.27340	1.17447	1.00780	1.19530
12	4.03348	4.76560	4.71441	4.33641	4.09869
13	2.74421	1.93525	2.75699	2.43532	2.87956
14	1.91128	1.69453	1.82733	1.82066	1.41111
15	1.36114	1.03096	1.34383	1.33599	1.21357
16	2.43769	1.78383	2.41769	1.98520	2.73802
17	4.00672	3.56231	3.52152	2.99579	4.04960

Notes:

Outlined values are maximum modeled concentrations for respective receptors.

Receptors #1 through 11 are nearby residences and the transfer station.

Receptors #12 through 17 are locations on roadways and driveways along the landfill perimeter.

Attachment B presents an example of model input/output. Attachment C presents receptor output for all runs.

Conclusions:

Ground 0 results were all higher than the release height of 5.2 meters.

Maximum modeled concentrations out of the five years will be used to determine contaminant concentrations at respective receptors.

METCALF & EDDY

ATTACHMENT A

Project	Rose Hill FS	Acct. No.	4609-18-10-11	Page 1	of 1
Subject	Air Modeling	Comptd. By	S. Czarniecki	Date	08/14/96
Detail	Model Runs Performed & Results	Ck'd. By	R. Porter	Date	08/26/96

C:\RH\AIR\ISCST3\RESULTS.WK1

RESULTS.WK1

The most recent meteorological data available on EPA's SCRAM electronic bulletin board for the Rose Hill Regional Landfill area was 1991. Surface data utilized was from the NOAA weather station at T.F. Green Airport in Providence, Rhode Island (#14765). Mixing height data utilized was from the weather station located in Chatham, Massachusetts (#14684), the closest station with mixing height data.

ISCST3 model runs were performed for the years 1987, 1988, 1989, 1990 and 1991 to determine maximum residential receptor concentration impacts resulting from Solid Waste Area landfill gas emissions. All runs were performed with the landfill assumed to be at the same elevation as the receptors (worst case). Runs were also performed in 1989 and 1991 with the landfill elevation at 5.2 meters above the receptors (average landfill height is approximately 17 feet above the surrounding area as shown on topographic maps) to show the difference between emissions from two different elevations.

A contaminant emission rate of 1.77E−09 g/m^2−s was used in the model (based on a vinyl chloride concentration of 3,100 μg/m^3) rather than the 1.77E−06 g/m^2−s calculated in SOLGRID.WK1. This does not change the way model results are applied proportionally to all of the contaminants of concern.

Metcalf & Eddy, Inc.

Year ->	1987	1988	1989	1989	1990	1991	1991
Landfill El. (m)	0	0	0	5.2	0	0	5.2
Receptor #	Modeled Concentration Based on Input of 3,100 μg/m^3						
1	0.00217	0.00186	0.00204	0.00128	0.00204	0.00155	0.00098
2	0.00088	0.00072	0.00086	0.00069	0.00090	0.00069	0.00054
3	0.00094	0.00069	0.00097	0.00073	0.00100	0.00095	0.00068
4	0.00091	0.00066	0.00095	0.00072	0.00097	0.00095	0.00069
5	0.00165	0.00120	0.00168	0.00109	0.00165	0.00161	0.00099
6	0.00250	0.00175	0.00253	0.00157	0.00235	0.00246	0.00144
7	0.00268	0.00182	0.00270	0.00175	0.00241	0.00280	0.00171
8	0.00173	0.00135	0.00169	0.00132	0.00134	0.00224	0.00153
9	0.00337	0.00405	0.00426	0.00268	0.00388	0.00418	0.00254
10	0.00163	0.00201	0.00215	0.00171	0.00200	0.00221	0.00174
11	0.00236	0.00234	0.00215	0.00172	0.00185	0.00219	0.00171
12	0.00740	0.00874	0.00865	0.00313	0.00795	0.00752	0.00260
13	0.00503	0.00355	0.00506	0.00221	0.00447	0.00528	0.00220
14	0.00351	0.00311	0.00335	0.00148	0.00334	0.00259	0.00116
15	0.00250	0.00189	0.00246	0.00123	0.00245	0.00223	0.00103
16	0.00447	0.00327	0.00443	0.00213	0.00364	0.00502	0.00226
17	0.00735	0.00653	0.00646	0.00250	0.00549	0.00743	0.00279

Notes:
Outlined values are maximum modeled concentrations for respective receptors.
Receptors #1 through 11 are nearby residences and the transfer station.
Receptors #12 through 17 are locations on roadways and driveways along the landfill perimeter.
Attachment A presents an example of model input/output. Attachment B presents receptor output for all runs.

Conclusions:
Ground 0 results were all higher than the release height of 5.2 meters.
Maximum modeled concentrations out of the five years will be used to determine contaminant concentrations at respective receptors.

ATTACHMENT B

```
** Rosehill - ISCST3
** Area emissions from the Solid Waste Area
** Ground 0 (Landfill assumed same level as receptors - worst case)
** 1991 data
** 1997 LFG Emissions Check
** Vinyl chloride emissions (Concentration = 3,100,000 ug/m^3)

CO STARTING
   TITLEONE  ROSEHILL - SOLID WASTE AREA EMISSIONS - ISCST3
   MODELOPT  DFAULT  CONC  RURAL
   AVERTIME  PERIOD
   TERRHGTS  FLAT
   POLLUTID  UNIT
   RUNORNOT  RUN
CO FINISHED

SO STARTING

**  SOLID WASTE AREA (FS Version - 8/96)
**  x, y, and z coordinates, respectively (m)

SO LOCATION     SQUARE1     AREA        121.92    533.40        0.
SO LOCATION     SQUARE2     AREA        228.60    533.40        0.
SO LOCATION     SQUARE3     AREA        137.16    457.20        0.
SO LOCATION     SQUARE4     AREA        213.36    487.68        0.
SO LOCATION     SQUARE5     AREA        259.08    487.68        0.
SO LOCATION     SQUARE6     AREA        304.80    502.92        0.
SO LOCATION     SQUARE7     AREA        304.80    487.68        0.
SO LOCATION     SQUARE8     AREA        320.04    487.68        0.
SO LOCATION     SQUARE9     AREA        213.36    472.44        0.
SO LOCATION     SQUARE10    AREA        213.36    457.20        0.
SO LOCATION     SQUARE11    AREA        228.60    381.00        0.
SO LOCATION     SQUARE12    AREA        152.40    381.00        0.
SO LOCATION     SQUARE13    AREA        167.64    335.28        0.
SO LOCATION     SQUARE14    AREA        213.36    335.28        0.
SO LOCATION     SQUARE15    AREA        259.08    350.52        0.
SO LOCATION     SQUARE16    AREA        335.28    381.00        0.
SO LOCATION     SQUARE17    AREA        289.56    289.56        0.
SO LOCATION     SQUARE18    AREA        259.08    320.04        0.
SO LOCATION     SQUARE19    AREA        182.88    259.08        0.
SO LOCATION     SQUARE20    AREA        259.08    289.56        0.
SO LOCATION     SQUARE21    AREA        259.08    259.08        0.
SO LOCATION     SQUARE22    AREA        289.56    213.36        0.
SO LOCATION     SQUARE23    AREA        198.12    213.36        0.
SO LOCATION     SQUARE24    AREA        243.84    213.36        0.
SO LOCATION     SQUARE25    AREA        213.36    182.88        0.
SO LOCATION     SQUARE26    AREA        243.84    137.16        0.
SO LOCATION     SQUARE27    AREA        320.04    167.64        0.

**  Emission rate (g/m^2-s), release height (m), length of square (m)

SO SRCPARAM     SQUARE1     9.65E-07     0.0     106.68
SO SRCPARAM     SQUARE2     9.65E-07     0.0      91.44
SO SRCPARAM     SQUARE3     9.65E-07     0.0      76.20
SO SRCPARAM     SQUARE4     9.65E-07     0.0      45.72
SO SRCPARAM     SQUARE5     9.65E-07     0.0      45.72
SO SRCPARAM     SQUARE6     9.65E-07     0.0      30.48
SO SRCPARAM     SQUARE7     9.65E-07     0.0      15.24
SO SRCPARAM     SQUARE8     9.65E-07     0.0      15.24
SO SRCPARAM     SQUARE9     9.65E-07     0.0      15.24
SO SRCPARAM     SQUARE10    9.65E-07     0.0      15.24
SO SRCPARAM     SQUARE11    9.65E-07     0.0     106.68
SO SRCPARAM     SQUARE12    9.65E-07     0.0      76.20
SO SRCPARAM     SQUARE13    9.65E-07     0.0      45.72
SO SRCPARAM     SQUARE14    9.65E-07     0.0      45.72
SO SRCPARAM     SQUARE15    9.65E-07     0.0      30.48
SO SRCPARAM     SQUARE16    9.65E-07     0.0      30.48
SO SRCPARAM     SQUARE17    9.65E-07     0.0      91.44
SO SRCPARAM     SQUARE18    9.65E-07     0.0      30.48
SO SRCPARAM     SQUARE19    9.65E-07     0.0      76.20
SO SRCPARAM     SQUARE20    9.65E-07     0.0      30.48
SO SRCPARAM     SQUARE21    9.65E-07     0.0      30.48
SO SRCPARAM     SQUARE22    9.65E-07     0.0      76.20
SO SRCPARAM     SQUARE23    9.65E-07     0.0      45.72
SO SRCPARAM     SQUARE24    9.65E-07     0.0      45.72
SO SRCPARAM     SQUARE25    9.65E-07     0.0      30.48
SO SRCPARAM     SQUARE26    9.65E-07     0.0      76.20
SO SRCPARAM     SQUARE27    9.65E-07     0.0      45.72

SO SRCGROUP ALL
SO FINISHED

RE STARTING
**  Discreet Receptors
**  x, y coordinates (m)

** Receptor #1
RE DISCCART         99.06     670.56
** Receptor #2
RE DISCCART         30.48     662.94
** Receptor #3
RE DISCCART         22.86     563.88
** Receptor #4
```

```
RE DISCCART          15.24     541.02
** Receptor #5
RE DISCCART          60.96     533.40
** Receptor #6
RE DISCCART          91.44     434.34
** Receptor #7
r    SCCART         121.92     297.18
     :eptor #8
R  iSCCART          259.08      15.24
** Receptor #9
RE DISCCART         388.62     640.08
** Receptor #10
RE DISCCART         487.68     670.56
** Receptor #11
RE DISCCART         563.88     243.84
** Receptor #12
RE DISCCART         243.84     655.32
** Receptor #13
RE DISCCART         167.64     274.32
** Receptor #14
RE DISCCART         114.30     647.70
** Receptor #15
RE DISCCART          91.44     594.36
** Receptor #16
RE DISCCART         228.60     129.54
** Receptor #17
RE DISCCART         365.76     144.78

RE FINISHED


ME STARTING

** 1991
   INPUTFIL  lprov91.bin  unform
   ANEMHGHT  20. FEET
** SURFACE DATA FROM 1991 at Providence was utilized. MIXING FROM CHATHAM.
   SURFDATA  14765  1991  SURFNAME
   UAIRDATA  14684  1991  UAIRNAME

ME FINISHED

OU STARTING
   RECTABLE  ALLAVE FIRST
OU FINISHED

    ******************************
    SETUP Finishes Successfully ***
**********************************
```

**MODELOPTs: CONC RURAL FLAT DFAULT

*** MODEL SETUP OPTIONS SUMMARY ***

- -

**Intermediate Terrain Processing is Selected

**Model Is Setup For Calculation of Average CONCentration Values.

-- SCAVENGING/DEPOSITION LOGIC --
**Model Uses NO DRY DEPLETION. DDPLETE = F
**Model Uses NO WET DEPLETION. WDPLETE = F
**NO WET SCAVENGING Data Provided.
**Model Does NOT Use GRIDDED TERRAIN Data for Depletion Calculations

**Model Uses RURAL Dispersion.

**Model Uses Regulatory DEFAULT Options:
1. Final Plume Rise.
2. Stack-tip Downwash.
3. Buoyancy-induced Dispersion.
4. Use Calms Processing Routine.
5. Not Use Missing Data Processing Routine.
6. Default Wind Profile Exponents.
7. Default Vertical Potential Temperature Gradients.
8. "Upper Bound" Values for Supersquat Buildings.
9. No Exponential Decay for RURAL Mode

**Model Assumes Receptors on FLAT Terrain.

**Model Assumes No FLAGPOLE Receptor Heights.

**Model Calculates PERIOD Averages Only

**This Run Includes: 27 Source(s); 1 Source Group(s); and 17 Receptor(s)

**The Model Assumes A Pollutant Type of: UNIT

**Model Set To Continue RUNning After the Setup Testing.

**Output Options Selected:
Model Outputs Tables of PERIOD Averages by Receptor
Model Outputs Tables of Highest Short Term Values by Receptor (RECTABLE Keyword)

**NOTE: The Following Flags May Appear Following CONC Values: c for Calm Hours
m for Missing Hours
b for Both Calm and Missing Hours

**Misc. Inputs: Anem. Hgt. (m) = 6.10 ; Decay Coef. = 0.0000 ; Rot. Angle = 0.0
Emission Units = GRAMS/SEC ; Emission Rate Unit Factor = 0.10000E+07
Output Units = MICROGRAMS/M**3

**Input Runstream File: rhfs31.inp ; **Output Print File: rhfs31.out

**MODELOPTs: CONC RURAL FLAT DFAULT

*** AREA SOURCE DATA ***

SOURCE ID	NUMBER PART. CATS.	EMISSION RATE (GRAMS/SEC /METER**2)	COORD (SW CORNER) X (METERS)	Y (METERS)	BASE ELEV. (METERS)	RELEASE HEIGHT (METERS)	X-DIM OF AREA (METERS)	Y-DIM OF AREA (METERS)	ORIENT. OF AREA (DEG.)	INIT. SZ (METERS)	EMISSION RATE SCALAR VARY BY
SQUARE1	0	0.96500E-06	121.9	533.4	0.0	0.00	106.68	106.68	0.00	0.00	
SQUARE2	0	0.96500E-06	228.6	533.4	0.0	0.00	91.44	91.44	0.00	0.00	
SQUARE3	0	0.96500E-06	137.2	457.2	0.0	0.00	76.20	76.20	0.00	0.00	
SQUARE4	0	0.96500E-06	213.4	487.7	0.0	0.00	45.72	45.72	0.00	0.00	
SQUARE5	0	0.96500E-06	259.1	487.7	0.0	0.00	45.72	45.72	0.00	0.00	
SQUARE6	0	0.96500E-06	304.8	502.9	0.0	0.00	30.48	30.48	0.00	0.00	
SQUARE7	0	0.96500E-06	304.8	487.7	0.0	0.00	15.24	15.24	0.00	0.00	
SQUARE8	0	0.96500E-06	320.0	487.7	0.0	0.00	15.24	15.24	0.00	0.00	
SQUARE9	0	0.96500E-06	213.4	472.4	0.0	0.00	15.24	15.24	0.00	0.00	
SQUARE10	0	0.96500E-06	213.4	457.2	0.0	0.00	15.24	15.24	0.00	0.00	
SQUARE11	0	0.96500E-06	228.6	381.0	0.0	0.00	106.68	106.68	0.00	0.00	
SQUARE12	0	0.96500E-06	152.4	381.0	0.0	0.00	76.20	76.20	0.00	0.00	
SQUARE13	0	0.96500E-06	167.6	335.3	0.0	0.00	45.72	45.72	0.00	0.00	
SQUARE14	0	0.96500E-06	213.4	335.3	0.0	0.00	45.72	45.72	0.00	0.00	
SQUARE15	0	0.96500E-06	259.1	350.5	0.0	0.00	30.48	30.48	0.00	0.00	
SQUARE16	0	0.96500E-06	335.3	381.0	0.0	0.00	30.48	30.48	0.00	0.00	
SQUARE17	0	0.96500E-06	289.6	289.6	0.0	0.00	91.44	91.44	0.00	0.00	
SQUARE18	0	0.96500E-06	259.1	320.0	0.0	0.00	30.48	30.48	0.00	0.00	
SQUARE19	0	0.96500E-06	182.9	259.1	0.0	0.00	76.20	76.20	0.00	0.00	
SQUARE20	0	0.96500E-06	259.1	289.6	0.0	0.00	30.48	30.48	0.00	0.00	
SQUARE21	0	0.96500E-06	259.1	259.1	0.0	0.00	30.48	30.48	0.00	0.00	
SQUARE22	0	0.96500E-06	289.6	213.4	0.0	0.00	76.20	76.20	0.00	0.00	
SQUARE23	0	0.96500E-06	198.1	213.4	0.0	0.00	45.72	45.72	0.00	0.00	
SQUARE24	0	0.96500E-06	243.8	213.4	0.0	0.00	45.72	45.72	0.00	0.00	
SQUARE25	0	0.96500E-06	213.4	182.9	0.0	0.00	30.48	30.48	0.00	0.00	
SQUARE26	0	0.96500E-06	243.8	137.2	0.0	0.00	76.20	76.20	0.00	0.00	
SQUARE27	0	0.96500E-06	320.0	167.6	0.0	0.00	45.72	45.72	0.00	0.00	

**MODELOPTs: CONC RURAL FLAT DFAULT

*** SOURCE IDs DEFINING SOURCE GROUPS ***

GROUP ID	SOURCE IDs
ALL	SQUARE1 , SQUARE2 , SQUARE3 , SQUARE4 , SQUARE5 , SQUARE6 , SQUARE7 , SQUARE8 , SQUARE9 , SQUARE10, SQUARE11, SQUARE12, SQUARE13, SQUARE14, SQUARE15, SQUARE16, SQUARE17, SQUARE18, SQUARE19, SQUARE20, SQUARE21, SQUARE22, SQUARE23, SQUARE24, SQUARE25, SQUARE26, SQUARE27,

**MODELOPTs: CONC RURAL FLAT DFAULT

*** DISCRETE CARTESIAN RECEPTORS ***
(X-COORD, Y-COORD, ZELEV, ZFLAG)
(METERS)

(99.1,	670.6,	0.0,	0.0);	(30.5,	662.9,	0.0,	0.0);
(22.9,	563.9,	0.0,	0.0);	(15.2,	541.0,	0.0,	0.0);
(61.0,	533.4,	0.0,	0.0);	(91.4,	434.3,	0.0,	0.0);
(121.9,	297.2,	0.0,	0.0);	(259.1,	15.2,	0.0,	0.0);
(388.6,	640.1,	0.0,	0.0);	(487.7,	670.6,	0.0,	0.0);
(563.9,	243.8,	0.0,	0.0);	(243.8,	655.3,	0.0,	0.0);
(167.6,	274.3,	0.0,	0.0);	(114.3,	647.7,	0.0,	0.0);
(91.4,	594.4,	0.0,	0.0);	(228.6,	129.5,	0.0,	0.0);
(365.8,	144.8,	0.0,	0.0);				

**MODELOPTs: CONC RURAL FLAT DFAULT

*** METEOROLOGICAL DAYS SELECTED FOR PROCESSING ***
(1=YES; 0=NO)

```
1 1 1 1 1 1 1 1 1 1   1 1 1 1 1 1 1 1 1 1   1 1 1 1 1 1 1 1 1 1   1 1 1 1 1 1 1 1 1 1   1 1 1 1 1 1 1 1 1 1
1 1 1 1 1 1 1 1 1 1   1 1 1 1 1 1 1 1 1 1   1 1 1 1 1 1 1 1 1 1   1 1 1 1 1 1 1 1 1 1   1 1 1 1 1 1 1 1 1 1
1 1 1 1 1 1 1 1 1 1   1 1 1 1 1 1 1 1 1 1   1 1 1 1 1 1 1 1 1 1   1 1 1 1 1 1 1 1 1 1   1 1 1 1 1 1 1 1 1 1
1 1 1 1 1 1 1 1 1 1   1 1 1 1 1 1 1 1 1 1   1 1 1 1 1 1 1 1 1 1   1 1 1 1 1 1 1 1 1 1   1 1 1 1 1 1 1 1 1 1
1 1 1 1 1 1 1 1 1 1   1 1 1 1 1 1 1 1 1 1   1 1 1 1 1 1 1 1 1 1   1 1 1 1 1 1 1 1 1 1   1 1 1 1 1 1 1 1 1 1
1 1 1 1 1 1 1 1 1 1   1 1 1 1 1 1 1 1 1 1   1 1 1 1 1 1 1 1 1 1   1 1 1 1 1 1 1 1 1 1   1 1 1 1 1 1 1 1 1 1
1 1 1 1 1 1 1 1 1 1   1 1 1 1 1 1 1 1 1 1   1 1 1 1 1 1 1 1 1 1   1 1 1 1 1 1 1 1 1 1   1 1 1 1 1 1 1 1 1 1
1 1 1 1 1 1 1 1 1 1   1 1 1 1 1 1
```

NOTE: METEOROLOGICAL DATA ACTUALLY PROCESSED WILL ALSO DEPEND ON WHAT IS INCLUDED IN THE DATA FILE.

*** UPPER BOUND OF FIRST THROUGH FIFTH WIND SPEED CATEGORIES ***
(METERS/SEC)

1.54, 3.09, 5.14, 8.23, 10.80,

*** WIND PROFILE EXPONENTS ***

STABILITY CATEGORY	WIND SPEED CATEGORY 1	2	3	4	5	6
A	.70000E-01	.70000E-01	.70000E-01	.70000E-01	.70000E-01	.70000E-01
B	.70000E-01	.70000E-01	.70000E-01	.70000E-01	.70000E-01	.70000E-01
C	.10000E+00	.10000E+00	.10000E+00	.10000E+00	.10000E+00	.10000E+00
D	.15000E+00	.15000E+00	.15000E+00	.15000E+00	.15000E+00	.15000E+00
E	.35000E+00	.35000E+00	.35000E+00	.35000E+00	.35000E+00	.35000E+00
F	.55000E+00	.55000E+00	.55000E+00	.55000E+00	.55000E+00	.55000E+00

*** VERTICAL POTENTIAL TEMPERATURE GRADIENTS ***
(DEGREES KELVIN PER METER)

STABILITY CATEGORY	WIND SPEED CATEGORY 1	2	3	4	5	6
A	.00000E+00	.00000E+00	.00000E+00	.00000E+00	.00000E+00	.00000E+00
B	.00000E+00	.00000E+00	.00000E+00	.00000E+00	.00000E+00	.00000E+00
C	.00000E+00	.00000E+00	.00000E+00	.00000E+00	.00000E+00	.00000E+00
D	.00000E+00	.00000E+00	.00000E+00	.00000E+00	.00000E+00	.00000E+00
E	.20000E-01	.20000E-01	.20000E-01	.20000E-01	.20000E-01	.20000E-01
F	.35000E-01	.35000E-01	.35000E-01	.35000E-01	.35000E-01	.35000E-01

**MODELOPTs: CONC RURAL FLAT DFAULT

*** THE FIRST 24 HOURS OF METEOROLOGICAL DATA ***

FILE: lprov91.bin FORMAT: UNFORM
SURFACE STATION NO.: 14765 UPPER AIR STATION NO.: 14684
NAME: SURFNAME NAME: UAIRNAME
YEAR: 1991 YEAR: 1991

YEAR	MONTH	DAY	HOUR	FLOW VECTOR	SPEED (M/S)	TEMP (K)	STAB CLASS	MIXING HEIGHT (M) RURAL	MIXING HEIGHT (M) URBAN	USTAR (M/S)	M-O LENGTH (M)	Z-0 (M)	IPCODE	PRATE (mm/HR)
91	1	1	1	121.0	4.12	267.6	5	453.1	24.0	0.0000	0.0	0.0000	0	0.00
91	1	1	2	128.0	3.60	267.0	5	504.8	24.0	0.0000	0.0	0.0000	0	0.00
91	1	1	3	154.0	3.60	267.0	5	556.4	24.0	0.0000	0.0	0.0000	0	0.00
91	1	1	4	123.0	3.60	266.5	5	608.1	24.0	0.0000	0.0	0.0000	0	0.00
91	1	1	5	113.0	3.09	265.9	6	659.8	24.0	0.0000	0.0	0.0000	0	0.00
91	1	1	6	12.0	2.57	264.3	6	711.5	24.0	0.0000	0.0	0.0000	0	0.00
91	1	1	7	105.0	3.09	265.4	6	763.2	24.0	0.0000	0.0	0.0000	0	0.00
91	1	1	8	133.0	3.60	265.9	5	131.6	152.8	0.0000	0.0	0.0000	0	0.00
91	1	1	9	137.0	1.54	268.7	4	297.1	314.8	0.0000	0.0	0.0000	0	0.00
91	1	1	10	131.0	3.09	270.9	3	462.7	476.8	0.0000	0.0	0.0000	0	0.00
91	1	1	11	84.0	2.57	271.5	3	628.3	638.9	0.0000	0.0	0.0000	0	0.00
91	1	1	12	86.0	3.09	272.6	3	793.9	800.9	0.0000	0.0	0.0000	0	0.00
91	1	1	13	63.0	3.09	273.1	3	959.4	963.0	0.0000	0.0	0.0000	0	0.00
91	1	1	14	329.0	4.63	273.1	3	1125.0	1125.0	0.0000	0.0	0.0000	0	0.00
91	1	1	15	2.0	4.63	273.1	4	1125.0	1125.0	0.0000	0.0	0.0000	0	0.00
91	1	1	16	4.0	6.17	272.6	4	1125.0	1125.0	0.0000	0.0	0.0000	0	0.00
91	1	1	17	1.0	5.14	270.9	5	1120.4	1035.9	0.0000	0.0	0.0000	0	0.00
91	1	1	18	17.0	2.57	270.9	6	1114.5	919.5	0.0000	0.0	0.0000	0	0.00
91	1	1	19	54.0	2.57	269.8	6	1108.5	803.0	0.0000	0.0	0.0000	0	0.00
91	1	1	20	47.0	2.57	269.3	6	1102.5	686.6	0.0000	0.0	0.0000	0	0.00
91	1	1	21	50.0	1.00	268.7	7	1096.5	570.2	0.0000	0.0	0.0000	0	0.00
91	1	1	22	352.0	1.00	268.7	7	1090.6	453.8	0.0000	0.0	0.0000	0	0.00
91	1	1	23	160.0	1.03	268.7	7	1084.6	337.4	0.0000	0.0	0.0000	0	0.00
91	1	1	24	150.0	2.57	268.7	6	1078.6	221.0	0.0000	0.0	0.0000	0	0.00

*** NOTES: STABILITY CLASS 1=A, 2=B, 3=C, 4=D, 5=E AND 6=F.
FLOW VECTOR IS DIRECTION TOWARD WHICH WIND IS BLOWING.

**MODELOPTs: CONC RURAL FLAT DFAULT

*** THE PERIOD (8760 HRS) AVERAGE CONCENTRATION VALUES FOR SOURCE GROUP: ALL ***
INCLUDING SOURCE(S): SQUARE1 , SQUARE2 , SQUARE3 , SQUARE4 , SQUARE5 , SQUARE6 , SQUARE7 ,
SQUARE8 , SQUARE9 , SQUARE10, SQUARE11, SQUARE12, SQUARE13, SQUARE14, SQUARE15, SQUARE16, SQUARE17, SQUARE18, SQUARE19
SQUARE20, SQUARE21, SQUARE22, SQUARE23, SQUARE24, SQUARE25, SQUARE26, SQUARE27,

*** DISCRETE CARTESIAN RECEPTOR POINTS ***

** CONC OF UNIT IN MICROGRAMS/M**3 **

X-COORD (M)	Y-COORD (M)	CONC	X-COORD (M)	Y-COORD (M)	CONC
99.06	670.56	0.84685	30.48	662.94	0.37695
22.86	563.88	0.52044	15.24	541.02	0.51832
60.96	533.40	0.87818	91.44	434.34	1.34315
121.92	297.18	1.52731	259.08	15.24	1.22047
388.62	640.08	2.28048	487.68	670.56	1.20564
563.88	243.84	1.19530	243.84	655.32	4.09869
167.64	274.32	2.87956	114.30	647.70	1.41111
91.44	594.36	1.21357	228.60	129.54	2.73802
365.76	144.78	4.04960			

**MODELOPTs: CONC RURAL FLAT DFAULT

*** THE SUMMARY OF MAXIMUM PERIOD (8760 HRS) RESULTS ***

** CONC OF UNIT IN MICROGRAMS/M**3 **

GROUP ID		AVERAGE CONC	RECEPTOR (XR, YR, ZELEV, ZFLAG)	OF TYPE	NETWORK GRID-ID
ALL	1ST HIGHEST VALUE IS	4.09869 AT (	243.84, 655.32, 0.00, 0.00)	DC	NA
	2ND HIGHEST VALUE IS	4.04960 AT (	365.76, 144.78, 0.00, 0.00)	DC	NA
	3RD HIGHEST VALUE IS	2.87956 AT (	167.64, 274.32, 0.00, 0.00)	DC	NA
	4TH HIGHEST VALUE IS	2.73802 AT (	228.60, 129.54, 0.00, 0.00)	DC	NA
	5TH HIGHEST VALUE IS	2.28048 AT (	388.62, 640.08, 0.00, 0.00)	DC	NA
	6TH HIGHEST VALUE IS	1.52731 AT (	121.92, 297.18, 0.00, 0.00)	DC	NA

*** RECEPTOR TYPES: GC = GRIDCART
GP = GRIDPOLR
DC = DISCCART
DP = DISCPOLR
BD = BOUNDARY

**MODELOPTs: CONC RURAL FLAT DFAULT

*** Message Summary : ISCST3 Model Execution ***

--------- Summary of Total Messages --------

A Total of 0 Fatal Error Message(s)
A Total of 0 Warning Message(s)
A Total of 766 Informational Message(s)

A Total of 219 Calm Hours Identified

******** FATAL ERROR MESSAGES ********
*** NONE ***

******** WARNING MESSAGES ********
*** NONE ***

****
*** ISCST3 Finishes Successfully ***
****

→

ATTACHMENT C

**MODELOPTs: CONC RURAL FLAT DFAULT

*** THE PERIOD (8760 HRS) AVERAGE CONCENTRATION VALUES FOR SOURCE GROUP: ALL ***
INCLUDING SOURCE(S): SQUARE1 , SQUARE2 , SQUARE3 , SQUARE4 , SQUARE5 , SQUARE6 , SQUARE7 ,
SQUARE8 , SQUARE9 , SQUARE10, SQUARE11, SQUARE12, SQUARE13, SQUARE14, SQUARE15, SQUARE16, SQUARE17, SQUARE18, SQUARE19,
SQUARE20, SQUARE21, SQUARE22, SQUARE23, SQUARE24, SQUARE25, SQUARE26, SQUARE27,

*** DISCRETE CARTESIAN RECEPTOR POINTS ***

** CONC OF UNIT IN MICROGRAMS/M**3 **

X-COORD (M)	Y-COORD (M)	CONC	X-COORD (M)	Y-COORD (M)	CONC
99.06	670.56	1.18274	30.48	662.94	0.48215
22.86	563.88	0.51002	15.24	541.02	0.49541
60.96	533.40	0.89999	91.44	434.34	1.36069
121.92	297.18	1.45974	259.08	15.24	0.94580
388.62	640.08	1.83921	487.68	670.56	0.88957
563.88	243.84	1.28599	243.84	655.32	4.03348
167.64	274.32	2.74421	114.30	647.70	1.91128
91.44	594.36	1.36114	228.60	129.54	2.43769
365.76	144.78	4.00672			

1987 - 0 meters

**MODELOPTs: CONC RURAL FLAT DFAULT

*** THE PERIOD (8784 HRS) AVERAGE CONCENTRATION VALUES FOR SOURCE GROUP: ALL ***
INCLUDING SOURCE(S): SQUARE1 , SQUARE2 , SQUARE3 , SQUARE4 , SQUARE5 , SQUARE6 , SQUARE7 ,
SQUARE8 , SQUARE9 , SQUARE10, SQUARE11, SQUARE12, SQUARE13, SQUARE14, SQUARE15, SQUARE16, SQUARE17, SQUARE18, SQUARE19
SQUARE20, SQUARE21, SQUARE22, SQUARE23, SQUARE24, SQUARE25, SQUARE26, SQUARE27,

*** DISCRETE CARTESIAN RECEPTOR POINTS ***

** CONC OF UNIT IN MICROGRAMS/M**3 **

X-COORD (M)	Y-COORD (M)	CONC	X-COORD (M)	Y-COORD (M)	CONC
99.06	670.56	1.01664	30.48	662.94	0.39095
22.86	563.88	0.37796	15.24	541.02	0.36091
60.96	533.40	0.65198	91.44	434.34	0.95517
121.92	297.18	0.99421	259.08	15.24	0.73515
388.62	640.08	2.20794	487.68	670.56	1.09845
563.88	243.84	1.27340	243.84	655.32	4.76560
167.64	274.32	1.93525	114.30	647.70	1.69453
91.44	594.36	1.03096	228.60	129.54	1.78383
365.76	144.78	3.56231			

1988 - 0 meters

**MODELOPTs: CONC RURAL FLAT DFAULT

*** THE PERIOD (8760 HRS) AVERAGE CONCENTRATION VALUES FOR SOURCE GROUP: ALL ***
INCLUDING SOURCE(S): SQUARE1 , SQUARE2 , SQUARE3 , SQUARE4 , SQUARE5 , SQUARE6 , SQUARE7 , SQUARE8 , SQUARE9 , SQUARE10, SQUARE11, SQUARE12, SQUARE13, SQUARE14, SQUARE15, SQUARE16, SQUARE17, SQUARE18, SQUARE19, SQUARE20, SQUARE21, SQUARE22, SQUARE23, SQUARE24, SQUARE25, SQUARE26, SQUARE27,

*** DISCRETE CARTESIAN RECEPTOR POINTS ***

** CONC OF UNIT IN MICROGRAMS/M**3 **

X-COORD (M)	Y-COORD (M)	CONC	X-COORD (M)	Y-COORD (M)	CONC
99.06	670.56	1.11362	30.48	662.94	0.47060
22.86	563.88	0.52734	15.24	541.02	0.51535
60.96	533.40	0.91694	91.44	434.34	1.37748
121.92	297.18	1.47472	259.08	15.24	0.92235
388.62	640.08	2.32251	487.68	670.56	1.17092
563.88	243.84	1.17447	243.84	655.32	4.71441
167.64	274.32	2.75699	114.30	647.70	1.82733
91.44	594.36	1.34383	228.60	129.54	2.41769
365.76	144.78	3.52152			

1989 - 0 meters

**MODELOPTs: CONC RURAL FLAT DFAULT

*** THE PERIOD (8760 HRS) AVERAGE CONCENTRATION VALUES FOR SOURCE GROUP: ALL ***
INCLUDING SOURCE(S): SQUARE1 , SQUARE2 , SQUARE3 , SQUARE4 , SQUARE5 , SQUARE6 , SQUARE7
SQUARE8 , SQUARE9 , SQUARE10, SQUARE11, SQUARE12, SQUARE13, SQUARE14, SQUARE15, SQUARE16, SQUARE17, SQUARE18, SQUARE19
SQUARE20, SQUARE21, SQUARE22, SQUARE23, SQUARE24, SQUARE25, SQUARE26, SQUARE27,

*** DISCRETE CARTESIAN RECEPTOR POINTS ***

** CONC OF UNIT IN MICROGRAMS/M**3 **

X-COORD (M)	Y-COORD (M)	CONC	X-COORD (M)	Y-COORD (M)	CONC
99.06	670.56	1.11036	30.48	662.94	0.48857
22.86	563.88	0.54254	15.24	541.02	0.52779
60.96	533.40	0.89877	91.44	434.34	1.28185
121.92	297.18	1.31336	259.08	15.24	0.72892
388.62	640.08	2.11477	487.68	670.56	1.09215
563.88	243.84	1.00780	243.84	655.32	4.33641
167.64	274.32	2.43532	114.30	647.70	1.82066
91.44	594.36	1.33599	228.60	129.54	1.98520
365.76	144.78	2.99579			

1990 - 0 meters

**MODELOPTs: CONC RURAL FLAT DFAULT

*** THE PERIOD (8760 HRS) AVERAGE CONCENTRATION VALUES FOR SOURCE GROUP: ALL ***
INCLUDING SOURCE(S): SQUARE1 , SQUARE2 , SQUARE3 , SQUARE4 , SQUARE5 , SQUARE6 , SQUARE7 ,
SQUARE8 , SQUARE9 , SQUARE10, SQUARE11, SQUARE12, SQUARE13, SQUARE14, SQUARE15, SQUARE16, SQUARE17, SQUARE18, SQUARE19,
SQUARE20, SQUARE21, SQUARE22, SQUARE23, SQUARE24, SQUARE25, SQUARE26, SQUARE27,

*** DISCRETE CARTESIAN RECEPTOR POINTS ***

** CONC OF UNIT IN MICROGRAMS/M**3 **

X-COORD (M)	Y-COORD (M)	CONC	X-COORD (M)	Y-COORD (M)	CONC
99.06	670.56	0.84685	30.48	662.94	0.37695
22.86	563.88	0.52044	15.24	541.02	0.51832
60.96	533.40	0.87818	91.44	434.34	1.34315
121.92	297.18	1.52731	259.08	15.24	1.22047
388.62	640.08	2.28048	487.68	670.56	1.20564
563.88	243.84	1.19530	243.84	655.32	4.09869
167.64	274.32	2.87956	114.30	647.70	1.41111
91.44	594.36	1.21357	228.60	129.54	2.73802
365.76	144.78	4.04960			

1991 - 0 meters

Project	Rose Hill FS	Acct. No.	4609-18-10-11	Page 1	of 1
Subject	Air Modeling	Comptd. By	S. Czarniecki	Date	08/14/96
Detail	Results Table	Ck'd. By	R. Porter	Date	08/26/96

C:\RH\AIR\SCST3\RESTABLE.WK1

RESTABLE.WK1

The attached table presents modeled concentrations of analytes of concern at the Site. The maximum modeled concentrations from RESULTS.~~WK1~~ XLS were used to proportionally determine the analytes' concentration at various receptors. Some analytes were not detected in landfill gas SUMMA canister sampling, but are noted due to detections in ambient air at residences.

Metcalf & Eddy, Inc.

MODELED CONCENTRATIONS OF LANDF. GAS CONTAMINANTS AT RESIDENTIAL RECEPTORS, ROSE HILL REGIONAL LANDFILL SUPERFUND SITE
SOLID WASTE AREA - AREA SOURCE MODELING

Maximum Modeled Concentration Based on 3,100,000 (µg/m3) ->		1.18274	0.48857	0.54254	0.52779	0.91694	1.37748	1.52731	1.22047	2.32251	1.20564
		Concentration (µg/m^3)									
	SUMMA	Receptor #									
	Max (µg/m^3)	1	2	3	4	5	6	7	8	9	10
Acetone	0	0	0	0	0	0	0	0	0	0	0
Benzene	8,000	0.0031	0.0013	0.0014	0.0014	0.0024	0.0036	0.0039	0.0031	0.0060	0.0031
Carbon Disulfide	870	0.00033	0.00014	0.00015	0.00015	0.00026	0.00039	0.00043	0.00034	0.00065	0.00034
Dichlorodifluoromethane	110,000	0.042	0.017	0.019	0.019	0.033	0.049	0.054	0.043	0.082	0.043
1,1-Dichloroethane	140,000	0.053	0.022	0.025	0.024	0.041	0.062	0.069	0.055	0.10	0.054
1,1-Dichloroethene	32,000	0.012	0.0050	0.0056	0.0054	0.0095	0.014	0.016	0.013	0.024	0.012
cis-1,2-Dichloroethene	23,000,000	8.8	3.6	4.0	3.9	6.8	10	11	9.1	17	8.9
trans-1,2-Dichloroethene	27,000	0.010	0.0043	0.0047	0.0046	0.0080	0.012	0.013	0.011	0.020	0.011
Ethylbenzene	25,000	0.010	0.0039	0.0044	0.0043	0.0074	0.011	0.012	0.010	0.019	0.010
4-Methyl-2-pentanone	6,600	0.0025	0.0010	0.0012	0.0011	0.0020	0.0029	0.0033	0.0026	0.0049	0.0026
Methylene Chloride	66,000	0.025	0.010	0.012	0.011	0.020	0.029	0.033	0.026	0.049	0.026
1,1,2,2-Tetrachloroethane	0	0	0	0	0	0	0	0	0	0	0
Toluene	230,000	0.088	0.036	0.040	0.039	0.068	0.10	0.11	0.091	0.17	0.089
1,2,4-Trichlorobenzene	0	0	0	0	0	0	0	0	0	0	0
1,1,1-Trichloroethane	10,000	0.0038	0.0016	0.0018	0.0017	0.0030	0.0044	0.0049	0.0039	0.0075	0.0039
Trichloroethene	31,000	0.012	0.0049	0.0054	0.0053	0.0092	0.014	0.015	0.012	0.023	0.012
1,2,4-Trimethylbenzene	2,000	0.00076	0.00032	0.00035	0.00034	0.00059	0.00089	0.0010	0.00079	0.0015	0.00078
1,3,5-Trimethylbenzene	4,300	0.0016	0.00068	0.00075	0.00073	0.0013	0.0019	0.0021	0.0017	0.0032	0.0017
Vinyl Chloride	3,100,000	1.2	0.49	0.54	0.53	0.92	1.4	1.5	1.2	2.3	1.2
m,p-Xylene	41,000	0.016	0.0065	0.0072	0.0070	0.012	0.018	0.020	0.016	0.031	0.016
o-Xylene	11,000	0.0042	0.0017	0.0019	0.0019	0.0033	0.0049	0.0054	0.0043	0.0082	0.0043

MODELED CONCENTRATIONS OF LANDFILL GAS CONTAMINANTS AT RESIDENTIAL RECEPTORS, ROSE HILL REGIONAL LANDFILL SUPERFUND SITE
SOLID WASTE AREA - AREA SOURCE MODELING

Maximum Modeled Concentration Based on 3,100,000 (µg/m3) ->		1.28599	4.76560	2.87956	1.91128	1.36114	2.73802	4.04960
		Concentration (µg/m^3)						
	SUMMA	Receptor #						
	Max (µg/m^3)	11	12	13	14	15	16	17
Benzene	8,000	0.0033	0.012	0.0074	0.0049	0.0035	0.0071	0.010
Acetone	0	0	0	0	0	0	0	0
Carbon Disulfide	870	0.00036	0.0013	0.00081	0.00054	0.00038	0.00077	0.0011
Dichlorodifluoromethane	110,000	0.046	0.17	0.10	0.068	0.048	0.10	0.14
1,1-Dichloroethane	140,000	0.058	0.22	0.13	0.086	0.061	0.12	0.18
1,1-Dichloroethene	32,000	0.013	0.049	0.030	0.020	0.014	0.028	0.042
cis-1,2-Dichloroethene	23,000,000	10	35	21	14	10	20	30
trans-1,2-Dichloroethene	27,000	0.011	0.042	0.025	0.017	0.012	0.024	0.035
Ethylbenzene	25,000	0.010	0.038	0.023	0.015	0.011	0.022	0.033
4-Methyl-2-pentanone	6,600	0.0027	0.010	0.0061	0.0041	0.0029	0.0058	0.0086
Methylene Chloride	66,000	0.027	0.10	0.061	0.041	0.029	0.058	0.086
1,1,2,2-Tetrachloroethane	0	0	0	0	0	0	0	0
Toluene	230,000	0.10	0.35	0.21	0.14	0.10	0.20	0.30
1,2,4-Trichlorobenzene	0	0	0	0	0	0	0	0
1,1,1-Trichloroethane	10,000	0.0041	0.015	0.0093	0.0062	0.0044	0.0088	0.013
Trichloroethene	31,000	0.013	0.048	0.029	0.019	0.014	0.027	0.040
1,2,4-Trimethylbenzene	2,000	0.00083	0.0031	0.0019	0.0012	0.00088	0.0018	0.0026
1,3,5-Trimethylbenzene	4,300	0.0018	0.007	0.0040	0.0027	0.0019	0.0038	0.006
Vinyl Chloride	3,100,000	1.3	4.8	2.9	1.9	1.4	2.7	4.0
m,p-Xylene	41,000	0.017	0.06	0.038	0.025	0.018	0.036	0.054
o-Xylene	11,000	0.0046	0.017	0.010	0.007	0.0048	0.010	0.014

Notes:

1) ISCST3 model utilized.
2) Receptors #1 through 10 are nearby residences.
   Receptors #11 is the transfer station.
   Receptors #12 through 17 are locations on roadways and driveways along the landfill perimeter.
3) Modeling assumptions are presented in RECEPTOR.WK1, SOLGRID.WK1, SUMMA.WK1 and RESULTS.WK1.

F-2 Point Source Modeling - Flare

FLARE.XLS

Revised: 10/14/98

ISCLT3 dispersion modeling from a flare will be performed using the same concentrations as for the area source modeling - see SUMMA.WK1. The flare burns landfill gas collected in the Solid Waste Area. The modeling will be based on a vinyl chloride concentration of 3,100 mg/m^3.

The ISCLT3 model was used for flare dispersion modeling to determine if the more time-consuming ISCST3 runs would be needed. Since ISCLT3 models a five-year average of meteorologic data, peak values may not be presented. However, the flare properties are expected to reduce the impacts significantly so that further short-term modeling will be unnecessary.

The receptors and flare stack location are presented on Attachment A. Coordinates for the receptors have been presented in RECEPTOR.WK1 for the area source modeling. The coordinates for the flare stack are:

Grid squares on Attachment A are 50 ft on each side = 15.24 m

			Input for model (all values in meters) Values are the X, Y coords. times square length	
	X	Y	X	Y
Flare	24.5	31.5	373.38	######

Emission Rate (g / s)

Assuming 100% capture of the landfill gas:

Using a landfill gas generation rate of	0.0282	m^3 / s	see SOLGRID.XLS
and a vinyl chloride concentration of	3,100	mg / m^3	
We get	0.087	g / s	
Assuming a conservative 95% destruction efficiency,			
the model input becomes	0.0044	g / s	coming out of the flare.

Other Flare Input Parameters

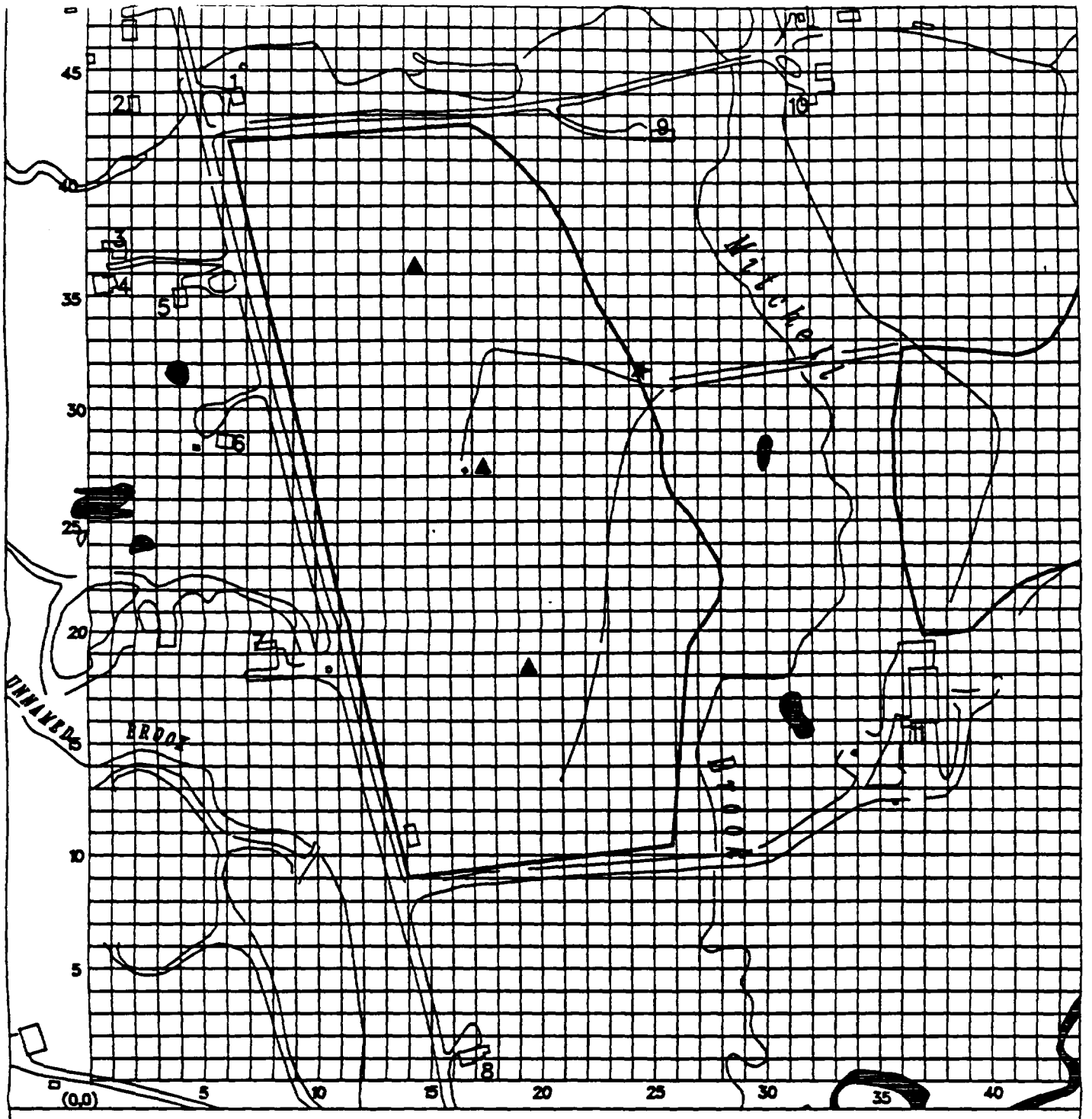
From John Zink Co. quotation (see Appendix E),

Stack Height	9.14	m	=	30	ft
Gas Exit Temperature	1,089	K	=	1,500	°F
Gas Exit Velocity	3.63	m / s	=	11.9	ft/s
Stack Diameter (ID)	0.95	m	=	3.125	ft

Other Assumptions

Rural dispersion parameters were used.

Flat terrain was assumed since area receptors were below 1/2 the stack height.



Primary Road

Secondary Road

Stream or Brook

Landfill Area

Lake, Pond, or River

Stack Location: System 1

Stack Location: Systems 2&3

Residential Receptor

Receptor 11 is Non-Residential: Transfer Station

SCALE IN FEET

250 0 100 250

ATTACHMENT A

~~FIGURE C-1~~

AIR DISPERSION MODEL GRID AND RESIDENTIAL RECEPTOR LOCATIONS

ROSE HILL LANDFILL

SOUTH KINGSTOWN, RI

METCALF & EDDY

The ISCLT3 model uses joint frequency distributions of wind speed class, by wind direction sector, and by stability category, known as STAR summaries (for STability ARray). Seasonal and annual STAR data for the NOAA weather station at T.F. Green Airport, Providence, Rhode Island (#14765), spanning the dates of October 1, 1987 and September 30, 1992, was obtained for use as input in this model. Included in the data are seasonal and annual frequencies of wind speed and direction.

An average ambient air temperature of 50°F for the area was calculated from data collected at Providence, Rhode Island (NOAA, 1991). Mixing layer heights were calculated using data available on EPA's SCRAM Bulletin Board System for Chatham, Massachusetts (#14684), the closest weather station with mixing height data. The mixing height calculation cited (USEPA, 1992) was used to estimate mixing height data by stability class.

Discreet Receptor Results

Receptor #	Modeled Concentration Based on Input of 3.100 mg/m^3 (µg/m^3)
1	0.000614
2	0.000649
3	0.000793
4	0.000870
5	0.000805
6	0.001061
7	0.001822
8	0.004416
9	0.001258
10	0.002604
11	0.006901
12	0.000478
13	0.002057
14	0.000582
15	0.000592
16	0.002633
17	0.007737

Notes:
Receptors #1 through 11 are nearby residences and the transfer station.
Receptors #12 through 17 are locations on roadways and driveways along the landfill perimeter.
Modeled concentrations are annual average values over 5 years.

Maximum Modeled Concentration

The maximum modeled concentration is 0.00806 µg/m^3
and is located in the southern direction of the flare stack, approximately 350 meters from the stack.

Model input/output is presented as Attachment A.

METCALF & EDDY

Attachment A

```
** Rosehill - ISCLT3
** Point source emissions from an alternative flare burning landfill gas
**    from the Solid Waste Area (1997 LFG flow rates)
** 1987-1992 meteorological data
** Vinyl chloride emissions (Concentration = 3,100 mg/m^3)

CO STARTING
   TITLEONE  ROSEHILL - ALT. FLARE EMISSIONS - ISCLT3
   MODELOPT  DFAULT  CONC  RURAL
   AVERTIME  ANNUAL
   TERRHGTS  FLAT
   POLLUTID  VYCL
   RUNORNOT  RUN
CO FINISHED

SO STARTING

**  FLARE FOR SOLID WASTE AREA

SO LOCATION   STACK1  POINT      373.38   480.06     0.

**  Emission rate (g/s), stack height (m), gas temp (K),
**     gas velocity (m/s), stack diameter (m)

SO SRCPARAM   STACK1   0.0044  9.14  1089.  3.63  0.95

SO SRCGROUP ALL
SO FINISHED


RE STARTING
RE GRIDPOLR POL STA
RE GRIDPOLR POL ORIG   375. 480.
RE GRIDPOLR POL DIST   50. 100. 150. 200. 250. 300. 350. 400. 450.
RE GRIDPOLR POL DIST   500. 550. 600. 650. 700. 750. 800. 850. 900.
** RE GRIDPOLR POL DIST   950. 1000. 1050. 1100. 1150. 1200. 1300.
** RE GRIDPOLR POL DIST   1400. 1500. 1600. 1700. 1800. 1900. 2000.
** RE GRIDPOLR POL DIST   2100. 2200. 2300. 2400. 2500. 2600. 2700.
RE GRIDPOLR POL DIST   2800. 2900. 3000. 3100. 3200. 3300. 3400.
RE GRIDPOLR POL DIST   3500. 3600. 3700. 3800. 3900. 4000. 4100.
RE GRIDPOLR POL DIST   4200. 4300. 4400. 4500. 4600. 4700. 4800.
** RE GRIDPOLR POL DIST   4900. 5000. 5100. 5200. 5300. 5400. 5500.
** RE GRIDPOLR POL DIST   5600. 5700. 5800. 5900. 6000. 6100. 6200.
RE GRIDPOLR POL GDIR   8    0.  45.
RE GRIDPOLR POL END

**  Discreet Receptors
**  x, y coordinates (m)

** Receptor #1
RE DISCCART         99.06    670.56
** Receptor #2
RE DISCCART         30.48    662.94
** Receptor #3
RE DISCCART         22.86    563.88
** Receptor #4
RE DISCCART         15.24    541.02
** Receptor #5
RE DISCCART         60.96    533.40
** Receptor #6
RE DISCCART         91.44    434.34
** Receptor #7
RE DISCCART        121.92    297.18
** Receptor #8
RE DISCCART        259.08     15.24
** Receptor #9
RE DISCCART        388.62    640.08
** Receptor #10
RE DISCCART        487.68    670.56
** Receptor #11
RE DISCCART        563.88    243.84
** Receptor #12
RE DISCCART        243.84    655.32
** Receptor #13
RE DISCCART        167.64    274.32
** Receptor #14
RE DISCCART        114.30    647.70
** Receptor #15
RE DISCCART         91.44    594.36
** Receptor #16
RE DISCCART        228.60    129.54
** Receptor #17
RE DISCCART        365.76    144.78

RE FINISHED


ME STARTING
   INPUTFIL  TEST.DAT FREE
   ANEMHGHT  20. FEET
** Stardata from 1987 through 1992 at Providence was utilized.
```

```
   SURFDATA  14765  1987  PROVIDENCE
   UAIRDATA  14765  1987  PROVIDENCE

**                - AMBIENT AIR TEMPERATURE (DEGREES KELVIN) -
**
**                   STAB    STAB    STAB    STAB    STAB    STAB
**                   CAT 1   CAT 2   CAT 3   CAT 4   CAT 5   CAT 6
                     -----   -----   -----   -----   -----   -----

   AVETEMPS  ANNUAL   283.2   283.2   283.2   283.2   283.2   283.2


**                        - MIXING LAYER HEIGHT (METERS) -
**                  S
**                  T    WS       WS       WS       WS       WS       WS
**            SEAS  A   CAT 1    CAT 2    CAT 3    CAT 4    CAT 5    CAT 6
**            ----  B   -----    -----    -----    -----    -----    -----

   AVEMIXHT  ANNUAL 1 .142E+04 .142E+04 .142E+04 .142E+04 .142E+04 .142E+04
   AVEMIXHT  ANNUAL 2 .944E+03 .944E+03 .944E+03 .944E+03 .944E+03 .944E+03
   AVEMIXHT  ANNUAL 3 .944E+03 .944E+03 .944E+03 .944E+03 .944E+03 .944E+03
   AVEMIXHT  ANNUAL 4 .944E+03 .944E+03 .944E+03 .944E+03 .944E+03 .944E+03
   AVEMIXHT  ANNUAL 5 .100E+05 .100E+05 .100E+05 .100E+05 .100E+05 .100E+05
   AVEMIXHT  ANNUAL 6 .100E+05 .100E+05 .100E+05 .100E+05 .100E+05 .100E+05
ME FINISHED

OU STARTING
   RECTABLE  INDSRC
   MAXTABLE  10 INDSRC
OU FINISHED

***********************************
*** SETUP Finishes Successfully ***
***********************************

 *** ISCLT3 - VERSION 96113 ***    ***  ROSEHILL - ALT. FLARE EMISSIONS - ISCLT3                          ***        10/14/98
                                   ***                                                                      ***        13:49:37
                                                                                                                       PAGE   1

 *** MODELING OPTIONS USED:  CONC   RURAL  FLAT          DFAULT

                                          ***     MODEL SETUP OPTIONS SUMMARY       ***
- - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - -

**Model Is Setup For Calculation of Average CONCentration Values.
**Model Does NOT Use GRIDDED TERRAIN Data for Depletion Calculations

 **Model Uses NO plume DEPLETION.

 **Model Uses RURAL Dispersion.

**Model Uses Regulatory DEFAULT Options:
          1. Final Plume Rise.
          2. Stack-tip Downwash.
          3. Buoyancy-induced Dispersion.
          4. Default Wind Profile Exponents.
          5. Default Vertical Potential Temperature Gradients.
          6. "Upper Bound" Values For Supersquat Buildings.
          7. No Exponential Decay for RURAL Mode

**Model Assumes Receptors on FLAT Terrain.

**Model Assumes No FLAGPOLE Receptor Heights.

**Model Calculates   1 STAR Average(s) for the Following Months:  0  0  0  0  0  0  0  0  0  0  0  0
                                              Seasons/Quarters:  0  0  0  0
                                                    and Annual:  1

**Model Assumes  1 STAR Summaries In Data File for the Averaging Periods Identified Above

**This Run Includes:    1 Source(s);      1 Source Group(s); and    329 Receptor(s)

**The Model Assumes A Pollutant Type of:  VYCL

**Model Set To Continue RUNning After the Setup Testing.

**Output Options Selected:
         Model Outputs Tables of Long Term Values by Receptor (RECTABLE Keyword)
         Model Outputs Tables of Maximum Long Term Values (MAXTABLE Keyword)

**Misc. Inputs:  Anem. Hgt. (m) =     6.10 ;    Decay Coef. =   0.0000     ;    Rot. Angle =     0.0
                 Emission Units = GRAMS/SEC                                ;  Emission Rate Unit Factor =   0.10000E+07
                 Output Units   = MICROGRAMS/M**3

**Input Runstream File: rhflare5.inp                          ;  **Output Print File: rhflare5.out
 *** ISCLT3 - VERSION 96113 ***    ***  ROSEHILL - ALT. FLARE EMISSIONS - ISCLT3                          ***        10/14/98
                                   ***                                                                      ***        13:49:37
                                                                                                                       PAGE   2

  ** MODELING OPTIONS USED:  CONC   RURAL  FLAT          DFAULT


                                                  *** POINT SOURCE DATA ***

            NUMBER EMISSION RATE                    BASE     STACK   STACK    STACK     STACK    BUILDING EMISSION RATE
```

SOURCE ID	PART. CATS.	(GRAMS/SEC)	X (METERS)	Y (METERS)	ELEV. (METERS)	HEIGHT (METERS)	TEMP. (DEG.K)	EXIT VEL. (M/SEC)	DIAMETER (METERS)	EXISTS	SCALAR VARY BY
STACK1	0	0.44000E-02	373.4	480.1	0.0	9.14	1089.00	3.63	0.95	NO	

*** MODELING OPTIONS USED: CONC RURAL FLAT DFAULT

*** SOURCE IDs DEFINING SOURCE GROUPS ***

GROUP ID	SOURCE IDs
ALL	STACK1 ,

*** MODELING OPTIONS USED: CONC RURAL FLAT DFAULT

*** GRIDDED RECEPTOR NETWORK SUMMARY ***

*** NETWORK ID: POL ; NETWORK TYPE: GRIDPOLR ***

*** ORIGIN FOR POLAR NETWORK ***
X-ORIG = 375.00 ; Y-ORIG = 480.00 (METERS)

*** DISTANCE RANGES OF NETWORK ***
(METERS)

50.0,	100.0,	150.0,	200.0,	250.0,	300.0,	350.0,	400.0,	450.0,	500.0,
550.0,	600.0,	650.0,	700.0,	750.0,	800.0,	850.0,	900.0,	2800.0,	2900.0,
3000.0,	3100.0,	3200.0,	3300.0,	3400.0,	3500.0,	3600.0,	3700.0,	3800.0,	3900.0,
4000.0,	4100.0,	4200.0,	4300.0,	4400.0,	4500.0,	4600.0,	4700.0,	4800.0,	

*** DIRECTION RADIALS OF NETWORK ***
(DEGREES)

360.0,	45.0,	90.0,	135.0,	180.0,	225.0,	270.0,	315.0,

*** MODELING OPTIONS USED: CONC RURAL FLAT DFAULT

*** DISCRETE CARTESIAN RECEPTORS ***
(X-COORD, Y-COORD, ZELEV, ZFLAG)
(METERS)

(99.1,	670.6,	0.0,	0.0);	(30.5,	662.9,	0.0,	0.0);
(22.9,	563.9,	0.0,	0.0);	(15.2,	541.0,	0.0,	0.0);
(61.0,	533.4,	0.0,	0.0);	(91.4,	434.3,	0.0,	0.0);
(121.9,	297.2,	0.0,	0.0);	(259.1,	15.2,	0.0,	0.0);
(388.6,	640.1,	0.0,	0.0);	(487.7,	670.6,	0.0,	0.0);
(563.9,	243.8,	0.0,	0.0);	(243.8,	655.3,	0.0,	0.0);
(167.6,	274.3,	0.0,	0.0);	(114.3,	647.7,	0.0,	0.0);
(91.4,	594.4,	0.0,	0.0);	(228.6,	129.5,	0.0,	0.0);
(365.8,	144.8,	0.0,	0.0);				

*** MODELING OPTIONS USED: CONC RURAL FLAT DFAULT

*** AVERAGE SPEED FOR EACH WIND SPEED CATEGORY ***
(METERS/SEC)

1.50, 2.50, 4.30, 6.80, 9.50, 12.50,

*** WIND PROFILE EXPONENTS ***

STABILITY CATEGORY	WIND SPEED CATEGORY 1	2	3	4	5	6
A	.70000E-01	.70000E-01	.70000E-01	.70000E-01	.70000E-01	.70000E-01
B	.70000E-01	.70000E-01	.70000E-01	.70000E-01	.70000E-01	.70000E-01
C	.10000E+00	.10000E+00	.10000E+00	.10000E+00	.10000E+00	.10000E+00
D	.15000E+00	.15000E+00	.15000E+00	.15000E+00	.15000E+00	.15000E+00
E	.35000E+00	.35000E+00	.35000E+00	.35000E+00	.35000E+00	.35000E+00
F	.55000E+00	.55000E+00	.55000E+00	.55000E+00	.55000E+00	.55000E+00

*** VERTICAL POTENTIAL TEMPERATURE GRADIENTS ***
(DEGREES KELVIN PER METER)

STABILITY CATEGORY	WIND SPEED CATEGORY 1	2	3	4	5	6

A	.00000E+00	.00000E+00	.00000E+00	.00000E+00	.00000E+00	.00000E+00
B	.00000E+00	.00000E+00	.00000E+00	.00000E+00	.00000E+00	.00000E+00
C	.00000E+00	.00000E+00	.00000E+00	.00000E+00	.00000E+00	.00000E+00
D	.00000E+00	.00000E+00	.00000E+00	.00000E+00	.00000E+00	.00000E+00
E	.20000E-01	.20000E-01	.20000E-01	.20000E-01	.20000E-01	.20000E-01
F	.35000E-01	.35000E-01	.35000E-01	.35000E-01	.35000E-01	.35000E-01

*** AVERAGE AMBIENT AIR TEMPERATURE (KELVIN) ***

	STABILITY CATEGORY A	STABILITY CATEGORY B	STABILITY CATEGORY C	STABILITY CATEGORY D	STABILITY CATEGORY E	STABILITY CATEGORY F
ANNUAL	283.2000	283.2000	283.2000	283.2000	283.2000	283.2000

*** MODELING OPTIONS USED: CONC RURAL FLAT DFAULT

*** AVERAGE MIXING LAYER HEIGHT (METERS) ***

	ANNUAL WIND SPEED CATEGORY 1	WIND SPEED CATEGORY 2	WIND SPEED CATEGORY 3	WIND SPEED CATEGORY 4	WIND SPEED CATEGORY 5	WIND SPEED CATEGORY 6
STABILITY CATEGORY A	1420.0000	1420.0000	1420.0000	1420.0000	1420.0000	1420.0000
STABILITY CATEGORY B	944.0001	944.0001	944.0001	944.0001	944.0001	944.0001
STABILITY CATEGORY C	944.0001	944.0001	944.0001	944.0001	944.0001	944.0001
STABILITY CATEGORY D	944.0001	944.0001	944.0001	944.0001	944.0001	944.0001
STABILITY CATEGORY E	10000.0000	10000.0000	10000.0000	10000.0000	10000.0000	10000.0000
STABILITY CATEGORY F	10000.0000	10000.0000	10000.0000	10000.0000	10000.0000	10000.0000

*** MODELING OPTIONS USED: CONC RURAL FLAT DFAULT

*** FREQUENCY OF OCCURRENCE OF WIND SPEED, DIRECTION AND STABILITY ***

FILE: TEST.DAT FORMAT: FREE
SURFACE STATION NO.: 14765 UPPER AIR STATION NO.: 14765
NAME: PROVIDENCE NAME: PROVIDENCE
YEAR: 1987 YEAR: 1987

ANNUAL: STABILITY CATEGORY A

RECTION EGREES)	WIND SPEED CATEGORY 1 (1.500 M/S)	WIND SPEED CATEGORY 2 (2.500 M/S)	WIND SPEED CATEGORY 3 (4.300 M/S)	WIND SPEED CATEGORY 4 (6.800 M/S)	WIND SPEED CATEGORY 5 (9.500 M/S)	WIND SPEED CATEGORY 6 (12.500 M/S)
0.000	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000
22.500	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000
45.000	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000
67.500	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000
90.000	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000
112.500	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000
135.000	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000
157.500	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000
180.000	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000
202.500	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000
225.000	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000
247.500	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000
270.000	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000
292.500	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000
315.000	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000
337.500	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000

ANNUAL: STABILITY CATEGORY B

DIRECTION (DEGREES)	WIND SPEED CATEGORY 1 (1.500 M/S)	WIND SPEED CATEGORY 2 (2.500 M/S)	WIND SPEED CATEGORY 3 (4.300 M/S)	WIND SPEED CATEGORY 4 (6.800 M/S)	WIND SPEED CATEGORY 5 (9.500 M/S)	WIND SPEED CATEGORY 6 (12.500 M/S)
0.000	0.00013000	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000
22.500	0.00025000	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000
45.000	0.00038000	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000
67.500	0.00038000	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000
90.000	0.00038000	0.00000000	0.00009000	0.00000000	0.00000000	0.00000000
112.500	0.00038000	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000
135.000	0.00038000	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000
157.500	0.00050000	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000
180.000	0.00050000	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000
202.500	0.00013000	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000
225.000	0.00016000	0.00009000	0.00000000	0.00000000	0.00000000	0.00000000
247.500	0.00025000	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000
270.000	0.00013000	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000
292.500	0.00013000	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000
315.000	0.00016000	0.00009000	0.00000000	0.00000000	0.00000000	0.00000000
337.500	0.00013000	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000

*** MODELING OPTIONS USED: CONC RURAL FLAT DFAULT

*** FREQUENCY OF OCCURRENCE OF WIND SPEED, DIRECTION AND STABILITY ***

FILE: TEST.DAT FORMAT: FREE
SURFACE STATION NO.: 14765 UPPER AIR STATION NO.: 14765
NAME: PROVIDENCE NAME: PROVIDENCE
YEAR: 1987 YEAR: 1987

ANNUAL: STABILITY CATEGORY C

DIRECTION (DEGREES)	WIND SPEED CATEGORY 1 (1.500 M/S)	WIND SPEED CATEGORY 2 (2.500 M/S)	WIND SPEED CATEGORY 3 (4.300 M/S)	WIND SPEED CATEGORY 4 (6.800 M/S)	WIND SPEED CATEGORY 5 (9.500 M/S)	WIND SPEED CATEGORY 6 (12.500 M/S)
0.000	0.00047000	0.00130000	0.00296000	0.00019000	0.00000000	0.00000000
22.500	0.00025000	0.00037000	0.00065000	0.00000000	0.00000000	0.00000000
45.000	0.00005000	0.00037000	0.00046000	0.00000000	0.00000000	0.00000000
67.500	0.00097000	0.00028000	0.00028000	0.00009000	0.00000000	0.00000000
90.000	0.00007000	0.00056000	0.00009000	0.00000000	0.00000000	0.00000000
112.500	0.00024000	0.00028000	0.00028000	0.00000000	0.00000000	0.00000000
135.000	0.00048000	0.00056000	0.00074000	0.00000000	0.00000000	0.00000000
157.500	0.00003000	0.00028000	0.00083000	0.00000000	0.00000000	0.00000000
180.000	0.00094000	0.00176000	0.00139000	0.00000000	0.00000000	0.00000000
202.500	0.00042000	0.00093000	0.00074000	0.00000000	0.00000000	0.00000000
225.000	0.00026000	0.00046000	0.00120000	0.00000000	0.00000000	0.00000000
247.500	0.00048000	0.00139000	0.00269000	0.00009000	0.00000000	0.00000000
270.000	0.00071000	0.00157000	0.00296000	0.00000000	0.00000000	0.00000000
292.500	0.00044000	0.00102000	0.00269000	0.00000000	0.00000000	0.00000000
315.000	0.00039000	0.00065000	0.00278000	0.00000000	0.00000000	0.00000000
337.500	0.00028000	0.00056000	0.00167000	0.00000000	0.00000000	0.00000000

ANNUAL: STABILITY CATEGORY D

DIRECTION (DEGREES)	WIND SPEED CATEGORY 1 (1.500 M/S)	WIND SPEED CATEGORY 2 (2.500 M/S)	WIND SPEED CATEGORY 3 (4.300 M/S)	WIND SPEED CATEGORY 4 (6.800 M/S)	WIND SPEED CATEGORY 5 (9.500 M/S)	WIND SPEED CATEGORY 6 (12.500 M/S)
0.000	0.00274000	0.01083000	0.03380000	0.03593000	0.00694000	0.00074000
22.500	0.00192000	0.00639000	0.01417000	0.00981000	0.00102000	0.00019000
45.000	0.00171000	0.00630000	0.01167000	0.00824000	0.00102000	0.00037000
67.500	0.00084000	0.00565000	0.00833000	0.00546000	0.00019000	0.00000000
90.000	0.00091000	0.00426000	0.00704000	0.00259000	0.00000000	0.00000000
112.500	0.00089000	0.00194000	0.00380000	0.00157000	0.00000000	0.00000000
135.000	0.00052000	0.00231000	0.00333000	0.00093000	0.00009000	0.00000000
157.500	0.00138000	0.00500000	0.00583000	0.00222000	0.00019000	0.00000000
180.000	0.00186000	0.00796000	0.02130000	0.01157000	0.00148000	0.00037000
202.500	0.00093000	0.00454000	0.01204000	0.01167000	0.00296000	0.00120000
225.000	0.00171000	0.00528000	0.01343000	0.02065000	0.00491000	0.00185000
247.500	0.00123000	0.00343000	0.01519000	0.02694000	0.00315000	0.00074000
270.000	0.00139000	0.00509000	0.02194000	0.03037000	0.00380000	0.00111000
292.500	0.00040000	0.00426000	0.01907000	0.04454000	0.01315000	0.00222000
315.000	0.00051000	0.00324000	0.01435000	0.04204000	0.01157000	0.00167000
337.500	0.00114000	0.00454000	0.01491000	0.02833000	0.00667000	0.00102000

*** MODELING OPTIONS USED: CONC RURAL FLAT DFAULT

*** FREQUENCY OF OCCURRENCE OF WIND SPEED, DIRECTION AND STABILITY ***

FILE: TEST.DAT FORMAT: FREE
SURFACE STATION NO.: 14765 UPPER AIR STATION NO.: 14765
NAME: PROVIDENCE NAME: PROVIDENCE
YEAR: 1987 YEAR: 1987

ANNUAL: STABILITY CATEGORY E

DIRECTION (DEGREES)	WIND SPEED CATEGORY 1 (1.500 M/S)	WIND SPEED CATEGORY 2 (2.500 M/S)	WIND SPEED CATEGORY 3 (4.300 M/S)	WIND SPEED CATEGORY 4 (6.800 M/S)	WIND SPEED CATEGORY 5 (9.500 M/S)	WIND SPEED CATEGORY 6 (12.500 M/S)
0.000	0.00000000	0.00630000	0.01019000	0.00000000	0.00000000	0.00000000
22.500	0.00000000	0.00102000	0.00111000	0.00000000	0.00000000	0.00000000
45.000	0.00000000	0.00148000	0.00074000	0.00000000	0.00000000	0.00000000
67.500	0.00000000	0.00231000	0.00028000	0.00000000	0.00000000	0.00000000
90.000	0.00000000	0.00111000	0.00000000	0.00000000	0.00000000	0.00000000
112.500	0.00000000	0.00056000	0.00009000	0.00000000	0.00000000	0.00000000
135.000	0.00000000	0.00093000	0.00028000	0.00000000	0.00000000	0.00000000
157.500	0.00000000	0.00204000	0.00111000	0.00000000	0.00000000	0.00000000
180.000	0.00000000	0.00954000	0.00500000	0.00000000	0.00000000	0.00000000
202.500	0.00000000	0.00546000	0.00380000	0.00000000	0.00000000	0.00000000
225.000	0.00000000	0.00509000	0.00546000	0.00000000	0.00000000	0.00000000
247.500	0.00000000	0.00593000	0.00694000	0.00000000	0.00000000	0.00000000
270.000	0.00000000	0.00583000	0.01806000	0.00000000	0.00000000	0.00000000
292.500	0.00000000	0.00389000	0.01981000	0.00000000	0.00000000	0.00000000
315.000	0.00000000	0.00565000	0.01685000	0.00000000	0.00000000	0.00000000
337.500	0.00000000	0.00583000	0.01074000	0.00000000	0.00000000	0.00000000

ANNUAL: STABILITY CATEGORY F

DIRECTION (DEGREES)	WIND SPEED CATEGORY 1 (1.500 M/S)	WIND SPEED CATEGORY 2 (2.500 M/S)	WIND SPEED CATEGORY 3 (4.300 M/S)	WIND SPEED CATEGORY 4 (6.800 M/S)	WIND SPEED CATEGORY 5 (9.500 M/S)	WIND SPEED CATEGORY 6 (12.500 M/S)
0.000	0.00110000	0.00593000	0.00000000	0.00000000	0.00000000	0.00000000
22.500	0.00026000	0.00083000	0.00000000	0.00000000	0.00000000	0.00000000
45.000	0.00028000	0.00120000	0.00000000	0.00000000	0.00000000	0.00000000
67.500	0.00094000	0.00074000	0.00000000	0.00000000	0.00000000	0.00000000

90.000	0.00072000	0.00046000	0.00000000	0.00000000	0.00000000	0.00000000
112.500	0.00040000	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000
135.000	0.00094000	0.00065000	0.00000000	0.00000000	0.00000000	0.00000000
157.500	0.00110000	0.00157000	0.00000000	0.00000000	0.00000000	0.00000000
180.000	0.00291000	0.00491000	0.00000000	0.00000000	0.00000000	0.00000000
202.500	0.00140000	0.00454000	0.00000000	0.00000000	0.00000000	0.00000000
225.000	0.00168000	0.00565000	0.00000000	0.00000000	0.00000000	0.00000000
247.500	0.00220000	0.01037000	0.00000000	0.00000000	0.00000000	0.00000000
270.000	0.00148000	0.01287000	0.00000000	0.00000000	0.00000000	0.00000000
292.500	0.00132000	0.01194000	0.00000000	0.00000000	0.00000000	0.00000000
315.000	0.00151000	0.00898000	0.00000000	0.00000000	0.00000000	0.00000000
337.500	0.00166000	0.00824000	0.00000000	0.00000000	0.00000000	0.00000000

SUM OF FREQUENCIES, FTOTAL = 0.98123

*** MODELING OPTIONS USED: CONC RURAL FLAT DFAULT

*** THE ANNUAL AVERAGE CONCENTRATION VALUES FOR SOURCE: STACK1 ***

*** NETWORK ID: POL ; NETWORK TYPE: GRIDPOLR ***

** CONC OF VYCL IN MICROGRAMS/M**3 **

DIRECTION (DEGREES)	DISTANCE (METERS) 50.00	100.00	150.00	200.00	250.00	300.00	350.00	400.00	450.00
360.00	0.000000	0.000109	0.001093	0.002126	0.002967	0.003519	0.003769	0.003849	0.003825
45.00	0.000000	0.000252	0.001767	0.003080	0.003905	0.004280	0.004320	0.004210	0.004029
90.00	0.000000	0.000296	0.002335	0.004202	0.005454	0.006083	0.006218	0.006108	0.005880
135.00	0.000000	0.000467	0.003333	0.005741	0.007117	0.007614	0.007525	0.007187	0.006756
180.00	0.000000	0.000330	0.002849	0.005253	0.006933	0.007827	0.008060	0.007969	0.007707
225.00	0.000000	0.000063	0.000659	0.001285	0.001782	0.002095	0.002226	0.002260	0.002235
270.00	0.000000	0.000022	0.000245	0.000514	0.000766	0.000955	0.001058	0.001109	0.001124
315.00	0.000000	0.000018	0.000186	0.000355	0.000499	0.000601	0.000655	0.000679	0.000685

*** MODELING OPTIONS USED: CONC RURAL FLAT DFAULT

*** THE ANNUAL AVERAGE CONCENTRATION VALUES FOR SOURCE: STACK1 ***

*** NETWORK ID: POL ; NETWORK TYPE: GRIDPOLR ***

** CONC OF VYCL IN MICROGRAMS/M**3 **

DIRECTION (DEGREES)	DISTANCE (METERS) 500.00	550.00	600.00	650.00	700.00	750.00	800.00	850.00	900.00
360.00	0.003738	0.003616	0.003476	0.003330	0.003184	0.003042	0.002905	0.002776	0.002654
45.00	0.003818	0.003601	0.003390	0.003190	0.003004	0.002832	0.002674	0.002530	0.002397
90.00	0.005599	0.005302	0.005009	0.004730	0.004470	0.004227	0.004003	0.003798	0.003609
135.00	0.006303	0.005863	0.005453	0.005078	0.004740	0.004433	0.004157	0.003908	0.003683
180.00	0.007359	0.006976	0.006587	0.006209	0.005851	0.005513	0.005199	0.004909	0.004641
225.00	0.002173	0.002092	0.002001	0.001906	0.001812	0.001720	0.001632	0.001548	0.001470
270.00	0.001115	0.001090	0.001055	0.001016	0.000974	0.000931	0.000889	0.000848	0.000809
315.00	0.000676	0.000660	0.000639	0.000615	0.000590	0.000565	0.000540	0.000516	0.000493

*** MODELING OPTIONS USED: CONC RURAL FLAT DFAULT

*** THE ANNUAL AVERAGE CONCENTRATION VALUES FOR SOURCE: STACK1 ***

*** NETWORK ID: POL ; NETWORK TYPE: GRIDPOLR ***

** CONC OF VYCL IN MICROGRAMS/M**3 **

DIRECTION (DEGREES)	DISTANCE (METERS) 2800.00	2900.00	3000.00	3100.00	3200.00	3300.00	3400.00	3500.00	3600.00
360.00	0.000856	0.000822	0.000790	0.000760	0.000732	0.000705	0.000681	0.000657	0.000635
45.00	0.000716	0.000687	0.000659	0.000634	0.000610	0.000587	0.000566	0.000547	0.000529
90.00	0.001136	0.001091	0.001048	0.001009	0.000972	0.000937	0.000904	0.000873	0.000844
135.00	0.001047	0.001004	0.000963	0.000925	0.000890	0.000857	0.000826	0.000796	0.000769
180.00	0.001246	0.001190	0.001139	0.001091	0.001047	0.001006	0.000967	0.000931	0.000897
225.00	0.000392	0.000374	0.000358	0.000342	0.000328	0.000315	0.000302	0.000291	0.000280
270.00	0.000228	0.000218	0.000209	0.000200	0.000192	0.000185	0.000178	0.000171	0.000165
315.00	0.000152	0.000146	0.000140	0.000135	0.000130	0.000125	0.000120	0.000116	0.000112

** MODELING OPTIONS USED: CONC RURAL FLAT DFAULT

*** THE ANNUAL AVERAGE CONCENTRATION VALUES FOR SOURCE: STACK1 ***

*** NETWORK ID: POL ; NETWORK TYPE: GRIDPOLR ***

** CONC OF VYCL IN MICROGRAMS/M**3 **

DIRECTION | DISTANCE (METERS)

(DEGREES)	3700.00	3800.00	3900.00	4000.00	4100.00	4200.00	4300.00	4400.00	4500.00
360.00	0.000614	0.000595	0.000576	0.000558	0.000542	0.000526	0.000511	0.000496	0.000482
45.00	0.000510	0.000494	0.000478	0.000463	0.000449	0.000436	0.000423	0.000411	0.000399
90.00	0.000817	0.000791	0.000766	0.000743	0.000720	0.000699	0.000679	0.000660	0.000642
135.00	0.000743	0.000718	0.000695	0.000673	0.000653	0.000633	0.000614	0.000597	0.000580
180.00	0.000864	0.000834	0.000806	0.000779	0.000754	0.000729	0.000707	0.000685	0.000665
225.00	0.000270	0.000260	0.000251	0.000242	0.000234	0.000227	0.000219	0.000212	0.00
270.00	0.000159	0.000153	0.000148	0.000143	0.000139	0.000134	0.000130	0.000126	0.0
315.00	0.000109	0.000105	0.000102	0.000099	0.000096	0.000093	0.000090	0.000088	0.000

*** MODELING OPTIONS USED: CONC RURAL FLAT DFAULT

*** THE ANNUAL AVERAGE CONCENTRATION VALUES FOR SOURCE: STACK1 ***

*** NETWORK ID: POL ; NETWORK TYPE: GRIDPOLR ***

** CONC OF VYCL IN MICROGRAMS/M**3 **

DIRECTION (DEGREES)	DISTANCE (METERS) 4600.00	4700.00	4800.00
360.00	0.000469	0.000457	0.000445
45.00	0.000388	0.000378	0.000368
90.00	0.000625	0.000608	0.000593
135.00	0.000564	0.000548	0.000534
180.00	0.000645	0.000626	0.000609
225.00	0.000200	0.000194	0.000188
270.00	0.000119	0.000115	0.000112
315.00	0.000083	0.000081	0.000078

*** MODELING OPTIONS USED: CONC RURAL FLAT DFAULT

*** THE ANNUAL AVERAGE CONCENTRATION VALUES FOR SOURCE: STACK1 ***

*** DISCRETE CARTESIAN RECEPTOR POINTS ***

** CONC OF VYCL IN MICROGRAMS/M**3 **

X-COORD (M)	Y-COORD (M)	CONC	X-COORD (M)	Y-COORD (M)	CONC
99.06	670.56	0.000614	30.48	662.94	0.000649
22.86	563.88	0.000793	15.24	541.02	0.000870
60.96	533.40	0.000805	91.44	434.34	0.001061
121.92	297.18	0.001822	259.08	15.24	0.004416
388.62	640.08	0.001258	487.68	670.56	0.002604
563.88	243.84	0.006901	243.84	655.32	0.000478
167.64	274.32	0.002057	114.30	647.70	0.000582
91.44	594.36	0.000592	228.60	129.54	0.002633
365.76	144.78	0.007737			

*** MODELING OPTIONS USED: CONC RURAL FLAT DFAULT

*** THE MAXIMUM 10 ANNUAL AVERAGE CONCENTRATION VALUES FOR SOURCE: STACK1 ***

** CONC OF VYCL IN MICROGRAMS/M**3 **

RANK	CONC	AT	RECEPTOR (XR,YR)	OF TYPE	RANK	CONC	AT	RECEPTOR (XR,YR)	OF TYPE
1.	0.008060	AT (	375.00, 130.00)	GP	6.	0.007614	AT (	587.13, 267.87)	GP
2.	0.007969	AT (	375.00, 80.00)	GP	7.	0.007525	AT (	622.49, 232.51)	GP
3.	0.007827	AT (	375.00, 180.00)	GP	8.	0.007359	AT (	375.00, -20.00)	GP
4.	0.007737	AT (	365.76, 144.78)	DC	9.	0.007187	AT (	657.84, 197.16)	GP
5.	0.007707	AT (	375.00, 30.00)	GP	10.	0.007117	AT (	551.78, 303.22)	GP

*** RECEPTOR TYPES: GC = GRIDCART
GP = GRIDPOLR
DC = DISCCART
DP = DISCPOLR
BD = BOUNDARY

*** MODELING OPTIONS USED: CONC RURAL FLAT DFAULT

*** Message Summary : ISCLT3 Model Execution ***

--------- Summary of Total Messages --------

A Total of 0 Fatal Error Message(s)
A Total of 0 Warning Message(s)
A Total of 0 Informational Message(s)

******** FATAL ERROR MESSAGES ********

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          ***  NONE  ***

********   WARNING MESSAGES   ********
          ***  NONE  ***

************************************
*** ISCLT3 Finishes Successfully ***
************************************
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RESTABLT.WK1

The attached table presents modeled concentrations of analytes of concern at the Site for dispersion from a flare. The maximum modeled concentrations from LTRESULT were used to proportionally determine the analytes' concentration at various receptors. Some analytes were not detected in landfill gas SUMMA canister sampling, but are noted due to detections in ambient air at residences.

Metcalf & Eddy, Inc.

MODELED CONCENTRATIONS OF LANDFILL GAS CONTAMINANTS AT RESIDENTIAL RECEPTORS, ROSE HILL REGIONAL LANDFILL SUPERFUND SITE
SOLID WASTE LANDFILL - POINT SOURCE MODELING - FLARE

Maximum Modeled Concentration Based on 3,100 (mg/m^3) ->		6.14E-04	6.49E-04	7.93E-04	8.70E-04	8.05E-04	1.06E-03	1.82E-03	4.42E-03	1.26E-03	2.60E-03
		Concentration (μg/m^3)									
	SUMMA	Receptor #									
	Max (μg/m^3)	1	2	3	4	5	6	7	8	9	10
Acetone	0	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Benzene	8,000	1.58E-06	1.67E-06	2.05E-06	2.25E-06	2.08E-06	2.74E-06	4.70E-06	1.14E-05	3.25E-06	6.72E-06
Carbon Disulfide	870	1.72E-07	1.82E-07	2.23E-07	2.44E-07	2.26E-07	2.98E-07	5.11E-07	1.24E-06	3.53E-07	7.31E-07
Dichlorodifluoromethane	110,000	2.18E-05	2.30E-05	2.81E-05	3.09E-05	2.86E-05	3.76E-05	6.47E-05	1.57E-04	4.46E-05	9.24E-05
1,1-Dichloroethane	140,000	2.77E-05	2.93E-05	3.58E-05	3.93E-05	3.64E-05	4.79E-05	8.23E-05	1.99E-04	5.68E-05	1.18E-04
1,1-Dichloroethene	32,000	6.34E-06	6.70E-06	8.19E-06	8.98E-06	8.31E-06	1.10E-05	1.88E-05	4.56E-05	1.30E-05	2.69E-05
cis-1,2-Dichloroethene	23,000,000	4.56E-03	4.82E-03	5.88E-03	6.45E-03	5.97E-03	7.87E-03	1.35E-02	3.28E-02	9.33E-03	1.93E-02
trans-1,2-Dichloroethene	27,000	5.35E-06	5.65E-06	6.91E-06	7.58E-06	7.01E-06	9.24E-06	1.59E-05	3.85E-05	1.10E-05	2.27E-05
Ethylbenzene	25,000	4.95E-06	5.23E-06	6.40E-06	7.02E-06	6.49E-06	8.56E-06	1.47E-05	3.56E-05	1.01E-05	2.10E-05
4-Methyl-2-pentanone	6,600	1.31E-06	1.38E-06	1.69E-06	1.85E-06	1.71E-06	2.26E-06	3.88E-06	9.40E-06	2.68E-06	5.54E-06
Methylene Chloride	66,000	1.31E-05	1.38E-05	1.69E-05	1.85E-05	1.71E-05	2.26E-05	3.88E-05	9.40E-05	2.68E-05	5.54E-05
1,1,2,2-Tetrachloroethane	0	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Toluene	230,000	4.56E-05	4.82E-05	5.88E-05	6.45E-05	5.97E-05	7.87E-05	1.35E-04	3.28E-04	9.33E-05	1.93E-04
1,2,4-Trichlorobenzene	0	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
1,1,1-Trichloroethane	10,000	1.98E-06	2.09E-06	2.56E-06	2.81E-06	2.60E-06	3.42E-06	5.88E-06	1.42E-05	4.06E-06	8.40E-06
Trichloroethene	31,000	6.14E-06	6.49E-06	7.93E-06	8.70E-06	8.05E-06	1.06E-05	1.82E-05	4.42E-05	1.26E-05	2.60E-05
1,2,4-Trimethylbenzene	2,000	3.96E-07	4.19E-07	5.12E-07	5.61E-07	5.19E-07	6.85E-07	1.18E-06	2.85E-06	8.12E-07	1.68E-06
1,3,5-Trimethylbenzene	4,300	8.52E-07	9.00E-07	1.10E-06	1.21E-06	1.12E-06	1.47E-06	2.53E-06	6.13E-06	1.74E-06	3.61E-06
Vinyl Chloride	3,100,000	6.14E-04	6.49E-04	7.93E-04	8.70E-04	8.05E-04	1.06E-03	1.82E-03	4.42E-03	1.26E-03	2.60E-03
m,p-Xylene	41,000	8.12E-06	8.58E-06	1.05E-05	1.15E-05	1.06E-05	1.40E-05	2.41E-05	5.84E-05	1.66E-05	3.44E-05
o-Xylene	11,000	2.18E-06	2.30E-06	2.81E-06	3.09E-06	2.86E-06	3.76E-06	6.47E-06	1.57E-05	4.46E-06	9.24E-06

MODELED CONCENTRATIONS OF LANDFILL GAS CONTAMINANTS AT RESIDENTIAL RECEPTORS, ROSE HILL REGIONAL LANDFILL SUPERFUND SITE
SOLID WASTE LANDFILL - POINT SOURCE MODELING - FLARE

Maximum Modeled Concentration Based on 3,100 (mg/m^3) ->		6.90E-03	4.78E-04	2.06E-03	5.82E-04	5.92E-04	2.63E-03	7.74E-03	8.06E-03
		Concentration (µg/m^3)							
	SUMMA	Receptor #							Maximum
	Max (µg/m^3)	11	12	13	14	15	16	17	Receptor
Benzene	8,000	1.78E-05	1.23E-06	5.31E-06	1.50E-06	1.53E-06	6.79E-06	2.00E-05	2.08E-05
Acetone	0	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Carbon Disulfide	870	1.94E-06	1.34E-07	5.77E-07	1.63E-07	1.66E-07	7.39E-07	2.17E-06	2.26E-06
Dichlorodifluoromethane	110,000	2.45E-04	1.70E-05	7.30E-05	2.07E-05	2.10E-05	9.34E-05	2.75E-04	2.86E-04
1,1-Dichloroethane	140,000	3.12E-04	2.16E-05	9.29E-05	2.63E-05	2.67E-05	1.19E-04	3.49E-04	3.64E-04
1,1-Dichloroethene	32,000	7.12E-05	4.93E-06	2.12E-05	6.01E-06	6.11E-06	2.72E-05	7.99E-05	8.32E-05
cis-1,2-Dichloroethene	23,000,000	5.12E-02	3.55E-03	1.53E-02	4.32E-03	4.39E-03	1.95E-02	5.74E-02	5.98E-02
trans-1,2-Dichloroethene	27,000	6.01E-05	4.16E-06	1.79E-05	5.07E-06	5.16E-06	2.29E-05	6.74E-05	7.02E-05
Ethylbenzene	25,000	5.57E-05	3.85E-06	1.66E-05	4.69E-06	4.77E-06	2.12E-05	6.24E-05	6.50E-05
4-Methyl-2-pentanone	6,600	1.47E-05	1.02E-06	4.38E-06	1.24E-06	1.26E-06	5.61E-06	1.65E-05	1.72E-05
Methylene Chloride	66,000	1.47E-04	1.02E-05	4.38E-05	1.24E-05	1.26E-05	5.61E-05	1.65E-04	1.72E-04
1,1,2,2-Tetrachloroethane	0	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Toluene	230,000	5.12E-04	3.55E-05	1.53E-04	4.32E-05	4.39E-05	1.95E-04	5.74E-04	5.98E-04
1,2,4-Trichlorobenzene	0	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
1,1,1-Trichloroethane	10,000	2.23E-05	1.54E-06	6.64E-06	1.88E-06	1.91E-06	8.49E-06	2.50E-05	2.60E-05
Trichloroethene	31,000	6.90E-05	4.78E-06	2.06E-05	5.82E-06	5.92E-06	2.63E-05	7.74E-05	8.06E-05
1,2,4-Trimethylbenzene	2,000	4.45E-06	3.08E-07	1.33E-06	3.75E-07	3.82E-07	1.70E-06	4.99E-06	5.20E-06
1,3,5-Trimethylbenzene	4,300	9.57E-06	6.63E-07	2.85E-06	8.07E-07	8.21E-07	3.65E-06	1.07E-05	1.12E-05
Vinyl Chloride	3,100,000	6.90E-03	4.78E-04	2.06E-03	5.82E-04	5.92E-04	2.63E-03	7.74E-03	8.06E-03
m,p-Xylene	41,000	9.13E-05	6.32E-06	2.72E-05	7.70E-06	7.83E-06	3.48E-05	1.02E-04	1.07E-04
o-Xylene	11,000	2.45E-05	1.70E-06	7.30E-06	2.07E-06	2.10E-06	9.34E-06	2.75E-05	2.86E-05

Notes:

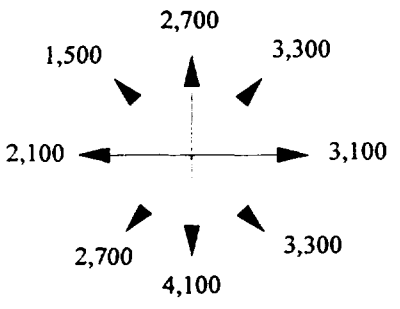
1) ISCLT3 model utilized.
2) Receptors #1 through 10 are nearby residences.
   Receptors #11 is the transfer station.
   Receptors #12 through 17 are locations on roadways and driveways along the landfill perimeter.
   Maximum Receptor is the maximum modeled concentration located in the southern direction from the flare stack, approximately 350 meters away.
3) Modeling assumptions are presented in RECEPTOR.WK1, SUMMA.WK1, FLARE.WK1 and LTRESULT.

F-3 PRG Exceedances

Utilizing ISCST3 model runs, the extent of PRG exceedances for vinyl chloride was determined. The PRG (Preliminary Remediation Guideline) utilized was 0.03 $\mu g/m^3$. As with model runs performed for risk assessment purposes, five runs were performed to cover the years 1987 to 1991. A site center point was selected (shown on Attachment A) and a polar grid was used to define distances that annual average dispersion concentrations were above PRGs. Although meteorologic data for ISCST3 is for every 10 degrees, just to get an approximation of the extent of impact, results were only determined for every 45 degrees. Maximum distances in each direction from the five years are presented below. 1991 results had many of the maximum distances and the model output for this year is presented as Attachment B. The extent of PRG exceedence was assumed to be halfway between the last distance above the PRG and the next distance below the PRG.

Vinyl Chloride

Meters from site center point shown on attached figure:



Meters	Miles
1,500	0.9
2,100	1.3
2,700	1.7
3,100	1.9
3,300	2.1
4,100	2.5

Other Compounds

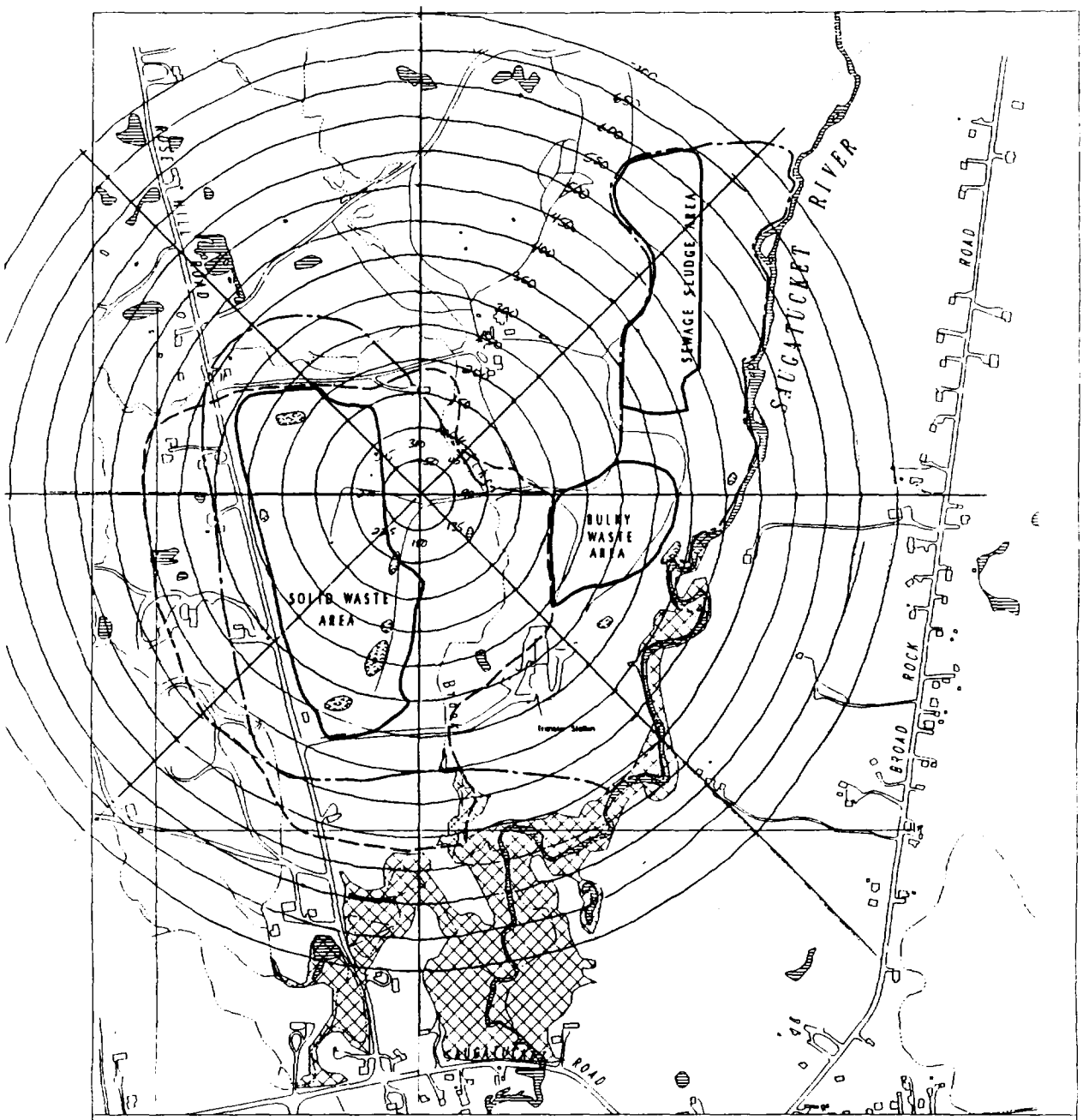
Other compound impact concentrations may be determined proportionally from the vinyl chloride results and then compared to respective PRGs to see if impacts are extended at all. By determining what each compound's concentration would be at vinyl chloride's PRG, we can say if impacts are extended.

Analyte	SUMMA Maximum Concentration ($\mu g/m^3$)	PRG	Model Result Corresponding to Vinyl Chloride = 0.03
Vinyl Chloride	3,100,000	0.03	0.030
1,1-Dichloroethene	32,000	0.1	0.00031
Benzene	8,000	0.3	0.000077
1,1,2,2-Tetrachloroethane	0*	0.04	Not Applicable

* Not detected in SUMMA canister landfill gas samples

Since a modeled concentration of 0.03 $\mu g/m^3$ vinyl chloride corresponds to other analyte concentrations which are way below respective PRG's, vinyl chloride defines the extent of impacts.

METCALF & EDDY



LEGEND

- Primary Road
- Secondary Road
- Stream or Brook
- Limit of GA Non-Attainment GW Classification
- Limit of GW PRG Exceedance
- Limit of Waste Placement and Limit of GB GW Classification Area
- Lake, Pond, or River
- Area of Leachate Breakout
- 100-Year Flood Plain

500 0 500

SCALE IN FEET

FIGURE [redacted]

[redacted]

AIR MODELING BASE POINT

ROSE HILL LANDFILL

SOUTH KINGSTOWN, RI

METCALF & EDDY

ATTACHMENT A

ATTACHMENT B

```
** Rosehill - ISCST3
** Area emissions from the Solid Waste Area
** Ground 0 (Landfill assumed same level as receptors - worst case)
** 1991 data
** PRG Exceedance Run based on 1997 LFG flow rate
   Vinyl chloride emissions (Concentration = 3,100,000 ug/m^3)

CO STARTING
   TITLEONE  ROSEHILL - SOLID WASTE AREA EMISSIONS - ISCST3
   MODELOPT  DFAULT  CONC  RURAL
   AVERTIME  PERIOD
   TERRHGTS  FLAT
   POLLUTID  UNIT
   RUNORNOT  RUN
CO FINISHED

SO STARTING

**  SOLID WASTE AREA (FS Version - 8/96)
**  x, y, and z coordinates, respectively (m)

SO LOCATION     SQUARE1     AREA        121.92    533.40        0.
SO LOCATION     SQUARE2     AREA        228.60    533.40        0.
SO LOCATION     SQUARE3     AREA        137.16    457.20        0.
SO LOCATION     SQUARE4     AREA        213.36    487.68        0.
SO LOCATION     SQUARE5     AREA        259.08    487.68        0.
SO LOCATION     SQUARE6     AREA        304.80    502.92        0.
SO LOCATION     SQUARE7     AREA        304.80    487.68        0.
SO LOCATION     SQUARE8     AREA        320.04    487.68        0.
SO LOCATION     SQUARE9     AREA        213.36    472.44        0.
SO LOCATION     SQUARE10    AREA        213.36    457.20        0.
SO LOCATION     SQUARE11    AREA        228.60    381.00        0.
SO LOCATION     SQUARE12    AREA        152.40    381.00        0.
SO LOCATION     SQUARE13    AREA        167.64    335.28        0.
SO LOCATION     SQUARE14    AREA        213.36    335.28        0.
SO LOCATION     SQUARE15    AREA        259.08    350.52        0.
SO LOCATION     SQUARE16    AREA        335.28    381.00        0.
SO LOCATION     SQUARE17    AREA        289.56    289.56        0.
SO LOCATION     SQUARE18    AREA        259.08    320.04        0.
SO LOCATION     SQUARE19    AREA        182.88    259.08        0.
SO LOCATION     SQUARE20    AREA        259.08    289.56        0.
SO LOCATION     SQUARE21    AREA        259.08    259.08        0.
SO LOCATION     SQUARE22    AREA        289.56    213.36        0.
SO LOCATION     SQUARE23    AREA        198.12    213.36        0.
   LOCATION     SQUARE24    AREA        243.84    213.36        0.
   LOCATION     SQUARE25    AREA        213.36    182.88        0.
   LOCATION     SQUARE26    AREA        243.84    137.16        0.
SO LOCATION     SQUARE27    AREA        320.04    167.64        0.

**  Emission rate (g/m^2-s), release height (m), length of square (m)

SO SRCPARAM     SQUARE1      9.65E-07       0.0     106.68
SO SRCPARAM     SQUARE2      9.65E-07       0.0      91.44
SO SRCPARAM     SQUARE3      9.65E-07       0.0      76.20
SO SRCPARAM     SQUARE4      9.65E-07       0.0      45.72
SO SRCPARAM     SQUARE5      9.65E-07       0.0      45.72
SO SRCPARAM     SQUARE6      9.65E-07       0.0      30.48
SO SRCPARAM     SQUARE7      9.65E-07       0.0      15.24
SO SRCPARAM     SQUARE8      9.65E-07       0.0      15.24
SO SRCPARAM     SQUARE9      9.65E-07       0.0      15.24
SO SRCPARAM     SQUARE10     9.65E-07       0.0      15.24
SO SRCPARAM     SQUARE11     9.65E-07       0.0     106.68
SO SRCPARAM     SQUARE12     9.65E-07       0.0      76.20
SO SRCPARAM     SQUARE13     9.65E-07       0.0      45.72
SO SRCPARAM     SQUARE14     9.65E-07       0.0      45.72
SO SRCPARAM     SQUARE15     9.65E-07       0.0      30.48
SO SRCPARAM     SQUARE16     9.65E-07       0.0      30.48
SO SRCPARAM     SQUARE17     9.65E-07       0.0      91.44
SO SRCPARAM     SQUARE18     9.65E-07       0.0      30.48
SO SRCPARAM     SQUARE19     9.65E-07       0.0      76.20
SO SRCPARAM     SQUARE20     9.65E-07       0.0      30.48
SO SRCPARAM     SQUARE21     9.65E-07       0.0      30.48
SO SRCPARAM     SQUARE22     9.65E-07       0.0      76.20
SO SRCPARAM     SQUARE23     9.65E-07       0.0      45.72
SO SRCPARAM     SQUARE24     9.65E-07       0.0      45.72
SO SRCPARAM     SQUARE25     9.65E-07       0.0      30.48
SO SRCPARAM     SQUARE26     9.65E-07       0.0      76.20
SO SRCPARAM     SQUARE27     9.65E-07       0.0      45.72

SO SRCGROUP ALL
SO FINISHED

RE STARTING
   GRIDPOLR POL STA
   GRIDPOLR POL ORIG   375. 480.
   GRIDPOLR POL DIST   200. 400. 600. 800. 1000.
RE GRIDPOLR POL DIST   1200. 1400. 1600. 1800. 2000. 2200. 2400.
RE GRIDPOLR POL DIST   2600. 2800. 3000. 3200. 3400. 3600. 3800.
RE GRIDPOLR POL DIST   4000. 4200. 4400. 4600. 4800. 5000. 5200.
RE GRIDPOLR POL DIST   5400. 5600. 5800. 6000. 6200. 6400. 6600.
RE GRIDPOLR POL DIST   6800. 7000. 7200. 7400. 7600. 7800. 8000.
RE GRIDPOLR POL GDIR   8    0.  45.
RE GRIDPOLR POL END
```

```
RE FINISHED

ME STARTING

** 1991
   INPUTFIL  lprov91.bin  unform
   ANEMHGHT  20. FEET
** SURFACE DATA FROM 1991 at Providence was utilized. MIXING FROM CHATHAM.
   SURFDATA  14765  1991  SURFNAME
   UAIRDATA  14684  1991  UAIRNAME

ME FINISHED

OU STARTING
   RECTABLE  ALLAVE FIRST
OU FINISHED

**********************************
*** SETUP Finishes Successfully ***
**********************************
```

```
**MODELOPTs: CONC                      RURAL  FLAT          DFAULT

                                       ***     MODEL SETUP OPTIONS SUMMARY       ***
- - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - -

  ıtermediate Terrain Processing is Selected

**Model Is Setup For Calculation of Average CONCentration Values.

  -- SCAVENGING/DEPOSITION LOGIC --
**Model Uses NO DRY DEPLETION.  DDPLETE =  F
**Model Uses NO WET DEPLETION.  WDPLETE =  F
**NO WET SCAVENGING Data Provided.
**Model Does NOT Use GRIDDED TERRAIN Data for Depletion Calculations

**Model Uses RURAL Dispersion.

**Model Uses Regulatory DEFAULT Options:
          1. Final Plume Rise.
          2. Stack-tip Downwash.
          3. Buoyancy-induced Dispersion.
          4. Use Calms Processing Routine.
          5. Not Use Missing Data Processing Routine.
          6. Default Wind Profile Exponents.
          7. Default Vertical Potential Temperature Gradients.
          8. "Upper Bound" Values for Supersquat Buildings.
          9. No Exponential Decay for RURAL Mode

**Model Assumes Receptors on FLAT Terrain.

**Model Assumes No FLAGPOLE Receptor Heights.

**Model Calculates PERIOD Averages Only

**This Run Includes:   27 Source(s);      1 Source Group(s); and    320 Receptor(s)

**The Model Assumes A Pollutant Type of:  UNIT

**Model Set To Continue RUNning After the Setup Testing.

**Output Options Selected:
        Model Outputs Tables of PERIOD Averages by Receptor
        Model Outputs Tables of Highest Short Term Values by Receptor (RECTABLE Keyword)

   OTE:  The Following Flags May Appear Following CONC Values:  c for Calm Hours
                                                                m for Missing Hours
                                                                b for Both Calm and Missing Hours

**Misc. Inputs:  Anem. Hgt. (m) =     6.10 ;    Decay Coef. =   0.0000     ;    Rot. Angle =     0.0
                 Emission Units = GRAMS/SEC                                ;  Emission Rate Unit Factor =   0.10000E+07
                 Output Units   = MICROGRAMS/M**3

**Input Runstream File: rhfs32.inp                                ;  **Output Print File: rhfs32.out
```

**MODELOPTs: CONC RURAL FLAT DFAULT

*** AREA SOURCE DATA ***

SOURCE ID	NUMBER PART. CATS.	EMISSION RATE (GRAMS/SEC /METER**2)	COORD (SW CORNER) X (METERS)	Y (METERS)	BASE ELEV. (METERS)	RELEASE HEIGHT (METERS)	X-DIM OF AREA (METERS)	Y-DIM OF AREA (METERS)	ORIENT. OF AREA (DEG.)	INIT. SZ (METERS)	EMISSION RATE SCALAR VARY BY
SQUARE1	0	0.96500E-06	121.9	533.4	0.0	0.00	106.68	106.68	0.00	0.00	
SQUARE2	0	0.96500E-06	228.6	533.4	0.0	0.00	91.44	91.44	0.00	0.00	
SQUARE3	0	0.96500E-06	137.2	457.2	0.0	0.00	76.20	76.20	0.00	0.00	
SQUARE4	0	0.96500E-06	213.4	487.7	0.0	0.00	45.72	45.72	0.00	0.00	
SQUARE5	0	0.96500E-06	259.1	487.7	0.0	0.00	45.72	45.72	0.00	0.00	
SQUARE6	0	0.96500E-06	304.8	502.9	0.0	0.00	30.48	30.48	0.00	0.00	
SQUARE7	0	0.96500E-06	304.8	487.7	0.0	0.00	15.24	15.24	0.00	0.00	
SQUARE8	0	0.96500E-06	320.0	487.7	0.0	0.00	15.24	15.24	0.00	0.00	
SQUARE9	0	0.96500E-06	213.4	472.4	0.0	0.00	15.24	15.24	0.00	0.00	
SQUARE10	0	0.96500E-06	213.4	457.2	0.0	0.00	15.24	15.24	0.00	0.00	
SQUARE11	0	0.96500E-06	228.6	381.0	0.0	0.00	106.68	106.68	0.00	0.00	
SQUARE12	0	0.96500E-06	152.4	381.0	0.0	0.00	76.20	76.20	0.00	0.00	
SQUARE13	0	0.96500E-06	167.6	335.3	0.0	0.00	45.72	45.72	0.00	0.00	
SQUARE14	0	0.96500E-06	213.4	335.3	0.0	0.00	45.72	45.72	0.00	0.00	
SQUARE15	0	0.96500E-06	259.1	350.5	0.0	0.00	30.48	30.48	0.00	0.00	
SQUARE16	0	0.96500E-06	335.3	381.0	0.0	0.00	30.48	30.48	0.00	0.00	
SQUARE17	0	0.96500E-06	289.6	289.6	0.0	0.00	91.44	91.44	0.00	0.00	
SQUARE18	0	0.96500E-06	259.1	320.0	0.0	0.00	30.48	30.48	0.00	0.00	
SQUARE19	0	0.96500E-06	182.9	259.1	0.0	0.00	76.20	76.20	0.00	0.00	
SQUARE20	0	0.96500E-06	259.1	289.6	0.0	0.00	30.48	30.48	0.00	0.00	
SQUARE21	0	0.96500E-06	259.1	259.1	0.0	0.00	30.48	30.48	0.00	0.00	
SQUARE22	0	0.96500E-06	289.6	213.4	0.0	0.00	76.20	76.20	0.00	0.00	
SQUARE23	0	0.96500E-06	198.1	213.4	0.0	0.00	45.72	45.72	0.00	0.00	
SQUARE24	0	0.96500E-06	243.8	213.4	0.0	0.00	45.72	45.72	0.00	0.00	
SQUARE25	0	0.96500E-06	213.4	182.9	0.0	0.00	30.48	30.48	0.00	0.00	
SQUARE26	0	0.96500E-06	243.8	137.2	0.0	0.00	76.20	76.20	0.00	0.00	
SQUARE27	0	0.96500E-06	320.0	167.6	0.0	0.00	45.72	45.72	0.00	0.00	

**MODELOPTs: CONC RURAL FLAT DFAULT

*** SOURCE IDs DEFINING SOURCE GROUPS ***

GROUP ID	SOURCE IDs
ALL	SQUARE1 , SQUARE2 , SQUARE3 , SQUARE4 , SQUARE5 , SQUARE6 , SQUARE7 , SQUARE8 , SQUARE9 , SQUARE10, SQUARE11, SQUARE12, SQUARE13, SQUARE14, SQUARE15, SQUARE16, SQUARE17, SQUARE18, SQUARE19, SQUARE20, SQUARE21, SQUARE22, SQUARE23, SQUARE24, SQUARE25, SQUARE26, SQUARE27,

**MODELOPTs: CONC RURAL FLAT DFAULT

*** GRIDDED RECEPTOR NETWORK SUMMARY ***

*** NETWORK ID: POL ; NETWORK TYPE: GRIDPOLR ***

*** ORIGIN FOR POLAR NETWORK ***
X-ORIG = 375.00 ; Y-ORIG = 480.00 (METERS)

*** DISTANCE RANGES OF NETWORK ***
(METERS)

200.0,	400.0,	600.0,	800.0,	1000.0,	1200.0,	1400.0,	1600.0,	1800.0,	2000.0,
2200.0,	2400.0,	2600.0,	2800.0,	3000.0,	3200.0,	3400.0,	3600.0,	3800.0,	4000.0,
4200.0,	4400.0,	4600.0,	4800.0,	5000.0,	5200.0,	5400.0,	5600.0,	5800.0,	6000.0,
6200.0,	6400.0,	6600.0,	6800.0,	7000.0,	7200.0,	7400.0,	7600.0,	7800.0,	8000.0,

*** DIRECTION RADIALS OF NETWORK ***
(DEGREES)

360.0,	45.0,	90.0,	135.0,	180.0,	225.0,	270.0,	315.0,

**MODELOPTs: CONC RURAL FLAT DFAULT

*** METEOROLOGICAL DAYS SELECTED FOR PROCESSING ***
(1=YES; 0=NO)

```
1 1 1 1 1 1 1 1 1 1   1 1 1 1 1 1 1 1 1 1   1 1 1 1 1 1 1 1 1 1   1 1 1 1 1 1 1 1 1 1   1 1 1 1 1 1 1 1 1 1
1 1 1 1 1 1 1 1 1 1   1 1 1 1 1 1 1 1 1 1   1 1 1 1 1 1 1 1 1 1   1 1 1 1 1 1 1 1 1 1   1 1 1 1 1 1 1 1 1 1
1 1 1 1 1 1 1 1 1 1   1 1 1 1 1 1 1 1 1 1   1 1 1 1 1 1 1 1 1 1   1 1 1 1 1 1 1 1 1 1   1 1 1 1 1 1 1 1 1 1
1 1 1 1 1 1 1 1 1 1   1 1 1 1 1 1 1 1 1 1   1 1 1 1 1 1 1 1 1 1   1 1 1 1 1 1 1 1 1 1   1 1 1 1 1 1 1 1 1 1
1 1 1 1 1 1 1 1 1 1   1 1 1 1 1 1 1 1 1 1   1 1 1 1 1 1 1 1 1 1   1 1 1 1 1 1 1 1 1 1   1 1 1 1 1 1 1 1 1 1
1 1 1 1 1 1 1 1 1 1   1 1 1 1 1 1 1 1 1 1   1 1 1 1 1 1 1 1 1 1   1 1 1 1 1 1 1 1 1 1   1 1 1 1 1 1 1 1 1 1
1 1 1 1 1 1 1 1 1 1   1 1 1 1 1 1 1 1 1 1   1 1 1 1 1 1 1 1 1 1   1 1 1 1 1 1 1 1 1 1   1 1 1 1 1 1 1 1 1 1
1 1 1 1 1 1 1 1 1 1   1 1 1 1 1 1
```

NOTE: METEOROLOGICAL DATA ACTUALLY PROCESSED WILL ALSO DEPEND ON WHAT IS INCLUDED IN THE DATA FILE.

*** UPPER BOUND OF FIRST THROUGH FIFTH WIND SPEED CATEGORIES ***
(METERS/SEC)

1.54, 3.09, 5.14, 8.23, 10.80,

*** WIND PROFILE EXPONENTS ***

STABILITY CATEGORY	WIND SPEED CATEGORY 1	2	3	4	5	6
A	.70000E-01	.70000E-01	.70000E-01	.70000E-01	.70000E-01	.70000E-01
B	.70000E-01	.70000E-01	.70000E-01	.70000E-01	.70000E-01	.70000E-01
C	.10000E+00	.10000E+00	.10000E+00	.10000E+00	.10000E+00	.10000E+00
D	.15000E+00	.15000E+00	.15000E+00	.15000E+00	.15000E+00	.15000E+00
E	.35000E+00	.35000E+00	.35000E+00	.35000E+00	.35000E+00	.35000E+00
F	.55000E+00	.55000E+00	.55000E+00	.55000E+00	.55000E+00	.55000E+00

*** VERTICAL POTENTIAL TEMPERATURE GRADIENTS ***
(DEGREES KELVIN PER METER)

STABILITY CATEGORY	WIND SPEED CATEGORY 1	2	3	4	5	6
A	.00000E+00	.00000E+00	.00000E+00	.00000E+00	.00000E+00	.00000E+00
B	.00000E+00	.00000E+00	.00000E+00	.00000E+00	.00000E+00	.00000E+00
C	.00000E+00	.00000E+00	.00000E+00	.00000E+00	.00000E+00	.00000E+00
D	.00000E+00	.00000E+00	.00000E+00	.00000E+00	.00000E+00	.00000E+00
E	.20000E-01	.20000E-01	.20000E-01	.20000E-01	.20000E-01	.20000E-01
F	.35000E-01	.35000E-01	.35000E-01	.35000E-01	.35000E-01	.35000E-01

**MODELOPTs: CONC RURAL FLAT DFAULT

*** THE FIRST 24 HOURS OF METEOROLOGICAL DATA ***

FILE: lprov91.bin FORMAT: UNFORM
SURFACE STATION NO.: 14765 UPPER AIR STATION NO.: 14684
NAME: SURFNAME NAME: UAIRNAME
YEAR: 1991 YEAR: 1991

YEAR	MONTH	DAY	HOUR	FLOW VECTOR	SPEED (M/S)	TEMP (K)	STAB CLASS	MIXING HEIGHT (M) RURAL	MIXING HEIGHT (M) URBAN	USTAR (M/S)	M-O LENGTH (M)	Z-0 (M)	IPCODE	PRATE (mm/HR)
91	1	1	1	121.0	4.12	267.6	5	453.1	24.0	0.0000	0.0	0.0000	0	0.00
91	1	1	2	128.0	3.60	267.0	5	504.8	24.0	0.0000	0.0	0.0000	0	0.00
91	1	1	3	154.0	3.60	267.0	5	556.4	24.0	0.0000	0.0	0.0000	0	0.00
91	1	1	4	123.0	3.60	266.5	5	608.1	24.0	0.0000	0.0	0.0000	0	0.00
91	1	1	5	113.0	3.09	265.9	6	659.8	24.0	0.0000	0.0	0.0000	0	0.00
91	1	1	6	12.0	2.57	264.3	6	711.5	24.0	0.0000	0.0	0.0000	0	0.00
91	1	1	7	105.0	3.09	265.4	6	763.2	24.0	0.0000	0.0	0.0000	0	0.00
91	1	1	8	133.0	3.60	265.9	5	131.6	152.8	0.0000	0.0	0.0000	0	0.00
91	1	1	9	137.0	1.54	268.7	4	297.1	314.8	0.0000	0.0	0.0000	0	0.00
91	1	1	10	131.0	3.09	270.9	3	462.7	476.8	0.0000	0.0	0.0000	0	0.00
91	1	1	11	84.0	2.57	271.5	3	628.3	638.9	0.0000	0.0	0.0000	0	0.00
91	1	1	12	86.0	3.09	272.6	3	793.9	800.9	0.0000	0.0	0.0000	0	0.00
91	1	1	13	63.0	3.09	273.1	3	959.4	963.0	0.0000	0.0	0.0000	0	0.00
91	1	1	14	329.0	4.63	273.1	3	1125.0	1125.0	0.0000	0.0	0.0000	0	0.00
91	1	1	15	2.0	4.63	273.1	4	1125.0	1125.0	0.0000	0.0	0.0000	0	0.00
91	1	1	16	4.0	6.17	272.6	4	1125.0	1125.0	0.0000	0.0	0.0000	0	0.00
91	1	1	17	1.0	5.14	270.9	5	1120.4	1035.9	0.0000	0.0	0.0000	0	0.00
91	1	1	18	17.0	2.57	270.9	6	1114.5	919.5	0.0000	0.0	0.0000	0	0.00
91	1	1	19	54.0	2.57	269.8	6	1108.5	803.0	0.0000	0.0	0.0000	0	0.00
91	1	1	20	47.0	2.57	269.3	6	1102.5	686.6	0.0000	0.0	0.0000	0	0.00
91	1	1	21	50.0	1.00	268.7	7	1096.5	570.2	0.0000	0.0	0.0000	0	0.00
91	1	1	22	352.0	1.00	268.7	7	1090.6	453.8	0.0000	0.0	0.0000	0	0.00
91	1	1	23	160.0	1.03	268.7	7	1084.6	337.4	0.0000	0.0	0.0000	0	0.00
91	1	1	24	150.0	2.57	268.7	6	1078.6	221.0	0.0000	0.0	0.0000	0	0.00

*** NOTES: STABILITY CLASS 1=A, 2=B, 3=C, 4=D, 5=E AND 6=F.
FLOW VECTOR IS DIRECTION TOWARD WHICH WIND IS BLOWING.

**MODELOPTs: CONC RURAL FLAT DFAULT

*** THE PERIOD (8760 HRS) AVERAGE CONCENTRATION VALUES FOR SOURCE GROUP: ALL ***
INCLUDING SOURCE(S): SQUARE1 , SQUARE2 , SQUARE3 , SQUARE4 , SQUARE5 , SQUARE6 , SQUARE7 , SQUARE8 , SQUARE9 , SQUARE10, SQUARE11, SQUARE12, SQUARE13, SQUARE14, SQUARE15, SQUARE16, SQUARE17, SQUARE18, SQUARE19, SQUARE20, SQUARE21, SQUARE22, SQUARE23, SQUARE24, SQUARE25, SQUARE26, SQUARE27,

*** NETWORK ID: POL ; NETWORK TYPE: GRIDPOLR ***

** CONC OF UNIT IN MICROGRAMS/M**3 **

DIRECTION (DEGREES)	DISTANCE (METERS) 200.00	400.00	600.00	800.00	1000.00	1200.00	1400.00	1600.00	1800.00
360.00	1.91054	0.58048	0.28805	0.18325	0.13120	0.10098	0.08100	0.06682	0.05635
45.00	1.22781	0.57291	0.33408	0.22407	0.16288	0.12510	0.09991	0.08242	0.06972
90.00	1.19638	0.53016	0.30317	0.19995	0.14300	0.10857	0.08584	0.07043	0.05968
135.00	1.79083	0.72197	0.39162	0.25071	0.17482	0.13054	0.10300	0.08460	0.07136
180.00	9.61651	1.93100	0.69409	0.40229	0.27511	0.20142	0.15625	0.12603	0.10448
225.00	18.80016	0.94085	0.34567	0.19337	0.12960	0.09656	0.07669	0.06300	0.05299
270.00	16.92098	0.42519	0.15902	0.09605	0.06880	0.05425	0.04538	0.03924	0.03467
315.00	14.35342	0.54412	0.17208	0.09071	0.05981	0.04289	0.03229	0.02531	0.02058

**MODELOPTs: CONC RURAL FLAT DFAULT

*** THE PERIOD (8760 HRS) AVERAGE CONCENTRATION VALUES FOR SOURCE GROUP: ALL ***
INCLUDING SOURCE(S): SQUARE1 , SQUARE2 , SQUARE3 , SQUARE4 , SQUARE5 , SQUARE6 , SQUARE7 ,
SQUARE8 , SQUARE9 , SQUARE10, SQUARE11, SQUARE12, SQUARE13, SQUARE14, SQUARE15, SQUARE16, SQUARE17, SQUARE18, SQUARE19,
SQUARE20, SQUARE21, SQUARE22, SQUARE23, SQUARE24, SQUARE25, SQUARE26, SQUARE27,

*** NETWORK ID: POL ; NETWORK TYPE: GRIDPOLR ***

** CONC OF UNIT IN MICROGRAMS/M**3 **

DIRECTION (DEGREES)	DISTANCE (METERS) 2000.00	2200.00	2400.00	2600.00	2800.00	3000.00	3200.00	3400.00	3600.00
360.00	0.04837	0.04215	0.03714	0.03304	0.02965	0.02684	0.02448	0.02247	0.02072
45.00	0.06026	0.05293	0.04702	0.04215	0.03807	0.03468	0.03180	0.02930	0.02712
90.00	0.05194	0.04605	0.04132	0.03741	0.03412	0.03134	0.02897	0.02689	0.02506
135.00	0.06134	0.05354	0.04729	0.04215	0.03788	0.03431	0.03132	0.02875	0.02652
180.00	0.08850	0.07635	0.06688	0.05930	0.05310	0.04797	0.04368	0.04006	0.03694
225.00	0.04537	0.03940	0.03464	0.03074	0.02751	0.02479	0.02250	0.02056	0.01889
270.00	0.03111	0.02826	0.02594	0.02399	0.02232	0.02089	0.01965	0.01858	0.01762
315.00	0.01723	0.01476	0.01286	0.01136	0.01014	0.00914	0.00830	0.00760	0.00700

**MODELOPTs: CONC RURAL FLAT DFAULT

*** THE PERIOD (8760 HRS) AVERAGE CONCENTRATION VALUES FOR SOURCE GROUP: ALL ***
INCLUDING SOURCE(S): SQUARE1 , SQUARE2 , SQUARE3 , SQUARE4 , SQUARE5 , SQUARE6 , SQUARE7 , SQUARE8 , SQUARE9 , SQUARE10, SQUARE11, SQUARE12, SQUARE13, SQUARE14, SQUARE15, SQUARE16, SQUARE17, SQUARE18, SQUARE19, SQUARE20, SQUARE21, SQUARE22, SQUARE23, SQUARE24, SQUARE25, SQUARE26, SQUARE27,

*** NETWORK ID: POL ; NETWORK TYPE: GRIDPOLR ***

** CONC OF UNIT IN MICROGRAMS/M**3 **

DIRECTION (DEGREES)	DISTANCE (METERS) 3800.00	4000.00	4200.00	4400.00	4600.00	4800.00	5000.00	5200.00	5400.00
360.00	0.01920	0.01786	0.01668	0.01563	0.01468	0.01384	0.01307	0.01237	0.01173
45.00	0.02519	0.02350	0.02199	0.02064	0.01943	0.01833	0.01733	0.01642	0.01559
90.00	0.02344	0.02200	0.02072	0.01957	0.01852	0.01758	0.01671	0.01592	0.01519
135.00	0.02457	0.02285	0.02134	0.01999	0.01878	0.01770	0.01672	0.01583	0.01502
180.00	0.03424	0.03186	0.02977	0.02792	0.02626	0.02478	0.02343	0.02222	0.02111
225.00	0.01743	0.01616	0.01503	0.01404	0.01315	0.01236	0.01165	0.01100	0.01042
270.00	0.01675	0.01598	0.01527	0.01463	0.01404	0.01350	0.01300	0.01253	0.01210
315.00	0.00647	0.00602	0.00562	0.00526	0.00494	0.00466	0.00440	0.00416	0.00395

**MODELOPTs: CONC RURAL FLAT DFAULT

*** THE PERIOD (8760 HRS) AVERAGE CONCENTRATION VALUES FOR SOURCE GROUP: ALL ***
INCLUDING SOURCE(S): SQUARE1 , SQUARE2 , SQUARE3 , SQUARE4 , SQUARE5 , SQUARE6 , SQUARE7 ,
SQUARE8 , SQUARE9 , SQUARE10, SQUARE11, SQUARE12, SQUARE13, SQUARE14, SQUARE15, SQUARE16, SQUARE17, SQUARE18, SQUARE19
SQUARE20, SQUARE21, SQUARE22, SQUARE23, SQUARE24, SQUARE25, SQUARE26, SQUARE27,

*** NETWORK ID: POL ; NETWORK TYPE: GRIDPOLR ***

** CONC OF UNIT IN MICROGRAMS/M**3 **

DIRECTION (DEGREES)	DISTANCE (METERS) 5600.00	5800.00	6000.00	6200.00	6400.00	6600.00	6800.00	7000.00	7200.00
360.00	0.01115	0.01061	0.01012	0.00967	0.00925	0.00886	0.00849	0.00816	0.00784
45.00	0.01483	0.01413	0.01348	0.01288	0.01232	0.01181	0.01133	0.01089	0.01047
90.00	0.01452	0.01390	0.01333	0.01280	0.01231	0.01185	0.01142	0.01102	0.01065
135.00	0.01428	0.01361	0.01298	0.01241	0.01188	0.01139	0.01094	0.01052	0.01013
180.00	0.02009	0.01917	0.01831	0.01753	0.01680	0.01612	0.01549	0.01491	0.01437
225.00	0.00989	0.00940	0.00896	0.00855	0.00817	0.00782	0.00750	0.00720	0.00692
270.00	0.01169	0.01131	0.01095	0.01062	0.01030	0.01001	0.00973	0.00946	0.00921
315.00	0.00376	0.00358	0.00342	0.00326	0.00313	0.00300	0.00288	0.00277	0.00266

**MODELOPTs: CONC RURAL FLAT DFAULT

*** THE PERIOD (8760 HRS) AVERAGE CONCENTRATION VALUES FOR SOURCE GROUP: ALL ***
INCLUDING SOURCE(S): SQUARE1 , SQUARE2 , SQUARE3 , SQUARE4 , SQUARE5 , SQUARE6 , SQUARE7 ,
SQUARE8 , SQUARE9 , SQUARE10, SQUARE11, SQUARE12, SQUARE13, SQUARE14, SQUARE15, SQUARE16, SQUARE17, SQUARE18, SQUARE19,
SQUARE20, SQUARE21, SQUARE22, SQUARE23, SQUARE24, SQUARE25, SQUARE26, SQUARE27,

*** NETWORK ID: POL ; NETWORK TYPE: GRIDPOLR ***

** CONC OF UNIT IN MICROGRAMS/M**3 **

DIRECTION (DEGREES)	DISTANCE (METERS) 7400.00	7600.00	7800.00	8000.00
360.00	0.00755	0.00728	0.00702	0.00678
45.00	0.01009	0.00973	0.00938	0.00906
90.00	0.01030	0.00997	0.00966	0.00936
135.00	0.00977	0.00942	0.00911	0.00880
180.00	0.01386	0.01338	0.01293	0.01251
225.00	0.00666	0.00642	0.00619	0.00598
270.00	0.00897	0.00875	0.00853	0.00833
315.00	0.00256	0.00247	0.00239	0.00231

**MODELOPTs: CONC RURAL FLAT DFAULT

*** THE SUMMARY OF MAXIMUM PERIOD (8760 HRS) RESULTS ***

** CONC OF UNIT IN MICROGRAMS/M**3 **

GROUP ID		AVERAGE CONC	RECEPTOR (XR, YR, ZELEV, ZFLAG)	OF TYPE	NETWORK GRID-ID
ALL	1ST HIGHEST VALUE IS	18.80016 AT	(233.58, 338.58, 0.00, 0.00)	GP	POL
	2ND HIGHEST VALUE IS	16.92098 AT	(175.00, 480.00, 0.00, 0.00)	GP	POL
	3RD HIGHEST VALUE IS	14.35342 AT	(233.58, 621.42, 0.00, 0.00)	GP	POL
	4TH HIGHEST VALUE IS	9.61651 AT	(375.00, 280.00, 0.00, 0.00)	GP	POL
	5TH HIGHEST VALUE IS	1.93100 AT	(375.00, 80.00, 0.00, 0.00)	GP	POL
	6TH HIGHEST VALUE IS	1.91054 AT	(375.00, 680.00, 0.00, 0.00)	GP	POL

*** RECEPTOR TYPES:
GC = GRIDCART
GP = GRIDPOLR
DC = DISCCART
DP = DISCPOLR
BD = BOUNDARY

**MODELOPTs: CONC RURAL FLAT DFAULT

** Message Summary : ISCST3 Model Execution ***

------- Summary of Total Messages --------

A Total of 0 Fatal Error Message(s)
A Total of 0 Warning Message(s)
A Total of 766 Informational Message(s)

A Total of 219 Calm Hours Identified

******** FATAL ERROR MESSAGES ********
*** NONE ***

******** WARNING MESSAGES ********
*** NONE ***

****
*** ISCST3 Finishes Successfully ***
****

F-4 Basement Ambient Air Correlation

TABLE F-1. BASEMENT AMBIENT AIR CORRELATION WORKSHEET

PURPOSE:	Worksheet calculates the average concentration of vinyl chloride in ambient (i.e. household) air based on a direct correlation with concentration of indicator methane gas;	Developed by: Daniel Peters, M&E Version: *Jun-08-93* Checked by: D. Murray Date: *Jun-08-93*	Run Date: *Jun-08-93*
REFERENCES:	1)Roy F. Weston, Inc., analytical sampling results received on May 25, 1993 for February to March '93 sampling periods.	2)U.S. EPA, 1993; Letter from D. Tagliaferro (EPA) to S. Alfred, Town Manager, South Kingstown, RI, dated May 17, 1993 with attached Weston memorandum describing site visit, testing and installation of methane monitors in residential basements.	
PROCEDURE FOR USE:	1)Specify instrument detection limit of methane analyzer, Cch4_DL, in ppmv.	2) Observe the resultant concentration of vinyl chloride ($\mu g/m^3$) in basement indoor air.	
ASSUMPTIONS:	1)Data from Reference (1) utilized. 3)A mathematical correlation of the form: LOG (vinyl chloride conc.) versus the methane concentration was found to best fit the data as a linear function.	2)Only points where both vinyl chloride and methane were above analytical quantitation limits were used.	

TABLE F-1. BASEMENT AMBIENT AIR CORRELATION WORKSHEET

A. INPUT VARIABLES	Location	Date Sampled	Comments	Vinyl Chloride ($\mu g/m^3$)	Methane (ppmv)	Vinyl Chloride (ppbv)	Methane (mg/m^3)
1. Vinyl Chloride Concentrations:	121 Rose Hill Road	18-Feb-93		0.51 U	100 U	0.20 U	66 U
		11-Mar-93		0.51 U	100 U	0.20 U	66 U
a. Residential Basement Air: SUMMA™ Cannister Data Data Source (1)	220 Rose Hill Road	18-Feb-93	SA3126	4.09	850	1.60	558
		18-Feb-93	SA3127	4.09	800	1.60	525
		18-Feb-93	SA3128	1.30	100 U	0.51	66 U
		25-Feb-93		4.09	910	1.60	597
		04-Mar-93		5.62	890	2.20	584
		11-Mar-93		25.56	2,500	10.00	1,641
Note: "U" is the analytical quantitation limit.		18-Mar-93		40.89	2,500	16.00	1,641
		25-Mar-93		53.67	2,500	21.00	1,641
		25-Mar-93	Duplicate	56.22	2,500	22.00	1,641
	235 Rose Hill Road	11-Mar-93		28.11	2,700	11.00	1,772
	278 Rose Hill Road	18-Feb-93		1.25	100 U	0.49	66 U
		25-Feb-93	SA6903	0.51 U	100 U	0.20 U	66 U
		25-Feb-93	SA6904	0.51 U	100 U	0.20 U	66 U
		04-Mar-93		2.53	100 U	0.99	66 U
		11-Mar-93		1.56	100 U	0.61	66 U
		25-Mar-93	SA6935	0.51 U	100 U	0.20 U	66 U
		25-Mar-93	SA6936	0.51 U	100 U	0.20 U	66 U
	294 Rose Hill Road	25-Feb-93		0.51 U	100 U	0.20 U	66 U
		18-Mar-93		0.51 U	100 U	0.20 U	66 U
	320 Rose Hill Road	04-Mar-93		0.51 U	100 U	0.20 U	66 U
		25-Mar-93		0.51 U	100 U	0.20 U	66 U

TABLE F–1. BASEMENT AMBIENT AIR CORRELATION WORKSHEET

A. INPUT VARIABLES (continued)	Location	Date Sampled	Comments	Vinyl Chloride ($\mu g/m^3$)	Methane (ppmv)	Vinyl Chloride (ppbv)	Methane (mg/m^3)
a. Residential Basement Air: SUMMA™ Cannister Data (continued)	339A Rose Hill Road	18–Feb–93		0.51 U	100 U	0.20 U	66 U
		11–Mar–93		0.51 U	100 U	0.20 U	66 U
	339B Rose Hill Road	25–Feb–93		0.51 U	100 U	0.20 U	66 U
		18–Mar–93		0.51 U	100 U	0.20 U	66 U
	349 Rose Hill Road	18–Feb–93		0.51 U	100 U	0.20 U	66 U
		25–Feb–93		0.51 U	100 U	0.20 U	66 U
		04–Mar–93		0.77	100 U	0.30	66 U
		04–Mar–93	Duplicate	0.72	100 U	0.28	66 U
		11–Mar–93		0.51 U	100 U	0.20 U	66 U
		18–Mar–93		0.51 U	100 U	0.20 U	66 U
		25–Mar–93		0.51 U	100 U	0.20 U	66 U
	364 Rose Hill Road	04–Mar–93		0.51 U	100 U	0.20 U	66 U
		25–Mar–93		0.51 U	100 U	0.20 U	66 U

TABLE F-1. BASEMENT AMBIENT AIR CORRELATION WORKSHEET

A. INPUT VARIABLES (continued)	Location	Date Sampled	Comments	Vinyl Chloride ($\mu g/m^3$)	Methane (ppmv)	Vinyl Chloride (ppbv)	Methane (mg/m^3)
	Presented for Comparison Purposes only;						
b. Residential Outside Ambient Air: SUMMA™ Cannister Data Data Source (1)	220 Rose Hill Road	04-Mar-93		2.50	100 U	0.98	66 U
	278 Rose Hill Road	25-Feb-93		0.51 U	100 U	0.20 U	66 U
		11-Mar-93		4.34	100 U	1.70	66 U
		18-Mar-93		0.66	100 U	0.26	66 U
		25-Mar-93		0.51 U	100 U	0.20 U	66 U
	339A Rose Hill Road	04-Mar-93		2.45	100 U	0.96	66 U
		11-Mar-93		1.89	100 U	0.74	66 U
		25-Mar-93		0.51 U	100 U	0.20 U	66 U
	339B Rose Hill Road	25-Feb-93		0.51 U	100 U	0.20 U	66 U
		18-Mar-93		0.51 U	100 U	0.20 U	66 U
2. Methane Analyzer Detection Limit:	Standard combustion sensor operating in 0-100% LEL of CH4 range; Source: (2)						
Cch4_DL	"Alarm" limit of 2% of the LEL for CH4			1,000	ppmv CH4	656	mg CH4/m³ air
B. INTERIM CALCULATIONS:	Correlation of Vinyl Chloride versus Methane			Vinyl Chloride, Cvc ($\mu g/m^3$)	Methane, Cch4 (ppmv)	Log(Cvc) "y-value"	Cch4 "x-value"
1. Selected Data Points	Only data points with detected levels of both vinyl chloride and methane used; no outside ambient air data was used in the correlation.			4.09	850	0.6116	850
				4.09	800	0.6116	800
				4.09	910	0.6116	910
				5.62	890	0.7499	890
				25.56	2,500	1.4075	2,500
				40.89	2,500	1.6116	2,500
				53.67	2,500	1.7297	2,500
				56.22	2,500	1.7499	2,500
				28.11	2,700	1.4489	2,700

TABLE F-1. BASEMENT AMBIENT AIR CORRELATION WORKSHEET

B. INTERIM CALCULATIONS: (continued) 2. Linear Regression	Regression Output:					Comment: Linear regression using LOTUS 2.4 DATA/REGRESSION commands
	Constant		0.1744	"Y-intercept"		
	Std Err of Y Est		0.1476			
	R Squared		0.9271			
	No. of Observations		9			
	Degrees of Freedom		7			
	X Coefficient(s)	5.55E-04		"slope"		
	Std Err of Coef.	5.88E-05				
C. OUTPUT CALCULATIONS: 1. Correlation Equation	Correlation Equation of the form:					
	Log(Cvc) = m•(Cch4) + b ; alternatively					
	Cvc = 10 [m•(Cch4) + b]					
	Where:					
Cvc	Concentration of vinyl chloride in air (μg/m³)					
Cch4	Concentration of methane in air (ppmv)					
m	"slope" of the line			5.55E-04	---	---
b	"y-intercept" of the line			0.1744	---	---
2. Resultant Vinyl chloride Concentration						
Cch4_DL	Methane Analyzer Detection Limit (from above)			1,000	ppmv CH4	656 mg CH4/m³ air
Cvc_@DL	Vinyl Chloride Concentration at methane analyzer detection limit.			5.36	μg/m³	2.18 ppbv

F-5 Point Source Modeling: Non-Combustion Technology

Revised: 10-14-98

Non-combustion LFG treatment processes (such as photocatalytic oxidation) require dispersion modeling to determine if PRGs are exceeded off-site.

Feed Gas

Internal LFG + Perimeter Gas = 853 cfm = 14.2 cfs = 0.4 m^3/s

Ambient Temperature = 293 K

Stack Diameter

A reasonable stack diameter must be selected based on the gas flow:

Diam. (ft)	Diam. (m)	Area (ft^2)	Velocity (ft/s)	Velocity (m/s)	
0.5	0.15	0.20	72.4	22.1	
1	0.30	0.79	18.1	5.52	This will be used to be conservative, but a faster velocity would be desireable to avoid stack tip downwash.

This does not account for any process constraints, such as back pressure.

Emission Rate

Vinyl chloride will be assumed to be the limiting compound, even for photocatalytic oxidation.
Assuming the process is photocatalytic oxidation, the range of DREs is 95 to 98%.

Inlet concentration = 83,304 ppbv MW = 62.5
= 213 mg/m^3
= 0.21 g/m^3

Inlet mass rate = 0.086 g/s

DRE	Emission Rate (g/s)
95%	4.29E-03
98%	1.71E-03

Beginning with a stack height of 20 ft = 6.1 m
We will try the 98% run and see what results in ISCLT3.
Maximum discreet receptor conc. = 0.016 $\mu g/m^3$
Maximum grid receptor conc. = 0.048 $\mu g/m^3$ This receptor is located on site. (5 total impacts > PRG)
PRG = 0.03 $\mu g/m^3$

Trying with a stack height of 30 ft = 9.14 m (still 98% DRE) [Output - Attachment A]
Maximum discreet receptor conc. = 0.013 $\mu g/m^3$
Maximum grid receptor conc. = 0.023 $\mu g/m^3$ This receptor is also located on site.

If non-thermal treatment is utilized, various stack designs would need to be considered as well as designation of appropriate site boundaries (usually fencelines) to ensure PRGs are achieved.

METCALF & EDDY

```
** Rosehill - ISCLT3
** Point source emissions from a non-combustion source treating LFG
**    from the Solid Waste Area (1997 LFG flow rate)
** 1987-1992 meteorological data
** Vinyl chloride emissions

CO STARTING
   TITLEONE  ROSEHILL - NON-COMBUSTION EMISSIONS - ISCLT3
   MODELOPT  DFAULT  CONC  RURAL
   AVERTIME  ANNUAL
   TERRHGTS  FLAT
   POLLUTID  VYCL
   RUNORNOT  RUN
CO FINISHED

SO STARTING

**  PHOTOCAT FOR SOLID WASTE AREA

SO LOCATION   STACK1  POINT      373.38   480.06     0.

**  Emission rate (g/s), stack height (m), gas temp (K),
**     gas velocity (m/s), stack diameter (m)

SO SRCPARAM   STACK1   0.00171  9.144  293.  5.52  0.3048

SO SRCGROUP ALL
SO FINISHED


RE STARTING
RE GRIDPOLR POL STA
RE GRIDPOLR POL ORIG   375. 480.
RE GRIDPOLR POL DIST   50. 100. 150. 200. 250. 300. 350. 400. 450.
RE GRIDPOLR POL DIST   500. 550. 600. 650. 700. 750. 800. 850. 900.
** RE GRIDPOLR POL DIST   950. 1000. 1050. 1100. 1150. 1200. 1300.
** RE GRIDPOLR POL DIST   1400. 1500. 1600. 1700. 1800. 1900. 2000.
** RE GRIDPOLR POL DIST   2100. 2200. 2300. 2400. 2500. 2600. 2700.
RE GRIDPOLR POL DIST   2800. 2900. 3000. 3100. 3200. 3300. 3400.
RE GRIDPOLR POL DIST   3500. 3600. 3700. 3800. 3900. 4000. 4100.
RE GRIDPOLR POL DIST   4200. 4300. 4400. 4500. 4600. 4700. 4800.
** RE GRIDPOLR POL DIST   4900. 5000. 5100. 5200. 5300. 5400. 5500.
** RE GRIDPOLR POL DIST   5600. 5700. 5800. 5900. 6000. 6100. 6200.
RE GRIDPOLR POL GDIR   8    0.  45.
RE GRIDPOLR POL END

**  Discreet Receptors
**  x, y coordinates (m)

** Receptor #1
RE DISCCART         99.06    670.56
** Receptor #2
RE DISCCART         30.48    662.94
** Receptor #3
RE DISCCART         22.86    563.88
** Receptor #4
RE DISCCART         15.24    541.02
** Receptor #5
RE DISCCART         60.96    533.40
** Receptor #6
RE DISCCART         91.44    434.34
** Receptor #7
RE DISCCART        121.92    297.18
** Receptor #8
RE DISCCART        259.08     15.24
** Receptor #9
RE DISCCART        388.62    640.08
** Receptor #10
RE DISCCART        487.68    670.56
** Receptor #11
RE DISCCART        563.88    243.84
** Receptor #12
RE DISCCART        243.84    655.32
** Receptor #13
RE DISCCART        167.64    274.32
** Receptor #14
RE DISCCART        114.30    647.70
** Receptor #15
RE DISCCART         91.44    594.36
** Receptor #16
RE DISCCART        228.60    129.54
** Receptor #17
RE DISCCART        365.76    144.78

RE FINISHED


ME STARTING
   INPUTFIL  TEST.DAT FREE
   ANEMHGHT  20. FEET
** Stardata from 1987 through 1992 at Providence was utilized.
```

```
   SURFDATA  14765  1987  PROVIDENCE
   UAIRDATA  14765  1987  PROVIDENCE

**                 - AMBIENT AIR TEMPERATURE (DEGREES KELVIN) -
**
**                    STAB    STAB    STAB    STAB    STAB    STAB
**                    CAT 1   CAT 2   CAT 3   CAT 4   CAT 5   CAT 6
**                    -----   -----   -----   -----   -----   -----

   AVETEMPS  ANNUAL   283.2   283.2   283.2   283.2   283.2   283.2

**                         - MIXING LAYER HEIGHT (METERS) -
**                   S
**                   T    WS       WS       WS       WS       WS       WS
**            SEAS   A   CAT 1    CAT 2    CAT 3    CAT 4    CAT 5    CAT 6
**            ----   B   -----    -----    -----    -----    -----    -----

   AVEMIXHT  ANNUAL 1 .142E+04 .142E+04 .142E+04 .142E+04 .142E+04 .142E+04
   AVEMIXHT  ANNUAL 2 .944E+03 .944E+03 .944E+03 .944E+03 .944E+03 .944E+03
   AVEMIXHT  ANNUAL 3 .944E+03 .944E+03 .944E+03 .944E+03 .944E+03 .944E+03
   AVEMIXHT  ANNUAL 4 .944E+03 .944E+03 .944E+03 .944E+03 .944E+03 .944E+03
   AVEMIXHT  ANNUAL 5 .100E+05 .100E+05 .100E+05 .100E+05 .100E+05 .100E+05
   AVEMIXHT  ANNUAL 6 .100E+05 .100E+05 .100E+05 .100E+05 .100E+05 .100E+05
ME FINISHED

OU STARTING
   RECTABLE  INDSRC
   MAXTABLE  10 INDSRC
OU FINISHED

***********************************
*** SETUP Finishes Successfully ***
***********************************

 *** ISCLT3 - VERSION 96113 ***    ***  ROSEHILL - NON-COMBUSTION EMISSIONS - ISCLT3                    ***        10/14/98
                                   ***                                                                   ***        14:45:46
                                                                                                                    PAGE   1
 *** MODELING OPTIONS USED:  CONC   RURAL  FLAT          DFAULT

                                          ***     MODEL SETUP OPTIONS SUMMARY       ***
- - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - -

**Model Is Setup For Calculation of Average CONCentration Values.
**Model Does NOT Use GRIDDED TERRAIN Data for Depletion Calculations

**Model Uses NO plume DEPLETION.

  Model Uses RURAL Dispersion.

**Model Uses Regulatory DEFAULT Options:
          1. Final Plume Rise.
          2. Stack-tip Downwash.
          3. Buoyancy-induced Dispersion.
          4. Default Wind Profile Exponents.
          5. Default Vertical Potential Temperature Gradients.
          6. "Upper Bound" Values For Supersquat Buildings.
          7. No Exponential Decay for RURAL Mode

**Model Assumes Receptors on FLAT Terrain.

**Model Assumes No FLAGPOLE Receptor Heights.

**Model Calculates   1 STAR Average(s) for the Following Months:  0  0  0  0  0  0  0  0  0  0  0  0
                                                Seasons/Quarters:  0  0  0  0
                                                      and Annual:  1

**Model Assumes  1 STAR Summaries In Data File for the Averaging Periods Identified Above

**This Run Includes:    1 Source(s);      1 Source Group(s); and    329 Receptor(s)

**The Model Assumes A Pollutant Type of:  VYCL

**Model Set To Continue RUNning After the Setup Testing.

**Output Options Selected:
        Model Outputs Tables of Long Term Values by Receptor (RECTABLE Keyword)
        Model Outputs Tables of Maximum Long Term Values (MAXTABLE Keyword)

**Misc. Inputs:  Anem. Hgt. (m) =     6.10 ;    Decay Coef. =   0.0000     ;    Rot. Angle =     0.0
                 Emission Units = GRAMS/SEC                                ;  Emission Rate Unit Factor =   0.10000E+07
                 Output Units   = MICROGRAMS/M**3

**Input Runstream File: rhnonc2.inp                            ;  **Output Print File: rhnonc2.out
 *** ISCLT3 - VERSION 96113 ***    ***  ROSEHILL - NON-COMBUSTION EMISSIONS - ISCLT3                    ***        10/14/98
                                   ***                                                                   ***        14:45:46
                                                                                                                    PAGE   2
  ** MODELING OPTIONS USED:  CONC   RURAL  FLAT          DFAULT


                                                  *** POINT SOURCE DATA ***

             NUMBER EMISSION RATE                    BASE     STACK   STACK    STACK     STACK    BUILDING EMISSION RATE
```

SOURCE ID	PART. CATS.	(GRAMS/SEC)	X (METERS)	Y (METERS)	ELEV. (METERS)	HEIGHT (METERS)	TEMP. (DEG.K)	EXIT VEL. (M/SEC)	DIAMETER (METERS)	EXISTS	SCALAR VARY BY
STACK1	0	0.17100E-02	373.4	480.1	0.0	9.14	293.00	5.52	0.30	NO	

*** MODELING OPTIONS USED: CONC RURAL FLAT DFAULT

*** SOURCE IDs DEFINING SOURCE GROUPS ***

GROUP ID	SOURCE IDs
ALL	STACK1 ,

*** MODELING OPTIONS USED: CONC RURAL FLAT DFAULT

*** GRIDDED RECEPTOR NETWORK SUMMARY ***

*** NETWORK ID: POL ; NETWORK TYPE: GRIDPOLR ***

*** ORIGIN FOR POLAR NETWORK ***
X-ORIG = 375.00 ; Y-ORIG = 480.00 (METERS)

*** DISTANCE RANGES OF NETWORK ***
(METERS)

50.0,	100.0,	150.0,	200.0,	250.0,	300.0,	350.0,	400.0,	450.0,	500.0,
550.0,	600.0,	650.0,	700.0,	750.0,	800.0,	850.0,	900.0,	2800.0,	2900.0,
3000.0,	3100.0,	3200.0,	3300.0,	3400.0,	3500.0,	3600.0,	3700.0,	3800.0,	3900.0,
4000.0,	4100.0,	4200.0,	4300.0,	4400.0,	4500.0,	4600.0,	4700.0,	4800.0,	

*** DIRECTION RADIALS OF NETWORK ***
(DEGREES)

360.0,	45.0,	90.0,	135.0,	180.0,	225.0,	270.0,	315.0,

*** MODELING OPTIONS USED: CONC RURAL FLAT DFAULT

*** *DISCRETE CARTESIAN RECEPTORS* ***
(X-COORD, Y-COORD, ZELEV, ZFLAG)
(METERS)

(99.1,	670.6,	0.0,	0.0);	(30.5,	662.9,	0.0,	0.0);
(22.9,	563.9,	0.0,	0.0);	(15.2,	541.0,	0.0,	0.0);
(61.0,	533.4,	0.0,	0.0);	(91.4,	434.3,	0.0,	0.0);
(121.9,	297.2,	0.0,	0.0);	(259.1,	15.2,	0.0,	0.0);
(388.6,	640.1,	0.0,	0.0);	(487.7,	670.6,	0.0,	0.0);
(563.9,	243.8,	0.0,	0.0);	(243.8,	655.3,	0.0,	0.0);
(167.6,	274.3,	0.0,	0.0);	(114.3,	647.7,	0.0,	0.0);
(91.4,	594.4,	0.0,	0.0);	(228.6,	129.5,	0.0,	0.0);
(365.8,	144.8,	0.0,	0.0);				

*** MODELING OPTIONS USED: CONC RURAL FLAT DFAULT

*** AVERAGE SPEED FOR EACH WIND SPEED CATEGORY ***
(METERS/SEC)

1.50, 2.50, 4.30, 6.80, 9.50, 12.50,

*** WIND PROFILE EXPONENTS ***

STABILITY CATEGORY	WIND SPEED CATEGORY 1	2	3	4	5	6
A	.70000E-01	.70000E-01	.70000E-01	.70000E-01	.70000E-01	.70000E-01
B	.70000E-01	.70000E-01	.70000E-01	.70000E-01	.70000E-01	.70000E-01
C	.10000E+00	.10000E+00	.10000E+00	.10000E+00	.10000E+00	.10000E+00
D	.15000E+00	.15000E+00	.15000E+00	.15000E+00	.15000E+00	.15000E+00
E	.35000E+00	.35000E+00	.35000E+00	.35000E+00	.35000E+00	.35000E+00
F	.55000E+00	.55000E+00	.55000E+00	.55000E+00	.55000E+00	.55000E+00

*** VERTICAL POTENTIAL TEMPERATURE GRADIENTS ***
(DEGREES KELVIN PER METER)

STABILITY CATEGORY	WIND SPEED CATEGORY 1	2	3	4	5	6

A	.00000E+00	.00000E+00	.00000E+00	.00000E+00	.00000E+00	.00000E+00
B	.00000E+00	.00000E+00	.00000E+00	.00000E+00	.00000E+00	.00000E+00
C	.00000E+00	.00000E+00	.00000E+00	.00000E+00	.00000E+00	.00000E+00
D	.00000E+00	.00000E+00	.00000E+00	.00000E+00	.00000E+00	.00000E+00
E	.20000E-01	.20000E-01	.20000E-01	.20000E-01	.20000E-01	.20000E-01
F	.35000E-01	.35000E-01	.35000E-01	.35000E-01	.35000E-01	.35000E-01

*** AVERAGE AMBIENT AIR TEMPERATURE (KELVIN) ***

	STABILITY CATEGORY A	STABILITY CATEGORY B	STABILITY CATEGORY C	STABILITY CATEGORY D	STABILITY CATEGORY E	STABILITY CATEGORY F
ANNUAL	283.2000	283.2000	283.2000	283.2000	283.2000	283.2000

*** MODELING OPTIONS USED: CONC RURAL FLAT DFAULT

*** AVERAGE MIXING LAYER HEIGHT (METERS) ***

	WIND SPEED CATEGORY 1	WIND SPEED CATEGORY 2	ANNUAL WIND SPEED CATEGORY 3	WIND SPEED CATEGORY 4	WIND SPEED CATEGORY 5	WIND SPEED CATEGORY 6
STABILITY CATEGORY A	1420.0000	1420.0000	1420.0000	1420.0000	1420.0000	1420.0000
STABILITY CATEGORY B	944.0001	944.0001	944.0001	944.0001	944.0001	944.0001
STABILITY CATEGORY C	944.0001	944.0001	944.0001	944.0001	944.0001	944.0001
STABILITY CATEGORY D	944.0001	944.0001	944.0001	944.0001	944.0001	944.0001
STABILITY CATEGORY E	10000.0000	10000.0000	10000.0000	10000.0000	10000.0000	10000.0000
STABILITY CATEGORY F	10000.0000	10000.0000	10000.0000	10000.0000	10000.0000	10000.0000

*** MODELING OPTIONS USED: CONC RURAL FLAT DFAULT

*** FREQUENCY OF OCCURRENCE OF WIND SPEED, DIRECTION AND STABILITY ***

FILE: TEST.DAT FORMAT: FREE
SURFACE STATION NO.: 14765 UPPER AIR STATION NO.: 14765
NAME: PROVIDENCE NAME: PROVIDENCE
YEAR: 1987 YEAR: 1987

ANNUAL: STABILITY CATEGORY A

DIRECTION (DEGREES)	WIND SPEED CATEGORY 1 (1.500 M/S)	WIND SPEED CATEGORY 2 (2.500 M/S)	WIND SPEED CATEGORY 3 (4.300 M/S)	WIND SPEED CATEGORY 4 (6.800 M/S)	WIND SPEED CATEGORY 5 (9.500 M/S)	WIND SPEED CATEGORY 6 (12.500 M/S)
0.000	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000
22.500	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000
45.000	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000
67.500	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000
90.000	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000
112.500	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000
135.000	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000
157.500	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000
180.000	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000
202.500	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000
225.000	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000
247.500	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000
270.000	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000
292.500	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000
315.000	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000
337.500	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000

ANNUAL: STABILITY CATEGORY B

DIRECTION (DEGREES)	WIND SPEED CATEGORY 1 (1.500 M/S)	WIND SPEED CATEGORY 2 (2.500 M/S)	WIND SPEED CATEGORY 3 (4.300 M/S)	WIND SPEED CATEGORY 4 (6.800 M/S)	WIND SPEED CATEGORY 5 (9.500 M/S)	WIND SPEED CATEGORY 6 (12.500 M/S)
0.000	0.00013000	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000
22.500	0.00025000	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000
45.000	0.00038000	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000
67.500	0.00038000	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000
90.000	0.00038000	0.00000000	0.00009000	0.00000000	0.00000000	0.00000000
112.500	0.00038000	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000
135.000	0.00038000	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000
157.500	0.00050000	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000
180.000	0.00050000	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000
202.500	0.00013000	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000
225.000	0.00016000	0.00009000	0.00000000	0.00000000	0.00000000	0.00000000
247.500	0.00025000	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000
270.000	0.00013000	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000
292.500	0.00013000	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000
315.000	0.00016000	0.00009000	0.00000000	0.00000000	0.00000000	0.00000000
337.500	0.00013000	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000

*** MODELING OPTIONS USED: CONC RURAL FLAT DFAULT

*** FREQUENCY OF OCCURRENCE OF WIND SPEED, DIRECTION AND STABILITY ***

FILE: TEST.DAT FORMAT: FREE
SURFACE STATION NO.: 14765 UPPER AIR STATION NO.: 14765
NAME: PROVIDENCE NAME: PROVIDENCE
YEAR: 1987 YEAR: 1987

ANNUAL: STABILITY CATEGORY C

DIRECTION (DEGREES)	WIND SPEED CATEGORY 1 (1.500 M/S)	WIND SPEED CATEGORY 2 (2.500 M/S)	WIND SPEED CATEGORY 3 (4.300 M/S)	WIND SPEED CATEGORY 4 (6.800 M/S)	WIND SPEED CATEGORY 5 (9.500 M/S)	WIND SPEED CATEGORY 6 (12.500 M/S)
0.000	0.00047000	0.00130000	0.00296000	0.00019000	0.00000000	0.00000000
22.500	0.00025000	0.00037000	0.00065000	0.00000000	0.00000000	0.00000000
45.000	0.00005000	0.00037000	0.00046000	0.00000000	0.00000000	0.00000000
67.500	0.00097000	0.00028000	0.00028000	0.00009000	0.00000000	0.00000000
90.000	0.00007000	0.00056000	0.00009000	0.00000000	0.00000000	0.00000000
112.500	0.00024000	0.00028000	0.00028000	0.00000000	0.00000000	0.00000000
135.000	0.00048000	0.00056000	0.00074000	0.00000000	0.00000000	0.00000000
157.500	0.00003000	0.00028000	0.00083000	0.00000000	0.00000000	0.00000000
180.000	0.00094000	0.00176000	0.00139000	0.00000000	0.00000000	0.00000000
202.500	0.00042000	0.00093000	0.00074000	0.00000000	0.00000000	0.00000000
225.000	0.00026000	0.00046000	0.00120000	0.00000000	0.00000000	0.00000000
247.500	0.00048000	0.00139000	0.00269000	0.00009000	0.00000000	0.00000000
270.000	0.00071000	0.00157000	0.00296000	0.00000000	0.00000000	0.00000000
292.500	0.00044000	0.00102000	0.00269000	0.00000000	0.00000000	0.00000000
315.000	0.00039000	0.00065000	0.00278000	0.00000000	0.00000000	0.00000000
337.500	0.00028000	0.00056000	0.00167000	0.00000000	0.00000000	0.00000000

ANNUAL: STABILITY CATEGORY D

DIRECTION (DEGREES)	WIND SPEED CATEGORY 1 (1.500 M/S)	WIND SPEED CATEGORY 2 (2.500 M/S)	WIND SPEED CATEGORY 3 (4.300 M/S)	WIND SPEED CATEGORY 4 (6.800 M/S)	WIND SPEED CATEGORY 5 (9.500 M/S)	WIND SPEED CATEGORY 6 (12.500 M/S)
0.000	0.00274000	0.01083000	0.03380000	0.03593000	0.00694000	0.00074000
22.500	0.00192000	0.00639000	0.01417000	0.00981000	0.00102000	0.00019000
45.000	0.00171000	0.00630000	0.01167000	0.00824000	0.00102000	0.00037000
67.500	0.00084000	0.00565000	0.00833000	0.00546000	0.00019000	0.00000000
90.000	0.00091000	0.00426000	0.00704000	0.00259000	0.00000000	0.00000000
112.500	0.00089000	0.00194000	0.00380000	0.00157000	0.00000000	0.00000000
135.000	0.00052000	0.00231000	0.00333000	0.00093000	0.00009000	0.00000000
157.500	0.00138000	0.00500000	0.00583000	0.00222000	0.00019000	0.00000000
180.000	0.00186000	0.00796000	0.02130000	0.01157000	0.00148000	0.00037000
202.500	0.00093000	0.00454000	0.01204000	0.01167000	0.00296000	0.00120000
225.000	0.00171000	0.00528000	0.01343000	0.02065000	0.00491000	0.00185000
247.500	0.00123000	0.00343000	0.01519000	0.02694000	0.00315000	0.00074000
270.000	0.00139000	0.00509000	0.02194000	0.03037000	0.00380000	0.00111000
292.500	0.00040000	0.00426000	0.01907000	0.04454000	0.01315000	0.00222000
315.000	0.00051000	0.00324000	0.01435000	0.04204000	0.01157000	0.00167000
337.500	0.00114000	0.00454000	0.01491000	0.02833000	0.00667000	0.00102000

*** MODELING OPTIONS USED: CONC RURAL FLAT DFAULT

*** FREQUENCY OF OCCURRENCE OF WIND SPEED, DIRECTION AND STABILITY ***

FILE: TEST.DAT FORMAT: FREE
SURFACE STATION NO.: 14765 UPPER AIR STATION NO.: 14765
NAME: PROVIDENCE NAME: PROVIDENCE
YEAR: 1987 YEAR: 1987

ANNUAL: STABILITY CATEGORY E

DIRECTION (DEGREES)	WIND SPEED CATEGORY 1 (1.500 M/S)	WIND SPEED CATEGORY 2 (2.500 M/S)	WIND SPEED CATEGORY 3 (4.300 M/S)	WIND SPEED CATEGORY 4 (6.800 M/S)	WIND SPEED CATEGORY 5 (9.500 M/S)	WIND SPEED CATEGORY 6 (12.500 M/S)
0.000	0.00000000	0.00630000	0.01019000	0.00000000	0.00000000	0.00000000
22.500	0.00000000	0.00102000	0.00111000	0.00000000	0.00000000	0.00000000
45.000	0.00000000	0.00148000	0.00074000	0.00000000	0.00000000	0.00000000
67.500	0.00000000	0.00231000	0.00028000	0.00000000	0.00000000	0.00000000
90.000	0.00000000	0.00111000	0.00000000	0.00000000	0.00000000	0.00000000
112.500	0.00000000	0.00056000	0.00009000	0.00000000	0.00000000	0.00000000
135.000	0.00000000	0.00093000	0.00028000	0.00000000	0.00000000	0.00000000
157.500	0.00000000	0.00204000	0.00111000	0.00000000	0.00000000	0.00000000
180.000	0.00000000	0.00954000	0.00500000	0.00000000	0.00000000	0.00000000
202.500	0.00000000	0.00546000	0.00380000	0.00000000	0.00000000	0.00000000
225.000	0.00000000	0.00509000	0.00546000	0.00000000	0.00000000	0.00000000
247.500	0.00000000	0.00593000	0.00694000	0.00000000	0.00000000	0.00000000
270.000	0.00000000	0.00583000	0.01806000	0.00000000	0.00000000	0.00000000
292.500	0.00000000	0.00389000	0.01981000	0.00000000	0.00000000	0.00000000
315.000	0.00000000	0.00565000	0.01685000	0.00000000	0.00000000	0.00000000
337.500	0.00000000	0.00583000	0.01074000	0.00000000	0.00000000	0.00000000

ANNUAL: STABILITY CATEGORY F

DIRECTION (DEGREES)	WIND SPEED CATEGORY 1 (1.500 M/S)	WIND SPEED CATEGORY 2 (2.500 M/S)	WIND SPEED CATEGORY 3 (4.300 M/S)	WIND SPEED CATEGORY 4 (6.800 M/S)	WIND SPEED CATEGORY 5 (9.500 M/S)	WIND SPEED CATEGORY 6 (12.500 M/S)
0.000	0.00110000	0.00593000	0.00000000	0.00000000	0.00000000	0.00000000
22.500	0.00026000	0.00083000	0.00000000	0.00000000	0.00000000	0.00000000
45.000	0.00028000	0.00120000	0.00000000	0.00000000	0.00000000	0.00000000
67.500	0.00094000	0.00074000	0.00000000	0.00000000	0.00000000	0.00000000

90.000	0.00072000	0.00046000	0.00000000	0.00000000	0.00000000	0.00000000
112.500	0.00040000	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000
135.000	0.00094000	0.00065000	0.00000000	0.00000000	0.00000000	0.00000000
157.500	0.00110000	0.00157000	0.00000000	0.00000000	0.00000000	0.00000000
180.000	0.00291000	0.00491000	0.00000000	0.00000000	0.00000000	0.00000000
202.500	0.00140000	0.00454000	0.00000000	0.00000000	0.00000000	0.00000000
225.000	0.00168000	0.00565000	0.00000000	0.00000000	0.00000000	0.00000000
247.500	0.00220000	0.01037000	0.00000000	0.00000000	0.00000000	0.00000000
270.000	0.00148000	0.01287000	0.00000000	0.00000000	0.00000000	0.00000000
292.500	0.00132000	0.01194000	0.00000000	0.00000000	0.00000000	0.00000000
315.000	0.00151000	0.00898000	0.00000000	0.00000000	0.00000000	0.00000000
337.500	0.00166000	0.00824000	0.00000000	0.00000000	0.00000000	0.00000000

SUM OF FREQUENCIES, FTOTAL = 0.98123

*** MODELING OPTIONS USED: CONC RURAL FLAT DFAULT

*** THE ANNUAL AVERAGE CONCENTRATION VALUES FOR SOURCE: STACK1 ***

*** NETWORK ID: POL ; NETWORK TYPE: GRIDPOLR ***

** CONC OF VYCL IN MICROGRAMS/M**3 **

DIRECTION (DEGREES)	DISTANCE (METERS) 50.00	100.00	150.00	200.00	250.00	300.00	350.00	400.00	450.00
360.00	0.000951	0.009606	0.013544	0.012859	0.011206	0.009647	0.008352	0.007307	0.006455
45.00	0.000678	0.008328	0.011665	0.010942	0.009439	0.008057	0.006934	0.006040	0.005317
90.00	0.001229	0.012579	0.016675	0.015532	0.013534	0.011723	0.010231	0.009025	0.008034
135.00	0.001110	0.012589	0.016428	0.015062	0.012969	0.011123	0.009624	0.008422	0.007444
180.00	0.001023	0.015836	0.022894	0.021503	0.018386	0.015470	0.013098	0.011215	0.009711
225.00	0.000414	0.005254	0.008110	0.007740	0.006589	0.005478	0.004576	0.003866	0.003305
270.00	0.000396	0.003160	0.004713	0.004476	0.003806	0.003167	0.002652	0.002249	0.001931
315.00	0.000465	0.002561	0.003192	0.002876	0.002407	0.002003	0.001689	0.001449	0.001260

*** MODELING OPTIONS USED: CONC RURAL FLAT DFAULT

*** THE ANNUAL AVERAGE CONCENTRATION VALUES FOR SOURCE: STACK1 ***

*** NETWORK ID: POL ; NETWORK TYPE: GRIDPOLR ***

** CONC OF VYCL IN MICROGRAMS/M**3 **

DIRECTION (DEGREES)	DISTANCE (METERS) 500.00	550.00	600.00	650.00	700.00	750.00	800.00	850.00	900.00
360.00	0.005750	0.005157	0.004652	0.004218	0.003842	0.003510	0.003220	0.002965	0.002740
45.00	0.004723	0.004227	0.003807	0.003447	0.003137	0.002863	0.002624	0.002415	0.002230
90.00	0.007206	0.006501	0.005895	0.005368	0.004908	0.004498	0.004137	0.003819	0.003536
135.00	0.006634	0.005953	0.005372	0.004872	0.004438	0.004055	0.003721	0.003426	0.003166
180.00	0.008494	0.007495	0.006664	0.005966	0.005374	0.004864	0.004424	0.004043	0.003710
225.00	0.002858	0.002496	0.002199	0.001953	0.001746	0.001571	0.001421	0.001292	0.001180
270.00	0.001677	0.001471	0.001302	0.001162	0.001043	0.000941	0.000854	0.000779	0.000714
315.00	0.001110	0.000986	0.000884	0.000797	0.000723	0.000659	0.000603	0.000554	0.000511

*** MODELING OPTIONS USED: CONC RURAL FLAT DFAULT

*** THE ANNUAL AVERAGE CONCENTRATION VALUES FOR SOURCE: STACK1 ***

*** NETWORK ID: POL ; NETWORK TYPE: GRIDPOLR ***

** CONC OF VYCL IN MICROGRAMS/M**3 **

DIRECTION (DEGREES)	DISTANCE (METERS) 2800.00	2900.00	3000.00	3100.00	3200.00	3300.00	3400.00	3500.00	3600.00
360.00	0.000529	0.000502	0.000477	0.000454	0.000433	0.000414	0.000396	0.000379	0.000363
45.00	0.000431	0.000408	0.000388	0.000370	0.000353	0.000337	0.000322	0.000309	0.000296
90.00	0.000699	0.000663	0.000630	0.000601	0.000573	0.000548	0.000524	0.000502	0.000482
135.00	0.000613	0.000582	0.000553	0.000526	0.000502	0.000480	0.000459	0.000439	0.000421
180.00	0.000669	0.000633	0.000601	0.000572	0.000545	0.000520	0.000496	0.000475	0.000455
225.00	0.000203	0.000192	0.000182	0.000173	0.000165	0.000157	0.000150	0.000143	0.000137
270.00	0.000127	0.000120	0.000114	0.000108	0.000103	0.000098	0.000094	0.000090	0.000086
315.00	0.000097	0.000092	0.000087	0.000083	0.000079	0.000076	0.000072	0.000069	0.000066

*** MODELING OPTIONS USED: CONC RURAL FLAT DFAULT

*** THE ANNUAL AVERAGE CONCENTRATION VALUES FOR SOURCE: STACK1 ***

*** NETWORK ID: POL ; NETWORK TYPE: GRIDPOLR ***

** CONC OF VYCL IN MICROGRAMS/M**3 **

DIRECTION | DISTANCE (METERS)

(DEGREES)	3700.00	3800.00	3900.00	4000.00	4100.00	4200.00	4300.00	4400.00	4500.00
360.00	0.000349	0.000335	0.000322	0.000310	0.000299	0.000289	0.000279	0.000269	0.000261
45.00	0.000284	0.000273	0.000263	0.000253	0.000244	0.000235	0.000227	0.000219	0.000212
90.00	0.000462	0.000445	0.000428	0.000412	0.000397	0.000383	0.000370	0.000358	0.000346
135.00	0.000405	0.000389	0.000374	0.000360	0.000347	0.000335	0.000323	0.000313	0.000302
180.00	0.000436	0.000419	0.000403	0.000387	0.000373	0.000360	0.000347	0.000335	0.000324
225.00	0.000131	0.000126	0.000121	0.000116	0.000112	0.000108	0.000104	0.000100	0.000097
270.00	0.000083	0.000079	0.000076	0.000073	0.000071	0.000068	0.000066	0.000063	0.000061
315.00	0.000064	0.000061	0.000059	0.000057	0.000055	0.000053	0.000051	0.000049	0.000047

*** MODELING OPTIONS USED: CONC RURAL FLAT DFAULT

*** THE ANNUAL AVERAGE CONCENTRATION VALUES FOR SOURCE: STACK1 ***

*** NETWORK ID: POL ; NETWORK TYPE: GRIDPOLR ***

** CONC OF VYCL IN MICROGRAMS/M**3 **

DIRECTION (DEGREES)	DISTANCE (METERS) 4600.00	4700.00	4800.00
360.00	0.000252	0.000244	0.000237
45.00	0.000205	0.000199	0.000193
90.00	0.000335	0.000325	0.000315
135.00	0.000293	0.000283	0.000275
180.00	0.000313	0.000303	0.000293
225.00	0.000094	0.000091	0.000088
270.00	0.000059	0.000057	0.000055
315.00	0.000046	0.000044	0.000043

*** MODELING OPTIONS USED: CONC RURAL FLAT DFAULT

*** THE ANNUAL AVERAGE CONCENTRATION VALUES FOR SOURCE: STACK1 ***

*** DISCRETE CARTESIAN RECEPTOR POINTS ***

** CONC OF VYCL IN MICROGRAMS/M**3 **

X-COORD (M)	Y-COORD (M)	CONC	X-COORD (M)	Y-COORD (M)	CONC
99.06	670.56	0.001726	30.48	662.94	0.001411
22.86	563.88	0.001942	15.24	541.02	0.002094
60.96	533.40	0.002458	91.44	434.34	0.003849
121.92	297.18	0.004834	259.08	15.24	0.005568
388.62	640.08	0.012425	487.68	670.56	0.008719
563.88	243.84	0.010533	243.84	655.32	0.003365
167.64	274.32	0.005634	114.30	647.70	0.001879
91.44	594.36	0.001890	228.60	129.54	0.004612
365.76	144.78	0.013323			

*** MODELING OPTIONS USED: CONC RURAL FLAT DFAULT

*** THE MAXIMUM 10 ANNUAL AVERAGE CONCENTRATION VALUES FOR SOURCE: STACK1 ***

** CONC OF VYCL IN MICROGRAMS/M**3 **

RANK	CONC	AT	RECEPTOR (XR,YR)		OF TYPE	RANK	CONC	AT	RECEPTOR (XR,YR)		OF TYPE
1.	0.022894	AT (	375.00,	330.00)	GP	6.	0.015836	AT (	375.00,	380.00)	GP
2.	0.021503	AT (	375.00,	280.00)	GP	7.	0.015532	AT (	575.00,	480.00)	GP
3.	0.018386	AT (	375.00,	230.00)	GP	8.	0.015470	AT (	375.00,	180.00)	GP
4.	0.016675	AT (	525.00,	480.00)	GP	9.	0.015062	AT (	516.42,	338.58)	GP
5.	0.016428	AT (	481.07,	373.93)	GP	10.	0.013544	AT (	375.00,	630.00)	GP

*** RECEPTOR TYPES: GC = GRIDCART
GP = GRIDPOLR
DC = DISCCART
DP = DISCPOLR
BD = BOUNDARY

*** MODELING OPTIONS USED: CONC RURAL FLAT DFAULT

*** Message Summary : ISCLT3 Model Execution ***

--------- Summary of Total Messages --------

A Total of 0 Fatal Error Message(s)
A Total of 0 Warning Message(s)
A Total of 0 Informational Message(s)

******** FATAL ERROR MESSAGES ********

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          ***  NONE  ***

********   WARNING MESSAGES   ********
          ***  NONE  ***

************************************
*** ISCLT3 Finishes Successfully ***
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G. COST CALCULATIONS

G-1 Summary of Costs - Alternatives #1 through #5
G-2 Detailed Costs - Alternative #1
G-3 Detailed Costs - Alternative #2
G-4 Detailed Costs - Alternative #3a
G-5 Detailed Costs - Alternative #3b
G-6 Detailed Costs - Alternative #4a
G-7 Detailed Costs - Alternative #4b
G-8 Detailed Costs - Alternative #5a
G-9 Detailed Costs - Alternative #5b
G-10 Unit Cost Development and General Assumptions- All Alternatives

G-1 Summary of Costs - Alternatives #1 through #5

TABLE G-1. SUMMARY OF COSTS, ALTERNATIVE # 1

Version: November 6, 1997

		SENSITIVITY	BASE
CAPITAL COSTS (in $1,000's)			
1.0	GRADING & SITE PREP.: SOLID WASTE AREA		0
2.0	CAPPING: SOLID WASTE AREA		0
3.0	GRADING & SITE PREP.: BULKY WASTE AREA		0
4.0	CAPPING: BULKY WASTE AREA		0
5.0	LANDFILL MINING		0
6.0	PERIMETER WETLANDS MITIGATION		0
7.0	INTERNAL LF GAS COLLECTION SYSTEM		0
8.0	PERIMETER LF GAS COLLECTION SYSTEM		0
9.0	LF GAS TREATMENT PLANT		0
10.0	GW DEPRESSION SYSTEM: COLLECTION		0
11.0	LEACHATE COLLECTION SYSTEM		0
12.0	50 GPM WATER TREATMENT PLANT		0
13.0	5 GPM WATER TREATMENT PLANT		0
14.0	ENVIRONMENTAL MONITORING: CAPITAL COST		88
15.0	DECONTAMINATION AREA - TREATMENT PLANT AREA		0
16.0	INSTITUTIONAL CONTROLS	+	0
	TOTAL DIRECT CAPITAL COST		88
	REMEDIAL DESIGN ALLOWANCE		5
	CONTINGENCY	+	19
	TOTAL CAPITAL COSTS		$111
ANNUAL COSTS (Present Value in $1,000's)			
17.0	ENVIRONMENTAL MONITORING: ANNUAL		2,880
18.0	LANDFILL GAS COLLECTION AND TREATMENT		0
19.0	GW/LEACHATE COLLECTION & TREATMENT: 50 GPM		0
20.0	LEACHATE COLLECTION & TREATMENT: 5 GPM		0
21.0	INSTITUTIONAL CONTROLS: ANNUAL COSTS	+	0
	TOTAL DIRECT ANNUAL COST		2,880
	CONTINGENCY		576
	TOTAL ANNUAL COSTS		$3,456
TOTAL COST OF ALTERNATIVE (in $1,000's)			$3,568

TABLE G-2. SUMMARY OF COSTS, ALTERNATIVE # 2

Version November 6, 1997		SENSITIVITY	BASE
CAPITAL COSTS (in $1,000's)			
1.0	GRADING & SITE PREP.: SOLID WASTE AREA		71
2.0	CAPPING: SOLID WASTE AREA		0
3.0	GRADING & SITE PREP.: BULKY WASTE AREA		0
4.0	CAPPING: BULKY WASTE AREA		0
5.0	LANDFILL MINING		0
6.0	PERIMETER WETLANDS MITIGATION		0
7.0	INTERNAL LF GAS COLLECTION SYSTEM		0
8.0	PERIMETER LF GAS COLLECTION SYSTEM		0
9.0	LF GAS TREATMENT PLANT		0
10.0	GW DEPRESSION SYSTEM: COLLECTION		0
11.0	LEACHATE COLLECTION SYSTEM		0
12.0	50 GPM WATER TREATMENT PLANT		0
13.0	5 GPM WATER TREATMENT PLANT		0
14.0	ENVIRONMENTAL MONITORING: CAPITAL COST		88
15.0	DECONTAMINATION AREA - TREATMENT PLANT AREA		0
16.0	INSTITUTIONAL CONTROLS	+	127
	TOTAL DIRECT CAPITAL COST		285
	REMEDIAL DESIGN ALLOWANCE		17
	CONTINGENCY	+	60
	TOTAL CAPITAL COSTS		$363
ANNUAL COSTS (Present Value in $1,000's)			
17.0	ENVIRONMENTAL MONITORING: ANNUAL		2,880
18.0	LANDFILL GAS COLLECTION AND TREATMENT		0
19.0	GW/LEACHATE COLLECTION & TREATMENT: 50 GPM		0
20.0	LEACHATE COLLECTION & TREATMENT: 5 GPM		0
21.0	INSTITUTIONAL CONTROLS: ANNUAL COSTS	+	22
	TOTAL DIRECT ANNUAL COST		2,902
	CONTINGENCY		580
	TOTAL ANNUAL COSTS		$3,482
TOTAL COST OF ALTERNATIVE (in $1,000's)			$3,845

TABLE G-3a. SUMMARY OF COSTS, ALTERNATIVE # 3a

Version: November 6, 1997

		SENSITIVITY:	BASE
CAPITAL COSTS (in $1,000's)			
1.0	GRADING & SITE PREP.: SOLID WASTE AREA		100
2.0	CAPPING: SOLID WASTE AREA		2,442
3.0	GRADING & SITE PREP.: BULKY WASTE AREA		48
4.0	CAPPING: BULKY WASTE AREA		864
5.0	LANDFILL MINING		0
6.0	PERIMETER WETLANDS MITIGATION		4
7.0	INTERNAL LF GAS COLLECTION SYSTEM		681
8.0	PERIMETER LF GAS COLLECTION SYSTEM		338
9.0	LF GAS TREATMENT PLANT		338
10.0	GW DEPRESSION SYSTEM: COLLECTION		0
11.0	LEACHATE COLLECTION SYSTEM		0
12.0	50 GPM WATER TREATMENT PLANT		0
13.0	5 GPM WATER TREATMENT PLANT		0
14.0	ENVIRONMENTAL MONITORING: CAPITAL COST		94
15.0	DECONTAMINATION AREA - TREATMENT PLANT AREA		50
16.0	INSTITUTIONAL CONTROLS	+	88
	TOTAL DIRECT CAPITAL COST		5,047
	REMEDIAL DESIGN ALLOWANCE		303
	CONTINGENCY	+	1,070
	TOTAL CAPITAL COSTS		$6,420
ANNUAL COSTS (Present Value in $1,000's)			
17.0	ENVIRONMENTAL MONITORING: ANNUAL		3,051
18.0	LANDFILL GAS COLLECTION AND TREATMENT		2,787
19.0	GW/LEACHATE COLLECTION & TREATMENT: 50 GPM		0
20.0	LEACHATE COLLECTION & TREATMENT: 5 GPM		0
21.0	INSTITUTIONAL CONTROLS: ANNUAL COSTS	+	0
	TOTAL DIRECT ANNUAL COST		5,838
	CONTINGENCY		1,168
	TOTAL ANNUAL COSTS		$7,005
TOTAL COST OF ALTERNATIVE (in $1,000's)			$13,425

TABLE G-3b. SUMMARY OF COSTS, ALTERNATIVE # 3b

Version: November 6, 1997

		SENSITIVITY	BASE
CAPITAL COSTS (in $1,000's)			
1.0	GRADING & SITE PREP.: SOLID WASTE AREA		100
2.0	CAPPING: SOLID WASTE AREA		2,442
3.0	GRADING & SITE PREP.: BULKY WASTE AREA		48
4.0	CAPPING: BULKY WASTE AREA		864
5.0	LANDFILL MINING		0
6.0	PERIMETER WETLANDS MITIGATION		4
7.0	INTERNAL LF GAS COLLECTION SYSTEM		681
8.0	PERIMETER LF GAS COLLECTION SYSTEM		338
9.0	LF GAS TREATMENT PLANT		445
10.0	GW DEPRESSION SYSTEM: COLLECTION		0
11.0	LEACHATE COLLECTION SYSTEM		0
12.0	50 GPM WATER TREATMENT PLANT		0
13.0	5 GPM WATER TREATMENT PLANT		0
14.0	ENVIRONMENTAL MONITORING: CAPITAL COST		94
15.0	DECONTAMINATION AREA - TREATMENT PLANT AREA		50
16.0	INSTITUTIONAL CONTROLS	+	88
	TOTAL DIRECT CAPITAL COST		5,154
	REMEDIAL DESIGN ALLOWANCE		309
	CONTINGENCY	+	1,093
	TOTAL CAPITAL COSTS		$6,556
ANNUAL COSTS (Present Value in $1,000's)			
17.0	ENVIRONMENTAL MONITORING: ANNUAL		3,051
18.0	LANDFILL GAS COLLECTION AND TREATMENT		2,475
19.0	GW/LEACHATE COLLECTION & TREATMENT: 50 GPM		0
20.0	LEACHATE COLLECTION & TREATMENT: 5 GPM		0
21.0	INSTITUTIONAL CONTROLS: ANNUAL COSTS	+	0
	TOTAL DIRECT ANNUAL COST		5,526
	CONTINGENCY		1,105
	TOTAL ANNUAL COSTS		$6,631
TOTAL COST OF ALTERNATIVE (in $1,000's)			$13,187

TABLE G-4a. SUMMARY OF COSTS, ALTERNATIVE # 4a

Version: November 6, 1997

		SENSITIVITY:	BASE
CAPITAL COSTS (in $1,000's)			
1.0	GRADING & SITE PREP.: SOLID WASTE AREA		100
2.0	CAPPING: SOLID WASTE AREA		2,442
3.0	GRADING & SITE PREP.: BULKY WASTE AREA		48
4.0	CAPPING: BULKY WASTE AREA		864
5.0	LANDFILL MINING		0
6.0	PERIMETER WETLANDS MITIGATION		40
7.0	INTERNAL LF GAS COLLECTION SYSTEM		681
8.0	PERIMETER LF GAS COLLECTION SYSTEM		338
9.0	LF GAS TREATMENT PLANT		338
10.0	GW DEPRESSION SYSTEM: COLLECTION		0
11.0	LEACHATE COLLECTION SYSTEM		99
12.0	50 GPM WATER TREATMENT PLANT		0
13.0	5 GPM WATER TREATMENT PLANT		507
14.0	ENVIRONMENTAL MONITORING: CAPITAL COST		94
15.0	DECONTAMINATION AREA - TREATMENT PLANT AREA		50
16.0	INSTITUTIONAL CONTROLS	+	88
	TOTAL DIRECT CAPITAL COST		5,689
	REMEDIAL DESIGN ALLOWANCE		341
	CONTINGENCY	+	1,206
	TOTAL CAPITAL COSTS		$7,236
ANNUAL COSTS (Present Value in $1,000's)			
17.0	ENVIRONMENTAL MONITORING: ANNUAL		3,051
18.0	LANDFILL GAS COLLECTION AND TREATMENT		2,787
19.0	GW/LEACHATE COLLECTION & TREATMENT: 50 GPM		0
20.0	LEACHATE COLLECTION & TREATMENT: 5 GPM		1,519
21.0	INSTITUTIONAL CONTROLS: ANNUAL COSTS	+	0
	TOTAL DIRECT ANNUAL COST		7,357
	CONTINGENCY		1,471
	TOTAL ANNUAL COSTS		$8,828
TOTAL COST OF ALTERNATIVE (in $1,000's)			$16,064

TABLE G-4b. SUMMARY OF COSTS, ALTERNATIVE # 4b

Version November 6, 1997

		SENSITIVITY	BASE
CAPITAL COSTS (in $1,000's)			
1.0	GRADING & SITE PREP.: SOLID WASTE AREA		100
2.0	CAPPING: SOLID WASTE AREA		2,686
3.0	GRADING & SITE PREP.: BULKY WASTE AREA		46
4.0	CAPPING: BULKY WASTE AREA		0
5.0	LANDFILL MINING		2,652
6.0	PERIMETER WETLANDS MITIGATION		40
7.0	INTERNAL LF GAS COLLECTION SYSTEM		681
8.0	PERIMETER LF GAS COLLECTION SYSTEM		338
9.0	LF GAS TREATMENT PLANT		338
10.0	GW DEPRESSION SYSTEM: COLLECTION		0
11.0	LEACHATE COLLECTION SYSTEM		99
12.0	50 GPM WATER TREATMENT PLANT		0
13.0	5 GPM WATER TREATMENT PLANT		507
14.0	ENVIRONMENTAL MONITORING: CAPITAL COST		94
15.0	DECONTAMINATION AREA - TREATMENT PLANT AREA		50
16.0	INSTITUTIONAL CONTROLS	+	88
	TOTAL DIRECT CAPITAL COST		7,717
	REMEDIAL DESIGN ALLOWANCE		463
	CONTINGENCY	+	1,636
	TOTAL CAPITAL COSTS		$9,816
ANNUAL COSTS (Present Value in $1,000's)			
17.0	ENVIRONMENTAL MONITORING: ANNUAL		3,051
18.0	LANDFILL GAS COLLECTION AND TREATMENT		2,787
19.0	GW/LEACHATE COLLECTION & TREATMENT: 50 GPM		0
20.0	LEACHATE COLLECTION & TREATMENT: 5 GPM		83
21.0	INSTITUTIONAL CONTROLS: ANNUAL COSTS	+	0
	TOTAL DIRECT ANNUAL COST		5,921
	CONTINGENCY		1,184
	TOTAL ANNUAL COSTS		$7,105
TOTAL COST OF ALTERNATIVE (in $1,000's)			$16,922

TABLE G-5a. SUMMARY OF COSTS, ALTERNATIVE # 5a

Version: November 6, 1997

		SENSITIVITY	BASE
CAPITAL COSTS (in $1,000's)			
1.0	GRADING & SITE PREP.: SOLID WASTE AREA		100
2.0	CAPPING: SOLID WASTE AREA		2,442
3.0	GRADING & SITE PREP.: BULKY WASTE AREA		48
4.0	CAPPING: BULKY WASTE AREA		864
5.0	LANDFILL MINING		0
6.0	PERIMETER WETLANDS MITIGATION		40
7.0	INTERNAL LF GAS COLLECTION SYSTEM		623
8.0	PERIMETER LF GAS COLLECTION SYSTEM		338
9.0	LF GAS TREATMENT PLANT		338
10.0	GW DEPRESSION SYSTEM: COLLECTION		152
11.0	LEACHATE COLLECTION SYSTEM		99
12.0	50 GPM WATER TREATMENT PLANT		1,348
13.0	5 GPM WATER TREATMENT PLANT		0
14.0	ENVIRONMENTAL MONITORING: CAPITAL COST		94
15.0	DECONTAMINATION AREA - TREATMENT PLANT AREA		50
16.0	INSTITUTIONAL CONTROLS	+	88
	TOTAL DIRECT CAPITAL COST		6,624
	REMEDIAL DESIGN ALLOWANCE		397
	CONTINGENCY	+	1,404
	TOTAL CAPITAL COSTS		$8,426
ANNUAL COSTS (Present Value in $1,000's)			
17.0	ENVIRONMENTAL MONITORING: ANNUAL		3,051
18.0	LANDFILL GAS COLLECTION AND TREATMENT		2,787
19.0	GW/LEACHATE COLLECTION & TREATMENT: 50 GPM		4,006
20.0	LEACHATE COLLECTION & TREATMENT: 5 GPM		0
21.0	INSTITUTIONAL CONTROLS: ANNUAL COSTS	+	0
	TOTAL DIRECT ANNUAL COST		9,844
	CONTINGENCY		1,969
	TOTAL ANNUAL COSTS		$11,813
TOTAL COST OF ALTERNATIVE (in $1,000's)			$20,239

TABLE G-5b. SUMMARY OF COSTS, ALTERNATIVE # 5b

Version November 6, 1997

		SENSITIVITY	BASE
CAPITAL COSTS (in $1,000's)			
1.0	GRADING & SITE PREP.: SOLID WASTE AREA		100
2.0	CAPPING: SOLID WASTE AREA		2,686
3.0	GRADING & SITE PREP.: BULKY WASTE AREA		46
4.0	CAPPING: BULKY WASTE AREA		0
5.0	LANDFILL MINING		2,652
6.0	PERIMETER WETLANDS MITIGATION		40
7.0	INTERNAL LF GAS COLLECTION SYSTEM		623
8.0	PERIMETER LF GAS COLLECTION SYSTEM		338
9.0	LF GAS TREATMENT PLANT		338
10.0	GW DEPRESSION SYSTEM: COLLECTION		152
11.0	LEACHATE COLLECTION SYSTEM		99
12.0	50 GPM WATER TREATMENT PLANT		1,348
13.0	5 GPM WATER TREATMENT PLANT		0
14.0	ENVIRONMENTAL MONITORING: CAPITAL COST		94
15.0	DECONTAMINATION AREA - TREATMENT PLANT AREA		50
16.0	INSTITUTIONAL CONTROLS	+	88
	TOTAL DIRECT CAPITAL COST		8,653
	REMEDIAL DESIGN ALLOWANCE		519
	CONTINGENCY	+	1,834
	TOTAL CAPITAL COSTS		$11,006
ANNUAL COSTS (Present Value in $1,000's)			
17.0	ENVIRONMENTAL MONITORING: ANNUAL		3,051
18.0	LANDFILL GAS COLLECTION AND TREATMENT		2,787
19.0	GW/LEACHATE COLLECTION & TREATMENT: 50 GPM		4,006
20.0	LEACHATE COLLECTION & TREATMENT: 5 GPM		0
21.0	INSTITUTIONAL CONTROLS: ANNUAL COSTS	+	0
	TOTAL DIRECT ANNUAL COST		9,844
	CONTINGENCY		1,969
	TOTAL ANNUAL COSTS		$11,813
TOTAL COST OF ALTERNATIVE (in $1,000's)			$22,819

DETAILED COST TABLE: ALTERNATIVE # 1 SENSITIVITY: BASE

	ITEM	UNIT	UNIT COST ($ / unit)	QUAN-TITY	COST ($1,000's)
CAPITAL COSTS:					
1.0	GRADING & SITE PREP.: SOLID WASTE AREA				
1.1	Clearing and Grubbing	acre	335.00	0	0
1.2	Silt Fencing	lf	2.00	0	0
1.3	Drainage Ditches	lf	0.36	0	0
1.4	Detention Basins	cy	4.00	0	0
1.5	Fence 8' Chain Link	lf	15.00	0	0
Total					0
2.0	CAPPING: SOLID WASTE AREA				
2.1	Vegetation	sy	0.35	0	0
2.2	Topsoil: 6"	sy	3.50	0	0
2.3	Cover Layer: 18"	cy	12.00	0	0
2.4	Drainage Layer: Composite	sy	3.60	0	0
2.5	Geomembrane	sf	0.43	0	0
2.6	Low Permeability Layer: 12"	cy	8.00	0	0
2.7	Protective Layer: 6"	cy	12.00	0	0
2.8	Wetlands Replacement	acre	50,000	0	0
Total					0
3.0	GRADING & SITE PREP.: BULKY WASTE AREA				
3.1	Clearing and Grubbing	acre	335.00	0	0
3.2	Silt Fencing	lf	2.00	0	0
3.2	Drainage Ditches	lf	0.36	0	0
3.4	Detention Basins	cy	4.00	0	0
3.5	Fence 8' Chain Link	lf	15.00	0	0
Total					0
4.0	CAPPING: BULKY WASTE AREA				
4.1	Vegetation	sy	0.35	0	0
4.2	Topsoil: 6"	sy	3.50	0	0
4.3	Cover Layer: 18"	cy	12.00	0	0
4.4	Drainage Layer: Composite	sy	3.60	0	0
4.5	Geomembrane	sf	0.43	0	0
4.6	Low Permeability Layer: 12"	cy	8.00	0	0
4.7	Gas Vent Layer: Composite	sy	3.60	0	0
4.8	Passive Gas Vents	lf	196.00	0	0
Total					0
5.0	LANDFILL MINING				
5.1	Waste Removal and Segregation	cy	9.00	0	0
5.2	Scrap Metal Transport	cy	5.00	0	0
5.3	Transport Non-recyclables to Solid Waste Area	cy	1.50	0	0
5.4	Backfill With Reclaimed Soil	cy	2.15	0	0
5.5	Backfill With Clean Fill	cy	11.00	0	0
5.6	Vegetation	sy	0.35	0	0
5.7	Miscellaneous Allowances	ls	97,000	0	0
5.8	Scrap Metal Revenue	lb	0.02	0	0
5.9	Supervision & Monitoring Labor	day	300.00	0	0
Total					0
6.0	PERIMETER WETLANDS MITIGATION				
6.1	Wetlands & Buffer Zone replacement	ls	80,000	0	0
Total					0

DETAILED COST TABLE: ALTERNATIVE # 1 SENSITIVITY: BASE

	ITEM	UNIT	UNIT COST ($ / unit)	QUAN-TITY	COST ($1,000's)
7.0	INTERNAL LF GAS COLLECTION SYSTEM				
7.1	Vault, Gauges, Fittings and Other Costs	well	4,250	0	0
7.2	Screen, Casing and Other Well Footage Costs	lf	196.00	0	0
7.3	Header Pipe: HDPE				
7.3a	10" HDPE Header Pipe, buried	lf	27.60	0	0
7.3b	8" HDPE Header Pipe, buried	lf	23.60	0	0
7.3c	6" HDPE Header Pipe, buried	lf	18.50	0	0
7.3d	"Blueboard" thermal insulation	lf	1.50	0	0
7.3e	HDPE Tees 8" x 8" x 8", installed & buried	ea	310.00	0	0
7.3f	HDPE Tees 6" x 6" x 6", installed & buried	ea	250.00	0	0
7.4	Valves & Appurtenances				
7.4a	Buried butterfly isolation valves: 10"	ea	2000.00	0	0
7.4b	Buried butterfly isolation valves: 8"	ea	1600.00	0	0
7.4c	LANDTEC GEM-500 LFG analyzer	ls	6395.00	0	0
7.5	Condensate Piping	lf	5.00	0	0
7.6	Condensate Pump Stations	ea	50,000	0	0
7.7	Condensate Storage Tank Allowance	ea	25,000	0	0
Total					0
8.0	PERIMETER LF GAS COLLECTION SYSTEM				
8.1	Vault, Gauges, Fittings and Other Costs	well	4,250	0	0
8.2	Screen, Casing and Other Well Footage Costs	lf	196.00	0	0
8.3	Header Pipe: HDPE				
8.3a	10" HDPE Header Pipe, buried	lf	27.60	0	0
8.3b	6" HDPE Header Pipe, buried	lf	18.50	0	0
8.3c	"Blueboard" thermal insulation	lf	1.50	0	0
8.3d	HDPE Tees 10" x 10" x 6", installed & buried	ea	430.00	0	0
8.4	Valves & Appurtenances	ea	2000.00	0	0
Total					0
9.0	LF GAS TREATMENT PLANT				
9.1	Access Roads	sy	5.56	0	0
9.2	Electricity Service	lf	14.00	0	0
9.3	Water Service	lf	5.00	0	0
9.4	Internal & Perim. Coll. System Blowers & Motors	ls	60,000	0	0
9.5	Enclosed Flare and Appurtenances	ea	179,400	0	0
9.6	Foundation: 18" Structural Slab	cy	350.00	0	0
9.7	Photocatalytic Oxidation and Appurtenances	ls	286,000	0	0
9.8	Fence 8' Chain Link	lf	15.00	0	0
Total					0
10.0	GW DEPRESSION SYSTEM: COLLECTION				
10.1	Buried Piping	lf	8.00	0	0
10.2	Pump Electrical	lf	4.00	0	0
10.3	Pump Station	ls	75,000	0	0
10.4	Shallow Drain Piping & Installation	lf	40.00	0	0
Total					0
11.0	LEACHATE COLLECTION SYSTEM				
11.1	Buried Piping	lf	5.00	0	0
11.2	Pump Electrical	lf	4.00	0	0
11.3	Pump Station	ls	50,000	0	0
11.4	Shallow Drain Piping & Installation	lf	40.00	0	0
Total					

DETAILED COST TABLE: ALTERNATIVE # 1 SENSITIVITY: BASE

	ITEM	UNIT	UNIT COST ($ / unit)	QUAN-TITY	COST ($1,000's)
12.0	50 GPM WATER TREATMENT PLANT				
12.1	Not Used				
12.2	Not Used				
12.3	Not Used				
12.4	Equipment	ls	613,500	0	0
12.5	Instrumentation	ls	58,300	0	0
12.6	Foundation: 18" Structural Slab	cy	350.00	0	0
12.7	Structure: 20' Pre-engineered Building	sf	50.00	0	0
12.8	Discharge Line	lf	8.00	0	0
12.9	Groundwater Injection Wells	ea	9,000	0	0
12.10	Fence 8' Chain Link	lf	15.00	0	0
Total					0
13.0	5 GPM WATER TREATMENT PLANT				
13.1	Not Used				
13.2	Not Used				
13.3	Not Used				
13.4	Equipment	ls	213,500	0	0
13.5	Instrumentation	ls	20,289	0	0
13.6	Foundation: 18" Structural Slab	cy	350.00	0	0
13.7	Structure: 20' Pre-engineered Building	sf	50.00	0	0
13.8	Discharge Line	lf	5.00	0	0
13.9	Groundwater Injection Wells	ea	9,000	0	0
13.10	Fence 8' Chain Link	lf	15.00	0	0
Total					0
14.0	ENVIRONMENTAL MONITORING: CAPITAL COST				
14.1	Piezometer Installation	lf	50	0	0
14.2	Soil Gas Probe Construction	ea	2,500	35	88
Total					88
15.0	DECONTAMINATION AREA - TREATMENT PLANT AREA				
15.1	Decon Station Allowance	ls	50,000	0	0
Total					0
16.0	INSTITUTIONAL CONTROLS				
16.1	GW Access Restrictions: Legal Fees	lot	8,000	0	0
16.2	Not Used				
16.3	Not Used				
16.4	LFG Control Contingency	house	9,808	0	0
Total					0
	TOTAL DIRECT CAPITAL COST				88
	REMEDIAL DESIGN ALLOWANCE @	6%			5
	CONTINGENCY @	20%			19
	TOTAL CAPITAL COSTS				111

DETAILED COST TABLE: ALTERNATIVE # 1 SENSITIVITY: BASE

ITEM	UNIT	UNIT COST ($ / unit)	QUAN-TITY		COST ($1,000's)
ANNUAL COSTS:			Annual	Duration	Net Preser
17.0 ENVIRONMENTAL MONITORING: ANNUAL			Quantity	Req'd (yrs)	Value (1)
17.1 Five Year Review	ea	25,000	0.20	30	85
17.2 Cap Inspection and Reporting	ea	2500	0	0	0
17.3 Groundwater Monitoring	sample	1,740	51	30	1,511
17.4 SW/Sediment Monitoring	sample	2,710	22	30	1,015
17.5 Ambient Air Monitoring	sample	1,690	10	15	184
17.6 Soil Gas Monitoring	sample	83	94	15	85
TOTAL					2,880
18.0 LANDFILL GAS COLLECTION AND TREATMENT					
18.1 O&M Labor:					
18.1a Operator @ 1/2 shift/wk	hr	49	0	0	0
18.1b Overtime @ 10%	hr	65	0	0	0
18.1c Supervisory @ 10%	hr	75	0	0	0
18.1d Administrative Costs	ls	4,000	0	0	0
18.2 Equipment Repair/Replacement	ls	56,476	0	0	0
18.3 Electricity Usage Internal System Blower	kWhr	0.07	0	0	0
18.4 Elec. Usage Perimeter System Blower	kWhr	0.07	0	0	0
18.5 Condensate Transportation: Internal System	gal	0.35	0	0	0
18.6 Condensate Transportation: Perimeter System	gal	0.35	0	0	0
18.7 Condensate Disposal: Internal System	gal	1.44	0	0	0
18.8 Condensate Disposal: Perimeter System	gal	1.44	0	0	0
18.9 Auxiliary Fuel Usage	cf	0.02	0	0	0
18.10 Photocatalytic Oxidation O&M	ls	27,816	0	0	0
TOTAL					
19.0 GW/LEACHATE COLLECTION & TREATMENT: 50 GPM					
19.1 O&M Labor:					
19.1a Operator @ 1/2 shift/wk	hr	49	0	0	0
19.1b Overtime @ 10%	hr	65	0	0	0
19.1c Supervisory @ 10%	hr	75	0	0	0
19.1d Administrative Costs	ls	4,000	0	0	0
19.2 Feed Chemicals	1,000 gal	2.00	0	0	0
19.3 Equipment Repair/Replacement	ls	42,276	0	0	0
19.4 Electricity Usage: Collection	kWhr	0.07	0	0	0
19.5 Electricity Usage: Treatment	1,000 gal	1.65	0	0	0
19.6 Diposal of Residuals	1,000 gal	1.01	0	0	0
TOTAL					0
20.0 LEACHATE COLLECTION & TREATMENT: 5 GPM					
20.1 O&M Labor:					
20.1a Operator @ 1/2 shift/wk	hr	49	0	0	0
20.1b Overtime @ 10%	hr	65	0	0	0
20.1c Supervisory @ 10%	hr	75	0	0	0
20.1d Administrative Costs	ls	4,000	0	0	0
20.2 Feed Chemicals	1,000 gal	0.70	0	0	0
20.3 Equipment Repair/Replacement	ls	14,967	0	0	0
20.4 Electricity Usage: Collection	kWhr	0.07	0	0	0
20.5 Electricity Usage: Treatment	1,000 gal	0.55	0	0	0
20.6 Diposal of Residuals	1,000 gal	0.35	0	0	0
Total					0

DETAILED COST TABLE: ALTERNATIVE # 1 SENSITIVITY: BASE

	ITEM	UNIT	UNIT COST ($ / unit)	QUAN-TITY		COST ($1,000's)
21.0	INSTITUTIONAL CONTROLS: ANNUAL COSTS					
21.1	Groundwater Access Restrictions (Not Used)					
21.2	Not Used					
21.3	Not Used					
21.4	LFG Control Contingency (Annual Inspections)	house	500	0	0	0
Total						0
	TOTAL PRESENT COST					2,880
	CONTINGENCY @ 20%					576
	TOTAL ANNUAL COSTS (Present Value in $1,000's)					3,456
	TOTAL COST (in $1,000's)					3,568

Notes:

1) Net Present Value costs were calculated using the following formula:

$$\underset{(\$1,000's)}{NPV} = A_0 \cdot \frac{1 - (1 + i_{INF})^N / (1 + i_{DF})^N}{(i_{DF} - i_{INF})}$$

where:

A_0 = (Unit cost) · (Annual quantity)

N = duration of annual cost (years)

i_{DF} = discount factor or rate

i_{INF} = inflation rate

G-3 Detailed Costs - Alternative #2

DETAILED COST TABLE: ALTERNATIVE # 2 SENSITIVITY: BASE

	ITEM	UNIT	UNIT COST ($ / unit)	QUAN-TITY	COST ($1,000's)
CAPITAL COSTS:					
1.0	GRADING & SITE PREP.: SOLID WASTE AREA				
1.1	Clearing and Grubbing	acre	335.00	0	0
1.2	Silt Fencing	lf	2.00	0	0
1.3	Drainage Ditches	lf	0.36	0	0
1.4	Detention Basins	cy	4.00	0	0
1.5	Fence 8' Chain Link	lf	15.00	4,700	71
Total					71
2.0	CAPPING: SOLID WASTE AREA				
2.1	Vegetation	sy	0.35	0	0
2.2	Topsoil: 6"	sy	3.50	0	0
2.3	Cover Layer: 18"	cy	12.00	0	0
2.4	Drainage Layer: Composite	sy	3.60	0	0
2.5	Geomembrane	sf	0.43	0	0
2.6	Low Permeability Layer: 12"	cy	8.00	0	0
2.7	Protective Layer: 6"	cy	12.00	0	0
2.8	Wetlands Replacement	acre	50,000	0	0
Total					0
3.0	GRADING & SITE PREP.: BULKY WASTE AREA				
3.1	Clearing and Grubbing	acre	335.00	0	0
3.2	Silt Fencing	lf	2.00	0	0
3.2	Drainage Ditches	lf	0.36	0	0
3.4	Detention Basins	cy	4.00	0	0
3.5	Fence 8' Chain Link	lf	15.00	0	0
Total					0
4.0	CAPPING: BULKY WASTE AREA				
4.1	Vegetation	sy	0.35	0	0
4.2	Topsoil: 6"	sy	3.50	0	0
4.3	Cover Layer: 18"	cy	12.00	0	0
4.4	Drainage Layer: Composite	sy	3.60	0	0
4.5	Geomembrane	sf	0.43	0	0
4.6	Low Permeability Layer: 12"	cy	8.00	0	0
4.7	Gas Vent Layer: Composite	sy	3.60	0	0
4.8	Passive Gas Vents	lf	196.00	0	0
Total					0
5.0	LANDFILL MINING				
5.1	Waste Removal and Segregation	cy	9.00	0	0
5.2	Scrap Metal Transport	cy	5.00	0	0
5.3	Transport Non-recyclables to Solid Waste Area	cy	1.50	0	0
5.4	Backfill With Reclaimed Soil	cy	2.15	0	0
5.5	Backfill With Clean Fill	cy	11.00	0	0
5.6	Vegetation	sy	0.35	0	0
5.7	Miscellaneous Allowances	ls	97,000	0	0
5.8	Scrap Metal Revenue	lb	0.02	0	0
5.9	Supervision & Monitoring Labor	day	300.00	0	0
Total					0
6.0	PERIMETER WETLANDS MITIGATION				
6.1	Wetlands & Buffer Zone replacement	ls	80,000	0	0
Total					0

DETAILED COST TABLE: ALTERNATIVE # 2 SENSITIVITY: BASE

	ITEM	UNIT	UNIT COST ($ / unit)	QUAN-TITY	COST ($1,000's)
7.0	INTERNAL LF GAS COLLECTION SYSTEM				
7.1	Vault, Gauges, Fittings and Other Costs	well	4,250	0	0
7.2	Screen, Casing and Other Well Footage Costs	lf	196.00	0	0
7.3	Header Pipe: HDPE				
7.3a	10" HDPE Header Pipe, buried	lf	27.60	0	0
7.3b	8" HDPE Header Pipe, buried	lf	23.60	0	0
7.3c	6" HDPE Header Pipe, buried	lf	18.50	0	0
7.3d	"Blueboard" thermal insulation	lf	1.50	0	0
7.3e	HDPE Tees 8" x 8" x 8", installed & buried	ea	310.00	0	0
7.3f	HDPE Tees 6" x 6" x 6", installed & buried	ea	250.00	0	0
7.4	Valves & Appurtenances				
7.4a	Buried butterfly isolation valves: 10"	ea	2000.00	0	0
7.4b	Buried butterfly isolation valves: 8"	ea	1600.00	0	0
7.4c	LANDTEC GEM-500 LFG analyzer	ls	6395.00	0	0
7.5	Condensate Piping	lf	5.00	0	0
7.6	Condensate Pump Stations	ea	50,000	0	0
7.7	Condensate Storage Tank Allowance	ea	25,000	0	0
Total					0
8.0	PERIMETER LF GAS COLLECTION SYSTEM				
8.1	Vault, Gauges, Fittings and Other Costs	well	4,250	0	0
8.2	Screen, Casing and Other Well Footage Costs	lf	196.00	0	0
8.3	Header Pipe: HDPE				
8.3a	10" HDPE Header Pipe, buried	lf	27.60	0	0
8.3b	6" HDPE Header Pipe, buried	lf	18.50	0	0
8.3c	"Blueboard" thermal insulation	lf	1.50	0	0
8.3d	HDPE Tees 10" x 10" x 6", installed & buried	ea	430.00	0	0
8.4	Valves & Appurtenances	ea	2000.00	0	0
Total					0
9.0	LF GAS TREATMENT PLANT				
9.1	Access Roads	sy	5.56	0	0
9.2	Electricity Service	lf	14.00	0	0
9.3	Water Service	lf	5.00	0	0
9.4	Internal & Perim. Coll. System Blowers & Motors	ls	60,000	0	0
9.5	Enclosed Flare and Appurtenances	ea	179,400	0	0
9.6	Foundation: 18" Structural Slab	cy	350.00	0	0
9.7	Photocatalytic Oxidation and Appurtenances	ls	286,000	0	0
9.8	Fence 8' Chain Link	lf	15.00	0	0
Total					0
10.0	GW DEPRESSION SYSTEM: COLLECTION				
10.1	Buried Piping	lf	8.00	0	0
10.2	Pump Electrical	lf	4.00	0	0
10.3	Pump Station	ls	75,000	0	0
10.4	Shallow Drain Piping & Installation	lf	40.00	0	0
Total					0
11.0	LEACHATE COLLECTION SYSTEM				
11.1	Buried Piping	lf	5.00	0	0
11.2	Pump Electrical	lf	4.00	0	0
11.3	Pump Station	ls	50,000	0	0
11.4	Shallow Drain Piping & Installation	lf	40.00	0	0
Total					

DETAILED COST TABLE: ALTERNATIVE # 2 SENSITIVITY: BASE

	ITEM	UNIT	UNIT COST ($ / unit)	QUAN-TITY	COST ($1,000's)
12.0	50 GPM WATER TREATMENT PLANT				
12.1	Not Used				
12.2	Not Used				
12.3	Not Used				
12.4	Equipment	ls	613,500	0	0
12.5	Instrumentation	ls	58,300	0	0
12.6	Foundation: 18" Structural Slab	cy	350.00	0	0
12.7	Structure: 20' Pre-engineered Building	sf	50.00	0	0
12.8	Discharge Line	lf	8.00	0	0
12.9	Groundwater Injection Wells	ea	9,000	0	0
12.10	Fence 8' Chain Link	lf	15.00	0	0
Total					0
13.0	5 GPM WATER TREATMENT PLANT				
13.1	Not Used				
13.2	Not Used				
13.3	Not Used				
13.4	Equipment	ls	213,500	0	0
13.5	Instrumentation	ls	20,289	0	0
13.6	Foundation: 18" Structural Slab	cy	350.00	0	0
13.7	Structure: 20' Pre-engineered Building	sf	50.00	0	0
13.8	Discharge Line	lf	5.00	0	0
13.9	Groundwater Injection Wells	ea	9,000	0	0
13.10	Fence 8' Chain Link	lf	15.00	0	0
Total					0
14.0	ENVIRONMENTAL MONITORING: CAPITAL COST				
14.1	Piezometer Installation	lf	50	0	0
14.2	Soil Gas Probe Construction	ea	2,500	35	88
Total					88
15.0	DECONTAMINATION AREA - TREATMENT PLANT AREA				
15.1	Decon Station Allowance	ls	50,000	0	0
Total					0
16.0	INSTITUTIONAL CONTROLS				
16.1	GW Access Restrictions: Legal Fees	lot	8,000	11	88
16.2	Not Used				
16.3	Not Used				
16.4	LFG Control Contingency	house	9,808	4	39
Total					127
	TOTAL DIRECT CAPITAL COST				285
	REMEDIAL DESIGN ALLOWANCE @	6%			17
	CONTINGENCY @	20%			60
	TOTAL CAPITAL COSTS				363

DETAILED COST TABLE: ALTERNATIVE # 2 SENSITIVITY: BASE

ITEM	UNIT	UNIT COST ($ / unit)	QUAN-TITY		COST ($1,000's)
ANNUAL COSTS:			Annual	Duration	Net Presen.
17.0 ENVIRONMENTAL MONITORING: ANNUAL			Quantity	Req'd (yrs)	Value (1)
17.1 Five Year Review	ea	25,000	0.20	30	85
17.2 Cap Inspection and Reporting	ea	2500	0	0	0
17.3 Groundwater Monitoring	sample	1,740	51	30	1,511
17.4 SW/Sediment Monitoring	sample	2,710	22	30	1,015
17.5 Ambient Air Monitoring	sample	1,690	10	15	184
17.6 Soil Gas Monitoring	sample	83	94	15	85
TOTAL					2,880
18.0 LANDFILL GAS COLLECTION AND TREATMENT					
18.1 O&M Labor:					
18.1a Operator @ 1/2 shift/wk	hr	49	0	0	0
18.1b Overtime @ 10%	hr	65	0	0	0
18.1c Supervisory @ 10%	hr	75	0	0	0
18.1d Administrative Costs	ls	4,000	0	0	0
18.2 Equipment Repair/Replacement	ls	56,476	0	0	0
18.3 Electricity Usage Internal System Blower	kWhr	0.07	0	0	0
18.4 Elec. Usage Perimeter System Blower	kWhr	0.07	0	0	0
18.5 Condensate Transportation: Internal System	gal	0.35	0	0	0
18.6 Condensate Transportation: Perimeter System	gal	0.35	0	0	0
18.7 Condensate Disposal: Internal System	gal	1.44	0	0	0
18.8 Condensate Disposal: Perimeter System	gal	1.44	0	0	0
18.9 Auxiliary Fuel Usage	cf	0.02	0	0	0
18.10 Photocatalytic Oxidation O&M	ls	27,816	0	0	0
TOTAL					0
19.0 GW/LEACHATE COLLECTION & TREATMENT: 50 GPM					
19.1 O&M Labor:					
19.1a Operator @ 1/2 shift/wk	hr	49	0	0	0
19.1b Overtime @ 10%	hr	65	0	0	0
19.1c Supervisory @ 10%	hr	75	0	0	0
19.1d Administrative Costs	ls	4,000	0	0	0
19.2 Feed Chemicals	1,000 gal	2.00	0	0	0
19.3 Equipment Repair/Replacement	ls	42,276	0	0	0
19.4 Electricity Usage: Collection	kWhr	0.07	0	0	0
19.5 Electricity Usage: Treatment	1,000 gal	1.65	0	0	0
19.6 Diposal of Residuals	1,000 gal	1.01	0	0	0
TOTAL					0
20.0 LEACHATE COLLECTION & TREATMENT: 5 GPM					
20.1 O&M Labor:					
20.1a Operator @ 1/2 shift/wk	hr	49	0	0	0
20.1b Overtime @ 10%	hr	65	0	0	0
20.1c Supervisory @ 10%	hr	75	0	0	0
20.1d Administrative Costs	ls	4,000	0	0	0
20.2 Feed Chemicals	1,000 gal	0.70	0	0	0
20.3 Equipment Repair/Replacement	ls	14,967	0	0	0
20.4 Electricity Usage: Collection	kWhr	0.07	0	0	0
20.5 Electricity Usage: Treatment	1,000 gal	0.55	0	0	0
20.6 Diposal of Residuals	1,000 gal	0.35	0	0	0
Total					

DETAILED COST TABLE: ALTERNATIVE # 2 SENSITIVITY: BASE

	ITEM	UNIT	UNIT COST ($ / unit)	QUAN-TITY		COST ($1,000's)
21.0	INSTITUTIONAL CONTROLS: ANNUAL COSTS					
21.1	Groundwater Access Restrictions (Not Used)					
21.2	Not Used					
21.3	Not Used					
21.4	LFG Control Contingency (Annual Inspections)	house	500	4	15	22
Total						22
	TOTAL PRESENT COST					2,902
	CONTINGENCY @ 20%					580
	TOTAL ANNUAL COSTS (Present Value in $1,000's)					3,482
	TOTAL COST (in $1,000's)					3,845

Notes:

1) Net Present Value costs were calculated using the following formula:

$$\underset{(\$1,000's)}{NPV} = A_o \cdot \frac{1 - (1 + i_{INF})^N / (1 + i_{DF})^N}{(i_{DF} - i_{INF})}$$

where:

A_o = (Unit cost) · (Annual quantity)

N = duration of annual cost (years)

i_{DF} = discount factor or rate

i_{INF} = inflation rate

G-4 Detailed Costs - Alternative #3a

DETAILED COST TABLE: ALTERNATIVE # 3a SENSITIVITY: BASE

	ITEM	UNIT	UNIT COST ($ / unit)	QUAN-TITY	COST ($1,000's)
CAPITAL COSTS:					
1.0	GRADING & SITE PREP.: SOLID WASTE AREA				
1.1	Clearing and Grubbing	acre	335.00	22.9	8
1.2	Silt Fencing	lf	2.00	4,400	9
1.3	Drainage Ditches	lf	0.36	1,240	0
1.4	Detention Basins	cy	4.00	3,025	12
1.5	Fence 8' Chain Link	lf	15.00	4,700	71
Total					100
2.0	CAPPING: SOLID WASTE AREA				
2.1	Vegetation	sy	0.35	110,836	39
2.2	Topsoil: 6"	sy	3.50	110836	388
2.3	Cover Layer: 18"	cy	12.00	55,418	665
2.4	Drainage Layer: Composite	sy	3.60	110,836	399
2.5	Geomembrane	sf	0.43	997,524	429
2.6	Low Permeability Layer: 12"	cy	8.00	36,945	296
2.7	Protective Layer: 6"	cy	12.00	18,473	222
2.8	Wetlands Replacement	acre	50,000	0.1	5
Total					2,442
3.0	GRADING & SITE PREP.: BULKY WASTE AREA				
3.1	Clearing and Grubbing	acre	335.00	7.4	2
3.2	Silt Fencing	lf	2.00	2,200	4
3.2	Drainage Ditches	lf	0.36	1,100	0
3.4	Detention Basins	cy	4.00	484	2
3.5	Fence 8' Chain Link	lf	15.00	2,600	39
Total					48
4.0	CAPPING: BULKY WASTE AREA				
4.1	Vegetation	sy	0.35	35,816	13
4.2	Topsoil: 6"	sy	3.50	35,816	125
4.3	Cover Layer: 18"	cy	12.00	17,908	215
4.4	Drainage Layer: Composite	sy	3.60	35,816	129
4.5	Geomembrane	sf	0.43	322,344	139
4.6	Low Permeability Layer: 12"	cy	8.00	11,939	96
4.7	Gas Vent Layer: Composite	sy	3.60	35,816	129
4.8	Passive Gas Vents	lf	196.00	100	20
Total					864
5.0	LANDFILL MINING				
5.1	Waste Removal and Segregation	cy	9.00	0	0
5.2	Scrap Metal Transport	cy	5.00	0	0
5.3	Transport Non-recyclables to Solid Waste Area	cy	1.50	0	0
5.4	Backfill With Reclaimed Soil	cy	2.15	0	0
5.5	Backfill With Clean Fill	cy	11.00	0	0
5.6	Vegetation	sy	0.35	0	0
5.7	Miscellaneous Allowances	ls	97,000	0	0
5.8	Scrap Metal Revenue	lb	0.02	0	0
5.9	Supervision & Monitoring Labor	day	300.00	0	0
Total					0
6.0	PERIMETER WETLANDS MITIGATION				
6.1	Wetlands & Buffer Zone replacement	ls	80,000	0	4
Total					4

DETAILED COST TABLE: ALTERNATIVE # 3a SENSITIVITY: BASE

	ITEM	UNIT	UNIT COST ($ / unit)	QUAN-TITY	COST ($1,000's)
7.0	INTERNAL LF GAS COLLECTION SYSTEM				
7.1	Vault, Gauges, Fittings and Other Costs	well	4,250	36	153
7.2	Screen, Casing and Other Well Footage Costs	lf	196.00	900	176
7.3	Header Pipe: HDPE				
7.3a	10" HDPE Header Pipe, buried	lf	27.60	500	14
7.3b	8" HDPE Header Pipe, buried	lf	23.60	3,780	89
7.3c	6" HDPE Header Pipe, buried	lf	18.50	2,890	53
7.3d	"Blueboard" thermal insulation	lf	1.50	7,170	11
7.3e	HDPE Tees 8" x 8" x 8", installed & buried	ea	310.00	20	6
7.3f	HDPE Tees 6" x 6" x 6", installed & buried	ea	250.00	22	6
7.4	Valves & Appurtenances				
7.4a	Buried butterfly isolation valves: 10"	ea	2000.00	1	2
7.4b	Buried butterfly isolation valves: 8"	ea	1600.00	15	24
7.4c	LANDTEC GEM-500 LFG analyzer	ls	6395.00	1	6
7.5	Condensate Piping	lf	5.00	3,020	15
7.6	Condensate Pump Stations	ea	50,000	2	100
7.7	Condensate Storage Tank Allowance	ea	25,000	1	25
Total					681
8.0	PERIMETER LF GAS COLLECTION SYSTEM				
8.1	Vault, Gauges, Fittings and Other Costs	well	4,250	26	111
8.2	Screen, Casing and Other Well Footage Costs	lf	196.00	572	112
8.3	Header Pipe: HDPE				
8.3a	10" HDPE Header Pipe, buried	lf	27.60	3,210	89
8.3b	6" HDPE Header Pipe, buried	lf	18.50	260	5
8.3c	"Blueboard" thermal insulation	lf	1.50	3,470	
8.3d	HDPE Tees 10" x 10" x 6", installed & buried	ea	430.00	26	1[illegible]
8.4	Valves & Appurtenances	ea	2000.00	3	6
Total					338
9.0	LF GAS TREATMENT PLANT				
9.1	Access Roads	sy	5.56	4,222	23
9.2	Electricity Service	lf	14.00	1,600	22
9.3	Water Service	lf	5.00	1,600	8
9.4	Internal & Perim. Coll. System Blowers & Motors	ls	60,000	1	60
9.5	Enclosed Flare and Appurtenances	ea	179,400	1	179
9.6	Foundation: 18" Structural Slab	cy	350.00	111	39
9.7	Photocatalytic Oxidation and Appurtenances	ls	286,000	0	0
9.8	Fence 8' Chain Link	lf	15.00	400	6
Total					338
10.0	GW DEPRESSION SYSTEM: COLLECTION				
10.1	Buried Piping	lf	8.00	0	0
10.2	Pump Electrical	lf	4.00	0	0
10.3	Pump Station	ls	75,000	0	0
10.4	Shallow Drain Piping & Installation	lf	40.00	0	0
Total					0
11.0	LEACHATE COLLECTION SYSTEM				
11.1	Buried Piping	lf	5.00	0	0
11.2	Pump Electrical	lf	4.00	0	0
11.3	Pump Station	ls	50,000	0	0
11.4	Shallow Drain Piping & Installation	lf	40.00	0	0
Total					

DETAILED COST TABLE: ALTERNATIVE # 3a SENSITIVITY: BASE

	ITEM	UNIT	UNIT COST ($ / unit)	QUAN-TITY	COST ($1,000's)
12.0	50 GPM WATER TREATMENT PLANT				
12.1	Not Used				
12.2	Not Used				
12.3	Not Used				
12.4	Equipment	ls	613,500	0	0
12.5	Instrumentation	ls	58,300	0	0
12.6	Foundation: 18" Structural Slab	cy	350.00	0	0
12.7	Structure: 20' Pre-engineered Building	sf	50.00	0	0
12.8	Discharge Line	lf	8.00	0	0
12.9	Groundwater Injection Wells	ea	9,000	0	0
12.10	Fence 8' Chain Link	lf	15.00	0	0
Total					0
13.0	5 GPM WATER TREATMENT PLANT				
13.1	Not Used				
13.2	Not Used				
13.3	Not Used				
13.4	Equipment	ls	213,500	0	0
13.5	Instrumentation	ls	20,289	0	0
13.6	Foundation: 18" Structural Slab	cy	350.00	0	0
13.7	Structure: 20' Pre-engineered Building	sf	50.00	0	0
13.8	Discharge Line	lf	5.00	0	0
13.9	Groundwater Injection Wells	ea	9,000	0	0
13.10	Fence 8' Chain Link	lf	15.00	0	0
Total					0
14.0	ENVIRONMENTAL MONITORING: CAPITAL COST				
14.1	Piezometer Installation	lf	50	125	6
14.2	Soil Gas Probe Construction	ea	2,500	35	88
Total					94
15.0	DECONTAMINATION AREA - TREATMENT PLANT AREA				
15.1	Decon Station Allowance	ls	50,000	1	50
Total					50
16.0	INSTITUTIONAL CONTROLS				
16.1	GW Access Restrictions: Legal Fees	lot	8,000	11	88
16.2	Not Used				
16.3	Not Used				
16.4	LFG Control Contingency	house	9,808	0	0
Total					88
	TOTAL DIRECT CAPITAL COST				5,047
	REMEDIAL DESIGN ALLOWANCE @	6%			303
	CONTINGENCY @	20%			1,070
	TOTAL CAPITAL COSTS				6,420

DETAILED COST TABLE: ALTERNATIVE # 3a SENSITIVITY: BASE

ITEM	UNIT	UNIT COST ($ / unit)	QUAN-TITY		COST ($1,000's)
ANNUAL COSTS:			Annual	Duration	Net Presen
17.0 ENVIRONMENTAL MONITORING: ANNUAL			Quantity	Req'd (yrs)	Value (1)
17.1 Five Year Review	ea	25,000	0.20	30	85
17.2 Cap Inspection and Reporting	ea	2500	4	30	170
17.3 Groundwater Monitoring	sample	1,740	51	30	1,511
17.4 SW/Sediment Monitoring	sample	2,710	22	30	1,015
17.5 Ambient Air Monitoring	sample	1,690	10	15	184
17.6 Soil Gas Monitoring	sample	83	94	15	85
TOTAL					3,051
18.0 LANDFILL GAS COLLECTION AND TREATMENT					
18.1 O&M Labor:					
18.1a Operator @ 1/2 shift/wk	hr	49	1,040	15	555
18.1b Overtime @ 10%	hr	65	104	15	74
18.1c Supervisory @ 10%	hr	75	104	15	85
18.1d Administrative Costs	ls	4,000	1	15	44
18.2 Equipment Repair/Replacement	ls	56,476	1	15	615
18.3 Electricity Usage Internal System Blower	kWhr	0.07	36,291	15	28
18.4 Elec. Usage Perimeter System Blower	kWhr	0.07	108,872	15	83
18.5 Condensate Transportation: Internal System	gal	0.35	5,059	15	19
18.6 Condensate Transportation: Perimeter System	gal	0.35	53,348	15	201
18.7 Condensate Disposal: Internal System	gal	1.44	5,059	15	79
18.8 Condensate Disposal: Perimeter System	gal	1.44	53,348	15	837
18.9 Auxiliary Fuel Usage	cf	0.02	774,034	15	168
18.10 Photocatalytic Oxidation O&M	ls	27,816	0	0	0
TOTAL					2,78[illegible]
19.0 GW/LEACHATE COLLECTION & TREATMENT: 50 GPM					
19.1 O&M Labor:					
19.1a Operator @ 1/2 shift/wk	hr	49	0	0	0
19.1b Overtime @ 10%	hr	65	0	0	0
19.1c Supervisory @ 10%	hr	75	0	0	0
19.1d Administrative Costs	ls	4,000	0	0	0
19.2 Feed Chemicals	1,000 gal	2.00	0	0	0
19.3 Equipment Repair/Replacement	ls	42,276	0	0	0
19.4 Electricity Usage: Collection	kWhr	0.07	0	0	0
19.5 Electricity Usage: Treatment	1,000 gal	1.65	0	0	0
19.6 Diposal of Residuals	1,000 gal	1.01	0	0	0
TOTAL					0
20.0 LEACHATE COLLECTION & TREATMENT: 5 GPM					
20.1 O&M Labor:					
20.1a Operator @ 1/2 shift/wk	hr	49	0	0	0
20.1b Overtime @ 10%	hr	65	0	0	0
20.1c Supervisory @ 10%	hr	75	0	0	0
20.1d Administrative Costs	ls	4,000	0	0	0
20.2 Feed Chemicals	1,000 gal	0.70	0	0	0
20.3 Equipment Repair/Replacement	ls	14,967	0	0	0
20.4 Electricity Usage: Collection	kWhr	0.07	0	0	0
20.5 Electricity Usage: Treatment	1,000 gal	0.55	0	0	0
20.6 Diposal of Residuals	1,000 gal	0.35	0	0	0
Total					0

DETAILED COST TABLE: ALTERNATIVE # 3a SENSITIVITY: BASE

	ITEM	UNIT	UNIT COST ($ / unit)	QUAN-TITY		COST ($1,000's)
21.0	INSTITUTIONAL CONTROLS: ANNUAL COSTS					
21.1	Groundwater Access Restrictions (Not Used)					
21.2	Not Used					
21.3	Not Used					
21.4	LFG Control Contingency (Annual Inspections)	house	500	0	0	0
Total						0
	TOTAL PRESENT COST					5,838
	CONTINGENCY @ 20%					1,168
	TOTAL ANNUAL COSTS (Present Value in $1,000's)					7,005
	TOTAL COST (in $1,000's)					13,425

Notes:

1) Net Present Value costs were calculated using the following formula:

$$\underset{(\$1,000's)}{NPV} = A_o \cdot \frac{1 - (1 + i_{INF})^N / (1 + i_{DF})^N}{(i_{DF} - i_{INF})}$$

where:

A_o = (Unit cost) · (Annual quantity)

N = duration of annual cost (years)

i_{DF} = discount factor or rate

i_{INF} = inflation rate

DETAILED COST TABLE: ALTERNATIVE # 3b SENSITIVITY: BASE

	ITEM	UNIT	UNIT COST ($ / unit)	QUAN-TITY	COST ($1,000's)
CAPITAL COSTS:					
1.0	GRADING & SITE PREP.: SOLID WASTE AREA				
1.1	Clearing and Grubbing	acre	335.00	22.9	8
1.2	Silt Fencing	lf	2.00	4,400	9
1.3	Drainage Ditches	lf	0.36	1,240	0
1.4	Detention Basins	cy	4.00	3,025	12
1.5	Fence 8' Chain Link	lf	15.00	4,700	71
Total					100
2.0	CAPPING: SOLID WASTE AREA				
2.1	Vegetation	sy	0.35	110,836	39
2.2	Topsoil: 6"	sy	3.50	110836	388
2.3	Cover Layer: 18"	cy	12.00	55,418	665
2.4	Drainage Layer: Composite	sy	3.60	110,836	399
2.5	Geomembrane	sf	0.43	997,524	429
2.6	Low Permeability Layer: 12"	cy	8.00	36,945	296
2.7	Protective Layer: 6"	cy	12.00	18,473	222
2.8	Wetlands Replacement	acre	50,000	0.1	5
Total					2,442
3.0	GRADING & SITE PREP.: BULKY WASTE AREA				
3.1	Clearing and Grubbing	acre	335.00	7.4	2
3.2	Silt Fencing	lf	2.00	2,200	4
3.2	Drainage Ditches	lf	0.36	1,100	0
3.4	Detention Basins	cy	4.00	484	2
3.5	Fence 8' Chain Link	lf	15.00	2,600	39
Total					48
4.0	CAPPING: BULKY WASTE AREA				
4.1	Vegetation	sy	0.35	35,816	13
4.2	Topsoil: 6"	sy	3.50	35,816	125
4.3	Cover Layer: 18"	cy	12.00	17,908	215
4.4	Drainage Layer: Composite	sy	3.60	35,816	129
4.5	Geomembrane	sf	0.43	322,344	139
4.6	Low Permeability Layer: 12"	cy	8.00	11,939	96
4.7	Gas Vent Layer: Composite	sy	3.60	35,816	129
4.8	Passive Gas Vents	lf	196.00	100	20
Total					864
5.0	LANDFILL MINING				
5.1	Waste Removal and Segregation	cy	9.00	0	0
5.2	Scrap Metal Transport	cy	5.00	0	0
5.3	Transport Non-recyclables to Solid Waste Area	cy	1.50	0	0
5.4	Backfill With Reclaimed Soil	cy	2.15	0	0
5.5	Backfill With Clean Fill	cy	11.00	0	0
5.6	Vegetation	sy	0.35	0	0
5.7	Miscellaneous Allowances	ls	97,000	0	0
5.8	Scrap Metal Revenue	lb	0.02	0	0
5.9	Supervision & Monitoring Labor	day	300.00	0	0
Total					0
6.0	PERIMETER WETLANDS MITIGATION				
6.1	Wetlands & Buffer Zone replacement	ls	80,000	0	4
Total					4

DETAILED COST TABLE: ALTERNATIVE # 3b SENSITIVITY: BASE

	ITEM	UNIT	UNIT COST ($ / unit)	QUAN-TITY	COST ($1,000's)
7.0	INTERNAL LF GAS COLLECTION SYSTEM				
7.1	Vault, Gauges, Fittings and Other Costs	well	4,250	36	153
7.2	Screen, Casing and Other Well Footage Costs	lf	196.00	900	176
7.3	Header Pipe: HDPE				
7.3a	10" HDPE Header Pipe, buried	lf	27.60	500	14
7.3b	8" HDPE Header Pipe, buried	lf	23.60	3,780	89
7.3c	6" HDPE Header Pipe, buried	lf	18.50	2,890	53
7.3d	"Blueboard" thermal insulation	lf	1.50	7,170	11
7.3e	HDPE Tees 8" x 8" x 8", installed & buried	ea	310.00	20	6
7.3f	HDPE Tees 6" x 6" x 6", installed & buried	ea	250.00	22	6
7.4	Valves & Appurtenances				
7.4a	Buried butterfly isolation valves: 10"	ea	2000.00	1	2
7.4b	Buried butterfly isolation valves: 8"	ea	1600.00	15	24
7.4c	LANDTEC GEM-500 LFG analyzer	ls	6395.00	1	6
7.5	Condensate Piping	lf	5.00	3,020	15
7.6	Condensate Pump Stations	ea	50,000	2	100
7.7	Condensate Storage Tank Allowance	ea	25,000	1	25
Total					681
8.0	PERIMETER LF GAS COLLECTION SYSTEM				
8.1	Vault, Gauges, Fittings and Other Costs	well	4,250	26	111
8.2	Screen, Casing and Other Well Footage Costs	lf	196.00	572	112
8.3	Header Pipe: HDPE				
8.3a	10" HDPE Header Pipe, buried	lf	27.60	3,210	89
8.3b	6" HDPE Header Pipe, buried	lf	18.50	260	5
8.3c	"Blueboard" thermal insulation	lf	1.50	3,470	[illegible]
8.3d	HDPE Tees 10" x 10" x 6", installed & buried	ea	430.00	26	11
8.4	Valves & Appurtenances	ea	2000.00	3	6
Total					338
9.0	LF GAS TREATMENT PLANT				
9.1	Access Roads	sy	5.56	4,222	23
9.2	Electricity Service	lf	14.00	1,600	22
9.3	Water Service	lf	5.00	1,600	8
9.4	Internal & Perim. Coll. System Blowers & Motors	ls	60,000	1	60
9.5	Enclosed Flare and Appurtenances	ea	179,400	0	0
9.6	Foundation: 18" Structural Slab	cy	350.00	111	39
9.7	Photocatalytic Oxidation and Appurtenances	ls	286,000	1	286
9.8	Fence 8' Chain Link	lf	15.00	400	6
Total					445
10.0	GW DEPRESSION SYSTEM: COLLECTION				
10.1	Buried Piping	lf	8.00	0	0
10.2	Pump Electrical	lf	4.00	0	0
10.3	Pump Station	ls	75,000	0	0
10.4	Shallow Drain Piping & Installation	lf	40.00	0	0
Total					0
11.0	LEACHATE COLLECTION SYSTEM				
11.1	Buried Piping	lf	5.00	0	0
11.2	Pump Electrical	lf	4.00	0	0
11.3	Pump Station	ls	50,000	0	0
11.4	Shallow Drain Piping & Installation	lf	40.00	0	0
Total					

DETAILED COST TABLE: ALTERNATIVE # 3b SENSITIVITY: BASE

	ITEM	UNIT	UNIT COST ($ / unit)	QUAN-TITY	COST ($1,000's)
12.0	50 GPM WATER TREATMENT PLANT				
12.1	Not Used				
12.2	Not Used				
12.3	Not Used				
12.4	Equipment	ls	613,500	0	0
12.5	Instrumentation	ls	58,300	0	0
12.6	Foundation: 18" Structural Slab	cy	350.00	0	0
12.7	Structure: 20' Pre-engineered Building	sf	50.00	0	0
12.8	Discharge Line	lf	8.00	0	0
12.9	Groundwater Injection Wells	ea	9,000	0	0
12.10	Fence 8' Chain Link	lf	15.00	0	0
Total					0
13.0	5 GPM WATER TREATMENT PLANT				
13.1	Not Used				
13.2	Not Used				
13.3	Not Used				
13.4	Equipment	ls	213,500	0	0
13.5	Instrumentation	ls	20,289	0	0
13.6	Foundation: 18" Structural Slab	cy	350.00	0	0
13.7	Structure: 20' Pre-engineered Building	sf	50.00	0	0
13.8	Discharge Line	lf	5.00	0	0
13.9	Groundwater Injection Wells	ea	9,000	0	0
13.10	Fence 8' Chain Link	lf	15.00	0	0
Total					0
14.0	ENVIRONMENTAL MONITORING: CAPITAL COST				
14.1	Piezometer Installation	lf	50	125	6
14.2	Soil Gas Probe Construction	ea	2,500	35	88
Total					94
15.0	DECONTAMINATION AREA - TREATMENT PLANT AREA				
15.1	Decon Station Allowance	ls	50,000	1	50
Total					50
16.0	INSTITUTIONAL CONTROLS				
16.1	GW Access Restrictions: Legal Fees	lot	8,000	11	88
16.2	Not Used				
16.3	Not Used				
16.4	LFG Control Contingency	house	9,808	0	0
Total					88
	TOTAL DIRECT CAPITAL COST				5,154
	REMEDIAL DESIGN ALLOWANCE @	6%			309
	CONTINGENCY @	20%			1,093
	TOTAL CAPITAL COSTS				6,556

DETAILED COST TABLE: ALTERNATIVE # 3b SENSITIVITY: BASE

ITEM	UNIT	UNIT COST ($ / unit)	QUAN-TITY		COST ($1,000's)
ANNUAL COSTS:			Annual	Duration	Net Presen
17.0 ENVIRONMENTAL MONITORING: ANNUAL			Quantity	Req'd (yrs)	Value (1)
17.1 Five Year Review	ea	25,000	0.20	30	85
17.2 Cap Inspection and Reporting	ea	2500	4	30	170
17.3 Groundwater Monitoring	sample	1,740	51	30	1,511
17.4 SW/Sediment Monitoring	sample	2,710	22	30	1,015
17.5 Ambient Air Monitoring	sample	1,690	10	15	184
17.6 Soil Gas Monitoring	sample	83	94	15	85
TOTAL					3,051
18.0 LANDFILL GAS COLLECTION AND TREATMENT					
18.1 O&M Labor:					
18.1a Operator @ 1/2 shift/wk	hr	49	1,040	15	555
18.1b Overtime @ 10%	hr	65	104	15	74
18.1c Supervisory @ 10%	hr	75	104	15	85
18.1d Administrative Costs	ls	4,000	1	15	44
18.2 Equipment Repair/Replacement	ls	56,476	0	0	0
18.3 Electricity Usage Internal System Blower	kWhr	0.07	36,291	15	28
18.4 Elec. Usage Perimeter System Blower	kWhr	0.07	108,872	15	83
18.5 Condensate Transportation: Internal System	gal	0.35	5,059	15	19
18.6 Condensate Transportation: Perimeter System	gal	0.35	53,348	15	201
18.7 Condensate Disposal: Internal System	gal	1.44	5,059	15	79
18.8 Condensate Disposal: Perimeter System	gal	1.44	53,348	15	837
18.9 Auxiliary Fuel Usage	cf	0.02	774,034	15	168
18.10 Photocatalytic Oxidation O&M	ls	27,816	1	15	303
TOTAL					2,47
19.0 GW/LEACHATE COLLECTION & TREATMENT: 50 GPM					
19.1 O&M Labor:					
19.1a Operator @ 1/2 shift/wk	hr	49	0	0	0
19.1b Overtime @ 10%	hr	65	0	0	0
19.1c Supervisory @ 10%	hr	75	0	0	0
19.1d Administrative Costs	ls	4,000	0	0	0
19.2 Feed Chemicals	1,000 gal	2.00	0	0	0
19.3 Equipment Repair/Replacement	ls	42,276	0	0	0
19.4 Electricity Usage: Collection	kWhr	0.07	0	0	0
19.5 Electricity Usage: Treatment	1,000 gal	1.65	0	0	0
19.6 Diposal of Residuals	1,000 gal	1.01	0	0	0
TOTAL					0
20.0 LEACHATE COLLECTION & TREATMENT: 5 GPM					
20.1 O&M Labor:					
20.1a Operator @ 1/2 shift/wk	hr	49	0	0	0
20.1b Overtime @ 10%	hr	65	0	0	0
20.1c Supervisory @ 10%	hr	75	0	0	0
20.1d Administrative Costs	ls	4,000	0	0	0
20.2 Feed Chemicals	1,000 gal	0.70	0	0	0
20.3 Equipment Repair/Replacement	ls	14,967	0	0	0
20.4 Electricity Usage: Collection	kWhr	0.07	0	0	0
20.5 Electricity Usage: Treatment	1,000 gal	0.55	0	0	0
20.6 Diposal of Residuals	1,000 gal	0.35	0	0	0
Total					

DETAILED COST TABLE: ALTERNATIVE # 3b SENSITIVITY: BASE

	ITEM	UNIT	UNIT COST ($ / unit)	QUAN-TITY		COST ($1,000's)
21.0	INSTITUTIONAL CONTROLS: ANNUAL COSTS					
21.1	Groundwater Access Restrictions (Not Used)					
21.2	Not Used					
21.3	Not Used					
21.4	LFG Control Contingency (Annual Inspections)	house	500	0	0	0
Total						0
	TOTAL PRESENT COST					5,526
	CONTINGENCY @ 20%					1,105
	TOTAL ANNUAL COSTS (Present Value in $1,000's)					6,631
	TOTAL COST (in $1,000's)					13,187

Notes:

1) Net Present Value costs were calculated using the following formula:

$$\underset{(\$1,000's)}{NPV} = A_o \cdot \frac{1 - (1 + i_{INF})^N / (1 + i_{DF})^N}{(i_{DF} - i_{INF})}$$

where:

A_o = (Unit cost) · (Annual quantity)

N = duration of annual cost (years)

i_{DF} = discount factor or rate

i_{INF} = inflation rate

G-6 Detailed Costs - Alternative #4a

DETAILED COST TABLE: ALTERNATIVE # 4a SENSITIVITY: BASE

	ITEM	UNIT	UNIT COST ($ / unit)	QUAN-TITY	COST ($1,000's)
CAPITAL COSTS:					
1.0	GRADING & SITE PREP.: SOLID WASTE AREA				
1.1	Clearing and Grubbing	acre	335.00	22.9	8
1.2	Silt Fencing	lf	2.00	4,400	9
1.3	Drainage Ditches	lf	0.36	1,240	0
1.4	Detention Basins	cy	4.00	3,025	12
1.5	Fence 8' Chain Link	lf	15.00	4,700	71
Total					100
2.0	CAPPING: SOLID WASTE AREA				
2.1	Vegetation	sy	0.35	110,836	39
2.2	Topsoil: 6"	sy	3.50	110836	388
2.3	Cover Layer: 18"	cy	12.00	55,418	665
2.4	Drainage Layer: Composite	sy	3.60	110,836	399
2.5	Geomembrane	sf	0.43	997,524	429
2.6	Low Permeability Layer: 12"	cy	8.00	36,945	296
2.7	Protective Layer: 6"	cy	12.00	18,473	222
2.8	Wetlands Replacement	acre	50,000	0.1	5
Total					2,442
3.0	GRADING & SITE PREP.: BULKY WASTE AREA				
3.1	Clearing and Grubbing	acre	335.00	7.4	2
3.2	Silt Fencing	lf	2.00	2,200	4
3.2	Drainage Ditches	lf	0.36	1,100	0
3.4	Detention Basins	cy	4.00	484	2
3.5	Fence 8' Chain Link	lf	15.00	2,600	39
Total					48
4.0	CAPPING: BULKY WASTE AREA				
4.1	Vegetation	sy	0.35	35,816	13
4.2	Topsoil: 6"	sy	3.50	35,816	125
4.3	Cover Layer: 18"	cy	12.00	17,908	215
4.4	Drainage Layer: Composite	sy	3.60	35,816	129
4.5	Geomembrane	sf	0.43	322,344	139
4.6	Low Permeability Layer: 12"	cy	8.00	11,939	96
4.7	Gas Vent Layer: Composite	sy	3.60	35,816	129
4.8	Passive Gas Vents	lf	196.00	100	20
Total					864
5.0	LANDFILL MINING				
5.1	Waste Removal and Segregation	cy	9.00	0	0
5.2	Scrap Metal Transport	cy	5.00	0	0
5.3	Transport Non-recyclables to Solid Waste Area	cy	1.50	0	0
5.4	Backfill With Reclaimed Soil	cy	2.15	0	0
5.5	Backfill With Clean Fill	cy	11.00	0	0
5.6	Vegetation	sy	0.35	0	0
5.7	Miscellaneous Allowances	ls	97,000	0	0
5.8	Scrap Metal Revenue	lb	0.02	0	0
5.9	Supervision & Monitoring Labor	day	300.00	0	0
Total					0
6.0	PERIMETER WETLANDS MITIGATION				
6.1	Wetlands & Buffer Zone replacement	ls	80,000	1	40
Total					40

DETAILED COST TABLE: ALTERNATIVE # 4a SENSITIVITY: BASE

	ITEM	UNIT	UNIT COST ($ / unit)	QUAN-TITY	COST ($1,000's)
7.0	INTERNAL LF GAS COLLECTION SYSTEM				
7.1	Vault, Gauges, Fittings and Other Costs	well	4,250	36	153
7.2	Screen, Casing and Other Well Footage Costs	lf	196.00	900	176
7.3	Header Pipe: HDPE				
7.3a	10" HDPE Header Pipe, buried	lf	27.60	500	14
7.3b	8" HDPE Header Pipe, buried	lf	23.60	3,780	89
7.3c	6" HDPE Header Pipe, buried	lf	18.50	2,890	53
7.3d	"Blueboard" thermal insulation	lf	1.50	7,170	11
7.3e	HDPE Tees 8" x 8" x 8", installed & buried	ea	310.00	20	6
7.3f	HDPE Tees 6" x 6" x 6", installed & buried	ea	250.00	22	6
7.4	Valves & Appurtenances				
7.4a	Buried butterfly isolation valves: 10"	ea	2000.00	1	2
7.4b	Buried butterfly isolation valves: 8"	ea	1600.00	15	24
7.4c	LANDTEC GEM-500 LFG analyzer	ls	6395.00	1	6
7.5	Condensate Piping	lf	5.00	3,020	15
7.6	Condensate Pump Stations	ea	50,000	2	100
7.7	Condensate Storage Tank Allowance	ea	25,000	1	25
Total					681
8.0	PERIMETER LF GAS COLLECTION SYSTEM				
8.1	Vault, Gauges, Fittings and Other Costs	well	4,250	26	111
8.2	Screen, Casing and Other Well Footage Costs	lf	196.00	572	112
8.3	Header Pipe: HDPE				
8.3a	10" HDPE Header Pipe, buried	lf	27.60	3,210	89
8.3b	6" HDPE Header Pipe, buried	lf	18.50	260	5
8.3c	"Blueboard" thermal insulation	lf	1.50	3,470	
8.3d	HDPE Tees 10" x 10" x 6", installed & buried	ea	430.00	26	1[illegible]
8.4	Valves & Appurtenances	ea	2000.00	3	6
Total					338
9.0	LF GAS TREATMENT PLANT				
9.1	Access Roads	sy	5.56	4,222	23
9.2	Electricity Service	lf	14.00	1,600	22
9.3	Water Service	lf	5.00	1,600	8
9.4	Internal & Perim. Coll. System Blowers & Motors	ls	60,000	1	60
9.5	Enclosed Flare and Appurtenances	ea	179,400	1	179
9.6	Foundation: 18" Structural Slab	cy	350.00	111	39
9.7	Photocatalytic Oxidation and Appurtenances	ls	286,000	0	0
9.8	Fence 8' Chain Link	lf	15.00	400	6
Total					338
10.0	GW DEPRESSION SYSTEM: COLLECTION				
10.1	Buried Piping	lf	8.00	0	0
10.2	Pump Electrical	lf	4.00	0	0
10.3	Pump Station	ls	75,000	0	0
10.4	Shallow Drain Piping & Installation	lf	40.00	0	0
Total					0
11.0	LEACHATE COLLECTION SYSTEM				
11.1	Buried Piping	lf	5.00	2,100	11
11.2	Pump Electrical	lf	4.00	2,100	8
11.3	Pump Station	ls	50,000	1	50
11.4	Shallow Drain Piping & Installation	lf	40.00	750	3[illegible]
Total					

DETAILED COST TABLE: ALTERNATIVE # 4a SENSITIVITY: BASE

	ITEM	UNIT	UNIT COST ($ / unit)	QUAN-TITY	COST ($1,000's)
12.0	50 GPM WATER TREATMENT PLANT				
12.1	Not Used				
12.2	Not Used				
12.3	Not Used				
12.4	Equipment	ls	613,500	0	0
12.5	Instrumentation	ls	58,300	0	0
12.6	Foundation: 18" Structural Slab	cy	350.00	0	0
12.7	Structure: 20' Pre-engineered Building	sf	50.00	0	0
12.8	Discharge Line	lf	8.00	0	0
12.9	Groundwater Injection Wells	ea	9,000	0	0
12.10	Fence 8' Chain Link	lf	15.00	0	0
Total					0
13.0	5 GPM WATER TREATMENT PLANT				
13.1	Not Used				
13.2	Not Used				
13.3	Not Used				
13.4	Equipment	ls	213,500	1	214
13.5	Instrumentation	ls	20,289	1	20
13.6	Foundation: 18" Structural Slab	cy	350.00	200	70
13.7	Structure: 20' Pre-engineered Building	sf	50.00	3,600	180
13.8	Discharge Line	lf	5.00	500	3
13.9	Groundwater Injection Wells	ea	9,000	2	18
13.10	Fence 8' Chain Link	lf	15.00	150	2
Total					507
14.0	ENVIRONMENTAL MONITORING: CAPITAL COST				
14.1	Piezometer Installation	lf	50	125	6
14.2	Soil Gas Probe Construction	ea	2,500	35	88
Total					94
15.0	DECONTAMINATION AREA - TREATMENT PLANT AREA				
15.1	Decon Station Allowance	ls	50,000	1	50
Total					50
16.0	INSTITUTIONAL CONTROLS				
16.1	GW Access Restrictions: Legal Fees	lot	8,000	11	88
16.2	Not Used				
16.3	Not Used				
16.4	LFG Control Contingency	house	9,808	0	0
Total					88
	TOTAL DIRECT CAPITAL COST				5,689
	REMEDIAL DESIGN ALLOWANCE @	6%			341
	CONTINGENCY @	20%			1,206
	TOTAL CAPITAL COSTS				7,236

DETAILED COST TABLE: ALTERNATIVE # 4a SENSITIVITY: BASE

ITEM	UNIT	UNIT COST ($ / unit)	QUAN-TITY		COST ($1,000's)
ANNUAL COSTS:			Annual	Duration	Net Prese
17.0 ENVIRONMENTAL MONITORING: ANNUAL			Quantity	Req'd (yrs)	Value (1)
17.1 Five Year Review	ea	25,000	0.20	30	85
17.2 Cap Inspection and Reporting	ea	2500	4	30	170
17.3 Groundwater Monitoring	sample	1,740	51	30	1,511
17.4 SW/Sediment Monitoring	sample	2,710	22	30	1,015
17.5 Ambient Air Monitoring	sample	1,690	10	15	184
17.6 Soil Gas Monitoring	sample	83	94	15	85
TOTAL					3,051
18.0 LANDFILL GAS COLLECTION AND TREATMENT					
18.1 O&M Labor:					
18.1a Operator @ 1/2 shift/wk	hr	49	1,040	15	555
18.1b Overtime @ 10%	hr	65	104	15	74
18.1c Supervisory @ 10%	hr	75	104	15	85
18.1d Administrative Costs	ls	4,000	1	15	44
18.2 Equipment Repair/Replacement	ls	56,476	1	15	615
18.3 Electricity Usage Internal System Blower	kWhr	0.07	36,291	15	28
18.4 Elec. Usage Perimeter System Blower	kWhr	0.07	108,872	15	83
18.5 Condensate Transportation: Internal System	gal	0.35	5,059	15	19
18.6 Condensate Transportation: Perimeter System	gal	0.35	53,348	15	201
18.7 Condensate Disposal: Internal System	gal	1.44	5,059	15	79
18.8 Condensate Disposal: Perimeter System	gal	1.44	53,348	15	837
18.9 Auxiliary Fuel Usage	cf	0.02	774,034	15	168
18.10 Photocatalytic Oxidation O&M	ls	27,816	0	0	0
TOTAL					2,78
19.0 GW/LEACHATE COLLECTION & TREATMENT: 50 GPM					
19.1 O&M Labor:					
19.1a Operator @ 1/2 shift/wk	hr	49	0	0	0
19.1b Overtime @ 10%	hr	65	0	0	0
19.1c Supervisory @ 10%	hr	75	0	0	0
19.1d Administrative Costs	ls	4,000	0	0	0
19.2 Feed Chemicals	1,000 gal	2.00	0	0	0
19.3 Equipment Repair/Replacement	ls	42,276	0	0	0
19.4 Electricity Usage: Collection	kWhr	0.07	0	0	0
19.5 Electricity Usage: Treatment	1,000 gal	1.65	0	0	0
19.6 Diposal of Residuals	1,000 gal	1.01	0	0	0
TOTAL					0
20.0 LEACHATE COLLECTION & TREATMENT: 5 GPM					
20.1 O&M Labor:					
20.1a Operator @ 1/2 shift/wk	hr	49	1,040	30	868
20.1b Overtime @ 10%	hr	65	104	30	115
20.1c Supervisory @ 10%	hr	75	104	30	133
20.1d Administrative Costs	ls	4,000	1	30	68
20.2 Feed Chemicals	1,000 gal	0.70	2,628	30	31
20.3 Equipment Repair/Replacement	ls	14,967	1	30	255
20.4 Electricity Usage: Collection	kWhr	0.07	7,258	30	9
20.5 Electricity Usage: Treatment	1,000 gal	0.55	2,628	30	25
20.6 Diposal of Residuals	1,000 gal	0.35	2,628	30	16
Total					1,51

DETAILED COST TABLE: ALTERNATIVE # 4a SENSITIVITY: BASE

	ITEM	UNIT	UNIT COST ($ / unit)	QUAN-TITY		COST ($1,000's)
21.0	INSTITUTIONAL CONTROLS: ANNUAL COSTS					
21.1	Groundwater Access Restrictions (Not Used)					
21.2	Not Used					
21.3	Not Used					
21.4	LFG Control Contingency (Annual Inspections)	house	500	0	0	0
Total						0
	TOTAL PRESENT COST					7,357
	CONTINGENCY @	20%				1,471
	TOTAL ANNUAL COSTS (Present Value in $1,000's)					8,828
	TOTAL COST (in $1,000's)					16,064

Notes:

1) Net Present Value costs were calculated using the following formula:

$$\underset{(\$1,000's)}{NPV} = A_o \cdot \frac{1 - (1 + i_{INF})^N / (1 + i_{DF})^N}{(i_{DF} - i_{INF})}$$

where:

A_o = (Unit cost) · (Annual quantity)

N = duration of annual cost (years)

i_{DF} = discount factor or rate

i_{INF} = inflation rate

G-7 Detailed Costs - Alternative #4b

DETAILED COST TABLE: ALTERNATIVE # 4b SENSITIVITY: BASE

	ITEM	UNIT	UNIT COST ($ / unit)	QUAN-TITY	COST ($1,000's)
CAPITAL COSTS:					
1.0	GRADING & SITE PREP.: SOLID WASTE AREA				
1.1	Clearing and Grubbing	acre	335.00	22.9	8
1.2	Silt Fencing	lf	2.00	4,400	9
1.3	Drainage Ditches	lf	0.36	1,240	0
1.4	Detention Basins	cy	4.00	3,025	12
1.5	Fence 8' Chain Link	lf	15.00	4,700	71
Total					100
2.0	CAPPING: SOLID WASTE AREA				
2.1	Vegetation	sy	0.35	121,920	43
2.2	Topsoil: 6"	sy	3.50	121920	427
2.3	Cover Layer: 18"	cy	12.00	60,960	732
2.4	Drainage Layer: Composite	sy	3.60	121,920	439
2.5	Geomembrane	sf	0.43	1,097,276	472
2.6	Low Permeability Layer: 12"	cy	8.00	40,640	325
2.7	Protective Layer: 6"	cy	12.00	20,320	244
2.8	Wetlands Replacement	acre	50,000	0.1	5
Total					2,686
3.0	GRADING & SITE PREP.: BULKY WASTE AREA				
3.1	Clearing and Grubbing	acre	335.00	7	2
3.2	Silt Fencing	lf	2.00	2,200	4
3.2	Drainage Ditches	lf	0.36	0	0
3.4	Detention Basins	cy	4.00	0	0
3.5	Fence 8' Chain Link	lf	15.00	2,600	39
Total					46
4.0	CAPPING: BULKY WASTE AREA				
4.1	Vegetation	sy	0.35	0	0
4.2	Topsoil: 6"	sy	3.50	0	0
4.3	Cover Layer: 18"	cy	12.00	0	0
4.4	Drainage Layer: Composite	sy	3.60	0	0
4.5	Geomembrane	sf	0.43	0	0
4.6	Low Permeability Layer: 12"	cy	8.00	0	0
4.7	Gas Vent Layer: Composite	sy	3.60	0	0
4.8	Passive Gas Vents	lf	196.00	0	0
Total					0
5.0	LANDFILL MINING				
5.1	Waste Removal and Segregation	cy	9.00	114,000	1,026
5.2	Scrap Metal Transport	cy	5.00	37,500	188
5.3	Transport Non-recyclables to Solid Waste Area	cy	1.50	30,900	46
5.4	Backfill With Reclaimed Soil	cy	2.15	45,600	98
5.5	Backfill With Clean Fill	cy	11.00	50,000	550
5.6	Vegetation	sy	0.35	35,816	13
5.7	Miscellaneous Allowances	ls	97,000	1	97
5.8	Scrap Metal Revenue	lb	0.02	3.00E+07	600
5.9	Supervision & Monitoring Labor	day	300.00	114	34
Total					2,652
6.0	PERIMETER WETLANDS MITIGATION				
6.1	Wetlands & Buffer Zone replacement	ls	80,000	1	40
Total					40

DETAILED COST TABLE: ALTERNATIVE # 4b SENSITIVITY: BASE

	ITEM	UNIT	UNIT COST ($ / unit)	QUAN-TITY	COST ($1,000's)
7.0	INTERNAL LF GAS COLLECTION SYSTEM				
7.1	Vault, Gauges, Fittings and Other Costs	well	4,250	36	153
7.2	Screen, Casing and Other Well Footage Costs	lf	196.00	900	176
7.3	Header Pipe: HDPE				
7.3a	10" HDPE Header Pipe, buried	lf	27.60	500	14
7.3b	8" HDPE Header Pipe, buried	lf	23.60	3,780	89
7.3c	6" HDPE Header Pipe, buried	lf	18.50	2,890	53
7.3d	"Blueboard" thermal insulation	lf	1.50	7,170	11
7.3e	HDPE Tees 8" x 8" x 8", installed & buried	ea	310.00	20	6
7.3f	HDPE Tees 6" x 6" x 6", installed & buried	ea	250.00	22	6
7.4	Valves & Appurtenances				
7.4a	Buried butterfly isolation valves: 10"	ea	2000.00	1	2
7.4b	Buried butterfly isolation valves: 8"	ea	1600.00	15	24
7.4c	LANDTEC GEM-500 LFG analyzer	ls	6395.00	1	6
7.5	Condensate Piping	lf	5.00	3,020	15
7.6	Condensate Pump Stations	ea	50,000	2	100
7.7	Condensate Storage Tank Allowance	ea	25,000	1	25
Total					681
8.0	PERIMETER LF GAS COLLECTION SYSTEM				
8.1	Vault, Gauges, Fittings and Other Costs	well	4,250	26	111
8.2	Screen, Casing and Other Well Footage Costs	lf	196.00	572	112
8.3	Header Pipe: HDPE				
8.3a	10" HDPE Header Pipe, buried	lf	27.60	3,210	89
8.3b	6" HDPE Header Pipe, buried	lf	18.50	260	5
8.3c	"Blueboard" thermal insulation	lf	1.50	3,470	
8.3d	HDPE Tees 10" x 10" x 6", installed & buried	ea	430.00	26	11
8.4	Valves & Appurtenances	ea	2000.00	3	6
Total					338
9.0	LF GAS TREATMENT PLANT				
9.1	Access Roads	sy	5.56	4,222	23
9.2	Electricity Service	lf	14.00	1,600	22
9.3	Water Service	lf	5.00	1,600	8
9.4	Internal & Perim. Coll. System Blowers & Motors	ls	60,000	1	60
9.5	Enclosed Flare and Appurtenances	ea	179,400	1	179
9.6	Foundation: 18" Structural Slab	cy	350.00	111	39
9.7	Photocatalytic Oxidation and Appurtenances	ls	286,000	0	0
9.8	Fence 8' Chain Link	lf	15.00	400	6
Total					338
10.0	GW DEPRESSION SYSTEM: COLLECTION				
10.1	Buried Piping	lf	8.00	0	0
10.2	Pump Electrical	lf	4.00	0	0
10.3	Pump Station	ls	75,000	0	0
10.4	Shallow Drain Piping & Installation	lf	40.00	0	0
Total					0
11.0	LEACHATE COLLECTION SYSTEM				
11.1	Buried Piping	lf	5.00	2,100	11
11.2	Pump Electrical	lf	4.00	2,100	8
11.3	Pump Station	ls	50,000	1	50
11.4	Shallow Drain Piping & Installation	lf	40.00	750	30
Total					

DETAILED COST TABLE: ALTERNATIVE # 4b SENSITIVITY: BASE

	ITEM	UNIT	UNIT COST ($ / unit)	QUAN-TITY	COST ($1,000's)
12.0	50 GPM WATER TREATMENT PLANT				
12.1	Not Used				
12.2	Not Used				
12.3	Not Used				
12.4	Equipment	ls	613,500	0	0
12.5	Instrumentation	ls	58,300	0	0
12.6	Foundation: 18" Structural Slab	cy	350.00	0	0
12.7	Structure: 20' Pre-engineered Building	sf	50.00	0	0
12.8	Discharge Line	lf	8.00	0	0
12.9	Groundwater Injection Wells	ea	9,000	0	0
12.10	Fence 8' Chain Link	lf	15.00	0	0
Total					0
13.0	5 GPM WATER TREATMENT PLANT				
13.1	Not Used				
13.2	Not Used				
13.3	Not Used				
13.4	Equipment	ls	213,500	1	214
13.5	Instrumentation	ls	20,289	1	20
13.6	Foundation: 18" Structural Slab	cy	350.00	200	70
13.7	Structure: 20' Pre-engineered Building	sf	50.00	3,600	180
13.8	Discharge Line	lf	5.00	500	3
13.9	Groundwater Injection Wells	ea	9,000	2	18
13.10	Fence 8' Chain Link	lf	15.00	150	2
Total					507
14.0	ENVIRONMENTAL MONITORING: CAPITAL COST				
14.1	Piezometer Installation	lf	50	125	6
14.2	Soil Gas Probe Construction	ea	2,500	35	88
Total					94
15.0	DECONTAMINATION AREA - TREATMENT PLANT AREA				
15.1	Decon Station Allowance	ls	50,000	1	50
Total					50
16.0	INSTITUTIONAL CONTROLS				
16.1	GW Access Restrictions: Legal Fees	lot	8,000	11	88
16.2	Not Used				
16.3	Not Used				
16.4	LFG Control Contingency	house	9,808	0	0
Total					88
	TOTAL DIRECT CAPITAL COST				7,717
	REMEDIAL DESIGN ALLOWANCE @	6%			463
	CONTINGENCY @	20%			1,636
	TOTAL CAPITAL COSTS				9,816

DETAILED COST TABLE: ALTERNATIVE # 4b SENSITIVITY: BASE

ITEM	UNIT	UNIT COST ($ / unit)	QUAN-TITY		COST ($1,000's)
ANNUAL COSTS:			Annual	Duration	Net Preser
17.0 ENVIRONMENTAL MONITORING: ANNUAL			Quantity	Req'd (yrs)	Value (1)
17.1 Five Year Review	ea	25,000	0.20	30	85
17.2 Cap Inspection and Reporting	ea	2500	4	30	170
17.3 Groundwater Monitoring	sample	1,740	51	30	1,511
17.4 SW/Sediment Monitoring	sample	2,710	22	30	1,015
17.5 Ambient Air Monitoring	sample	1,690	10	15	184
17.6 Soil Gas Monitoring	sample	83	94	15	85
TOTAL					3,051
18.0 LANDFILL GAS COLLECTION AND TREATMENT					
18.1 O&M Labor:					
18.1a Operator @ 1/2 shift/wk	hr	49	1,040	15	555
18.1b Overtime @ 10%	hr	65	104	15	74
18.1c Supervisory @ 10%	hr	75	104	15	85
18.1d Administrative Costs	ls	4,000	1	15	44
18.2 Equipment Repair/Replacement	ls	56,476	1	15	615
18.3 Electricity Usage Internal System Blower	kWhr	0.07	36,291	15	28
18.4 Elec. Usage Perimeter System Blower	kWhr	0.07	108,872	15	83
18.5 Condensate Transportation: Internal System	gal	0.35	5,059	15	19
18.6 Condensate Transportation: Perimeter System	gal	0.35	53,348	15	201
18.7 Condensate Disposal: Internal System	gal	1.44	5,059	15	79
18.8 Condensate Disposal: Perimeter System	gal	1.44	53,348	15	837
18.9 Auxiliary Fuel Usage	cf	0.02	774,034	15	168
18.10 Photocatalytic Oxidation O&M	ls	27,816	0	0	0
TOTAL					2,78
19.0 GW/LEACHATE COLLECTION & TREATMENT: 50 GPM					
19.1 O&M Labor:					
19.1a Operator @ 1/2 shift/wk	hr	49	0	0	0
19.1b Overtime @ 10%	hr	65	0	0	0
19.1c Supervisory @ 10%	hr	75	0	0	0
19.1d Administrative Costs	ls	4,000	0	0	0
19.2 Feed Chemicals	1,000 gal	2.00	0	0	0
19.3 Equipment Repair/Replacement	ls	42,276	0	0	0
19.4 Electricity Usage: Collection	kWhr	0.07	0	0	0
19.5 Electricity Usage: Treatment	1,000 gal	1.65	0	0	0
19.6 Diposal of Residuals	1,000 gal	1.01	0	0	0
TOTAL					0
20.0 LEACHATE COLLECTION & TREATMENT: 5 GPM					
20.1 O&M Labor:					
20.1a Operator @ 1/2 shift/wk	hr	49	1,040	1	48
20.1b Overtime @ 10%	hr	65	104	1	6
20.1c Supervisory @ 10%	hr	75	104	1	7
20.1d Administrative Costs	ls	4,000	1	1	4
20.2 Feed Chemicals	1,000 gal	0.70	2,628	1	2
20.3 Equipment Repair/Replacement	ls	14,967	1	1	14
20.4 Electricity Usage: Collection	kWhr	0.07	7,258	1	0
20.5 Electricity Usage: Treatment	1,000 gal	0.55	2,628	1	1
20.6 Diposal of Residuals	1,000 gal	0.35	2,628	1	1
Total					8

DETAILED COST TABLE: ALTERNATIVE # 4b SENSITIVITY: BASE

	ITEM	UNIT	UNIT COST ($ / unit)	QUAN-TITY		COST ($1,000's)
21.0	INSTITUTIONAL CONTROLS: ANNUAL COSTS					
21.1	Groundwater Access Restrictions (Not Used)					
21.2	Not Used					
21.3	Not Used					
21.4	LFG Control Contingency (Annual Inspections)	house	500	0	0	0
Total						0
	TOTAL PRESENT COST					5,921
	CONTINGENCY @	20%				1,184
	TOTAL ANNUAL COSTS (Present Value in $1,000's)					7,105
	TOTAL COST (in $1,000's)					16,922

Notes:

1) Net Present Value costs were calculated using the following formula:

$$\underset{(\$1,000's)}{NPV} = A_o \cdot \frac{1 - (1 + i_{INF})^N / (1 + i_{DF})^N}{(i_{DF} - i_{INF})}$$

where:

A_o = (Unit cost) · (Annual quantity)

N = duration of annual cost (years)

i_{DF} = discount factor or rate

i_{INF} = inflation rate

DETAILED COST TABLE: ALTERNATIVE # 5a SENSITIVITY: BASE

	ITEM	UNIT	UNIT COST ($ / unit)	QUAN-TITY	COST ($1,000's)
CAPITAL COSTS:					
1.0	GRADING & SITE PREP.: SOLID WASTE AREA				
1.1	Clearing and Grubbing	acre	335.00	22.9	8
1.2	Silt Fencing	lf	2.00	4,400	9
1.3	Drainage Ditches	lf	0.36	1,240	0
1.4	Detention Basins	cy	4.00	3,025	12
1.5	Fence 8' Chain Link	lf	15.00	4,700	71
Total					100
2.0	CAPPING: SOLID WASTE AREA				
2.1	Vegetation	sy	0.35	110,836	39
2.2	Topsoil: 6"	sy	3.50	110836	388
2.3	Cover Layer: 18"	cy	12.00	55,418	665
2.4	Drainage Layer: Composite	sy	3.60	110,836	399
2.5	Geomembrane	sf	0.43	997,524	429
2.6	Low Permeability Layer: 12"	cy	8.00	36,945	296
2.7	Protective Layer: 6"	cy	12.00	18,473	222
2.8	Wetlands Replacement	acre	50,000	0.1	5
Total					2,442
3.0	GRADING & SITE PREP.: BULKY WASTE AREA				
3.1	Clearing and Grubbing	acre	335.00	7.4	2
3.2	Silt Fencing	lf	2.00	2,200	4
3.2	Drainage Ditches	lf	0.36	1,100	0
3.4	Detention Basins	cy	4.00	484	2
3.5	Fence 8' Chain Link	lf	15.00	2,600	39
Total					48
4.0	CAPPING: BULKY WASTE AREA				
4.1	Vegetation	sy	0.35	35,816	13
4.2	Topsoil: 6"	sy	3.50	35,816	125
4.3	Cover Layer: 18"	cy	12.00	17,908	215
4.4	Drainage Layer: Composite	sy	3.60	35,816	129
4.5	Geomembrane	sf	0.43	322,344	139
4.6	Low Permeability Layer: 12"	cy	8.00	11,939	96
4.7	Gas Vent Layer: Composite	sy	3.60	35,816	129
4.8	Passive Gas Vents	lf	196.00	100	20
Total					864
5.0	LANDFILL MINING				
5.1	Waste Removal and Segregation	cy	9.00	0	0
5.2	Scrap Metal Transport	cy	5.00	0	0
5.3	Transport Non-recyclables to Solid Waste Area	cy	1.50	0	0
5.4	Backfill With Reclaimed Soil	cy	2.15	0	0
5.5	Backfill With Clean Fill	cy	11.00	0	0
5.6	Vegetation	sy	0.35	0	0
5.7	Miscellaneous Allowances	ls	97,000	0	0
5.8	Scrap Metal Revenue	lb	0.02	0	0
5.9	Supervision & Monitoring Labor	day	300.00	0	0
Total					0
6.0	PERIMETER WETLANDS MITIGATION				
6.1	Wetlands & Buffer Zone replacement	ls	80,000	1	40
Total					40

DETAILED COST TABLE: ALTERNATIVE # 5a SENSITIVITY: BASE

	ITEM	UNIT	UNIT COST ($ / unit)	QUAN-TITY	COST ($1,000's)
7.0	INTERNAL LF GAS COLLECTION SYSTEM				
7.1	Vault, Gauges, Fittings and Other Costs	well	4,250	36	153
7.2	Screen, Casing and Other Well Footage Costs	lf	196.00	900	176
7.3	Header Pipe: HDPE				
7.3a	10" HDPE Header Pipe, buried	lf	27.60	500	14
7.3b	8" HDPE Header Pipe, buried	lf	23.60	3,780	89
7.3c	6" HDPE Header Pipe, buried	lf	18.50	2,890	53
7.3d	"Blueboard" thermal insulation	lf	1.50	7,170	11
7.3e	HDPE Tees 8" x 8" x 8", installed & buried	ea	310.00	20	6
7.3f	HDPE Tees 6" x 6" x 6", installed & buried	ea	250.00	22	6
7.4	Valves & Appurtenances				
7.4a	Buried butterfly isolation valves: 10"	ea	2000.00	1	2
7.4b	Buried butterfly isolation valves: 8"	ea	1600.00	15	24
7.4c	LANDTEC GEM-500 LFG analyzer	ls	6395.00	1	6
7.5	Condensate Piping	lf	5.00	1,470	7
7.6	Condensate Pump Stations	ea	50,000	1	50
7.7	Condensate Storage Tank Allowance	ea	25,000	1	25
Total					623
8.0	PERIMETER LF GAS COLLECTION SYSTEM				
8.1	Vault, Gauges, Fittings and Other Costs	well	4,250	26	111
8.2	Screen, Casing and Other Well Footage Costs	lf	196.00	572	112
8.3	Header Pipe: HDPE				
8.3a	10" HDPE Header Pipe, buried	lf	27.60	3,210	89
8.3b	6" HDPE Header Pipe, buried	lf	18.50	260	5
8.3c	"Blueboard" thermal insulation	lf	1.50	3,470	5
8.3d	HDPE Tees 10" x 10" x 6", installed & buried	ea	430.00	26	11
8.4	Valves & Appurtenances	ea	2000.00	3	6
Total					338
9.0	LF GAS TREATMENT PLANT				
9.1	Access Roads	sy	5.56	4,222	23
9.2	Electricity Service	lf	14.00	1,600	22
9.3	Water Service	lf	5.00	1,600	8
9.4	Internal & Perim. Coll. System Blowers & Motors	ls	60,000	1	60
9.5	Enclosed Flare and Appurtenances	ea	179,400	1	179
9.6	Foundation: 18" Structural Slab	cy	350.00	111	39
9.7	Photocatalytic Oxidation and Appurtenances	ls	286,000	0	0
9.8	Fence 8' Chain Link	lf	15.00	400	6
Total					338
10.0	GW DEPRESSION SYSTEM: COLLECTION				
10.1	Buried Piping	lf	8.00	1,550	12
10.2	Pump Electrical	lf	4.00	1,550	6
10.3	Pump Station	ls	75,000	1	75
10.4	Shallow Drain Piping & Installation	lf	40.00	1,450	58
Total					152
11.0	LEACHATE COLLECTION SYSTEM				
11.1	Buried Piping	lf	5.00	2,100	11
11.2	Pump Electrical	lf	4.00	2,100	8
11.3	Pump Station	ls	50,000	1	50
11.4	Shallow Drain Piping & Installation	lf	40.00	750	30
Total					

DETAILED COST TABLE: ALTERNATIVE # 5a SENSITIVITY: BASE

	ITEM	UNIT	UNIT COST ($ / unit)	QUAN-TITY	COST ($1,000's)
12.0	50 GPM WATER TREATMENT PLANT				
12.1	Not Used				
12.2	Not Used				
12.3	Not Used				
12.4	Equipment	ls	613,500	1	614
12.5	Instrumentation	ls	58,300	1	58
12.6	Foundation: 18" Structural Slab	cy	350.00	500	175
12.7	Structure: 20' Pre-engineered Building	sf	50.00	9,000	450
12.8	Discharge Line	lf	8.00	500	4
12.9	Groundwater Injection Wells	ea	9,000	5	45
12.10	Fence 8' Chain Link	lf	15.00	150	2
Total					1,348
13.0	5 GPM WATER TREATMENT PLANT				
13.1	Not Used				
13.2	Not Used				
13.3	Not Used				
13.4	Equipment	ls	213,500	0	0
13.5	Instrumentation	ls	20,289	0	0
13.6	Foundation: 18" Structural Slab	cy	350.00	0	0
13.7	Structure: 20' Pre-engineered Building	sf	50.00	0	0
13.8	Discharge Line	lf	5.00	0	0
13.9	Groundwater Injection Wells	ea	9,000	0	0
13.10	Fence 8' Chain Link	lf	15.00	0	0
Total					0
14.0	ENVIRONMENTAL MONITORING: CAPITAL COST				
14.1	Piezometer Installation	lf	50	125	6
14.2	Soil Gas Probe Construction	ea	2,500	35	88
Total					94
15.0	DECONTAMINATION AREA - TREATMENT PLANT AREA				
15.1	Decon Station Allowance	ls	50,000	1	50
Total					50
16.0	INSTITUTIONAL CONTROLS				
16.1	GW Access Restrictions: Legal Fees	lot	8,000	11	88
16.2	Not Used				
16.3	Not Used				
16.4	LFG Control Contingency	house	9,808	0	0
Total					88
	TOTAL DIRECT CAPITAL COST				6,624
	REMEDIAL DESIGN ALLOWANCE @	6%			397
	CONTINGENCY @	20%			1,404
	TOTAL CAPITAL COSTS				8,426

DETAILED COST TABLE: ALTERNATIVE # 5a SENSITIVITY: BASE

	ITEM	UNIT	UNIT COST ($ / unit)	QUAN-TITY		COST ($1,000's)
ANNUAL COSTS:				Annual	Duration	Net Presen
17.0	ENVIRONMENTAL MONITORING: ANNUAL			Quantity	Req'd (yrs)	Value (1)
17.1	Five Year Review	ea	25,000	0.20	30	85
17.2	Cap Inspection and Reporting	ea	2500	4	30	170
17.3	Groundwater Monitoring	sample	1,740	51	30	1,511
17.4	SW/Sediment Monitoring	sample	2,710	22	30	1,015
17.5	Ambient Air Monitoring	sample	1,690	10	15	184
17.6	Soil Gas Monitoring	sample	83	94	15	85
TOTAL						3,051
18.0	LANDFILL GAS COLLECTION AND TREATMENT					
18.1	O&M Labor:					
18.1a	Operator @ 1/2 shift/wk	hr	49	1,040	15	555
18.1b	Overtime @ 10%	hr	65	104	15	74
18.1c	Supervisory @ 10%	hr	75	104	15	85
18.1d	Administrative Costs	ls	4,000	1	15	44
18.2	Equipment Repair/Replacement	ls	56,476	1	15	615
18.3	Electricity Usage Internal System Blower	kWhr	0.07	36,291	15	28
18.4	Elec. Usage Perimeter System Blower	kWhr	0.07	108,872	15	83
18.5	Condensate Transportation: Internal System	gal	0.35	5,059	15	19
18.6	Condensate Transportation: Perimeter System	gal	0.35	53,348	15	201
18.7	Condensate Disposal: Internal System	gal	1.44	5,059	15	79
18.8	Condensate Disposal: Perimeter System	gal	1.44	53,348	15	837
18.9	Auxiliary Fuel Usage	cf	0.02	774,034	15	168
18.10	Photocatalytic Oxidation O&M	ls	27,816	0	0	0
TOTAL						2,78
19.0	GW/LEACHATE COLLECTION & TREATMENT: 50 GPM					
19.1	O&M Labor:					
19.1a	Operator @ 1/2 shift/wk	hr	49	1,040	30	868
19.1b	Overtime @ 10%	hr	65	104	30	115
19.1c	Supervisory @ 10%	hr	75	104	30	133
19.1d	Administrative Costs	ls	4,000	1	30	68
19.2	Feed Chemicals	1,000 gal	2.00	26,280	30	895
19.3	Equipment Repair/Replacement	ls	42,276	1	30	720
19.4	Electricity Usage: Collection	kWhr	0.07	14,516	30	17
19.5	Electricity Usage: Treatment	1,000 gal	1.65	26,280	30	738
19.6	Diposal of Residuals	1,000 gal	1.01	26,280	30	452
TOTAL						4,006
20.0	LEACHATE COLLECTION & TREATMENT: 5 GPM					
20.1	O&M Labor:					
20.1a	Operator @ 1/2 shift/wk	hr	49	0	0	0
20.1b	Overtime @ 10%	hr	65	0	0	0
20.1c	Supervisory @ 10%	hr	75	0	0	0
20.1d	Administrative Costs	ls	4,000	0	0	0
20.2	Feed Chemicals	1,000 gal	0.70	0	0	0
20.3	Equipment Repair/Replacement	ls	14,967	0	0	0
20.4	Electricity Usage: Collection	kWhr	0.07	0	0	0
20.5	Electricity Usage: Treatment	1,000 gal	0.55	0	0	0
20.6	Diposal of Residuals	1,000 gal	0.35	0	0	0
Total						0

DETAILED COST TABLE: ALTERNATIVE # 5a SENSITIVITY: BASE

	ITEM	UNIT	UNIT COST ($ / unit)	QUAN-TITY		COST ($1,000's)
21.0	INSTITUTIONAL CONTROLS: ANNUAL COSTS					
21.1	Groundwater Access Restrictions (Not Used)					
21.2	Not Used					
21.3	Not Used					
21.4	LFG Control Contingency (Annual Inspections)	house	500	0	0	0
Total						0
	TOTAL PRESENT COST					9,844
	CONTINGENCY @	20%				1,969
	TOTAL ANNUAL COSTS (Present Value in $1,000's)					11,813
	TOTAL COST (in $1,000's)					20,239

Notes:

1) Net Present Value costs were calculated using the following formula:

$$\underset{(\$1,000's)}{NPV} = A_o \cdot \frac{1 - (1 + i_{INF})^N / (1 + i_{DF})^N}{(i_{DF} - i_{INF})}$$

where:

A_o = (Unit cost) · (Annual quantity)

N = duration of annual cost (years)

i_{DF} = discount factor or rate

i_{INF} = inflation rate

G-9 Detailed Costs - Alternative #5b

DETAILED COST TABLE: ALTERNATIVE # 5b SENSITIVITY: BASE

	ITEM	UNIT	UNIT COST ($ / unit)	QUAN-TITY	COST ($1,000's)
CAPITAL COSTS:					
1.0	GRADING & SITE PREP.: SOLID WASTE AREA				
1.1	Clearing and Grubbing	acre	335.00	22.9	8
1.2	Silt Fencing	lf	2.00	4,400	9
1.3	Drainage Ditches	lf	0.36	1,240	0
1.4	Detention Basins	cy	4.00	3,025	12
1.5	Fence 8' Chain Link	lf	15.00	4,700	71
Total					100
2.0	CAPPING: SOLID WASTE AREA				
2.1	Vegetation	sy	0.35	121,920	43
2.2	Topsoil: 6"	sy	3.50	121920	427
2.3	Cover Layer: 18"	cy	12.00	60,960	732
2.4	Drainage Layer: Composite	sy	3.60	121,920	439
2.5	Geomembrane	sf	0.43	1,097,276	472
2.6	Low Permeability Layer: 12"	cy	8.00	40,640	325
2.7	Protective Layer: 6"	cy	12.00	20,320	244
2.8	Wetlands Replacement	acre	50,000	0.1	5
Total					2,686
3.0	GRADING & SITE PREP.: BULKY WASTE AREA				
3.1	Clearing and Grubbing	acre	335.00	7	2
3.2	Silt Fencing	lf	2.00	2,200	4
3.2	Drainage Ditches	lf	0.36	0	0
3.4	Detention Basins	cy	4.00	0	0
3.5	Fence 8' Chain Link	lf	15.00	2,600	39
Total					46
4.0	CAPPING: BULKY WASTE AREA				
4.1	Vegetation	sy	0.35	0	0
4.2	Topsoil: 6"	sy	3.50	0	0
4.3	Cover Layer: 18"	cy	12.00	0	0
4.4	Drainage Layer: Composite	sy	3.60	0	0
4.5	Geomembrane	sf	0.43	0	0
4.6	Low Permeability Layer: 12"	cy	8.00	0	0
4.7	Gas Vent Layer: Composite	sy	3.60	0	0
4.8	Passive Gas Vents	lf	196.00	0	0
Total					0
5.0	LANDFILL MINING				
5.1	Waste Removal and Segregation	cy	9.00	114,000	1,026
5.2	Scrap Metal Transport	cy	5.00	37,500	188
5.3	Transport Non-recyclables to Solid Waste Area	cy	1.50	30,900	46
5.4	Backfill With Reclaimed Soil	cy	2.15	45,600	98
5.5	Backfill With Clean Fill	cy	11.00	50,000	550
5.6	Vegetation	sy	0.35	35,816	13
5.7	Miscellaneous Allowances	ls	97,000	1	97
5.8	Scrap Metal Revenue	lb	0.02	3.00E+07	600
5.9	Supervision & Monitoring Labor	day	300.00	114	34
Total					2,652
6.0	PERIMETER WETLANDS MITIGATION				
6.1	Wetlands & Buffer Zone replacement	ls	80,000	1	40
Total					40

DETAILED COST TABLE: ALTERNATIVE # 5b SENSITIVITY: BASE

	ITEM	UNIT	UNIT COST ($ / unit)	QUAN-TITY	COST ($1,000's)
7.0	INTERNAL LF GAS COLLECTION SYSTEM				
7.1	Vault, Gauges, Fittings and Other Costs	well	4,250	36	153
7.2	Screen, Casing and Other Well Footage Costs	lf	196.00	900	176
7.3	Header Pipe: HDPE				
7.3a	10" HDPE Header Pipe, buried	lf	27.60	500	14
7.3b	8" HDPE Header Pipe, buried	lf	23.60	3,780	89
7.3c	6" HDPE Header Pipe, buried	lf	18.50	2,890	53
7.3d	"Blueboard" thermal insulation	lf	1.50	7,170	11
7.3e	HDPE Tees 8" x 8" x 8", installed & buried	ea	310.00	20	6
7.3f	HDPE Tees 6" x 6" x 6", installed & buried	ea	250.00	22	6
7.4	Valves & Appurtenances				
7.4a	Buried butterfly isolation valves: 10"	ea	2000.00	1	2
7.4b	Buried butterfly isolation valves: 8"	ea	1600.00	15	24
7.4c	LANDTEC GEM-500 LFG analyzer	ls	6395.00	1	6
7.5	Condensate Piping	lf	5.00	1,470	7
7.6	Condensate Pump Stations	ea	50,000	1	50
7.7	Condensate Storage Tank Allowance	ea	25,000	1	25
Total					623
8.0	PERIMETER LF GAS COLLECTION SYSTEM				
8.1	Vault, Gauges, Fittings and Other Costs	well	4,250	26	111
8.2	Screen, Casing and Other Well Footage Costs	lf	196.00	572	112
8.3	Header Pipe: HDPE				
8.3a	10" HDPE Header Pipe, buried	lf	27.60	3,210	89
8.3b	6" HDPE Header Pipe, buried	lf	18.50	260	5
8.3c	"Blueboard" thermal insulation	lf	1.50	3,470	[illegible]
8.3d	HDPE Tees 10" x 10" x 6", installed & buried	ea	430.00	26	11
8.4	Valves & Appurtenances	ea	2000.00	3	6
Total					338
9.0	LF GAS TREATMENT PLANT				
9.1	Access Roads	sy	5.56	4,222	23
9.2	Electricity Service	lf	14.00	1,600	22
9.3	Water Service	lf	5.00	1,600	8
9.4	Internal & Perim. Coll. System Blowers & Motors	ls	60,000	1	60
9.5	Enclosed Flare and Appurtenances	ea	179,400	1	179
9.6	Foundation: 18" Structural Slab	cy	350.00	111	39
9.7	Photocatalytic Oxidation and Appurtenances	ls	286,000	0	0
9.8	Fence 8' Chain Link	lf	15.00	400	6
Total					338
10.0	GW DEPRESSION SYSTEM: COLLECTION				
10.1	Buried Piping	lf	8.00	1,550	12
10.2	Pump Electrical	lf	4.00	1,550	6
10.3	Pump Station	ls	75,000	1	75
10.4	Shallow Drain Piping & Installation	lf	40.00	1,450	58
Total					152
11.0	LEACHATE COLLECTION SYSTEM				
11.1	Buried Piping	lf	5.00	2,100	11
11.2	Pump Electrical	lf	4.00	2,100	8
11.3	Pump Station	ls	50,000	1	50
11.4	Shallow Drain Piping & Installation	lf	40.00	750	30
Total					

DETAILED COST TABLE: ALTERNATIVE # 5b SENSITIVITY: BASE

	ITEM	UNIT	UNIT COST ($ / unit)	QUAN-TITY	COST ($1,000's)
12.0	50 GPM WATER TREATMENT PLANT				
12.1	Not Used				
12.2	Not Used				
12.3	Not Used				
12.4	Equipment	ls	613,500	1	614
12.5	Instrumentation	ls	58,300	1	58
12.6	Foundation: 18" Structural Slab	cy	350.00	500	175
12.7	Structure: 20' Pre-engineered Building	sf	50.00	9,000	450
12.8	Discharge Line	lf	8.00	500	4
12.9	Groundwater Injection Wells	ea	9,000	5	45
12.10	Fence 8' Chain Link	lf	15.00	150	2
Total					1,348
13.0	5 GPM WATER TREATMENT PLANT				
13.1	Not Used				
13.2	Not Used				
13.3	Not Used				
13.4	Equipment	ls	213,500	0	0
13.5	Instrumentation	ls	20,289	0	0
13.6	Foundation: 18" Structural Slab	cy	350.00	0	0
13.7	Structure: 20' Pre-engineered Building	sf	50.00	0	0
13.8	Discharge Line	lf	5.00	0	0
13.9	Groundwater Injection Wells	ea	9,000	0	0
13.10	Fence 8' Chain Link	lf	15.00	0	0
Total					0
14.0	ENVIRONMENTAL MONITORING: CAPITAL COST				
14.1	Piezometer Installation	lf	50	125	6
14.2	Soil Gas Probe Construction	ea	2,500	35	88
Total					94
15.0	DECONTAMINATION AREA - TREATMENT PLANT AREA				
15.1	Decon Station Allowance	ls	50,000	1	50
Total					50
16.0	INSTITUTIONAL CONTROLS				
16.1	GW Access Restrictions: Legal Fees	lot	8,000	11	88
16.2	Not Used				
16.3	Not Used				
16.4	LFG Control Contingency	house	9,808	0	0
Total					88
	TOTAL DIRECT CAPITAL COST				8,653
	REMEDIAL DESIGN ALLOWANCE @	6%			519
	CONTINGENCY @	20%			1,834
	TOTAL CAPITAL COSTS				11,006

DETAILED COST TABLE: ALTERNATIVE # 5b SENSITIVITY: BASE

ITEM	UNIT	UNIT COST ($ / unit)	QUAN-TITY		COST ($1,000's)
ANNUAL COSTS:			Annual	Duration	Net Present
17.0 ENVIRONMENTAL MONITORING: ANNUAL			Quantity	Req'd (yrs)	Value (1)
17.1 Five Year Review	ea	25,000	0.20	30	85
17.2 Cap Inspection and Reporting	ea	2500	4	30	170
17.3 Groundwater Monitoring	sample	1,740	51	30	1,511
17.4 SW/Sediment Monitoring	sample	2,710	22	30	1,015
17.5 Ambient Air Monitoring	sample	1,690	10	15	184
17.6 Soil Gas Monitoring	sample	83	94	15	85
TOTAL					3,051
18.0 LANDFILL GAS COLLECTION AND TREATMENT					
18.1 O&M Labor:					
18.1a Operator @ 1/2 shift/wk	hr	49	1,040	15	555
18.1b Overtime @ 10%	hr	65	104	15	74
18.1c Supervisory @ 10%	hr	75	104	15	85
18.1d Administrative Costs	ls	4,000	1	15	44
18.2 Equipment Repair/Replacement	ls	56,476	1	15	615
18.3 Electricity Usage Internal System Blower	kWhr	0.07	36,291	15	28
18.4 Elec. Usage Perimeter System Blower	kWhr	0.07	108,872	15	83
18.5 Condensate Transportation: Internal System	gal	0.35	5,059	15	19
18.6 Condensate Transportation: Perimeter System	gal	0.35	53,348	15	201
18.7 Condensate Disposal: Internal System	gal	1.44	5,059	15	79
18.8 Condensate Disposal: Perimeter System	gal	1.44	53,348	15	837
18.9 Auxiliary Fuel Usage	cf	0.02	774,034	15	168
18.10 Photocatalytic Oxidation O&M	ls	27,816	0	0	0
TOTAL					2,787
19.0 GW/LEACHATE COLLECTION & TREATMENT: 50 GPM					
19.1 O&M Labor:					
19.1a Operator @ 1/2 shift/wk	hr	49	1,040	30	868
19.1b Overtime @ 10%	hr	65	104	30	115
19.1c Supervisory @ 10%	hr	75	104	30	133
19.1d Administrative Costs	ls	4,000	1	30	68
19.2 Feed Chemicals	1,000 gal	2.00	26,280	30	895
19.3 Equipment Repair/Replacement	ls	42,276	1	30	720
19.4 Electricity Usage: Collection	kWhr	0.07	14,516	30	17
19.5 Electricity Usage: Treatment	1,000 gal	1.65	26,280	30	738
19.6 Diposal of Residuals	1,000 gal	1.01	26,280	30	452
TOTAL					4,006
20.0 LEACHATE COLLECTION & TREATMENT: 5 GPM					
20.1 O&M Labor:					
20.1a Operator @ 1/2 shift/wk	hr	49	0	0	0
20.1b Overtime @ 10%	hr	65	0	0	0
20.1c Supervisory @ 10%	hr	75	0	0	0
20.1d Administrative Costs	ls	4,000	0	0	0
20.2 Feed Chemicals	1,000 gal	0.70	0	0	0
20.3 Equipment Repair/Replacement	ls	14,967	0	0	0
20.4 Electricity Usage: Collection	kWhr	0.07	0	0	0
20.5 Electricity Usage: Treatment	1,000 gal	0.55	0	0	0
20.6 Diposal of Residuals	1,000 gal	0.35	0	0	0
Total					0

DETAILED COST TABLE: ALTERNATIVE # 5b SENSITIVITY: BASE

	ITEM	UNIT	UNIT COST ($ / unit)	QUAN-TITY		COST ($1,000's)
21.0	INSTITUTIONAL CONTROLS: ANNUAL COSTS					
21.1	Groundwater Access Restrictions (Not Used)					
21.2	Not Used					
21.3	Not Used					
21.4	LFG Control Contingency (Annual Inspections)	house	500	0	0	0
Total						0
	TOTAL PRESENT COST					9,844
	CONTINGENCY @	20%				1,969
	TOTAL ANNUAL COSTS (Present Value in $1,000's)					11,813
	TOTAL COST (in $1,000's)					22,819

Notes:

1) Net Present Value costs were calculated using the following formula:

$$\underset{(\$1,000's)}{NPV} = A_0 \cdot \frac{1 - (1 + i_{INF})^N / (1 + i_{DF})^N}{(i_{DF} - i_{INF})}$$

where:

A_0 = (Unit cost) · (Annual quantity)

N = duration of annual cost (years)

i_{DF} = discount factor or rate

i_{INF} = inflation rate

G-10 Unit Cost Development and General Assumptions - All Alternatives

UNIT COST DEVELOPMENT ITEM			UNIT COST ($ / unit)	UNIT
GRADING & SITE PREP.: SOLID WASTE AREA				
1.1 Clearing & Grubbing				
Use Brush Mowing: Light Density - Modified to use $45/hr labor, 17% OH&P			$335	/ acre
[Means Heavy Construction Cost Data, 1997, p.41]				
Quantity: Use acreage of disposal area: Table 2-13		22.9 acres		
1.2 Silt Fencing				
Silt Fence, Polypropylene, ideal conditions			$2.00	/ ft
[M&E estimate, 1997]				
Quantity: Approximate perimeter of disposal area, measured from figures		4,400 ft		
1.3 Drainage Ditches				
Cut drainage Ditch-Common Earth, 1' deep			$0.36	/ ft
[Means, p.59]				
Quantity: Measured from figures		1,240 ft		
1.4 Detention Basins				
Detention Basins #1 and #2				
Excavation: Backhoe, hydraulic, crawler mtd., 1 cy capacity; 75 cy/hr			$4.00	/ cy
[M&E estimate, 1997]				
Quantity: Basin volumes in Appendix B	Basin #1	1,500 cy		
Add 50% capacity	Basin #2	1,525 cy		
1.5 Fence: 8' Chain Link				
Total Bare Cost			$15.00	/ ft
[M&E estimate, 1997]				
Quantity: Approximate, measured from figures		4,700 ft		
CAPPING: SOLID WASTE AREA				
[Increase all capping material quantities by 10% for Alternatives #4b & #5b due to waste placement from Bulky Waste Area]				
2.1 Vegetation				
Air seeding with mulch & fertilizer			$0.35	/ sy
[Basis: Danbury, CT Landfill, 1997]				
Quantity: Size of disposal area		110,836 sy		
2.2 Topsoil: 6"				
Spread conditioned topsoil 6" deep, 300 Hp dozer				
Total Bare Cost			$3.50	/ sy
[Basis: Danbury, CT Landfill, 1997]				
Quantity: Size of disposal area		110,836 sy		
2.3 Cover Layer: 18"				
Select granular fill borrow cost	[M&E estimate, 1997]		$12.00	/ cy
Compaction, 18" with roller, 4 passes				
Backfilling 300' haul, sand & gravel				
Quantity: Size of disposal area x depth		55,418 cy		
2.4 Drainage Layer: Composite				
Drainage composite: hydr. conductivity = 10 cm/s			$3.60	/ sy
[Carmo Environmental Systems, Inc., 1997]				
Quantity: Size of disposal area		110,836 sy		

UNIT COST DEVELOPMENT ITEM			UNIT COST ($ / unit)	UNIT
2.5 Geomembrane				
60 mil LLDPE installed			$0.43	/ sf
[Polyflex, Lou Jacobsen]				
Quantity: Size of disposal area		997,524 sf		
2.6 Low Permeability Layer: 12"				
Silt/Sand: hydr. conductivity = 1 x 10^{-4} cm/s			$8.00	/ cy
[M&E Estimate, 1997]				
Quantity: Size of disposal area		36,945 cy		
2.7 Protective Layer: 6"				
Select granular fill borrow cost	[M&E estimate, 1997]		$12.00	/ cy
Compaction, 6" with roller				
Backfilling 300' haul, sand & gravel				
Quantity: Size of disposal area x depth		18,473 cy		
2.8 Emergent Wetlands Replacement (1993 dollars)				
Assume similar to reference			$50,000	/ acre
[Figure 1, King and Bohlen, 1994]				
Quantity: Emergent Wetland on Figures, GIS measured		0.1 acres		
GRADING & SITE PREP.: BULKY WASTE AREA				
3.1 Clearing & Grubbing				
See 1.1			$335	/ acre
Quantity: Use acreage of disposal area; Table 2-13		7.4 acres		
3.2 Silt Fencing				
See 1.2			$2.00	/ ft
Quantity: Approximate perimeter of disposal area, measured from figures		2,200 ft		
3.3 Drainage Ditches				
See 1.3			$0.36	/ ft
Quantity: Measured from figures		1,100 ft		
3.4 Detention Basins				
Detention Basin #3				
Excavation: Backhoe, hydraulic, crawler mtd., 1 cy capacity; 75 cy/hr			$4.00	/ cy
[M&E estimate, 1997]				
Quantity: Basin volume in Appendix B	Basin #3	484 cy		
Add 50% capacity				
3.5 Fence: 8' Chain Link				
See 1.5			$15.00	/ ft
Quantity: Approximate, measured from figures		2,600 ft		
CAPPING: BULKY WASTE AREA				
4.1 Vegetation				
See 2.1			$0.35	/ sy
Quantity: Size of disposal area		35,816 sy		
4.2 Topsoil: 6"				
See 2.2			$3.50	/ sy
Quantity: Size of disposal area		35,816 sy		

UNIT COST DEVELOPMENT ITEM			UNIT COST ($ / unit)	UNIT
4.3 Cover Layer: 18"				
See 2.3			$12.00	/ cy
Quantity: Size of disposal area x depth		17.908 cy		
4.4 Drainage Layer: Composite				
See 2.4			$3.60	/ sy
Quantity: Size of disposal area		35.816 sy		
4.5 Geomembrane				
See 2.5			$0.43	/ sf
Quantity: Size of disposal area		322.344 sf		
4.6 Low Permeability Layer: 12"				
See 2.6			$8.00	/ cy
Quantity: Size of disposal area		11.939 cy		
4.7 Gas Vent Layer: Composite				
See 2.4			$3.60	/ sy
Quantity: Size of disposal area x depth		35.816 sy		
4.8 Passive Gas Vents				
Vent Installation			$196	/ ft
See 7.2				
Quantity: 10 penetrating cap at 10' deep; Table 4-3		100 ft		
LANDFILL MINING				
5.1 Waste Removal and Segregation				
[Appendix A]			$9	/ cy
Quantity: Estimated Bulky Waste Area Vol.; Table 2-13		114.000 cy		
5.2 Scrap Metal Transport				
[Appendix A]			$5	/ cy
Quantity: Estimated Volume; Appendix A		37.500 cy		
5.3 Transport Non-recyclables to Solid Waste Area				
[Appendix A]			$1.50	/ cy
Quantity: Estimated Volume; Appendix A		30.900 cy		
5.4 Backfill With Reclaimed Soil				
[Appendix A]			$2.15	/ cy
Quantity: Estimated Volume; Appendix A		45.600 cy		
5.5 Backfill With Clean Fill				
Fill consisting of common earth	[M&E estimate, 1997]		$11.00	/ cy
Quantity: Assumed Volume; Appendix A		50.000 cy		
5.6 Vegetation				
See 2.1			$0.35	/ sy
Quantity: Size of disposal area		35.816 sy		

UNIT COST DEVELOPMENT ITEM				UNIT COST ($ / unit)	UNIT
5.7 Miscellaneous Allowances					
[Appendix A]					
Hazardous Waste Disposal		$10,000	ls		
Dewatering System		$50,000	ls		
Health & Safety Training, Equipment		$37,000	ls		
Total		$97,000	ls		
				$97,000	/ ls
Quantity: One lump sum		1	ls		
5.8 Scrap Metal Revenue					
[Appendix A]				$0.02	/ lb
Quantity: Appendix A: 37,500 cy metal x 800 lb/cy		30,000,000	lb		
5.9 Supervision & Monitoring Labor					
[Appendix A: assumption]				$300	/ day
Quantity: Appendix A: 114,000 cy @ 1,000 cy/day		114	days		
PERIMETER WETLANDS MITIGATION					
6.1 Wetlands & Buffer Zone replacement					
Assume similar to reference				$80,000	/ acre
[Figure 1, King and Bohlen, 1994]					
Quantity: Estimated for each Alt.	Alt. #1	0.00	acres		
from figures	Alt. #2	0.00	acres		
	Alt. #3a/3b	0.05	acres		
	Alt. #4a	0.50	acres		
	Alt. #4b	0.50	acres		
	Alt. #5a	0.50	acres		
	Alt. #5b	0.50	acres		
INTERNAL LF GAS COLLECTION SYSTEM					
7.1 Vault, Gauges, Fittings and Other Costs					
Cost Per Well:					
Precast Concrete Vault & Hatch Door Installed	$3,625	per well	[M&E estimate, 1997]		
LANDTEC 2" Accu-Flo 200 Vertical Wellhead	$325	per well	[Landfill Control Technolgies]		
Well Head Installation	$300	per well	[M&E estimate, 1997]		
Total Cost	$4,250	per well			
				$4,250	/ well
Quantity: Number of wells: Section 3.1.8.3		36	wells		
7.2 Screen, Casing and Other Well Footage Costs					
[Source: Final Report Evaluation of LFG Migration Barrier Systems, M&E, 1993]					
11" O.D. boring for 4" well	$110	per foot	[ENVEST]		
Assume 2/3 of well depth is screened, 1/3 is unscreened					
4" PVC, Schedule 40 well screen	$25	per foot	[ENVEST]		
x 2/3 =	$17	per foot			
4" PVC, Schedule 40 well casing	$22	per foot	[ENVEST]		
x 1/3 =	$7	per foot			
Well Filter Pack	$44	per foot	[ENVEST]		
x 2/3 =	$29	per foot			
Total Direct Cost	$163	per foot			
Add 20% Overhead & Profit	$196	per foot		$196	/ ft
Quantity: Number of wells x assumed depth of 25 ft		900	ft		

UNIT COST DEVELOPMENT ITEM				UNIT COST ($ / unit)	UNIT
7.3 Header Pipe: HDPE					
Refer to the attached sketches for basis of quantities.					
7.3a	10" HDPE Header Pipe, buried	[M&E estimate, 1997]		$27.60	/ ft
	Quantity:		500 ft		
7.3b	8" HDPE Header Pipe, buried	[M&E estimate, 1997]		$23.60	/ ft
	Quantity:		3,780 ft		
7.3c	6" HDPE Header Pipe, buried	[M&E estimate, 1997]		$18.50	/ ft
	Quantity: 23 wells w/10' connectors (230'), 3 wells w/120' connectors (360'), 6 branch sections (2,300')		2,890 ft		
7.3d	"Blueboard" thermal insulation				
	1" thick by 3' wide	[M&E estimate, 1997]		$1.50	/ ft
	Quantity: Add 7.3a through 7.3c		7,170 ft		
7.3e	HDPE Tees 8" x 8" x 8", installed & buried				
		[M&E estimate, 1997]		$310	/ ea
	Quantity:		20 total		
7.3f	HDPE Tees 6" x 6" x 6", installed & buried				
		[M&E estimate, 1997]		$250	/ ea
	Quantity:		22 total		
7.4 Valves & Appurtenances					
Refer to back-up attachments for 7.3					
7.4a	Buried butterfly isolation valves: 10"				
	Header pipeline, 10"	[M&E estimate, 1997]		$2,000	/ ea
	Quantity:		1 total		
7.4b	Buried butterfly isolation valves: 8"				
	Header pipeline, 8"	[M&E estimate, 1997]		$1,600	/ ea
	Quantity:		15 total		
7.4c	LANDTEC GEM-500 LFG analyzer				
		[Landfill Technologies, 1997 - attached]		$6,395	/ ls
	Quantity:		1 ls		
7.5 Condensate Piping					
Assume 1" HDPE Line				$5.00	/ ft
	[M&E estimate, 1997]				
Quantity: Refer to backup for 7.3: Alts #3a to 4b			3,020 ft		
	Alts #5a & 5b (GW piping used for some)		1,470 ft		
7.6 Condensate Pump Stations					
	[M&E estimate, 1997]			$50,000	/ ea
Quantity: Refer to backup for 7.3: Alts #3a to 4b			2 ea		
	Alts #5a & 5b		1 ea		
7.6 Condensate Storage Tank Allowance					
	[M&E estimate, 1997]			$25,000	/ ea
Quantity: One required			1 ea		
PERIMETER GAS COLLECTION SYSTEM					
8.1 Vault, Gauges, Fittings and Other Costs					
	See 7.1			$4,250	/ well
Quantity: Number of wells			26 wells		
8.2 Screen, Casing and Other Well Footage Costs					
	See 7.2			$196	/ ft
Quantity: # of wells x assumed depth of 22 ft			572 ft		

UNIT COST DEVELOPMENT ITEM				UNIT COST ($ / unit)	UNIT
8.3 Header Pipe: HDPE					
Refer to Item 7.3 for basis of quantities.					
8.3a	10" HDPE Header Pipe, buried	[M&E estimate, 1997]		$27.60	/ ft
	Quantity:		3,210 ft		
8.3b	6" HDPE Header Pipe, buried	[M&E estimate, 1997]		$18.50	/ ft
	Quantity: 26 wells w/10' connectors		260 ft		
8.3c	"Blueboard" thermal insulation				
	1" thick by 3' wide	[M&E estimate, 1997]		$1.50	/ ft
	Quantity: Add 8.3a to 8.3b		3,470 ft		
8.3d	HDPE Tees 10" x 10" x 6", installed & buried				
		[M&E estimate, 1997]		$430	/ ea
	Quantity:		26 total		
8.4 Valves & Appurtenances					
Refer to back-up for 7.4					
	Buried butterfly isolation valves, header pipeline, 10"				
		[M&E estimate, 1997]		$2,000	/ ea
	Quantity:		3 total		
LF GAS TREATMENT PLANT					
9.1 Access Roads					
8" gravel depth, based on $25/cy				$5.56	/ sy
	[M&E estimate, 1997]				
Quantity: Measured from figs (1900) x 20 ft wide			4,222 sy		
9.2 Electricity Service					
[Source: Approximately Danbury LF, 1997]				$14.00	/ ft
Quantity: Measured from figures			1,600 ft		
9.3 Water Service					
Assume 1" HDPE Line					
	[M&E estimate, 1997]			$5.00	/ ft
Quantity: Measured from figures			1,600 ft		
9.4 Internal and Perimeter Collection System Blowers & Motors					
Blower sizes based on gas stream flows					
Installation costs assumed to be included with Item 9.5				$60,000	/ ls
	[John Zink Quotation, Appendix E]				
Quantity: 2 blowers w/backups in one lump sum			1 ls		

UNIT COST DEVELOPMENT ITEM		UNIT COST ($ / unit)	UNIT
9.5 Enclosed Flare and Appurtenances [John Zink Quotation, Appendix E]			
	Totals		
Enclosed Flare/Controls/Accessories w/Two Inlet Flame Arresters	$90.000		
2 Moisture Separators	$18.000		
2 Automatic Inlet Valves	$3.000		
2 Flow Meters	$7.000		
1 Chart Recorder	$3.300		
1 Autodialer	$3.300		
1 Ladder	$3.500		
1 Hinged Damper	$800		
1 Control Panel Weather Hood	$2.000		
1 Top-Coat Finish	$3.000		
6 Days of Field Construction, Start-Up & Operational Support	$10.500		
Estimated Freight	$5.000		
Installation/Erection [Danbury LF, 1997]	$30.000		
	$179.400	$179.400	/ ea
Quantity: One unit	1 ea		
9.6 Foundation: 18" Structural Slab [M&E estimate, 1997]		$350	/ cy
Quantity: Measured from figures (50x40)	111 cy		
9.7 Photocatalytic Oxidation and Appurtenances [Appendix A: Range: $75.000 to $350.000; use $286000]		$286.000	/ ls
Quantity: One lump sum	1 ls		
9.8 Fence: 8' Chain Link See 1.5		$15.00	/ ft
Quantity: Approximate, measured from figures	400 ft		
GW DEPRESSION SYSTEM: COLLECTION			
10.1 Buried Piping Assume 2" HDPE Line: submersible pump station located at NW corner of Solid Waste Area (condensate also transferred through this pipe) [M&E estimate, 1997]		$8.00	/ ft
Quantity: Measured from figures	1.550 ft		
10.2 Pump Electrical Electrical Utility Service to pumps, buried direct [M&E estimate, 1997]		$4.00	/ ft
Quantity: Measured from figures	1.550 ft		
10.3 Pump Station [M&E estimate, 1997]		$75.000	/ ls
Quantity: One lump sum	1 ls		
10.4 Shallow Drain Piping & Installation Trenching & Gravel Backfill: 4' wide, 12' deep [M&E estimate, 1997]		$40.00	/ ft
Quantity: Measured from figures	1.450 ft		

UNIT COST DEVELOPMENT ITEM		UNIT COST ($ / unit)	UNIT
LEACHATE COLLECTION SYSTEM			
11.1 Buried Piping			
Assume 1" HDPE Line: submersible pump station located near MW-03 well cluster See 9.3		$5.00	/ ft
Quantity: Measured from figures	2,100 ft		
11.2 Pump Electrical			
See 10.2		$4.00	/ ft
Quantity: Measured from figures	2,100 ft		
11.3 Pump Station			
[M&E estimate, 1997]		$50,000	/ ls
Quantity: One lump sum	1 ls		
11.4 Shallow Drain Piping & Installation			
See 10.4		$40.00	/ ft
Quantity: Measured from figures	750 ft		
50 GPM WATER TREATMENT PLANT			
12.1 Not Used			
12.2 Not Used			
12.3 Not Used			
12.4 Equipment			
[9/16/96 calculation attached]		$613,500	/ ls
Quantity: One lump sum	1 ls		
12.5 Instrumentation			
[9/16/96 calculation attached]		$58,300	/ ls
Quantity: One lump sum	1 ls		
12.6 Foundation: 18" Structural Slab			
See 9.7		$350	/ cy
Quantity: Measured from figures (150x60)	500 cy		
12.7 Structure: 20' Pre-engineered Building			
[M&E estimate, 1997]		$50.00	/ sf
Quantity: Measured from figures (150x60)	9,000 sf		
12.8 Discharge Line			
See 10.1		$8.00	/ ft
Quantity: Measured from figures	500 ft		
12.9 Groundwater Injection Wells			
[M&E estimate, 1997]		$9,000	/ ea
Quantity: Assumed	5 ea		
12.10 Fence: 8' Chain Link			
See 1.5		$15.00	/ ft
Quantity: Approximate, measured from figures	150 ft		
5 GPM WATER TREATMENT PLANT			
13.1 Not Used			
13.2 Not Used			
13.3 Not Used			

UNIT COST DEVELOPMENT ITEM		UNIT COST ($ / unit)	UNIT
13.4 Equipment			
[9/16/96 calculation attached]		$213,500	/ ls
Quantity: One lump sum	1 ls		
13.5 Instrumentation			
[9/16/96 calculation attached]		$20,289	/ ls
Quantity: One lump sum	1 ls		
13.6 Foundation: 18" Structural Slab			
See 9.7		$350	/ cy
Quantity: Measured from figures (150x60)*0.4	200 cy		
13.7 Structure: 20' Pre-engineered Building			
See 12.7		$50.00	/ sf
Quantity: Measured from figures (150x60)*0.4	3,600 sf		
13.8 Discharge Line			
See 11.1		$5.00	/ ft
Quantity: Measured from figures	500 ft		
13.9 Groundwater Injection Wells			
See 12.9		$9,000	/ ea
Quantity: Assumed	2 ea		
13.10 Fence: 8' Chain Link			
See 1.5		$15.00	/ ft
Quantity: Approximate, measured from figures	150 ft		
ENVIRONMENTAL MONITORING: CAPITAL COST			
14.1 Piezometer Installation			
[M&E Estimate, 1997]		$50	/ ft
Quantity: 5 under SW Area cap at 25' deep; Table 4-3	125 ft		
14.2 Soil Gas Probe Construction		$2,500	/ ea
[M&E Estimate, 1997]			
Quantity: Section 4.1.1.1 & Table 4-3	35 ea		
DECONTAMINATION AREA - TREATMENT PLANT AREA			
15.1 Decon Station Allowance			
[M&E Estimate, 1997]		$50,000	/ ls
Quantity: Assumed	1 ls		
INSTITUTIONAL CONTROLS			
16.1 GW Access Restrictions: Legal Fees			
Assumed one-time labor per lot		$8,000	/ lot
12 hrs @ $65/hr			
32 hrs @ $110/hr			
20 hrs @ $150/hr			
Misc. Expeditures @ $700			
Quantity: 11 potential lots	11 lots		
16.2 Not Used			

UNIT COST DEVELOPMENT ITEM					UNIT COST ($ / unit)	UNIT
16.3 Not Used						
16.4 LFG Control Contingency						
methane sensors:	number req'd		2			
		unit cost	$1,500	each		
instrumentation/controls allowance			$1,500	LS		
blower(s)/fan(s)	number req'd		1			
		unit cost	$500	each		
piping & mechanical allowance			$1,000	LS		
slab vents	number req'd		5			
		unit cost	$500	each		
			$8,500	per house		
[Jan '93 assumptions upgraded to '97 dollars by ENR cost indices]					$9,808	/ house
Quantity: 4 potential houses				4 houses		
ENVIRONMENTAL MONITORING: ANNUAL						
17.1 Five Year Review						
[Assumed]					$25,000	/ ea
Annual Quantity: Once every 5 years				0.20 ea		
17.2 Cap Inspection and Reporting						
Assumed labor per quarterly event					$2,500	/ ea
6 hrs @ $60/hr						
24 hrs @ $85/hr						
Misc. Exp. @ $100						
Annual Quantity: Quarterly				4 ea		
17.3 Groundwater Monitoring - Sample Collection and Analyses						
[9/16/96 calculation attached]					$1,740	/ sample
Annual Quantity: [9/16/96 calc.] - All Alts. but 4b & 5b				51 samples		
Alternatives #4b & #5b include a few more locations:						
Year 1: 46 locations, 4 times per year				184 samples		
Years 2-30: 24 locations, 2 times per year				1,392 samples		
QA/QC @ 10% of total:				158 samples		
				1,734		
Annual Quantity: Over 30 years				58 samples		
17.4 SW/Sediment Monitoring						
[9/16/96 calculation attached]					$2,710	/ sample
Annual Quantity: [9/16/96 calculation attached]				22 samples		
17.5 Ambient Air Monitoring						
[9/16/96 calculation attached]					$1,690	/ sample
Annual Quantity: [9/16/96 calculation attached]				10 samples		
17.6 Soil Gas Monitoring						
[9/16/96 calculation attached]					$83	/ sample
Annual Quantity: [9/16/96 calculation attached]				94 samples		

UNIT COST DEVELOPMENT ITEM			UNIT COST ($ / unit)	UNIT
LANDFILL GAS COLLECTION AND TREATMENT				
18.1 O&M Labor				
	[Source: PSG, Inc.]			
18.1a	Operator @ 1/2 shift/wk		$49	/ hr
	Annual Quantity:	1,040 hrs		
18.1b	Overtime @ 10%		$65	/ hr
	Annual Quantity:	104 hrs		
18.1c	Supervisory @ 10%		$75	/ hr
	Annual Quantity:	104 hrs		
18.1d	Administrative Costs		$4,000	/ ls
	Annual Quantity: One lump sum	1 ls		
18.2 Equipment Repair/Replacement				
	[9/16/96 calculation attached]		$56,476	/ ls
Annual Quantity: One lump sum per year		1 ls		
18.3 Electricity Usage Internal System Blower				
	Assume $0.07 / kWhr & 5 Hp		$0.07	/ kWhr
Annual Quantity: 5 Hp x 0.7457 kW/Hp @ 90% efficiency x				
	24 hrs/day x 365 days/yr	36,291 kWhr		
18.4 Electricity Usage Perimeter System Blower				
	Assume $0.07 / kWhr & 15 Hp		$0.07	/ kWhr
Annual Quantity: 15 Hp x 0.7457 kW/Hp @ 90% efficiency x				
	24 hrs/day x 365 days/yr	108,872 kWhr		
18.5 Condensate Transportation: Internal System				
[Source: Final Report Evaluation of LFG Migration Barrier Systems, M&E, 1993]				
	5,000 gal per trip @	$1,500 per trip	$0.35	/ gal
	(Updated from Jan. 1993 to 1997 costs by ENR indices)			
Annual Quantity: 77 cfm x 125/million cf (Section 3.1.8.2)		5,059 gal		
	Flow from Appendix E			
18.6 Condensate Transportation: Perimeter System				
	See 18.5		$0.35	/ gal
Annual Quantity: 812 cfm x 125/million cf (Section 3.1.8.2)		53,348 gal		
	Flow from Appendix E			
18.7 Condensate Disposal: Internal System				
[Source: Final Report Evaluation of LFG Migration Barrier Systems, M&E, 1993]			$1.44	/ gal
	(Updated from Jan. 1993 to 1997 costs by ENR indices)			
Annual Quantity: See 18.5		5,059 gal		
18.8 Condensate Disposal: Perimeter System				
	See 18.7		$1.44	/ gal
Annual Quantity: See 18.6		53,348 gal		
18.9 Auxiliary Fuel Usage				
	[Appendix E]		$0.02	/ cf
Annual Quantity: [Appendix E] - Basis 15-year average		774,034 cf		
18.10 Photocatalytic Oxidation Operations & Maintenance				
Includes electricity, bulb & catalyst replacement				
	[Appendix A: Range: $900 to $4,500 per month; use $2,318]		$27,816	/ ls
Annual Quantity: One lump sum		1 ls		

UNIT COST DEVELOPMENT ITEM			UNIT COST ($ / unit)	UNIT
GW/LEACHATE COLLECTION & TREATMENT: 50 GPM				
19.1 O&M Labor				
	[Source: PSG, Inc.]			
19.1a	Operator @ 1/2 shift/wk		$49	/ hr
	Annual Quantity:	1,040 hrs		
19.1b	Overtime @ 10%		$65	/ hr
	Annual Quantity:	104 hrs		
19.1c	Supervisory @ 10%		$75	/ hr
	Annual Quantity:	104 hrs		
19.1d	Administrative Costs		$4,000	/ ls
	Annual Quantity: One lump sum	1 ls		
19.2 Feed Chemicals				
	[9/16/96 calculation attached]		$2.00	/ 1,000 gal
Annual Quantity: 50 gpm		26,280,000 gal		
19.3 Equipment Repair/Replacement				
	[9/16/96 calculation attached]		$42,276	/ ls
Annual Quantity: One lump sum per year		1 ls		
19.4 Electricity Usage: Collection				
	Assume $0.07 / kWhr		$0.07	/ kWhr
Assume 2 submersible pumps @ 1 Hp each				
Annual Quantity: 2 x 1 Hp x 0.7457 kW/Hp x				
	24 hrs/day x 365 days/yr @ 90% motor effic.	14,516 kWhr		
19.5 Electricity Usage: Treatment				
	[9/16/96 calculation attached]		$1.65	/ 1,000 gal
Annual Quantity: 50 gpm		26,280,000 gal		
19.6 Disposal of Residuals				
	[9/16/96 calculation attached]		$1.01	/ 1,000 gal
Annual Quantity: 50 gpm		26,280,000 gal		
LEACHATE COLLECTION & TREATMENT: 5 GPM				
20.1 O&M Labor				
	[Source: PSG, Inc.]			
20.1a	Operator @ 1/2 shift/wk		$49	/ hr
	Annual Quantity:	1,040 hrs		
20.1b	Overtime @ 10%		$65	/ hr
	Annual Quantity:	104 hrs		
20.1c	Supervisory @ 10%		$75	/ hr
	Annual Quantity:	104 hrs		
20.1d	Administrative Costs		$4,000	/ ls
	Annual Quantity: One lump sum	1 ls		
20.2 Feed Chemicals				
	[9/16/96 calculation attached]		$0.70	/ 1,000 gal
Annual Quantity: 5 gpm		2,628,000 gal		
20.3 Equipment Repair/Replacement				
	[9/16/96 calculation attached]		$14,967	/ ls
Annual Quantity: One lump sum per year		1 ls		

UNIT COST DEVELOPMENT ITEM		UNIT COST ($ / unit)	UNIT
20.4 Electricity Usage: Collection			
Assume $0.07 / kWhr		$0.07	/ kWhr
Assume 1 submersible pump @ 1 Hp			
Annual Quantity: 1 x 1 Hp x 0.7457 kW/Hp x 24 hrs/day x 365 days/yr @ 90% motor effic.	7,258 kWhr		
20.5 Electricity Usage: Treatment			
[9/16/96 calculation attached]		$0.55	/ 1,000 gal
Annual Quantity: 5 gpm	2,628,000 gal		
20.6 Disposal of Residuals			
[9/16/96 calculation attached]		$0.35	/ 1,000 gal
Annual Quantity: 5 gpm	2,628,000 gal		
INSTITUTIONAL CONTROLS: ANNUAL COSTS			
21.1 Groundwater Access Restrictions			
Not Applicable			
21.2 Not Used			
21.3 Not Used			
21.4 LFG Control Contingency (Annual Inspections)			
Assumed Maintenance Allowance [1996]		$500	/ house
Annual Quantity: 4 potential houses	4 houses		

METCALF & EDDY, INC.

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Subject	Capital Costs --	Comptd. By	D. Peters/S. Czarniecki	Date	September 16, 1996
Detail	Back-up Detail for Unit Costs	Ck'd. By		Date	

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ITEM NO.	DESCRIPTION	UNIT	UNIT COST ($/unit)	QUANTITY	COMMENTS
12.4	**EQUIPMENT (INSTALLED) - 50 gpm PLANT**	**ls**	**$613,500**	**1**	**See detailed breakdown below**
12.41	UV/Chemical Oxidation system (F.O.B.)				See Appendix D for detailed quotes
	Vendor quotations:				
A.	Solarchem Environmental Systems: Markham, ONT Canada	ls	$80,000	1	30 kW Rayox™
B.	Ultrox; Santa Ana, CA	ls	$218,000	1	F-1300 system
C.	Peroxidation Systems, Inc. Tucson, AZ	ls	$250,000	1	Model S-135
		Estimated Unit Cost:	$218,000		
12.42	Installation of UV/chemical oxidation system	Estimated Unit Cost:	$8,500	1	Based on Peroxidation Quote
12.43	Design/treatability Testing for UV/chem. system	ls	$10,000	1	Vendor quotes + A/E fees
12.44	Metals precipitation system (F.O.B.)				See Appendix D for detailed quotes
	Vendor quotations:				
A.	U.S. Filter/Lancy Systems & Equipment Warrendale, PA	ls	$365,000	1	
		Estimated Unit Cost:	$365,000		
12.45	Installation of metals precipitation system	hours	$30.00	400	estimated allowance
		Estimated Unit Cost:	$12,000		
12.46	Membrane polishing system for metals treatment (F.O.B.)	Not Included in Final FS			
12.47	Installation of membrane polishing system	hours	$30.00	0	estimated
		Estimated Unit Cost:	$0		allowance
12.5	**INSTRUMENTATION - 50 gpm PLANT**	**ls**	**$58,300**	**1**	**see detail below**
12.51	estimated @ 10.0% of process equipment F.O.B. cost	ls	$21,800	1	UV/chem.
		ls	$36,500	1	metals precip.
		ls	$0	0	membrane polish.

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Detail	On-site Leachate Treatment System	Ck'd By	D. Peters	Date	09/13/96

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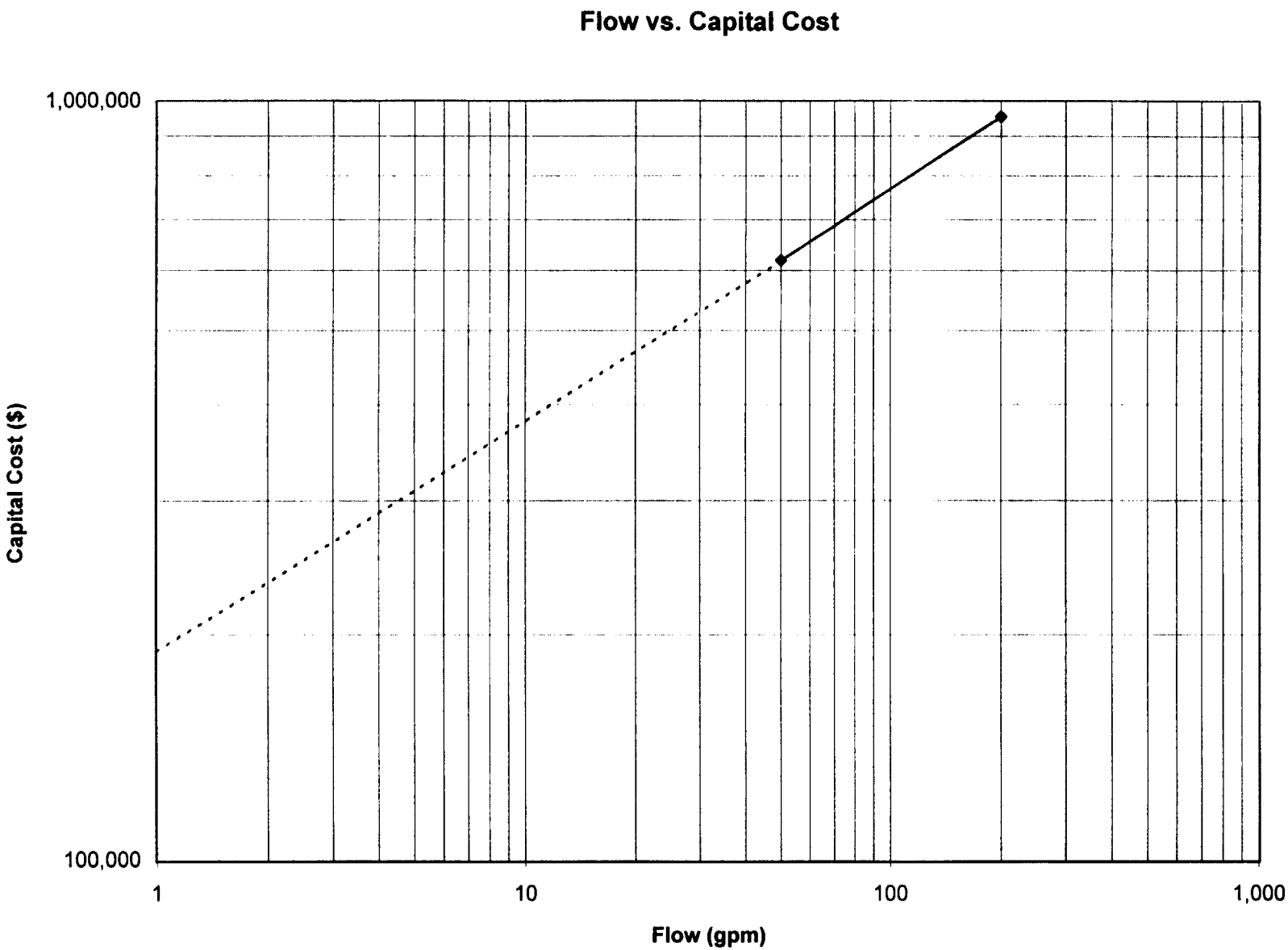
Leachate/groundwater treatment systems were originally sized based on 50 and 200 gpm flow rates in the Draft FS. Sizing for the current leachate treatment system (5 gpm) will be revised as follows.

Assumed scaling factor for 5 gpm system from the 50 gpm system - 0.4

As knowledge of system retention time is usually desired, the initial holding tank size will be calculated.

	50 gpm	5 gpm
Precipitation Holding/Equalization Tank	12,000 gal	4,800 gal
	Selected tank size:	5,000 gal
	This results in a holding time of	17 hrs

All other pieces of equipment will be scaled from respective vendor quotations.


Flow vs. Capital Cost
1,000,000
100,000
Capital Cost ($)
1
10
100
1,000
Flow (gpm)

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ITEM NO.	DESCRIPTION	UNIT	UNIT COST ($/unit)	QUANTITY	COMMENTS
13.4	**EQUIPMENT (INSTALLED) - 5 gpm PLANT**	**ls**	**$213,500**	**1**	**See attached graph**
	SCALE DOWN FACTOR (Use this factor to reduce 50 gpm costs)		34.8%		5 gpm cost/ 50 gpm cost
13.41	UV/Chemical Oxidation system (F.O.B.)	Estimated Unit Cost:	$75,865		
13.42	Installation of UV/chemical oxidation system	ls	$2,958	1	
13.43	Design/treatability Testing for UV/chem. system	ls	$3,480	1	
13.44	Metals precipitation system (F.O.B.)	Estimated Unit Cost:	$127,021		
13.45	Installation of metals precipitation system	hours Estimated Unit Cost:	$30.00 $4,176	139	
13.46	Membrane polishing system for metals treatment (F.O.B.)	Not Included in Final FS			
13.47	Installation of membrane polishing system	hours Estimated Unit Cost:	$30.00 $0	0	
13.5	**INSTRUMENTATION - 5 gpm PLANT**	**ls**	**$20,289**	**1**	**see detail below**
13.51	estimated @ 10.0% of process equipment F.O.B. cost	ls ls ls	$7,586 $12,702 $0	1 1 1	UV/chem. metals precip. membrane polish.

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ITEM NO.	DESCRIPTION	UNIT	UNIT COST ($/unit)	ANNUAL QUANTITY	COMMENTS
17.3	**GROUNDWATER MONITORING**	**samples**	**$1,740**	**51**	Annualized over first 30 years
17.31	Number of Quarterly Samples:				
	Basis:	4	times per year sampling frequency		
	Well Locations - See Table 4-2	43	well locations (at left)		Year 1 total:
	Same as RI	Estimated Annual Qty:		172	172 samples
	First Year Only				
17.32	Number of Semi-Annual Samples:				
	Basis:	2	times per year sampling frequency		
	Well Locations - See Table 4-2	21	well locations		
	Same as RI				
	Years 2-30				Years 2-30 total:
		Estimated Annual Qty:		42	1,218 samples
17.33	Number of QA/QC Samples:				
	Basis:	10%	of the collected samples over 30 years		
		sub-total - upgradient + site:		1,390	
		Estimated Annual Qty:		139	
17.34	Analytical Sample Cost:				
	Basis:				
	Analyses (U.S. EPA - CLP protocol) --				
	TCL organics: volatiles	sample	$200	1	
	TCL organics: semi-volatiles	sample	$400	1	
	TAL inorganics: metals	sample	$250	1	
	-validation allowance	sample	$250	1	
		Estimated Unit Cost:	$1,100		
17.35	Sample Collection Cost:				
	Basis:	6	man-hours per sample		
	collection labor	hours	$65.00	6	
	misc. costs (shipping, equipment,etc)	sample	$250.00	1	
		Estimated Unit Cost:	$640		Qty · $/unit

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ITEM N0.	DESCRIPTION		UNIT	UNIT COST ($/unit)	ANNUAL QUANTITY	COMMENTS
17.4	**SW/SEDIMENT MONITORING**		**samples**	**$2,710**	**22**	Annualized over first 30 years
17.41	Number of Quarterly Samples:	Basis:	4	times per year sampling frequency		
	Locations - See Table 4-2		18	locations		Year 1 total:
	Same as RI		Estimated		72	72 samples
	First Year Only		Annual Qty:			
17.42	Number of Semi-Annual Samples:	Basis:	2	times per year sampling frequency		
	Locations - See Table 4-2		9	locations		Years 2-30 total:
	Same as RI		Estimated		18	522 samples
	Years 2-30		Annual Qty:			
17.43	Number of QA/QC Samples:	Basis:	10%	of the collected samples over 30 years		
			sub-total - upgradient + site:		594	
			Estimated		59	
			Annual Qty:			
17.44	Analytical Sample Cost:	Basis:	Assume analytical costs are the same for SW/Sed			
	Analyses ---					
	TCL organics: volatiles		sample	$200	2	
	TCL organics: semi-volatiles		sample	$400	2	
	TAL inorganics: metals		sample	$250	2	
	-validation allowance		sample	$250	2	
			Estimated	$2,200		
			Unit Cost:			
17.45	Sample Collection Cost:	Basis:	4	man-hours per sample		
	collection labor		hours	$65.00	4	
	misc. costs (shipping, equipment,etc)		sample	$250.00	1	
			Estimated	$510		Qty · $/unit
			Unit Cost:			

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ITEM NO.	DESCRIPTION		UNIT	UNIT COST ($/unit)	ANNUAL QUANTITY	COMMENTS
17.5	**AMBIENT AIR MONITORING**		**samples**	**$1,690**	**10**	Annualized over first 15 years
17.51	Number of Quarterly Samples:	Basis:	4 times per year sampling frequency			
	Locations - See Table 4-3		6 locations (at left)			Year 1 total:
	Year 1 Only		Estimated Annual Qty:		24	24 samples
17.52	Number of Semi-Annual Samples:	Basis:	2 times per year sampling frequency			
	Locations - See Table 4-3		4 locations (at left)			
	Years 2-15					Years 2-15 total:
			Estimated Annual Qty:		8	112 samples
17.53	Number of QA/QC Samples:	Basis:	10% of the collected samples over 20 years			
			sub-total - upgradient + site:		136	
			Estimated Annual Qty:		14	
17.54	Analytical Sample Cost:	Basis:				
	Analyses ---					
	TO-14 organics: volatiles		sample	$400	1	
	H2S & sulphur compounds		sample	$220	1	
	methane		sample	$50	1	
	-validation allowance		sample	$250	1	
			Estimated Unit Cost:	$920		
17.55	Sample Collection Cost:	Basis:	8 man-hours per sample			
	collection labor		hours	$65.00	8	
	misc. costs (shipping, equipment,etc)		sample	$250.00	1	
			Estimated Unit Cost:	$770		Qty · $/unit

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ITEM NO.	DESCRIPTION	UNIT	UNIT COST ($/unit)	ANNUAL QUANTITY	COMMENTS
17.6	**SOIL GAS MONITORING**	**samples**	**$83**	**94**	Annualized over first 15 years
17.61	Number of Quarterly Samples:				
	Basis:	4	times per year sampling frequency		a) Source: M&E, 1993.
	Locations - See Table 4-3	2	points per well (deep, shallow)		
	Year 1 Only	35	locations (at left)		Year 1 total:
		Estimated Annual Qty:		280	280 samples
17.62	Number of Semi-Annual Samples:				
	Basis:	2	times per year sampling frequency		
	Locations - See Table 4-3	2	points per well (deep, shallow)		
	Years 2-15	18	locations (at left)		Years 2-15 total:
		Estimated Annual Qty:		72	1,008 samples
17.63	Number of QA/QC Samples:				
	Basis:	10%	of the collected samples over 15 years		
		sub-total - upgradient + site:		1,288	
		Estimated Annual Qty:		129	
17.64	Sample Collection Cost:				
	Basis:	0.5	man-hours per sample		assumes use of hand-held instru-struments only.
	collection labor	hours	$65.00	0.5	
	misc. costs (shipping, equipment.etc)	sample	$50.00	1	
		Estimated Unit Cost:	$83		Qty · $/unit

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ITEM NO.	DESCRIPTION	UNIT	UNIT COST ($/unit)	ANNUAL QUANTITY	COMMENTS
18.2	**EQUIPMENT REPAIR/ REPLACEMENT**	**ls**	**$56,476**	**1**	**See detailed breakdown below**
18.21	Internal LFG collection system:				
	Basis:	25%	of the equipment on a		M&E estimate;
	Processes requiring replacement --	15	year replacement schedule		
	7.1 Vault, Gauges, Fittings	ea	$8,145	128	
	7.2 Well footage costs	lf	$195	3,200	
	7.3 Header Pipe	lf	$51	10,000	
	7.4 Lateral Pipe	lf	$51	1,280	
	7.5 Condensate Piping	lf	$14	3,000	
	7.6 Condensate Holding Tanks	ea	$44,119	2	
		sub-total ($/unit·qty·%):	=	$592,870	
		Estimated Unit Cost:	$39,525		staight line depreciation (÷ yr replaced)
18.22	Perimeter LFG collection system:				
	Basis:	25%	of the equipment on a		M&E estimate
	Processes requiring replacement --	15	year replacement schedule		
	8.1 Vault, Gauges, Fittings	ea	$8,145	26	
	8.2 Well footage costs	lf	$195	390	
	8.3 Header Pipe	lf	$51	1,700	
	8.4 Lateral Pipe	lf	$51	260	
	8.5 Condensate Piping	ea	$14	1,700	
	8.6 Condensate Holding Tanks	ea	$44,119	2	
		sub-total ($/unit·qty·%):	=	$124,870	
		Estimated Unit Cost:	$8,325		staight line depreciation (÷ yr replaced)
18.23	LFG Treatment System:				
	Basis:	100%	of the equipment on a		M&E estimate;
	Processes requiring replacement --	15	year plant replacement		
	9.4 Internal Collection System Blower & Motor	ls	$14,194	1	Costs from prior sections
	9.5 Perimeter Collection System Blower & Motor	ls	$30,200	1	
	9.8 Flare and Appurtenances:	ls	$85,000	1	
		sub-total ($/unit·qty·%):	=	$129,394	
		Estimated Unit Cost:	$8,626		staight line depreciation (÷ yr replaced)

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ITEM NO.	DESCRIPTION	UNIT	UNIT COST ($/unit)	ANNUAL QUANTITY	COMMENTS
19.2	**FEED CHEMICALS - 50 gpm PLANT**	**1,000 US gal**	**$2.00**	**26,280**	**See detailed breakdown below**
19.21	UV/Chemical Oxidation system Vendor quotations for Hydrogen Peroxide:				See Appendix D for detailed quotes
A.	Solarchem Environmental Systems; Markham, ONT Canada	1,000 US gal	$0.15	---	
B.	Ultrox; Santa Ana, CA	1,000 US gal	$0.75	---	includes H2O2 & UV lamp replacement as well as electricity
C.	Peroxidation Systems, Inc. Tucson, AZ	1,000 US gal	$0.47	---	
		Estimated Unit Cost:	$0.40		
19.22	Metals precipitation system Vendor quotations:				
A.	U.S. Filter Warrendale, PA	1,000 US gal	$1.60	---	Includes: caustic, sulfuric acid, ferrous sulfate, polymer, sodium sulfide, sorption filter media
		Estimated Unit Cost:	$1.60		

METCALF & EDDY, INC.

Project	Rose Hill FS	Acct. No.	4609-18-10-11	Page	of
Subject	Operations & Maintenance Costs --	Comptd. By	S. Czarniecki	Date	September 16, 1996
Detail	Back-up Detail for Unit Costs	Ck'd. By	D. Peters	Date	September 24, 1996

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ITEM NO.	DESCRIPTION	UNIT	UNIT COST ($/unit)	ANNUAL QUANTITY	COMMENTS
19.3	**EQUIPMENT REPAIR/ REPLACEMENT**	**ls**	**$42,276**	**1**	**See detailed breakdown below**
19.31	Groundwater/Leachate collection system:				
	Basis:	25%	of the equipment on a 15 year replacement schedule		M&E estimate
	Processes requiring replacement --				
	10.1 Buried Piping	lf	$51	1610	
	10.2 Submersible pump	ea	$7,922	2	
	10.3 Drain Piping & Installation	lf	$51	2090	
		sub-total ($/unit·qty·%):	=	$51,136	
		Estimated Unit Cost:	$3,409		staight line depreciation (÷ yr replaced)
19.32	50 gpm Treatment System:				
	Basis:	100%	of the equipment on a 15 year replacement schedule		M&E estimate
	Processes requiring replacement --				
	12.41 UV/Chemical Oxidation system	ls	$218,000	1	Costs from prior sections
	12.44 Metals precipitation system	ls	$365,000	1	
		sub-total ($/unit·qty·%):	=	$583,000	
		Estimated Unit Cost:	$38,867		staight line depreciation (÷ yr replaced)
19.5	**ELECTRICITY USAGE - 50 gpm PLANT**	**1,000 US gal**	**$1.65**	**26,280**	**See detailed breakdown below**
19.51	Electricity usage for UV/Chemical oxidation system				Adjusted to $0.07/kWh
	Vendor quotations:				
A.	Solarchem Environmental Systems; Markham, ONT Canada	1,000 US gal	$0.70	---	
B.	Ultrox; Santa Ana, CA	1,000 US gal	$0.75	---	includes H2O2 & UV lamp replacement as well as electricity
C.	Peroxidation Systems, Inc. Tucson, AZ	1,000 US gal	$3.15	---	
		Estimated Unit Cost:	$1.50		
19.52	Additional plant electrical usage estimated @ 10.0% of UV/chem costs	1,000 US gal	$0.15	---	Based on Peroxidation Quote

METCALF & EDDY, INC.

Project	Rose Hill FS	Acct. No.	4609-18-10-11	Page	of
Subject	Operations & Maintenance Costs --	Comptd. By	S. Czarniecki	Date	September 16, 1996
Detail	Back-up Detail for Unit Costs	Ck'd. By	D. Peters	Date	September 24, 1996

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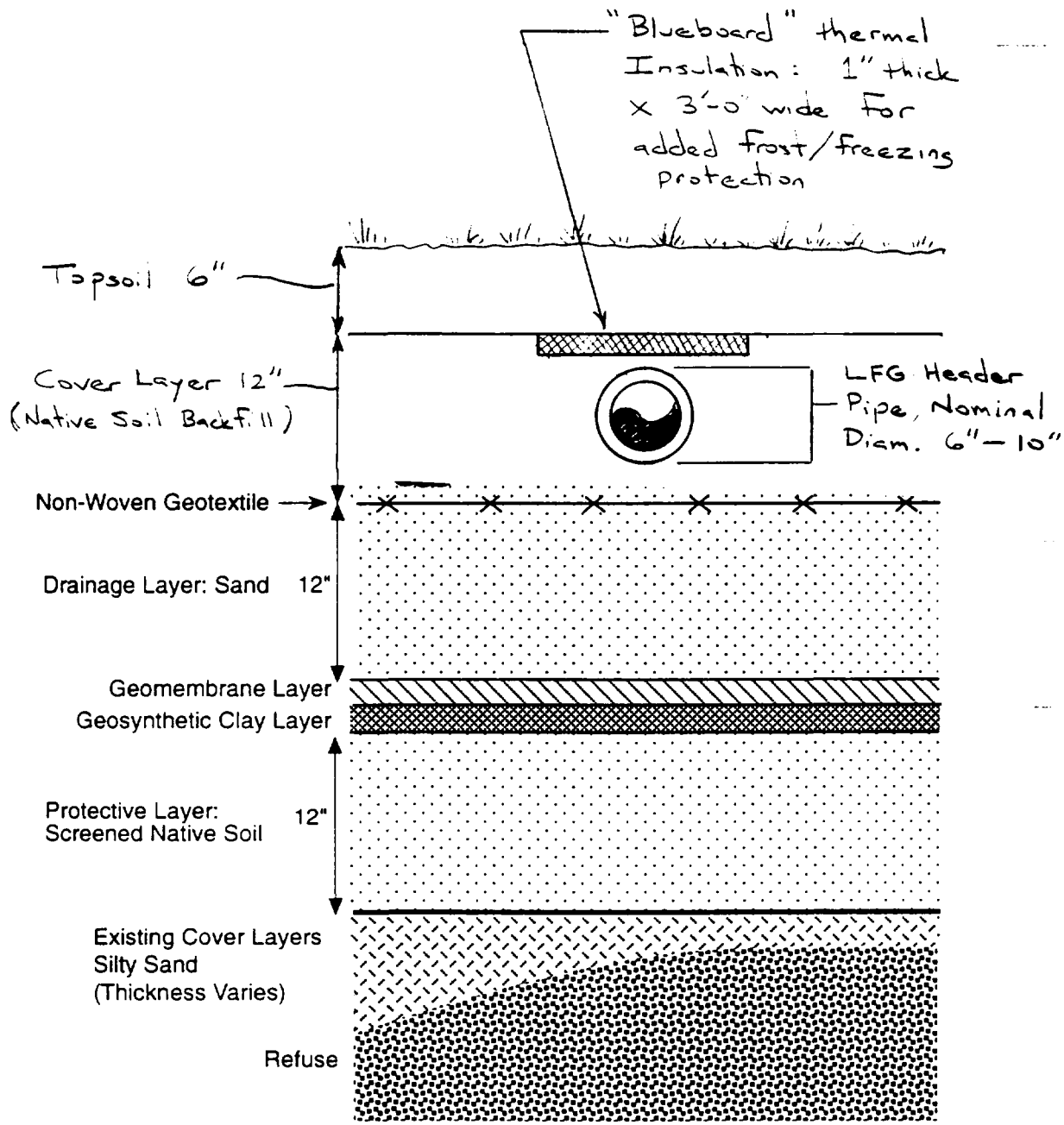
ITEM NO.	DESCRIPTION	UNIT	UNIT COST ($/unit)	ANNUAL QUANTITY	COMMENTS
19.6	**DISPOSAL OF RESIDUALS - 50 gpm PLANT**	**1,000 US gal**	**$1.01**	**26,280**	**Unit Price Based on Feed Water**
19.61	Sludge generation & disposal	1,000 US gal	$1.01	---	M&E estimate based on calculations in Appendix D
20.2	**FEED CHEMICALS - 5 gpm PLANT**	**1,000 US gal**	**$0.70**	**2,628**	
	SCALE DOWN FACTOR (Use this factor to reduce 50 gpm costs)		34.8%		See Capital Costs
20.21	UV/Chemical Oxidation system	estimated:	$0.14		
20.22	Metals precipitation system	total:	$0.56		
20.3	**EQUIPMENT REPAIR/ REPLACEMENT**	**ls**	**$14,967**	**1**	
20.31	Leachate collection system:				
	Basis:	25%	of the equipment on a 15 year replacement schedule		
	Processes requiring replacement --				
	10.1 Buried Piping	lf	$51	900	
	10.2 Submersible pump	ea	$7,922	1	
	10.3 Drain Piping & Installation	lf	$51	640	
		sub-total ($/unit·qty·%):	=	$21,616	
		Unit Cost:	$1,441		
20.32	5 gpm Treatment System:	Estimated Unit Cost:	$13,526		
20.5	**ELECTRICITY USAGE - 5 gpm PLANT**	**1,000 US gal**	**$0.55**	**2,628**	
20.51	Electricity usage for UV/Chemical oxidation system	Estimated Unit Cost:	$0.52		
20.53	Additional plant electrical usage estimated @ 5.0% of UV/chem costs	1,000 US gal	$0.03	---	
20.6	**DISPOSAL OF RESIDUALS - 5 gpm PLANT**	**1,000 US gal**	**$0.35**	**2,628**	
20.61	Sludge generation & disposal	1,000 US gal	$0.35	---	

Project _____ Acct. No. _____ Page _____ of _____
Subject _____ Comptd. By _____ Date Oct. 22, 1997
Detail _____ Ck'd. By _____ Date _____

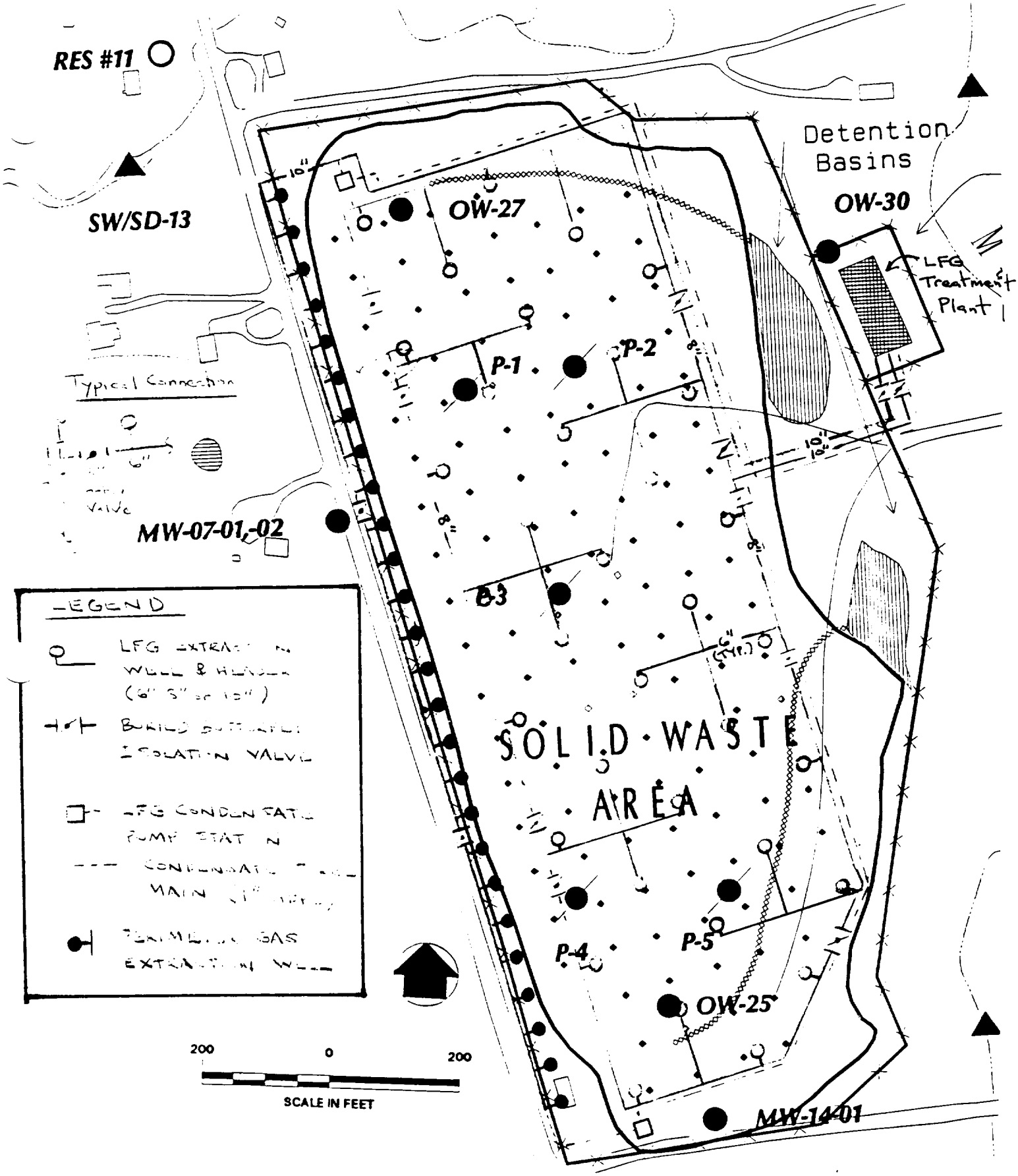
INTERNAL LFG COLLECTION SYSTEM – SOLID WASTE AREA

Item 7.3 Header Pipe : HDPE

Trench Detail – Buried HDPE header pipe (above synthetic liner)



NONREPRODUCIBLE GRID FORM 145
METCALF & EDDY, ENGINEERS



INTERNAL LFG COLLECTION SYSTEM - SOLID WASTE AREA ITEM 7.3 HEADER PIPE : HDPE

METCALF & EDDY

LANDTEC
LANDFILL CONTROL TECHNOLOGIES

Facsimile Transmission

To: Dan Peters
Company: Metcalf & Eddy
Fax No: 781-245-6293
From: Dick Dooly
Date: October 22, 1997
Page: 1 of 7
Re: GEM-500 and Accu-Flo Wellhead Bulletins

Dan:

Here are the bulletine we discussed. Again, list pricing for the GEM-500 is $6,395.00, which includes hoses, filters, soft case, software diskette and cable. List price for the 2" vertical Accu-Flo wellhead with gate valve, quantity of 36, is $325.00 each. We will be faxing you a quote for these items, plus the additional GEM-500 accessories that we discussed.

If you have any further questions, please call our Northeastern Regional Sales Representative, John Johnson, at (800) 390-7745. He's located in Danascus, MD. If you have questions regarding this fax or the quotation, please contact me at (909) 430-3571.

Regards,

Dick Dooly
LANDTEC Sales

LANDFILL CONTROL TECHNOLOGIES
633 W. 5th Street, Los Angeles, CA 90071-2006 (213) 895-5353 (800) 821-0496 fax: (213) 895-5866

GEM®
Series: 500

METERING/INSTRUMENTATION
Gas Extraction Monitor

LANDTEC®
LANDFILL CONTROL TECHNOLOGIES

GEM-500® Integrates Nine Landfill Gas Field Instruments with On-Board Computer

Versatile Analyzer Simplifies LFG Monitoring and Control

The GEM-500 was specifically designed by Landfill Control Technologies (LANDTEC) for use on landfills to monitor landfill gas (LFG) migration control systems, gas extraction systems, flares, migration probes, LEL levels, subsurface fires, and more.

The light-weight, portable unit integrates nine field instruments with an on-board computer. The versatile monitor provides landfill technicians with an array of analysis and computation functions. The results can be stored, printed and later down-loaded to a personal computer to provide error-free data management.

Multi-Functional Features

The GEM-500 automatically samples and analyzes the methane, carbon dioxide and oxygen content of landfill gas. The easy to read LCD screen shows the results as percentages of CH_4, CO_2, O_2 and "balance" gas (typically nitrogen). The GEM-500 also calculates and displays gas flow rate, Btu content, temperature, pressures and LEL (Lower Explosive Limit).

In addition, the user can recall prior data stored at up to 500 monitoring points for contrast with current data. Alarms can easily be set for methane and oxygen.

The GEM-500 can automatically calculate gas flow rates, adjusted to standard temperature and pressure (STP). The results can be displayed in either Imperial (USA) or SI (metric) units.

LANDTEC'S versatile GEM-500 can be used with Orifice plate and Pitot tube meters, but most effectively on LANDTEC's Accu-Flo™ wellheads, which incorporates a built-in precalibrated gas flow meter and quick-connect sample ports.

The Accu-Flo™ wellhead and GEM-500 were designed to work together to expedite the time required to sample and adjust LFG wellheads.

Rugged, User-Friendly Design

The GEM-500 is an all-weather, self-contained portable monitor which uses a self-compensating infrared gas analyzer, rechargeable power supply for all day use, an internal sample pump capable of drawing a gas sample at up to 70" vacuum. WC.

An easy to follow, on-screen menu guides the operator through the sampling process which can be completed in less than a minute. I.D. codes allow the user to store and recall prior measurements for each monitoring point. Preset maintenance codes can be used to note field work required. The stored data can be later retrieved for viewing or down-loaded to a personal computer for use in a database.

Time Saving Conveniences

Users will readily appreciate the built-in, time-saving conveniences provided by the GEM-500 instead of fumbling with data sheets, temperature gauges, flow meters, methane/oxygen/carbon dioxide analyzers, pressure gauges, calculators and other field equipment, the GEM-500 provides it all, and more, in an easy to carry light-weight case.

LANDTEC's Family of Landfill Products

The GEM-500 is part of a family of products developed by LANDTEC for the solid waste industry. These products are based on over a decade of corporate operating and regulatory experience at multiple client sites by LANDTEC's parent, Pacific Energy along with years of field proven reliability and experience.

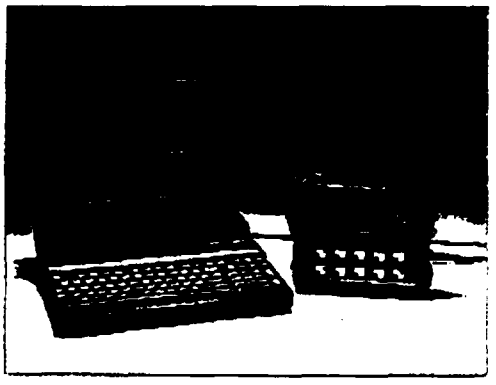
©1993-1996 Landfill Control Technologies. Corporate Headquarters 633 West Fifth Street, Suite 4900, Los Angeles, California 90071-2006 U.S.A.
Phone (213) 895-5353, (800) 621-0496. Fax (213) 895-5866

LANDTEC's GEM-500® Analyzer Provides a Convenient Link Between Your Landfill Data and Office Computer

Key GEM-500 Features:

Multi-Functional Analyzer...provides automatic sampling and analysis of gas composition (% by volume CH_4 (100% & LEL), CO_2, O_2 and % remaining gas-balance), temperature, pressures. Also calculates gas flow rates as well as Btu rates.
Diverse Field Applications...monitors migration control systems, gas extraction systems, flares, migration probes, temperatures, and more.
Light-Weight Compact Size...is easy to carry. Weighs less than five pounds
Quick Analysis...completes sampling and displays gas analysis and flow results in usually less than one minute.
Infrared Gas Analyzer...provides high-tech accurate measurements of methane (CH_4), and carbon dioxide (CO_2).
Reference Beam...provided by infrared analyzer for self compensation.
Durable Oxygen Sensor...provided by the galvanic cell principle, unaffected by other gases such as CH_4, CO_2, or H_2S.
User Friendly On-Screen Menu...guides the user step-by-step through all functions and options available.
PC Data Downloading...provided by RS232 interface with optional software.
Data Storage/Retrieval...stores prior measurements taken for each monitoring point, over 500 monitoring points total.
Prior Data Recall...allows user to recall prior data for each monitoring point.
Methane Analysis...displayed as either $\%CH_4$ by volume or LEL (Lower Explosive Limit).
Durable Construction...built of strong, durable plastic material suitable for harsh landfill environments. Sealed tactile keyboard.
All Weather Use...designed to operate in hot/wet weather extremes from 14°F to 104°F. Weather tight case.
Built-in Adjustable Alarms...allows user to set alarm limits for CH_4 and O_2.
Rechargeable Batteries...provides all day field use.
Battery Check...monitors battery life remaining.
Monitoring Point I.D. Codes...provides alphanumeric identification of monitoring points for data storage and recall.
Maintenance Codes...allows user to note typical maintenance needs using eight preset or eight user defined maintenance codes.
Date/Time Stamp...recorded for all stored data.
Imperial vs. SI Units...displays measurements in Imperial (USA) or SI (metric) units.
Interfaces to LANDTEC Data Management Software...which provides statistical management and reporting of LFG data.
Multiple Flow Meter Analysis...supported to calculate gas flow rates from Accu-Flo™ wellheads, Orifice plates and Pitot tubes.

From: Landfill Field Data *To: Computerized Data Management*



Quality Landfill Gas Management Begins with Accurate Field Data Correctly Recorded and Quickly Retrieved

GEM-500 Packs Nine LFG Instruments and Computer into Five Pound Case

The highly accurate and reliable GEM-500 provides field technicians with the most commonly used LFG instrumentation, linked to an on-board computer for quick data calculations, storage and retrieval – all within a compact, all weather case the size of a dictionary.

The GEM-500 was designed by LANDTEC to support the ever-increasing instrumentation requirements of LFG monitoring. The multi-functional unit expedites the analysis and storage of field data. Software allows easy downloading of stored data to a personal computer for further analysis and reporting.

Couple the GEM-500 with a LANDTEC Accu-Flo™ landfill gas wellhead, and field monitoring becomes more accurate and more efficient. With the GEM-500 and Accu-Flo™ combination, you can forget about carrying analyzers for methane, carbon dioxide and oxygen. You can also eliminate handling high and low pressure and temperature sensors, Pitot tube, Orifice plate or other cumbersome flow meters, vacuum pump, flow calculator and data sheets.

GEM-500 Specifications

	Sensor Range Imperial	Resolution Imperial
Methane-CH_4	0-100%	0.1%
Carbon dioxide-CO_2	0-60%	0.1%
Oxygen-O_2	0-25%	0.1%
Pressures (diff)	0-10" W.C.	0.01" H_2O
(static)	0-100" W.C.	0.1" W.C.

GEM-500™ Typical Accuracy

Concentration	% CH_4 by Volume	% CO_2 by Volume	% O_2 by Volume
5% (LEL CH_4)	±0.3%	n.a.	±0.25%
75%	±1.9%	±3.0%	n.a.

Additional Information

Technical information is available on the GEM-500 including product specifications and user instructions. Information is also available on LANDTEC's family of integrated landfill gas/liquid management products including: wellheads, well-bore seals, knock-outs, instrumentation, condensate/leachate treatment, flares and landfill gas management software.

LANDTEC also provides technical and educational literature on specific landfill subjects and issues. Please call our toll free telephone number (800) 821-0496 (8 a.m. - 5 p.m. Pacific Time) for additional information and placement on our mailing list.

SWANA MEMBER

NSWMA

An involved and contributing member of the Solid Waste Association of North America and the National Solid Waste Management Association

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Product designs and specifications are subject to change without notice. User is responsible for determining suitability of product. LANDTEC and GEM are registered with the U.S. Patent and Trademark Office

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Southwest Sales Office
(213) 895-5625, (213) 895-5866 FAX
Northeast Sales Office
(703) 425-9894, (703) 425-6026 FAX
Southeast Sales Office
(404) 869-0102, (404) 869-0103 FAX

Accu-Flo™

Series: 150, 200, 300

WELLHEAD
Landfill Gas Control
Patent #5,458,006

LANDTEC®
LANDFILL CONTROL TECHNOLOGIES

Choose Accu-Flo™ Wellheads for Optimum Landfill Gas Control, Accuracy and Dependability

Accu-Flo™ Helps Prevent LFG Migration, LFG Emissions & Subsurface Fires

Landfill owners and operators will appreciate Accu-Flo's™ proven design that meets the special requirements of landfill gas (LFG) recovery for environmental compliance or energy production.

Accu-Flo™ wellheads, developed by Landfill Control Technologies (LANDTEC) provide operators with the gas extraction control necessary to meet more restrictive environmental and safety regulations thus preventing unnecessary and costly violations. Accu-Flo™ helps maximize gas recovery, minimize surface emissions and subsurface migration, helps control hot spots and prevent subsurface fires.

Simplified Data Collection

Accu-Flo™ simplifies the complexity of measuring wellhead data by incorporating key built-in features including a LFG flow measuring device, gas temperature gauge, quick-connect gas sample ports and a flow control gate valve.

The patented design also helps expedite the time required to obtain key wellhead data and determine necessary flow adjustments using either standard field instrumentation or LANDTEC's GEM-500 unit which integrates the function of nine field instruments and a computer into one compact, portable, light weight, simple to operate unit.

Quick and Versatile Installation

The prefabricated Accu-Flo™ assembly is factory tested and is shipped ready for immediate installation – eliminating the cost and uncertainties of field fabricated units. Accu-Flo™ models are available for installation above or below ground on vertical wells or horizontal branch laterals in flows ranging from 1 to over 500 ACFM. The compact patented design allows for installation in small 18" x 24" x 16" vaults.

LANDTEC's Family of Compatible Components

Accu-Flo™ wellheads are one in a group of LANDTEC's family of products designed to work together in an integrated landfill gas management program with other proven LANDTEC products including: well-bore seals, knock outs, pump stations, instrumentation, condensate/leachate treatment, and landfill gas management software.

The versatile GEM-500 is designed to interact with Accu-Flo™ wellheads. The unit analyzes and records the methane, carbon dioxide and oxygen composition of the gas stream, measures static and differential pressures, as well as gas temperature. It calculates Btu content, Btu flow rate, and gas flow rates. One keystroke stores all the measured information from each well which can then be down-loaded to a personal computer.

LANDTEC's Approach to Solving Specific Needs

All LANDTEC products are designed to serve the specific needs of the solid waste industry. These products are based on a decade of corporate operating experience applying landfill gas management principles at multiple client sites and sites operated by LANDTEC's parent, Pacific Energy. LANDTEC products are backed by a clear and unconditional warranty that our customers can depend upon.

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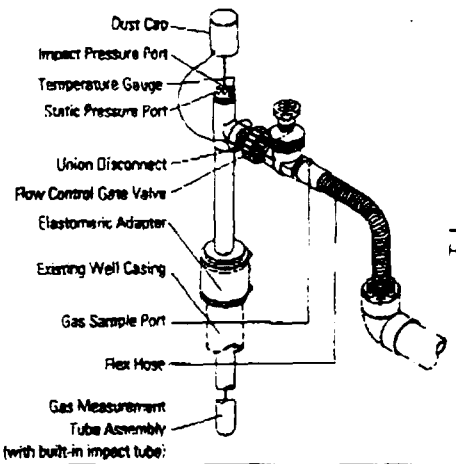
Phone (213) 895-5353, (800) 821-0496, Fax (213) 895-5866

Accu-Flo™ Offers Time-Saving, Multi-Functional Wellheads at Less Than Field Fabrication Prices

Vertical – Accu-Flo well casing configuration



Key Accu-Flo™ Features:

Gas Flow Meter (impact tube design)... The gas measuring assembly incorporates a pre-positioned and modified impact tube within a pre-calibrated measurement tube (Accu-Flo™ body). The assembly extends into a well casing or branch lateral to provide installation compactness.

Temperature Gauge... Provides gas flow temperature required for calculating accurate gas flow rates and detecting subsurface fires.

Gas Pressure Ports... Provides quick-connect, positive sealing convenience when taking impact tube, static and differential pressure measurements.

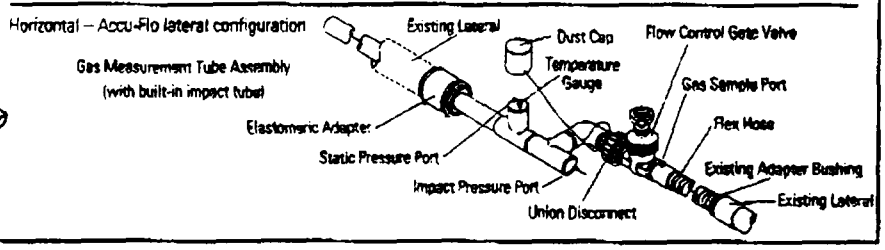
Flow Control Gate Valve... Provides controlled throttling of gas flow and positive shut-off. Incorporates durable PVC construction and inert seal materials.

Gas Sample Port... Provides convenient, quick-connect gas sampling port immediately downstream of the flow control gate valve.

Adapter Bushing... Provides versatile mounting utilizing standard fittings or convenient Accu-Flo™ adapter kits.

Union Disconnect... Provides convenient removal of Accu-Flo™ assembly for inspection or periodic maintenance.

Horizontal – Accu-Flo lateral configuration



Flow Accuracy and Reliability

The Accu-Flo™ system is designed to operate in the wet, abrasive environment typical of landfill gas and still provide exacting control and accurate flow measurements with high dependability and repeatability.

A patented feature of the Accu-Flo™ design is the pre-calibrated gas measurement tube assembly (Accu-Flo™ body) which extends into a standard vertical or horizontal well casing or branch lateral, creating a compact installation.

The measurement tube assembly houses a modified stainless steel impact tube specifically designed by LANDTEC for harsh landfill gas applications. Pressure differential readings between the impact tube and measurement tube are used to calculate flow.

To help protect the impact tube from condensate and particulate clogging, common with conventional designs, Pitot tubes and Orifice ports, LANDTEC uses an enlarged total pressure port opening and a separate protected static pressure port. Also, pre-calibration of the measurement tube with a pre-positioned impact tube eliminates the need to take time-consuming traverse measurements normally required for accuracy.

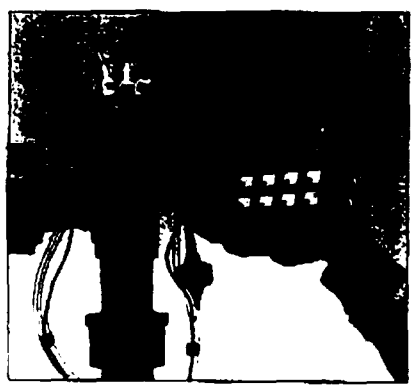
Key Accu-Flo™ Benefits

- Compact size
- Easy installation and maintenance
- Built-in gas flow measurement
- Built-in flow control gate valve
- Quick connect measurement ports
- High accuracy and repeatability of measurements
- Durable Materials: Sch. 80 PVC or PE housing and couplings, stainless steel impact tube, and polypropylene fittings, Elastomer couplings and PVC Flexible interconnects.

Standard Accu-Flo™ Models

Model Size/Dia. Inches	Flow Rate SCFM	Pressure Drop (Inches H_2O)
150 1.5"	0 - 50+	0.1 - 1.5
200 2.0"	5 - 75+	0.1 - 3.5
300 3.0"	10 - 500+	0.1 - 11.5

Specify vertical or horizontal design. Optional adapter kits are available for well casings up to 8" in diameter.



Expedite LFG Measurements with Accu-Flo™ and GEM-500

LANDTEC - Ready To Help You

At LANDTEC we take pride in the quality and experience built into our products. We are equally proud of our warranty and technical support which back these products. As a Pacific Energy company, with a diversity of operating and regulatory experience in gas recovery, we can help you provide practical solutions to your landfill requirements.

Please call our toll free West Coast number 1-800-821-0496 (8 a.m. - 5 p.m.) and ask for a sales engineer to discuss your landfill needs. We're here to help.

Additional Information

Technical information is available on the Accu-Flo™ wellhead including product specifications, installation instructions and drawings.

Additional product information is available on well-bore seals, knock-outs, pump-stations, instrumentation, condensate/leachate treatment, flares and landfill gas management software.

LANDTEC also has technical and educational literature available on specific landfill subjects and issues. Please call for additional information and/or to be placed on our mailing list.

MEMBER NSWMA

An involved and contributing member of the Solid Waste Association of North America and the National Solid Waste Management Association.

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(703) 425-9894, (703) 425-6026 FAX
Southeast Sales Office
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Product designs and specifications are subject to change without notice. User is responsible for determining suitability of product. LANDTEC is registered with the U.S. Patent and Trademark Office. Accu-Flo is a product trademark.

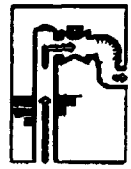
PRODUCT SPECIFICATIONS

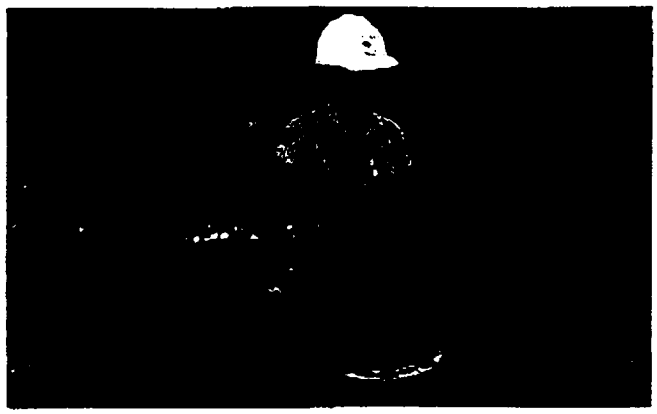
LANDTEC®
LANDFILL CONTROL TECHNOLOGIES

Accu-Flo™

Series: 150, 200, 300

WELLHEAD
Landfill Gas Control
Patent #5,458,006





Accu-Flo™ Description

The patented Accu-Flo™ series wellhead is a prefabricated gas flow control system developed specifically for installation on landfill gas (LFG) management systems. The assembly incorporates a built-in gas flow meter, gas temperature guage, quick-connect gas sample and pressure ports, and flow control gate valve. Models are available for installation above or below ground, on vertical wells or horizontal branch laterals, and for flow rates ranging from one to over 500 cfm (cubic feet per minute). Adapter kits are available for installing Accu-Flo™ wellheads on a multitude of gas well casings or laterals.

Landfill Gas Flow Measurements at Wellheads

Step A – The following measurements should be taken directly at the wellhead using appropriate instrumentation.

- Static Pressure – measure s.p. range, 0-100" W.C., 0.1 resolution.
- Differential Pressure – measure d.p. range, 0-10" W.C., 0.01 resolution.
- Gas Temperature – read built-in thermometer, degrees Fahrenheit, 2.0 resolution.
- Gas Composition – use any port to extract a gas sample of analysis.

Step B – Calculate gas flow volume (SCFM) using one of the following methods:

- Use LANDTEC Chart: Velocity Pressure vs. Flow provided with each wellhead.
- Use LANDTEC GEM-500 (Gas Extraction Monitor) for automatic gas sampling, pressure measurements, analysis, and flow calculations.
- Use LANDTEC's propriotory equations

Accu-Flo™ Maintenance

Accu-Flo™ wellheads are designed to provide maintenance free operation. The quick-connect ports are threaded for easy inspection or replacement. The union disconnect allow convenient removal of the Accu-Flo™ assembly for periodic inspection. The built-in impact tube is mounted to a standard PVC plug for easy removal. Removal of the plug also allows operators to "sound" a gas well to determine the approximate liquid depth within the well casing.

Primary Accu-Flo™ Features and Components

Gas Flow Meter: (Gas Measurement Tube assembly) incorporates a prepositioned, impact tube within a precalibrated (lab certified) measurement tube assembly (Accu-Flo™ body). Assembly can extend into the well casing to provide installation compactness.

Flow Control Gate Valve: Designed for full flow with minimal pressure drop or throttled flow, non-rising stem, positive shut-off gas flow, PVC materials, and a polypropylene wedge.

Impact Tube: Pre-positioned within the gas measurement tube assembly. Mounted to a threaded PVC plug. Stainless steel construction. Design incorporates an enlarged pressure port and a separate static pressure port to protect the tube from particulate and condensate clogging common with conventional Pitot designs used in LFG applications.

Gas Pressure Ports and Sample Port: Provide quick-connect convenience when taking gas samples and impact tube static/differential pressure readings required for calculating gas flow rates. Constructed of polypropylene with Viton seals for positive sealing. Threaded fittings are easily removed for inspection or replacement.

Temperature Gauge: Indicates gas flow temperature on a scale ranging from 0° to 220°F with ±2°F accuracy. Stainless steel probe, plastic water tight dial cover and a recalibration nut. Easily removed from quick-connect fitting for inspection, or other use of fitting.

Flex hose: A 5' long flexible "PVC spa hose" is provided, with all Accu-Flo™ models to connect the outlet of the Accu-Flo™ wellhead to an existing LFG laterial or header.

Dust Cover: Protects sample ports and temperature gauge from the sun and landfill elements.

Accu-Flo™ Compatible Instrumentation and LANDTEC Products

Landfill Control Technologies (LANDTEC) distributes or manufactures the following products that can be used with Accu-Flo™ wellheads:

- ***LANDTEC* GEM-500 (Gas Extraction Monitor)** – incorporates nine landfill gas instruments with on-board computer. Data can be downloaded to PC.
- ***LANDTEC* WBS-100™ (Well Bore Seal)** – dense PVC sheeting provides durable, impermeable membrane seal around well casing to prevent well-bore air intrusion and LFG emissions.

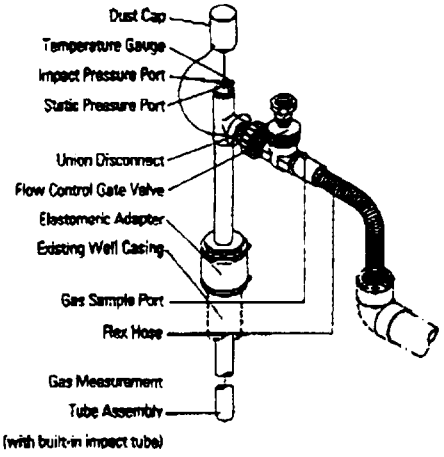
©1992-1996 Landfill Control Technologies. Corporate Headquarters 633 West Fifth Street, Suite 4900, Los Angeles, California 90071-2006 U.S.A.
Phone (213) 895-5353, (800) 821-0496, Fax (213) 895-5866

TABLE 1
Accu-Flo™ Model Specifications

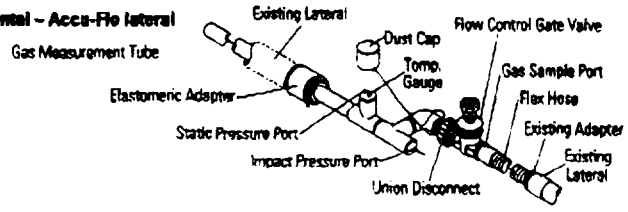
Style	Model No.	Recommended Flow Range C.F.M.	Pressure Drop Flow Range Inches of H_2O	Dimensions A x B	Actual Weight (lbs.)	Shipping Weight (lbs.)
1.5" Vertical	150V	1 Thru 50	0.1 Thru 1.5	16" x 54"	9.6	10.0
1.5" Horizontal	150H	1 Thru 50	0.1 Thru 2.1	10" x 61"	12.3	13.0
2" Vertical	200V	5 Thru 75	0.1 Thru 3.2	16" x 55"	11.6	12.0
2" Horizontal	200H	5 Thru 75	0.1 Thru 3.5	10" x 61"	12.5	13.0
3" Vertical	300V	10 Thru 500	0.1 Thru 11.5 +	23" x 82"	37.5	38.0*
3" Horizontal	300H	10 Thru 500	0.1 Thru 19.0 +	13" x 71"	46.4	47.0*

V = Vertical H = Horizontal *Includes 3" valves shipped separately, weight 22 lbs.
To order basic wellhead without flow measurement element add "NF" to model number.

Vertical – Accu-Flo well casing configuration



Horizontal – Accu-Flo lateral



Accu-Flo™ Wellhead Shipment and Installation

Shipment: Accu-Flo™ wellheads are shipped as a complete assembly, plus separate flex hose (glued fitting).

Installation: Accu-Flo™ wellheads (vertical and horizontal) are installed on top of or extend into 2" through 8" well casing or laterals. Accu-Flo™ wellheads are typically installed on a well casing or branch lateral by using appropriate reducer bushings, couplings, flanges, gaskets and bolts (as required and provided by others) – or by using LANDTEC Installation Adapter Kits.
No special tools are required. Assembly and installation of an Accu-Flo™ wellhead typically takes less than an hour.

Vault Installation: All Accu-Flo™ models can be installed below ground in a vault. Because the patented Accu-Flo™ body can extend into a well casing, installation for models 150 and 200 wellheads can be in vaults as small as 18" x 24" x 16" deep.

Warranty

LANDTEC products are backed by a clear and unconditional warranty. It guarantees that for twelve months after delivery, the product will operate properly and meet design specifications, or we will repair or resolve the problem to the customer's satisfaction, otherwise we will provide a complete refund of the purchase price. Our warranty reflects our commitment to our products and customers.

Accu-Flo™ Product Selection/Order Instructions

To select the proper Accu-Flo™ models and Adapter Kits for a gas collection system, determine:
1) Model Style: Select the "installation style" required for each model, either: **(V) vertical style or (H) horizontal style.**
2) Model Size: Select the "model size" required for each wellhead to meet the design flow and pressure drop requirements by using Table 1 – Accu-Flo™ Model Specifications. Full range pressure drop charts are available upon request for each model:
Model no's. 150V, 150H, 200V, 200H, 300V, 300H.
3) Optional Adapter Kits: To order Adapter Kit, specify well casing size and type (either slip or flange).

Elastomeric Adapter Kit contains: Elastomeric Coupling, Concentric Bushing and Stainless Steel Clamps.

Flange Kit contains: Elastomeric Adapter Kit, Van Stone Flange, Neoprene Gasket and Bolt Kit.

Please call our toll-free number (800) LANDTEC and ask for a Sales Engineer to assist you.

LANDTEC Products, Support Services and Spare Parts

LANDTEC provides full technical support for our products. A spare parts list is provided with each product. Additional information can be obtained on products including: product short and long form CSI specifications, installation instructions and CAD drawings. LANDTEC products are designed to work together in an integrated landfill gas management program with other products which include: wellheads, well-bore seals, knockouts, pump stations, flares, condensate/leachate treatment, field instruments and landfill gas management software.

For additional information or placement on our mailing list, please call our toll free West Coast number (800) 821-0496 (8 a.m. - 5 p.m. PST) and ask for a sales engineer to discuss your landfill needs.

LANDTEC®
Landfill Control Technologies
(800) LANDTEC

Northwest Sales Office
(213) 895-5621, (213) 895-5866 FAX
Southwest Sales Office
(213) 895-5625, (213) 895-5866 FAX
Northeast Sales Office
(703) 425-9894, (703) 425-6026 FAX
Southeast Sales Office
(404) 869-0102, (404) 869-0103 FAX

Printed on Recycled Paper
Product designs and specifications are subject to change without notice. User is responsible for determining suitability of product. LANDTEC is registered with the U.S. Patent and Trademark Office. Accu-Flo is a product trademark.

Project _____ Acct. No. _____ Page _____ of _____

Subject _____ Comptd. By _____ Date _____

Detail _____ Ck'd. By _____ Date _____

NONREPRODUCIBLE GRID FORM 145

METCALF & EDDY, ENGINEERS

Scan: Cost indices used to upgrade from '93 to '97 dollars

ENR Construction Cost Sept. '97 Index Value
= 5850.69

ENR Construction Cost Jan. '93 Index Value
= 5070.66

Ratio used = $\frac{5850.69}{5070.66}$ = 1.15383

DP

METCALF & EDDY, INC.

TELECON MEMORANDUM

JOB NO. 4609-18-10-10

DATE: 5/20/93

SUBJECT: Air Monitoring

M&E ENGINEER: D. Bowman

MADE CALL (X)

REC'D CALL ( )

OUTSIDE PARTY: Alexis Meredith / Eric Wenger
Air Toxics Limited
(916) 638-9892

COMMENTS

SUMMARY OF CONVERSATION:

What are options for Perimeter Ambient Air monitoring at Rose Hill
Options Depend on Cost, ~~and~~ Detection limits and Turnaround Required
- Canisters or Sorbents
- On-Site GC
- Optical Remote Sensing

Optical remote sensing is new and experimental and probably expensive
On-site automated GC is also probably expensive to-and expensive but is very timely
Canisters are the ~~co~~ conventional method but have a longer turnaround time
Eric will send me a brochure describing capabilities
Summa Canister Sampling Costs
$270/Sample
$50/Methane
$50/Summa Canister Rental
$50/Flow Control Meter
$420/Sample

CC:

M&E FORM NO. 196 (9/78)

METCALF & EDDY, INC.

TELECON MEMORANDUM

JOB NO. 4609-18-10-9

DATE: 5/20/93

SUBJECT: Air Monitoring at Rose Hill During Remediation

M&E ENGINEER: Paul Carbonneau

MADE CALL ( )

REC'D CALL ( )

OUTSIDE PARTY: Bill Phillips
Anderson Equipment
(800) 241-6898

COMMENTS

SUMMARY OF CONVERSATION:

Anderson furnishes two whole air sampling packages
87-100 24 hour controlled sampler
Price is $7,150 requires canisters but
no other significant operational costs -
excluding sampling
Only real time monitors that they provide are for
particulate
High vol samplers are more appropriate for pesticides
and PCB's

CC:

M&E FORM NO. 196 (9/78)

METCALF & EDDY, INC.

TELECON MEMORANDUM

JOB NO. 1609-13-10-10

DATE: 5/20/93

SUBJECT: Rosa Hill Sampling Cost Analytical

M&E ENGINEER: D. Chadwick

OUTSIDE PARTY: Ed Lasker
Net Cambridge Division

MADE CALL ( )

REC'D CALL ( )

COMMENTS

SUMMARY OF CONVERSATION:

Budget Rough Costs for Analytical Work

	List	Discount	Deep Discount
524.2 For Volatiles	300	270	235
TAL Metals	250	230	220
SW-846	450	410	

Do not need many semi-volatile parameters - not much efficient for limited number of parameters

Acrylamide will either come out with the VOAs in 524.2 or the Semi's in SW-846

CC:

M&E FORM NO. 196 (9/78)

METCALF & EDDY, INC.

TELECON MEMORANDUM

JOB NO. 4609-18-10-10

DATE: 6/2/93

SUBJECT: Rose Hill Cap Cost

M&E ENGINEER: David Carbonneau

OUTSIDE PARTY: Russell Wells

MADE CALL ( )

Gundell Lining Systems Inc.

REC'D CALL ( )

1(800) 435-2008

COMMENTS

SUMMARY OF CONVERSATION:

Cap Gundell VLT 50 mil

1.5 Million SF

$0.56/SF Installed - Assume Union Labor

50% Labor 50% Material

Polyfelt (TS500) $0.52/SY

Health & Safety Premium

Level C 25%

Level D 50%

CC:

M&E FORM NO. 196 (9/78)

METCALF & EDDY, INC.

TELECON MEMORANDUM

JOB NO. 4609-18-10-10 DATE: 6/2/93

SUBJECT: Rose Hill Cap Cost : Geomembrane

M&E ENGINEER: D. Arnuzzera

MADE CALL ( )

REC'D CALL ( )

OUTSIDE PARTY: Shawn B. McGrath
Genesis Clean Corporation
(410) 712-8402

COMMENTS

SUMMARY OF CONVERSATION:

Budgetary Quote for Geomembrane
Assume: - 36 Acres (1.5 million SF)
- Superfund Site
- Claymax 500SP

Material Cost To R.I. = $0.45/sf
(Includes Freight)

Installation Cost = $0.10/sf to $0.15/sf

Installed
Total Cost = $0.60/sf (Includes Overhead and Profit)

Maximum Friction ~~angle~~ angle on Textured VLDPE/
Geomembrane Interface = 27°

Strength of sticking reinforcing bentonite = 500psf.

CC:

M&E FORM NO. 196 (9/78)

METCALF & EDDY, INC.

TELECON MEMORANDUM

JOB NO. 4609-18-10-10

DATE: June 22, 1993

SUBJECT: Rose Hill FS - Cost Detail: Property Aquisition

M&E ENGINEER: Daniel Peters

MADE CALL (✓) 9:30

REC'D CALL ( )

OUTSIDE PARTY: South Kingstown, RI - Town Hall, P.O. Box 31, 180 High Street Wakefield, RI 02879

COMMENTS

SUMMARY OF CONVERSATION: TEL (401) 789-9331
~~FAX (401) 789-5280~~

9:30 I talked with the Town Assessor re: the following -

1) what is the Tax rate for South Kingstown?

$27.31 / $1,000 property value

2) What is the average housing price in South Kingstown?

unknown, local realtor may know

CC:

M&E FORM NO. 196 (9/78)

METCALF & EDDY, INC.

TELECON MEMORANDUM

JOB NO. 4609-18-10-10

DATE: June 22, 199-

SUBJECT: Rose Hill FS - Cost Detail: Property Acquisition

M&E ENGINEER: Daniel Peters

MADE CALL (✓) 10:00

REC'D CALL ( )

OUTSIDE PARTY: Ms. Ginny Kearns, Hallmark Realty, 235 Main Street Wakefield, RI 02879

COMMENTS

SUMMARY OF CONVERSATION: TEL (401) 783-9611

10:00 I talked with Ginny Kearns, a local realtor in South Kingstown re: average residential prices

- the price can vary significantly ($80,000 - $500,000) depending on area; average price ~~$~~ not known
- I talked w/ Ginny re: prices in the Kingston & Moorefield districts of South Kingstown .... she will send some information to M&E ("Guide to Homes"); I will follow-up with questions once received.

- Site not mentioned → I discussed this project only as an "Engineering Study"

CC:

M&E FORM NO. 196 (9/78)