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INDUSTRI-PLEX SITE REMEDIAL TRUST

WOBURN, MASSACHUSET

100% DESIGN REPORT PART I

INDUSTRI-PLEX SITE WOBURN, MASSACHUSETTS

Volume 5 of 8

Prepared by:

Golder Associates
Mt. Laurel, New Jersey

In Association with:

Jordan, Jones and Goulding
Normandeau Associates
Sasaki Associates
Husch & Eppenberger
Environmental Systems Group Monsanto

SRT-DESIGN-11
)03-6400

APRIL 199

Golder Associates Inc.

20000 Horizon Way, Suite 500
Mt. Laurel, NJ USA 08054
Telephone (609) 273-1110
Fax (609) 273-0778

100% DESIGN REPORT
PART I

INDUSTRI-PLEX SITE
WOBURN, MASSACHUSETTS

VOLUME 5 OF 8

ISRT-DESIGN-11

Prepared for:

Industri-Plex Site Remedial Trust
36 Commerce Way
Woburn, Massachusetts

Prepared by:

GOLDER ASSOCIATES INC.

In Association with:

Jordan, Jones and Goulding
Normandeau Associates
Sasaki Associates
Husch and Eppenberger
Environmental Systems Group Monsanto

April 1992

Project No.: 903-6400

100% DESIGN REPORT
PART I

INDUSTRI-PLEX SITE

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ADDENDUM

ADDENDUM NO: 3

DATE: May 14, 1993

TITLE: Industri-Plex Site
Remedial Work For Soil, Sediments and Air

LOCATION: Woburn, Massachusetts

DOCUMENTS AFFECTED:

1. Volume 8 of the 100% Design Report, Part I
2. Volume 5 and 6 of the 100% Design Report, Part I

CHANGES OR ADDITIONS:

1. Volume 8 of the 100% Design Report, Part I

Drawing	Summary of Revision
Sheet 14-4	Revised to incorporate Agency Comments
Sheet 14-5	Revised to incorporate Agency Comments
Sheet 14-8	A new drawing added to show the revised lined area and the detail of berm

2. Volume 5 and 6 of the 100% Design Report, Part I

Volume 5

Section	Page	Summary of Revision
14.6	63 to 83	Revised to incorporate Agency Comments on created wetland design and buffer requirements
Table 14-16		Revised to include species in created wetland berms
19.3.4.1	19-10	Revise to refer to Hydrology Management Plan
19.3.4.2	19-11	Potential problems expanded
19.3.4.3	19-11 and 19-12	Created wetland berm included for inspection
19.3.4.5	19-13	Reporting requirements revised per Agency Comments Revised to refer to Hydrology Management Plan
19.4.4	19-18	Methods of controlling wildlife added
19.5.2.1	19-22	Sampling locations revised per Agency Comments

Section	Page	Summary of Revision
19.5.2.2	19-22 to 19-24	Parameters and locations of monitoring revised per Agency comments
19.5.2.3	19-24	Monitoring schedule revised
19.5.2.4	19-25	Reporting requirements revised per Agency Comments
19.6	19-26 to 19-29	Hydrology Management Plan added
Table 19-1		A potential performance deficiency added
Figure 19-1		Sampling location revised and notes added

Volume 6

Section	Page	Summary of Revision
02937 1.03(a)	02927-1	Test requirements added per Agency Comment
1.03(b)	02927-1	Geotechnical test requirements for created wetland added
1.04(d)	02927-2	Created wetland berm included for planting
2.05(b)	02927-4 and 5	Soil permeability revised and geotechnical test requirements for created wetland added
3.03(d)	02927-6	Planting time revised
3.06	02927-8	CQC requirements added
Table 02937-1		Revised to include species in created wetland berms

CHAPTER 14

STREAM AND WETLAND IMPACT MITIGATION

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CHAPTER 14
STREAM AND WETLAND IMPACT MITIGATION

14.1 INTRODUCTION

This chapter describes the functional assessments of wetlands and drainways at the Industri-Plex Site and the effects of sediment remediation on their beneficial functions, and provides a specific plan for mitigating functional losses to ensure compliance with all wetland-related ARARs.

Wetland resources within the project Site have been identified and described in a report by Wetland Management Specialists, Inc. (WMS) entitled Wetland Assessment, Industriplex 128 Superfund Site, Woburn, Massachusetts (ca. 1986) which was previously submitted as part of the Remedial Investigation Feasibility Study (RIFS). All subsequent wetland assessment and mitigation design has proceeded based on the wetlands as delineated in the WMS report. Sheet 5-6 shows the Wetlands Location Map reproduced from Figure 1 of the WMS (ca. 1986) report, and the present Site boundary. The WMS (ca. 1986) report covered a study area larger than the present Site and identified the wetlands with numbers from 1 through 9; some of the wetlands were further designated with suffixes A, B, C, etc. Thirteen of the wetlands, streams, and drainways (channelized streams) shown on Figure 1 of the WMS (ca. 1986) report are located within the present Site limits; these are: 1C, 2A, 2B, 3A, 3B, 3C, 3D, 3E, 7A, 7B, 7C, 8 and part of 6A.

Six of the thirteen WMS-delineated wetlands and drainways indicated above with sediments containing arsenic, lead and/or chromium above Consent Decree Action Levels will be remediated; these are: 1C, 2A, 7A, 7B, 7C and 8. The New Boston Street Drainway and a channel draining into the New Boston Street Drainway from the west will also be remediated. The eight wetlands and drainways with sediments that will be remediated are shown on Sheet 13-1.

A functional assessment of wetlands, streams, and drainways to be restored or impacted by remedial activities was conducted. This assessment was based on the Hollands-Magee Functional Assessment methodology (Hollands and Magee, 1986; Michener and Stevens, 1989) and was used to develop functionality goals for each wetland impacted. A detailed impact analysis was conducted. The Site-specific remedies, prescribed in the Consent Decree, and the satisfaction of the ARARs form the regulatory basis for mitigating the impacts of sediment remediation. Plans for revegetating remaining remediated wetlands and creating functionally viable compensatory wetlands were developed to comply with wetland-related ARARs. ARAR compliance is discussed in Chapter 4.

14.2 REMEDIAL DESIGN WORK PLAN REQUIREMENTS

The Remedial Design Work Plan (RDWP; Golder, 1990) specifies the deliverables associated with stream and wetland remediation at the 60%, 95%, and 100% Design Stages as:

> "development of preliminary sediment excavation methodology, additional remediation and/or revitalization techniques", and
>
> "definition of functionality goals" (p. 55);
>
> "Draft plans and sections for wetlands revitalization from hide pile stabilization and Hazardous Substance removal, monitoring plan and wetland replacement plan." (p. 57); and
>
> "Sections for wetlands revitalization, additional remediation and/or revitalization techniques, and monitoring plan. Definition of functionality goals." (p.59)

Sediment excavation methodology is presented in Chapter 13. Wetland functional assessments and functionality goals are described in Section 14.3. Section 14.5 of this report includes a narrative describing the revitalization plans for Wetland 1C and remediated drainways. Design drawings showing plan and cross-section views are included on Sheets 14-1 through 14-3 and 14-7. Section 14.6 provides the design for compensatory wetlands (enhancement and creation areas) and restoration areas which will supplement the functionality goals not otherwise met by revitalization. Design drawings showing plan and cross-section views of the compensatory wetlands and restoration area are included in Sheets 14-4, 14-5, and 14-6. A wetland inspection and maintenance plan is included in Chapter 19, Sections 19.3.4 and 19.4.4.

14.3 WETLAND FUNCTIONAL ASSESSMENT

The objective of the functional assessment is to assess the level of public benefit presently provided by each wetland that must undergo sediment remediation. Present wetland functions were evaluated using professional interpretation of the Hollands-Magee Functional Assessment methodology (Hollands and Magee, 1986; Michener and Stevens, 1989).

14.3.1 Methods

Wetland protection regulations are based on the premise that the public derives from such areas certain benefits unique to wetland environments. These benefits are listed in the various federal, state and local regulations and include: 1) biological contribution to wildlife and fisheries, 2) hydrological support for downstream systems, 3) groundwater supply, 4) flood control, 5) protection of shorelines from erosion, 6) water pollution attenuation, 7) economic value, 8) recreation, 9) aesthetic value, and 10) educational value.

The modified Hollands-Magee wetland assessment method (Hollands and Magee, 1986; Michener and Stevens, 1989) was employed as a procedure to assess a wetland's capacity to perform the functions listed above. Each model is designed to evaluate those biological and physical characteristics of a wetland (e.g., surficial geology, vegetation type) that give rise to a public benefit (e.g., flood storage, pollution control). The wetland is ranked for each function in comparison with a data base of over 1,000 wetlands in the region. Its rank among regional wetlands is reported to the nearest ten percent or decile. The deciles have been grouped to provide a "high" (8 to 10), "moderate" (4 to 7), and "low" (1 to 3) ranking.

A model which predicts wetland functions and values from a set of biological and physical variables represents a simplification of a natural system. It is a tool for collecting a consistent set of observations in a variety of settings so that comparisons among similar but diverse systems can be made. Such models are never intended by their authors to stand alone without interpretation, because natural systems cannot be accurately simplified. Model results require interpretation to provide perspective to the generalizations produced by the simplification process. Sometimes these generalizations produce model results that do not accurately reflect the natural system. This is true of the modified Hollands-Magee models in certain situations. For example, the modified Hollands-Magee models do not address the presence or absence of arsenic, lead, chromium or hide residues in the sediments at the Site or the quality of undeveloped but disturbed upland surrounding a wetland. The impact of such conditions must be established through professional judgement. Professional interpretations of each functional assessment are presented and based on thorough understanding of the models and field observations made by wetland professionals with regard to wetland functions.

In order to collect the field data required for the functional models, site visits with an interdisciplinary team were conducted on April 16, May 3, and November 6, 1990. The information gathered consisted of an overview of site hydrology, geology, wetland vegetation cover types and surrounding land use. An interim report, Wetland Evaluation of the East-West Hide Pile Wetland, Industri-Plex Site, Woburn, Massachusetts (Normandeau Associates Inc., 1990) was submitted to the EPA for the ISRT on June 25, 1990 (ISRT-PDI-4, 1990). During 1990, all areas important to the functional analyses of the Site's wetlands

were investigated, including areas adjacent to the WMS-delineated wetlands. This report discusses the impact of Site remediation on the WMS-delineated wetlands. To satisfy several input parameters of the modified Hollands-Magee models, vegetational cover types as classified according to Cowardin et al. (1979) were used. The classification was also done by WMS (ca. 1986).

14.3.2 Results and Discussion

A total of eight wetlands and drainways contain sediments that require remediation on the Industri-Plex Site as described in Chapter 13. Of these, six are WMS-delineated and WMS-classified wetlands or streams, and the other two are drainways (Sheet 13-1). Wetlands 2A, 2B (the Aberjona River), and the New Boston Street Drainway are perennial streams which have been previously channelized (ditched). Wetland 7C is a channelized intermittent stream. The culverted portion of the New Boston Street Drainway is not discussed in this chapter.

Wetland 1C is the largest wetland with sediments that require remediation. It is located adjacent to hide piles, and is dominated by open water, emergent, and scrub-shrub wetland classes. Surface water passes through Wetland 1C into the Aberjona River. Two wetlands, 7A and 7B, are small (0.4 and 0.3 acres, respectively) man-made excavations which lack surface water outlets to other wetlands; Wetlands 7A and 7B were previously used as settling ponds for effluent with high chromium levels, and are now vegetated with common reed (*Phragmites australis*). Wetland 8 is an emergent and scrub-shrub wetland located in the Boston Edison Right-of-Way No. 9, which passes intermittent flow to Halls Brook.

Descriptions for each wetland and channelized stream follow. Detailed information about the species composition of each vegetation stratum is contained in Appendix 14-A. A list of wildlife species observed during wetland assessments appears in Table 14-1. This list is a good indicator of the types of wildlife using the area, but is not a complete inventory. This species list, along with wildlife habitat information, is adequate to prepare a mitigation design. An exhaustive wildlife inventory is not necessary to meet the mitigation goals of this project. The modified Hollands-Magee functional assessment model results are also discussed. It should be understood that a low model rank does not imply that a wetland is not valuable for a particular function. It simply means that many other wetlands in the region have a similar or better capacity for serving that function. The complete modified Hollands-Magee computer results are provided in Appendix 14-A. Each functional assessment result also contains a final ranking based on professional judgement to account for the presence of arsenic, lead, chromium or hide residues in the sediments and the disturbed character of much of the surrounding landscape.

14.3.2.1 Wetland 1C - East-West Hide Pile Wetland

Wetland 1C, also known as the East-West Hide Pile Wetland, is a palustrine wetland system located in the northwestern portion of the Site. The wetland is associated with an inlet originating from a series of smaller palustrine wetlands to the north. It appears these basins have been previously modified to enhance floodwater storage capacity. Surface water enters the study wetland via a spillway structure contained within a rip-rap dike which forms the northern border of the wetland (Figure 14-1). Surface waters discharge from the southwestern corner of the wetland into a steep-sided, channelized tributary of the

Aberjona River. The wetland is bounded by the hide piles to the east and west and an exposed arsenic and lead deposit to the south. Additional soils having heavy metal concentrations above natural background levels are located along the northwestern shoreline (Roux, 1983). The substrate of this wetland consists of approximately 0.1 to 2.5 feet of soft silty and organic sediments over coarser mineral soils.

The wetland consists of a fairly large, shallow (approximately 3-5 feet deep) pond with an irregularly shaped vegetated wetland fringe. Based on the delineation and classification performed by WMS (ca. 1986), Wetland 1C is approximately 4 acres in size with the dominant wetland class consisting of open water (Figure 14-2). Emergent marsh habitats also comprise a relatively large proportion of this wetland complex. The shallow emergent habitat consists of robust persistent emergents dominated by common reed. Common reed is also the dominant vegetation on the hide piles. The deeper emergent areas consist of robust persistent emergents dominated by purple loosestrife (*Lythrum salicaria*). Both common reed and purple loosestrife represent exotic invasive species, which typically out-compete native vegetation and form nearly monotypic plant communities. In addition, both species have limited wildlife food value and can reduce structural diversity within the wetland.

Wet meadow and scrub-shrub swamp habitats also exist as minor components of the wetland system. The small wet meadow habitat is dominated by wool grass (*Scirpus cyperinus*). Common woody species within the several small scrub-shrub swamp habitats include: European buckthorn (*Rhamnus frangula*), pussy willow (*Salix discolor*) and elderberry (*Sambucus canadensis*). Although forested

wetlands were not identified by WMS (ca. 1986), several small wooded swamp habitats were encountered within and adjacent to Wetland 1C during field visits. One forested wetland habitat lies between the outlet streams in the southeastern end of the wetland system. Another small forested wetland was encountered along the southwestern border of the wetland. This latter forested wetland and the main wetland are separated by an approximately 10-foot high berm (Figure 14-1). A limited hydrological connection is provided by a small culvert within the berm. Red maple (*Acer rubrum*) is the dominant overstory component within these habitats with cottonwood (*Populus deltoides*), northern red oak (*Quercus rubra*) and swamp white oak (*Quercus bicolor*) as associated overstory species. A listing of vegetation inventoried within Wetland 1C is included in Appendix 14-A.

14.3.2.1.1 Functional Assessment

The modified Hollands-Magee Functional Assessment ratings and final professional rankings for Wetland 1C appear in Table 14-2. The computer printouts appear in Appendix 14-A.

Biological-Wildlife Function

The high biological function model rating for Wetland 1C indicates high wildlife habitat value. This model score is based on many factors including: the number of wetland types and subtypes that make up the wetland complex, the interspersion and juxtaposition of these types, the location of the wetland along a stream with other wetlands in close proximity, and the amount of undeveloped land surrounding the wetland. These factors provide habitat diversity that attracts a variety of wildlife species to the wetland.

The high biological function model score may be misleading. The model does not take into account the presence of hazardous substances or the amount of disturbance on the "undeveloped" land surrounding the wetland. The chemicals known to be present in the area are a potential hazard to wildlife living in the area, especially those species that are chronically exposed to heavy metals in soils and sediments. Some upland areas adjacent to the wetland are unvegetated or sparsely vegetated because certain plants will not tolerate the heavy metal concentrations in the soils. These areas do not provide food or cover for wildlife. This reduces the habitat value of the adjacent wetlands, since the life cycle requirements of many species of birds, mammals, reptiles, amphibians and invertebrates are satisfied partly in uplands and partly in wetlands. The presence of the industrial and office parks and I-93 on the outer boundaries of the property also limits the wildlife habitat value of the area. The site is completely fenced in. This restricts movements of some large mammals such as white-tailed deer (*Odocoileus virginianus*). Therefore, the biological function score is inflated; actual wildlife habitat value is moderate.

Many wildlife species were observed in Wetland 1C and in the surrounding area (Table 14-1) during the April and May 1990 field work and by other investigators. Several species of waterfowl (Canada goose (*Branta canadensis*), mallard (*Anas platyrhynchos*), black duck (*Anas rubripes*), and green-winged teal (*Anas crecca*)) were observed using the pond between the East and West Hide Piles. A Canada goose nest was found at the western end of the slough that enters the pond on the west shore. It is likely that the mallards and black ducks observed at the pond also nest in the area, because suitable nesting habitat is available.

The wetland would also provide brood-rearing cover for these species. Green-winged teal do not nest in the region and likely were migrating through the area. The pond and wetland may attract other migratory species as well. Such stopover sites are important resting and foraging areas during migration. Numerous songbird nests were also observed in the wetland, and many species, such as grackles (*Quiscalus quiscula*) and red-winged blackbirds (*Agelaius phoeniceus*), were observed foraging in the area.

Evidence of reptiles and amphibians breeding in the area also is abundant. Several turtle nests were found in sandy areas adjacent to the wetland, and many turtles (more than 100 painted turtles (*Chrysemys picta*) and several large snapping turtles (*Chelydra s. serpintina*) were observed in the pond and on its banks. This is an unusually large number of turtles for a single wetland pond. A few gray treefrogs (*Hyla versicolor*) and northern spring peepers (*Hyla c. crucifer*) were heard singing in nearby wetlands during the April 1990 field work. None were heard in Wetland 1C, but it is likely that they are also breeding in the open water in this wetland.

River otter (*Lutra canadensis*) sign (scat composed of fish scales) was found on the point of land where the slough enters the pond on the west shore. This indicates the presence of fish in the pond and stream. These fish may be a food source for belted kingfishers (*Ceryle alcyon*), herons (Ardeidae), mink (*Mustela vison*) and other fish-eating species as well as for otters. It is possible that otters have bred in the area; an apparent abandoned den site was also found on the west shore of the pond.

Muskrat (*Ondatra zibethicus*) houses and sign were found in the pond and marsh areas. They are likely breeding here. Numerous woodchuck (*Marmota monax*) burrows and cottontail rabbits (*Sylvilagus floridanus*) were observed on the edges of the wetland. These species, although denning outside of the wetland, probably forage within the wetland.

The wetland complex is used as a permanent residence by many wildlife species and is used for breeding and foraging by other species despite the disturbed nature of the site and the heavy metal concentrations in the area. Heavy metals can affect the health and productivity of the local wildlife populations (Bellrose, 1980) and, therefore, reduce the present Biological-Wildlife functional value of this wetland. It is also likely that wildlife species that are particularly sensitive to the heavy metals are no longer using the area.

Hydrologic Support Function

The hydrologic support model assesses the wetland's ability to affect the quantity and quality of water that it discharges to downgradient aquatic resources. Important input parameters include: wetland size, dominant hydrologic condition, downgradient hydrologic connections and percent bordering open water. The moderate hydrologic support score indicates an average ability to perform this function.

As an indication of Wetland 1C's ability to provide hydrologic support to downgradient aquatic resources, the moderate score appears valid. This ability is enhanced by the configuration of the wetland basin, which supports diffuse (low-energy) water flow. The increased residence time allows inflowing water to interact with the water quality enhancement mechanisms. In addition, the wetland

functions as a groundwater discharge system due to the geologic conditions (see Chapter 6).

Groundwater Recharge Function

The groundwater model assesses the wetland's ability to recharge an underlying aquifer. Important input parameters involve the nature of the local surficial geology, water table characteristics and surface water connections. The low groundwater function score indicates that recharge of groundwater resources is not a primary function of this wetland.

As an indication of the wetland's ability to recharge an underlying aquifer, the low score is accurate. Although the majority of the wetland basin is underlain by well sorted glaciofluvial outwash, deposits within this portion of the Site are generally less than 10 feet thick (see Chapter 6).

Floodwater Storage Function

The floodwater storage model assesses the wetland's ability to store water and retard water flows during storm or flood events. The model scores are influenced by many variables. The more important factors include: the nature of the vegetative cover, percent open water, topographic configuration and position, and dominant hydrologic condition. Wetland 1C demonstrated a low ability to provide a floodwater storage function in comparison to other wetlands in the region.

The low ranking is primarily a function of the dominant wetland class being open water, which the model interprets as a paucity of vegetation to reduce the energy of inflowing stormwater. However, the size and topographic configuration of the wetland basin are well suited for

floodwater storage. The model does not consider the extent of industrial development within the watershed or the steeply sloped, partially vegetated hide piles immediately adjacent to the wetland. Both factors increase runoff rates, thus enhancing the wetland's opportunity to provide a floodwater storage benefit. In addition, the importance of this benefit should be elevated considering the level of emphasis placed on floodwater storage in the surrounding area (i.e., Halls Brook Holding Area, Phillips Pond, and the basins created to the north of Wetland 1C). Therefore, in the context of local needs and conditions, the floodwater storage function is misleadingly low and is thus ranked moderate.

Shoreline Protection Function

The shoreline protection model is a measure of the wetland's ability to buffer wave and current energy of adjacent waterbodies or streams. The model scores are influenced primarily by the nature of the vegetative cover, percent bordering open water and fetch. Wetland 1C demonstrated a moderate ability to protect the shoreline from erosion.

This moderate ranking is generally accurate. Although the wetland has a relatively high percentage of edge bordering open water, the open water habitat is generally shallow with little fetch. As a result, minimal wave energy would be generated within this system. In addition, the shoreline edge is well protected from erosion due to the density of the emergent vegetation along the fringe. In fact, the presence of invasive emergent species (i.e., purple loosestrife and common reed), which is due in part to past site disturbances, likely increased the stem density along the shoreline. The dense fibrous root systems within the shallow emergent zone effectively

stabilize the soil along the water's edge. The past site disturbances also increase the local importance of this function, because metalladen sediments that become suspended through processes of erosion could be transported to downstream aquatic resources.

Water Quality Maintenance Function

The water quality maintenance model assesses the wetland's ability to improve the quality of water passing through the system through chemical, physical and biological pollutant removal mechanisms. Important components of this model include: the nature of the vegetative cover, topographic setting and hydrological connections. In comparison to other wetlands in the region, Wetland 1C scored low for this function.

Several factors contributed to the low ranking received for the water quality maintenance function. Most of these factors relate to the amount of open water within the Wetland 1C system. Similar to the floodwater storage model, this is interpreted as a lack of vegetation within the wetland complex as a whole. The importance of persistent vegetation with high stem density in providing water quality enhancement benefits such as nutrient removal has been reported by several researchers (Hammer, 1989). Although open water comprises the majority of the wetland complex, the topographic configuration of the basin increases residence time of inflowing waters, allowing for interaction with the emergent fringe. The diffuse flow of surface waters within the system also promotes sediment deposition and chemical and biological removal mechanisms along the soil/water interface. Shallow water depths and high organic anaerobic substrates, similar to those within Wetland 1C, have also been reputed as factors contributing to a wetland's ability to enhance water quality.

The importance of this function in the context of local needs is elevated due to the extent of development within the watershed and past site disturbances adjacent to the wetland. Both factors increase the opportunity for runoffborne substances to enter the wetland system. It is important to recognize that some heavy metals and nutrients that accumulate within the wetland basin may be subsequently exported downgradient on a seasonal basis or during storm events. The water quality maintenance function is moderate, higher than the model results indicate.

Economic, Recreational, Aesthetic and Educational Functions

The economic, recreational, aesthetic, and educational functions, although somewhat more abstract than the other functions, are not inconsequential in a region that is subject to considerable development pressure. The models for these functions, although not comprehensive, are based on such elements as accessibility, size, ecological diversity, presence of trees or hayfields, and commonly accepted notions of aesthetic appeal. The models are intended to provide a general assessment of potential economic, recreational, aesthetic and educational opportunities. Wetland 1C scored low for economic value and high for the other three functions.

The low economic value is appropriate, due to the lack of harvestable timber, inaccessibility, absence of mowable wet meadows, etc. The high rankings for the recreational, aesthetic, and educational functions are primarily attributable to the presence of open water and the ecological diversity within the wetland. In addition to increasing the recreational and educational potential, these factors also contribute to the visual appeal of the

site. However, the models do not account for the degraded visual quality of the surrounding landscape, the presence of wetland sediments with lead, arsenic and chromium levels above Consent Decree Action Levels, or the odor emitted from the adjacent hide piles. Furthermore, access to the site to exploit these mostly intangible uses is prohibited at present by a fence. Consequently, the rankings for these models are judged to be low rather than high.

14.3.2.1.2 Functionality Goals

The functions and values of Wetland 1C which offer the greatest public benefits include the biological contribution of wildlife and fisheries, hydrologic support for downstream systems, floodwater storage, shoreline protection, and water pollution attenuation. Maintenance of these functions on Site is a primary goal of the wetland/drainway revitalization plans. In most of the Site wetlands, the social functions (economic value, recreation, aesthetic value, and education value) are professionally ranked low because of Site inaccessibility, sediment metal concentrations, and surrounding conditions. After remediation and revitalization, the aesthetic and educational values will improve for all remaining wetland areas. Access to the Site and passive recreational opportunities will increase (i.e., bird watching) although fishing and boating may be precluded. The economic values of these wetlands will always be intangible, since haying, timber management, trapping, etc. will be unlikely.

14.3.2.2 Wetland 2A - Channelized Stream Outlet of Wetland 1C

This wetland (Figure 14-3) includes the two channelized stream outlets of Wetland 1C, which flow southeast through a forested area, then pass under a dirt road through two culverts. These drainways converge just before passing

through a culvert under the western lane of the Commerce Way extension. Here the outlet stream joins the channelized portion of the Aberjona River. The channels are classified as riverine, with substrates of mud and sand with occasional stones. The vegetation along the banks of these streams includes black cherry (*Prunus serotina*) and cottonwood trees, red maple and grey birch (*Betula populifolia*) saplings, and several species of shrubs, including European buckthorn and meadowsweet (*Spiraea latifolia*). Herbaceous vegetation includes common reed, purple loosestrife and bracken fern (*Pteridium aquilinum*). Dirt roads parallel the drainways on the north and south, and adjacent lands have been disturbed by waste disposal and grading. The soils in, and adjacent to, the drainways have hide residues and metal concentrations above Consent Decree Action Levels.

14.3.2.2.1 Functional Assessment

The functional assessment input data and results for Wetland 2A are presented in Table 14-3 and Appendix 14-A. These results also apply to Wetland 7C, because these streams are reasonably similar in hydrology, vegetation, geology, and physical configuration (see Section 14.3.2.5).

Biological-Wildlife Function

A low rating for the biological function model indicates low wildlife and fisheries habitat value. This wetland's small size, low vegetation diversity and class richness, and lack of open water contribute to this low rating. In our professional judgement, this rating was considered an accurate reflection of Wetland 2A's relative ability to provide wildlife habitat.

Hydrologic Support Function

The low ranking for this function is due to the wetland unit's small size, channelized bed, absence of perennial inlets and outlets, and remoteness from open water. What little water volume there is moves through with minimal detention. Alienation from receptor bodies of open water further reduces the utility of this wetland's contribution to surface water downstream.

Groundwater Recharge Function

In common with the foregoing hydrologic support function, two major limitations influence this function: small wetland size and insubstantial water supply. In addition, the presence of bedrock within 10 feet of the surface (see Chapter 6) impedes percolation downward and transmission laterally below that point.

Floodwater Storage Function

As above, small size reduces the wetland's utility, in this case during storms with heavy runoff. Within the wetland, lowlying vegetation in a position to intercept sedimentladen water is of only moderate stem density. Aided by soil impermeability and ditching, the water runs aboveground with little topographic detention, despite the gentle slope.

Water Quality Maintenance

Small size, low flow, poor detention and percolation capacity, and only moderate vegetation stem density combine to keep this ranking low.

Economic, Recreational, Aesthetic and Educational Functions

Economic resources of this wetland unit are essentially nil, as are those for recreation and education. The aesthetic rating is moderate mainly because the dominant wetland class is streamside, and the showy purple loosestrife constitutes 5% of plant cover. The channelized character and disturbed surroundings reduce the aesthetic value; therefore, the ranking for this function was changed to low.

14.3.2.2.2 Functionality Goals

The low relative functional values for Wetland 2A reflect its small size, lack of open, permanent water, and channelized condition. A logical goal of wetland remediation and revitalization in this area is the prevention of downstream heavy metal and hide residue transport while permitting the continued flow of water, detritus, and microflora and fauna from Wetland 1C to the Aberjona River. The replacement of a culvert to allow passage of aquatic life from the Aberjona River to Wetland 1C (which is currently impossible) would also enhance this drainway's low biological value.

14.3.2.3 Wetland 2B - The Aberjona River

Wetland 2B (Figure 14-4) is the channelized section of the Aberjona River within the median strip of Commerce Way from Wetland 2A to its confluence with the South Branch of the Aberjona (the outlet of Phillips Pond). This section of the Aberjona River and the New Boston Street Drainway are, based on currently available information, perennial streams. Wetland 2B receives flow from the North Branch of the Aberjona River, Wetland 1C, and occasionally Wetland 3C, and conducts it south through the industrial park. It passes through four culverts north of Phillips Pond outlet.

The steepsided banks are densely covered with common reed and purple loosestrife. Several other shrubby and herbaceous wetland plants are present in small numbers, including cottonwood and quaking aspen (*Populus tremuloides*) saplings, European buckthorn, silky dogwood (*Cornus amomum*), jewelweed (*Impatiens capensis*), bluejoint grass (*Calamagrostis canadensis*), and common horsetail (*Equisetum arvense*). The unvegetated channel, a riverine wetland, is partially shaded by this dense cover. The channel substrate is typically coarse textured (sand, loamy sand, or sandy loam). Hide residues and metal concentrations above Consent Decree Action Levels have been found in the stream channel. Wetland 2B passes through the East-Central Hide Pile.

14.3.2.3.1 Functional Assessment

The modified Hollands-Magee Functional Assessment ratings and final professional rankings for Wetland 2B appear in Table 14-4, and the computer printouts are presented in Appendix 14-A.

Biological-Wildlife Function

The artificial channeling and straightening of this stream segment has reduced to a minimum such important factors as wetland type diversity and length of edge between types. Total wetland area has also been reduced by the same means. The disturbed, developed condition of surrounding upland habitat further reduces the biological value of this wetland unit to low.

Hydrologic Support Function

Although there is perennial outflow, the volume in such a small wetland system is negligible and the hydrologic support function ranks low. Ditching promotes the outflow, so that nothing is held back in storage as a reserve to augment downstream flow during periods of drought.

Groundwater Recharge Function

The moderate rating attained by this function must be considered at best marginal. Stream flow scarcely qualifies as perennial, thus reducing the significance of this wetland unit as a receptor and contributor of groundwater benefits. Although the insubstantial organic sediment offers little resistance to downward percolation, the mineral substrate and shallow bedrock immediately below promote little further vertical transmission of water; therefore, the professional judgement ranking was adjusted to low.

Floodwater Storage Function

Ditching is the most important factor in reducing the value of the flood control function for this wetland unit to low. Perennial inflow is efficiently moved on through and out, with minimal detention time. Since floodwater inflow fluctuations in this very small wetland system are minimal, the potential for flood storage can never have been significant, even without the ditching.

Water Quality Maintenance Function

With water in continual straightline motion, the high stem density of the surrounding streambank plant community has little chance to filter out suspended solids. This brief retention time combines with small wetland size and low organic sediment accumulation to register a low ranking for this function.

Economic, Recreational, Aesthetic and Educational Functions

The recreational model is sensitive enough to the presence of perennial flowing water and good accessibility by road that it attains a rating, however marginal, as moderate. The aesthetic model is also weighted to value moderately both streams and road accessibility. Together with the estimated 30% cover of purple loosestrife these factors raise this wetland unit's aesthetic ranking to moderate. However, on the basis of small size, industrial disturbance, restricted access rights and channelization, all these functions rank low.

14.3.2.3.2 Functionality Goals

As in Wetland 2A, the functionality goals of remediation and revitalization are the prevention of transport of sediment containing heavy metals or hide residues to downstream waters, and the continuation of stream flow. While low values for all functions does not imply a complete lack of value, any impacts to these relatively low abilities would be offset by the benefits of isolating sediments with arsenic, lead and chromium above Consent Decree Action Levels or hide residues from the surface water system.

14.3.2.4 Wetland 3A - North Branch of the Aberjona River

Wetland 3A, the North Branch of the Aberjona River, does not require sediment remediation. Nonetheless, its functionality assessment is included in this report because part of this wetland will be restored as part of the compensatory design.

The North Branch of the Aberjona River enters the Site from a box culvert under Route 93 and flows through emergent and scrub-shrub wetlands to the northern extension of Commerce Way (Figure 14-5). This is the least disturbed wetland on the Site, although some fill and disturbance from previous development activities is visible. The western end of this branch of the River has been channelized. Where flow from the river is confined to channels, substrates are mud, sand, or coarser materials. Diffusion of flow through emergent marsh areas also occurs. The dominant plants in this wetland include arrowwood (*Viburnum recognitum*), red maple saplings, sensitive fern (*Onoclea sensibilis*), and jewelweed. A variety of other shrubs and herbaceous plants thrive along the stream edge. Upland forest borders Wetland 3A to the north. The southern shore is largely undeveloped, but disturbed, old-field habitat.

14.3.2.4.1 Functional Assessment

The modified Hollands-Magee Functional Assessment ratings and final professional rankings for Wetland 3A appear in Table 14-5. The computer printouts appear in Appendix 14-A.

Biological-Wildlife Function

The large variety of cover types and plant species, moderate vegetation density and interspersion with water, and location along a perennial river with connections to other wetlands are characteristics which give this wetland a high biological value. Wetland wildlife species benefit from the food, cover, and travel corridor it provides, and the emergent vegetation and mix of substrates are of value to aquatic communities of Wetland 3A and downstream.

Hydrologic Support Function

The most important features which provide Wetland 3A with a moderate hydrologic support value relative to other wetlands in the northeast are its semi-closed basin shape and perennial inlet and outlet. Groundwater levels are near the soil surface most of the year in this stream basin.

Groundwater Recharge Function

Wetland 3A attains a moderate ranking for groundwater recharge. This portion of the Site is comprised of glacial till, not the sandy outwash soils found at the southern end of the Site. The water table is close to the soil surface, however, and no restrictive soil structures appear to prevent recharge.

Floodwater Storage Function

Despite the semi-closed basin shape and moderately dense vegetation, Wetland 3A ranks low relative to other wetlands in the northeast for floodwater storage. The small wetland size, low permeability of surface soils, and low percentage of open water are indicative of minimal floodflow capacity.

Shoreline Protection Function

Moderately dense emergent and scrub-shrub vegetation along the channel of the Aberjona River in Wetland 3A are important for stabilizing streambanks and preventing erosion by flowing water. Roots of saplings and shrubs and tufts of cinnamon fern and tussock sedge hold soil particles in place. This function ranked high.

Water Quality Maintenance Function

Factors which contribute to Wetland 3A's ability to enhance water quality include its semi-closed basin shape and the semi-diffuse flow through the emergent and shrubby vegetation within the basin. The opportunity to take up nutrients and bind hazardous materials is provided by the permanent flow of the Aberjona River, which passes through upstream areas with potential non-point sources of pollutants. This function is ranked high.

Economic, Recreational, Aesthetic and Educational Functions

The social values for this wetland ranked low, with the exception of educational value which ranks moderate. There are no harvestable resources of high value to humans, the wetland is small in size and access is partly restricted by the Site fence and limited access highway. Portions of this wetland are aesthetically pleasing but opportunities to view it are few. High diversity of cover types and plant species enhances the educational value of this wetland, though current educational opportunities are low.

14.3.2.4.2 Functionality Goals

Functions performed by Wetland 3A which should be improved during wetland restoration, as part of the compensatory design (Section 14.6.2), include biological-wildlife habitat, hydrologic support, water pollution attenuation, protection of the river shoreline, and recharge of groundwater. Social values will be enhanced by Site remediation.

14.3.2.5 Wetlands 7A, 7B, and 7C - Chromium Lagoons and Channelized Swale

The two Chromium Lagoons, Wetlands 7A and 7B, are small (0.3 and 0.4 acres, respectively) S-shaped excavations previously used as sedimentation ponds for waste water

containing chromium (Figures 14-6 and 14-7). Both lagoons are dominated by purple loosestrife and common reed, with a few scattered shrubs around the edge, including European buckthorn, meadowsweet, grey birch, pussy willow, and blackberry (*Rubus allegheniensis*). The water depth is typically 3 to 4 feet in 7A and 2.5 to 3 feet in 7B, and the 5-foot high banks are steep. A berm separates Wetland 7B from a small red maple swamp.

The channelized swale, Wetland 7C, is also steep-sided and densely vegetated with common reed. It conducts surface water runoff from the Janpet and Chestnut Hill Realty Trust properties, and storm drain flow from Atlantic Avenue, under the railroad tracks, to the Halls Brook Holding Area. There are no surface water connections between Wetlands 7A, 7B and 7C.

Rocky debris has been placed at the northern edge of the Chromium Lagoons. The grassy lot to the north contains hides and remnants of structures associated with the previous land use. The lagoons, the swale, and the surrounding land have metal concentrations above Consent Decree Action Levels.

14.3.2.5.1 Functional Assessment

This functional assessment was performed only on Wetland 7B, but the results (Table 14-6) are equally valid for Wetland 7A. The functional values of Wetland 7C are similar to Wetland 2A, another channelized drainway (see Section 14.3.2.2.1).

Biological-Wildlife Function

Classification of Wetland 7B as a shallow, freshwater marsh attains a moderate ranking for the biological-wildlife function despite the assignment of relatively low-value scores throughout most of the remainder of the model. For instance, there are low values for both habitat and species diversity, for the interspersion of cover types among each other as well as with water. The wetland is not connected hydrologically with other wetlands, nor is it very close to any other significant wetland area. It is small and dominated (to 90% of cover) by two plant species of low value to most wetland wildlife, purple loosestrife and common reed. Both muskrat and Canada geese were observed nesting in Wetland 7A, however it is less than ideal or healthy habitat, and its ranking was modified to low.

Hydrologic Support Function

A small wetland, with no inlets or outlets, and a closed basin, rates low for this function both in the model calculations and in the final qualitative appraisal.

Groundwater Recharge Function

Wetland 7B attains a moderate rating for recharge by virtue almost exclusively of its closed basin shape. In most other ways, it provides few actual or potential benefits, because of its small size, low flow and relatively low substrate permeability and transmissivity.

Floodwater Storage Function

This wetland's basin shape benefits catching storm runoff and releasing it belatedly, thus attenuating flood crests downstream. Otherwise, the wetland has little to enhance this function except high stem density and a headwater position in its catchment. Factors reducing its flood control ranking from moderate to low are its small size,

low substrate permeability and transmissivity, and lack of inlets and outlets.

Water Quality Maintenance Function

The dominant wetland class of shallow freshwater marsh confers high value for this function, as does the lesser but related factor of high stem density. The most supportive factor is the confining basin shape, which realizes maximum detention time, indeed complete retention in the case of all but the biggest, most infrequent runoff events. Limiting the wetland's calculated rating for this function are its small size, thin organic substrate, and headwater topographic position. In this last case, the site's concentrations of heavy metals affords ample opportunity for wetland purification, despite the wetland's location high in the catchment basin. This combination of characteristics yields a reasonable rating of moderate value.

Economic, Recreational, Aesthetic and Educational Functions

The absence of exploitable wetland products dictates a low economic rating. Small size, low diversity, low scarcity value, poor physical and legal accessibility all act to depress the recreational and educational model ratings. The aesthetic rating also responds negatively to some of the same factors. However, the dominant wetland class of shallow freshwater marsh accords it some importance in the model calculations, as does the presence of purple loosestrife (50% cover). Given the artificial nature of this wetland's steep slopes and the unhealthful, unsightly residues of past industrial activity in the adjacent upland, the rating was adjusted downward to low.

14.3.2.5.2 Functionality Goals

The two Chromium Lagoons appear to benefit the public only by their moderate groundwater recharge and water quality maintenance functions. Groundwater recharge can best be accomplished elsewhere in the Halls Brook watershed. Water quality improvements will occur through Site remediation. The value of the remaining functions is exceeded by the benefits of Site remediation.

14.3.2.6 Wetland 8

Wetland 8 (Figure 14-8) is a 0.2-acre scrub-shrub/emergent wetland located just west of the MBTA rail line. The vegetation has been maintained in an early successional stage, and includes common reed, hardhack (*Spiraea tomentosa*), European buckthorn, and several grass and sedge species. Shallow standing water is present seasonally. This wetland drains to the New Boston Street Drainway and to Halls Brook, which then flows under the railroad into the Halls Brook Holding Area. Metal concentrations above Consent Decree Action Levels were found in the sediments in the vicinity of Wetland 8 together with hide residues.

14.3.2.6.1 Functional Assessment

The modified Hollands-Magee Functional Assessment ratings and final professional rankings for Wetland 8 appear in Table 14-7.

Biological-Wildlife Function

The moderate rating attained by this function is only marginal. The main factors favoring the moderate rating are the shrub-swamp dominant wetland class, moderate cover dispersion, availability of a groundwater supply and juxtaposition to adjacent wetlands downstream. Hydrologic support of the above factors is, however, minimal, given the fact that surface water (both ponded and running)

occurs only seasonally. The main factors indicating low biological value include small size, poor quality surrounding habitat, low habitat and species diversity and low interspersion of plant cover types. These negatives are here considered sufficient to reduce the rating of this function to low.

Hydrologic Support Function

This function also attains a calculated rating (moderate) greater than the facts allow. By far the single biggest factor favoring the moderate rating is the wetland's semi-closed basin shape. However, the wetland neither collects much water nor discharges much. There are no inlets, and its outlet is ephemeral.

Groundwater Recharge Function

Small wetland size, low flow, low permeability and transmissivity of the wetland substrate all contribute to a low rating for this function.

Floodwater Storage Function

The wetland is small and its flow volume low, but other factors raised the model rating for this function to moderate. These include the shrub-swamp dominant wetland type with its low-set stem and foliage density; the semi-closed basin shape that detains ponded water; the position of this wetland high in its catchment, where flood-crest desynchronization is often most readily effected. The small size and absence of inlets makes a low ranking more reasonable.

Water Quality Maintenance

A wetland of such small size and low flow cannot be rated especially high for this function. On the other hand, the dominant plant cover, shrub swamp, serves as a filter to trap suspended particulates. The semi-closed basin also improves the wetland's water-processing potential, as does the moderately permeable organic sediment, and the rating for water pollution attenuation is moderate.

Economic, Recreational, Aesthetic and Educational Functions

All of these functions rate low. Contributing factors common to all or most functions include small wetland size, absence of open water, and the more or less homogeneous shrub-swamp plant cover.

14.3.2.6.2 Functionality Goals

Wetland 8 benefits the public most by its moderate hydrologic support of low flows to Halls Brook, and water quality maintenance. Hydrologic support for Halls Brook is minor relative to that provided by other streams and wetlands in the watershed, so maintenance of hydrologic support is not a primary goal. Maintenance of water quality functions on Site will be a primary goal of mitigation design.

14.3.2.7 The New Boston Street Drainway

The New Boston Street Drainway is a channelized stream that directs surface water flow from north and west of the Site south along New Boston Street into the storm drain system of the industrial park and out to Halls Brook. The New Boston Street Drainway is assumed to be a perennial stream, and is so symbolized on the U.S.G.S. Topographic Map, Wilmington Quadrangle.

The New Boston Street Drainway receives surface water flow from a culvert under New Boston Street and from a wetland just east of the Woburn municipal landfill. This perennial drainway flows south parallel to New Boston Street, then enters a culvert at its confluence with the channel draining into New Boston Street Drainway from the west. It surfaces in the Boston Edison Right-of-Way No. 9 and flows aboveground to Halls Brook. The banks of this drainway range from steep to gradual, and are vegetated with early successional species of shrubs, herbaceous plants, and small trees. The stream substrate is a combination of sand, silt, and gravel, with submergent vegetation present.

Both hide residues and metals above action levels have been detected in this area. Odors and algae growth in the stream may be evidence of water quality degradation by discharges from sources upstream of the site.

14.3.2.7.1 Functional Assessment

An individual functional assessment was not undertaken for this drainway. The functions and values of the New Boston Street Drainway are assumed to be virtually identical (within the resolution of the modified Hollands-Magee models) with those of the perennial stream they resemble, Wetland 2B (the channelized Aberjona River). The discussions of Section 14.3.2.3.1 can be applied to this drainway. The only characteristic which differs is site accessibility. Access to the New Boston Street Drainway is not restricted by fencing, but social values are still low.

14.3.2.7.2 Functionality Goals

The functionality goals of the New Boston Street Drainway are also similar to those of Wetlands 2B and 2A. The flow of water across this project site must be maintained, and prevention of downstream transport of hide residues and heavy metals is a priority.

14.3.3 Summary of Results

The professional rankings of wetland functions and functionality goals are summarized in Table 14-8. Most of the wetlands rank low for the social functions (economic, recreational, aesthetic and educational functions). Although improving the ability of remediated wetlands to perform these functions is not a primary functionality goal, aesthetic and passive recreational opportunities will increase when sediments with metals above Consent Decree Action Levels and/or hide residues are covered and revegetated, and Site access is no longer restricted. The groundwater recharge function, for which most of these wetlands also rank low, will not be substantially impacted by the permeable cover prescribed for Wetlands 1C, 7A, 7B and 8 and portions of the surrounding uplands.

The drainways on the Site conduct surface water across the Site from north to south. The functionality goals for these drainways are to continue to permit the flow of water and the nutrients and biological organisms it carries to downstream wetlands and water bodies, while preventing downstream transport of sediments with metals above Consent Decree Action Levels and/or hide residues.

Wetlands 7A and 7B, the isolated Chromium Lagoons, have functions which primarily rank low relative to other wetlands in the northeast. The sediments in these wetlands have chromium above Consent Decree Action Levels and hide

residues, and the primary functionality goal is to eliminate the negative values of the sediments by isolating them from the biological systems on Site.

The functionality goals of Wetland 1C, a larger, more diverse wetland, includes maintaining the wildlife habitat values, floodwater storage capabilities, shoreline protection, and water pollution attenuation properties currently exhibited.

14.4 IMPACT ASSESSMENT

The development of a wetland mitigation design for remediated wetlands at the Site involved the following steps:

1. assessment of remediation impacts to wetlands and drainways, including loss of area by resource type, loss of flood water storage volume, and loss or gain of functional value;

2. development of wetland revitalization plans for remediated wetlands which still retain hydrology sufficient to support hydrophytic vegetation (Wetland 1C);

3. identification of functionality goals not met by revitalization alone;

4. design of wetland mitigation which incorporates the physical and biological elements most influential in determining a wetland's ability to provide the lost or impaired functions, and that also meets other mitigation requirements which appear in the ARARs; and

5. establishment of design and dynamic performance standards, and creation of inspection and maintenance plans for attaining those standards.

These steps were initially discussed in the 95% Design Report and are presented here in final form.

14.4.1 Calculation of Impacts to WMS-delineated Wetlands and Drainways

14.4.1.1 Wetlands

The areas of Wetlands 1C, 7A, 7B and 8 were obtained through planimetry of areas depicted on 1 inch = 100 feet plan sheets onto which WMS-delineated wetlands and drainways were drawn. Remedial activities for each wetland were identified from plan Sheet 13-1. This information was transferred to the 1991 bathymetric survey plans (Appendix 10-H) to determine the post-remedial wetland area.

Dredging to a depth of at least 16 inches before placement of a permeable cover of the same thickness (the proposed remedy for 0.7 acres of Wetland 1C) is considered to result in no permanent loss of wetland area. This dredged and capped wetland area will, however, require revitalization following remediation. The placement of a 16-inch above-grade permeable cover over wetland sediments was considered to result in the permanent loss of all wetland areas with less than 10 inches of standing water at seasonal high water levels. This elevation was chosen because restoration plans call for replanting these wetlands with plants having fibrous root systems (thus creating only wet meadows or marshes). These fibrous-rooted species were chosen because they are less likely to penetrate through 16 inches of cover soils and the geotextile to the sediments below than dicotyledonous species with long tap roots. It was assumed that such shallow-rooted wetland vegetation can only be sustained in those areas saturated within 6 inches of the new soil surface. Therefore, it has been conservatively estimated that the new wetland boundary will occur approximately at a point where the top of the 16 inch cover is 6 inches higher than the seasonal high water elevation. Wetland above this elevation will be permanently changed to upland, and the impacts will be mitigated through compensatory measures. Wetland areas below this elevation will be altered and mitigated by revitalization in place, and additional compensation for wildlife habitat and floodwater storage will be provided in a compensatory wetland.

Above-grade permeable covers are planned for Wetlands 7A, 7B, 8, and parts of 1C. Wetlands 7A and 7B (0.7 acres based on planimetering of WMS wetland boundaries on 1 inch = 100 feet plan sheets) will be covered and additional fill placed for an added measure of safety due to high metal

concentrations in sediments and the presence of hide residues, thus eliminating the wetlands. Wetland 8 (0.2 acres) will also be completely eliminated since all of its area appears to be less than 10 inches below the seasonal high water table. In Wetland 1C, placement of an above-grade permeable cover will be coupled with a rise in water levels due to remedial activities in the outlet stream (Wetland 2A). The boundary of Wetland 1C as originally drafted on 1 inch = 100 feet topographic plans corresponds approximately to the 72-foot contour. Using this elevation as the wetland boundary on the 1991 bathymetric survey allows computation of the wetland impact area resulting from Site remediation. Placement of the above-grade permeable cover and raising water levels from approximately 70.4 feet msl to 71.0 feet msl (the elevation of the new outlet channels) will result in a net loss of approximately 2.1 acres of wetland. The total WMS-delineated wetland area converted to upland as a result of remediation is approximately 3.0 acres.

The resource areas within Wetlands 1C, 7A, 7B, and 8 as defined by the Massachusetts Wetlands Regulations (310 C.M.R. 10.00-10.99), were identified based in part on the 1991 bathymetric survey (Table 14-9). All resource areas within wetlands receiving above-grade permeable covers will be impacted. The predominant resource area within Wetland 1C is Land Under Water. Some of this resource area will become more shallow and be converted to Bordering Vegetated Wetland as a result of remediation. Steep Banks will be altered in some wetlands as a result of either above-grade or at-grade covers, and will become gentle slopes. The shrubby and emergent border of Wetland 1C, a Bordering Vegetated Wetland which provides important wildlife habitat, will be permanently impacted. Other resource areas are not expected to be permanently impacted by the

at-grade permeable cover. No impacts to Bordering Land Subject to Flooding are expected based on the Flood Insurance Rate maps for the City of Woburn (Federal Emergency Management Agency, 1977). Changes to wetland flood storage volumes as a result of remediation are described in Chapter 10.

14.4.1.2 Drainways

Remedial activities for the drainways are depicted on Sheet 13-1. No loss of stream length is anticipated as a result of remediation, since all of the drainways are already ditched and straight. One culvert will be installed within Wetland 2A (the outlet of Wetland 1C) to pass water safely past the East-Central Hide Pile. This culvert will reduce the amount of low quality fisheries and wildlife habitat by 0.2 acres, but will improve the quality of downstream habitats. Sediments in portions of the New Boston Street Drainway, the channel draining into the New Boston Street Drainway from the west, Wetland 7C, and the remaining portions of 2A will be dredged and replaced with clean gravel/cobble material. The top of the banks will be revegetated with shallow rooted shrubs and herbs to provide shade for aquatic habitats and cover for wildlife (see Section 14.5.2). No permanent impacts are expected and no additional revitalization is planned for these areas.

14.4.2 Impacts to Wildlife and Aquatic Communities

14.4.2.1 Wildlife Impacts

The Industri-Plex Site, although in a highly disturbed condition, is used by many wildlife species as noted during Site visits by various project personnel (Table 14-1). It is also likely that additional wildlife species use the Site. Although no rare wildlife species are known to occur in the area, the Site may be important to local populations of common wildlife species. The surrounding development

limits the amount of wildlife habitat available in the area, thus raising the value of the remaining undeveloped land. On parts of the Site, however, metals and hide residues are present above Consent Decree Action Levels and may potentially affect wildlife living in these areas.

The proposed remediation plan for the Site includes placing permeable and impermeable covers over much of the western portion of the Site (Sheet 11-3A through 3D) to isolate the metals and hide piles from humans and animals. Most of the eastern part of the Site and the Boston Edison powerline Right-of-Way No. 9 on the western side will be left in their existing conditions. This includes less disturbed forested habitats and ponds that have higher existing wildlife habitat value than much of the western part of the site.

Permeable covers in uplands require clearing and grubbing vegetation, grading, and placing 16 inches of cover soil over a geotextile. In other areas sediments will be dredged first and replaced with clean soils. A few areas will be paved with asphalt or have a gravel surface (see Sheets 11-3A through 11-3D for locations); all others will be planted. Most of the planted area will become grassland, but several wetland mitigation areas will be constructed (Sheets 14-1, 14-4 and 14-6; also see Section 14.5 and 14.6). The grasslands will be maintained by mowing to prevent woody species from invading the area and damaging the cap with their deep root systems. The wetland mitigation and enhancement areas will include several cover types including shallow marsh, wet meadow, shrub and forested wetland.

These changes in habitat will have both short- and long-term effects on wildlife at the Site. Short-term impacts include removal of vegetation (food and cover for wildlife), soil disturbance (which may destroy wildlife dens and burrows), increased noise and human activity on the Site (which can result in animals leaving adjacent areas to avoid the disturbance), and direct mortality of some on-Site wildlife caused by physically moving or covering over soils and vegetation in which animals live (such as turtles in the wetland sediments). Long-term effects include reduction of the metals and hide residues to which wildlife are exposed on Site, elimination of on-Site debris and foundations, changes in habitat types available to wildlife, reduction of both structural and vegetation species diversity, and alteration of substrate types available for burrowing wildlife species. These effects are described in greater detail in the following sections.

Temporary Impacts

The process of clearing and grubbing vegetation, grading land, laying down the 16-inch permeable cover, and dredging and sediment replacement in other areas will have short-term impacts on wildlife including direct mortality of some animals, displacement of others, increased disturbances caused by human activities, and sudden changes in habitat types.

Direct mortality would be most likely for fossorial mammals, reptiles and amphibians (especially during winter hibernation) and breeding animals and their young whose dens or nests are destroyed by clearing and grading. More mobile animals may migrate to other habitats when disturbed by construction. These migrants may find habitat that has

sufficient food and cover to support them if adjacent habitats are not already at carrying capacity.

Much of the eastern portion of the site is undeveloped and in a less disturbed condition than the western portion and will likely provide habitat for some of the animals displaced by the remediation. There is a limited amount of undeveloped habitat adjacent to the Site where displaced wildlife could also attempt to relocate. Commercial/industrial development surrounds three sides of the property and Interstate Route 93 forms the eastern boundary. It is likely that mobile animals displaced by the remediation, such as birds, squirrels, raccoons (*Procyon lotor*), muskrats, cottontails, otter, and woodchucks, may find new habitat. Less mobile animals, such as frogs, snakes and small mammals, may be unable to reach suitable alternative habitats. Those animals that are unable to locate sufficient food, cover or territorial space may fail to breed successfully, be forced to wander further, and may die.

The construction process would increase disturbance on-Site by increasing noise levels, vehicle traffic and the number of workers on foot. Many animal species habituate to continuous noise including traffic noise; however, sudden loud noises, such as construction noise, are more of a disturbance. Wildlife using the Site habitats are probably tolerant of traffic noise due to the surrounding development, but may be sensitive to construction noise and activities. Loud noises associated with construction also could mask territorial vocalizations of species, temporarily interfering with breeding.

Vehicle and pedestrian traffic also could disturb wildlife. Sections of the Site are fenced and have restricted public access; therefore, the amount of vehicle and pedestrian activity in these sections is limited to the occasional presence of workers. The presence of heavy machinery and people on foot would increase during construction. Pedestrian activity is generally more of a disturbance to wildlife than noise or vehicular movements and may cause some animals to leave the Site.

Sudden changes in habitat types and quality due to construction can have important effects on wildlife, especially if the changes occur during critical periods. Disturbance of wildlife habitat during the breeding season and while young are being reared can reduce or prevent successful reproduction. Amphibians breed in ponds and streams in early spring and their young may stay in these areas for up to two years. Birds breed and rear their young from approximately April through July in eastern Massachusetts. Small mammals may have several litters of young throughout the spring, summer and early fall months. As these areas are revegetated, wildlife habitat value will be reestablished, although changes in habitat types and successional stages create long-term effects on wildlife in the area.

Long-Term Impacts

The proposed remediation will reduce the exposure of metals and hide residues on the Site and thus reduce their potential effects on wildlife resources. This is one of the objectives of the remediation.

The clearing and grading of the Site will include removal of old foundations and debris, such as bricks, iron reinforcement bars and other materials left on Site from past industrial operations. Areas that are currently occupied by foundations and debris have extremely limited wildlife habitat value. These areas will gain value as wildlife habitats when they are cleared, graded and replanted.

The most significant impact of the planned remediation on wildlife is the long-term change in habitat types on much of the western part of the Site, from a mosaic of forests, shrubs, common reed, disturbed-field areas, and wetlands to an area dominated by maintained grasslands and shallow marsh. A few other habitat types will be present on the western side. Two wetland areas will be constructed: a wetland enhancement area south of the West Hide Pile, and a shrub/forest compensatory wetland area west of the East Central Hide Pile with a revegetated upland buffer. Two open water sections of Wetland 1C will be left uncapped. Most of remaining areas on the west side of the property that will be left in their current condition are developed. A few small areas of young hardwood, shrub and disturbed soils with sparse herbaceous vegetation also will be left unchanged (Sheet 11-3A).

Grasslands have lower structural and vegetation species diversity than much of the existing habitat at the Site. A reduction in diversity reduces the variety of food and cover resources available to wildlife. This results in changes in the numbers and types of wildlife species that will potentially use the area after remediation. Vegetation species diversity will increase to some degree over time due to natural recruitment from the surrounding area.

Grasslands are used by such species as eastern American toad (*Bufo a. americanus*), eastern box turtle (*Terrapene c. carolina*), northern brown snake (*Storeria dekayi*), killdeer (*Charadrius vociferus*), savannah sparrow (*Passerculus sandwichensis*), ring-necked pheasant (*Phasianus colchicus*), eastern cottontail, woodchuck, meadow vole (*Microtus pennsylvanicus*), and red fox (*Vulpes vulpes*). The remediated Site would provide habitat for these species, but species that rely on shrubby or forested habitats would have less area available to them. Some shrubland and forest species that could be affected by this change include red-spotted newt (*Notophthalmus v. viridescens*), common yellowthroat (*Geothylypis trichas*), ruffed grouse (*Bonasa umbellus*), black-capped chickadee (*Parus atricapillus*), southern red-backed vole (*Clethrionomys gapperi*), striped skunk (*Mephitis mephitis*), and raccoon.

Another issue related to the conversion to grassland is that burrowing animals, such as woodchucks and muskrats, may potentially damage the permeable cover by burrowing through it. The construction of animal burrows in the permeable cover within wetlands will be discouraged by manipulation of soil texture. A 4 to 8-inch layer of gravel will be placed directly on the geotextile and covered with an additional 8 inches of the appropriate topsoil cover. This gravel medium should prove difficult to burrow through for the mammals, reptiles, and amphibians expected to inhabit the remediated wetlands. An inspection and wildlife damage control program will be implemented to prevent burrowing in uplands from damaging the permeable and impermeable covers.

Mowing is required to prevent woody vegetation from invading the grasslands. The schedule of mowing can have a significant effect on the wildlife habitat value of a grassland. Mowing during the spring and early summer can interfere with breeding, nesting and brood-rearing. Protective cover of tall grasses and forbs is particularly important for nesting birds. Tall vegetation also contains more insects and other food resources for wildlife. Ideally, mowing should occur once annually during late summer after seed heads have formed and this is reflected in the Operations and Maintenance Plan for the Site (Chapter 19). This ensures that the seeds are available as a wildlife food resource and also to provide future generations of plants. Mowing before the end of the growing season also allows the stubble to continue growing before winter. This creates better winter cover for small mammals and birds.

There will be a small loss of open water and stream habitat in the area. Some of the open water in Wetland 1C will be partially filled by the permeable cover, creating more shallow marsh and wet meadow and less open water habitat. This reduction in open water and stream habitat will reduce food and cover availability for water-dependent species such as painted turtle (*Chrysemys picta*), snapping turtle (*Chelydra s. serpentina*), green frog (*Rana clamitans melanota*), great blue heron (*Ardea herodias*), belted kingfisher (*Ceryle alcyon*), muskrat (*Ondatra zibethicus*) and river otter (*Lutra canadensis*). A 550-foot long section of the drainway from Wetland 1C (Wetland 2A) north of the East Central Hide Pile will flow through a concrete culvert to the confluence with the North Branch of the Aberjona River. This loss of low quality stream habitat and wetland wildlife habitat will be mitigated.

The New Boston Street Drainway, its inlet channel from the west, and the remaining part of Wetland 2A will be dredged and sediment will be replaced with clean cobble and gravel. This process will remove vegetation that may be used by wildlife from the banks and bottoms of these areas. This temporarily reduces the already low habitat value of the drainways, but the value will be regained when the area naturally recolonizes. Shallow-rooted overhanging shrub cover will be reestablished so these areas will continue to have aquatic and wildlife habitat value.

The eastern part of the Site and much of the Boston Edison Right-of-Way No. 9 on the western side will be left in their existing conditions. This includes the less disturbed northeast corner of the Site where hardwood forest is dominant and shrublands are present along the North Branch of the Aberjona River. There is also an area of wetlands and young hardwood trees and shrubs northeast of the north end of Commerce Way that will be left in its existing condition. The Phillip's Pond area, Wetland 3B, and Wetland 3C will not be adversely impacted, thus most existing pond habitat will be maintained on the eastern side of the property. These areas, being in a less disturbed state than much of the western side of the property, have a relatively high wildlife habitat value.

14.4.2.2 Aquatic Community Impacts

The ecological risk assessment for the Industri-Plex Site (Roux et al., 1991) includes an evaluation of existing fish and macroinvertebrate communities at upstream, downstream, and on-Site locations. Some of the on-Site ponds were found to support common warm water fish such as pumpkinseeds (*Lepomis gibbosus*) and golden shiners (*Notemigonus crysoleucas*). Chironomids (midges) and oligochaetes (worms) were common benthic macroinvertebrates

observed in ponds (Roux et al., 1991). The Aberjona River just south of the Site supported pumpkinseeds and American eels (*Anguilla rostrata*) and a benthic community that included flies, midges and worms. The study concluded that all aquatic species observed were common and relatively tolerant of pollutants and other adverse water conditions. Community diversity was low for upstream and on-Site samples; however, on-Site samples had a greater proportion of the most pollution tolerant species, indicating possible Site-related aquatic impacts. Low diversity at all biological sampling stations was attributed to naturally low productivity of headwaters, non-point source pollution (stormwater highway runoff), and past channelization of streams. Conditions within the New Boston Street Drainway and Halls Brook Holding Area appear to pose the greatest risk to the aquatic community, but any effect of metals on the aquatic community is likely the result of combined chronic effects, since acute toxicity levels were not observed (Roux et al., 1991). Remediation activities at the Site are expected to have some long- and short-term effects on these aquatic resources.

Temporary Impacts

Temporary impacts to aquatic communities on-Site and downstream will occur in areas to be dredged and capped (i.e., New Boston Street Drainway and its inlet channel from the west). Recolonization of the new substrate with a macroinvertebrate community common to gravel/cobble substrate is expected over time. Potential erosion and sedimentation impacts will be controlled through implementation of standard measures, such as silt fences, barriers, check dams, natural vegetation buffers, mulches, temporary vegetative cover, etc. Specifications for products and execution of erosion and sedimentation control are included in Volume 7.

Long-Term Impacts

Long-term remediation effects on aquatic communities include both positive and negative impacts. Positive effects on the health and diversity of aquatic communities is expected from a reduction in exposure to sediments with metals above Consent Decree Action Levels which may currently be depressing community diversity (Roux et al., 1991). Creation of compensatory wetlands and wetland restoration will also have a long-term positive effect on aquatic communities.

Minor long-term negative effects may occur from placement of a culvert in Wetland 2A, and diversion of some flow from Wetland 1C to the compensatory mitigation area. In their current state, the benthic habitats in Wetland 2A and the other drainways on-Site are considered less than adequate to support diverse aquatic communities (Roux et al., 1991). However, the covering of this habitat with a concrete culvert in part of Wetland 2A will result in a further reduction of common macroinvertebrate populations. This habitat loss will be mitigated by restoring a 0.3 acre portion of the North Branch of the Aberjona River (Wetland 3A) which was previously filled with road construction materials placed prior to entry of the Consent Decree. The clean gravel/cobble substrate to be placed in other parts of Wetland 2A, the New Boston Street Drainway, and the channel to the west of the New Boston Street Drainway will eventually be colonized by new aquatic communities, and the long-term effects are expected to be positive.

The vegetation on the upland soil covers of the Site will be actively maintained as herbaceous meadows to protect the underlying geotextile from penetration by large, woody roots of trees and shrubs, but drainways adjacent to these

covers will be revegetated with shallow-rooted overhanging vegetation which will eventually provide cooling shade and organic input in the form of leaves. The revitalization of covered wetland areas and creation of a compensatory wetland will provide densely vegetated shallow marshes and shrub swamps which will contribute additional organic matter to the aquatic system. While a rise in water temperature is possible shortly after remediation, the aquatic communities of the Site are comprised of species which are tolerant of warm water. The streams contributing the most flow to the downstream aquatic resources (i.e., Halls Brook, and the North and South Branches of the Aberjona River) will not be impacted by remediation.

Mitigation of wetland remediation impacts will be accomplished by creating a new wetland, enhancing a section of Wetland 1C, and restoration activities in the North Branch of the Aberjona River. The created wetland will require surface water flow from Wetland 1C, thus reducing the flow which enters the Aberjona River during low flow months by approximately 10 percent, at a point just below the confluence with the Western Branch. This minor impact to an already disturbed system will be offset by the habitat improvements gained through wetland and stream mitigation (see further discussion in Section 14.6.1).

An investigation was conducted to determine if the proposed sediment remediation would impact habitats for rare vertebrate or invertebrate species on the Industri-Plex Site (see Appendix 14-B). The Massachusetts Natural Heritage and Endangered Species Program indicated that a Species of Special Concern, the Mystic Valley amphipod (*Crangonyx aberrans*) may occur within the immediate vicinity of the Site. Field investigations were conducted

to determine if suitable habitat for *C. aberrans* or the amphipods themselves are present on-Site.

Suitable habitat for *C. aberrans*, as described by Smith (1983) and the Massachusetts Natural Heritage and Endangered Species Program (no date), appears to be present on the Site. Wetland 3A provides the most suitable habitat, a lowland swamp with slow moving water. Small, isolated ponds are also considered suitable for *C. aberrans*. A wide variety of habitat types were sampled.

Twenty-six macroinvertebrate samples were taken from seven streams and wetlands on-Site (including Wetland 3A), and two locations off-Site in June of 1991. *C. aberrans* was not identified in any of the samples. Other species of amphipods that are not classified as Species of Special Concern, including *C. pseudogracilis*, were collected.

Based on these findings, it appears there are no populations of *C. aberrans* present and the remedial actions will improve Wetland 3A, that appears to be the most suitable potential *C. aberrans* habitat.

14.4.3 Summary of Impacts

Minor permanent losses of wildlife habitat diversity and floodwater storage functions will occur within the portion of Wetland 1C receiving an above-grade permeable cover, even though 1.8 acres of this area will be revitalized and will retain many other wetland functions (Table 14-10). Approximately 3.0 acres of wetland habitat (in Wetlands 1C, 7A, 7B and 8) will be permanently impacted by remedial activities with total loss of wetland function. Approximately 0.2 acres of stream and bank habitat will be permanently impacted with total loss of biological

function. Loss of floodwater storage capacity for the Site is discussed in Chapter 10.

The permanent loss of 3.0 acres of wetland habitat and a portion of the floodwater storage loss (a minimum of approximately 703,500 cubic feet) will be compensated by a 2.8-acre created wetland with a 1.0-acre upland buffer. A 2.2 acre wetland enhancement area will also be created contiguous to the southwest portion of Wetland 1C. This shrub swamp/wet meadow/marsh community will be connected to the compensatory wetland by a stream, providing a wildlife travel corridor. The resulting wildlife habitat within Wetland 1C and the created wetland will mitigate for the minor habitat losses within the portion of Wetland 1C receiving an above-grade permeable cover. The 0.2 acres of permanent stream impacts will be compensated by an additional 0.3-acre stream restoration area adjacent to the North Branch of the Aberjona River. This mitigation area will provide aquatic habitat adjacent to permanently flowing water. In addition, the tree and shrub buffer will be supplemented along the south shore of Wetland 3A to further enhance the wildlife habitat values, and trash and debris in this stream will be removed.

The remediation plan includes removal of sediments from some areas and covering much of the western part of the Site with a vegetated soil cover. This will result in short-term impacts to fish, wildlife, and aquatic macroinvertebrates including sudden and temporary loss of food and cover resources, increased human disturbance, and direct mortality of some animals during the construction process. Sedimentation and erosion control measures will reduce potential impacts to aquatic habitats. More significant long-term effects include reduced exposure of heavy metals and permanent changes in habitat types. Much

of the uplands on the western part of the Site will be converted to grassland habitat that has lower structural and vegetation species diversity than the existing mosaic of habitats. This will alter the composition of wildlife species using those parts of the Site. The revitalized and compensatory wetland areas and much of the eastern portion of the Site, which will be left unaltered, will contribute some habitat diversity to the Site.

The negative impacts described above are necessary if the Site is to be remediated. The changes in habitat types are less significant than the positive effects of reducing the potential exposure of people, wildlife and fish to metals and hide residues that are currently on the Site.

14.5 REVITALIZATION OF WETLAND 1C AND DRAINWAYS

14.5.1 Wetland 1C Revitalization Design

The goal of wetland revitalization is the restoration of the functional values of the original wetlands before remediation, which are summarized in Table 14-11. Elements important to the performance of each of the functions according to the Hollands-Magee models are listed in Table 14-12. The elements which can be manipulated to most nearly achieve the specific functionality goals given the required remediation techniques include soil characteristics, vegetation species composition and vegetation density. Topsoil characteristics suitable for maintaining wetland vegetation are described in Section 14.5.3 (Product Specifications). The design plans and cross-sections for revitalization of Wetland 1C are presented on Sheets 14-1 through 14-3.

General Considerations

In order to meet the functionality goals, it is essential that the revitalization design result in the development of viable wetland communities. Therefore, general design considerations focus on the reestablishment of wetland hydrology. Topsoil characteristics suitable for maintaining wetland vegetation and the selection of appropriate hydrophytic vegetation are described in Section 14.5.3 (Product Specifications). Performance standards and success criteria for both revitalized and compensatory wetland designs are listed in Table 14-13.

Seasonal high water elevations in Wetland 1C were assumed to be equal to the proposed invert elevations for the controlling outlet streams. Wetland 1C will have two outlets with invert elevations at 71.0 feet (Sheet 13-1). One will be a 4-foot wide gravel/cobble-lined stream flowing to the created wetland and the other outlet will be

a gravel/cobble-lined stream channel connecting to the West Branch of the Aberjona River. Consistent with the proposed outlet elevations, the future regulated water level for Wetland 1C was estimated to be at 71.0 feet NGVD. The establishment of wetland vegetation is conservatively expected to extend at least out to the 71.5-foot contour due to soil saturation in the upper topsoil layer.

Design guidance provided by Marble (1990) was utilized to determine the wetland community types most appropriate for the hydroregimes within the revitalized wetland. Wetland community types, hydrologic regimes necessary for the establishment and maintenance of these communities, and appropriate water levels are listed in Table 14-14.

The proposed post-remediation wet meadow, shallow marsh, and deep marsh/open water habitats are depicted on Sheet 14-1. Cross-sectional views showing the relationship of these habitats to water level elevations and estimated final grade contours appear on Sheets 14-2 and 14-3. The plan view depicts approximate wetland community boundaries. Cross-sections depict anticipated final grade elevations. Upland habitats are also labelled. Upland grading plans are shown in Sheets 11-7A through 11-7D. Wetland to upland cover transition details can be found on Sheet 12-7.

Actual water levels will be recorded monthly during the growing season starting immediately after final grading is completed. Shallow groundwater piezometers will be installed in wetland areas to a depth of 16 inches using a hand soil auger. A minimum of one well will be set for each 0.5 acre of wetland. Piezometers will consist of 2-inch interior diameter, schedule 40 PVC with 0.01 inch horizontal slots on at least 12 inches of the lower portion

of the well. Soils recovered during augering will be used as back fill around the well. Once firmly in place, the height of each piezometer above ground surface will be determined. The information generated will be used to refine the planting plan if necessary.

Specific Design Elements

Specific design elements to address the revitalization functionality goals are described below for the areas receiving an above-grade cap. Revitalization plans and specific design elements for the area to be dredged prior to capping are discussed in Section 14.6.1. The revitalization design for the portion of Wetland 1C to be dredged and covered was developed in conjunction with the compensatory mitigation designs of the creation and enhancement wetlands; the direct hydrologic connections among all three areas require close coordination of designs. Thus, the remaining revitalization goals as well as the compensatory mitigation goals are addressed in Section 14.6 (Additional Wetland Mitigation).

Functionality goals for the revitalization of the 1.8 acres of Wetland 1C receiving an above-grade permeable cover are to maintain its biological, hydrological support, flood water storage, water quality maintenance, and shoreline protection functions, and to improve aesthetic values. Because of the loss of valuable shrub and bank habitat during remediation, incorporation of design elements to maintain and enhance the value of the remaining wetland area for wildlife habitat is a primary concern. Design elements that concurrently address the maintenance of both high quality habitat and hydrological value are utilized as much as possible; aesthetic and shoreline protection considerations enter primarily into the final choice of

species. Specific design elements incorporated to maintain the wildlife habitat value of Wetland 1C are

- creation of three vegetation classes (deep marsh/open water, shallow marsh and wet meadow) to promote structural diversity;
- creation of a densely vegetated shallow marsh adjacent to the nonrevitalized open water/deep marsh area;
- planting a variety of wet meadow, emergent, floating leaf, and submergent species;
- planting species of high wildlife food value; and
- planting different plant species in distinct clusters, rather than uniformly, within vegetation types.

Most of these design elements concurrently address the other functionality goals. For example, a critical design element listed above for wildlife habitat value is the creation of a dense emergent wetland in contact with open water to provide much needed cover. This is also a critical design element for flood water storage, water quality protection, and shoreline protection as the dense vegetation provides frictional resistance to incoming surface waters. This serves to prolong the residence time, which desynchronizes downstream flows and permits a more gradual release of surface waters. Furthermore, it allows for the settling of particulates out of the water column. The remediation of sediments in the wetland should also have a positive effect on the water quality of this wetland system and downstream waters.

Many of the plant species selected for their high wildlife value such as cattail (*Typha latifolia*), bulrushes (*Scirpus* sp.) and burreed (*Sparganium* sp.) are robust, persistent emergents providing high frictional resistance throughout

the water column. Other species selected for their wildlife food value, such as millet (*Echinochloa* sp.), are also aesthetically pleasing. Conversely, some aesthetically pleasing plants selected also contribute towards other functionality goals (e.g., blue flag iris [*Iris versicolor*] provides an extremely showy flower and also has high nutrient retention and transformation capabilities [Marble 1990]).

14.5.2 Drainway Revitalization

Dredging and replacement of drainway sediments and covering of adjacent uplands will alter the substrate texture and eliminate bank vegetation. The new gravel/cobble substrate will gradually recolonize with aquatic life. The geotextile under drainway bank crests will be placed at 24 inches below ground surface locally rather than 16 inches to allow the planting of shallow-rooted shrubs on the bank crests of drainways (Sheet 14-7). These shrubs will be placed in 5-foot wide strips on each side of the remediated drainways to provide shade and detritus for the aquatic community and food, cover, and nesting habitat for small mammals and birds. Appropriate vegetation and planting specifications are included in Section 14.5.3 and Table 14-16.

14.5.3 Product Specifications

Wetland Topsoil

A minimum 8-inch layer of sandy loam topsoil will be placed as the upper layer of the 16-inch cover within the remediated portions of Wetland 1C and within the wetland enhancement area (see Sheet 13-4). Along the remediated drainways, which will support shallow-rooted shrubs, 8 inches of topsoil will be underlain by 16 inches of cover soil (see Sheet 14-7). The topsoil will be obtained from clean, off-Site, well-drained, borrow areas and be free of

purple loosestrife seeds, common reed tubers, debris, trash, stumps, rocks, and roots. It will not contain any substances that are toxic to plant growth or a hindrance to grading or planting. Table 14-15 summarizes the major physical and chemical characteristics with which the topsoil must comply.

Soil samples will be collected from topsoil stock at a minimum of two samples per acre. Agricultural soil tests will be performed to determine soil fertility. These tests will include pH, total phosphorus, calcium, exchangeable potassium, soluble salts, nitrogen, soil texture, magnesium, and organic matter content.

Soil amendments can be utilized to increase the organic matter content of the soil. These amendments should contain low levels of nitrogen and phosphorus to minimize the impact to water quality. The amendment should be mixed thoroughly with the soil prior to placement.

A soil texture of sandy loam was selected to minimize the impact to water quality from the movement of fine soil particles into the water column during placement. The values for organic matter are minimum values and should not exceed 20 percent to minimize erosion by flowing water.

Vegetation

General selection criteria for plants and seeds specified for wetland and drainway revegetation included

- endemic to Central Massachusetts;
- tolerant of full sun and water level fluctuations;
- hydrophytic;

- easily established, with fibrous root systems rather than long taproots; and
- perennials, or prolific annuals.

Fast growth and high germination rates were also preferred characteristics to stabilize soils and inhibit the establishment of invasive weed species such as purple loosestrife and common reed. For those portions of the wetland in which the groundwater table is expected to decrease to a depth greater than 1.4 feet below the surface at seasonal low elevations, species also tolerant of alternating flooding and drought conditions (e.g., millet [*Echinochloa crusgalli*] and reed canary grass [*Phalaris arundinacea*]) were also included. Table 14-16 lists the plant and seed species suitable for establishment in each of the community zones (deep marsh, shallow marsh, wet meadow, and drainway bank) specified in Sections 14.5.1 and 14.5.2. The functional contribution, propagule type, and planting specifications described for each species in the table are based on data provided in Martin et al. (1951), Michener and Stevens (1989), Hightshoe (1988), and Marble (1990). Seed for the mixed plant communities shown on Sheet 14-1 will be sown at the rate of 35 pounds/acre (15 lbs/acre millet, 10 lbs/acre rattlesnake grass (*Glyceria canadensis*), 5 lbs/acre each of *Scirpus atrovirens* and *Juncus effuses*). This sowing rate insures the development of a dense vegetative cover by the millet in the first year, while still allowing for the establishment and spread of the native species.

14.5.4 Evaluation of Functionality Goal Attainment

Changes in functional values of Wetland 1C were assessed by running the Hollands-Magee Functional Assessment models with new input variables corresponding to the expected characteristics of the revitalized wetland. The post-

revitalization model results were compared to the final professional ranking of preremediation model results and functionality goals for this wetland. The computer model printout appears in Appendix 14-A. The post-revitalization wetland assessment indicates that flood storage and water quality functions which were professionally assessed to be moderate in the existing wetland, would rate low after revitalization. A loss of flood storage capacity is expected. However, the remediation of sediments containing metals above Consent Decree Action Levels will have a positive effect on water quality, an effect the model cannot evaluate. The overall water quality maintenance function should at least remain moderate once vegetation is reestablished. The recreational and aesthetic functions will increase, since public access to the Site will not need to be restricted, and the revitalized wetland will have a variety of attractive plants.

The biological value will be moderate after revitalization, which is equivalent to the final professional ranking for pre-remediation biological value. However, several of the Site characteristics which negatively influenced the original model interpretation are also expected to change, including the detrimental effects of metals and hides in the surrounding landscape, the chainlink fence, the common reed monocultures and disturbed soils. The post-revitalization biological values could be expected to be high rather than moderate, and additional biological function compensation can be achieved through compensatory mitigation.

The functionality goals of Wetlands 7A, 7B and 8 (totalling 0.9 acres) will not be met by revitalization, as these wetlands are eliminated by sediment remediation. Approximately 0.2 acres of aquatic habitat and banks will

be permanently impacted by remediation of Wetland 2A. The loss of hydrologic support, water quality maintenance, flood storage and biological functions of the drainway and wetlands will be mitigated through the compensatory wetland mitigation described in the next section.

14.6 ADDITIONAL WETLAND MITIGATION

In addition to meeting the functionality goals for the remediated wetlands, the mitigation design must incorporate other requirements of wetland-related ARARs within the framework of the Consent Decree (see Chapter 4 for a discussion of compliance with ARARs for all remediation and mitigation activities on the Site). Wetland performance standards and mitigation criteria contained in the ARARs which have been incorporated into the design include:

- compensation for loss of wildlife habitat associated with Stream Banks which will be culverted [310 CMR 10.54(4)];
- construction adjacent to the same waterbody as lost Bordering Vegetated Wetland with at least as great a surface area, and similar surface water elevation [310 CMR 10.55(4)];
- compensation for loss of wildlife and fisheries habitat associated with Land Under Water Bodies and Waterways [310 CMR 10.56(4)];
- partial compensation for loss of flood storage capacity within the same reach as storage loss [310 CMR 10.56(4)]; and
- restoration and maintenance of wetland functions and values (40 CFR Part 6, Appendix 14-A).

Compliance with these ARARs requires compensation for a minimum of 3.0 acres of wetland lost as result of remedial activities in Wetland 1C, 7A, 7B and 8 (see Section 14.4.1) and loss of floodwater storage. Other functionality goals not met by revitalization alone are hydrologic support and water quality maintenance. The direct loss of 0.2 acres of aquatic habitat value through culvert placement necessitates that wildlife and aquatic stream habitat creation be a primary functionality goal. Approximately 6.3 acres of additional mitigation were designed which include creating 2.8 acres of emergent, shrub and forested

swamp with a 1.0-acre upland buffer; 2.2 acres of deep marsh enhancement with a shrub border in Wetland 1C, and 0.3 acres of stream restoration in the North Branch of the Aberjona River (Wetland 3A). In addition, the vegetated buffer will be supplemented along portions of Wetland 3A which currently have sparse vegetation. Approximately 750,000 cubic feet of floodwater storage will be available in the created wetland. Additional flood storage will be created elsewhere on-Site (Chapter 10).

14.6.1 Wetland Enhancement and Creation Design

Specific Design Elements

As discussed in Section 14.5.1, the revitalization design for the portion of Wetland 1C to be dredged and covered was developed in conjunction with the compensatory mitigation wetland design. This allows a close coordination of plans within contiguous wetland areas and ensures that the revitalization design does not alter the anticipated hydrologic regime within the compensatory wetlands. The compensatory wetland design includes a 2.2-acre enhancement area adjacent to the revitalization areas in Wetland 1C, and a 2.8-acre created wetland in close proximity and hydrogically connected to Wetland 1C by a new stream channel. The proposed creation wetland site is currently highly disturbed, and functions as a temporary retention basin for overflows from Wetland 1C during storm events. Pockets of surface water perch on the disturbed soils and construction debris. The wetland creation design enhances this existing drainage pattern by expanding flood storage capacity and designing features that provide additional wetland functions such as wildlife habitat, production export, water pollution attenuation, aquatic habitat, and aesthetic value. This mitigation site offers a large potential functional gain for effort expended due to its current disturbed conditions, and connection to other

wetland mitigation efforts in Wetland 1C. There will be a 100 foot buffer zone around most of Wetland 1C and the enhancement area, which are the areas most likely to be used by shy wading birds, semi-aquatic mammals, and basking reptiles. In addition, a shrub border will shield the enhancement area from adjacent uplands. The created wetland will be buffered by a forested upland buffer on the north side, maintained meadows on the northern and eastern side, and by a man-made berm on the western and southern boundaries. On the west and south sides, the total width of the berm including slopes will be a minimum of 30 to 40 feet wide, and the ground surface of the wetland will be 5 to 6 feet below the top of the berm. Shrubs will be planted along the top side of the berm to further screen the created wetland from developed or potentially developable properties, and to discourage people from entering the wetland (see Sheet 14-8). The shrubs and trees planted within the wetland will also provide screening and cover for wildlife using the wetland. The need for additional buffer width should be assessed during planning for development of the properties adjacent to the created wetland berm. The design of the site remedy precludes anthropogenic surface water discharges into the created and enhanced wetlands. The following discussion of specific wetland design elements refers to both the enhancement and creation wetlands (see Sheets 14-4 and 14-5).

In contrast to the previously presented revitalization designs in which the remedial strategies limit the design elements that can be manipulated, most of the important design elements listed in Table 14-12 are incorporated into the compensatory wetland design. This will ensure compliance with the water quality maintenance, flood water storage and hydrologic support functionality goals, because

the percent and depth of open water, topographic configuration, and inlet and outlet characteristics are key design elements. Specific design elements utilized to address all functionality goals concurrently include

- creation of four vegetative classes (deep marsh/open water (1.6 acres) shallow marsh (0.8 acres), shrub swamp (2.3 acres) and forested swamp (0.3 acres)) and planting of species in distinct clusters to promote structural diversity;
- creation of a densely vegetated shallow marsh adjacent to the deep marsh/open water area to provide cover for wildlife species utilizing the open water area, spawning sites for warmwater fish, and to provide frictional resistance to incoming surface water;
- planting of woody vegetation to provide important nesting habitat and cover that is no longer present in revitalized wetland areas due to remedial constraints;
- restricting the open water area to 40% or less of the total wetland area to provide for both waterfowl habitat and flood water storage;
- planting a variety of woody and herbaceous species of high wildlife food value;
- basinlike morphology to increase available flood water storage volume; and
- provision of a constricted outlet to assist in the desynchronization of downstream peak flows.

Hydrology

Measured seasonal high groundwater elevations at the location of the created wetland currently range between 70.0 to 66.0 feet NGVD sloping downward from east to west away from the East-Central Hide Pile. Saturated thickness of outwash sediments above bedrock also increases from east to west from 5 to 10 feet.

The possible effects of constituents of concern identified on-Site were also considered in the wetland design. Concentrations of the constituents of interest documented in GSIP, Phase 2 are significantly higher in the groundwater than in the surface waters. No arsenic plume was identified up-gradient or within the footprint of the created wetland. However, since some groundwater seepage might be expected along the northern and eastern sides of the created wetland if groundwater elevations meet or exceed surface grade elevations, the created wetland was conservatively designed to ensure separation of the groundwater and surface water. Only surface water flow will be utilized to sustain the necessary hydrologic conditions in these wetlands.

A low permeability clay loam liner will be placed under the created wetland topsoil to minimize the discharge of groundwater into the wetland community and to prolong the retention time of surface water. To calculate the appropriate liner permeability, mass balance procedures were applied to determine the impact of surface water quality within the created wetland that would result from infiltration of groundwater. This analysis was based on measured concentrations in the surface water discharge from Wetland 1C (Station SW-2) and in the groundwater sampled from Well OW-22 which is directly up-gradient of the wetland. Since well OW-45 is located on the down-gradient side of the created wetland and the water level in OW-45 is lower than the created wetland liner, groundwater flow from OW-45 is away from the wetland. Therefore water quality data from OW-45 was not used in this analysis.

Several worst-case assumptions were made in this analysis:

- It was assumed that no attenuation of metals would occur in the newly placed clay liner and topsoil as groundwater migrates through these layers.
- Although arsenic was the only expressed constituent of interest, other metal concentrations which could adversely impact aquatic life or vegetation were analyzed.
- Total metal concentrations were utilized since chemistry data pertaining to dissolved quantities was limited. Total concentrations include the metal fraction that are associated with particulates which are not likely to migrate through the soil water environment and into the surface medium.
- Surface water inputs were based on low flow conditions.
- Reductions in future groundwater and surface water concentration as a result of capping and remediation activities were not included.

The results of this analysis indicate that the concentration for all of the metals tested would be below chronic aquatic life criteria using a clay loam liner having a permeability of 1×10^{-6} cm/s. Monitoring of water and sediment quality, vegetation health, and macroinvertebrate communities (see Chapter 19) has been specified to assess the integrity of the liner.

A water budget analysis (Appendix 14-C) has been conducted using long-term hydrological data for the Aberjona River watershed and regional meteorological data (Delaney and Gay, 1980) to evaluate the availability of surface flows to meet the soil moisture requirements for created wetland vegetation establishment. For successful wetland

development, it is generally accepted that soils must be saturated within the vegetation root zone (generally within 12 to 18 inches of the soil surface for shrubs and trees) for a sufficient period of the growing season to support hydrophytic vegetation. Since the surface water inflow data used in the budget analysis was based on average flow conditions, a worst case analysis was conducted by assuming that the soil must be saturated to the surface throughout the month of June to successfully maintain wetland plant species. This analysis overestimates the volume of surface flow required during average conditions but may closely represent the flow requirements during dry years.

The results of this analysis indicate that during average flow conditions there is an excess of surface water flow available to support the compensatory wetland area through the months of April and May. In June, however, the surface water losses due to evapotranspiration, groundwater recharge and soil moisture utilization generally tend to exceed surface water inputs. To compensate for this soil moisture deficit, approximately 0.10 cubic feet per second (cfs) or 50 percent of the average June discharge of 0.20 cfs from Wetland 1C would need to be diverted to the created wetland. This diversion of flow will be accomplished by establishing the inverts of the Wetland 1C outlets to the Western Branch of the Aberjona River (Wetland 2A) and to the created wetland at the same elevation of 71.0 feet NGVD (Sheet 13-1). The stream channel to the created wetland will slope down to an exit invert of 68.9 feet NGVD.

The culvert regulating base flow from the created wetland will be placed at 68.0 feet NGVD (Sheet 13-5). As a means of assuring the desired hydroregime, the headwall structure of the outlet culvert will be designed to permit the

installation of a flashboard. This will allow for some manipulation of the water level within the mitigation area during remediation activities or during the five year maintenance period. Protocols for regulating water levels in the created wetland and inspecting and maintaining the outflow structure are included in Chapter 19, the Operations and Maintenance Plan. The outlet level will be permanently fixed after the five year maintenance period. The forested wetland plant community will be established between the 68.0 and 69.0-foot contours and the emergent community will be within the 67.0 to 68.0-foot contour interval.

Floodwater storage will be approximately 760,000 cubic feet in the created wetland. Flood volumes will be released through an 18-inch diameter flood stage outlet at 70.0 feet above msl. Maximum flood stage elevation has been estimated to be 72.3 feet NGVD for a short period during a 100-year, 24-hour design storm (Appendix 10-G).

For mitigation purposes, an assessment of impacts related to the proposed streamflow diversion from the Aberjona River to the Halls Brook drainage system was performed based on surface water flow analysis by Roux et al. (1991). The creation wetland design requires seasonal surface water input from Wetland 1C which will be discharged to the Halls Brook drainage system and reunited with the Aberjona River just north of Route 128. A similar flow pattern appears to have existed in the past, according to 1966 City of Woburn topographic maps. Additional stream channelization and filling of wetlands since 1966 have resulted in the current drainage system.

Pre-remediation surface water discharges from Wetland 1C to the Aberjona River (Wetland 2A) in 1990 ranged from a high

flow of 0.17 cfs in April to less than <0.0023 cfs in August (Roux et al., 1991). These contributions comprise approximately 16 percent to 22 percent of the total flow in this portion of the Aberjona River. During low flow seasons, the flow from Wetland 1C contributes approximately 0.04 percent of the total flow in the Aberjona River just south of its confluence with the South Branch and 0.02 percent of the total flow downstream of its confluence with Halls Brook Holding Area. Consequently, the discharge from Wetland 1C is only a very minor component of the base flow of the Aberjona River during low flow conditions. See Chapter 10 for a discussion of storm-related flows.

The aquatic community within the Aberjona River at the Site was evaluated in 1990 (Roux et al., 1991). The channelized stream beds were described as shallow, narrow, and lacking in substrates suitable for colonization by periphyton and aquatic insects. Low diversity indices for all streams on-Site were attributed to a number of factors, including naturally low productivity of headwater streams; off-Site, non-point source pollution inputs; previous channelization; substrate type; and stress from on-Site water constituents (Roux et al., 1991). Some common, warmwater, fish species were observed in the Aberjona River and Wetland 1C, but the culvert at the outlet of Wetland 2A into the Aberjona River (Wetland 2B) is approximately two feet above the stream, allowing only downstream passage of water and aquatic life through this corridor and preventing fish from migrating to Wetland 1C from the Aberjona River. The new culvert invert elevation will be established at streambed grade to eliminate this obstruction to upstream migration. Wildlife use of the Aberjona River corridor on the Site is currently limited by the steep banks and location between the lanes of Commerce Way, and therefore will not be further degraded by the new configuration.

The culvert required in Wetland 2A to satisfy Consent Decree requirements will further reduce its already low value as aquatic habitat, although the new provision for upstream fish travel represents some improvement in conditions. Downstream passage of detritus and aquatic life during high flows can still occur. The diversion of flow from the Aberjona River is estimated to reduce low flows by approximately 10 percent or less at a point just below the confluence of Wetland 2A and the Aberjona River. This expected change in flow will have a negligible effect on the amount of wetted perimeter within the Aberjona River channel based on measured cross-sectional data at various transects within the channel (Appendix 14-D). The wetted perimeter has been previously used by researchers as a measure of the amount of aquatic habitat within a stream channel (Nelson, 1984). This minor impact to an already disturbed system will be offset by the habitat improvements gained through wetland and stream mitigation.

14.6.2 Wetland 3A Restoration

The restoration of Wetland 3A will mitigate for stream habitat impacted by the remediation of Wetland 2A and for general wildlife habitat impacts due to remedial activities. The primary mitigation goal for Wetland 3A (Table 14-8) will be to increase the wildlife value of the stream by restoring it to a more natural configuration that is similar to adjacent upstream and downstream segments (Sheet 14-6). Coupled with plantings of trees, shrubs, and herbaceous vegetation in the wetland and along the south bank, the restoration of the stream will enhance wildlife feeding and nesting habitat, and travel corridors. Trash and debris will be removed from the wetland also. Additional wetland functions that will be improved by the restoration of Wetland 3A include flood control, aesthetic

value, water quality maintenance functions, and stabilization of the stream shore.

Specific design elements utilized to address the above functionality goals include

- removal of the roadbed fill intruding into the floodplain of the Aberjona River to improve wetland wildlife habitat and increase flood storage capacity;
- creation of three wetland vegetative classes (shallow marsh, shrub swamp and forested swamp) and planting of species in distinct clusters in the former roadbed fill restoration area to promote structural diversity for wildlife nesting and feeding;
- restoration of the stream channel in the former roadbed fill restoration area into a broader bed directed through densely vegetated shallow marsh to enhance aquatic habitat, provide frictional resistance to stream flows, and improve water quality;
- planting a variety of woody and herbaceous species of high wildlife nesting and feeding values within the former roadbed fill restoration area and along the south bank; and
- removal of trash and debris within Wetland 3A to improve its aesthetic value and habitat quality.

Removal of Road Fill and Wetland Restoration

Final grade elevations within the former roadbed fill restoration area were developed to achieve the desired hydrologic regimes to support shallow marsh, shrub and forested wetland communities. Seasonal low water level was estimated to be 64.5 feet NGVD, or 0.1 foot above the bottom of the stream channel, based on cross-sections 16 and 17 (Ditch G, Appendix 10-H). This estimate is also based on the very low flow rate, 0.012 cfs, observed in August, 1990, at Station SW 4 located approximately 700 feet downstream of the restoration area (Roux et al.,

1991). The seasonal high water level was estimated to be at 66 feet NGVD, or 1.5 feet above the seasonal low. This estimate was derived from the top of the first definable change in slope within the stream bank which was assumed to be the mean annual flood level. The April, 1991, flow rate at Station SW 4 was 0.62 cfs.

Substrates in the restored wetland will consist of 8 inches of sandy loam to minimize downstream sedimentation (Table 14-15). The shallow marsh community will be established within the new stream bed with a top elevation of 65 feet NGVD, and an anticipated hydrologic regime of seasonal flooding and saturated year round conditions. The shrub swamp will be established between the 65.0- and 66.0-foot contours with an anticipated hydrologic regime of seasonal flooding and saturated conditions from groundwater discharge for much of the year. The forested wetland will be established between the 66.0- and 68.0-foot contours. Saturated conditions from groundwater discharging from the small wetland northwest of the restoration area are expected for a portion of the growing season, and flooding may occur during major storm events. This drier hydrologic regime will provide appropriate site conditions for tree species such as red maple and green ash (*Fraxinus pennsylvanica*).

Supplemental Planting

Currently, the uplands adjacent to Wetland 3A are in various stages of succession, from mature forest at the northeastern end of the site to sparse herbaceous cover near the Commerce Way extension. The establishment of vegetation in these sparsely vegetated areas will serve to screen adjacent stream and wetland habitats, provide a corridor for wildlife travel and provide cover and nesting habitat for upland and semi-aquatic animals. It will

increase shade and provide a source of food (leaf litter) for aquatic macroinvertebrates. Buffer strips also filter sediment and nutrients from upland runoff and stabilize stream banks. Available literature indicates that such buffers provide many riparian functions (U.S. Army Corps of Engineers, 1991). A nominal 50-foot wide area along the southwest end of Wetland 3A (see Sheet 14-6) will be supplemented with one of the following techniques:

- Supplemental planting: Where low to moderately dense vegetation (i.e., 25 to 50 percent total vegetation cover in all strata) dominates, a mix of early and later successional trees and shrubs with high wildlife values will be planted within gaps to achieve 75 percent cover. Successional forested species will be specified for the wetland edge and the rest of the buffer will be planted with upland buffer species (see Section 14.6.3, Product Specifications, and Table 14-16). Careful preparation of the planting holes including use of soil amendments and timed-release fertilizers will be necessary.

- Loam, seed, and plant: Portions of the buffer with disturbed soils and sparse vegetation (less than 25 percent cover) will require soil preparation and stabilization prior to planting of nursery stock. Where topsoil is absent, it will be replaced, mixed slightly at the topsoil/substratum interface, and graded. A minimum of 6 inches of topsoil is necessary. The newly graded soil will be stabilized with upland or wetland seed mix (see Construction Specification Sections 02936 and 02937) depending on proximity to Wetland 3A, and planted with successional forested wetland or upland buffer trees and shrubs (see Section 14.6.3, Product Specifications, and Table 14-16).

Approximate location of the prescribed supplemental planting area appears on Sheet 14-6. Actual planting locations will be determined in the field and will be designed to meet the buffer performance standards as described in Table 14-13.

Trash and Debris Removal

Wetland 3A will be cleaned of visible trash and debris to improve its habitat quality and aesthetic values. The collected debris will be disposed of following the protocols described in Section 02110 of the construction specifications.

14.6.3 Product Specifications

Wetland Topsoil and Subsoil

A soil texture of sandy loam will be used in the enhancement, creation, and restoration wetlands. The soil will comply with the other specifications in Table 14-15, and will be tested for the parameters listed in Construction Specification Sections 02937 and 02242 prior to placement.

Within the created wetland only, a subsoil of low permeability material will be installed to minimize seepage losses to groundwater. This soil shall have as-built permeability of 1×10^{-6} centimeters per second or less typical of silty clay or silty clay loam soils. Grain size distribution should range between 28 to 50 percent clay, 40 to 70 percent silt and 20 to 40 percent sand. Clay content in natural soils may be augmented by a bentonite mix. Permeability may also be reduced through compaction during installation.

Vegetation

General selection criteria for plants and seeds specified for planting within the restored and compensatory wetlands and adjacent uplands included

- endemic to central Massachusetts;
- tolerant of full sun and water level fluctuations;

- o easily established with generally high survival rates; and
- o contributes to the performance of multiple functions.

Fast growth and/or high germination rates are preferred characteristics to stabilize soils and inhibit the establishment of invasive weed species such as purple loosestrife and common reed. Within the shrub and forested wetland areas, the water levels are expected to fluctuate from within 6 inches of the surface to a depth greater than 1.4 feet below the surface during the growing season. Hydrophytic species having tolerance of both saturated and dry conditions, in addition to having the characteristics listed above (e.g., red maple) were selected for wetland areas. These trees and shrubs will be planted on 6- to 16-inch high hummocks. Table 14-16 lists the plant species suitable for establishment in each of the community zones specified in Section 14.6.1: deep marsh, shallow marsh, shrub swamp, forested wetland, upland buffer and upland berm. The functional contribution, seed and propagule type, and planting specifications are described for each species based on data provided in Martin et al. (1951), Hightshoe (1988), Michener and Stevens (1989), and Marble (1990).

Although the compensatory wetland has been redesigned as a surface water system, some deeper roots of the trees and shrubs specified for planting in the compensatory wetland may intercept groundwater that contains metals and other constituents of concern. Arsenic and chromium are readily taken up by plants and can be accumulated and stored in plant tissue without phytotoxic effects (Eisler, 1988; Fitter and Hay, 1987; Tyler et al., 1989; Woodhouse, 1983). The degree of uptake is species specific, as is the concentration at which phytotoxicity occurs. For example,

acute toxic effect levels for arsenic range from 812 ppb to 97,000 ppb (in water) for freshwater plants to more than 250,000 ppb (in soil) for some woody plants. Lower order aquatic plants, such as algae, tend to exhibit toxic effects at lower concentrations of arsenic and chromium than more advanced plants. Dissolved arsenic concentrations in two filtered groundwater samples taken in the proposed compensatory wetland area were 4 and 999 ppb (Golder, 1991). Even at the highest arsenic concentration of 999 ppb observed at the site, acute toxic effects to woody vegetation (the vegetation type most likely to contact arsenic in groundwater) would be considered unlikely.

Accumulation primarily occurs within roots, but arsenic compounds can also be stored in stem and leaf tissue. Several studies of arsenic translocation patterns within woody plants have documented a maximum of 6 percent of accumulated arsenic stored within foliage, with the remaining 94 percent stored in woody tissue (Eisler, 1988; Woodhouse, 1983). In spite of the low percent accumulation, the arsenic stored in leaf tissue may be available for consumption by herbivores. However, Merry et al. (1986), as cited in Eisler (1988), considered foliar accumulations of up to 580 ppb to be nonhazardous to grazing animals. Additionally, several factors lessen the opportunity of woody plants to absorb metals from on-Site groundwater. Primary feeder roots of trees are generally located within the upper 6 inches of soil, the portion richest in organic matter (Raven et al., 1976). In the created wetland, this is above the low permeability liner. Plants in saturated soil conditions also tend to have shallow root systems. It is therefore concluded that any absorption of metals by deep roots will not have a significant impact on the plant or wildlife community.

14.7 MITIGATION CONSTRUCTION QUALITY ASSURANCE

Critical to the evaluation of the Design Performance Standards are the development of as-built plans of the mitigation sites as part of the Construction Quality Assurance program. The plans will indicate the general location, quantity and species of vegetation as planted, and the species composition, quantity and area covered by seeding mixtures.

A brief written record of construction activities, to accompany the as-built plans, will include any pertinent construction information which cannot be easily shown or listed on the as-built plan. For example, planting dates will be provided and any modifications made to construction designs during their implementation will be detailed. Photographs will be included to document pre- and post-construction Site conditions.

Development of these plans and accompanying data will require detailed information which must be gathered during careful monitoring of all phases of construction. The as-built plans and accompanying data will serve as a basis for the evaluation of the Design Performance Standards, which will be submitted as part of the first annual inspection report. Wetland inspection, maintenance and monitoring will continue for an additional four years after construction (Chapter 19).

14.8 SUMMARY

Remedial actions on the Industri-Plex Site will impact six WMS-delineated wetlands, as well as the New Boston Street Drainway and a channel draining into the New Boston Street Drainway from the west. Wetland areas and drainways remediated with an at-grade permeable cover (dredge and cap) will be revitalized to retain wetland functions and values, and no permanent loss of area, flood storage volume, or other functional loss will result. A portion of Wetland 2A will be culverted, resulting in a permanent loss of poor quality aquatic habitat. Wetlands which receive an above-grade permeable cover will be revitalized. Loss of area, flood storage volume, and any functionality goals not achieved by revitalization (particularly biological values), will be compensated by 6.3 acres of mitigation which includes newly created wetland with an upland buffer (3.8 acres), partial enhancement of Wetland 1C (2.2 acres), and restoration of 0.3 acres of the Aberjona River (Wetland 3A). The shoreline along the south bank of Wetland 3A will also be enhanced with supplemental vegetation plantings.

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TABLE 14-1.

COMPOSITE LIST OF WILDLIFE SPECIES OBSERVED ON THE INDUSTRI-PLEX SITE, WOBURN, MA

COMMON NAME	SCIENTIFIC NAME	OBSERVED BY WMS, INC.	NORMANDEAU ASSOC. INC.	ES&E INC.
MAMMALS				
Cottontail (unidentified)	*Sylvilagus* spp.		X	X
Domestic cat	*Felis catus*		X	
Eastern Cottontail	*Sylvilagus floridanus*	X		
Gray squirrel	*Sciurus carolinensis*		X	X
Mole (unidentified)	--		X	X
Muskrat	*Ondatra zibethicus*		X	X
Raccoon	*Procyon lotor*	X	X	X
River otter	*Lutra canadensis*		X	X
White-tailed deer	*Odocoileus virginianus*	X		
Woodchuck	*Marmota monax*		X	X
AMPHIBIANS				
Gray treefrog	*Hyla versicolor*		X	
Green frog	*Rana clamitans melanota*		X	X
Northern leopard frog	*Rana pipiens*	X		X
Northern spring peeper	*Hyla c. crucifer*		X	
Tadpoles (unidentified)	--		X	X
REPTILES				
Common snapping turtle	*Chelydra s. serpentina*		X	X
Eastern painted turtle	*Chrysemys picta*	X	X	X
Garter snake	*Thamnophis sirtalis*		X	X
FISH				
Pumpkinseed	*Lepomis gibbosus*	X		X
Golden Shiner	*Notemigonus crysoleucas*			X
White Sucker	*Catostomus commersoni*			X
American Eel	*Anguilla rostrata*			X
Largemouth Bass	*Micropterus salmoides*			X
SHELLFISH				
Crayfish	*Orconectes* spp.	X		X

(continued)

TABLE 14-1. (CONTINUED)

COMMON NAME	SCIENTIFIC NAME	OBSERVED BY WMS, INC.	NORMANDEAU ASSOC. INC.	ES&E INC.
BIRDS				
American crow	*Corvus brachyrhynchos*	X	X	X
American goldfinch	*Carduelis tristis*		X	
American kestrel	*Falco sparverius*		X	X
American robin	*Turdus migratorius*		X	X
Barred owl	*Strix varia*		X	
Belted kingfisher	*Ceryle alcyon*		X	X
Black duck	*Anas rubripes*		X	
Black-capped chickadee	*Parus atricapillus*		X	X
Blue jay	*Cyanocitta cristata*		X	X
Brown thrasher	*Toxostoma rufum*		X	
Canada goose	*Branta canadensis*	X	X	X
Common grackle	*Quiscalus quiscula*		X	X
Common snipe	*Gallinago gallinago*		X	X
Downy woodpecker	*Picoides pubescens*		X	X
European starling	*Sturnus vulgaris*		X	X
Great blue heron	*Ardea herodias*		X	X
Green-backed heron	*Butorides striatus*		X	X
Green-winged teal	*Anas crecca*		X	
Hairy woodpecker	*Picoides villosus*		X	
Herring gull	*Larus argentatus*		X	X
Killdeer	*Charadrius vociferus*	X	X	
Mallard	*Anas platyrhynchos*	X	X	X
Mourning dove	*Zenaidura macroura*	X	X	
Northern flicker	*Colaptes auratus*	X	X	
Northern mockingbird	*Mimus polyglottos*		X	X
Pine warbler	*Dendroica pinus*		X	
Red-tailed hawk	*Buteo lineatus*		X	X
Red-winged blackbird	*Agelaius phoeniceus*	X	X	X
Ring-necked pheasant	*Phasianus colchicus*	X	X	X
Ruffed grouse	*Bonasa umbellus*		X	
Song sparrow	*Melospiza melodia*	X	X	X
Wood thrush	*Hylocichla mustelina*		X	X
Wren (unidentified)	--		X	
Yellow warbler	*Dendroica petechia*	X		X

TABLE 14-2.

SUMMARY OF MODIFIED HOLLANDS-MAGEE FUNCTIONAL ASSESSMENT MODEL RESULTS FOR WETLAND 1C.

	WETLAND FUNCTION	MODEL RATING	PROFESSIONAL FINAL RANKING
1.	Biological-Wildlife	High	Moderate
2.	Hydrologic Support	Moderate	Moderate
3.	Groundwater Recharge	Low	Low
4.	Floodwater Storage	Low	Moderate
5.	Shoreline Protection	Moderate	Moderate
6.	Water Quality Maintenance	Low	Moderate
7.	Economic Value	Low	Low
8.	Recreation	High	Low
9.	Aesthetic Value	High	Low
10.	Education	High	Low

TABLE 14-3.

SUMMARY OF MODIFIED HOLLANDS-MAGEE FUNCTIONAL ASSESSMENT MODEL RESULTS FOR WETLAND 2A.

	WETLAND FUNCTION	MODEL RATING	PROFESSIONAL FINAL RANKING
1.	Biological-Wildlife	Low	Low
2.	Hydrologic Support	Low	Low
3.	Groundwater Recharge	Low	Low
4.	Floodwater Storage	Low	Low
5.	Shoreline Protection	N/A	N/A
6.	Water Quality Maintenance	Low	Low
7.	Economic Value	Low	Low
8.	Recreation	Low	Low
9.	Aesthetic Value	Moderate	Low
10.	Education	Low	Low

TABLE 14-4.

SUMMARY OF MODIFIED HOLLANDS-MAGEE FUNCTIONAL ASSESSMENT MODEL RESULTS FOR WETLAND 2B.

WETLAND FUNCTION	MODEL RATING	PROFESSIONAL FINAL RANKING
1. Biological-Wildlife	Low	Low
2. Hydrologic Support	Low	Low
3. Groundwater Recharge	Moderate	Low
4. Floodwater Storage	Low	Low
5. Shoreline Protection	N/A	N/A
6. Water Quality Maintenance	Low	Low
7. Economic Value	Low	Low
8. Recreation	Moderate	Low
9. Aesthetic Value	Moderate	Low
10. Education	Low	Low

TABLE 14-5.

SUMMARY OF MODIFIED HOLLANDS-MAGEE FUNCTIONAL ASSESSMENT MODEL RESULTS FOR WETLAND 3A.

WETLAND FUNCTION	MODEL RATING	PROFESSIONAL FINAL RANKING
1. Biological-Wildlife	High	High
2. Hydrologic Support	Moderate	Moderate
3. Groundwater Recharge	Moderate	Moderate
4. Floodwater Storage	Low	Low
5. Shoreline Protection	High	High
6. Water Quality Maintenance	High	High
7. Economic Value	Low	Low
8. Recreation	Low	Low
9. Aesthetic Value	Low	Low
10. Education	Moderate	Low

TABLE 14-6.

SUMMARY OF MODIFIED HOLLANDS-MAGEE FUNCTIONAL ASSESSMENT MODEL RESULTS FOR WETLAND 7B.

WETLAND FUNCTION	MODEL RATING	PROFESSIONAL FINAL RANKING
1. Biological-Wildlife	Moderate	Low
2. Hydrologic Support	Low	Low
3. Groundwater Recharge	Moderate	Moderate
4. Floodwater Storage	Moderate	Low
5. Shoreline Protection	N/A	N/A
6. Water Quality Maintenance	Moderate	Moderate
7. Economic Value	Low	Low
8. Recreation	Low	Low
9. Aesthetic Value	High	Low
10. Education	Low	Low

TABLE 14-7.

SUMMARY OF MODIFIED HOLLANDS-MAGEE FUNCTIONAL ASSESSMENT MODEL RESULTS FOR WETLAND 8.

WETLAND FUNCTION	MODEL RATING	PROFESSIONAL FINAL RANKING
1. Biological-Wildlife	Moderate	Low
2. Hydrologic Support	Moderate	Moderate
3. Groundwater Recharge	Low	Low
4. Floodwater Storage	Moderate	Low
5. Shoreline Protection	N/A	N/A
6. Water Quality Maintenance	Moderate	Moderate
7. Economic Value	Low	Low
8. Recreation	Low	Low
9. Aesthetic Value	Low	Low
10. Education	Low	Low

TABLE 14-8.
SUMMARY OF FUNCTIONAL ASSESSMENTS AND FUNCTIONALITY GOALS
FOR WETLANDS AND DRAINWAYS TO BE REMEDIATED AT THE INDUSTRI-PLEX SITE.

WETLAND FUNCTION - PROFESSIONAL RANKING

Wetland	Biol	Hydr	GrWat	Flood	ShLi	WQual	Econ	Recr	Aest	Educ	Functionality Goals
1C	M	M	L	M	M	M	L	L	L	L	Maintain wildlife habitat; Floodwater storage; Water pollution attenuation
2A	L	L	L	L	N/A	L	L	L	L	L	Maintain water and nutrient transport; prevent metal and hide transport
2B	L	L	L	L	N/A	L	L	L	L	L	Maintain water and nutrient transport; prevent metal and hide transport
3A	H	M	M	L	H	H	L	L	L	L	Maintain wildlife habitat; Hydrologic Support; Shoreline; Water Qual.
7A*	L	L	M	L	N/A	M	L	L	L	L	Eliminate negative functions (biological impacts of chromium)
7B	L	L	M	L	N/A	M	L	L	L	L	Eliminate negative functions (biological impacts of chromium)
7C*	L	L	L	L	N/A	L	L	L	L	L	Maintain water transport; prevent metal and hide transport
8	L	M	L	L	N/A	M	L	L	L	L	Maintain water pollution attenuation functions
New Boston St.* Drainway	L	L	L	L	N/A	L	L	L	L	L	Maintain water and nutrient transport; prevent metal and hide transport

*** Wetland Functional Assessment results adopted from similar wetlands within the Industri-Plex Site.**

TABLE 14-9.

MASSACHUSETTS RESOURCE AREAS WITHIN EACH OF THE DRAINWAYS AND WMS-DELINEATED WETLANDS TO BE IMPACTED BY REMEDIAL ACTIVITIES.

	WMS-DELINEATED WETLANDS AND STREAMS								
	1C	2A	2B	3A	7A	7B	7C	8	NBSD
BVW	X			X					
ILSF					X	X		X	
BANKS	X	X	X	X	X	X	X		X
LUW	X	X	X	X			X		X

LEGEND

BVW = Bordering Vegetated Wetland
ILSF = Isolated Land Subject to Flooding
LUW = Land Under Water Body
NBSD = New Boston Street Drainway

TABLE 14-10.

SUMMARY OF WETLAND AND DRAINWAY REMEDIATION IMPACT AREAS TO BE REVITALIZED IN PLACE OR COMPENSATED FOR IN A MITIGATION AREA.

WETLAND	REVITALIZATION AREA (ACRES)	IMPACT AREA TO BE COMPENSATED FOR (ACRES)	FUNCTIONS AND VALUES TO BE COMPENSATED FOR IN MITIGATION AREA
1C	1.8	2.1	floodwater storage; wildlife habitat
	2.2	0	(to become enhancement area)
7A	0.0	0.4	floodwater storage, groundwater recharge
7B	0.0	0.3	floodwater storage, groundwater recharge
8	0.0	0.2	wildlife habitat
	Total 4.0	3.0	
DRAINWAYS			
2A	0.1	0.2	wildlife/aquatic habitat
7C	0.5	0.0	wildlife habitat
NBSD*	0.5	<0.0	wildlife/aquatic habitat
Channel to NBSD	0.2	0.0	Wildlife/aquatic habitat
	Total 1.3	0.2	

*NBSD - New Boston Street Drainway

TABLE 14-11.

FUNCTIONALITY GOALS OF REVITALIZATION/MITIGATION PLANS FOR WETLANDS AND DRAINWAYS.

	WETLAND							
FUNCTION	1C	2A	3A	7A	7B	7C	8	NBSD*
Biological Value-Wildlife Habitat	x		x					
Biological Value-Aquatic Habitat	x							
Hydrological Support	x	x	x	x	x	x	x	x
Flood Water Storage	x							
Water Quality Maintenance	x	x	x	x	x		x	x
Shoreline Protection	x		x					
Aesthetics	x							

*NBSD - New Boston Street Drainway

TABLE 14-12.

ELEMENTS IMPORTANT TO THE PERFORMANCE OF KEY WETLAND FUNCTIONS*.

DESIGN ELEMENT	FUNCTION					
	BIOL (WH+AH)	FWS	WQ	HS	SP	A
Vegetation Structure & Composition						
Dominant wetland class	x	x	x		x	x
Vegetation class diversity	x					
Vegetation and open water interspersion	x					
Vegetation density	x	x	x		x	
Species richness	x					
Proportion wildlife food plants	x					
Proportion showy plants						x
Hydrologic-Geologic Characteristics						
Percent and depth open water	x	x	x		x	x
Topographic configuration		x	x	x		
Hydrologic condition		x	x	x		
Inlets and outlets		x	x	x		
Surficial geology		x			x	
Permeability		x	x			
Water level fluctuation	x	x		x		
Thickness of organic matter			x			
Other						
Surrounding habitat	x					
Landscape position		x	x			
Wetland juxtaposition	x			x		
Wetland size	x	x	x	x	x	

*Hollands and Magee, 1985.

LEGEND
Biol (WH+AH) = Biological value - both wildlife and aquatic habitat
FWS = Flood water storage
WC = Water quality protection
HS = Hydrologic support
SP = Shoreline protection
A = Aesthetic

TABLE 14-13.

DESIGN PERFORMANCE STANDARDS AND SUCCESS CRITERIA FOR MITIGATION SITES.

STANDARD	SUCCESS CRITERIA
TOPSOIL AND GRADING	
Topsoil treatment	min. depth of 12-24 in. within created wetland and adjacent buffer, 8 in. within other wetland mitigation areas, 6 in. within Wetland 3A buffer
Organic matter content	at least 5-8% but less than 20%
Slope	≥20:1 within seasonally and semi-permanently flooded zones
Finish grades	±6 in. of proposed elevation with 6-16 in. hummocks for shrubs and trees in created wetland
Zone configuration	predominantly sinuous (irregular) edges where feasible
Floodwater storage volume	consistent with proposed grading plans and outlet structure in created wetland
PLANT COMMUNITY	
Vegetation class richness	establishment of at least 2 classes within revitalized wetlands and at least 4 classes within the compensatory mitigation wetland
Vegetation cover in upland buffers	≥75% cover at the end of each growing season (total for all strata)
Seed cover in graded areas	≥75% cover at the end of each growing season
Percent hydrophytes	>50% OBL, FACW, or FAC species in wetland areas
Survival of tree and shrub nursery stock in the compensatory wetland and upland buffers	≥75% survival over the course of the monitoring period
HYDROLOGY	
Revitalized and Compensatory wetland hydrology	Meets general hydroperiod design; meets Federal Interagency Committee for Wetland Delineation minimum hydrologic criteria

TABLE 14-14.

RELATIONSHIP OF PROPOSED WETLAND COMMUNITY TYPES TO EXPECTED HYDROLOGIC CONDITIONS.

WETLAND COMMUNITY	HYDROLOGICAL REGIME	LOCATION RELATIVE TO ESTIMATED SEASONAL WATER LEVELS
Deep marsh/open water	Permanently flooded	Below seasonal low water level
Shallow marsh	Semi-permanently flooded to intermittently exposed	Intercepts seasonal low water level
Shallow marsh	Seasonally flooded	Between seasonal high and seasonal low water level
Wet meadow, shrub swamp, or forested wetland	Saturated-seasonally flooded	Intercepts seasonal high water table for a minimum of 30 days within the early part of growing season; water level may decrease substantially thereafter for woody plants

TABLE 14-15.

PROPOSED TOPSOIL COMPOSITION FOR CAPPING WITHIN WETLAND AREAS AT THE INDUSTRI-PLEX SITE.

PARAMETER	DESCRIPTION
Organic matter[1]	5-8%
pH	6 - 7
Soil texture	sandy loam[2]
Soluble salts	not to exceed 500 ppm
Nitrogen	based on plant requirements[3]
Total Phosphorus	≤50 ppm
Potassium	3-5% saturation[4]
Magnesium	10-25% saturation
Calcium	60-80% saturation

[1]Organic matter content of the soil can be increased to reach 5 to 8 percent through the addition of soil amendments such as leaf compost or aged sawdust. these soils amendments should contain low levels of nitrogen and phosphorus to minimize the impact to water quality. These are minimum values for organic matter content. The maximum values should not exceed 20 percent.

[2]Sandy loam: 20 percent or less clay and 52 percent or more sand and the percentage of silt plus twice the percentage of clay exceeds 30; or less than 7 percent clay, less than 50 percent silt, and between 43 and 52 percent sand. (USDA - SCS, 1981. Chapter 4, Examination and descriptions of soils in the field. Soil Survey Manual. 430-V, Issue 1. USDA - SCS, Washington, DC).

[3]Nitrogen and phosphorus fertilizer should be lightly broadcast in areas to receive seed. A slow release tablet form fertilizer should be used in the planting holes of nursery stock.

[4]Magnesium, potassium and calcium ranges are provided in terms of base saturation. Percent saturation is calculated by dividing the milli-equivalents of each ion by the cation exchange capacity and multiplying by 100. The standard soil test from the Maine Soil Testing Service, University of Maine, Orono, Maine, provides results in terms of plant nutrient needs based on specific crop recommendations.

TABLE 14-16.

SPECIES TO BE PLANTED WITHIN EACH OF THE WETLAND AREAS. AN ASTERISK (*) INDICATES THE SPECIES WAS OBSERVED WITHIN THE ONSITE OR ADJACENT WETLANDS

SPECIES	FUNCTIONAL VALUE[1]	PROPOSED SIZE/TYPE	PLANTING SPECIFICATIONS[2]
DEEP MARSH - OPEN WATER, WATER DEPTH 1-3 FEET			
Potamogeton spp./Pondweeds	WF,NRT,AB	Weighted tuber	A
Nuphar variegatum/Spatterdock	WF,A	Weighted tuber	A
Nymphaea odorata/Water lily*	WF,A	Weighted tuber	A
Scirpus validus/Softstem bulrush	WQ/FW,NRT,WF,SS	Tuber	B
SHALLOW MARSH - SEMIPERMANENTLY FLOODED TO INTERMITTENTLY EXPOSED			
Typha latifolia/Broad-leaved cattail*	WF,WQ/FW,SS,NRT,AB,WC	Tuber	B
Scirpus validus/Softstem bulrush	WQ/FW,NRT,WF,SS	Tuber	B
Sagittaria latifolia/Arrowhead*	WF,AB,A	Tuber	A
Polygonum spp./Smartweeds	WF	Roots	A
Pontederia cordata/Pickerel weed*	A,AB	Tuber	A
Sparganium eurycarpum/Giant bur-reed	WF,WQ/FW,SS,AB	Tuber	B
SHALLOW MARSH - SEASONALLY FLOODED			
Wetland seed mix[1] (*Echinochloa crusgalli, Juncus effusus*, Scirpus atrovirens, Glyceria canadensis*)	WF,NRT,WQ/FW,SS,WC	Seed mix	C
Iris versicolor/Blue flag iris	NRT,A	Bulb	D
Carex lurida, C. stricta, C. crinita/sedges*	WF,SS,WC	2" potted plants	A
WET MEADOW - SATURATED			
Wetland seed mix[2] *Echinochloa crusgalli, Juncus effusus, Glyceria canadensis, Phalaris arundinacea*	SS,WC,WF,WQ/FW	Seed mix	C
Spirea latifolia/meadowsweet	WC,A	Container grown	E

TABLE 14-16.

SPECIES TO BE PLANTED WITHIN EACH OF THE WETLAND AREAS. AN ASTERISK (*) INDICATES THE SPECIES WAS OBSERVED WITHIN THE ONSITE OR ADJACENT WETLANDS

SPECIES	FUNCTIONAL VALUE[1]	PROPOSED SIZE/TYPE	PLANTING SPECIFICATIONS[2]
DEEP MARSH - OPEN WATER, WATER DEPTH 1-3 FEET			
Potamogeton spp./Pondweeds	WF,NRT,AB	Weighted tuber	A
Nuphar variegatum/Spatterdock	WF,A	Weighted tuber	A
Nymphaea odorata/Water lily*	WF,A	Weighted tuber	A
Scirpus validus/Softstem bulrush	WQ/FW,NRT,WF,SS	Tuber	B
SHALLOW MARSH - SEMIPERMANENTLY FLOODED TO INTERMITTENTLY EXPOSED			
Typha latifolia/Broad-leaved cattail*	WF,WQ/FW,SS,NRT,AB,WC	Tuber	B
Scirpus validus/Softstem bulrush	WQ/FW,NRT,WF,SS	Tuber	B
Sagittaria latifolia/Arrowhead*	WF,AB,A	Tuber	A
Polygonum spp./Smartweeds	WF	Roots	A
Pontederia cordata/Pickerel weed*	A,AB	Tuber	A
Sparganium eurycarpum/Giant burreed	WF,WQ/FW,SS,AB	Tuber	B
SHALLOW MARSH - SEASONALLY FLOODED			
Wetland seed mix[1] (*Echinochloa crusgalli, Juncus effusus*, Scirpus atrovirens, Glyceria canadensis*)	WF,NRT,WQ/FW,SS,WC	Seed mix	C
Iris versicolor/Blue flag iris	NRT,A	Bulb	D
Carex lurida, C. stricta, C. crinita/sedges*	WF,SS,WC	2" potted plants	A
WET MEADOW - SATURATED			
Wetland seed mix[2] *Echinochloa crusgalli, Juncus effusus, Glyceria canadensis, Phalaris arundinacea*	SS,WC,WF,WQ/FW	Seed mix	C
Spirea latifolia/meadowsweet	WC,A	Container grown	E

BLE 14-16. (Continued)

SPECIES	FUNCTIONAL VALUE[1]	PROPOSED SIZE/TYPE	PLANTING SPECIFICATIONS[2]
SHRUB SWAMP - SEASONALLY FLOODED TO SATURATED			
Cornus amomum/Silky dogwood*	WQ/FW,NRT,A,WC,WF	Container grown, 2-3 ft.	F
Ilex verticillata/Winterberry*	WQ/FW,NRT,A,WF	Container grown, 2-3 ft.	F,MF
Vaccinium corymbosum/Highbush blueberry*	A,WF	Container grown, 2-3 ft.	F
Viburnum recognitum/Northern arrowwood*	WQ/FW,NRT,WF,WC	Container grown, 2-3 ft.	F
Salix sp./Willow*	WC,WF	Container grown, 2-3 ft.	F
Wetland seed mix[1] (*Echinochloa crusgalli, Glyceria canadensis, Scirpus atrovirens, Juncus effusus*	WF,NRT,SS,WC,WQ/FW	Seed mix	G
SUCCESSIONAL FORESTED WETLAND - SATURATED			
Acer rubrum/Red maple*	WC,WF,A	Balled, Burlapped 4-6 ft.	H
Acer rubrum/Red maple seedlings*	WC,WF,A	Bare root, 18-24 in.	H
Fraxinus pennsylvanica/Green ash*	WF,WC,A	Bare root, 18-24 in.	H
Sambucus canadensis/Common elder*	WC,WF,A	Container grown, 2-3 ft.	I
Vaccinium corymbosum/Highbush blueberry*	WC,WF	Container grown, 2-3 ft.	I
Cornus amomum/Silky dogwood*	WC,WF	Container grown, 2-3 ft.	I
Wetland seed mix[1] (*Echinochloa crusgalli, Glyceria canadensis, Scirpus atrovirens, Juncus effusus*)	SS,WF,NRT	Seed mix	G
Osmunda cinnamomea/Cinnamon fern*	A,SS	Container grown (qt. size)	D

(3LE 14-16. (Continued)

SPECIES	FUNCTIONAL VALUE[1]	PROPOSED SIZE/TYPE	PLANTING SPECIFICATIONS[2]
UPLAND BUFFER[3]			
Acer rubrum/Red maple seedlings*	WC,WF,A	Bare root, 18-24 in.	H
Pinus strobus/White pine	WC,WF	Bare root, 1-2 ft.	H
Quercus rubra/Red oak*[4]	WC,WF	Bare root, 1-2 ft.	H
Populus tremula/Trembling aspen*	WC,WF	Bare root, 1-2 ft.	H
Prunus serotina/Black cherry*[4]	WC,WF,A	Bare root, 1-2 ft.	H
Cornus racemosa/Gray dogwood	WC,WF	Container grown, 2-3 ft	I
Corylus sp./Hazlenut	WC,WF	Container grown, 2-3 ft.	I
Upland seed mix	SS,WF	Seed mix	G
DRAINWAY BANKS			
Alnus rugosa/Speckled Alder*	WC,WF,SS,AB	Container grown, 2-3 ft.	J
Cornus amomum/Silky dogwood*	WC,WF,SS,AB	Container grown, 2-3 ft.	J
Viburnum recognitum/Northern arrowwood*	WC,WF,SS,AB	Container grown, 2-3 ft.	J
CREATED WETLAND BERM			
Cornus racemosa/Gray dogwood	WC,WF	Container grown, 2-3 ft..	K
Corylus sp./Hazlenut	WC,WF	Container grown, 2-3 ft.	K
Rosa rugosa/Rugosa rose[5]	WC,WF,A	Container grown, 2-3 ft.	K
Viburnum acerifolium/Maple-leaved viburnum	WC,WF	Container grown, 2-3 ft.	K

TABLE .-16 (Continued)

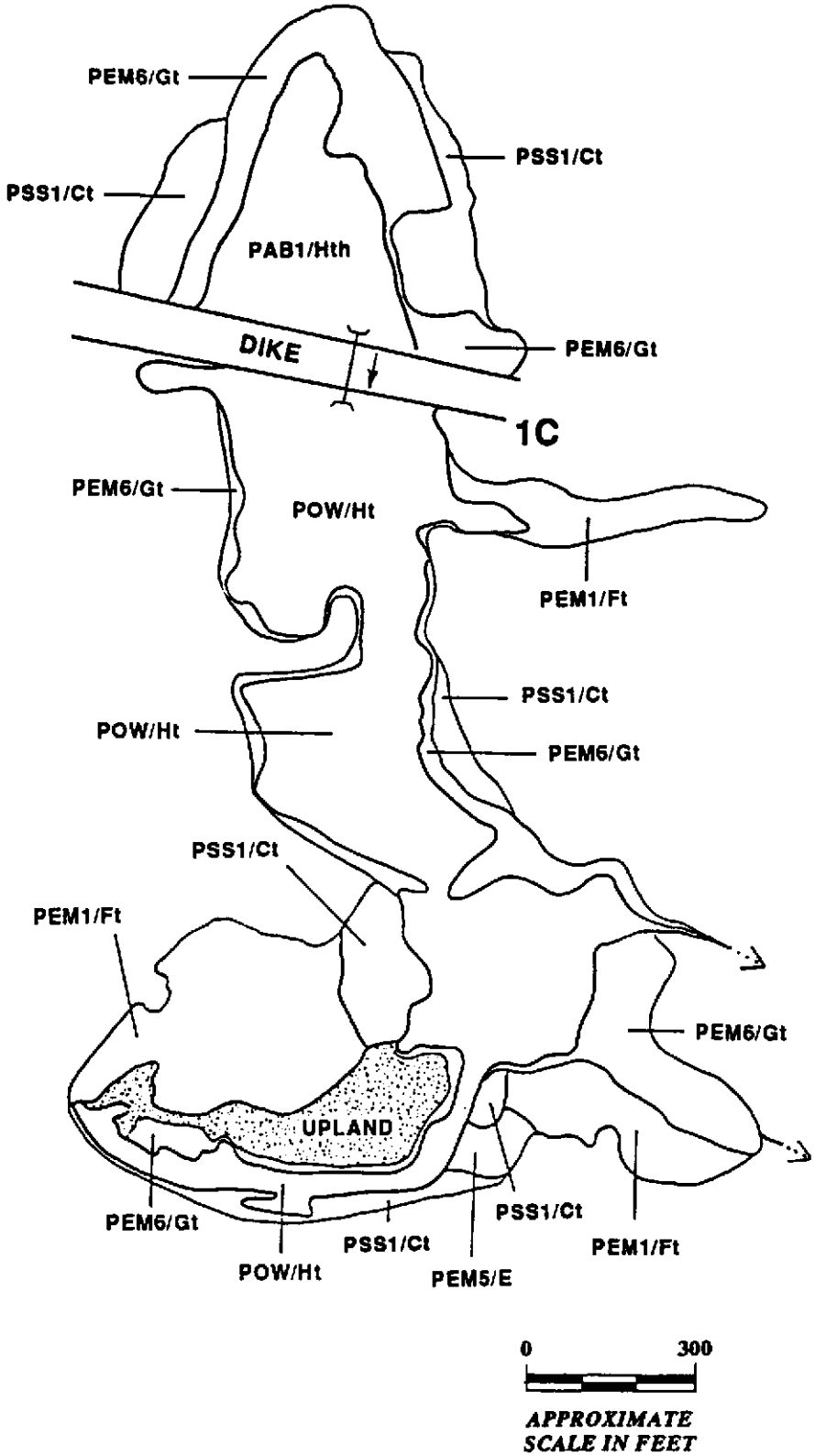
[2]PLANTING SPECIFICATIONS

A - Mix of species[+]/cluster; planted on 3-foot centers; 15 propagules/12-foot diameter cluster, 160 clusters/acre
B - Single species/cluster; planted on 3-foot centers; 30 propagules/12x24 foot cluster; 3 clusters/acre
C - 35 lbs. seed/acre (15 lbs. *Echinocloa crusgalli*, 20 lbs. mix of other species)
D - Propagules planted irregularly throughout habitat; minimum spacing of 4 feet; 500 plants/acre
E - Single species/cluster; planted on 6-foot centers; 6 plants/12-foot diameter cluster; 10 clusters/acre
F - Mix of species[+]/cluster; planted on 6-foot centers; 15 plants/25-foot diameter cluster, 45 clusters/acre; planted on 6 to 16 in. high soil hummocks
G - 25 lbs. seed/acre (15 lbs. *Echinocloa crusgalli*, 10 lbs. mix of other species)
H - Mix of species[+]/cluster; planted on 10-foot centers; 15 plants/40-foot diameter cluster, 15 clusters/acre
I - Plants spaced irregularly throughout habitat; minimum spacing of 15 feet; 50 plants/acre
J - Mix of species[+]/row; planted on 5-foot centers in 2 staggered rows along drainways; 1 row 1 foot from edge of bank; another row 3 feet from edge of bank
MF - Both male and female plants must be planted

[+]Include in mix only those species listed within a habitat.

[3]UPLAND BUFFER - Planting specifications are for unvegetated areas only. For areas to receive supplemental plantings only (i.e., areas that currently have ≤50 percent total vegetation cover), plant enough seed and nursery stock to achieve 75 percent cover.

[4]*Quercus rubra* and *Prunus serotina* will be planted along Wetland 3A only, not within the created wetland buffer, due to long tap roots.



LEGEND
(Cowardin, et al. 1979)

P Palustrine System
- **EM** Emergent Class
  - **1** - Persistant
  - **5** - Narrow-leaved persistant
  - **6** - Broad-leaved persistant
- **SS** Scrub-Shrub Class
  - **1** - Broad-leaved deciduous
- **FO** Forested Class
  - **1** - Broad-leaved deciduous
- **AB** Aquatic Bed Class
  - **1** - Submerged algal
- **OW** Open Water Class
  - Unknown bottom

R Riverine System
- **2** Lower Perennial Subsystem
- **UB** Unconsolodated Bottom
  - **3** - Mud

Modifying Terms

- **C** Seasonally Flooded
- **E** Seasonal/Saturated
- **F** Semipermanently Flooded
- **G** Intermittently Exposed
- **H** Permanently Flooded
- **t** Circumneutral pH
- **d** Partially Drained/Ditched
- **g** Organic Soil
- **h** Diked/Impounded
- **r** Artificial
- **s** Spoil

Figure 14-1. Classification of Wetland 1C. Adapted from WMS (ca. 1986).

Figure 14-2a. Wetland 1C - northern end of East-West Hide Pile Wetland.

Figure 14-2b. Wetland 1C - southern end of East-West Hide Pile Wetland.

Originals in color.

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Figure 14-3. Wetland 2A - Channelized Stream Outlet of the East-West Hide Pile Wetland, looking east (downstream).

Figure 14-4. Wetland 2B - Aberjona River in the median of Commerce Way, looking south (downstream).

Originals in color.

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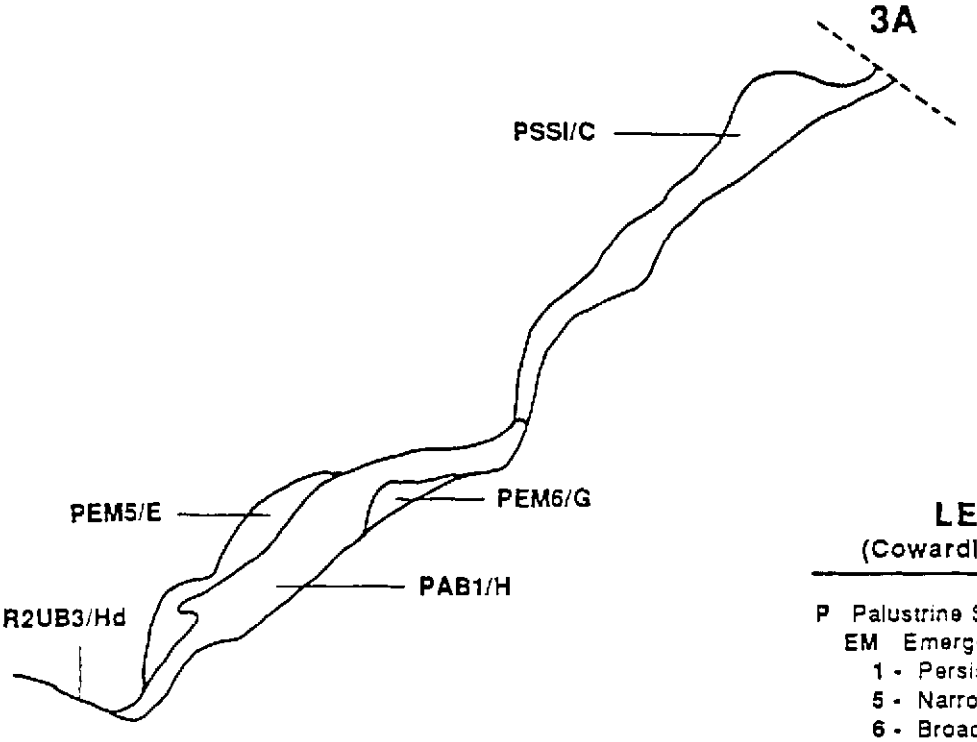

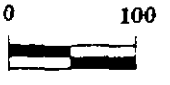

APPROXIMATE SCALE IN FEET

LEGEND
(Cowardin, et al. 1979)

P Palustrine System
- EM Emergent Class
  - 1 - Persistant
  - 5 - Narrow-leaved persistant
  - 6 - Broad-leaved persistant
- SS Scrub-Shrub Class
  - 1 - Broad-leaved deciduous
- FO Forested Class
  - 1 - Broad-leaved deciduous
- AB Aquatic Bed Class
  - 1 - Submerged algal
- OW Open Water Class
  - Unknown bottom

R Riverine System
- 2 Lower Perennial Subsystem
- UB Unconsolodated Bottom
  - 3 - Mud

Modifying Terms

- C Seasonally Flooded
- E Seasonal/Saturated
- F Semipermanently Flooded
- G Intermittently Exposed
- H Permanently Flooded
- t Circumneutral pH
- d Partially Drained/Ditched
- g Organic Soil
- h Diked/Impounded
- r Artificial
- s Spoil

Figure 14-5. Classification of Wetland 3A. Adapted from WMS (ca. 1986).

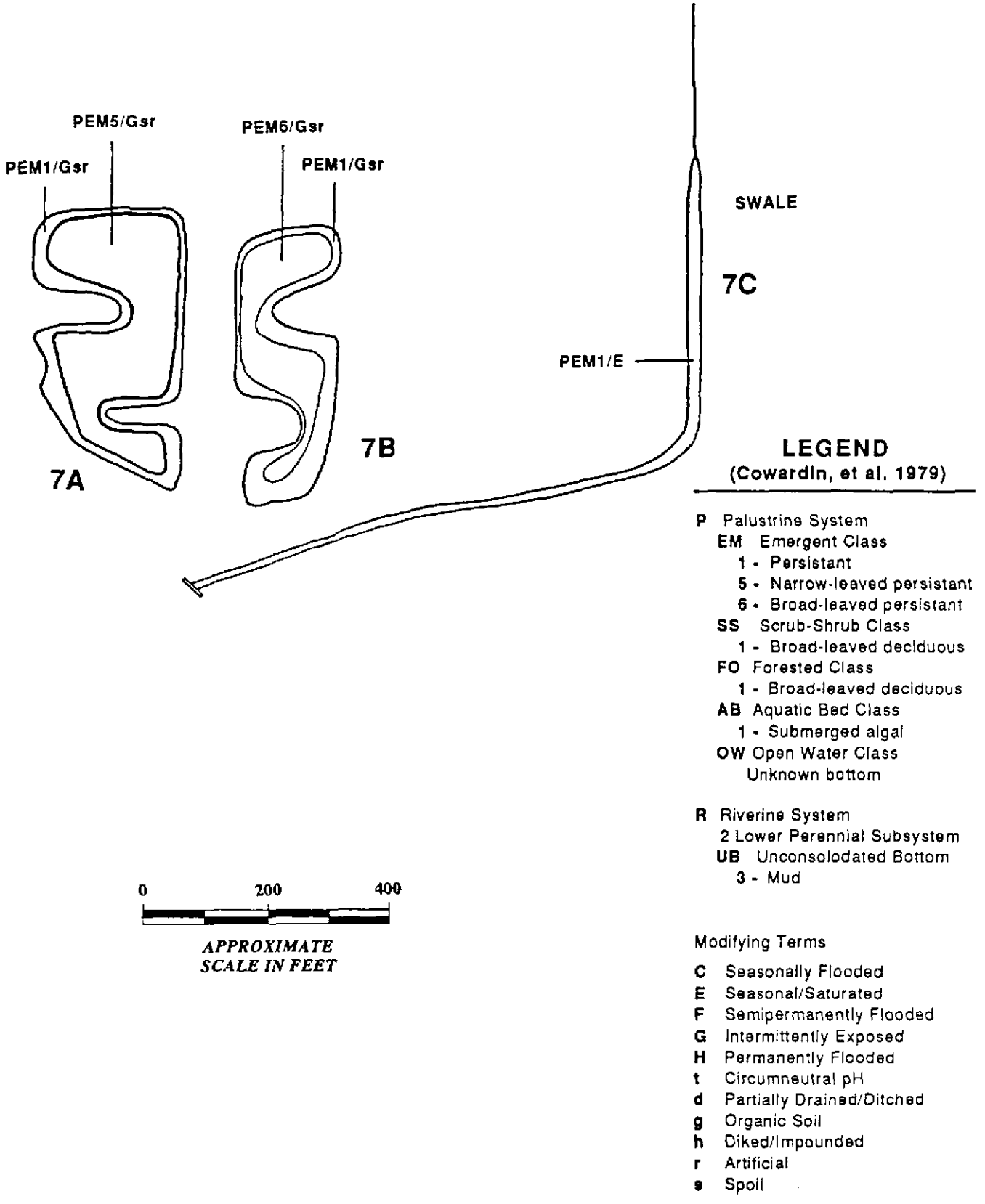

Figure 14-6. Classification of Wetlands 7A, 7B, and 7C. Adapted from WMS (ca. 1986).

Figure 14-7. Wetland 7A - Western Chromium Lagoon, looking south from its northern edge.

Figure 14-8. Wetland 8, looking southeast towards the railroad tracks.

Originals in color.

APR 25 1992

APPENDIX 14-A

Modified Hollands-Magee

Functional Assessment Results

MODEL RESULT SUMMARY APPENDIX: Industri-plex Wetland Assessment Results

These wetland functional models were developed in 1981 to meet the requirements of the state of Wisconsin in protecting ten benefits which accrue to the public from wetlands. They were published in 1981 as part of a site review for Exxon Minerals Co., Rhinelander, WI, and later in a conference proceedings (Hollands & Magee, 1985, Association of State Wetlands Managers, Portland).

The models were modified to fulfill the requirements of wetlands laws in New England, although they still contain the elements originally specified by the Wisconsin models. The software was designed as a resource management tool, to sort and compare groups of wetlands by Wet ID.

Model values do not represent the actual value of a wetland in performing each function, however they do provide a numerical figure, ranging between 0 and 100, suitable for ranking wetlands one against another. It is important to understand that a result of zero does not indicate zero importance, only that the wetland is at the low end as compared to other wetlands in the region. Each score summary is followed by a ranking summary, where each wetland's score is compared to those of over 1000 other New England freshwater wetlands, and its rank is established to the nearest ten percent (decile).

Plant Community Index values are also provided to summarize the wetland preference of those species found in each wetland. The Wetland Site Index (WSI) is the average frequency with which the plants in each wetland generally grow in wetland areas, each weighted by its respective abundance.

	NO. AND NAME OF BENEFIT MODEL									
WETLAND	1	2	3	4	5	6	7	8	9	10
ID NO.	Biol	Hydro	GrWat	Flood	ShLi*	WQual	Econ	Recr*	Aest*	Educ*
Model ranking by decile										
1C	9	7	3	2	7	2	1	9	10	8
2A	3	2	3	1	NA	1	1	3	4	2
2B	1	2	5	1	NA	1	1	5	7	3
3A	10	7	5	2	8	8	1	3	3	6
7B	5	1	5	7	NA	7	2	3	8	1
8	4	4	2	4	NA	5	3	2	3	2

* Model modified from Wisconsin original

SITE: W0001 ECOLOGICAL SUMMARY Michener Software 01/10/91
Normandeau Associates Inc.

Location: 1-C EAST-WEST HIDE PILE WETLAND, WOBURN, MA
Field Date: 04/16/90 Report Date: 03/05/91 Observer: CAW

Scientific name	Common name	Abun-dance	Wetl Freq	Food Value
TREES:				
Acer rubrum	Red maple	5.0	0.50	3
Populus tremuloides	Quaking aspen	2.0	0.00	2
Populus deltoides	Cottonwood	2.0	0.50	2
Prunus serotina	Black cherry	1.0	0.18	3
Rhus typhina	Staghorn sumac	1.0	0.00	2
Quercus rubra	Northern red oak	1.0	0.09	4
Quercus bicolor	Swamp white oak	1.0	0.91	4
Quercus alba	White oak	0.5	0.18	4
Amelanchier sp.	Shadbush	0.5		1
SHRUBS:				
Rhamnus frangula	Europ. buckthorn	5.0	0.50	0
Spiraea latifolia	Meadowsweet	2.0	0.60	0
Salix discolor	Pussy willow	1.0	0.82	1
Spiraea tomentosa	Steeplebush	1.0	0.82	0
Sambucus canadensis	Elderberry	1.0	0.71	1
Acer rubrum	Red maple	1.0	0.50	2
Vaccinium corymbosum	Highbush blueberry	0.5	0.71	2
Aronia melanocarpa	Black chokeberry	0.5	0.50	1
Alnus rugosa	Speckled alder	0.5	0.91	1
Viburnum recognitum	Northern arrowwood	0.5	0.71	1
Rhus glabra	Smooth sumac	0.5	0.00	2
Cornus amomum	Silky dogwood	0.5	0.82	3
Kalmia angustifolia	Sheep laurel	0.5	0.50	0
LIANAS:				
Rhus radicans	Poison ivy	2.0	0.50	2
Celastrus scandens	Climbing bittersweet	0.5	0.00	1
HERBS:				
Phragmites australis	Reed	30.0	0.82	0
Lythrum salicaria	Purple loosestrife	20.0	0.91	0
Impatiens capensis	Jewelweed	4.0	0.82	0
Scirpus cyperinus	Woolgrass	3.0	0.91	3
Typha latifolia	Cattail	3.0	1.00	1
Lemna sp.	Duckweed	1.0	1.00	1
Carex stricta	Tussock sedge	1.0	1.00	3
Onoclea sensibilis	Sensitive fern	1.0	0.82	0
Phytolacca americana	Pokeweed	0.5	0.29	1
Melilotus alba	White sweetclover	0.5	0.09	0
Maianthemum canadense	Canada mayflower	0.5	0.40	0
Carex pensylvanica	Upland sedge	0.5	0.00	3
Solanum dulcamara	Bittersweet	0.5	0.40	0

Table Continued on Next Page

(Continued Plant Table)
SITE: W0001 ECOLOGICAL SUMMARY Michener Software 01/10/91
Normandeau Associates Inc.

Location: 1-C EAST-WEST HIDE PILE WETLAND, WOBURN, MA
Field Date: 04/16/90 Report Date: 03/05/91 Observer: CAW

Scientific name	Common name	Abun-dance	Wetl Freq	Food Value

WSI: 0.725 By Layer: Trees: 0.353 Shrubs: 0.596 Herbs: 0.843
Layer Composition: Trees: 14.5% Shrubs: 15.0% Herbs: 67.9%
Wetland Type: Open Fresh Water
NOTE: Water quality degradation observed;

RESULTS OF RANKING HOLLANDS-MAGEE MODEL COMPUTATIONS

Benefit Description	Decile Rank: 1 - - - - 10
1 Biological function, incl. productivity & wildlife	:*****:**** :
2 Hydrologic ability to maintain flows in dry periods	:*****:** :
3 Ground Water recharge through wetland	:*** : :
4 Flood storage by crest desynchronization	:** : :
5 Shoreline, protection from erosion	:*****:** :
6 Water Quality protection by treatment of pollutants	:** : :
7 Economic values, primarily timber or hay	:* : :
8 Recreational values, access to nature, fish or game	:*****:**** :
9 Aesthetic values, primarily scenic appeal	:*****:*****:
10 Educational value, public access to wetland ecology	:*****:*** :

SITE: W0021 ECOLOGICAL SUMMARY Michener Software 01/10/91
Normandeau Associates Inc.

Location: Wetland 1-C Post Remediation/Revitalization
Field Date: 07/09/91 Report Date: 12/04/91 Observer: LEC

RESULTS OF RANKING HOLLANDS-MAGEE MODEL COMPUTATIONS

Benefit Description	Decile Rank: 1 - - - - 10
1 Biological function, incl. productivity & wildlife	:*****:** :
2 Hydrologic ability to maintain flows in dry periods	:*****:** :
3 Ground Water recharge through wetland	:*** : :
4 Flood storage by crest desynchronization	:** : :
5 Shoreline, protection from erosion	:*****:** :
6 Water Quality protection by treatment of pollutants	:** : :
7 Economic values, primarily timber or hay	:* : :
8 Recreational values, access to nature, fish or game	:*****:*** :
9 Aesthetic values, primarily scenic appeal	:*****:*** :
10 Educational value, public access to wetland ecology	:** : :

SITE: W0002 ECOLOGICAL SUMMARY Michener Software 01/10/91
Normandeau Associates Inc.

Location: 2A CHANNELIZED OUTLET STREAM, WOBURN, MA
Field Date: 04/16/90 Report Date: 03/05/91 Observer: CAW

Scientific name	Common name	Abun-dance	Wetl Freq	Food Value
TREES:				
Prunus serotina	Black cherry	2.0	0.18	3
Populus deltoides	Cottonwood	2.0	0.50	2
SHRUBS:				
Rhamnus frangula	Europ. buckthorn	15.0	0.50	0
Acer rubrum	Red maple	5.0	0.50	2
Betula populifolia	Grey birch	4.0	0.50	1
Spiraea latifolia	Meadowsweet	4.0	0.60	0
Populus tremuloides	Quaking aspen	2.0	0.00	1
Berberis thunbergii	Japanese barberry	1.0	0.18	1
Salix discolor	Pussy willow	1.0	0.82	1
Spiraea tomentosa	Steeplebush	1.0	0.82	0
HERBS:				
Phragmites australis	Reed	5.0	0.82	0
Lythrum salicaria	Purple loosestrife	5.0	0.91	0
Pteridium aquilinum	Bracken	4.0	0.18	0

WSI: 0.528 By Layer: Trees: 0.340 Shrubs: 0.492 Herbs: 0.669
Layer Composition: Trees: 7.8% Shrubs: 64.7% Herbs: 27.5%
Wetland Type: Streamside Wetland

RESULTS OF RANKING HOLLANDS-MAGEE MODEL COMPUTATIONS

Benefit Description	Decile Rank: 1 - - - - 10
1 Biological function, incl. productivity & wildlife	:*** : :
2 Hydrologic ability to maintain flows in dry periods	:** : :
3 Ground Water recharge through wetland	:*** : :
4 Flood storage by crest desynchronization	:* : :
5 Shoreline, protection from erosion: No open water	
6 Water Quality protection by treatment of pollutants	:* : :
7 Economic values, primarily timber or hay	:* : :
8 Recreational values, access to nature, fish or game	:*** : :
9 Aesthetic values, primarily scenic appeal	:**** : :
10 Educational value, public access to wetland ecology	:** : :

SITE: W0009 ECOLOGICAL SUMMARY Michener Software 01/10/91
Normandeau Associates Inc.

Location: 2B ABERJONA RIVER, WOBURN, MA
Field Date: 04/16/90 Report Date: 03/05/91 Observer: CAW

Scientific name	Common name	Abun-dance	Wetl Freq	Food Value
SHRUBS:				
Rhamnus frangula	Europ. buckthorn	2.0	0.50	0
Populus deltoides	Cottonwood	2.0	0.50	1
Populus tremuloides	Quaking aspen	2.0	0.00	1
Cornus amomum	Silky dogwood	2.0	0.82	3
Betula populifolia	Grey birch	1.0	0.50	1
Sambucus canadensis	Elderberry	1.0	0.71	1
Salix nigra	Black willow	1.0	0.91	0
Salix discolor	Pussy willow	1.0	0.82	1
HERBS:				
Phragmites australis	Reed	45.0	0.82	0
Lythrum salicaria	Purple loosestrife	30.0	0.91	0
Impatiens capensis	Jewelweed	4.0	0.82	0
Calamagrostis canadensis	Bluejoint grass	4.0	0.91	0
Equisetum arvense	Common horsetail	3.0	0.50	0

WSI: 0.808 By Layer: Trees: Shrubs: 0.548 Herbs: 0.844
Layer Composition: Trees: 0.0% Shrubs: 12.2% Herbs: 87.8%
Wetland Type: Streamside Wetland

RESULTS OF RANKING HOLLANDS-MAGEE MODEL COMPUTATIONS

Benefit Description	Decile Rank: 1 - - - - 10
1 Biological function, incl. productivity & wildlife	:* : :
2 Hydrologic ability to maintain flows in dry periods	:** : :
3 Ground Water recharge through wetland	:*****: :
4 Flood storage by crest desynchronization	:* : :
5 Shoreline, protection from erosion: No open water	
6 Water Quality protection by treatment of pollutants	:* : :
7 Economic values, primarily timber or hay	:* : :
8 Recreational values, access to nature, fish or game	:*****: :
9 Aesthetic values, primarily scenic appeal	:*****:** :
10 Educational value, public access to wetland ecology	:*** : :

SITE: W0004 ECOLOGICAL SUMMARY Michener Software 01/10/91
Normandeau Associates Inc.

Location: 3A NORTH BRANCH - ABERJONA RIVER, WOBURN, MA
Field Date: 04/16/90 Report Date: 11/15/91 Observer: CAW

Scientific name	Common name	Abun-dance	Wetl Freq	Food Value
TREES:				
Acer rubrum	Red maple	2.0	0.50	3
SHRUBS:				
Viburnum recognitum	Northern arrowwood	10.0	0.71	1
Acer rubrum	Red maple	10.0	0.50	2
Betula populifolia	Grey birch	7.0	0.50	1
Spiraea latifolia	Meadowsweet	5.0	0.60	0
Alnus rugosa	Speckled alder	4.0	0.91	1
Betula papyrifera	Paper birch	4.0	0.18	1
Populus tremuloides	Quaking aspen	3.0	0.18	1
Cornus amomum	Silky dogwood	3.0	0.82	3
Quercus ilicifolia	Bear (scrub) oak	2.0	0.00	4
Spiraea tomentosa	Steeplebush	2.0	0.82	0
Kalmia angustifolia	Sheep laurel	2.0	0.50	0
Lonicera xylosteum	European fly-honeysuckle	1.0	0.00	2
Rosa palustris	Marsh rose	1.0	1.00	1
Sambucus canadensis	Elderberry	1.0	0.71	1
Chamaedaphne calyculata	Leatherleaf	1.0	1.00	0
Rhododendron canadense	Rhodora	1.0	0.82	0
INTERMEDIATE:				
Rubus hispidus	Trailing bramble	3.0	0.82	3
HERBS:				
Onoclea sensibilis	Sensitive fern	17.0	0.82	0
Impatiens capensis	Jewelweed	12.0	0.82	0
Osmunda cinnamomea	Cinnamon fern	5.0	0.82	0
Carex stricta	Tussock sedge	4.0	1.00	3
Juncus effusus	Soft rush	4.0	0.91	0
Symplocarpus foetidus	Skunk cabbage	4.0	1.00	0
Lythrum salicaria	Purple loosestrife	3.0	0.91	0
Typha latifolia	Cattail	3.0	1.00	1
Scirpus cyperinus	Woolgrass	2.0	0.91	3
Sphagnum sp.	Sphagnum moss	2.0	1.00	0
Juncus canadensis	Canada rush	2.0	1.00	0
Veratrum viride	White hellebore	2.0	0.91	0
Caltha palustris	Marsh marigold	2.0	1.00	0
Phalaris arundinacea	Reed canary grass	2.0	0.91	2
Phragmites australis	Reed	2.0	0.82	0
Polygonum saggitatum	Arrow-leaved tearthumb	2.0	1.00	3
Athyrium filix-femina	Lady fern	1.0	0.50	0

WSI: 0.736 By Layer: Trees: 0.500 Shrubs: 0.564 Herbs: 0.882
Layer Composition: Trees: 1.5% Shrubs: 43.5% Herbs: 52.7%
Wetland Type: Shrub/Scrub Swamp

Evaluation continued from previous page
SITE: WO004 ECOLOGICAL SUMMARY Michener Software 01/10/91
Normandeau Associates Inc.

Location: 3A NORTH BRANCH - ABERJONA RIVER, WOBURN, MA
Field Date: 04/16/90 Report Date: 03/05/91 Observer: CAW

RESULTS OF RANKING HOLLANDS-MAGEE MODEL COMPUTATIONS

Benefit Description	Decile Rank: 1 - - - - 10
1 Biological function, incl. productivity & wildlife	:*****:*****:
2 Hydrologic ability to maintain flows in dry periods	:*****:* :
3 Ground Water recharge through wetland	:*****: :
4 Flood storage by crest desynchronization	:** : :
5 Shoreline, protection from erosion	:*****:*** :
6 Water Quality protection by treatment of pollutants	:*****:*** :
7 Economic values, primarily timber or hay	:* : :
8 Recreational values, access to nature, fish or game	:*** : :
9 Aesthetic values, primarily scenic appeal	:*** : :
10 Educational value, public access to wetland ecology	:*****:* :

SITE: W0003 ECOLOGICAL SUMMARY Michener Software 01/10/91
Normandeau Associates Inc.

Location: 7B CHROMIUM LAGOON, WOBURN, MA
Field Date: 04/16/90 Report Date: 03/05/91 Observer: CAW

Scientific name	Common name	Abun-dance	Wetl Freq	Food Value
TREES:				
Populus tremuloides	Quaking aspen	2.0	0.00	2
SHRUBS:				
Rhamnus frangula	Europ. buckthorn	5.0	0.50	0
Spiraea latifolia	Meadowsweet	5.0	0.60	0
Betula populifolia	Grey birch	3.0	0.50	1
Salix discolor	Pussy willow	2.0	0.82	1
INTERMEDIATE:				
Rubus allegheniensis	Blackberry	3.0	0.09	3
HERBS:				
Lythrum salicaria	Purple loosestrife	50.0	0.91	0
Phragmites australis	Reed	40.0	0.82	0

WSI: 0.793 By Layer: Trees: 0.000 Shrubs: 0.576 Herbs: 0.870
Layer Composition: Trees: 1.8% Shrubs: 13.6% Herbs: 81.8%
Wetland Type: Shallow Fresh Marsh
NOTE:

RESULTS OF RANKING HOLLANDS-MAGEE MODEL COMPUTATIONS

Benefit Description	Decile Rank: 1 - - - - 10
1 Biological function, incl. productivity & wildlife	:*****: :
2 Hydrologic ability to maintain flows in dry periods	:* : :
3 Ground Water recharge through wetland	:*****: :
4 Flood storage by crest desynchronization	:*****:** :
5 Shoreline, protection from erosion: No open water	
6 Water Quality protection by treatment of pollutants	:*****:** :
7 Economic values, primarily timber or hay	:** : :
8 Recreational values, access to nature, fish or game	:*** : :
9 Aesthetic values, primarily scenic appeal	:*****:*** :
10 Educational value, public access to wetland ecology	:* : :

SITE: W0011 ECOLOGICAL SUMMARY Michener Software 01/10/91
Normandeau Associates Inc.

Location: 8 RIGHT-OF-WAY WETLAND, WOBURN, MA
Field Date: 04/16/90 Report Date: 03/05/91 Observer: CAW

Scientific name	Common name	Abun-dance	Wetl Freq	Food Value
SHRUBS:				
Spiraea tomentosa	Steeplebush	56.0	0.82	0
Spiraea latifolia	Meadowsweet	5.0	0.60	0
Rhamnus frangula	Europ. buckthorn	5.0	0.50	0
Betula populifolia	Grey birch	3.0	0.50	1
Betula papyrifera	Paper birch	3.0	0.18	1
HERBS:				
Phragmites australis	Reed	15.0	0.82	0
Scirpus cyperinus	Woolgrass	15.0	0.91	3
Lythrum salicaria	Purple loosestrife	8.0	0.91	0
Juncus effusus	Soft rush	8.0	0.91	0
Carex stricta	Tussock sedge	7.0	1.00	3
Cyperus strigosus	Umbrella sedge	6.0	0.82	0
Eupatorium maculatum	Spotted joe pye weed	4.0	0.82	0
Epilobium coloratum	Purple willowweed	4.0	1.00	1
Verbena hastata	Blue vervain	2.0	0.91	0

WSI: 0.816 By Layer: Trees: Shrubs: 0.742 Herbs: 0.892
Layer Composition: Trees: 0.0% Shrubs: 51.1% Herbs: 48.9%
Wetland Type: Shrub/Scrub Swamp

RESULTS OF RANKING HOLLANDS-MAGEE MODEL COMPUTATIONS

Benefit Description	Decile Rank: 1 - - - - 10
1 Biological function, incl. productivity & wildlife	:**** : :
2 Hydrologic ability to maintain flows in dry periods	:**** : :
3 Ground Water recharge through wetland	:** : :
4 Flood storage by crest desynchronization	:**** : :
5 Shoreline, protection from erosion: No open water	
6 Water Quality protection by treatment of pollutants	:*****: :
7 Economic values, primarily timber or hay	:*** : :
8 Recreational values, access to nature, fish or game	:** : :
9 Aesthetic values, primarily scenic appeal	:*** : :
10 Educational value, public access to wetland ecology	:** : :

APPENDIX 14-B

A Survey for the Mystic Valley Amphipod (*Crangonyx aberrans*) on the Industri-Plex Site

APPENDIX 14-B

A Survey for the Mystic Valley Amphipod (*Crangonyx aberrans*) at the Industri-Plex Site, Woburn, Massachusetts

Prepared for

GOLDER ASSOCIATES, INC.
20000 Horizon Way, Suite 500
Mt. Laurel, New Jersey 08054

Prepared by

NORMANDEAU ASSOCIATES INC.
25 Nashua Road
Bedford, New Hampshire 03110

August 1991

10538.10

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Figure 14-B2 Amphipod Sampling Stations

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Attachment C. Qualifications of Investigators

1.0 INTRODUCTION

The objective of this report is to present the results of the investigation conducted at the ISRT Industri-Plex Site to determine the presence of the Mystic Valley Amphipod or its habitat. The Applicable or Relevant and Appropriate Regulations (ARARs) for these remedial actions include the Massachusetts Wetlands Protection Act (M.G.L. c. 131 s. 40) and the associated regulations (310 C.M.R. Sec. 10.00). Compliance with these regulations requires correspondence with the Massachusetts Natural Heritage and Endangered Species Program to determine if the proposed work will alter the habitat of State-listed rare wetlands wildlife as mapped by the State of Massachusetts. The Estimated Habitat Map for the Wilmington, Massachusetts quadrangle identifies two potential habitat areas near the Industri-Plex Site for the Mystic Valley Amphipod, *Crangonyx aberrans* (Figure 14-B1). This study was undertaken to confirm or refute the presence of *C. aberrans* and/or its preferred habitat at Industri-Plex.

2.0 LITERATURE REVIEW

2.1 TAXONOMY

Crangonyx aberrans is a freshwater amphipod commonly known as the Mystic Valley Amphipod (Massachusetts Natural Heritage and Endangered Species Program, no date). Amphipods have small (5 to 20 mm long) laterally compressed, segmented bodies and large, kidney shaped eyes. Most species of amphipods are marine. Of the three suborders of the Order Amphipoda, only one, the Gammaroidea, is found in the freshwaters of the U.S.

Crangonyx aberrans was described as a new species relatively recently by Smith (1983). It is similar to both *C. pseudogracilis*, which also occurs in New England, and *C. shoemakeri* (Smith, 1983). The morphological characteristics used to separate adult *C. aberrans* from other species of *Crangonyx* include the presence of subapical spines on the sides of the telson; the presence of both notched spines on the palm of the gnathopods (grasping front legs) and singly spaced setae on the inner face of the second to last gnathopod segment; and the distinctive morphology of the second and third abdominal uropods (Massachusetts Natural Heritage and Endangered Species Program, no date). Its range seems to be limited to eastern Massachusetts, which makes it one of only a few amphipods restricted to New England (Mass. Natural Heritage and Endangered Species Program, no date; Smith, 1983). Its distribution and morphological distinctiveness may contribute to knowledge about species movements during and after the last period of glaciation (Smith, 1983). *C. aberrans* is listed as a Species of Special Concern by the Massachusetts Natural Heritage Inventory.

2.2 NATURAL HISTORY

Freshwater amphipods typically occur in unpolluted clear water. They hide in vegetation or under debris and stones during the day. Little is known about the microhabitat requirements of *C. aberrans*. It has been documented from several streams in Massachusetts, including Halls Brook and the Aberjona River (Smith, 1983; Massachusetts Natural Heritage and

Endangered Species Program, no date). In eastern Massachusetts, *C. aberrans* appears to prefer cool, shallow, slow moving water with leaf litter where it often forages among plant roots (Massachusetts Natural Heritage and Endangered Species Program, no date). Juveniles live in the sediment. Suitable habitats include red maple (*Acer rubrum*) and white cedar (*Chamaecyparis thyoides*) forested wetlands, and small, permanent, stagnant or almost stagnant bodies of water.

The life history of *C. aberrans* is poorly known. This species breeds in spring or early summer. Its life span is approximately one year (Massachusetts Natural Heritage and Endangered Species Program, no date).

3.0 METHODS

3.1 FIELD INVESTIGATIONS

Field sampling was conducted during June 5-7, 1991 and July 12, 1991 at 26 sites on the Aberjona River, Halls Brook, and some of their tributaries; and several isolated ponds. Qualitative kick samples were collected from each habitat type found in the streams selected. Habitats that were sampled included riffles, runs, and pools. Criteria used to separate habitat types included: substrate; vegetative canopy cover and species composition; water velocity; presence of plant detritus; and water depth. Physical characteristics of each station were recorded in a field notebook (Table 14-B1) and photographs were taken. In addition to physical characteristics, water quality data (Table 14-B2) were collected at each station. These data included temperature, dissolved oxygen, pH, and conductivity. The sampling station descriptions are included in Attachment A.

Amphipods were collected by using a "D" framed net to agitate the substrate, root wads, and undercut banks, and to catch dislodged animals. Net contents were emptied into a labeled sample container, preserved with 10% formalin, and returned to the laboratory for processing. Sampling procedures followed guidelines included in the Health and Safety Plan (dated June 14, 1991). Personal Protective Equipment (PPE) was used at all on-Site stations as well as off-Site stations which were downstream of the Industri-Plex Site.

3.2 LABORATORY PROCEDURES

The 26 benthic samples were sieved through a 600 micron mesh screen. All amphipods were sorted and placed in 70 percent ethanol for subsequent identification. Amphipods of the genus *Crangonyx* were speciated and enumerated (Table 14-B3). References aiding identification included Bousfield (1958), Smith (1977), Smith (1983), and Pennak (1989). Remaining sample residues were also preserved in 70 percent ethanol. Amphipod samples will be archived for a minimum of one year. Specimens

were sent to Dr. Les Watling at the University of Maine Darling Marine Center, Walpole, Maine, for verification. A copy of his letter confirming the identifications appears in Attachment B.

4.0 DISCUSSION

Adult *C. aberrans* were not found at any station sampled during this study although Smith (1983) and the Massachusetts Natural Heritage and Endangered Species Program listed the Aberjona River and Willow Halls Brook as habitat for this species. Some of the juvenile *Crangonyx sp.* cannot be identified to species. *C. pseudogracilis* and/or immature *Crangonyx sp.* were collected at 12 sites. These 12 sites were located on the North and South Branches of the Aberjona River, Phillips Pond, the New Boston Street Drainway, and Halls Brook Holding Area. Smith (1983) stated that *C. aberrans* is sympatric with *C. pseudogracilis*. Sympatric species occupy the same habitat and are commonly found in comparable numbers within a habitat type. Both species breed in the spring and summer (Bousfield, 1958; Massachusetts Natural Heritage and Endangered Species Program, no date). Since *C. pseudogracilis* was found at several stations, it would seem possible that these areas are suitable *C. aberrans* habitat also, but *C. aberrans* was not collected.

Pennak (1989) listed habitats for *Hyalella azteca*, *Gammarus spp.* and *Crangonyx gracilis* as unpolluted clear waters, springs, springbrooks, streams, pools, ponds, and lakes. Bousfield (1958) stated that *C. pseudogracilis* has been recorded from large freshwater habitats that tend to be somewhat turbid and warm in the summer. He also found that *C. pseudogracilis* is frequently collected with *Gammarus fasciatus* and *Hyalella azteca*. All species collected during this study are commonly found in a variety of habitats. Every effort was made to sample the variety of habitats on-Site. Virtually all stations supported at least one species of amphipod, but none were collected in Wetland 3B.

5.0 CONCLUSIONS

C. aberrans has been previously recorded from Willow Halls Brook and the Aberjona River. The habitat described for this species is lowland streams with cool, shallow, moving water with leaf litter, and red maple and white cedar swamps. Several streams on or near the Industri-Plex Site, particularly the North Branch of the Aberjona, can be considered lowland streams which are characterized by sand and mud substrates, shallow depth, and slow current velocity. Macroinvertebrate samples were taken in these streams and several additional habitat types, including stagnant pools, riffles with cobble substrates, and ponds. However, *C. aberrans* was not found in any of the samples.

The wetlands and streams on-Site which are now known to support amphipods of the genus *Crangonyx* include the North and South Branches of the Aberjona River upstream of Commerce Way, Phillips Pond, the New Boston Street Drainway, and the Halls Brook Holding Area.

Wetland 3A, the North Branch of the Aberjona River, most nearly matches the preferred habitat of *C. aberrans*, and if *C. aberrans* is normally present on-Site, one might expect to find it in this wetland. The proposed remediation of the Industri-Plex Site will improve aquatic habitat in a short section of this stream through the restoration of Wetland 3A. These remedial activities will not adversely impact what appears to be the most suitable potential *C. aberrans* habitat and may result in a minor habitat improvement.

6.0 REFERENCES

Bousfield, E. L., 1958. "Fresh-Water Amphipod Crustaceans of Glaciated North America," The Canadian Field-Naturalist. Vol. 72, No. 2, pp. 55-113.

Massachusetts Natural Heritage and Endangered Species Program, No date. Massachusetts Rare and Endangered Wildlife, Mystic Valley Amphipod (*Crangonyx aberrans*). Commonwealth of Massachusetts, Division of Fisheries and Wildlife, Boston, MA, 2 pp.

Pennak, R. W., 1989. Fresh-water Invertebrates of the United States, 3rd Ed, John Wiley & Sons, Inc., 628 pp.

Smith, D. G., 1977. "The Genus *Crangonyx* (Amphipoda: Gammaridae) in the Central Connecticut River System," Canadian Field-Naturalist Vol. 91, No. 3, pp. 256-261.

Smith, D. G., 1982. "Range Extensions for Two Species of Gammaroidean Amphipods in Northeastern North America," Crustaceana Vol. 42, No. 3, pp. 315-316.

Smith, D. G., 1983. "A New Species of Fresh-water Gammaroidean Amphipod (Crangonyctidae) from Southeastern New England," Trans. Am. Microsc. Soc. Vol. 102, No. 4, pp. 355-365.

United States Environmental Protection Agency, 1986. Summary of Remedial Alternatives Selection, Industri-Plex Site, Woburn, Massachusetts, 102 pp + Appendices.

Table 14-B1. Physical Characteristics of Sampling Stations for the Industri-Plex Amphipod Study

STATION	WIDTH (ft)	DEPTH (ft)	VEL. (fps)	HABITAT TYPE	CANOPY COVER	SUBSTRATE % COMPOSITION							
						BOULDER	COBBLE	LARGE GRAVEL	SMALL GRAVEL	SAND	MUD/MUCK	SILT	DETRITUS
1	15.0	2.2	0.0	pool	open					50	50		
2	5.0	1.0	0.2	run	partly closed	2	65		15	10		8	
3	2.5	0.5	0.5	run	mostly closed					80			20
4	4.0	1.0	0.0	pool	open		10			50		20	20
5	7.5	1.0	0.3	riffle	open		25	25	25			10	15
6	1.5	0.2	0.0	pool	partly closed						75		25
7	10.0	1.0	0.2	run	open		10			80		10	
8	8.5	1.0	0.0	pool	mostly closed					80		15	5
9	8.5	0.2	0.8	riffle	mostly closed		50			30			20
10	5.0	1.0	0.0	pool	open						80		20
11	3.0	0.5	0.0	pool	open					100			
12	1.5	0.5	0.5	riffle	open		5	70	10	15			
13	6.0	1.0	0.0	pool	mostly closed					50	30		20
14	15.0	0.5	0.0	pool	mostly closed						80		20
15	8.0	0.5	0.0	pool	mostly closed						80		20
16	35.0	3.0	0.0	pool	open						100		
17	35.0	3.0	0.0	pool	open						80		20 (algae)
18	15.0	3.0	0.0	pool	open						100		
19	6.0	1.0	0.0	pool	mostly closed		40				60		
20	2.0	0.5	0.6	riffle	partly closed					90	10		
21	6.0	1.0	0.2	riffle	open		90					10	
22	6.0	0.5	0.0	pool	mostly closed					20	75		5
23	100.0	1.0	0.0	pool	open		40				50		10 (algae)
24	5.0	0.5	0.3	riffle	partly closed			50		10		40	
25	8.0	0.2	0.6	run	partly closed						50	10	40
26	5.0	0.5	0.0	pool	open						90	10	

* Open = 0.25% closed, partly closed = 25-50% closed, mostly closed = 50-75% closed, closed = 75-100% closed

NORMANDEAU ASSOCIATES

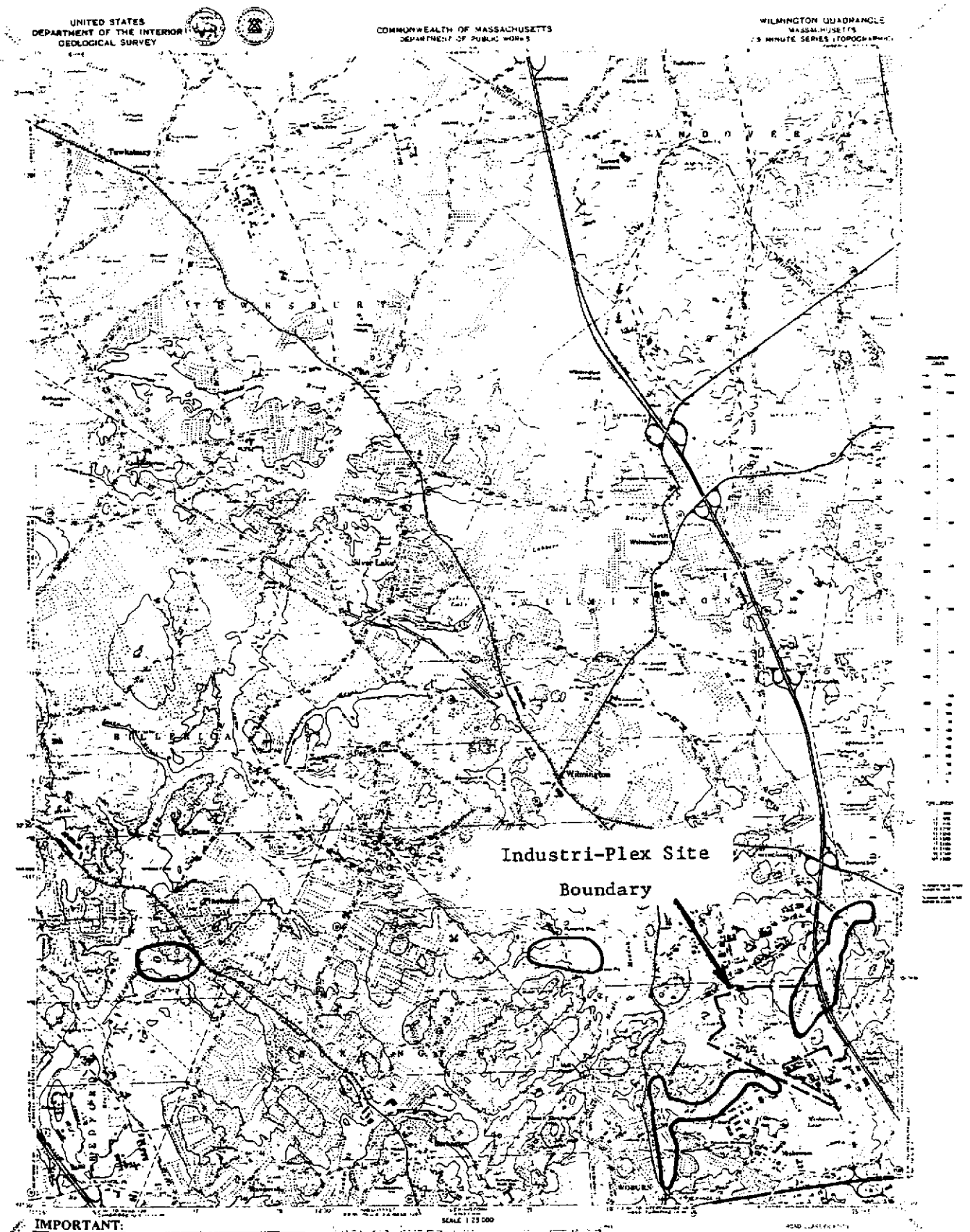
Table 14-B2. Water Quality Characteristics at Sampling Stations for the Industri-Plex Amphipod Study.

STATION	TEMP.	DISSOLVED OXYGEN	pH	CONDUCTIVITY
1	13.2	8.7	6.7	350
2	13.2	8.7	6.7	350
3	13.2	8.7	6.7	350
4	13.9	8.0	6.5	280
5	13.9	8.0	6.5	280
6	19.5	9.9	6.6	378
7	19.5	9.9	6.6	378
8	22.2	7.8	6.9	370
9	22.2	7.8	6.9	370
10	27.9	7.0	7.3	510
11	16.3	7.4	6.8	353
12	16.3	7.4	6.8	353
13	16.3	7.4	6.8	353
14	19.4	5.8	5.9	331
15	19.4	5.8	5.9	331
16	22.8	4.8	5.2	125
17	22.8	4.8	5.2	125
18	27.9	7.0	7.3	510
19	32.0	10.8	8.2	470
20	27.0	4.6	7.3	820
21	26.0	3.5	7.3	890
22	18.0	6.1	6.0	1010
23	23.7	9.0	6.9	770
24	21.5	8.5	6.8	590
25	22.5	9.1	7.2	610
26	20.5	6.4	7.3	1000

Table 14-B3. Amphipods Collected from Streams in the Vicinity of the Industri-Plex Site.

STATION	SAMPLE I.D. NUMBER	*Crangonyx pseudogracilis*	*Crangonyx* sp. juv.	*Hyalella azteca*	*Gammarus* spp.
1	126621		18	2	
2	126622		1		
3	126623	1	10		
4	126624	2	7	5	2
5	126625		9		
6	126626	9	1		
7	126627			100	
8	126628			333	
9	126629			245	1
10	126630			78	
11	126631		2	57	
12	126632			1	
13	126633	7	22	33	
14	126634	2			
15*	126635				
16*	126636				
17*	126637				
18	126638			37	
19	126639			125	
20	126640			3	
21	126641			2	
22	126652	1	4		
23	126653	3		156	
24	126654	13	6	7	
25	126655	15	2		
26	126656	17	1	12	

* = amphipods not found



IMPORTANT:

This map is to be used only in reference to the Wetlands Protection Act regulations (310 CMR 10). This map does not show the location of rare plants, upland wildlife, or ecologically significant natural communities. If you are completing an Environmental Notification Form (ENF), or if you require comprehensive rare species information for a particular area, you should contact the Natural Heritage and Endangered Species Program by writing to:

Environmental Reviewer
Natural Heritage and Endangered Species Program
100 Cambridge Street
Boston, MA 02202

ESTIMATED HABITAT MAP
Of State-listed Rare Wetlands Wildlife

Natural Heritage & Endangered Species Program
Massachusetts Division of Fisheries and Wildlife
JANUARY 1989 EDITION

Figure 14-B1.

LEGEND

- SITE BOUNDARY
- GRID LINE
- TRAIL
- SOIL AND WOOD CHIP PILES
- STREAMS AND WATERCOURSES
- RAILROAD TRACKS
- BUSH
- TREE
- SIGN
- UTILITY POLE
- CATCH BASIN
- MANHOLE
- FIRE HYDRANT
- (62.1) TYPICAL SPOT ELEVATION
- DEPRESSION
- 1986 DELINEATED WETLANDS (W.M.S.)
- HIDE PILES
- ● 1 AMPHIPOD SAMPLING STATION

NOTES

1.) TOPOGRAPHY FROM PHOTOGRAMMETRIC MAP COMPILED BY LIU AERIAL SURVEYS 15 APRIL 90, FOR SAIC ENGINEERING, INC. AT 1 IN. TO 100 FT. AERIAL PHOTOS TAKEN 22 NOVEMBER 90, SCALE 1 IN. TO 800 FT.

2.) SITE AND PROPERTY BOUNDARIES SURVEYED BY SAIC ENGINEERING, INC. APRIL 1, 1990 AND JANUARY 1991.

3.) ELEVATIONS TO NATIONAL GEODETIC VERTICAL DATUM OF 1929 GRID COORDINATES BASED ON MASSACHUSETTS COORDINATE SYSTEM.

4.) WETLANDS DELINEATED BY WETLAND MANAGEMENT SPECIALISTS, INC., JULY, 1986. "WETLANDS ASSESSMENT VOLUME II", WOBURN INDUSTRI-PLEX 128 SUPERFUND SITE, WOBURN, MA.

Figure 14-B2. Amphipod Sampling Stations.

200 0 200 400
scale feet

REV	DATE	DESCRIPTION	DR BY	RVW BY

SCALE: AS SHOWN		PROJECT: INDUSTRI-PLEX SITE REMEDIAL TRUST WOBURN, MASSACHUSETTS	
PROJECT No. 903-8400			
DES BY	BWM	07/10/91	SHEET TITLE: WETLANDS
DR BY	RDH	04/08/91	
CHK BY	[illegible]	04/12/91	
RVW BY	[illegible]	4-12-91	
Golder Associates, Mt. Laurel, New Jersey			SHEET 1 OF 1; DRAWING No. MAO-513; SHEET 8-8

ATTACHMENT A

SAMPLE STATION DESCRIPTIONS

ATTACHMENT A

SAMPLE STATION DESCRIPTIONS

Stations 1, 2, and 3 were on the North Branch of the Aberjona River, an area considered suitable habitat for *C. aberrans* (Figure 2). Station 1 was a pool which had undercut banks and a sand and mud/muck substrate (Table 1). Station 2 was located in a run approximately 100 ft upstream of Station 1. Station 3 was in a run approximately 350-400' downstream of Station 1.

Stations 4 and 5 (off-Site), and 6 (on-Site) were located on the south branch of the Aberjona River upstream of its entrance to Phillips Pond. Station 4 was at the downstream end of a wetland dominated by cattails. Station 5 was approximately 30 ft downstream of Station 4 in a riffle. Station 6 was located where this stream enters Phillips Pond. Station 7 was located at Phillips Pond outlet.

Stations 8 and 9 were respectively located on an on-Site pool and riffle in the north branch of the Aberjona River just upstream of Commerce Way. Both stations were mostly shaded due to a closed tree canopy.

Station 10 was located at the pond outlet in Wetland 3C. This Station had a soft mud/muck substrate with little aquatic vegetation.

Stations 11, 12, and 13 were located on the North Branch of the Aberjona River downstream of Stations 1, 2 and 3 on the Industri-Plex Site. Stations 11 and 13 represented pool habitats with open and closed canopies respectively. Station 12 was a riffle habitat.

Stations 14 and 15 were located on the Route 93 drainage ditch at the Industri-Plex boundary fence. This stream supported a dense growth of cattails and had an orange colored flocculent material covering the substrate.

Stations 16 and 17 were located in an open pond bordered by a red maple swamp in Wetland 3B. Both stations represented a soft-bottomed pond habitat with a substrate covered with leaf litter.

Station 18 was located in a shallow ponded area of Wetland 3C (the same wetland as in Station 10). The habitat sampled here included the littoral zone and a dense algae mat.

Stations 19 and 20 were located on the outlet from Wetland 1C. Water color at these stations was milky-white which may indicate altered water quality.

Station 21 was on the Aberjona River where it runs along Commerce Way. When the substrate was agitated during sampling, an oil sheen appeared on the water's surface.

Station 22 was located off-Site on the North Branch of the Aberjona River. This sampling station is beyond the area covered in Figure 2. Water levels were very low and standing/flowing water was absent in portions of the streambed. Samples were taken in a pool with virtually no flow.

Station 23 was located where Halls Brook enters the Halls Brook Holding Area. This Station had a cobble and mud substrate, open canopy, and approximately 10% algae cover.

Station 24 was located immediately downstream of the entrance culvert for the PX Realty Depression.

Stations 25 and 26 were located on the New Boston Street drainway. Station 25 was upstream of this stream's confluence with the tributary channel to the New Boston Drainway and Station 26 was downstream of the confluence.

ATTACHMENT B

TAXONOMIC VERIFICATION LETTER

UNIVERSITY OF MAINE

Ira C. Darling Center for Research, Teaching and Service

DARLING MARINE CENTER
Walpole, Maine 04573
207 563-3146

1 August 1991

Ms. Lee Carbonneau
Normandeau Assoc.
25 Nashua Rd
Bedford NH 03102-5999

Dear Lee:

This is to confirm that the amphipods sent to me were *Crangonyx pseudogracilis*, as identified by you and Ms. Hannah Proctor, and are definitely not the rare species, *C. aberrans*.

If I can be of further assistance, please let me know.

With best regards,

Les Watling
Assoc. Prof. Oceanography

ATTACHMENT C

QUALIFICATIONS OF INVESTIGATORS

ATTACHMENT C

QUALIFICATIONS OF INVESTIGATORS

Field sampling for amphipods at the Industri-Plex Site was performed by a multi-disciplinary team including an Aquatic Ecologist (Donald Mason) and a Wetland Scientist (Lee Carbonneau; J. Leslie Gecy). Identification of amphipod species was performed by Senior Benthic Scientist Hannah Proctor and verified by Dr. Les Watling (Darling Marine Center). Mark Mattson, Principal Aquatic Ecologist, provided scientific input and quality assurance throughout the survey. Overall project management was the responsibility of Lee Carbonneau. Resumes for each of these investigators follow.

MARK T. MATTSON
Assistant Vice President/Principal Aquatic Ecologist

Dr. Mattson is an Assistant Vice President who manages the New York Studies Group for NAI. He has over 14 years experience in aquatic ecology and is a specialist in biostatistics, sampling design and the population dynamics of aquatic organisms.

SELECTED PROJECT EXPERIENCE

New York Power Authority; Indian Point Unit 3 Nuclear Power Plant Zebra Mussel Monitoring Project; 1990; Project Manager. Managed a monitoring program designed to detect the first occurrence of zebra mussels at Indian Point Station on the Hudson River.

Central Hudson Gas & Electric Corporation; Zebra Mussel Monitoring at Roseton and Danskammer Point Stations; 1990; Project Manager. Managed a monitoring program at two fossil fuel power plants in the middle section of the Hudson River estuary. Program consisted of the collection of biweekly plankton samples and monthly settlement plate samples at in-plant and intake locations of each plant.

Central Hudson Gas & Electric Corporation; Survey of Hudson River Marinas for the Presence of Zebra Mussels; 1990; Project Manager. Supervised a survey of suitable substrates at 19 sites on the Hudson River for the presence of settled zebra mussels.

Empire State Electric Energy Research Corporation, Demonstration of an Acoustic Fish Deterrence System at the James A. Fitzpatrick Nuclear Power Plant Cooling Water Intake (NY); 1990-present; Project Manager. Supervised NAI's participation as a subcontractor to Sonalysts, Inc. in a feasibility study to evaluate the effectiveness of electronically produced high frequency sound to reduce seasonal impingement of fish (alewives) at a Lake Ontario cooling water intake.

Niagara Mohawk Power Corporation, Fish Guidance Study at Albany Steam Station (NY); 1990-present; Project Manager/Technical Advisor. Supervised and provided technical guidance for a study to select and compare the effectiveness of fish deterrence technologies for reducing impingement of fish (river herring and white perch) at a fossil fuel power generating station cooling water intake located on the Hudson River.

SELECTED PROJECT EXPERIENCE (Continued)

Central Hudson Gas and Electric Corporation, Roseton and Danskammer Point Stations Impingement Monitoring Program (NY); 1989-present; Project Manager. Managed a project that quantified fish impingement on the cooling water intake traveling screens at two Hudson River fossil fuel power generating stations. Prepared an annual report in compliance with New York State Pollution Discharge Elimination System (SPDES) permit requirements.

Consolidated Edison Company of New York, Inc., Indian Point Nuclear Generating Station Ristroph Screen Impingement Mitigation Study (NY); 1985-present; Project Manager. Managed a project which evaluated the design and installation configuration of dual flow Ristroph screens and fish return pipes at the Hudson River cooling water intake structure for two nuclear power generating stations. Studies were conducted to determine the screen rotation speed, wash pressures, washwater flow rate, and return pipe configuration (diameter, pitch, number of bends and discharge point location) which minimized the initial and latent (96 hour) mortality of impinged fish species throughout the year.

New York Power Authority, Hudson River Striped Bass Hatchery Evaluation Program (NY); 1985-present; Project Manager. Manager and report author for a hatchery evaluation and tagging program which determines the percent contribution of hatchery released striped bass to the wild stock, and estimates the winter striped bass population size in lower Hudson River.

Consolidated Edison Company of New York, Inc., Hudson River Atlantic Tomcod Spawning Stock Survey (NY); 1982-present; Project Manager. Manager and report author for a study which develops methodology and obtains precise and reliable mark-recapture estimates of the annual abundance of the winter spawning population of Atlantic tomcod in the Hudson River estuary. Fecundity, age, size and sexual composition of the population are also characterized.

Consolidated Edison Company of New York, Inc., Indian Point Impingement Studies (NY); 1984-1986 and 1989-present; Project Manager. Supervised a major project to quantify fish impingement on the cooling water intake traveling screens at two Hudson River nuclear power generating stations. The data was used to prepare an annual report in compliance with New York State Pollution Discharge Elimination System (SPDES) permit requirements.

SELECTED PROJECT EXPERIENCE (Continued)

Great Northern Paper Company, Penobscot Mills and Ripogenus Dam Hydropower Relicensing Projects (ME); 1986-present; Project Aquatic Ecologist. Supervised and conducted field and analytical studies and prepared a Federal Energy Regulatory Commission (FERC) Exhibit E document to determine existing and future conditions of river and impoundment aquatic communities (phytoplankton, periphyton, zooplankton and macroinvertebrates) in the West Branch of the Penobscot River. The study encompassed more that 55,000 acres of impoundments in 15 lake basins and 34 miles of connecting river segments.

The Upjohn Company, Quinnipiac River Study (CT); 1982, 1987-1990; Project Aquatic Ecologist. Supervised and conducted a baseline macroinvertebrate survey to evaluate biological indicators of water quality. Prepared and presented testimony on the interpretation of benthic macroinvertebrate data to delineate the zone of influence of an effluent discharge on river water quality conditions for state NPDES permit hearings and federal class action litigation. Also assisted in cross examination of expert witnesses.

New York Power Authority, Indian Point Fish Deterrence Studies (NY); 1986-1990; Corporate Officer/Technical Reviewer. Provided technical review and corporate supervision for a series of studies evaluating the effectiveness of current deterrence methodologies for reducing fish impingement at the cooling water intakes of two nuclear power generating stations on the Hudson River. These studies emphasized the use of underwater sound to create an acoustic barrier that would reduce the number of fish exposed to the traveling screens at the cooling water intake structure. Underwater sound was produced by pneumatic air gun (popper), mechanical hammer (fish pulser), and electronically, by high and low frequency transducers.

Consolidated Edison Company of New York, Inc., Hudson River Ichthyoplankton and Juvenile Surveys (NY); 1984-1989 and 1991-1992; Project Manager/ Corporate Officer. Supervised and managed the Hudson River Ichthyoplankton and Juvenile Fish Surveys which weekly sampled 152 miles of the Hudson River between New York City and Albany. Ichthyoplankton and juvenile fish density data was obtained which served as input to annual monitoring reports.

SELECTED PROJECT EXPERIENCE (Continued)

Consolidated Edison Company of New York, Inc., Hudson River Ichthyoplankton Laboratory Program (NY); 1988-1989 and 1991-1992; Project Manager/Corporate Officer. Managed a project that enumerated and identified 25 or more species of fish eggs and larvae from more than 6400 samples collected in the Hudson River during 1988 and 1989, 1991 and 1992.

Consolidated Edison Company of New York, Inc., Relative Probability of Entrainment Study for Indian Point Station (NY); 1989; Project Manager. Managed a project which simultaneously sampled both fish exposed to the cooling water intakes of two Hudson River nuclear power generating stations and fish actually entrained to determine the relative probability of entrainment (withdrawal probability).

Central Hudson Gas and Electric Corporation, Danskammer Point Station Fine Mesh Fish Impingement Studies (NY); 1986-1988; Project Manager. Manager of a project which evaluated the effectiveness of using fine mesh traveling screens and a fish return system to mitigate fish impingement at the cooling water intakes of Danskammer Point Station. Prepared a report in compliance with New York State Pollutant Discharge Elimination System (SPDES) permit regulations.

Consolidated Edison Company of New York, Inc., Special Studies to Examine Fish Abundance in Unsampled Areas of the Hudson River (NY); 1986-1987; Project Manager. Responsible for sample design for a survey of juvenile fish, eggs and ichthyoplankton in previously unsampled areas of the Hudson River. Resulted in collection of data necessary to test assumptions regarding the distribution of fish in unsampled areas.

Consolidated Edison Company of New York, Inc., Indian Point Entrainment Abundance Studies (NY) 1986-1987; Technical Advisor. Provided technical advice concerning sampling design and statistical methods for quantifying the abundance of entrained larval fish, and for estimating the mitigative value of reduced cooling water flows during peak periods of larval abundance at two nuclear power generating stations on the Hudson River.

SELECTED PROJECT EXPERIENCE (Continued)

Great Northern Paper Company, Hydroelectric Development Project (ME); 1981-1985; Project Aquatic Ecologist. Supervised and conducted field and analytical studies and prepared a Federal Energy Regulatory Commission (FERC) Exhibit E document which evaluated the impacts of a proposed new hydro project on river and lake aquatic communities (phytoplankton, zooplankton, periphyton, and macroinvertebrates) along 22 miles of a large river system. Provided hearings testimony before the Maine Land Use Regulatory Commission (LURC).

Consolidated Edison Company of New York, Inc., Sampling Design Evaluation for Indian Point Fish Impingement Programs (NY); 1981-1984; Project Manager. Evaluated the accuracy and precision of selected impingement sampling designs to estimate daily fish impingement collections at Indian Point Nuclear Generating Station. Recommendations from this study resulted in a 70% reduction of the daily sampling program to 110 days per year without significant loss in accuracy or precision.

New York Power Authority, Hudson River Gear Evaluation Studies (NY); 1980-1985; Project Manager. Evaluated the optimum deployment performance and relative efficiency of fisheries sampling gear for obtaining abundance estimates of young of the year striped bass and other fishes in the Hudson River Estuary. A 1.0 m^2 epibenthic sled, 3.0 m beam trawl and 6.2 m high-rise trawl were compared.

New York Power Authority, Hudson River Adult Striped Bass Tagging Program (NY); 1984; Project Manager. Evaluated the cost effectiveness of several sampling methods for obtaining and tagging adult striped bass during their annual spring spawning migration in the Hudson River. Methods evaluated included: a Scottish seine, trawl, gill nets and trammel nets.

Orange and Rockland Utilities, Inc., Hudson River White Perch Stock Assessment Study (NY); 1983-1985; Project Manager. Evaluated the appropriate sampling design, methodologies and biological characteristics required to effectively monitor long term changes in the status of the white perch population in the Hudson River Estuary.

SELECTED PROJECT EXPERIENCE (Continued)

Consolidated Edison Company of New York, Inc., Indian Point Juvenile Fish Entrainment Study (NY); 1981-1982; Project Manager. Evaluated the appropriate sampling gear and methodologies to quantify the abundance of juvenile fish entrained in cooling water for the Indian Point Station. A pump was compared with a 1.0 m^2 and a 0.5 m diameter plankton net.

Consolidated Edison Company of New York, Inc., 1982 and 1983 Year Class Reports for the Hudson River Monitoring Program (NY); 1984-1985; Technical Reviewer. Reviewed technical analyses and conclusions in two reports prepared to evaluate the impacts of five electrical generating stations on fish populations in the Hudson River estuary.

Bangor Hydro Basin Mills Hydroelectric Project (ME); 1983-1984; Project Aquatic Ecologist. Supervised and conducted field and analytical studies and prepared a FERC Exhibit E Document for a proposed new hydro project's impacts on the lower Penobscot River fish and aquatic communities.

Chicopee Falls Hydropower Project (MA); 1981; Project Aquatic Ecologist. Supervised and conducted field and analytical studies and prepared FERC Environmental Impact Report (EIR) of project impacts on fish communities of the Chicopee Falls River.

Metropolitan District Commission, Water Supply Alternatives (MA); 1982-1983; Project Aquatic Ecologist. Supervised fish and macroinvertebrate sampling of Miller's, Merrimack, Tulley's and Connecticut Rivers at proposed diversion sites for withdrawal of water into the Quabbin Reservoir. Evaluated impacts of projected water quality and habitat changes on fish and macroinvertebrate communities.

Town of Concord, Water Supply Study (MA); 1981; Project Aquatic Ecologist. Evaluated phytoplankton sources of taste and odor problems in a public water supply reservoir. Developed management plan for town to alternate surface and ground water sources to minimize phytoplankton taste and odor problems.

Bangor Hydro Telos Dam Reconstruction Project (ME); 1982; Project Aquatic Ecologist. Evaluated impacts of dam reconstruction on macroinvertebrate community of Telos Stream.

EDUCATION

Ph.D.	1979	Zoology (Limnology)	University of New Hampshire
M.S.	1975	Zoology	University of New Hampshire
B.A.	1973	Biology	University of Connecticut

SPECIAL TRAINING

U.S. Fish and Wildlife Instream Flow Incremental Methodology Negotiations and Strategies, 1981; Conducting Field Studies, 1984

NAUI Certified SCUBA diver

PROFESSIONAL EMPLOYMENT HISTORY

1981-Present	Normandeau Associates Inc.
1979-1981	Texas Instruments Incorporated, Ecological Services

PROFESSIONAL AFFILIATIONS

American Society of Limnology and Oceanography
International Limnological Society
American Fisheries Society
North American Lake Management Society

SELECTED PRESENTATIONS AND PUBLICATIONS

Mattson, M.T., P. Geoghegan, D.J. Dunning. In Press. Accuracy of catch per unit effort indices of Atlantic tomcod in the Hudson River. In: C.L. Smith ed., Fisheries Research in the Hudson River. Hudson River Environmental Society.

Mattson, M.T., J.R. Waldman, D.J. Dunning, and Q.E. Ross. 1989. Abrasion and protrusion of internal anchor tags in Hudson River striped bass. American Fisheries Society Symposium 7: Fish Marking Techniques. p. 121-126.

SELECTED PRESENTATIONS AND PUBLICATIONS (Continued)

Mattson, M.T., D.J. Dunning, Q.E. Ross and B.R. Friedman. 1989. Magnetic tag detection efficiency in a Hudson River striped bass hatchery evaluation program. American Fisheries Society Symposium 7: Fish Marking Techniques. p. 267-277.

Mattson, M.T., J.B. Waxman and D.A. Watson. 1988. Reliability of impingement sampling designs: an example from Indian Point Station. American Fisheries Society Monograph 4:161-169.

Geoghegan, P., M.T. Mattson, D.J. Dunning and Q.E. Ross. 1989. Improved data through quality control and quality assurance in a large scale striped bass tagging program. American Fisheries Society Symposium 7: Fish Marking Techniques.

Geoghegan, P., M.T. Mattson, and R. Keppel. In Press. Distribution of the shortnose sturgeon in the Hudson River Estuary, 1983-1988. In: C.L. Smith ed., Fisheries Research in the Hudson River. Hudson River Environmental Society.

Humphreys, M., M.T. Mattson, R.E. Park, J.J. Reichle, D.J. Dunning and Q.E. Ross. 1989. Stocking checks on scales for identifying hatchery striped bass in the Hudson River. Proceedings, International Symposium and Educational Workshop on Fish Marking Techniques, American Fisheries Society.

Dunning, D.J., Q.E. Ross, M.T. Mattson, P. Geoghegan and J.R. Waldman. 1989. Reducing mortality of striped bass captured in seines and trawls. North American Journal of Fisheries Management 9(2):171-176.

Dunning, D.J., Q.E. Ross, J. Waldman, and M.T. Mattson. 1987. Tag retention and tagging mortality in Hudson River striped bass. North American Journal of Fisheries Management 7(4):535-538.

Waldman, J.R., D.J. Dunning, Q.E. Ross, and M.T. Mattson. 1990. Range dynamics of Hudson River striped bass along the Atlantic coast. Transactions of the American Fisheries Society 119.

Waldman, J.R., D.J. Dunning and M.T. Mattson. 1990. A morphological explanation for size-differential anchor tag loss in Hudson River striped bass. Transactions of the American Fisheries Society 119.

SELECTED PRESENTATIONS AND PUBLICATIONS (Continued)

Geoghegan, P., M.T. Mattson, DJ. Dunning and Q.E. Ross. 1986. Effects of water temperature, collection gear, and tag type on handling mortality of striped bass. Presented at the 1986 Northeast Fish and Wildlife Conference, Hershey, Pennsylvania USA.

Mattson, M.T., D.J. Dunning and Q.E. Ross. 1985. Relative catch efficiency of a 3 m beam trawl, 6.2 m high-rise trawl and 1.0 m epibenthic sled for sampling young of the year striped bass and other fishes in the Hudson River Estuary. American Fisheries Society, August 1985.

Mattson, M.T. and J. B. Waxman. 1985. Movements of spawning Atlantic tomcod (Microgadus tomcod) in the Lower Hudson River, Northeast Fish and Wildlife Conference; May 1985.

Mattson, M.T. 1980. Diel and seasonal horizontal movements in a population of the predatory cladocean Polyphemus pediculus. American Society of Limnology and Oceanography, December 1980.

Mattson, M.T. and J.F. Haney. 1980. Factors influencing intra-zooplankton predation by Polyphemus pediculus, Research Report No. 29. Water Resources Research Center, University of New Hampshire, Durham, NH.
149 pp.

In addition, Dr. Mattson has contributed to over 30 technical reports in the areas of aquatic ecology and sampling design.

DONALD P. MASON
Aquatic Ecologist

Mr. Mason has over nine years experience at assessing the effects of habitat alteration on aquatic ecosystems. His specialties include evaluating the effects of hazardous substances, hydropower, and commercial development on fish and benthic macroinvertebrate communities, conducting fish and benthic population studies, using freshwater macroinvertebrates as pollution indicators, and assessing the impacts of road and highway construction on aquatic communities.

SELECTED PROJECT EXPERIENCE

CWS Landfill (ME) Expansion Project; 1991-present; Aquatic Studies Technical Director. Studied the effects of landfill expansion on aquatic communities. Responsibilities included collecting, analyzing, and reporting baseline data on fish and benthic communities from streams near proposed expansion areas.

Turners Falls (MA) Fisheries Study, Connecticut River; 1991; Crew Leader. This study mapped the summer and fall spatial distribution of juvenile American shad in a 20 mile section of the Connecticut River between the Turners Falls and Vernon Dams. Responsible for leading the beach seine field crew during biweekly sampling trips from July through October.

Lowell (MA) Juvenile Clupeid Studies, Merrimack River; 1990-1991; Senior Field Biologist. Helped conduct a mark and recapture study that assessed the use of a downstream fish bypass system by juvenile American shad, alewives, and blueback herring, emigrating past the Lowell Hydroelectric Project.

Farmington River (CT) Aquatic Studies; 1991; Senior Aquatic Ecologist. Collected habitat data for assessing flow requirements for Atlantic salmon, brook trout, brown trout, smallmouth bass, and American shad. Also conducted a baseline investigation of Farmington River benthic communities using EPA's Rapid Bioassessment Protocols (RBP). Duties included data collection, analysis, and report preparation.

Peshtigo River (WI) IFIM Study; 1990; Senior Field Biologist. Responsible for collecting physical habitat data for assessing minimum and maximum flow requirements for walleye and smallmouth bass populations.

SELECTED PROJECT EXPERIENCE (Continued)

Brassua Dam (ME) Hydropeaking Licensing Project; 1990-1991; Project Manager. Assessed the effects of hydropeaking operations on downstream benthic communities. Responsibilities included data analysis, report preparation, and project administration.

Sherman Hollow (VT) Aquatic Biota Impacts Project; 1988-1990; Technical Director-Aquatic Biota. Worked closely with the Vermont DEC to develop a comprehensive biomonitoring program to detect the effects of pesticide and fertilizer runoff on aquatic biota. Responsibilities included data collection, analysis, report preparation, and witness testimony for a Vermont Act 250 environmental board hearing.

Maine Turnpike Widening Project; 1987-1991; Senior Aquatic Ecologist. Assessed the effects of widening a 30 mile section of the Maine Turnpike, from four lanes to six lanes, on 39 streams crossed by the highway. This study required an evaluation of habitat and sport fishery value at all streams affected by the widening.

Great Northern Paper Hydroelectric Relicensing; 1986-1989; Aquatic Ecologist. Investigated the impacts of water level fluctuations on aquatic benthic macroinvertebrate, zooplankton, phytoplankton, and periphyton communities along the West Branch of the Penobscot River and its impoundments. Also assisted in collecting IFIM (Instream Flow Incremental Methodology) data used to determine suitable minimum flows to maintain adequate suitable salmonid habitat.

Conway (NH) Route 16 Bypass Project; 1986-1988; Aquatic Ecologist. Determined the effects of highway construction on fish and benthic communities in the Saco and Swift Rivers and their tributaries. Data from this study were incorporated into an environmental impact statement (EIS) to determine the impacts of nineteen different highway corridors on the surrounding stream ecosystems.

Pontook Dam (NH) Licensing; 1987-1988; Technical Director-Macroinvertebrate Communities. Assessed the impacts of discharge fluctuations on benthic macroinvertebrate communities downstream from Pontook Dam, NH. Also assisted in collecting IFIM data used to determine suitable minimum flows through the dam to maintain adequate salmonid habitat.

SELECTED PROJECT EXPERIENCE (Continued)

Aziscohos Dam (ME) Minimum Flow Study; 1985-1986; Aquatic Ecologist. Assisted in developing mitigation for lost habitat due to a proposed hydropower generating facility. This study required the use of Habitat Evaluation Procedures (HEP) to assess the values of habitats lost to brook trout (*Salvelinus fontinalis*) and landlocked salmon (*Salmo salar*).

Cochato River (MA) Fish Study; 1985; Field Director. Collected fish samples to assess the extent of bioaccumulation of toxic contaminants in tissues. This river flows through an EPA Superfund Hazardous Waste Site, therefore, sample collection required expertise in electrofishing as well as safety protocols regarding hazardous waste exposure.

Modeling of the Transport, Distribution, and Fate of PCBs and Heavy Metals in the Acushnet River/New Bedford Harbor/Buzzards Bay Systems; 1984-1985; Health and Safety Officer. Responsible for designing and implementing a comprehensive health and safety program to prevent contamination of personnel sampling harbor sediments heavily contaminated with polychlorinated biphenyls (PCBs).

Acute and Chronic Effects of Dissolved Gases H_2S and CO_2 on Marine Species; 1984-1985; Marine Toxicologist. Constructed and monitored acute and early life stage toxicity studies observing the effects of hydrogen sulfide and carbon dioxide on the mysid shrimp *Mysidopsis bahia* and the sheepshead minnow *Cyprinodon variegatus*. This study was conducted under Good Laboratory Practice (GLP) guidelines and followed strict QA/QC protocols.

GRADUATE STUDIES

Merrill Creek Reservoir Project; Private Consultant. Provided technical expertise by identifying stream insects for a proposed flow augmentation reservoir.

Effects of Bacillus thuringiensis on Stream Ecosystems; Private Consultant. Identified stream insects to determine the effects of *Bacillus thuringiensis* var. *israeliensis* on non-target organisms.

GRADUATE STUDIES (Continued)

White Mountain Aquatic Insect Survey; U.S. Forest Service; Research Assistant. Studied the effects of hydrochemical and substrate composition on stream insect communities in the White Mountain National Forest. Sampled and identified insect communities from sixteen sites throughout the national forest.

EDUCATION

M.S.	1982	Entomology	University of New Hampshire
B.A.	1976	Biology	Plymouth State College

SPECIAL TRAINING

Rapid Bioassessment Protocols
Hazardous Material Handling (OSHA)
First Aid and CPR
Habitat Evaluation Procedures (HEP)

PROFESSIONAL AFFILIATIONS

North American Benthological Society
New England Association of Environmental Biologists

PROFESSIONAL EMPLOYMENT HISTORY

1985-present	Normandeau Associates, Inc.
1983-1985	Battelle New England Marine Research Laboratory
1982-1983	Normandeau Associates, Inc.
1982	Charles T. Main, Inc.
1979-1982	University of New Hampshire
1974-1976	Plymouth State College

PAPER PRESENTATION

Mason, D.P. and W.E. Hearn. Effects of fluctuating flows on benthic communities. Presented to the 37th Annual Meeting of the North American Benthological Society, May 1989, Guelph, Ontario, Canada.

PAPER PRESENTATION (Continued)

Mason, D.P., S.L. Radke, K.T. Tracewski, and P.C. Johnson. Eclosion of gypsy moth (Lepidoptera: Lymantriidae) egg masses held under constant conditions as a function of sampling date. Presented to the 52nd Annual Meeting of the Eastern Branch of the Entomological Society of America, September 1980, Baltimore, MD.

PUBLICATIONS

Haney, J.F., T.R. Beaulieu, R.P. Berry, D.P. Mason, C.R. Miner, E.S. McLean, K.L. Price, M.A. Trout, R.A. Vinton, and S.J. Weiss. 1983. Light intensity and relative light change as factors regulating stream drift. Archiv fur Hydrobiologie 97(1):73-88.

Johnson, P.C., D.P. Mason, S.L. Radke, and K.T. Tracewski. 1983. Gypsy moth, *Lymantria dispar* (L) (Lepidoptera: Lymantriidae), egg eclosion: degree-day accumulation. Environmental Entomology 12(3):929-932.

Mason, D.P. 1982. Physical and hydrochemical effects on stream insect communities in the White Mountain National Forest of New Hampshire. M.S. Thesis, University of New Hampshire, Durham, New Hampshire. 106 pp.

LEE E. CARBONNEAU
Wetland Scientist, Terrestrial Ecologist

Ms. Carbonneau has nine years of experience assessing and delineating natural communities throughout the northeastern United States. She has been involved in wetland delineations, functional assessments, mitigation plans, wildlife inventories, natural resource management plans, and drafting and coordinating EAs, EISs and other technical documents.

SELECTED PROJECT EXPERIENCE

Golder Associates, Inc, Wetland Mitigation at New England Superfund Site; 1990-present; Project Manager and Technical Coordinator. Providing wetland and stream mitigation expertise to a remedial engineering firm for the predesign and design work at a major Superfund site. Requires wetland restoration, enhancement, and compensation specifications for functional values lost to contamination and remedial dredging, capping, and groundwater treatment. A maintenance and operations package and bid package for remediation activity will be included in the final product.

Confidential Client, Wetland Resource Delineation at New England Hazardous Waste Site; 1990; Project Manager. Flagged and mapped wetland, stream, and floodplain resources under state and federal jurisdiction at an industrial site contaminated with asbestos, volatile organics, and metals.

New Hampshire Department of Transportation, Newington-Dover Environmental Assessment; 1990-1991; Project Manager. Responsible for managing all ecological studies required for the upgrading of the Spaulding Turnpike in Newington and Dover Point. The upgrade design includes interchange relocations and a bridge expansion. Major issues are potential impacts to freshwater and coastal wetlands, estuarine fishery and invertebrate resources, possible endangered species, and archeologic/historic resources. Impact assessments and conceptual mitigation designs will be performed.

Great Northern Paper Company, Groundwood Pulp and Light Weight Coated Paper Project (ME); 1989-1990; Wetland Scientist and Wildlife Biologist. Conducted wetland delineations, cover type descriptions and breeding bird inventories, and prepared natural resource documentation for Site Location of Development, Natural Resource Protection Act, and federal wetland permit applications. Principal author of Wetland, Wildlife, and Botanical Information in Support of the Environmental Information Document for EPA review.

New Hampshire Department of Transportation, Wetland Retainer Contracts; 1988-present; Project Manager. Managed and performed wetland delineations, mapping, and functional assessments in accordance with federal wetland delineation criteria for various DOT projects awarded under this contract.

SELECTED PROJECT EXPERIENCE (Continued)

Urban Associates, Inc., Nottingham Country Club (NH); 1989; Project Manager. Performed cover type mapping from aerial photographs, wetland delineations and wetland assessments on a proposed 250-acre golf course. Prepared reports, computer evaluations, and sketch maps, and participated in local Conservation Commission review process.

Central Maine Power Company, Moosehead Lake Dam Relicensing Project (ME); 1989; Wetland Scientist. Cover typed shoreline of Moosehead Lake and outflow streams from aerial photo and topographic map review. Field checked delineations by seaplane and boat. Project designed to evaluate potential habitat and wildlife impacts of water level drawdowns.

Vermont Agency of Transportation, Missisquoi Bay Bridge Relocation (VT); 1986; Senior Ecologist, Field Supervisor. Coordinated and conducted fisheries, water quality, wetland, and wildlife habitat inventories in Lake Champlain for an Environmental Assessment Report.

The Nature Conservancy and US Forest Service, Research Natural Area Establishments; 1986; Principal Investigator. Performed field inventories, literature and agency record reviews, documentation of research values and delineation of ecological boundaries for the establishment of five proposed Research Natural Areas in the White Mountain National Forest.

University of New Hampshire, Study of Old-growth Forests in New Hampshire; 1983-1986; Graduate Research Assistant. Worked under a research agreement with U.S. Forest Service and several cooperating state and private conservation organizations to develop criteria for identifying old-growth forests in New Hampshire; researched the vegetative composition and structural characteristics of tree, snag, and log strata in 12 old-growth stands; described implications for eastern wildlife; provided additional baseline data for future research purposes. Also performed breeding bird survey in an Atlantic white cedar swamp.

EIP Northeast (NY); 1982; Masterplan Coordinator. Identified key management and protection objectives for nine Nature Conservancy Preserves; created inventory and monitoring schedules and management plans for each preserve. Researched land ownership and protection priorities for 2400 acre pine barrens acquisition project.

EDUCATION

M.S.	1986	Wildlife Ecology	University of New Hampshire, Durham
B.S.	1981	Environmental Biology	SUNY College of Environmental Science and Forestry, Syracuse, New York

SPECIAL TRAINING

Wetland Evaluation Technique Version 2.0 Certification (U.S. Army Corps of Engineers Course), 1988.
Personnel Protection and Safety Training for Hazardous Waste Site Activities (OSHA Course), 1989.
NASDS SCUBA Certification, 1980.

PROFESSIONAL AFFILIATIONS

New Hampshire Association of Wetland Scientists, Founding Member of Board of Directors
Society of Wetland Scientists
The Wildlife Society
Natural Areas Association

PROFESSIONAL EMPLOYMENT HISTORY

1989-present	Normandeau Associates Inc.
1986-1989	The Smart Associates, Environmental Consultants, Inc.
1985-1986	Self Employed, Environmental Consultant
1983-1985	Institute of Natural and Environmental Resources, University of New Hampshire
1982	EIP Northeast and The Nature Conservancy - Long Island Chapter
1981	The Nature Conservancy - Lower Hudson Chapter

SELECTED PUBLICATIONS

Carbonneau, L.E. 1986. Old Growth Forests in New Hampshire - A Preliminary Investigation. M.S. Thesis, University of New Hampshire. 124 pp.

Carbonneau, L.E. 1986. Old Growth Forests - Forest Notes, Winter 1986. Society for the Protection of New Hampshire Forests. 5 pp.

SELECTED PUBLICATIONS (Continued)

Miller, D., W.B. Leak, L.E. Gradischer (Carbonneau), and J.H. Orzel. 1985. Breeding Bird Census of an Atlantic White Cedar Swamp. Proceedings, Atlantic White Cedar Swamp Symposium, Woods Hole, MA

HANNAH PROCTOR
Assistant Manager of the Biological Laboratory

Ms. Proctor has over 11 years experience in benthic-related work. She is a Senior Benthic Taxonomist, specializing in polychaetes. Ms. Proctor is responsible for supervision of lab personnel, data production and quality control procedures. She also has extensive field experience and is involved in wetland delineation.

SELECTED PROJECT EXPERIENCE

Seabrook (NH) Environmental Studies; 1978-present; Senior Taxonomist, Report Author. Identified benthic infaunal samples; report author of macrofauna, estuarine and selected species sections of report.

National Park Service Pier 2 for Boston Harbor; 1989; Taxonomist, Laboratory Supervisor. Identified benthic samples; supervised sorters and identifiers.

Winthrop Harbor (MA) Studies; 1989; Taxonomist. Identified benthic arthropods.

Hudson River (NY) Ichthyoplankton Laboratory Program; 1989; Laboratory Coordinator. Coordinated hiring and training of lab personnel.

Indian Point (NY) Relative Probability of Capture Study; 1988-1989; Laboratory Coordinator. Coordinated hiring and training of lab personnel.

Surf Clam Survey (NJ); 1987, 1989; Laboratory Supervisor, Taxonomist. Supervised sorters and identifiers; identified polychaetes.

New York Bight Ecological Studies (NOAA); 1984-1985, 1989; Taxonomist, Laboratory Supervisor. Supervised sorters and identifiers; identified benthic samples.

Newark Bay (NJ) ACE Study; 1987-1988; Laboratory Supervisor, Taxonomist. Supervised sorters and identifiers; identified benthic samples.

Saugus River and Tributaries (MA) Wetland Estuary Assessment; 1987; Field Leader, Taxonomist. Supervised sorters and identifiers; identified polychaetes; co-coordinated and conducted field work.

Searsport Harbor (ME); 1986-1987; Laboratory Supervisor, Taxonomist. Identified benthic samples; supervised sorters and identifiers.

SELECTED PROJECT EXPERIENCE (Continued)

Indian Point (NY) Entrainment Abundance Program; 1985-1986; Data Control Supervisor. Supervised quality control of laboratory data.

Schrafft Center, Mystic River (MA) Studies; 1985; Laboratory Supervisor, Taxonomist. Identified benthic samples; conducted stomach content analysis of marine fish species.

Hudson River (NY) Adult Striped Bass Tagging Study; 1984; Field Leader. Supervised fishing effort for striped bass using a Scottish seine.

New Haven Harbor (CT) Ecological Studies; 1978-1984; Laboratory Supervisor, Taxonomist. Supervised sorters and identifiers; identified benthic infaunal samples.

Mamaroneck Harbor (NY) Studies; 1984; Laboratory Supervisor, Taxonomist. Supervised sorters and identifiers; identified benthic infaunal samples.

Gosport Harbor (MA) Studies; 1983; Laboratory Supervisor, Taxonomist. Supervised sorters and identifiers; identified benthic infaunal samples.

Belfast Bay (ME) Studies; 1983; Laboratory Supervisor, Taxonomist. Supervised sorters and identifiers; identified benthic infaunal samples.

New Bedford Harbor (MA) Studies; 1983; Laboratory Supervisor, Taxonomist. Supervised sorters and identifiers; identified benthic infaunal samples.

Piscataqua River (NH) Ecological Studies; 1978-1980, 1983; Taxonomist, Laboratory Supervisor. Supervised sorters and identifier; identified benthic samples.

Gargner Mill (OR) Discharge Monitoring Studies; 1981; Laboratory Supervisor, Taxonomist. Supervised sorters and identifiers; identified benthic samples.

Bristol Harbor (ME) Studies; 1981; Laboratory Supervisor, Taxonomist. Supervised the processing of benthic infaunal samples; identified benthic samples.

International Paper (OR); 1981; Taxonomist. Identified benthic polychaetes.

SELECTED PROJECT EXPERIENCE (Continued)

EG&G Off Shore Monitoring Studies; 1980; Laboratory Supervisor, Taxonomist. Supervised the processing of benthic infaunal samples; identified benthic samples.

Georges Bank Exploratory Oil Drilling Permits (OCS Lease Sale 42); 1980-1982; Sample Processing Coordinator, Report Author. Supervised the processing of benthic infaunal samples; report author of finfish section of Environmental Reports.

Georges Bank Benchmark Survey OCS/BLM; 1977; Field Supervisor, Taxonomist. Watch Crew Leader RV Gyre; Field Crew Leader RV *Gillis*; identified benthic infaunal samples.

EDUCATION

B.S.	1976	Fisheries Biology	University of Washington

PROFESSIONAL EMPLOYMENT HISTORY

1978-present	Normandeau Associates Inc.
1977-1978	Taxon, Inc., Salem, MA
1974-1976	University of Washington Fisheries Cooperative
1975	Bioproducts, Inc., Warrengton, Oregon
1973-1974	Temperate Gallery, New England Aquarium, Boston, MA
1973-1974	Bacteriology Laboratory, Harvard University
1973	University of Massachusetts Marine Science Station, Gloucester, MA

LESLIE GECY
Plant Ecologist
Wetland and Riparian Scientist

Leslie Gecy has over nine years experience as an ecologist. Her experience includes wetland delineation, functional assessment and mitigation, riparian revegetation and management, plant community sampling and analysis, and ecological risk assessment. She has served as project manager on numerous wetland-related projects and ecological risk assessments. She has worked on projects located in 14 states throughout the country, including the Pacific Northwest, California, Midwest, and the Northeast. She has also taught plant taxonomy, with an emphasis on the flora of the Pacific Northwest and Northern California.

SELECTED PROJECT EXPERIENCE

NY Department of Environmental Conservation (NY) Ecological Risk Assessment; 1989-present; Project Manager. Managed an ecological risk assessment of a stream as part of a remedial investigation and feasibility study of a nearby landfill. Identified habitats and species potentially exposed to high levels of metals, pesticides, and unionized ammonia. Also identified exposure pathways and impacts to key species and aquatic and riparian community structure. Evaluated proposed remedial alternatives for the stream and riparian communities as well as the impacts of the proposed remedial alternatives for the landfill.

Alliance Technologies Corporation (Northeast) Ecological Support Services for Hazardous Waste Site Assessment and Remediation; 1991-present; Ecologist. Provided biological support services for various Superfund sites located throughout the Northeast. Tasks include the review of proposed ecological risk assessment work plans, development of risk assessment work and field sampling plans and field oversight activities.

Detroit Edison (MI) Power Plant Vegetation Surveillance Program; 1990-present; Plant Ecologist. Evaluated the effects of cooling tower salt drift on soils and vegetation. Determined if observable vegetation stress within a 5 mile radius of the site could be attributable to power plant operation through a combination of color infrared aerial photograph analysis and field verification.

Route 101 (NH) Environmental Impact Statement; 1990-present; Wetland Scientist. Delineated wetlands according to federal standards and assessed the functional value of these wetlands using WET 2.0. Evaluation results were used to evaluate wetland impacts and to develop mitigation goals for compensation wetlands.

SELECTED PROJECT EXPERIENCE (Continued)

New York Power Authority, Plattsburg (NY), Mitigation Monitoring; 1990-present; Wetland Scientist. Developed and implemented an innovative 8 year monitoring program to evaluate the success of a mitigaton wetland. Measures of mitigation success were based on functional replacement of lost wetland functions and values.

Approved Design Inc. (NH) Wetland Mitigation; Project Manager; 1989-present. Developed a mitigation plan including avoidance/minimization of wetland impacts and restoration of a degraded wetland adjacent to the project site.

BHP-Utah, Jackman (ME), Baseline Vegetation and Wetland Assessment of a Proposed Mine Site; 1989-present; Plant Ecologist. Conducted a survey to characterize plant community composition structure and successional relationships. Assessed the functional value of the wetland communities and delineated wetland boundaries.

Wisconsin Power Authority (WI) Macrophyte and Rare Plant Surveys; Plant Ecologist; 1990. Macrophyte and rare plant surveys conducted as part of a FERC-relicensing procedure.

Dartmouth College, Hanover (NH), Acid Rain - Forest Response Research; 1988; Plant Ecologist. Measured and analyzed changes in tree growth in relation to stand age and composition, disturbance history, soil type, elevation, aspect and air quality parameters as part of the acid rain forest response research program.

The Nature Conservancy, Portland (OR), Investigation of the population Dynamics of an Introduced Salt Marsh Species; 1986-1988; Principal Investigator. Analyzed salt marsh community structure and experimentally examined the effects of a non-native species on the salt marsh community.

Oregon State University, (OR), Analysis of Riparian Community Structure in Western Cascade Headwater Streams; 1986-1988; Plant Ecologist. Designed the sampling scheme and sampled riparian vegetation in relation to geomorphic surfaces and disturbance characteristics along five headwater streams. Responsible for coordination among members of an interdisciplinary team and interpretation of results.

Bureau of Reclamation (VA & NM) Assessment of Waterlevel Fluctuation Impacts; Ecologist; 1975-1976. Assessed impacts of water level fluctuations on plant and animal communities along the Susquehanna and Rio Grande Rivers.

EDUCATION

M.S. 1988 Botany Oregon State University
Minor emphasis Biostatistics

Secondary Science Teaching Certificate 1978 University of Massachusetts

B.S. 1975 Wildlife Biology University of Massachusetts and University of Nevada-Reno (Natural Student Exchange Program)

SPECIAL TRAINING

"Personnel Protection Safety Training for Hazardous Waste Site Activities" course, Normandeau Associates Inc., January 1991. Forty hours course in compliance with OSHA Standard 19 CFR 1910 and SARA Section 126(d).

PROFESSIONAL EMPLOYMENT

1989-present	Normandeau Associates Inc.
1989	Natural Resources Consulting Services
1988	Dartmouth College
1985-1988	Oregon State University and The Nature Conservancy
1978-1980	Green Mountain Union High School
1976	National Park Service (Grand Canyon)
1975-1976	Jason Cortell Associates
1974	Bureau of Reclamation (Carson City, NV)

PROFESSIONAL AFFILIATIONS

Society of Wetland Scientists
Northwest Scientific Association
Ecological Society of America
Sigma Xi-the Scientific Research Honor Society
New Hampshire Society of Wetland Scientists
Society for Ecological Restoration

SELECTED PRESENTATIONS AND PUBLICATIONS

Gecy, J.L. and M.V. Wilson. 1990. Initial establishment of riparian vegetation after debris flows in Oregon. American Midland Naturalist, 123:282-291.

Gecy, J.L. and M.V. Wilson. 1990. Vegetation recovery after experimental debris flow treatments. American Midland Naturalist, In press.

Gecy, J.L. and M.V. Wilson. 1988. Effects of the type and intensity of debris torrent disturbance on early successional patterns. Ecological Society of America Bulletin 69: Proceedings of the 73rd Annual Meeting of The Ecological Society of America.

Gecy, J.L. and M.V. Wilson. 1988. Expectations vs reality in early succession after debris torrents. Northwest Science 62: Proceedings of the 61st Annual Meeting of the Northwest Scientific Association.

Gecy, L. 1988. Species responses and seed bank characteristics as determinants of riparian revegetation patterns. Invited Speaker, Oregon State University Stream Research Meeting.

Gecy, L. 1987. Population influences on salt marsh community development: a review, and preliminary research on the population dynamics of an introduced species. Report to The Nature Conservancy. 40 pp.

Leslie Edward Watling

Present Address:
Darling Marine Center
University of Maine
Walpole Maine 04573
Phone: 207-563-3146 FAX:207-563-3119

Social Security Number: 562-78-9683

Date and Place of Birth: 13 October 1945; Calgary, Alberta, Canada

Citizenship: Canadian (possess U.S. Permanent Immigrant Visa)

Education:
B.Sc., Zoology, University of Calgary, 1965
M.S., Marine Science, University of the Pacific, 1969
Ph.D., Marine Studies, University of Delaware, 1974

Professional Experience:
Museum Curator, University of the Pacific, 1965-67
Research Assistant, University of the Pacific, 1967-68
Resident Biologist, University of Delaware, 1968-1970, 1971-72
Research Biologist, University of Delaware, 1974-76
Assistant Professor, Dept. of Oceanography, University of Maine, 1976-80
Associate Professor, Dept. of Oceanography, University of Maine, 1980-
Acting Chairman, Dept. of Oceanography, University of Maine, 1980-81
Associate Professor, Dept. Zoology and Oceanography Prog., University of Maine, 1981-
Associate Editor, *Journal of Crustacean Biology*, 1980-81
Member, Governing Board, The Crustacean Society, 1980-84
Acting Director, Darling Marine Center, University Maine, 1985-1990

Teaching Experience
University of the Pacific, Teaching Assistant for Advanced Invertebrate Zoology
University of Delaware, Teaching Assistant for Introduction to Marine Biology
Decapoda--A short course, Summer 1978
University of Maine, have taught or am teaching the following courses:
Biological Oceanography
Marine Invertebrate Zoology
Anatomy and Phylogeny of Crustacea
Ecology of Marine Sediment Dwellers
Interpretation of Biostatistics

Memberships:
Society of Systematic Zoology
Assoc. of Meiobenthologists
The Crustacean Society
Amer. Soc. Limnologists and Oceanographers
Society of Sigma Xi
Palaeontological Assoc.
Biological Society of Washington
Ecological Society of America
American Society of Zoologists
Amer. Assoc. Zool. Nomenclature

Awards, Honors, etc.:

National Science Foundation Stipend for summer course, Pacific Marine Station, June 1965

Pacific Marine Station Fellowship, 1965–66, 1966–67

National Science Foundation Stipend for Summer Institute in Systematics, Smithsonian Institution, June 1971

Who's Who Among Students in American Colleges and Universities, 1974

The cumacean *Spilocuma watlingi* Omholt and Heard, named in my honor.

Smithsonian Senior Postdoctoral Fellowship, January to May, 1990.

Theses Directed:

Smith, R.D. 1977. The feeding habits of the sand dollar, *Echinarachnius parma* (Lamarck). M.S.

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APPENDIX 14-C

Water Budget Analysis for the Compensatory Wetland

RESPONSE TO COMMENTS ON 100% DESIGN REPORT

INDUSTRI-PLEX SITE, WOBURN, MASSACHUSETTS

HYDROLOGIC BUDGET ANALYSIS FOR COMPENSATORY WETLAND

ASSUMPTIONS:

1) In order to successfully maintain wetland shrub vegetation, saturated soil conditions must prevail through the month of June during an average precipitation year: NOTE: This is considered to be a conservative assumption since shrub wetlands in the Northeast generally exist when saturated conditions prevail to end of May or mid-June.

2) The proposed compensatory wetland area of 2.8 acres will be supported entirely by surface flow.

3) Saturated soil conditions are assumed to be met if monthly inflow exceeds the monthly evapotranspiration (ET) and seepage within the compensatory wetland.

4) The average monthly watershed yield for June equals 0.75 inches or 0.06 feet per acre of drainage area based on 34 years of streamflow data compiled at the Winchester gaging station on the Aberjona River (Delaney and Gray 1980).

5) Fifty percent of the wetland 1C discharge will be diverted to the compensatory wetland by establishing the invert of the outlet culvert at the same elevation as the main outlet.

6) The average June precipitation and evapotranspiration totals for the site are similar to that measured at Logan Airport in Boston based on 100 years of weather records.

7) The compensatory wetland will be at full pond (seasonal high water) at the end of May.

METHODOLOGY

Inflow and outflow are represented by the following equations:

INFLOW = Wetland 1C Discharge + Watershed Runoff + Precipitation + Storage

OUTFLOW = Evapotranspiration & Seepage

1.0 DETERMINE MONTHLY INFLOW FOR JUNE

1.1 ESTIMATE YIELD FROM WETLAND 1C DISCHARGE

Drainage Area = 190 acres; includes subwatersheds 5A, 5B, 5C, 5D and HP3A as presented in Sec 10 of Volume 2 of 8: 100% Design Report.

TOTAL RUNOFF VOLUME = 190 acres x 0.06 feet = 11.4 ac-ft*
Outflow to Comp. Wetland = 11.4 ac-ft x 0.50 = 5.7 ac-ft

* NOTE: The 11.4 ac-ft translates to approximately 0.20 cfs which compares well with the instantaneous measurement of 0.15 cfs recorded by Roux Associates on June 20, 1990 during a month where precipitation was well below normal. Slightly greater runoff volumes are expected under proposed conditions due to less pervious caps proposed for the hide piles.

1.2 ESTIMATE RUNOFF FROM DRAINAGE AREA OF THE COMPENSATORY WETLAND (Subwatershed 6PS)

Drainage Area = 9.6 acres: less 2.8 acres of the wetland = 6.8 acres

Runoff volume; 6.8 acres x 0.06 feet = 0.41 ac-ft

1.3 ESTIMATE PRECIPITATION VOLUME CONTRIBUTED TO WETLAND

Wetland Area = 2.8 acres

Average June rainfall total = 2.3 inches or 0.27 feet

thus;

Precipitation Inflow = 2.8 acres x 0.27 feet = 0.76 ac-ft

1.4 ESTIMATE STORAGE VOLUME

Assume 2 foot of standing water at the end of May within 67 foot contour and 1 foot of standing water within 68 foot contour.

1.0 acre x 2.0 feet = 2.0 ac-ft

1.0 acre x 1.0 feet = 1.0 ac-ft
3.0 ac-ft

Total Monthly Storage = 3.0 ac-ft

TOTAL INFLOW = 5.7 + 0.41 + 0.76 + 3.0 ac-ft = 9.87 ac-ft (using 50% of Wet. 1C Discharge)

or 15.57 ac-ft (using 100% of Wet. 1C Discharge)

2.0 DETERMINE MONTHLY ET AND SEEPAGE LOSSES FOR JUNE

2.1 ESTIMATE EVAPOTRANSPIRATION (ET) LOSSES

Mean ET total for June = 4.5 inches or 0.37 feet*

NOTE: ET totals are based on the potential ET which assumes that available soil moisture is unlimited

TOTAL ET LOSS

2.2 acres x 0.37 feet = 1.04 ac-ft

2.2 ESTIMATE SEEPAGE LOSSES

Assume a maximum infiltration rate of 0.05 inches/hr or 3.0 feet/month for silty clay loam material based on SCS information.

2.8 acres x 3.0 ft = 8.4 ac-ft

TOTAL LOSSES = 8.4 + 1.04 ac-ft = 9.44 ac-ft

INFLOW - (ET & SEEPAGE) = excess discharge

9.87 ac-ft-9.44 ac-ft = 0.43 ac-ft or .007 cfs

Note: The infiltration rates provided by SCS assume "free drainage" or a well drained situation. Seepage associated with a poorly drained situation such as an impeding layer or shallow depth to groundwater is not factored in.

APPENDIX 14-D

Wetted Perimeter Calculations

Golder Associates	SUBJECT Wetted Perimeter Calcs for SW-17		
	Job No. 903-6400.912	Made by UEE7	Date 10-25-91
	Ref. ISRT	Checked MJC	Sheet 1 of 4
		Reviewed RER	

Objective: To determine the wetted Perimeter at SW-17 before and after the remedy for April and August. (ie high baseflow and low baseflow)

Method: Having flow data at SW-2 (Western Branch of the Aberjona River) and SW-4 (Northern Branch of the Aberjona River as measured in the field by Roux Associates for April and August of 1990, the sum of these values is maintained as the flow at SW-17 for each month. Assuming that 60% of the flow at SW-2 will be diverted after the remedy, determine the wetted perimeter using Manning's equation for pre- and post- remedy.

Assumptions:

1. The flow from SW-2 and SW-4 can be summed to equal the flow at SW-17 [i.e. no flow is lost to/gained from groundwater] ignoring the influence of the culverts on flow.
2. 60% of the flow at SW-2 will be diverted.

References:

1. Flow data for SW-2 and SW-4 from GSIP by Roux Ass dated July, 1991.
2. Channel cross-section at SW-17 from bathymetry by TWM Northeast dated 3-14-91
3. Andrew L. Simon, "Hydraulics", 1986

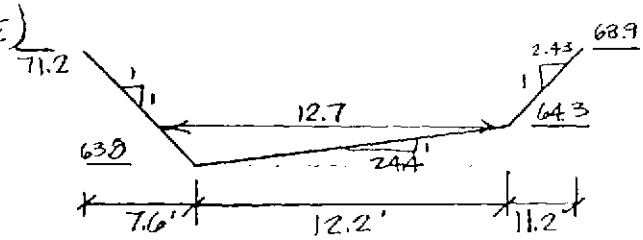
Golder Associates	SUBJECT Wetted Perimeter Calcs for SW-17		
	Job No. 903-6400.912 Ref. ISDT	Made by VEE 7 Checked MYC Reviewed MCM	Date 10-25-91 Sheet 2 of 4

Flow Data

	April	August
SW-2	0.17 cfs	0.0023 cfs
SW-4	0.62 cfs	0.012 cfs
SW-17 (before)	0.79 cfs	0.0143 cfs
SW-17 (after)	0.69 cfs	0.013 cfs

Manning's Equation $Q = \frac{1.49}{n} R^{2/3} S^{1/2} A = \frac{1.49}{n} \frac{A^{5/3}}{P^{2/3}} S^{1/2}$

SW-17 (D-2 TWMNE) geometry



Q = given

$n = 0.035$ (Simon)

if $d > 0.5$ft $A = \frac{1}{2}(0.5)(12.2+0.5) + (d-0.5)\left[\frac{25.4 + 3.43(d-0.5)}{2}\right]$

$A = 3.18 + (d-0.5)[12.7 + 1.72(d-0.5)]$

if $d \le 0.5$ft $A = \frac{1}{2}(d)(24.4d + d) = 12.7d^2$

if $d > 0.5$ft $P = [12.7 + (d-0.5)(\sqrt{2} + \sqrt{6.90})]$

if $d \le 0.5$ft $P = [\sqrt{2} + \sqrt{596}]\, d = 25.8d$

$S = 0.0056\%$

$R = \frac{A}{P}$

Golder Associates	SUBJECT Wetted Perimeter Calcs for SW-17		
	Job No. 903-6400.912	Made by UEEZ	Date 10-25-91
	Ref. ISRT	Checked mjk	Sheet 3 of 4
		Reviewed NCR	

APRIL

Before Remedy ⇒ Plugging in the numbers (if $d \leq 0.5$ ft)

$$(0.79) = \frac{1.49}{(0.035)} \frac{(12.7d^2)^{5/3}}{(25.8d)^{2/3}} (0.0056)^{1/2}$$

Simplifying and solving for d,

$$0.0153 = (0.248)^3 = \frac{(12.7d^2)^5}{(25.8d)^2} = 496.3d^8$$

$$d = 0.273 \text{ ft}$$

$$\therefore P = 25.8d = 7.0 \text{ ft}$$

AFTER Remedy ⇒ Plugging in the numbers.

$$(0.69) = \frac{1.49}{(0.035)} \frac{(12.7d^2)^{5/3}}{(25.8d)^{2/3}} (0.0056)^{1/2}$$

Simplifying and solving for d,

$$(0.217)^3 = \frac{(12.7d^2)^5}{(25.8d)^2}$$

$$0.0102 = 496.3d^8$$

$$d = 0.259 \text{ ft}$$

$$\therefore P = 25.8d = 6.69 \text{ ft}$$

Golder Associates	SUBJECT Wetted Perimeter Calcs for SW-17		
	Job No. 903-6400912	Made by UEE7	Date 10-25-91
	Ref. ISRT	Checked MK	Sheet 4 of 4
		Reviewed MR	

AUGUST

BEFORE REMEDY ⇒ Plugging in the numbers

$$(0.0143) = \frac{1.49}{(0.035)} \frac{(12.7d^2)^{5/3}}{(25.8d)^{2/3}} (0.0056)^{1/2}$$

Simplifying and solving for d,

$$(0.0045)^3 = \frac{(12.7d^2)^5}{(25.8d)^2} = 496.3d^8$$

$$d = 0.061 \text{ ft}$$

$$\therefore P = 25.8d = 1.56 \text{ ft}$$

AFTER REMEDY ⇒ Plugging in the numbers,

$$0.013 = \frac{1.49}{(0.035)} \frac{(12.7d^2)^{5/3}}{(25.8d)^{2/3}} (0.0056)^{1/2}$$

Simplifying and solving for d,

$$(0.0041)^3 = \frac{(12.7d^2)^5}{(25.8d)^2} = 496.3d^8$$

$$d = 0.0585 \text{ ft}$$

$$\therefore P = 25.8d = 1.51 \text{ ft}$$

CHAPTER 15

GAS COLLECTION SYSTEM

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Appendix 15-B Collection Pipe Spacing Calculations

CHAPTER 15
GAS COLLECTION SYSTEM

15.1 REMEDIAL DESIGN REQUIREMENTS

15.1.1 Consent Decree Requirements

The Remedial Design Action Plan (RDAP) is included as Appendix I of the Consent Decree. The air remedy for the East Hide Pile as stated in the RDAP is as follows:

> "The remedial action for control of air emissions is intended to mitigate the release or threat of release of Hazardous Substances, including odors associated with decaying hide waste, in the East Hide Pile. The remedial action shall consist of stabilizing the side slopes of the East Hide Pile, installing a gas collection layer, capping with a synthetic membrane to establish impermeability, and soil cover (in accordance with Attachment A), and treating gaseous emissions with either activated carbon or thermal oxidation. EPA in consultation with the Commonwealth will approve the final decision as to which gas treatment system to install after the impermeable cover and gas collection system have been constructed and the pile allowed to reach equilibrium. Settlers shall operate a temporary gas treatment system and shall monitor gas generation and pile settlement until the pile has reached equilibrium. The final decision regarding the permanent gas treatment system will be to provide the most efficient and cost effective long-term remedy to the emission of odors and other hazardous substances based on the characteristics of the gaseous discharge and other engineering criteria established during the Remedial Design process. EPA in consultation with the Commonwealth will specify the final treatment decision in a subsequent document..."

15.1.2 Remedial Design Work Plan Requirements

The Remedial Design Work Plan (RDWP; Golder, 1990a) establishes that the 100% Design Report is to include the following gas collection system design elements:

1. Final determination of gas flow rates;
2. Final selection of piping; and,

3. Final gas system design package.

15.2 GAS FLOW RATE

As discussed in Chapter 12, the East Hide Pile will have an impermeable cover system including a gas collection layer. A small negative pressure will be developed within the gas collection layer to facilitate flow to the treatment system.

The gas collection system is expected to convey gas from two different sources. First, gas generated through the biodegradation of the hides wastes within the pile; and second, air from the atmosphere that could leak through the cover system. In order to design the gas collection and treatment systems, an estimate of the total gas flow from these two sources was completed. Procedures used for this estimate are discussed below. The calculations are presented in Appendix 15-A.

15.2.1 Degradation of Hides

In the Pre-Design Investigation Task A-2, Gas Treatability Interim Final Report (Golder, 1990b), the flow rate of gas from the pile was measured at six locations using a flux chamber placed at ground surface.

Based upon two rounds of flux chamber field sampling, total gas emission rates for targeted compounds on the East Hide Pile were as follows, based on an area of 3.72 acres:

Emission Rates (scfm)

Area	Minimum	Maximum
Sloped Areas	.07	15
Other Areas	<0.1	0.3
Total Hide Piles	<0.1	15

Methane is nearly 100 percent of the target compounds. Sampling indicates that methane constitutes 24 percent by volume of the total gas emissions based on gas vent measurements. Therefore, the highest total gas flow rate emission from the East Hide Pile was established as 62.6 scfm from this survey. This value was calculated based upon an area of the hide pile of 3.72 acres which is the footprint area. The actual surface area corrected for the hide pile topography is 4.41 acres. Applying the emissions value to this area, the total gas flow estimate is 74 scfm (Appendix 15-A). This is considered to be the peak surface gas flow rate from the decay of hides in the East Hide Pile.

A literature search produced no specific information concerning gas production rates for hides; however, several sources list gas production rates for other types of organic refuse (Atlas and Bartha, 1981; EMCON Associates, 1980; and Jones, Larson and Malone, 1984). Literature values are often cited on the basis of weights of refuse in place. By estimating the volume of East Hide Pile in place and an average unit weight, an estimate could be developed for gas generation from the hide pile. By applying this methodology a gas flow rate from 56 scfm to 112 scfm was estimated. If it is assumed that the surface flow rate is equal to the gas generation rate of the hides, then the measured rate of gas generation 74 scfm, is within the range of values estimated for decomposable materials. This rate was thus considered a reasonable estimate of gas flow for this portion of the total.

15.2.2 Atmospheric Leakage

The gas collection system may also draw in air from the atmosphere through leaks in the cover system. As discussed in Chapter 12, the cover system above the gas collection layer includes a geotextile, a geomembrane, a geocomposite drainage layer and 18 inches of vegetative soil cover at the surface. Water infiltrating through the cover soil and into the geocomposite will drain to a drainage collection pipe at the edge of the hide pile. Under general conditions the drainage pipe and geocomposite will be dry, thus allowing air to move through the geocomposite. A constant source of air can thus be considered to be available on the surface of the geomembrane.

Studies on geomembrane liners indicate that leakage rates through geomembranes vary with the level of QA/QC (Darilek, G.T., Laine, D.L. and Parra, J.O., 1989; and Giroud, J.P. and Bonaparte, R., 1989). As discussed in Section 15.3.2, the gas collection pipes have been designed considering a vacuum equivalent to 4 inches of water acting in them. Making the assumption of a 2 inch vacuum acting over the entire gas collection layer, and accounting for resistance to flow provided by the geotextile, it has been estimated that leakage through the geomembrane could range from 5 cfm for normal QA/QC to as high as 135 cfm if no QA/QC is performed.

The project specifications are written to provide for a high degree of QA/QC. Therefore the estimate of leakage associated with normal QA/QC is considered to be applicable to the calculation of gas flow rate.

15.2.3 Total Estimated Gas Flow

Adding the estimated contributions from the two sources of gas flow, and considering that normal QA/QC will be conducted, the estimated total gas flow based on field gas measurements is approximately 80 cfm. Applying the range of rates estimated from information on organic waste gas generation, the total flow rate would vary from approximately 60 cfm to 120 cfm. These estimates are below the gas flow rate of 150 cfm selected during early stages of design of both the collection and treatment systems. Due to the degree of uncertainly associated with these estimated rates, 150 cfm has been conservatively used for the final system design to provide supplementary system capacity.

15.3 GAS COLLECTION SYSTEM DESIGN

As a remedy to the emission of gases from the East Hide Pile, a collection system has been designed to capture the hide pile gases and transport them to a gas treatment plant. The design of the gas treatment system is discussed in Chapter 16.

15.3.1 System Components

The gas collection system is incorporated in the impermeable cover design for the East Hide Pile. The system consists of a 12 inch thick layer of gravel with a network of ten 6 inch perforated fiberglass collection pipes radiating bilaterally from a central 6 inch fiberglass manifold pipe. The manifold will run along the crest of the hide pile, and will deliver the gases to the gas treatment system to be constructed adjacent to the hide pile. The system will operate under a limited negative pressure equivalent to approximately 4 inches of water in the collection pipes, induced by a fan in the treatment system. The gas collection system layout is shown on Sheet 15-1.

Gas flow in the individual collection pipes and in the manifold will be controlled by a system of pneumatically controlled butterfly valves. The pneumatic control system will be operated by compressed nitrogen, provided by a compressed gas nitrogen generating system mounted adjacent to the treatment system. Nitrogen gas will flow to the system through vinyl plastic tubing linked to a series of polymer concrete vaults installed at each collection pipe-manifold junction. The top of each control vault will include a removable cover to allow for maintenance access. Details of control vaults, piping and nitrogen gas systems are shown on Sheets 15-1 and 15-2.

The gas collection pipes and the central manifold will be constructed of fiberglass. The material was chosen on the basis of its resistance to potentially corrosive substances in the hide pile gases. The collection pipes and the manifold include a series of flame arrestors as a precaution against combustion of the hide pile gases.

15.3.2 Pipe Spacing Analysis

The flow rate and pressure drop of the hide pile gas stream through the collection layer and into the collection pipes was modeled by assuming isothermal flow of an ideal gas through a bed of granular material. For the bed thickness of 12 inches, the maximum velocity of the gas under the design vacuum is approximately 1 foot per minute, demonstrating laminar purely viscous flow. By applying Darcy's law, the viscous resistance coefficient for the gas collection media was evaluated. An iterative procedure utilizing the isothermal ideal gas flow equation was then used to calculate collection pipe spacings required for the values of pressure drop. A small pressure differential equal to 4 inches of water below atmospheric pressure was selected. The mean pressure was assumed to be -2 inches of water with atmospheric pressure farthest from the collection pipe and a 4 inch of water negative pressure at the collection pipe. Applying this methodology the mean distance between collection pipes was calculated to be 104 feet. Calculations for pipe spacing are presented in Appendix 15-B.

15.4 NATURAL GAS SUPPLY LINE

A gas line is required to provide supplementary fuel to the treatment system. The line will be connected to the existing gas main located at the present termination of Commerce Way. The new gas line shall follow the clean utility corridors detailed in Chapter 11. Gas line installation shall be performed by the gas company or a contractor to the gas company. The location of the new and existing gas line is illustrated in Sheet 15-3.

REFERENCES

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Darilek, G.T., Laine, D.L. and Parra, J.O., 1989. Electrical Leak Location Method for Geomembrane Liners: Development and Applications, Geosynthetics '89.

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Jones, L.W., Larson, R.J., and Malone, P.G., 1984. Landfill Gas Production From Large Landfill Simulators.

APPENDIX 15-A

Gas Flow Rate Calculations

Golder Associates	SUBJECT Design value for total emissions From East Hide Pile		
	Job No. 903-6400.610 Ref. ISPT/Woburn/Ma.	Made by Cheryl Brooks Checked CBS Reviewed JHW PCR	Date 7/17/91 Sheet 1 of 5

Objective :

Determine the design value for total emissions from the East Hide Pile.

Reference :

Golder Associates Inc, Pre-Design Investigation Task, A-2, Gas Treatability, Interim Final Report, Industri-Plex Site, Woburn, Ma.

Calculations:

The highest estimated emission based on first round results for methane using a flux chamber was from HP2. see page 5

The value was 927×10^{-7} SCFM/FT^2 of CH_4. Since CH_4 made up only 24% of the total surface emissions, it was estimated that the total gas emissions rate was

$$927 \times 10^{-7} \text{ SCFM/FT}^2 \left(\frac{1}{.24}\right) = .0003863 \text{ SCFM/ft}^2$$

The area of the Hide Pile was estimated to be 162,071.2 ft^2 (3.72 acres) (BASED ON HORIZONTAL PROJECTION OF SLOPES) RD.

Golder Associates	SUBJECT Design value for total emissions from East Hide Pile		
	Job No. 903-6400-610	Made by CB	Date 7/17/91
	Ref. ISOT/[illegible]	Checked CRS	Sheet 2 of 45
		Reviewed [illegible]	

Calculations continued

This area is smaller than the one used in the "Leakage Rate of Air Through Cover System" calculations (4.41 acres).

For a hide pile area of 3.72 acres *
(* HORIZONTAL PROJECTION)

Design total emissions (worst case)

$= .0003863 \text{ SCFM/FT}^2 \times 162071.2 \text{ Ft}^2$

$= \underline{\underline{62.6 \text{ scfm}}}$

For a hide pile area of 4.41 acres *
(* CORRECTED SURFACE AREA, CONSERVATIVE ASSUMPTION.

Design total emissions (worst case)

$= .0003863 \text{ SCFM/FT}^2 \times 192{,}100.0 \text{ Ft}^2$

$= \underline{\underline{74.2 \text{ scfm}}}$

Conclusion:

The design emissions rate from the East Hide Pile is 3.863×10^{-4} SCFM/Ft^2. The total emissions rate will depend on the estimated surface area of the Hides.

29.6 inches of Hg and 30.29 and 30.14 inches of Hg, respectively. Therefore, the temperature was generally 10°F higher during the second round and the barometric pressure 0.5 inches of Hg higher. It appears that higher pressure systems (as during the second round) cause decreased surface emission rates while increasing gas vent emission rates. The slight overall increase in the gas vent emission rates during the second round may have been due to the increased resistances exhibited at the surface due to higher atmospheric pressures hence a tendency for the gas to move latterly toward the gas vents. Similarly, lower atmospheric pressures as exhibited during round one caused an increase in total surface emission rates while decreasing the total gas vent emission rate.

In order to characterize the composition of the emissions from the East Hide Pile, discrete samples were collected from gas vent B1. Results for these analyses indicated that emissions from the East Hide Pile were comprised of 24% methane, 0.28% hydrogen sulfide and <0.004% volatile organics. The other 75.7% is most likely comprised of carbon dioxide with smaller amounts of nitrogen, and oxygen gas as typically found at landfills.

Initial results for total estimated emission based on first round results for methane using flux chamber sampling did not account for additional gases such as carbon dioxide, nitrogen and oxygen. A more realistic total emission rate is needed for design of the gas collection and treatment system and can be obtained by multiplying the results for the first round by a

factor of 4.17. This factor was obtained by ratioing the percent of methane emissions determined at B1 to the total emission rate measured using a calibrated bag and stop watch. It was assumed that the composition of the East Hide Pile gas was homogeneous. Using the factor of 4.17, the total emission rates determined from using first round results for HP2 (worse case) and a sloped/unsloped sector approach using HP2 and HP7 as representative emissions would increase accordingly from 15 and 7.8 scfm to 62.6 and 32.5 scfm, respectively. Therefore, the design value for total emissions from the East Hide Pile would be 62.6 scfm.

8.0 CONCLUSIONS

Massachusetts Department of Environmental Protection (MDEP) does not set limits for methane, hydrogen sulfide or the total volatile organic compounds which are found in the East Hide Piles gas emissions. The ROD states that the National Ambient Air Quality Standards (NAAQS) are applicable to operations at the site. The MDEP requires that the best available control technology (BACT) be used. Therefore the gas treatment peformance requirements will be dictated by best available techology.

The recommended alternatives for remediating odor emissions at the Industri-Plex site given in the ROD involves stabilizing the East Hide Pile's slopes and installing an active gas collection system and flexible membrane liner. The collected gases are to be treated with either activated carbon or by

TABLE 4
COMPOUND SPECIFIC EMISSION RATES (SCFM/FT2)

LOCATION	CH4 X 10-7		H2S X 10-7		CH3SH X 10-7		ACETONE X 10-7		BENZENE X 10-7		TOLUENE X 10-7		CHLOROBENZENE X 10-7		ETHYLBENZENE X 10-7		DICHLOROBENZENE X 10-7	
	MAY	AUG	MAY	AUG	MAY	AUG	MAY	AUG	MAY	AUG	MAY	AUG	MAY	AUG	MAY	AUG	MAY	AUG
HP1	<4.9	NA	<0.037	NA	<0.027	NA	0.064	NA	<0.010	NA	<0.008	NA	<0.006	NA	<0.006	NA	<0.005	NA
HP2	927	8.9	<0.038	0.03	<0.027	<0.05	0.029	<0.012	<0.010	<0.009	<0.008	<0.007	<0.006	<0.006	<0.006	<0.006	<0.005	<0.005
HP3	<4.9	NA	<0.010	NA	<0.008	NA	<0.013	NA	0.013	NA	<0.008	NA	<0.006	NA	<0.006	NA	<0.005	NA
HP4	10.1	NA	<0.038	NA	<0.027	NA	<0.013	NA	<0.010	NA	<0.008	NA	<0.006	NA	<0.006	NA	<0.005	NA
HP7	17.2	6.7	0.31	0.04	<0.027	<0.05	<0.038	<0.012	<0.010	<0.009	<0.008	<0.007	<0.006	<0.006	<0.006	<0.006	<0.005	<0.005
HP9	46	NA	<0.038	NA	<0.027	NA	<0.013	NA	<0.010	NA	<0.008	NA	<0.006	NA	<0.006	NA	<0.005	NA
B1	NA	1056000	NA	12144	NA	<0.814	NA	<0.012	NA	16.3	NA	14.1	NA	0.189	NA	0.132	NA	0.37
DUPLICATE HP2	<4.9	NA	<0.038	NA	<0.027	NA	<0.013	NA	<0.010	NA	<0.008	NA	<0.006	NA	<0.006	NA	<0.005	NA
DUPLICATE B1	NA	484000	NA	12716	NA	<0.814	NA	<0.05	NA	19.4	NA	14.1	NA	<0.03	NA	<0.03	NA	0.34
FIELD BLANK	<4.9	<6.1	<0.038	<0.04	<0.027	<0.04	0.103	<0.013	<0.010	<0.010	<0.009	<0.009	<0.006	<0.006	<0.007	<0.007	<0.005	<0.005
TRIP BLANK	NA	<6.1	<0.18	<0.04	NA	<0.04	<0.013	<0.013	<0.010	<0.010	<0.009	<0.009	<0.006	<0.006	<0.007	<0.007	<0.005	<0.005

NA - NOT ANALYZED

Objectives:

(1) Obtain through a literature search "typical" gas generation rates for decaying animal hides (ft^3/lbs waste/min)

(2) Obtain the value of the unit weight of the hides. (lbs/ft^3)

(3) Estimate the volume of waste. (ft^3)

(4) Multiply the values of (1) (2) + (3) and compare that flow rate to the highest surface gas emissions flow rate actually measured at the site, 62.6 ft^3/min*. (Ref 1)

(*BASED UPON HORIZONTAL PROJECTION OF SURFACE AREA)

Calculations:

(1) "typical" gas generation rates.

No mention of the gas generation rate for decaying animal hides was found in literature. However, several sources give the following "typical" landfill gas generation rates:

Golder Associates	SUBJECT Total Emissions From Hill Pile		
	Job No. 903-3400.610 Ref. ICRT/Woburn/Ma	Made by CB Checked SRS Reviewed [illegible]	Date 5/29/91 Sheet 7 of 45

calculations continued...

a) Between 17.75 $\frac{ml}{kg \cdot day}$ and 20.1 $\frac{ml}{kg \cdot day}$ (Ref 2)

b) Between 2.6 $\frac{L}{kg \cdot yr}$ and 15.0 $\frac{L}{kg \cdot yr}$ (Ref 3)

c) Ultimate yield between 57 $\frac{L}{kg}$ and 174 $\frac{L}{kg}$ (Ref 3)

d) Total gas yield = .61 $\frac{m^3}{kg}$ Municipal Garbage (Ref 4)
.24 $\frac{m^3}{kg}$ Cattle Manure (Ref 4)

Find the average gas generation rate in ft^3/lb waste/yr

a) $17.75 \frac{ml}{kg \cdot day} \cdot \frac{cm^3}{ml} \cdot \frac{m^3}{(100\,cm)^3} \cdot \frac{16\ kg/m^3}{1\ lb/ft^3} \cdot \frac{day}{24\,hr} \cdot \frac{hr}{60\,min}$

$= \underline{1.9722 \times 10^{-7}\ ft^3/lb \cdot min}$

$20.1 \frac{ml}{kg \cdot day} \cdot \frac{cm^3}{ml} \cdot \frac{m^3}{(100\,cm)^3} \cdot \frac{16\ kg/m^3}{lb/ft^3} \cdot \frac{day}{24\,hr} \cdot \frac{hr}{60\,min}$

$= \underline{2.2333 \times 10^{-7}\ ft^3/lb \cdot min}$

b) $2.6 \frac{L}{kg \cdot yr} \cdot \frac{1000\,cm^3}{L} \cdot \frac{m^3}{(100\,cm)^3} \cdot \frac{16\ kg/m^3}{lb/ft^3} \cdot \frac{yr}{365\,days} \cdot \frac{day}{24\,hr} \cdot \frac{hr}{60\,min}$

$= \underline{7.9148 \times 10^{-8}\ ft^3/lb \cdot min}$

Golder Associates	SUBJECT Total Emissions From Hide Pile		
	Job No. 903-6402.610	Made by CB	Date 5/29/91
	Ref. ISRT/[illegible]/Ma[illegible]	Checked SRS	Sheet 8 of 45
		Reviewed [illegible]	

calculations continued...

$$15\ L/Kg\cdot yr \cdot \frac{1000\ cm^3}{L} \cdot \frac{m^3}{(100\ cm)^3} \cdot \frac{16\ Kg/m^3}{1\ lb/ft^3} \cdot \frac{yr}{365\ days} \cdot \frac{day}{24\ hr} \cdot \frac{hr}{60\ min}$$

$$= \underline{4.5662 \times 10^{-7}\ ft^3/lb\ waste/min}$$

c) To convert the gas yield to an average gas generation rate, the yield must be divided by the length of time that the gas is generated. To date, very little information exists concerning the length of time landfills produce gas. The length of time is generally considered to be between 6 and 103 years (Reference 3). It will be assumed that the length of time gas is produced is 20 years. (Reference 5)

$$57\ L/Kg \cdot \frac{1}{20\ yr} \cdot \frac{1000\ cm^3}{L} \cdot \frac{m^3}{(100\ cm)^3} \cdot \frac{16\ Kg/m^3}{1\ lb/ft^3} \cdot \frac{yr}{365\ days} \cdot \frac{day}{24\ hrs} \cdot \frac{hr}{60\ min}$$

$$= \underline{8.6758 \times 10^{-8}\ ft^3/lb\ waste/min}$$

$$174\ L/K \cdot \frac{1}{20\ yr} \cdot \frac{1000\ cm^3}{L} \cdot \frac{m^3}{(100\ cm)^3} \cdot \frac{16\ Kg/m^3}{1\ lb/ft^3} \cdot \frac{yr}{365\ days} \cdot \frac{day}{24\ hrs} \cdot \frac{hr}{60\ min}$$

$$= \underline{2.6484 \times 10^{-7}\ ft^3/lb\ waste/min}$$

Golder Associates	SUBJECT Total Emissions From Hide Pile		
	Job No. 903-6400.610	Made by CB	Date 5/27/9[illegible]
	Ref. ISRT/Woburn/Ma.	Checked SRS	Sheet 9 of 45
		Reviewed [illegible]	

calculations continued...

d) $.61\ m^3/Kg \cdot \frac{1}{20\ yrs} \cdot \frac{16\ Kg/m^3}{1\ lb/ft^3} \cdot \frac{yr}{365\ days} \cdot \frac{day}{24\ hr} \cdot \frac{hr}{60\ min}$

$= \underline{9.2846 \times 10^{-7}\ ft^3/lb\ waste/min}$

$.24\ m^3/Kg \cdot \frac{1}{20\ yrs} \cdot \frac{16\ Kg/m^3}{1\ lb/ft^3} \cdot \frac{yr}{365\ days} \cdot \frac{day}{24\ hr} \cdot \frac{hr}{60\ min}$

$= \underline{3.6530 \times 10^{-7}\ ft^3/lb\ waste/min}$

For the average gas generation rate, throw out the high and low values then calculate the average

$(1.9722 + 2.2333 + 4.5662 + .86758 + 2.6484 + 3.6530) \times 10^{-7}\ ft^3/lb \cdot min\ /6$

$= \underline{2.6568 \times 10^{-7}\ ft^3/lb \cdot min}$

(2) Obtain the value of the unit weight of the hides (lbs/ft^3).

Unit weights for the hides were determined from undisturbed Shelby tube samples of Fill and Hide Residue. The values ranged from 65 to 130 lb/ft^3 depending on the degree of saturation. (Reference 6)

Golder Associates	SUBJECT Total Emissions From Hide Pile		
	Job No. 903-6400 Ref. ISRT/Woburn/Ma.	Made by CJS Checked JRS Reviewed JLH	Date 5/24/91 Sheet 10 of 45

(3) Objective: Determine the approximate volume of fill and hide residues in the East Hide Pile.

Approach: Use the Geotechical Cross Sections and boring logs (Reference 1) to estimate the thickness of the hides at different areas. Draw N-S cross-sections every 50 feet and find (using a planimeter) the area of fill and hide residues at each cross-section. Use the average-end-area method to determine the volume of residues at the East Hide Pile.

Golder Associates

SUBJECT Total Emissions from Hide Pile.		
Job No. 903-6400.610	Made by JB	Date 5/2[illegible]/[illegible]
Ref. ISRT/Woburn/Ma.	Checked SRS	Sheet 11 of 45
	Reviewed [illegible]	

Cross Section	Area (ft^2)	Average Area (ft^2)	distance Between (ft)	Volume (ft^3)	Cumulative Volume (ft^3)
—	0				
		1171	50	58550	58550
G - G'	2342				
		3606	50	180,300	238,550
H - H'	4870				
		5585	50	279250	518,100
I - I'	6300				
		6972.5	50	348,625	866,725
J - J'	7645				
		7656.5	50	382,825	1,249,550
K - K'	7668				
		7996.5	50	399,825	1,649,375
L - L'	8325				
		8408.5	50	420,425	2,069,800
M - M'	8492				
		8643	50	432,150	2,501,950
N - N'	8794				
		7436.5	50	371,825	2,873,775
O - O'	6079				
		5370.5	50	268,525	3,142,300
P - P'	4662				
		2331	50	116550	3,258,850
—					

Approximate volume of waste in East Hide Pile = 3,258,850 ft^3

(4) Flow rate of gas

$2.6568 \times 10^{-7}\ ft^3/(lb\ waste \cdot min) \cdot 65\ lb/ft^3$

$\cdot 3258850\ ft^3 = \underline{56.28}\ ft^3/min$

$2.6568 \times 10^{-7}\ ft^3/(lb \cdot min) \cdot 130\ lb/ft^3 \cdot 3258850\ ft^3$

$= \underline{112.56}\ ft^3/min$

∴ The flow rate measured on the site is within the range of flow rates found in literature. The measured value of 62.6 ft^3/min may be on the low end of the range because gas emissions from the surface of the pile are probably less than the gas generation rate (some of the gas seeps into the underlying soil).

Golder Associates

SUBJECT Total Emissions From Hide Pile

Job No. 903-6400.610 | Made by CB | Date 5/29/91
Ref. ISPT/Woburn/M. | Checked SRS | Sheet 13 of 45
Reviewed

Conclusion:

The design emissions flow rate of 62.6 ft^3/min is within the range of values given in literature for gas generation in landfills. Therefore, this value seems reasonable to use as a design flow rate.

References:

(1) Golder Associates, Pre-Design Investigation, Task A-2, Gas Treatability, Interim Final Report, Industri-Plex Site, Woburn, Massachusetts, prepared for Industri-Plex Site Remedial Trust, October 1990.

(2) L. W. Jones, R. J. Larson, and P. G. Malone, "Landfill Gas Production From Large Landfill Simulators," 1984

References continued...

(3) EMCON ASSOCIATES, "Methane Generation and Recovery From Landfills," prepared for Consolidated Concrete Limited and Alberta Environment, Ann Arbor Science Publishers, 1980.

(4) R. M. Atlas and R. Bartha, Microbial Ecology: Fundamentals and Applications, Addison-Wesley Publishing Company, August 1981.

(6) Michael J. Carolan, "Methane-Fueled Power Plant Lights County Despite Delays" Reprinted from WORLD WASTES, June 1985.

(7) Golder Associates, Pre-Design Investigation, Task S-2, Stability of Hide Piles, Interim Final Report, Industri-Plex Site, Woburn, Massachusetts, prepared for Industri-Plex Site Remedial Trust, September, 1990.

Golder Associates	SUBJECT Leakage Rate of Air through Cover System		
	Job No. 903-6400.610 Ref. ICRT/Woburn/MA.	Made by Checked GWA Reviewed	Date 6/18/91 Sheet 15 of 45

Objective:

Estimate the expected flow rate of air through leaks in the cover system into the gas collection pipes.

Approach:

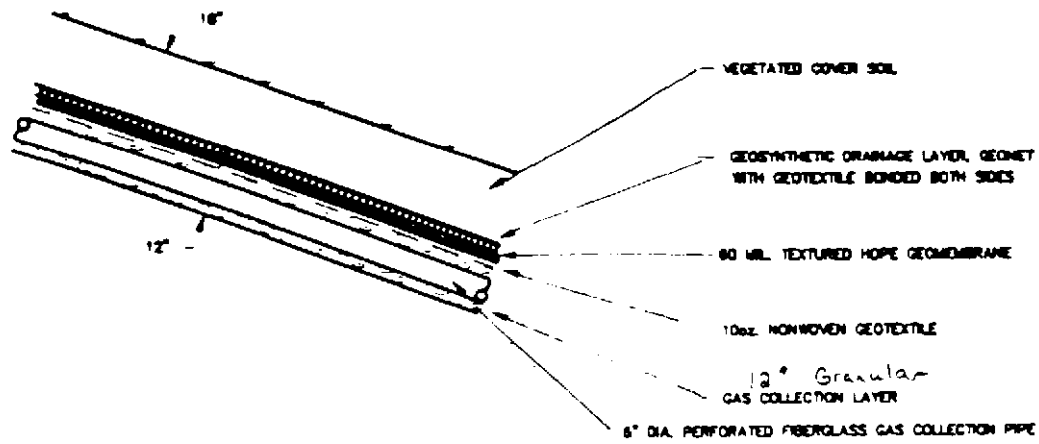
1) Determine flow through holes in the geomembrane using the orifice equation.

2) Determine the flow rate through geotextile using product testing information.

3) The expected flow rate of air through leaks in the cover system will be the smaller of 1) and 2)

Golder Associates	SUBJECT Leakage Rate of Air through Cover System		
	Job No. 903-6400.610	Made by CB	Date 6/19/9
	Ref. ISRT/Woburn/Ma.	Checked Gwt	Sheet 16 of 45
		Reviewed [illegible]	

Data / Assumptions:

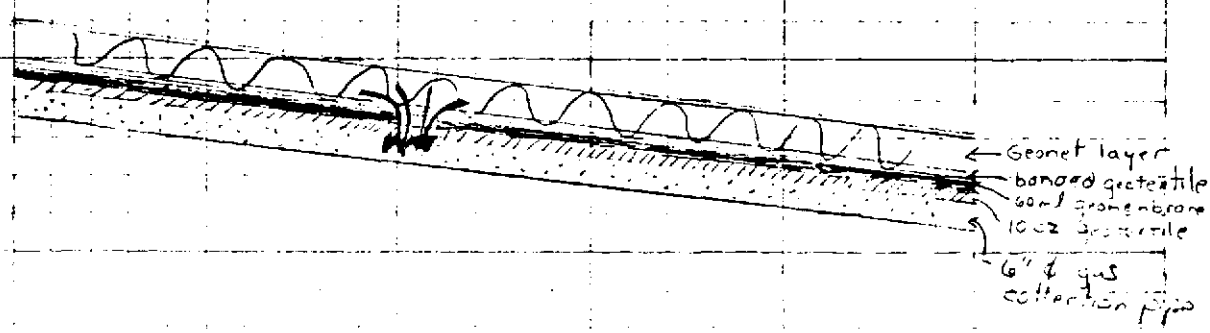


1 / 12-5 IMPERMEABLE COVER SYSTEM

2 0 2 4
scale feet

Water within the geonet layer drains to a 6" drainage collection pipe. Under most conditions (except during very high flows) the collection pipe does not flow full. Therefore, air is able to freely flow from the drainage collection pipe through the geonet layer. If there is a hole or tear in the 60 ml geomembrane, air may flow

from the geonet, through the bonded geotextile, through the hole or tear in the geomembrane, through the 10 oz. nonwoven geotextile, into the 6" gas collection pipe.



Air flows through the hole in the geomembrane. As a conservative estimate, assume that 2 inches of negative pressure is acting at each hole in the geomembrane.

at standard atmospheric pressure and 60° F

$\gamma_{air} = .0764$ lbs/ft^3 (Reference 1)

speed of sound of air at sea level = 340 m/s = 1115.5 ft/s (Reference 2)

Golder Associates	SUBJECT Leakage Rate of Air through [illegible]		
	Job No. 903-2403.010 Ref. ISRT/Woburn/Ira.	Made by Checked GWA Reviewed [illegible]	Date 6/19/91 Sheet 18 of 45

Calculations:

For an incompressible fluid, the flow through a hole in a geomembrane may be described by the oriface equation:

$$Q = C_d A_o \sqrt{2g(\Delta H)}$$ (Equation 12.9 Ref 3)

Q = flow rate (cfs)

C_d = Coefficient of discharge = .61 (Fig 12.11 Ref 3)

A_o = area of hole (ft^2)

g = gravitational constant ($32.2\ ft/s^2$)

ΔH = head (ft of fluid)

From page 39 + 40 of Reference 2

"Gas flows... may be considered incompressible provided the flow speeds are small relative to the speed of sound." Gas Flows with a Mach number less than .3 may be treated as incompressible.

$$M = V/S$$ (Ref 2)

M = Mach number

V = velocity of gas (ft/s)

S = speed of sound in gas (ft/s)

Golder Associates	SUBJECT Leakage Rate of Air Through Cover System		
	Job No. 903-6400.610	Made by CB	Date 6/19/91
	Ref. ISRT/Woburn/ina	Checked GWA	Sheet 19 of 45
		Reviewed [illegible]	

calculations continued...

First assume that flow is incompressible.

Then check to see if it is.

$$\Delta H_{air} = \Delta H_{water} \cdot \frac{\gamma_{water}}{\gamma_{air}} = 2\,in\left(\frac{ft}{12\,in}\right)\left(\frac{62.37\ lbs/ft^3}{.0764\ lbs/ft^3}\right)$$

$$\Delta H_{air} = 136.06\ ft$$

$$Q = \left[.61\ A_o \sqrt{2(32.2\ ft/s^2)(136.06\ ft)}\right] \frac{60\ sec}{min}$$

$$Q = 3426.018\ A_o\ ft/min$$

where A_o is the area of the hole the air flows through (ft²)

Area of Hide Pile was measured using a planimeter on a 1" = 100' drawing.

Area ≅ 4.41 acres

Is flow incompressible?

$$Q = VA_o = 3426.018\ ft/min\ A_o\left(\frac{min}{60\ sec}\right) = 57.1\ A_o\ ft/s$$

$$\therefore V = 57.1\ ft/s$$

$$M = V/S = \frac{57.1\ ft/s}{1115.5\ ft/s} = .0512$$

∴ Since $M < .3$ the air may be treated as incompressible.

Calculations continued...

Typical Geomembrane Hole Size and Frequency:

(References 4 + 5)

Geomembrane installed with QA/QC: 1 Hole/acre (.16 in²)
3 Holes/acre (.005 in²)

Geomembrane installed with limed QA/QC: 3 Holes/acre (.16 in²)
(1 person inspecting) 8 Holes/acre (.005 in²)

Geomembrane installed with no QA/QC: 30 Holes/acre (.16 in²)
90 Holes/acre (.005 in²)

For the site 4.41 acres

With QA/QC

1 hole/ac (4.41 ac) = 5 holes 0.16 in²

3 holes/ac (4.41 ac) = 14 holes 0.005 in²

With limited QA/QC
(one inspector)

3 holes/acre (4.41 ac) = 14 holes (0.16 in²)

8 holes/ac (4.41 ac) = 36 holes (0.005 in²)

With no QA/QC

30 holes/ac (4.41 ac) = 133 holes (0.16 in²)

90 holes/ac (4.41 ac) = 397 holes (0.005 in²)

Golder Associates	SUBJECT Leakage Rate of Air through Cover System		
	Job No. 903-6400.010	Made by JB	Date 2/21/91
	Ref. ISPT/Woburn/Ma.	Checked GWA	Sheet 21 of 45
		Reviewed [illegible]	

calculations, continued...

With QA/QC total leakage rate:

$Q = 3426.018\ ft/min\ (5\ holes)(.16\ in^2)(ft^2/144\ in^2)$

$+ 3426.018\ ft/min\ (14\ holes)(.005\ in^2)(ft^2/144\ in^2)$

$\underline{Q = 20.7\ cfm}$

With limited QA/QC total leakage rate:

$Q = 3426.018\ ft/min\ (14\ holes)(.16\ in^2)(ft^2/144\ in^2)$

$+ 3426.018\ ft/min\ (36\ holes)(.005\ in^2)(ft^2/144\ in^2)$

$\underline{Q = 57.6\ cfm}$

without QA/QC total leakage rate:

$Q = 3426.018\ ft/min\ (133\ holes)(.16\ in^2)(ft^2/144\ in^2)$

$+ 3426.018\ ft/min\ (397\ holes)(.005\ in^2)(ft^2/144\ in^2)$

$\underline{Q = 553.5\ cfm}$

2) Determine the flow rate through the geotextile using product testing information.

If there is a hole in the geomembrane, air will flow through both a 10 oz nonwoven geotextile (0.125 inches thick) and a geotextile bonded

calculations continued...

to a geonet (probably about .075 inches thick).
The two geotextiles together will act like a geotextile approximately 0.2 inches thick.

The approximate flow rate for a geotextile 0.2 inches thick is 198 $ft^3/min/ft^2$ (Reference 6)

The value of 198 $ft^3/min/ft^2$ was measured using the Frazier Air Permeability Test with a .185 inch thick nonwoven geotextile.
The head used for the Test is 1/2 inch H_2O.
To estimate a flow at 2 inches H_2O, multiply 198 $ft^3/min/ft^2$ by 4. (Reference 7)

flow = 198 $ft^3/min/ft^2 \times 4$ = 792 $ft^3/min/ft^2$

With QA/QC total leakage rate:

$Q = 792\ ft^3/min/ft^2\ (5\ holes)(.16\ in^2)(ft^2/144\ in^2)$
$+ 792\ ft^3/min/ft^2\ (14\ holes)(.005\ in^2)(ft^2/144\ in^2)$

$Q = 4.79$ cfm

Golder Associates	SUBJECT Leakage Rate of Air Through Cover System		
	Job No. 903-6400.610 Ref. ISPT/Woburn/Mo	Made by CB Checked GWA Reviewed AH	Date 6/21/91 Sheet 23 of 45

calculations continued...

With limited (one inspector) QA/QC total leakage Rate:

$Q = 792\ ft^3/min/ft^2\ (14\ holes)(.16\ in^2)(ft^2/144\ in^2)$

$+ 792\ ft^3/min/ft^2\ (36\ holes)(.005\ in^2)(ft^2/144\ in^2)$

$\underline{Q = 13.3\ cfm}$

With no QA/QC total leakage rate:

$Q = 792\ ft^3/min/ft^2\ (133\ holes)(.16\ in^2)(ft^2/144\ in^2)$

$+ 792\ ft^3/min/ft^2\ (397\ holes)(.005\ in^2)(ft^2/144\ in^2)$

$\underline{Q = 128.0\ cfm}$

3) Since the flow rate of air through the geotextile is smaller than the flow rate through unobstructed holes in the geomembrane, flow through the geotextile controls. Therefore, the expected flow rate of air through leaks in the cover system will be 4.79 cfm if QA/QC is performed, 13.3 cfm if limited QA/QC is performed, and 128.0 cfm if no QA/QC

calculations continued:

is performed.

Conclusion:

If intensive QA/QC is performed, the expected leakage rate through the the cover system will be approximately 4.79 cfm. If limited QA/QC is performed (one inspector) the expected leakage rate will be approx. 13.3 cfm. If no QA/QC is performed, the expected leakage rate will be approximately 128.0 cfm. Therefore, it is recommended that at least limited QA/QC be performed.

References :

(1) Roberson / Crowe, Engineering Fluid Mechanics, Third Edition, 1985.

(2) Fox, R.W. and McDonald, A.T., Introduction to Fluid Mechanics, Third Edition, 1985.

(3) Daugherty, R.L., Franzini, J.B., and Finnemore, E.J., Fluid Mechanics With Engineering Applications, Eighth Edition, 1985.

(4) Darilek, G.T., Laine, D.L., & Parra, J.O., "The Electrical Leak Location Method for Geomembrane Liners: Development and Applications" Geosynthetics Conference Proceedings, February 21-23, 1989.

(5) Giroud, J.P. & Bonaparte, R. "Leakage through Liners Constructed with Geomembranes - Part I. Geomembrane Liners", Geotextiles and Geomembranes, 1989.

(6) Phone conversation with Jack Hodge of Tensar Corporation, 6/19/91 at 1:17 PM.

Golder Associates	SUBJECT Leakage Rate of Air through Paper System		
	Job No. 903-64007610 Ref. ISKT/Woburn/Ma.	Made by CD Checked GWA Reviewed JAK	Date 6/24/91 Sheet 26 of 45

References continued...

(7) Phone conversation with Chris Jarvis of Clemson University, 6/21/91 at 10:19 AM.

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Reference 2

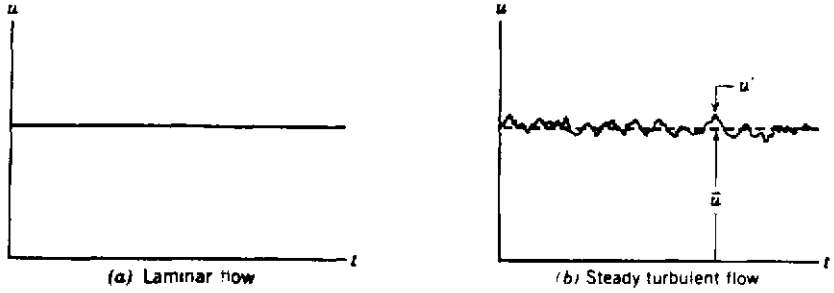

Fig. 2.14 Variation of axial velocity with time.

appear as shown in Fig. 2.14. For steady laminar flow, the velocity at a point remains constant with time. In turbulent flow the velocity trace indicates random fluctuations of the instantaneous velocity, u, about the time mean velocity, $\bar{u}$. We can consider the instantaneous velocity, u, as the sum of the time mean velocity, $\bar{u}$, and the fluctuating component, u',

$$u = \bar{u} + u'$$

Because the flow is steady, the mean velocity, $\bar{u}$, does not vary with time.

Although many turbulent flows of interest are steady in the mean ($\bar{u}$ is not a function of time), the presence of the random, high-frequency velocity fluctuations makes the analysis of turbulent flows extremely difficult. In a one-dimensional laminar flow, the shear stress is related to the velocity gradient by the simple relation

$$\tau_{yx} = \mu \frac{du}{dy} \tag{2.10}$$

For a turbulent flow in which the mean velocity field is one-dimensional, no such simple relation is valid. Random, three-dimensional velocity fluctuations (u', v', and w') transport momentum across the mean flow streamlines, increasing the effective shear stress. Consequently, in turbulent flow there is no universal relationship between the stress field and the mean-velocity field. Thus in turbulent flows we must rely heavily on semi-empirical theories and on experimental data.

2-5.3 Compressible and Incompressible Flows

Flows in which variations in density are negligible are termed *incompressible*; when density variations within a flow are not negligible, the flow is called *compressible*. If one considers the two states of matter, liquid and gas, included within the definition of a fluid, one is tempted to make the general statement that all liquid flows are incompressible flows and all gas flows are compressible flows. For many practical cases the first portion of the statement is correct; most liquid flows are essentially incompressible. However, water hammer and cavitation are examples of the importance of compressibility effects in liquid flows. Gas flows also may be considered incompressible provided the flow speeds are small relative to the speed of sound; the *

28/45

Reference 2

ratio of the flow speed, V, to the local speed of sound, c, in the gas is defined as the Mach number,

$$M \equiv \frac{V}{c}$$

For values of $M < 0.3$, changes in density are less than 2 percent of the mean value. Thus gas flows with $M < 0.3$ can be treated as incompressible; a value of $M = 0.3$ in air at standard conditions corresponds to a speed of approximately 100 m/sec.

Compressible flows occur frequently in engineering applications. Common examples include compressed air systems used to power shop tools and dental drills, transmission of gases in pipelines at high pressure, and pneumatic or fluidic control and sensing systems. Compressibility effects are very important in the design of modern high-speed aircraft and missiles, power plants, fans, and compressors.

2-5.4 Internal and External Flows

Flows completely bounded by solid surfaces are called internal or duct flows. Internal flows may be laminar or turbulent, compressible or incompressible.

In the case of incompressible flow through a pipe, the nature of the flow (laminar or turbulent) is determined by the value of a dimensionless parameter, the Reynolds number, $Re = \rho \bar{V} D/\mu$, where ρ is the density of the fluid, $\bar{V}$ the average flow velocity, D the pipe diameter, and μ the viscosity of the fluid. Pipe flow is laminar when $Re \leq 2300$; it may be turbulent for larger values. (The Reynolds number and other important dimensionless parameters encountered in fluid mechanics will be discussed in Chapter 7.) Chapter 8 will be devoted to a study of internal incompressible flow.

In the case of internal compressible flows, proper duct design is necessary to attain supersonic flow. The variation of fluid properties within a variable-area flow passage is not the same for supersonic flow ($M > 1$) as it is for subsonic flow ($M < 1$). Likewise the boundary conditions on the flow at the exit of an internal flow (e.g. the discharge from a nozzle) are different in the two cases. For subsonic flow discharge, the pressure in the exit plane of the nozzle is ambient pressure. For sonic flow, the nozzle exit pressure may be greater than ambient. For a supersonic jet, the pressure in the exit plane of the nozzle may be greater than, equal to, or less than ambient pressure. One-dimensional, steady compressible flow will be treated in Chapters 11 and 12.

External flows occur over bodies immersed in an unbounded fluid. The flow over a semi-infinite flat plate (Fig. 2.11) and the flow over a cylinder (Fig. 2.12*a*) are examples of external flows.

Boundary-layer flows also may be laminar or turbulent; the definitions of laminar and turbulent flows given earlier also apply to boundary-layer flows; the details of a flow field may be significantly different depending on whether the boundary layer is laminar or turbulent. In Chapter 9, boundary-layer flows and flow over immersed bodies will be discussed in detail.

Flows of liquids in which the duct does not flow full—where there is a free surface subject to a constant pressure—are termed *open-channel* flows. Common examples of open-channel flow include flow in rivers, irrigation ditches, and aqueducts. Open-channel flow will be treated in Chapter 10.

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12.13.

Coefficient of Velocity C_v

Reference 3

The velocity that would be attained in the jet if friction did not exist may be termed the ideal velocity V_i.[1] It is practically the value of u_c in Fig. 12.14. Because of friction the actual average velocity V is less than the ideal velocity, and the ratio V/V_i is called the *coefficient of velocity*. Thus $V = C_v V_i$.

Coefficient of Discharge C_d

The ratio of the actual rate of discharge Q to the ideal rate of discharge Q_i (the flow that would occur if there were no friction and no contraction) is defined as the coefficient of discharge. Thus $Q = C_d Q_i$. By observing that $Q = AV$ and $Q_i = A_o V_i$, it is seen that $C_d = C_c C_v$.

Determining the Coefficients

The coefficient of contraction can be determined by using outside calipers to measure the jet diameter at the vena contracta and then comparing the jet area with the orifice area. The contraction coefficient is very sensitive to small variations in the edge of the orifice or in the upstream face of the plate. Thus slightly rounding the edge of the orifice in Fig. 12.11*b* or roughening the orifice plate will increase the contraction coefficient materially.

The average velocity V of a free jet may be determined by a velocity traverse of the jet with a fine pitot tube or it may be obtained by measuring the flow rate and dividing by the cross-sectional area of the jet. The velocity may also be computed approximately from the coordinates of the trajectory of the jet, as discussed in Sec. 4.17. The ideal velocity V_i is computed by the Bernoulli theorem. Thus C_v for an orifice, nozzle, or tube may be computed by dividing V by V_i.

The coefficient of discharge is the one that can most readily be obtained and with a high degree of accuracy. It is also the one that is of the most practical value. For a liquid the actual Q can be determined by some standard method such as a volume or a weight measurement over a known time. For a gas one can note the change in pressure and temperature in a container of known volume from which the gas may flow. Obviously, if any two of the coefficients are measured, the third can be computed from them. Thus, in equation form

Ideal flow rate: $$Q_i = A_i V_i = A_o\sqrt{2g(\Delta H)} \tag{12.8}$$

Actual flow rate: $$Q = AV = C_c A_o(C_v\sqrt{2g(\Delta H)}) \tag{12.9}$$

and $$C_d = \frac{Q}{Q_i} = C_c C_v \tag{12.10}$$

[1] This is frequently called the *theoretical velocity*, but the authors feel this is a misuse of the word "theoretical." Any correct theory should allow for the fact that friction exists and affects the result. Otherwise it is not correct theory but merely an incorrect hypothesis.

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Reference 3

example of the first type of device is the household water meter in which a nutating disk oscillates in a chamber. On each oscillation a known quantity of water passes through the meter. The second type of flow-measuring device, dependent on basic principles of fluid mechanics in combination with empirical data, will be discussed in the following sections.

12.6 ORIFICES, NOZZLES, AND TUBES

Among the devices used for the measurement of discharge are orifices and nozzles. Tubes are rarely so used but are included here because their theory is the same and experiments upon tubes provide information relating to entrance losses from reservoirs into pipelines. An *orifice* is an opening (usually circular) in the wall of a tank or in a plate normal to the axis of a pipe, the plate being either at the end of the pipe or in some intermediate location. An orifice is characterized by the fact that the thickness of the wall or plate is very small relative to the size of the opening. A *standard orifice* is one with a sharp edge as in Fig. 12.11*a* or an absolutely square shoulder as in Fig. 12.11*b* so that there is only a line contact with the fluid. Those shown in Fig. 12.11*c* and *d* are not standard because the flow through them is affected by the thickness of the plate, the roughness of the surface, and for (*d*) the radius of curvature. Hence such orifices should be calibrated if high accuracy is desired.

A *nozzle* is a converging tube, as in Fig. 12.12, if it is used for liquids; but for a gas or a vapor a nozzle may first converge and then diverge (Sec. 9.8) to produce supersonic flow. In addition to possible use as a flow measuring device a nozzle has other important uses, such as providing a high-velocity stream for fire fighting or for power in a steam turbine or a Pelton water wheel.[1]

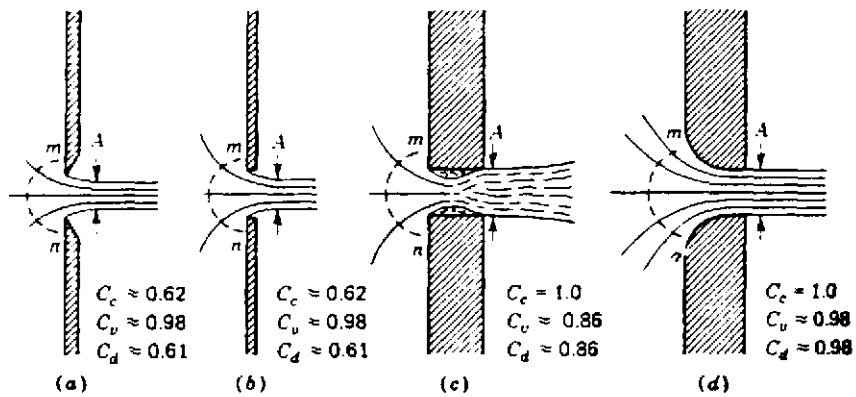

Figure 12.11 Orifices. (*a*) Sharp-edge. (*b*) Square shoulder. (*c*) Thick-plate, square edge. (*d*) Rounded.

[1] Pelton water wheel is the common name for an impulse turbine (Sec. 15.2).

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Reference 3

and $$\Delta\left(\frac{p}{\gamma}+z\right)=\frac{2}{12}=0.167\text{ ft}$$

Thus $$Q=1.06\times 0.0218\sqrt{64.4\times 0.167}=0.0757\text{ cfs}$$

With this first determination of Q,

$$V_1=\frac{Q}{A}=\frac{0.0757}{0.0492}=1.54\text{ fps}$$

Then $$D_1^2V_1=3\times 1.54=4.62$$

From Fig. 12.21, $K=1.04$ and

$$Q=\frac{1.04}{1.06}\times 0.0757=0.0743\text{ cfs}$$

No further correction is necessary.

12.10 FLOW MEASUREMENT OF COMPRESSIBLE FLUIDS

Strictly speaking, most of the equations that have been presented in the preceding part of this chapter apply only to incompressible fluids, but practically, they may be used for all liquids and even for gases and vapors where the pressure differential is small relative to the total pressure. As this is the condition usually encountered in the metering of all fluids, even compressible ones, the preceding treatment has extensive application. However, there are conditions in metering fluids where compressibility must be considered.

As in the case of incompressible fluids, equations may be derived for ideal frictionless flow and then a coefficient introduced to obtain a correct result. The ideal condition that will be imposed on the compressible fluid is that the flow be isentropic, i.e., frictionless adiabatic process (no transfer of heat—Sec. 1.8). The latter is practically true for metering devices, as the time for the fluid to pass through is so short that very little heat transfer can take place. An expression applicable to *pitot tubes* for subsonic flow of compressible fluids can be derived by introducing the conditions at the upstream tip of the tube (that is, $V_2=0$ and $p_2=p_s$) in Eq. (9.16) and substituting the first expression for R from Eq. (9.4). Doing so gives for pitot tubes

$$\frac{V_1^2}{2}=c_pT_1\left[\left(\frac{p_2}{p_1}\right)^{(k-1)/k}-1\right]=c_pT_2\left[1-\left(\frac{p_1}{p_2}\right)^{(k-1)/k}\right] \qquad (12.20)$$

The static pressure p_1 may be obtained from the side openings of the pitot tube or from a regular piezometer, and the stagnation pressure p_s ($=p_2$) is indicated by the pitot tube itself. A coefficient must be applied if the side openings do not measure the true static pressure. Equation (12.20) does not apply to supersonic conditions because a shock wave would form upstream of the stagnation point. In such a case a special analysis considering the effect of the shock wave is required.

To develop an expression applicable to compressible flow through *venturi tubes* we take Eq. (9.16) and combine it with continuity ($G=\gamma_1A_1V_1=\gamma_2A_2V_2$) to get

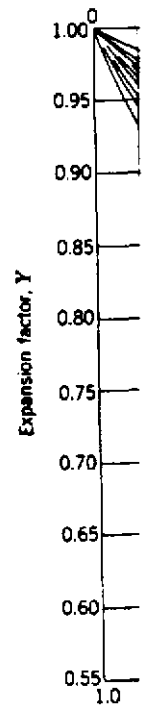

Figure 12.24

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In Fig
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[1] For a

Reference 6

TELEPHONE MEMORANDUM

INCOMING ____ OUTGOING X

JOB: ISRT/Woburn/Ma		ROUTE TO:	JOB NO: 903-6400.610
PERSON: Jack Hodge — Jay Cariveau			DATE: 6/19/91
FIRM: Tensar	Jack Hodge		TIME: 1317
PHONE NO: 1-800-845-7597	803-579-5202		BY: C Brooks

REMARKS:

Do you have air permeability test information?
Could you send the info?

How were the tests performed?

Jay Cariveau will send the information

~~Frasier Air Per.~~

From Jack Hodge → 1150 > 409 ft³/min/ft² — ½ inch head
1140

geonet with geotextile .075 in — 1120 > 521 ft³/min/ft² — air comes only in normal direction

1127 - 372 "
10 oz. .125 in — 1135 353 "
.15 in 1145 285 "
.185 in 1155 198 "

Shouldn't effect it

nonwoven

ACTION REQUIRED:

Chris Jarvis 803-656-3176
Clemson University

803-646-8454

Reference 7

TELEPHONE MEMORANDUM

INCOMING ____ OUTGOING X

JOB:	ISRT / Woburn / Ma.	ROUTE TO:	JOB NO: 903-6400.610
PERSON:	Chris Jarvis		DATE: 6/21/91
FIRM:	Clemson University		TIME: 10:19
PHONE NO:	1-803-646-8454		BY: C Brooks

REMARKS:

If you get an air permeability of 353 $ft^3/min/ft^2$ doing a Frazier test on a geotextile, what would be the air permeability if

1) Air is comming in all directions (not just normal)

2) the air pressure differential is 2 in H_2O rather than 1/2 inch H_2O.

answer:

1) Shouldn't have much effect

2) Multiply the 353 by 4 to get a reasonable estimate.

She says that Clemson can run the test up to 1 in H_2O - They would be happy to do it but she thinks that a linear relationship is not unreasonable with air.

ACTION REQUIRED:

Golder Associates	SUBJECT Geomembrane Hole Size And Frequency		
	Job No. 903-6400.61	Made by LKO	Date 6/21/91
	Ref.	Checked GWA	Sheet 34 of 45
		Reviewed MR	

OBJECTIVE: Determine The Size And Frequency Of Holes To Expect In A Geomembrane Closure Cover.

APPROACH: Use Existing Literature Data To Estimate The Sizes And Frequencies To Expect.

SOLUTION: Although The Literature (1) (2) Is Somewhat Conflicting, Based On (Darilek, et al) Assume There Are 10 Holes In Every 10,000 m^2 Of Geomembrane. Therefore, There Are Approximately 4 Holes Per Acre.

Based On (Giroud & Bonaparte) The Holes May Be Categorized Into 2 Groupings: A 1 cm^2 (0.15 in^2) Hole And A 3.1 mm^2 (0.005 in^2) Hole.

Based On A Telephone Conversation With D.L. Laine Of The Southwest Research Institute 80% Of The Holes Are Likely To Be Small.

Therefore,

4 Holes/Acre · 0.8 = 3.2 Holes say 3

And There 1 Large Hole.

Note That This Frequency Assumes That QA/QC Is Performed During The Installation Of The Geomembrane.

Based On (Giroud & Bonaparte) Without Independent QA/QC This Number Could Be Expected To Increase To 30 Times That Expressed Above. Also, With Limited QA/QC This Number Could Be Expected To Be 2.5 Times That Above.

Leo K. Ultmann

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GEOSYNTHETICS '89

FEBRUARY 21-23 TOWN & COUNTRY HOTEL, SAN DIEGO, CA

CONFERENCE PROCEEDINGS

Town & Country Hotel
San Diego, California
February 21-23, 1989

Volume 2

Geosynthetics '89 Conference
San Diego, USA

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G.T. DARILEK
D.L. LAINE
J.O. PARRA
Southwest Research Institute, U.S.A.

The Electrical Leak Location Method for Geomembrane Liners: Development and Applications

SUMMARY

A new electrical technique has been developed to accurately locate leaks in geomembrane liners. The electrical technique takes advantage of the insulating properties of the geomembrane liner material. When no leaks are present, a voltage impressed between electrically conductive media above and below the liner produces a relatively uniform electrical potential distribution in the material above the liner. If the liner is physically punctured or separated, an electrical current path is established. Leaks in the geomembrane are located by measuring potential gradients near the surface of the liner to detect areas of high current density caused by current flowing through leaks in the liner.

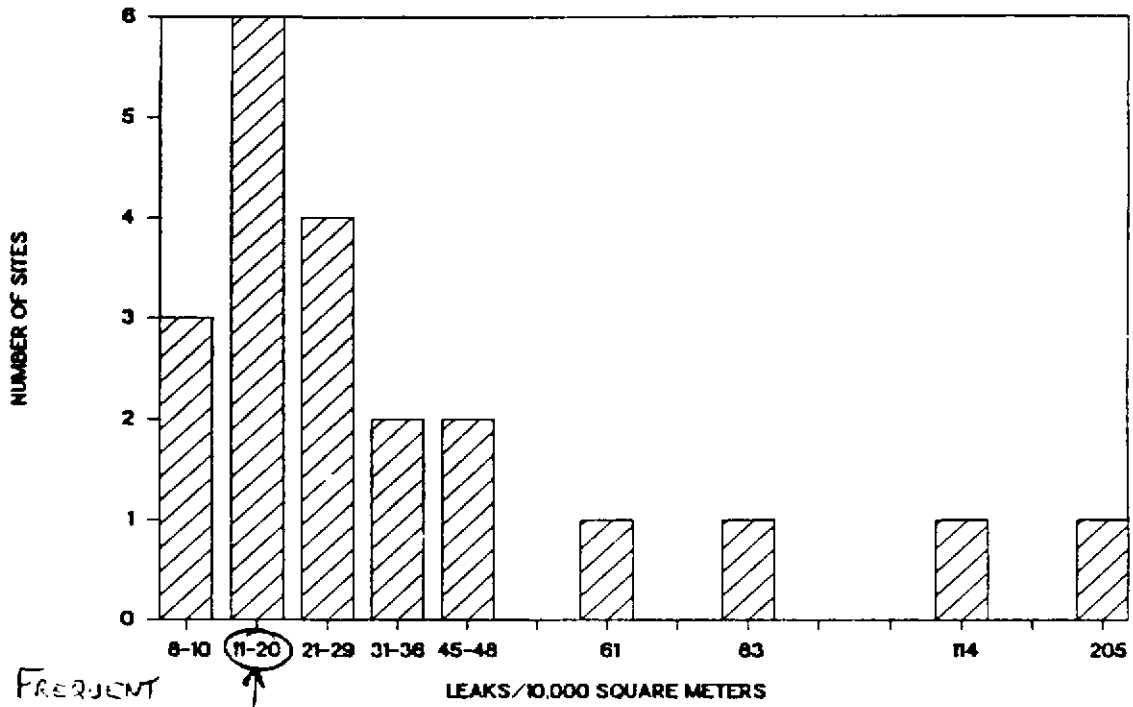
A mathematical analysis of conductive media above and below an insulating liner with a leak was developed to characterize the three-dimensional response of single and multiple leaks. A computer simulation model was developed to evaluate the technique and to efficiently predict the effect of a wide range of parameters on the leak signature.

Tests on a double-lined physical model demonstrated the applicability of the method to a variety of drainage layers with various test parameters such as leak size, electrode depth, and protective cover soil. Leaks with a diameter of 0.8 mm and greater in the primary liner were reliably located to within 10 mm. When the top liner is in place, leaks in the bottom liner can be detected, but not located.

The electrical leak location method was adapted for locating leaks in geomembrane liners with protective soil covers. Scale model tests demonstrated the applicability of the method under a wide range of cover soil thicknesses and leak sizes. Non-polarizing electrodes were used to locate leaks with diameters of 3 mm and greater under 600 mm of cover soil.

Leak location instrumentation and techniques were developed to perform geomembrane leak location surveys for preservice inspection of water-filled impoundments and landfills and non-hazardous liquid-filled impoundments. The manual survey system consists of a lightweight man-portable electrical probe and associated instrumentation. Horizontal traverse lines are scanned with a coverage of 2 m on each side of the traverse line. Surveys of the side slopes are accomplished using a probe with a long handle and small wheels to support the electrodes. Leaks are accurately located to within 10 mm or less and marked with lead sinkers and floats.

Figure 8 is a histogram of the distribution of the number of leaks found in liners that were larger than 500 square meters. Because of the small area involved, liners smaller than 500 square meters typically had either zero leaks or more than 200 leaks per 10,000 square meters. Therefore, the small liners were not included in the histogram. The least number of leaks found in the liners greater than 500 square meters was 8.2 per 10,000 square meters. From this data, typical installations had from 10 to 30 leaks per 10,000 square meters. Installation and field seaming problems were experienced on the liners with greater than 45 leaks per 10,000 square meters.



MOST FREQUENT

ASSUME LOW END OF RANGE (AND ROUND FROM 11 TO 20).

FIGURE 8. HISTOGRAM OF THE NUMBER OF LEAKS FOUND

Because some leak location surveys were initiated in response to a known leakage problem, a significantly higher number of leaks might be expected for these installations. However, this has not proven to be the case. The density of leaks at the 14 installations with a known leak problem had 27.2 leaks per 10,000 square meters. The density of leaks in the installations where the leak location surveys were performed for construction quality assurance was 25.7 leaks per 10,000 square meters. The comparable leak densities are particularly surprising considering that the installer might be expected to be particularly careful and thorough when a third party leak location survey will be performed.

These techniques have proven to be very effective in finding leaks, including many leaks that had not been previously found with conventional inspection techniques. Many of the leaks were not detectable using visual inspection.

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Leakage through Liners Constructed with Geomembranes—Part I. Geomembrane Liners*

J. P. Giroud & R. Bonaparte

GeoServices Inc. Consulting Engineers, 1200 South Federal Highway, Suite 204
Boynton Beach, Florida 33435, USA

(Received 18 June 1987; revised version received and accepted 23 September 1988)

ABSTRACT

How impermeable are 'impermeable liners'? All liners leak, including geomembranes, but how much? What are the mechanisms of leakage through liners constructed with geomembranes? To answer these questions, a detailed review of leakage mechanisms, published and unpublished test data, and analytical studies has been carried out with the goal of providing practical design recommendations. In particular, it appears that a composite liner (i.e. geomembrane on low-permeability soil) is more effective in reducing the rate of leakage through the liner than either a geomembrane alone or a soil liner (low-permeability soil layer) alone. However, the paper shows that the effectiveness of composite liners depends on the quality of the contact between the geomembrane and the underlying low-permeability soil layer.

NOTATION

A	Area (m^2)
A_s	Cross-sectional area of flow in soil (m^2)
a	Hole area (m^2)
B	Width (m)
b	Width of a two-dimensional hole (slot) in the geomembrane (m)
C_B	Dimensionless coefficient
C_F	Dimensionless coefficient

*Part II of this paper will follow in *Geotextiles and Geomembranes* 8(2).

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Calculations. Equation (22) has been used to calculate leakage rates for two typical hole sizes:

- a 2·0 mm (0·08 in) diameter hole, assumed to be due to defective seaming (as discussed in Section 2.3.8), that might escape detection by a construction quality assurance program; and
- a 11·3 mm (0·445 in) diameter hole that might result from failure of the geomembrane due to poor design, damage to the geomembrane during placement of overlying materials, etc.

The first hole ('small hole') has an area of 3·1 mm^2 (0·005 in^2) and the second hole ('large hole') has an area of 1 cm^2 (0·16 in^2). Both hole sizes can be considered for design calculations (see Section 2.3.9).

Results from calculations using eqn (22) are given in Table 6. Hydraulic heads considered in these calculations are equal to the liquid depths defined in Section 1.3.6. (Note: When liquid depth on the geomembrane is very small, the flow through an orifice may not be free as a result of surface tensions. The use of eqn (22) for a liquid depth of 0·003 m (0·01 ft) in Table 6 is therefore questionable. However, eqn (22) is used for lack of a better method and to ensure the consistency of comparisons.)

2.3.4 Geomembrane defects

Defects that are likely to occur in geomembranes are numerous and may be caused by a wide variety of factors including improper design, defective manufacturing and defective installation. A number of publications are available which discuss the various types of defects that have been observed in geomembrane-lined units.[2,10–12]

Typical defects observed in geomembranes include:

- discontinuous or defective seams resulting from fabrication or installation factors including excessive moisture or humidity, improper ambient or seaming temperature, contamination by dust or dirt, and inadequate workmanship or quality assurance;
- seam failures caused by excessive stresses during placement of cover materials or operation of the lined facility;
- damage to geomembranes during construction or facility operation as a result of excessive stresses caused by equipment traffic;
- puncturing of geomembranes by stones in the support or cover material when compressive stresses are applied as a result of equipment traffic or the weight of stored material;
- tensile failure of geomembranes due to excessive stresses generated by the weight of stored material or movements of materials in contact with the lining system;

- brittle failures caused by slow crack growth mechanisms due to constant stresses such as overburden stresses;
- brittle failures caused by fatigue due to repeated stresses such as stresses resulting from thermal expansion–contraction; and
- defective connections between geomembranes and appurtenances, due to inadequate workmanship or quality assurance.

The last type of defect is illustrated by the following case history: after the construction of a lining system for a landfill, and before placement of the waste, the lower portion of the landfill was filled with water to test the lining system; a leakage rate through the geomembrane top liner of 1000 liters/day (250 gallons/day) was observed at the connection between the geomembrane and the sump, with a water depth of only 0·15 m (6 in) above the defective connection. Equation (22) shows that this leakage rate could have resulted from a circular hole with a 4 mm (0·16 in) diameter.

The potential for the above-mentioned defects is small in properly designed and constructed geomembrane-lined facilites. However, even in properly designed and constructed units, there is no guarantee that these defects will not occur. A discussion of the frequency and size of geomembrane defects is presented in Sections 2.3.7 and 2.3.8, on the basis of data presented in Sections 2.3.5 and 2.3.6.

2.3.5 Data on geomembrane defects from quality assurance

Small liquid reservoir. This project, constructed in 1981, is described in detail by Giroud and Stone,[13] and Stone.[14] Information from the project regarding seam defects can be summarized as follows.

The double liner system includes two 2·5 mm (100 mil) thick HDPE geomembranes which were welded using an automated extrusion welder operating in a flat area with good working conditions. Ultrasonic testing, carried out as part of the construction quality assurance program, showed that approximately 0·5% of the seam length was defective. The detected defects were repaired and the reservoir was filled with water. Leakage occurred and an inspection showed that leakage was taking place through approximately 0·015% of the seam length. The ratio 0·5/0·015 shows that, in this project, intensive quality assurance reduced the length of defective seams by a factor of approximately 30.

This project is particularly interesting because it provides an evaluation of the benefit derived from construction quality assurance.

Large landfill with single liner. Kastman[15] indicates that, in a carefully monitored landfill liner installation done in 1983, approximately one defect every 15 m (50 ft) of seam was detected and repaired, as part of the construction quality assurance program. The liner was a 1 mm (40 mil)

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thick HDPE geomembrane and seaming was achieved with a fillet extrusion weld done using a hand welder.

Large landfill with double liner. Giroud and Fluet[16] report the results of an analysis conducted on the basis of data collected during the construction quality assurance program for a liner installation in a large landfill lined in 1985 with a 1·5 mm (60 mil) thick HDPE geomembrane. The surface area of the liner is approximately 35 000 m^2 (350 000 ft^2) and the seam length is approximately 5000 m (16 000 ft). During the quality assurance program, an average of approximately one seam defect every 9 m (30 ft) of seam length was detected and repaired.

Large landfill with single liner. The following data were collected during the installation of the lining system in a large landfill, in 1987, as part of the quality control provided by the geomembrane installer and quality assurance provided by an independent firm. The surface area of the liner is approximately 53 000 m^2 (570 000 ft^2) and the seam length is approximately 8000 m (26 000 ft). The liner is a 1·5 mm (60 mil) thick HDPE geomembrane. Half of the seam length was welded using a hand welder which made fillet extrusion welds; the other half was welded using an automated welder which made injection extrusion welds. Seam inspection was performed first by the installer, and then by the independent firm after the installer had completed his inspection. The installer detected approximately one seam defect every 17 m (56 ft) of seam length and the independent firm detected approximately one additional seam defect every 35 m (115 ft) of seam length. Therefore, a total average of approximately one seam defect every 11·5 m (38 ft) of seam length was detected by the geomembrane installer and the independent quality assurance firm. All these defects were repaired.

The defects discovered by the independent firm totaled one third of the total seam defects. The benefits of quality assurance are probably greater than that: it is probable that, without the continuous presence at the site of the independent quality assurance firm, the geomembrane installer would have found fewer defects than he did as part of his quality control effort.

2.3.6 *Data on geomembrane defects from forensic analyses*

Small indoor tank. The following case history is reported by Giroud and Fluet.[16] A power generating station required a small acid holding tank. The tank was constructed of concrete and lined in 1985 with a 2·5 mm (100 mil) thick HDPE geomembrane. The geomembrane installation required approximately 100 m (300 ft) of field seaming. The seams were fillet extrusion welds done with a hand welder. The design and installation included no third party quality assurance, but careful quality control of

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seaming was provided by the installer, using visual inspection and vacuum box.

Upon completion of the liner installation, the tank was filled with water to check for leaks. The liner did leak, so the tank was emptied, repairs were made and the tank was filled again. This cycle was repeated several times, with leaks found on every filling. Leaks were found at 15 different locations, i.e. an average of one leak per 7 m (23 ft) of seam. Because of the complex geometry of the tank, this incidence of seam defects was probably larger than the incidence which would be experienced in more typical installations. However, the complex geometry of this tank is probably representative of the difficulties encountered in waste disposal units, dams, or other facilities at the connections between geomembranes and appurtenances such as pipe penetrations, sumps, manholes, intake towers, spillways, etc.

Large surface impoundment. The following case history is reported by Giroud and Fluet.[16] A large reservoir, lined with a single reinforced 1 mm (40 mil) thick chlorosulfonated polyethylene (CSPE-R) geomembrane, had been constructed to contain phosphoric acid. The reservoir was approximately 3 m (10 ft) deep and its surface area was approximately 20 000 m^2 (200 000 ft^2).

One year after the first filling, the reservoir suddenly emptied. The analysis of the failure indicated that phosphoric acid, leaking through several defective seams, attacked the ground, thereby creating cavities. The largest cavity was 1 m (3 ft) in diameter and 0·5 m (20 in) deep. Under the pressure of the impounded liquid, the geomembrane spanning this largest cavity burst, releasing all of the impounded phosphoric acid into the ground.

Quality assurance during installation had consisted of only two one-day visits by an engineer who specialized in roofing membranes. Therefore, it is not surprising that defective seams were not detected prior to filling.

During the forensic analysis, visual observation showed that approximately 0·1% of the seam length (including factory seams and field seams) was defective. It is probable that a higher percentage would have been obtained if a vacuum box had been used instead of visual inspection. It is also probable that a higher percentage would have been obtained if only field seams had been considered to calculate the above percentage.

2.3.7 Frequency of geomembrane defects

Consistency of the observations. Sections 2.3.5 and 2.3.6 present data related to frequency of seam defects. Some of these data are expressed as an average seam length exhibiting one defect (e.g. one defect per 7 m (23 ft) of seam), while other data are expressed as a percentage of

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defective seam length (e.g. 0·5% of the total seam length was defective).

If an average length of seam defect (prior to quality assurance) of 10 mm (0·4 in) is considered, a percentage of defective seam length of 0·1% is equivalent to one defect every 10 m (30 ft). Therefore, the observations made in the above case studies appear to be consistent.

Conclusion regarding frequency of seam defects. It is not possible to draw general conclusions from only six cases. However, since the observations made in these six cases were consistent, the following tentative conclusions may be drawn for analysis and design purposes:

- An average of one defect per 10 m (30 ft) of field seam can be expected without quality assurance by an independent firm, and without adequate quality control by the geomembrane installer. w/o QA/QC
- An average of one defect per 300 m (1000 ft) of field seam can be expected with reasonably good installation, adequate quality assurance (which implies adequate quality control), and repair of noted defects. (Quality assurance followed by adequate repair drastically decreases the number of seam defects but does not totally eliminate them.) WITH QA/QC

The average of one seam defect per 10 m (30 ft) *without or before quality assurance* will probably decrease in the future as a result of the increasing use of new, automated methods of seaming which are now available. However, the number of seam defects *after quality assurance* may not decrease significantly because, in the present state of practice for construction quality assurance, great emphasis is put on finding seam defects and repairing them. Nonetheless, the better seaming methods that are now available are highly beneficial for at least the following reasons: (i) less seam repair is required during installation; (ii) frequency of destructive seam testing may be decreased; (iii) although quality assurance of seaming will always be essential, emphasis in the quality assurance efforts may shift toward other areas where improvement is sorely needed such as connections of geomembranes with appurtenances and placement of drainage materials (which is essential for the functioning of leakage collection layers); and (iv) stronger seams are less likely to fail when subjected to stresses.

As a result of the above discussion, a frequency of one defect per 300 m (1000 ft) of seam will be used as a working assumption for analysis and design purposes. If geomembrane panels 6–10 m (20–30 ft) wide are used, one defect per 300 m (1000 ft) of seam is equivalent to 3–5 seam defects per hectare (1–2 seam defects per acre) of installed geomembrane.

As soon as possible, these assumed defect frequencies must be modified as required by conclusions established on a broader base of well-

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documented case histories. In the meantime (and in the absence of better data), a defect frequency of one per 4000 m^2 (acre) will be used in calculations for estimating leakage rates in order to size leakage collection layers. This frequency is assumed to include all types of defects, not only seam defects.

2.3.8 Estimation of size of defects

The seam defect documentation reported above addressed primarily the frequency of seam defects. Extensive documentation of defect size does not exist. On the basis of interviews with quality assurance personnel it appears that the maximum size of defects which may still exist after intensive quality assurance is equivalent to hole diameters of the order of 1–3 mm (0·04–0·12 in) for seam defects and possibly up to 5 mm (0·2 in) for special areas such as connections of geomembranes with appurtenances. (This is consistent with the case history presented in Section 2.3.4.) Finally, larger hole diameters, e.g. 10 mm (0·4 in), can be considered to represent larger defects, such as those due to accidental punctures.

There are also defects that cannot be observed by the quality assurance personnel, such as: (i) puncture of the geomembrane during installation of the protective earth cover or granular drainage layer overlying the geomembrane; and (ii) puncture of the geomembrane as a result of stresses due to the weight of the impounded material or traffic related to the operation of the facility. Defects due to these causes may result in hole sizes larger than those referred to above.

For analysis and design purposes, it is appropriate to consider a range of hole diameters from at least 2 mm (0·08 in), to represent seam defects, to at least 10 mm (0·4 in), to represent accidental punctures.

2.3.9 Hole sizes and frequency recommended for design

Guidance regarding hole size and frequency is useful for engineers designing lining systems. As a result of the discussion presented in Section 2.3.7, a frequency of one hole per 4000 m^2 (acre) should be considered, and, on the basis of the discussion presented in Section 2.3.8, two hole sizes are recommended:

- A hole size of 1 cm^2 (0·16 in^2) is recommended for calculations conducted to size the components of the lining system, and, in particular, the leakage detection, collection, and removal system (i.e. to determine the required hydraulic transmissivity or thickness of the leakage collection layer, to select pipe spacings and diameters, to select the sump size, etc.).
- A hole size of 3·1 mm^2 (0·005 in^2) is recommended for calculations conducted to evaluate the performance of the lining system (i.e.

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serviceability calculations, such as flow in the leakage collection layer under typical operating conditions).

In other words, the small hole, which probably exists, is recommended for calculations related to typical operating conditions, and the large hole, which may exist, is recommended for calculations related to maximum flow conditions.

It should be kept in mind that the above hole sizes and frequency have been selected with the assumption that intensive quality assurance monitoring will be performed. A frequency of 25 holes/ha (10 holes/acre) or more is possible when quality assurance is limited to an engineer spot-checking the work done by the geomembrane installer. Also, the above hole sizes and frequency do not take into account cases where design flaws or poor construction practices lead to a greater number of seam defects or a large tear in the geomembrane.

2.4 Conclusions on leakage through geomembrane liners

2.4.1 Summary

In Section 2, the results of permeameter tests and water vapor transmission tests were used to evaluate permeation rates through geomembranes. Equations to evaluate leakage rates through pinholes and holes were also presented. Finally, the following recommendations regarding frequency and size of holes to be assumed for analysis and design were made on the basis of field experience:

- a frequency of one hole per 4000 m^2 (acre); and
- two hole sizes, 1 cm^2 (0·16 in^2) for calculations to size the components of the lining system, and 3·1 mm^2 (0·005 in^2) for performance calculations.

2.4.2 Leakage rates

By combining Tables 5 and 6, it is possible to establish Table 7. This table gives orders of magnitude of unitized leakage rates that may be expected when a geomembrane is used alone as a liner.

It appears that the unitized leakage rates due to only one hole per 4000 m^2 (acre) are large, especially for the large hole, while unitized leakage rates due to permeation and pinholes are small. It must be remembered that the unitized rates given in Table 7 are related to a liner comprised of a geomembrane placed directly on the leakage collection layer or other very permeable layer. As indicated in Section 2.3.3, the equation used to evaluate leakage rates through geomembrane holes is valid if the hydraulic conductivity of the leakage collection layer is larger than 10^{-3} m/s (0·1 cm/s), which will often be the case.

APPENDIX 15-B

Collection Pipe Spacing Calculations

SUBJECT	GAS COLLECTION SYSTEM HIDE PILE
JOB NO. 903-6400 610	MADE BY ROH DATE 8/1/91
REF ESRT/WOOQW/ma	REVIEWED PER SHEET 1 OF 5

OBJECTIVES:

(1) SELECTION OF GAS COLLECTION LAYER PERMEABILITY.

(2) DETERMINATION OF GRADIENT PRESSURE DRIVING FORCE REQUIRED TO INDUCE GAS COLLECTION.

(3) DETERMINE THE MEAN DISTANCE BETWEEN GAS COLLECTION PIPES.

APPROACH:

(1) MODEL THE COLLECTION OF GAS FOR THE EAST HIDE PILE USING A GEOMETRIC CONFIGURATION.

(2) MAINTAIN THE AVERAGE GAS COLLECTION LAYER PRESSURE AT ATMOSPHERIC PRESSURE TO KEEP GAS PRODUCTION FROM THE HIDE PILE AT OR NEAR EXISTING CONDITIONS.

(3) MODEL THE GAS COLLECTION PIPING USING A CENTRAL MANIFOLD PIPE WITH GAS COLLECTION PIPES RADIATING LATERALLY IN THE GAS COLLECTION LAYER.

(4) ITERATE THE EQUATION FOR GAS FLOW RATE (EQ #2) TO SOLVE SIMULTANIOUSLY FOR MEAN DISTANCE BETWEEN GAS COLLECTION PIPES & THE PRESSURE GRADIENT DRIVING FORCE FOR INDUCTION OF GAS FLOW INTO THE GAS COLLECTION PIPES

SUBJECT Gas Collection System Hloe Pile
JOB NO. 903-6400-WO MADE BY RDH DATE 8/1/91
REF ESRT/WOBORN/MA REVIEWED PCR SHEET 2 OF 5

References

(1) Estimating Gas Volumes East Hloe Pile 95% Design Report — Appendix 15A

(2) Leakage Rate of Air Through Cover System 95% Design Report — Appendix 15A

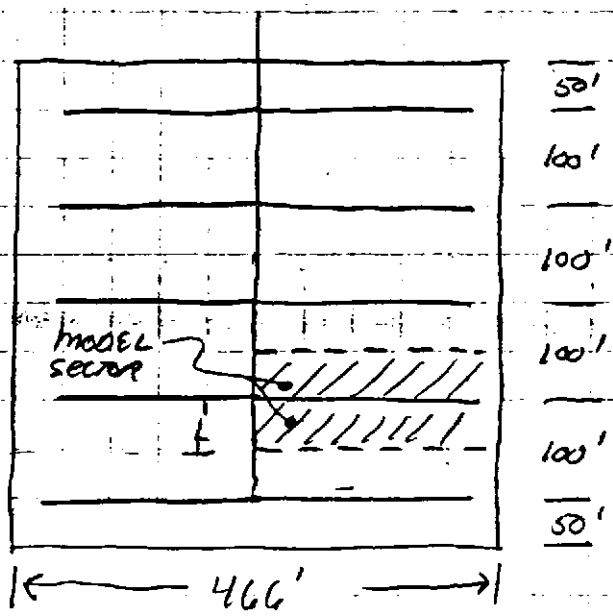
(3) Perry's Chemical Engineer's Handbook 1966

Data / Assumptions

(1) Gas modeled as ideal gas displaying incompressible isothermal flow.

(2) Gas production including infiltration of atmospheric air equals 150 SCFM. (1),(2)

(3) Hloe Pile Model



Gas Production = 150 SCFM
Assume L = 50'
Area 2.17×10^5 Ft^2
Gas Production = 6.9×10^{-4} $\frac{SCFM}{Ft^2}$

Each Sector Production = 16 SCFM
or 8 SCFM per side

SUBJECT	GAS COLLECTION SYSTEM HOE PLC
JOB NO. 903-6400-60	MADE BY RDH DATE 8/1/91
REF ISRT/WOBURN/MA	REVIEWED PER SHEET 3 OF 5

(4) DARCY EQUATION FOR WATER (Eq #1)

$$\frac{P_1 - P_2}{L} = \frac{\alpha \mu V}{g_c} \qquad Eq\ \#1$$

$P_1 - P_2 = (14.7\ psi)(144)\ lbf/Ft^2$

$L = 1\ ft$

α = VISCOUS RESISTANCE COEFFICIENT Ft^{-2}

μ = FLUID VISCOSITY FOR WATER $6.72 \times 10^{-4}\ lb/ft \cdot sec$

$g_c = 32.17\ lb \cdot Ft / lb_f \cdot Sec^2$

V = PERMEABILITY $5.0 \times 10^{-1}\ cm/sec = 1.65 \times 10^{-2}\ FT/sec$

SOLVING FOR α

$$\alpha = (P_1 - P_2)(g_c) / L \cdot \mu \cdot V$$

$$\alpha = \frac{(14.7)(144)(32.17)}{(1)(6.72 \times 10^{-4})(1.65 \times 10^{-2})}$$

$\alpha = 6.14 \times 10^{9}\ Ft^{-2}$ FOR SAVOY GRAVEL

SUBJECT Gas Collection System Hide Pile
JOB NO. 903-6400-610 MADE BY RDH DATE 8/1/91
REF 1SRT/WOBURN/Mo REVIEWED PCR SHEET 4 OF 5

(5) Equation for Isothermal Flow of an Incompressible Ideal Gas through Granular Solids

$$\frac{P_1^1 - P_2^2}{L} = \frac{2\alpha R T \mu G}{M g_c} \qquad \text{Eq \#2}$$

Where

α = 6.14×10^9 Ft^{-2} - Viscous Resistance Coef

R = 1546 Ft·lbf / lb·mole °R - Gas Constant

T = 520°R

M = 16 lb/lb·mole

g_c = 32.17 lb·Ft / lbf·sec²

μ = 6.72×10^{-6} Viscosity for Methane

G = Superficial mass vel lb/sec·Ft²

L = Gas Flow Path Length Ft

P_1 = Upstream Pressure lbf/Ft²

P_2 = Downstream Pressure lbf/Ft²

SUBJECT Gas Collection System Hide Pile
JOB NO. 903-640066 MADE BY RDH DATE 8/1/91
REF ISRT/WOBORN/MA REVIEWED PCR SHEET 5 OF 5

CALCULATIONS

(1) G = SUPERFICIAL MASS VELOCITY lb/sec·Ft²

$$\text{MAX MASS VEL} = \frac{8\ \text{SCFM} \times .046\ \text{lb/ft}^3\ (\text{DENSITY OF METHANE})}{233\ \text{FT} \times 1\ \text{FT HIGH}}$$

$$= 1.58 \times 10^{-3}\ \text{lb/min·Ft}^2$$

$$G = 1.58 \times 10^{-3} \frac{\text{lb}}{\text{min·Ft}^2} \times \frac{1\ \text{min}}{60\ \text{sec}} = 2.63 \times 10^{-5} \frac{\text{lb}}{\text{sec·Ft}^2}$$

$$G\ (\text{AVG VEL}) = 2.63 \times 10^{-5}/2 = 1.316 \times 10^{-5}\ \text{lb/sec Ft}^2$$

(2) Solve Eq #2 For L

$$L = \frac{(P_1^2 - P_2^2)\, M g_c}{2 \alpha R T \omega G}$$

$$L = \frac{(P_1^2 - P_2^2)(16)(32.17)}{2 \times 6.14 \times 10^9 \times 1546 \times 520 \times 6.72 \times 10^{-6} \times 1.316 \times 10^{-5}}$$

$$L = (P_1^2 - P_2^2) \times 5.89 \times 10^{-4}$$

Assume $P_1 - P_2 = \pm 2''$ WATER

$$L = \left[(14.769 \times 144)^2 - (14.622 \times 144)^2\right] \times 5.89 \times 10^{-4}$$

L = 52 Feet ⟹ FITS MODEL

CHAPTER 16
GAS TREATMENT SYSTEM

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CHAPTER 16
GAS TREATMENT SYSTEM DESIGN

16.1 REMEDIAL DESIGN WORK PLAN REQUIREMENTS

The Remedial Design Work Plan (RDWP; Golder, 1990a) establishes that the Final (100%) Design Report is to include the following gas treatment system design elements:

1. Final design package with Agency comments;
2. Completion of bid documents.

This section of the 100% Design Report Part I presents the final design package for the treatment system for the gas collected from the East Hide Pile. All comments which the Agencies have provided on previous gas treatment design submittals have been addressed. Specifications and bid documents for the construction of the gas treatment system are contained in Volume 6 of this report.

16.2 GAS CHARACTERIZATION

In order to characterize the composition of the gaseous emission emanating from the East Hide Pile, several sampling and analysis efforts have been performed at the Site.

During September and October 1983, 370 gas samples were collected from the shallow soils across the Site. According to the RI/FS (Stauffer, 1983, 1984, 1985), the samples from the East Hide Pile contained combustible gas (methane) and hydrogen sulfide at concentrations in excess of 250 parts per million by volume (ppmv). In addition, four gas vents were installed in the East Hide Pile and sampled for gaseous components. The samples contained hydrogen sulfide at concentrations ranging from 5,600 ppmv to 21,000 ppmv and several other sulfur based compounds at lesser concentrations (up to 180 ppmv each).

Subsequent gas characterization investigation work was performed in May and August 1990 and is discussed in the Pre-Design Investigation (PDI) Task A-2, Gas Treatability Interim Final Report (Golder, 1990b). The purpose of the investigation was to characterize the gas emissions and the rate of discharge from the East Hide Pile. Samples were collected from the four gas vents according to protocols outlined in the PDI Work Plan and analyzed for volatile organic compounds, hydrogen sulfide, methane, and methyl mercaptan. The results of the Task A-2 characterization are summarized in the following paragraphs.

Benzene, toluene, ethylbenzene, chlorobenzene, dichlorobenzene, methane, and hydrogen sulfide were all detected in selected samples from the East Hide Pile. Methane was the most common constituent detected and ranged from 5.5 ppmv to 240,000 ppmv. Hydrogen sulfide was

present at concentrations ranging from 0.027 ppmv to 2,890 ppmv. The remaining constituents were detected at trace levels from 4.4 ppmv to below detection limits (0.005 ppmv). Conclusions provided in the PDI Task A-2 report indicated that the waste gas is comprised of approximately 24 percent methane, 0.28 percent hydrogen sulfide, and less than 0.004 percent volatile organics. According to the report, the remaining 75.5 percent is likely carbon dioxide. In addition, the gas stream probably contains water vapors which may affect thermal oxidation of the gas.

16.3 TREATMENT TECHNOLOGY EVALUATION

In accordance with the Consent Decree, consideration was given to the performance of both thermal oxidation and activated carbon to treat offgases from the East Hide Pile. In the following sections, each odor control technology is evaluated using the following performance criteria:

- Destruction Efficiency;
- Maintenance and Operation; and,
- System Flexibility.

16.3.1 Destruction Efficiency

Flare systems have historically been used for the treatment of landfill gases. Open and enclosed flare systems thermally oxidize a variety of mercaptans, H_2S, and organics, including methane, associated with landfill offgases. The USEPA recognizes a flare's destruction removal efficiency (DRE) at 95 percent. However, with today's better controllers on the newer systems, enclosed flares have achieved closer to 98 percent DRE for H_2S. This efficiency is achieved even with varied pollutant emissions and floss (i.e., pollutant surges) that are inherent to landfill offgases.

Activated carbon, on the other hand, has not been widely used for landfill operations. Activated carbon will control only specific mercaptans and organics, and will allow the organic with highest concentration (methane) to pass through to the atmosphere. To control hydrogen sulfide (H_2S), a special impregnated carbon is required. The impregnated carbon will control 99 percent of the H_2S only.

16.3.2 Maintenance and Operation

Flare systems will sustain operation with little maintenance. Destruction of the mercaptans and organics (including methane) is totally on-Site and requires no off-Site transportation or disposal. Varied flow rates and pollutant loading can be instantly controlled without human intervention.

A minor risk of the flare is the potential of a flame "burnout". Upon a flare burnout, controllers will immediately shut off the gas collection system's blower and alarm proper personnel. The collection system will continue to vent to the top of the stack at the natural emission rate of the hide pile. The odor air quality standard for the Site will still be attained under these circumstances even if the controller fails to shutdown the blower, as shown by the air dispersion modelling included in Appendix 4-A of this report.

Activated carbon requires replacement after it is exhausted. The spent carbon is usually transported off-Site for regeneration or incineration. Furthermore, increases (surges) in the pollutant loading can cause premature breakthrough of the carbon bed. Breakthrough will cause a shut-down of the gas treatment system until replacement carbon can be delivered and put into place.

16.3.3 System Flexibility

As previously described, a flare system can better handle a variety of pollutants and flows, inherent to landfill offgases. Carbon will allow various organics, including methane, to pass through the bed to the atmosphere. Surges of pollutant loads can cause premature breakthrough the carbon bed.

16.3.4 Conclusion

Enclosed flares, with a DRE of 95 to 98 percent, provide on-Site destruction of the mercaptans and organics, including methane. Activated carbon, on the other hand, provides a media for off-Site destruction of the H_2S only. In conclusion, on-Site thermal oxidation offers a better overall control of the offgases with no off-Site transportation and disposal. Therefore, thermal oxidation is recommended to control the offgases of the East Hide Pile. However, in accordance with the Consent Decree, the Agencies may make a final selection of treatment technology.

16.4 GAS TREATMENT SYSTEM DESIGN SUMMARY

The following sections describe the design of the thermal oxidation system and associated facilities. Major process components and operating parameters are summarized in Table 16-1. Equipment and other technical specifications are included in Volume 6 of this report. Design drawings showing process, instrumentation, mechanical, structural, and electrical systems are presented in Volume 8 of this report.

16.4.1 Facility Description

The gas treatment system will be located east of the East Hide Pile partially within the Boston Edison Right-of-Way No. 14. The facility arrangement is such that the flare stack is outside the Right-of-Way to satisfy Boston Edison requirements. A roadway will be constructed to the facility to allow access by operations and maintenance personnel. The facility will be enclosed by a 6 foot galvanized chain-link fence with lockable gate to prevent access by unauthorized personnel.

The equipment will be installed on reinforced concrete foundations as shown on the design drawings. Due to subsurface conditions at the Site, isolated equipment foundations have been selected. A 6 inch slab will be constructed around the footings with a 4 foot deep perimeter grade beam. The overall slab will be about 31 feet by 19 feet in size.

16.4.2 Utilities

Services to the treatment facility site will include the incoming waste gas line from the East Hide Pile, natural gas for supplemental fuel, and electricity.

A small amount of water will be required to provide a water seal. However, the amount of water is not enough to justify a water line to the facility, so a small storage tank will be installed.

Natural gas service will be supplied at 15 psig to the waste gas treatment facility to provide supplemental fuel. The natural gas usage rate is projected to average about 330 scfh with a minimum usage of 45 scfh (pilot only). The natural gas service will be via an underground pipeline and pressure regulator station to be provided by the local gas utility company.

Electrical service (480V, 3-Phase) will be required at the waste gas treatment facility. A minimum of 80 KVA electrical service is required.

16.4.3 Thermal Oxidizer

The flare and ancillary equipment will be provided as a skid-mounted package system by a single supplier who shall have performance responsibility for the system. The specified performance of the system is 99 percent removal of hydrogen sulfide.

The flare itself will consist of a burner and stack. The stack will be constructed of carbon steel with ceramic refractory lining. The size of the stack will vary somewhat between manufacturers. However, approximate overall dimensions are expected to be 30 feet height, 30 inch diameter.

The burner system is specified to maintain up to 1,800 ^{o}F internal temperature, when supplied with 10 psig natural gas, and have a rated capacity of 9,000 scfh. The burner will have a continuous flame nozzle with a long-profile

16.4 GAS TREATMENT SYSTEM DESIGN SUMMARY

The following sections describe the design of the thermal oxidation system and associated facilities. Major process components and operating parameters are summarized in Table 16-1. Equipment and other technical specifications are included in Volume 6 of this report. Design drawings showing process, instrumentation, mechanical, structural, and electrical systems are presented in Volume 8 of this report.

16.4.1 Facility Description

The gas treatment system will be located east of the East Hide Pile partially within the Boston Edison Right-of-Way No. 14. The facility arrangement is such that the flare stack is outside the Right-of-Way to satisfy Boston Edison requirements. A roadway will be constructed to the facility to allow access by operations and maintenance personnel. The facility will be enclosed by a 6 foot galvanized chain-link fence with lockable gate to prevent access by unauthorized personnel.

The equipment will be installed on reinforced concrete foundations as shown on the design drawings. Due to subsurface conditions at the Site, isolated equipment foundations have been selected. A 6 inch slab will be constructed around the footings with a 4 foot deep perimeter grade beam. The overall slab will be about 31 feet by 19 feet in size.

16.4.2 Utilities

Services to the treatment facility site will include the incoming waste gas line from the East Hide Pile, natural gas for supplemental fuel, and electricity.

A small amount of water will be required to provide a water seal. However, the amount of water is not enough to justify a water line to the facility, so a small storage tank will be installed.

Natural gas service will be supplied at 15 psig to the waste gas treatment facility to provide supplemental fuel. The natural gas usage rate is projected to average about 330 scfh with a minimum usage of 45 scfh (pilot only). The natural gas service will be via an underground pipeline and pressure regulator station to be provided by the local gas utility company.

Electrical service (480V, 3-Phase) will be required at the waste gas treatment facility. A minimum of 80 KVA electrical service is required.

16.4.3 Thermal Oxidizer

The flare and ancillary equipment will be provided as a skid-mounted package system by a single supplier who shall have performance responsibility for the system. The specified performance of the system is 99 percent removal of hydrogen sulfide.

The flare itself will consist of a burner and stack. The stack will be constructed of carbon steel with ceramic refractory lining. The size of the stack will vary somewhat between manufacturers. However, approximate overall dimensions are expected to be 30 feet height, 30 inch diameter.

The burner system is specified to maintain up to 1,800 ^{o}F internal temperature, when supplied with 10 psig natural gas, and have a rated capacity of 9,000 scfh. The burner will have a continuous flame nozzle with a long-profile

flame. An automatically controlled forced draft fan will provide combustion air and control combustion temperature by air quenching.

16.4.4 Gas Booster Blowers

Two gas booster blowers will feed gas to the flare system. The blowers will each be capable of supplying the design gas flow of 150 scfm (one duty, one stand-by). The blowers will be constructed of fiberglass reinforced plastic (FRP) and will be rated for 40 inch WC discharge pressure. All electrical components will be explosion proof (NEMA 7).

16.4.5 Piping and Valves

Waste gas piping will be FRP rated at a minimum of 225 psig at 225°F. Valves will be butterfly-type constructed of plastic (PVC body, glass reinforced polypropylene disc).

Natural gas piping will be carbon steel (black steel pipe). Shutoff valves will be gas cock, cast iron body.

16.4.6 Monitoring System

The flare package system will be provided with a Continuous Emissions Monitoring System (CEMS). The CEMS will be equipped with an ultraviolet total reduced sulfur analyzer to detect hydrogen sulfide in the stack off-gas. The system has been designed to provide an alarm upon detection of hydrogen sulfide above a setpoint of 30 ppm which corresponds to 99% DRE for the anticipated H_2S loading. Output signals (4-20 ma) will be provided for a remote alarm system.

16.4.7 Instrumentation and Control System

All instrumentation and control elements will be supplied by the flare system manufacturer. A control panel will be mounted in an explosion proof enclosure and will contain an

PLC which will be programmed by the flare manufacturer with all safety interlocks. An audio/visual alarm will be mounted on top of the control panel and signal outputs will be provided for remote alarm monitoring and recording.

The main control element of the flare system will be combustion chamber temperature. Thermocouples will detect temperature in the combustion zone and regulate assist gas and quench air to strive to maintain temperature within specified limits. Local and remote alarms will signal failure of the system to maintain temperature within the specified setpoints.

REFERENCES

Golder Associates Inc, 1990a. Remedial Design Work Plan, Industri-Plex Site, Woburn, Massachusetts, July.

Golder Associates Inc., 1990b. Pre-Design Investigation, Task A-2, Gas Treatability, Interim Final Report, Industri-Plex Site, Woburn, MA, October.

Stauffer Chemical Company, 1983. Woburn Environmental Studies, Phase I Report, Environmental Assessment, April.

Stauffer Chemical Company, 1984. Woburn Environmental Studies, Phase II Report, Volume 1, Remedial Investigation, August.

Stauffer Chemical Company, 1985. Woburn Environmental Studies, Phase II Report, Volume 2, Feasibility Study, April.

TABLE 16-1

PROCESS CRITERIA
EAST HIDE PILE THERMAL OXIDATION

Waste Gas Flow	150 scfm maximum
Oxidizer Type	Shrouded Flare
Oxidizer Size*	
Diameter	30 inches
Height	30 feet
Oxidizer Construction	Ceramic Fiber Lined Steel
Oxidizer Temperature	1,400° to 1,800°F
Supplemental Fuel	Natural Gas
Quantity (max)	330 scfh
Waste Loading	
Methane	0 to 24 percent
Hydrogen Sulfide	0.3 percent
Trace Volatiles	0.004 percent
Removal Efficiency to Prevent Odors	95% of Hydrogen Sulfide
Specified Removal Efficiency	99% of Hydrogen Sulfide

* Oxidizer dimensions are approximate and may vary between suppliers

CHAPTER 17
INSTITUTIONAL CONTROLS

This Chapter has been deferred consistent with instructions from the Agencies

CHAPTER 18
SITE PLANNING

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CHAPTER 18
SITE PLANNING

18.1 REMEDIAL DESIGN WORK PLAN REQUIREMENTS

The Remedial Design Work Plan (RDWP) establishes that the goal of the Site planning effort is to protect the remedial design and allow development of the Site following closure. This goal has been subsequently clarified as follows:

> "The objective of the site planning effort is to achieve a remedial design that allows for a range of future development options for the Custodial Trust property, while maintaining the primary goal of the remedy, which is to be protective of human health and the environment. Site plan options are developed to ensure that remediation activities anticipate and do not unnecessarily preclude viable uses of the site. The intent of the ISRT in initiating site planning of the future use of the Site is to identify a range of development opportunities for the land and to integrate an understanding of the opportunities into the development of the remedial design. The actual future uses and the location and layouts of these uses on the Site will be determined by the future owners based on several, now unknown, future influences, within the limitations of the Institutional Controls."

Consistent with these goals and objectives, the RDWP specifies that the following site planning deliverables are to be a part of the 100% Design Report:

- Final master drainage plan, grading, lot sizes, and landscaping;
- Final utility layout; and,
- Completion of Master Plan options.

8.2 MASTER PLAN OPTIONS, GRADING, LANDSCAPING, AND DRAINAGE

The conceptual master planning options designed to assist in the development of the remediation design were developed early in the remediation design process to maximize their usefulness. These options culminated in the development of the Industri-Plex Site Potential Development Plan presented as Figure 18-1. This plan identifies a potential arrangement of development areas and a conceptual design for internal and external circulation. Consistent with the objectives of the Site Planning effort, this plan was not developed to represent a definitive master plan, as such a plan can only be prepared by a future developer of the property.

The Potential Development Plan anticipates that the new I-93/Commerce Way Connector and a Regional Transportation Center, including a 4 to 5 acre vertiport, will be constructed as conceptually indicated in Figure 18-1. This plan also contemplates future development of the Industri-Plex Site with a mix of land uses, all of which would be consistent with the City of Woburn Zoning By-Laws applicable at the time of development.

The actual future form of development to occur on the Site will be determined by the future landowner(s) consistent with the requirements of the Institutional Controls. Until such development of the site occurs, the future condition of the Site relative to grading, landscaping, drainage, and utilities will be as described in Chapters 6 through 16 of this report.

LEGEND

- SITE BOUNDARY
- N 553,000 — GRID LINE
- SOIL PILES
- STREAMS AND WATERCOURSES
- RAILROAD TRACKS
- BOUNDARY OF PLAN
- REGIONAL TRANSPORTAION CENTER
- APPROXIMATE "FOOTPRINT" OF DEVELOPMENT PARCELS (AREA IN ACRES)
- DEVELOPMENT PARCEL ACCESS

NOTES

1.) TOPOGRAPHY FROM PHOTOGRAMMETRIC MAP COMPILED BY LIU AERIAL SURVEY 15 APRIL 1990, FOR SAIC ENGINEERING, INC. AT 1 IN. TO 100 FT. AERIAL PHOTOS TAKEN 22 NOVEMBER 1989, SCALE 1 IN. TO 800 FT.

2.) SITE BOUNDARY SURVEY BY SAIC ENGINEERING, INC. APRIL, 1990 AND JANUARY, 1991.

3.) ELEVATIONS TO NATIONAL GEODETIC VERTICAL DATUM OF 1929. GRID COORDINATES BASED ON MASSACHUSETTS COORDINATE SYSTEM.

4.) TOPOGRAPHIC CONTOUR INTERVAL 2 FEET.

5.) DESIGN OF COMMERCE WAY CONNECTOR IS CONCEPTUAL ONLY. ACTUAL DESIGN IS TO BE DETERMINED.

6.) DEVELOPMENT PARCELS ARE INTENDED TO INDICATE A CONCEPTUAL DIVISION OF THE INDUSTRI-PLEX SITE INTERIM CUSTODIAL TRUST PROPERTY INTO GROSSLY-DEFINED DEVELOPMENT AREAS. SUCH PARCELS MAY INCLUDE AREAS OF WETLANDS, STEEP SLOPES, AND OTHER NATURAL FEATURES, THE FUTURE DEVELOPMENT OF WHICH WOULD BE SUBJECT TO REGULATORY REVIEW AND POTENTIAL RESTRICTIONS.

200 0 200 400
scale feet

APR 25 1992

REV	DATE	DESCRIPTION	DR BY	RVW BY

SCALE: 1" = 200'
PROJECT No. 90940.00
DES BY
DR BY
CHK BY
RVW BY

PROJECT: INDUSTRI-PLEX SITE REMEDIAL TRUST WOBURN, MASSACHUSETTS

SHEET TITLE: **SITE POTENTIAL DEVELOPMENT PLAN**

Sasaki Associates, Inc.
64 Pleasant Street, Watertown, Massachusetts 02172
617/926-3300 Telex 92/2471 Fax 617/924-2748

SHEET OF
DRAWING No.

FIGURE 18-1

CHAPTER 19

OPERATIONS AND MAINTENANCE PLAN

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CHAPTER 19
OPERATIONS AND MAINTENANCE PLAN

19.1 REMEDIAL DESIGN WORK PLAN REQUIREMENTS

The Remedial Design Work Plan (RDWP; Golder, 1990) establishes that the final Operation and Maintenance (O&M) Plan is to be submitted as part of the 100% Design Report completion.

19.2 INTRODUCTION

This Operations and Maintenance Plan will be implemented during the post-closure period for the Industri-Plex Site in Woburn, Massachusetts. This plan is applicable to the Remedy for Contaminated Soils, the Air Remedy for the East Hide Pile, wetland mitigation and the groundwater recharge system. The Operations and Maintenance Plan for the groundwater extraction and treatment systems will be provided in Part II of the 100% Design Report.

The objective of an Operations and Maintenance Plan is to preserve and evaluate the effectiveness of the remedial actions through periodic inspection, maintenance, and monitoring. This plan comprises the following elements:

1. Inspection Plan,
2. Maintenance Plan, and
3. Monitoring Plan.

A cost estimate to perform the specified activities is also included together with a demonstration of financial assurance that monies will be available to perform the specified activities, and general guidelines for Health and Safety considerations during performance of the specified activities.

Operations procedures as such are only applicable to the gas collection system and the gas treatment plant. Provisions of Operations and Maintenance Plans for these systems will be a vendor requirement under the procurement contract. Subsequent Operations and Maintenance activities of these system will follow the vendors plans. Operating and Maintenance manuals and guidelines will be kept at the treatment plant and also in a secure off-Site archive facility.

19.3 INSPECTION PLAN

This inspection plan will be used for periodic inspections of components of the various Site remedies in order to identify any components requiring maintenance or repair. Guidelines for inspection of the various components of the Site remedies are presented below. For each component, the purpose of the inspection is stated, reasonably anticipated potential problems are identified, and minimum inspection requirements, schedules, documentation, and reporting are presented. Inspection schedules are based upon the operational mode of the remedial component, potential failure modes, and the potential hazard associated with failure.

19.3.1 Permeable and Impermeable Covers

19.3.1.1 Purpose

The permeable and impermeable covers are intended to prevent direct physical contact with the hide piles and soils containing arsenic, lead, and/or chromium above Consent Decree action levels. Other ground covering features such as existing or new buildings, roadways, railroad lines, and parking lots also serve as cover equivalents to prevent direct physical contact. Periodic inspection of the cover and cover equivalents is necessary in order to ensure and document the continued effectiveness of the remedy.

19.3.1.2 Reasonably Anticipated Potential Problems

Reasonably anticipated potential problems which could affect the continued effectiveness of the remedy include:

1. Insufficient vegetation resulting in erosion of the cover material by storm water runoff and/or wind,

2. Animal burrows,

3. Cracks or fissures of the cover resulting from excessive differential settlement,

4. Unauthorized disturbances by personnel and/or equipment, damage to the permanent surveyed monuments, or damage to any security fences.

These items will be considered during inspection of the cover and cover equivalents as described below.

19.3.1.3 Inspection Requirements

Elements to be monitored during inspection of the cover and cover equivalents and associated drainage structures are described below. The inspection will involve a Site walkover, with special emphasis as described below. These requirements do not apply to wetlands.

Integrity of the Cover and Cover Equivalents

The main focus of this inspection is on the hide pile slopes, the most likely place for wash-outs, erosion gullies, and other breaks in the cover soil to occur. Areas with insufficient vegetation to prevent wind and/or water erosion should be noted.

Any subsidences as a result of differential settlement within the hide piles will be recorded for continued monitoring, especially with regard to integrity of the geotextile fabric. Damage to the geotextile fabric is not anticipated, but small quantities of the geotextile fabrics will be kept on Site for the case of minor repairs.

Cover equivalents will be inspected for damage or deterioration affecting their ability to prevent direct contact with underlying soils containing arsenic, lead, and/or chromium at or above Consent Decree action levels.

Vegetative Cover

The vegetation will be monitored for bare areas, or areas without sufficient growth. Any woody growth will also be recorded for removal before the roots can penetrate the geotextile fabric. Other undesirable vegetation (e.g., phragmites, purple loosestrife, etc.) will also be noted for removal.

Associated Drainage Structures
Gravel/cobble lined swales will be inspected for blockages caused by leaves, grass clippings, silt deposits, or excessive vegetative growth which could impede or change the course of the flow and cause erosion along the edges of the gravel/cobble lining. Culverts will be inspected for blockage by debris and cleaned out as appropriate to prevent flooding of upstream areas. The stormwater storage areas will be checked for erosion, accumulation of sediment, and clogging of outlet structures.

Surveyed Monuments and Security Fences
The permanent surveyed monuments and security fences around the treatment plant and consolidation area will be inspected for possible damage.

19.3.1.4 Inspection Schedule

Quarterly inspections of the cover materials will be performed during the first three years following completion of construction, with annual inspections thereafter. Annual inspections will be performed in the spring in order to assess potential damage from the freeze-thaw cycle. In addition, inspections will be performed after each 25 year 24-hour storm event (5.2 inches).

Inspections of the cover materials shall be performed when snow and ice are not covering the ground and within 3 days after mowing of the cover vegetation if inspected during the summer months.

The integrity of the permanent survey monuments shall be inspected annually. The integrity of security fences shall be inspected monthly in conjunction with fencing around the Site treatment facilities.

19.3.1.5 Documentation/Reporting

A written inspection report will be prepared in conjunction with each monitoring event (quarterly for the first three years and annually thereafter). Any required repair and maintenance work will be assessed and documented on the inspection report. Repairs will be carried out by a repair crew as soon as practicable following the inspection. If necessary, modifications to the as-built drawings will be made. As-built drawings shall be certified by a Professional Engineer licensed by the Commonwealth of Massachusetts.

Copies of the inspection reports will be maintained on-Site and submitted to USEPA as part of the O&M Report on a quarterly basis for the first three years and on an annual basis thereafter.

19.3.2 Gas Collection System

19.3.2.1 Purpose

The gas collection system on the East Hide Pile is intended, in conjunction with the gas treatment system, to mitigate the release of odors from the East Hide Pile. Periodic inspection of the gas collection system pipe vaults and pneumatic valve system are necessary in order to ensure the continued effectiveness of the remedy.

19.3.2.2 Reasonably Anticipated Potential Problems

Reasonably anticipated potential problems which could affect the continued effectiveness of the remedy include:

1. Leaks at the gas collection piping vaults,
2. Failure of the o-ring seals on the pipe vaults,
3. Failure of pneumatic butterfly valves,
4. Equipment failures such as broken bearings, electrical malfunctions, etc., and,

5. Leaks at pipe connections.

These items will be considered during inspection of the gas collection piping and blower system as described below.

19.3.2.3 Inspection Requirements

Elements to be monitored during inspection of the gas collection system are described below.

Equipment vaults will be checked for signs of deterioration or indications of malfunction or cracking at fiberglass pipe to vault vinyl ester adhesive bond connections. The vault cover gasket shall be inspected for deterioration every time the vault is opened. The presence of water or liquid indicating a leak in the vault or condensate leaking from the piping will be noted. The presence of any hydrogen sulfide odors in the manhole should also be noted. The results of confined space air monitoring of the vault prior to entry should be recorded.

The tightness of the anchor points and flange connections will be checked along with a visual inspection of the flange gaskets.

The gas collection system shall operate at a negative pressure in the main gas transportation manifold as induced by the blower fan at the gas treatment system. The gas collection arms connected to the gas transportation manifold shall be maintained at a slightly negative pressure (-4 inches water vacuum) as controlled by damper butterfly valves and pressure sensing valve controllers.

The damper butterfly valves shall be controlled by a pneumatic controller receiving its supply from a distributed nitrogen system with the nitrogen generating system located at the gas treatment plant. The damper butterfly valves are designed for failsafe operation to open in the event of loss of power or loss of pneumatic air. The damper butterfly valve control system, once adjusted for proper operation, will be checked for indication of the established negative pressure and adjusted accordingly. All pneumatic tubing will be visually checked and replaced or repaired as required.

Detonation flame arrestors installed approximately every 52 feet in each of the access vaults are of a passive design with no adjustments for operation required.

The breather vent system located on the top of the vault consists of a foot valve with a return bend and a flanged pipe connection into the vault. This allows the vault to breath while preventing high water levels from entering the vault. The foot valve should be visually inspected for signs of deterioration and free movement of the ball.

Provision of pneumatic nitrogen shall be maintained by a standard nitrogen generation system which derives nitrogen from free air compressed and cooled before introduction into the generator. After generation, the pneumatic nitrogen is regulated and distributed via underground tubing in conduits to the control points. The function of the nitrogen generating system should be checked on a daily basis according to procedures recommended by the manufacturer including the proper operation of the regulators, simultaneous operation of the compressors, drains on the compressor tank, the aftercooler, and the nitrogen generator. Special attention should be paid to proper drainage of accumulated moisture, proper operation of the fan and start/stop thermostatic controller on the aftercooler, accumulation of ice on the nitrogen generator gas vents, and function of heat trace cables in cold weather.

Any manufacturer-recommended inspections will also be performed during routine preventative maintenance as described in Section 19.4.2 below.

19.3.2.4 Inspection Schedule

Inspection of the gas collection piping vaults, the damper butterfly valve control system, and negative pressure in the arms of the gas collection system will be performed on a monthly basis.

19.3.2.5 Documentation/Reporting

A written inspection report will be prepared in conjunction with each monitoring event. Any required repair and maintenance work will be assessed and documented on the inspection report. Repairs will be carried out by a repair

crew as soon as practicable following the inspection. If necessary, modifications to the as-built drawings will be made. As-built drawings shall be certified by a Professional Engineer licensed by the Commonwealth of Massachusetts.

Copies of the inspection reports will be maintained on-Site and submitted to USEPA as part of the O&M Report on a quarterly basis for the first three years and on an annual basis thereafter.

19.3.3 Gas Treatment System

19.3.3.1 Purpose

The gas treatment system on the East Hide Pile is intended, in conjunction with the gas collection system, to mitigate the release of odors from the East Hide Pile. Periodic inspection of the components is necessary in order to ensure the continued effectiveness of the remedy.

19.3.3.2 Reasonably Anticipated Potential Problems

Reasonably anticipated potential problems which could affect the continued effectiveness of the remedy are documented in the manufacturer's operating instructions. Those items will be considered during inspection of the gas treatment system. In addition, the fence around the treatment plant might become damaged.

19.3.3.3 Inspection Requirements

Elements to be monitored during inspection of the gas treatment system will be as described in the manufacturer's operating instructions. The fence around the gas treatment system will be inspected for breakage, open gates, or missing locks. The blower fan will be inspected on a daily basis for signs of malfunction.

19.3.3.4 Inspection Schedule

Inspection of the gas treatment system will be performed at a minimum on the schedule recommended by the manufacturer. The fencing will be inspected on a monthly basis.

19.3.3.5 Documentation/Reporting

Except for monthly fencing inspections, a written inspection report will be prepared in conjunction with each monitoring event. Any required repair and maintenance work will be assessed and documented on the inspection report. Repairs will be carried out by a repair crew as soon as practicable following the inspection. If necessary, modifications to the as-built drawings will be made. As built drawings shall be certified by a Professional Engineer licensed by the Commonwealth of Massachusetts.

Copies of the inspection reports will be maintained on-Site and submitted to USEPA as part of the O&M Report on a quarterly basis for the first three years and on an annual basis thereafter.

19.3.4 Wetlands

19.3.4.1 Purpose

The post-construction inspection and maintenance program involves the evaluation of revitalized, restored, enhanced, and compensatory wetlands over time to document achievement of performance standards as stated in Table 14-13 of this report. In addition, water quality, sediments and aquatic macroinvertebrates will be monitored in the remediated wetlands as described in Section 19.5.2. A Hydrology Management Plan for the created wetland is provided in Section 19.6. The inspection program will identify the need for maintenance actions to correct deficiencies or other problems.

19.3.4.2 Reasonably Anticipated Potential Problems

Reasonably anticipated potential problems which could affect the continued effectiveness of the remedy include:

1. Death or poor health of planted nursery stock,
2. Vegetation depredation by wildlife species during the establishment period,
3. Invasion of unwanted species, and
4. Groundwater elevations which are consistently lower than design values.

These items will be considered during inspection of the wetlands vegetation as described below.

19.3.4.3 Inspection Requirements

Compliance with the performance standards over time will require collection of hydrologic and vegetative data within permanent plots. A stratified random sampling design will be utilized to ensure both the collection of statistically usable data and adequate sampling of all cover types. Two to four transects will be randomly established parallel to the moisture gradient. Nested plots (0.1 square meter quadrants for herbaceous species density, and 1.0 square meter for herbaceous species cover, and 5.0 square meter quadrants for woody vegetation) will be located randomly within each cover type intersected by the transects. A minimum of 5 plots will be established within each wetland mitigation area for a total of at least 20 plots on-Site.

Vegetation data will be collected within each plot. Vegetation parameters to be measured include total plot cover, individual species cover, density, and vigor. Vegetation data will be compared to Performance Standards as detailed in Table 14-13 of this report. Any deviation from these standards, i.e. less than 50 percent OBl, FACW,

or FAC species in wetlands, or less than 75 percent survival of woody plants, will be recorded. Maintenance activities will be implemented to rectify the deficiencies.

Shallow observation wells or staff gauges (see Section 14.5.1 for details) will be installed within each wetland plot to record surface and groundwater hydrology. Soil saturation within the rooting zone will also be measured within the areas lacking standing water. This will provide a measure of soil-water content above the water table within seasonally flooded areas. Hydrologic data will be compared to pre-construction groundwater elevations, hydroperiod design information, and commonly accepted hydrologic criteria for maintaining wetland vegetation. Additional hydrologic monitoring will occur in the created wetland as described in Section 19.6.

In addition, shrub plantings along remediated drainways and the created wetland berm will be inspected for health and at least 75 percent survival.

Permanent photographic stations will be set up to allow comparisons to be made in successive years.

19.3.4.4 Inspection Schedule

Vegetation will be inspected once a month during the first growing season (April through September), and annually for the next four years at the height of the growing season (July). Hydrology data in vegetation plots will be measured monthly during the growing season (April through September) for the first year and annually at the height of the growing season for the next four years.

19.3.4.5 Documentation/Reporting

An inspection report will be prepared and submitted by November 1 of each year for five years after construction. The monitoring report will include a comparison of wetland conditions and performance standards, description of maintenance activities, wildlife observations, evidence of vandalism or storm damage, observation of algae, odors, oil sheens, litter, results of water/sediment and aquatic macroinvertebrate monitoring (Section 19.5.2), and recommendations for additional maintenance activities. Maintenance will be carried out by a maintenance crew as soon as practicable following the inspection. If necessary, as-built documentation will be modified, and the drawings will be certified by a Professional Engineer licensed by the Commonwealth of Massachusetts. The fifth year monitoring report will include a Hollands-Magee wetland functional assessment for Wetland 1C, the created wetland, and an undisturbed reference wetland.

Copies of the inspection reports will be maintained on-Site and submitted to the frollowing by November 1 of each year for five years.

1. EPA Project Officer, 5 copies
2. DEP, 2 copies
3. U.S. Fish and Wildlife, 1 copy
4. FACE, 2 copies
5. NOAA,1 copy

19.3.5 Groundwater Recharge System

19.3.5.1 Purpose

The groundwater recharge system is intended to return treated groundwater to the unconsolidated aquifer. Periodic inspection is necessary in order to ensure the continued effectiveness of the remedy.

19.3.5.2 Reasonably Anticipated Potential Problems

Reasonably anticipated potential problems which could affect the continued effectiveness of the remedy include:

1. Erosion of the gravel/cobble lining the basin,
2. Growth of vegetation which might impede the throughput of storm water and recharge of treated water, and
3. Clogging of the basin by fine sediments and/or biomass.

These items will be considered during inspection of the groundwater recharge basin as described below.

19.3.5.3 Inspection Requirements

Elements to be monitored during inspection of the groundwater recharge basin are described below.

Gravel/Cobble

The integrity of the gravel/cobble channel lining will be visually inspected for damage such as displaced gravel/cobble, and unprotected or exposed soil. The presence of vegetation will also be noted. The presence of floating biological matter (e.g. algae) should be described and the percentage of the water surface which is covered should be estimated.

Fine Sediments/Biomass

If the groundwater treatment plant is shut down for any reason, the bottom of the basin should be inspected, to the extent possible, for the presence of fine sediments and biomass. Estimates of the thickness, types of materials, and quantities should be noted.

19.3.5.4 Inspection Schedule

Inspection of the groundwater recharge system will be performed on an annual basis, after each 25 year, 24-hour storm event (5.2 inches) and whenever the groundwater treatment plant is shut down.

19.3.5.5 Documentation/Reporting

An inspection report will be prepared in conjunction with each monitoring event and submitted with the annual O&M report. Any required repair and maintenance work will be assessed and documented on the inspection report.

Maintenance will be carried out by a maintenance crew as soon as practicable following the inspection. If necessary, as-built documentation will be modified, and the drawings will be certified by a Professional Engineer licensed by the Commonwealth of Massachusetts. Copies of the inspection reports will be maintained on-Site and submitted to USEPA as part of the O&M Report on an annual basis.

19.4 MAINTENANCE PLAN

This maintenance plan will be used for scheduled routine preventative maintenance and repairs of components of the various Site remedies, to ensure the continued effectiveness of the remedies. Repairs will be performed in a manner and with materials as close as possible to those used during initial construction of the subject remedial component. Repairs will be carried out by a repair crew as soon as practicable following discovery of damage. A repair report will be prepared following completion of the repairs. If the repairs are such that the as-built drawings need to be modified, the report shall include as-built drawings of the repairs certified by a Professional Engineer registered in the Commonwealth of Massachusetts. Copies of the repair report will be maintained on-Site and also sent to USEPA as part of the quarterly O&M Report.

Anticipated routine maintenance and repair items for the various components of the Site remedies are presented below. Any other repairs which are not identified below, but are necessary in order to ensure the continued effectiveness of the remedies, will also be performed in a manner to restore the remedy to its designed condition to the extent feasible.

19.4.1 Permeable and Impermeable Covers

The following routine maintenance and repair tasks will be performed:

1. Mowing of the vegetative cover once annually during late summer after seed heads have formed,

2. Removal of young trees and other woody plants,

3. Repair of potential erosional features on the cap which are not part of the design, along with re-seeding and temporary stabilization of repaired areas,

4. Repair of potholes and cracks in roadways and parking lots,

5. Removal of debris from drainage channels and culverts,

6. If necessary, removal of accumulated sediment in the stormwater storage areas and restoration of the permeable cover in the basins to their design specifications.

19.4.2 Gas Collection System

The following routine maintenance and repair tasks will be performed:

1. The equipment manhole cover gaskets will be replaced at least every two years, or sooner as required.

2. Replace the first stage filter on the nitrogen generator when the pressure drop exceeds 12 pounds per square inch. Once each year, or as recommended by the manufacturer, replace all filters (1st, 2nd, and 3rd stage) and replace nitrogen generation cartridge. The old cartridge should be returned to the factory for regeneration.

3. Anchor points and flange connections will be tightened, and flange gaskets will be replaced as necessary.

4. Tubing and connections for the pneumatic damper butterfly valve control system will be replaced as necessary.

19.4.3 Gas Treatment System

Routine maintenance and repairs to the gas treatment system will be per the manufacturer's recommendations.

19.4.4 Wetland and Buffer Vegetation

Maintenance activities will include both general care of the landscape and rectification of specific problems. Table 19-1 lists potential performance deficiencies and the maintenance activities which rectify them. Most of these actions are minor, requiring hand labor and some additional seed, plant stock, fertilizer, or erosion control materials.

Vegetation inspection will identify any deficiencies in plant community characteristics. Supplementary seeding or planting can address low densities and low diversity. Fertilizing can encourage vigorous growth but application will be carefully monitored to prevent problems with weeds and water quality. Invasion of the emergent or wet meadow zones by *Lythrum salicaria* generally occurs by transport of the seeds by surface water. *Lythrum* populations can be minimized by hand pulling of small plants; selectively spraying individual larger plants with USEPA approved biodegradable systemic herbicides; maintaining high spring water levels through outlet control to flood exposed soil when seeds are germinating; and heavily seeding *Echinocloa crusgalli*, which has been shown to effectively suppress *Lythrum* establishment in many instances (Thompson et al., 1987).

Phragmites, a perennial grass, usually spreads vegetatively with stout, creeping rhizomes (Cross and Fleming, 1989). It is anticipated that the grading and capping of soils and sediments on the Site will effectively suppress *Phragmites* in these areas. Further control may require a combination of mowing, application of herbicides, and water level manipulation. In all wetland mitigation areas, fast and vigorous growth of preferred wetland species will be encouraged and subsequent exposure of bare soil will be

minimized to reduce invasion opportunities. Depredation by wildlife, particularly Canada geese and muskrat, can impair vegetation establishment. Waterfowl may be frightened away during the establishment period by mechanical frightening devices, such as exploders, "shells", helium balloons, etc. Muskrat may be live trapped and relocated.

Insufficient proportions of hydrophytic plants in wetlands may be a temporary condition treatable with supplemental seeding or planting or it may be a symptom of inadequate wetland hydrology, as is insufficient soil saturation or inundation. Water levels in the created wetland can be manipulated during the monitoring period through adjustment of the outlet water control structure. Guidelines for regulating water levels are discussed in Section 19.6.1. At the conclusion of the five year inspection and maintenance period the level of the outlet water control structure will be permanently fixed to prevent subsequent manipulation of water levels.

19.4.5 Groundwater Recharge System

Routine preventative maintenance of the recharge basin includes removal of vegetation, skimming of floating biomass which could clog the basin, and replacement of gravel/cobble lining as necessary.

19.5 MONITORING PLAN

This monitoring plan will be used for environmental monitoring (testing) of specific media in order to assess the effectiveness of the various Site remedies and to serve as a warning system if the remedies are not performing as designed. No monitoring of the Remedy for Contaminated Soils is appropriate, other than the inspection and maintenance described above. Monitoring of the Groundwater Remedy will be included in Part II of the 100% Design Report. In the wetlands, certain environmental parameters will be monitored to determine the reasons for any failure of plant or animal colonization, with the goal of creating viable, self-sustaining wetlands. For the air remedy, monitoring of the gas treatment plant effluent is necessary in order to demonstrate compliance with design parameters. Such monitoring also tracks the progress of remediation and provides a basis for decisions to modify operating parameters. Monitoring guidelines are presented below, including the purpose and locations of the monitoring, sampling and analysis procedures, monitoring schedules, and reporting requirements.

19.5.1 Gas Treatment System

19.5.1.1 Purpose

The purpose of gas treatment system effluent monitoring is to ensure that ambient air quality is within the standards for nuisance odors which were established during the Pre-Design Investigation Baseline Air Survey (Golder Associates Inc., 1991a).

19.5.1.2 Sampling Locations

The gas treatment system stack will be approximately 2-1/2 feet in diameter and 30 feet in height. The influent to the gas treatment system will be monitored during annual audit testing at a point approximately 5 feet upstream from

the burner. The effluent from the gas treatment system will be monitored at a sampling port 6 feet below the stack outlet. There will be four sampling ports at 90 degree angles at the effluent sampling location. These will allow for continuous total reduced sulfur (TRS) compound monitoring in one port along with a volatile organic sampling train (VOST), grab sampling, and flow rate measurements in the other three ports.

19.5.1.3 Sampling and Analysis Procedures

One continuous monitor measuring TRS compounds will be operated in the outlet sampling location of the stack. The TRS concentration will be determined and recorded once every minute. An audible alarm in the Groundwater Treatment Plant operations office will be connected to the sensor to alert appropriate personnel when TRS exceeds 30 ppm. The monitor will be calibrated on a daily basis.

In addition to this continuous monitor, annual audits will be performed. The composition of the influent and the effluent will be determined such that destruction removal efficiencies (DRE) can be calculated and compared to design performance criteria. The following audit measurements will be performed in accordance with procedures given in 40 CFR Part 60, Appendix 19-A:

1. Flow rate (USEPA Method 2),
2. Bulk composition (USEPA Method 3),
3. TRS speciation (USEPA Method 15),
4. TRS continuous (USEPA Method 16A),
5. Volatile organic compounds (USEPA Sampling Method 0030 and SW-846 analysis method 4060).

Sampling and analysis will be performed in accordance with Section 5 of the Site Monitoring Plan (Golder Associates Inc., 1991b).

19.5.1.4 Monitoring Schedule

The TRS monitoring system will operate continuously and be audited annually. Annual sampling and analysis will be performed to audit the performance of the TRS monitoring system and the DRE of the gas treatment system.

19.5.1.5 Reporting

The results will be reported to the Agencies as part of the annual O&M Report. The audit report shall be included as an attachment. The sampling date, analysis date, sample results, and the results of all quality control samples shall be included in the audit report.

19.5.2 Wetlands

19.5.2.1 Sampling Locations

Seven monitoring stations (MS) will be staked in the field or marked with buoys for the purpose of identifying a location for the consistent measurement of water quality and sampling of sediments and aquatic macroinvertebrates. These stations, presented in Figure 19-1 as MS-25, MS-26, MS-27, MS-28, MS-29, MS-30, and MS-31 will be numbered upstream to downstream, although monitoring will proceed in a contrary manner.

19.5.2.2 Sampling and Analysis Procedures

The following parameters will be monitored at each station in May, August and October for the purpose of the determination of water quality:

- Dissolved Oxygen
- Temperature

- Specific Conductivity
- Biological Oxygen Demand
- Chemical Oxygen Demand
- Salinity
- Hardness
- Total Suspended Solids
- Total Kiedahl Nitrogen
- Total Phosphate
- pH
- Eh
- Turbidity
- Nitrate/Nitrite
- Ammonia
- Total Sulfate
- Volatile Organics
- Semi-volatiles
- Cyanide
- Total Metals (COC's plus mercury)
- Dissolved Metals (chromium, arsenic, lead)

Water samples will be grab samples from the water surface.

Sediment samples to be taken biannually in May and October will be cores from the top 6 inches of sediments. Composite of the 6-inch sediment cores will be analyzed for grain size (seive analysis), total organic carbon, total metals, cyanide, volatile organics and semi-volatiles. Sediment samples for metal analyses will be divided into samples at each location, 0-3 inches and 3-6 inches. Detection levels for all analyses must be consistent with aquatic life criteria.

Aquatic macroinvertebrates will be monitored, at each station, on a biannual basis in May and October for the purpose of determining if colonization of the revitalized

wetlands is occurring and, if so, at what rate. The sampling program will utilize artificial substrates (multiple plate samplers) for benthic macroinvertebrates at all seven stations. Sediments from all appropriate stations will be analyzed for macroinvertebrate communities. Fauna expected to colonize vegetation will be collected by sweeping with a D-net at all appropriate stations. Samples of insects will be labelled and preserved in the field with 70 percent ethanol/Rose Bengal. Sorting of insects will be done in the laboratory and identification of taxa will be to genus or lowest practical taxonomic level.

Metric endpoints chosen for the analysis of the macroinvertebrate community will include the following:

- Taxa richness
- Total Abundance
- % Functional Feeding Group
- % Dominant Taxon
- EPT Index

If Chironomidae are dominant, as is typical of other locations with the Study Area (Roux Associates, 1991), then this family will be subsampled and keyed to subfamily/tribe.

19.5.2.3 Monitoring Schedule

The wetlands environmental monitoring will be carried out biannually for the duration of the 5 year inspection and maintenance period. If additional maintenance or monitoring after this period will enhance the success of the wetland mitigation, the five-year monitoring report will include appropriate recommendaitons.

19.5.2.4 Reporting

All data gathered during wetland monitoring will be statistically analyzed as appropriate. Assessments of wetland conditions, conclusions, and recommendations will be included in each monitoring report. The monitoring data will be presented in the five annual maintenance and monitoring reports described in Section 19.3.4.5. Copies of each report will be maintained on-Site and submitted to the following by November 1 of each monitoring year:

1. EPA Project Officer, 5 copies
2. DEP, 2 copies
3. U.S. Fish and Wildlife, 1 copy
4. FACE, 2 copies
5. NOAA, 1 copy

19.6 HYDROLOGY MANAGEMENT PLAN

19.6.1 Protocol for Water Level Regulation

The created wetland will be equipped with an outlet structure that will enable the use of flashboards to capture and store excess surface water volumes above "full pond" levels (i.e., 68 feet msl). Storage of additional water will be done on a contingency basis to compensate for unanticipated water losses within the wetland causing a greater than expected decline in water levels. Water regulation is principally important during the early part of the growing season (i.e., April through June) when water levels are expected to be at or near full pond levels creating the proposed seasonally flooded or saturated conditions. Evapotranspiration and seepage losses represent the two primary outflows from the wetland excluding the surface discharges through the outlet structure. Based on the water budget calculations, seepage and evapotranspiration, during normal precipitation and temperature conditions, would cause water levels to decline at a rate of 2.0, 2.25 and 2.5 inches per week, assuming no inflow, during the months of April, May and June, respectively. Greater rates of decline would indicate higher than expected seepage rates due to a flaw in the subsurface liner or increased evapotranspiration losses due to atypically warmer temperatures. If water levels decline at a rate greater than the anticipated rate during the period of April through June, a flashboard will be installed temporarily to capture additional flow during storm events and maintain higher water levels.

Water levels and climatological conditions will be monitored weekly throughout the growing season according to protocol specified in Section 19.6.2. Climatological data will be reviewed as a means of assessing whether the excessive rates of water level decline are weather related

or due to a problem with the subsurface liner. If precipitation and average daily temperature measurements were at or near normal conditions during the period of excessive rates of water decline, then additional seepage losses would be implicated as the likely cause. The size of the flashboard used will be dependent on the observed departure from expected rates of water level decline as shown in the following table:

FLASHBOARD SIZE VS WATER LEVEL DECLINE RATE

RATE OF WATER LEVEL DECLINE	APRIL	MAY	JUNE	FLASHBOARD SIZE
	(inches/week)			
Normal(anticipated)	2.0	2.25	2.50	None
0-10% above normal	2.20	2.48	2.75	4 inch
11-20% above normal	2.40	2.70	3.00	6 inch
>21% above normal	2.60	2.90	3.25	12 inch

The flashboard will remain in place until the cause of the excessive decline in water levels is determined and/or the excessive rate of water level decline ceases. Water level regulation is not considered necessary during July, August and September when minimal standing water is expected and any recharge to the wetland will occur only as stormflow during precipitation events.

19.6.2 Water Level Monitoring

19.6.2.1 Station Locations

Water levels will be recorded at each of the following stations as shown on Figure 19-1.

1. MS-29; created wetland at the mouth of the inlet stream
2. MS-30; lowest elevation within created wetland
3. MS-31; outlet to the created wetland

Each monitoring station will be equipped with a securely anchored staff gauge graduated in tenths of feet with a minimum vertical range of 0 to 3 feet. Each gauge shall be placed in a manner to allow for easy access and visual reading. The base of the gauge should be placed at grade level. Hardware used to anchor the gauge must not penetrate the subsurface clay loam layer.

19.6.2.2 Water Level Monitoring Schedule

Water levels shall be recorded at each of the three stations on a weekly basis during the first two growing seasons beginning April 1 through October 1. For the remainder of the five year monitoring period, water levels will be recorded on a monthly basis during the growing season.

19.6.3 Climatological Data Monitoring

Daily precipitation and average daily temperature will be monitored on a weekly basis from April 1 to October 1 and on a monthly basis for the remaining portion of the year. Data will be collected from the National Weather Station located at Logan Airport, Boston. Monthly precipitation totals and mean monthly temperature will be compared to long term average monthly data to determine departure from normal values on a monthly basis.

19.6.4 Flow Monitoring

19.6.4.1 Station Location and Establishment

Two flow monitoring stations will be established coinciding with the water level monitoring stations in the inflow stream (MS-29) and at the outlet of the Created Wetland (MS-31). At the inflow stream station, the cross-section of the stream should be surveyed in terms of vertical and horizontal distances as well as the channel slope. Flow determination will be based on Mannings Equation, using the

measured depth of water, channel slope, cross-sectional area, and an assumed roughness coefficient. This procedure should be calibrated using the timed-bucket method under lowflow conditions. If depth of water in the channel cannot be accurately measured due to interference with riprap, the use of a 90°V-notch weir may be necessary to determine flow.

At the outlet structure, rate of outflow will be determined by the measured depth of water in the pipe multiplied by the cross-sectional area of the pipe.

19.6.4.2 Flow Monitoring Schedule

Flow monitoring shall be conducted on a weekly basis during the first two growing seasons coincidental with water level measurements and then monthly for the remainder of the monitoring period.

19.6.5 Inspection and Maintenance of Outflow Structure

19.6.5.1 Outflow Inspection Schedule

The outflow structure for the Created Wetland will be inspected on a weekly basis for the first two growing seasons from April 1 through October 1 to insure no blockage of flow from debris, beaver activity or sediment buildup. An inspection log should be maintained noting structural integrity and any maintenance requirements needed to allow continued operations.

19.7 COST ESTIMATE

The cost estimate for inspection, operation, maintenance, and monitoring of the Remedy for Contaminated Soils, the Air Remedy for the East Hide Pile, and the groundwater recharge system is detailed in Appendix 19-A. Annual costs for the first three years are estimated to be around $225,000. Costs for the fourth year are reduced to approximately $215,000 due to less frequent cover inspections. Costs for subsequent years when wetlands vegetation inspection maintenance and monitoring are not envisioned are reduced to approximately $56,000 per year.

19.8 FINANCIAL ASSURANCE

Per the Remedial Design/Remedial Action Consent Decree, Post-Closure activities will be financed by Monsanto Chemical Company and ICI Americas on an equal basis.

19.9 HEALTH AND SAFETY

Inspections, maintenance, repairs, and monitoring shall be performed in accordance with the health and safety plan to be prepared by the Operations and Maintenance Contractor. Health and Safety specifications are given in Appendix 19-B.

REFERENCES

Cross, D.H. and K.L. Fleming, 1989. Control of *Phragmites* or Common Reed. U.S. Fish and Wildlife Service Leaflet 13.4.12. 5 pp.

Golder Associates Inc., 1990. Remedial Design Work Plan, Industri-Plex Site, Woburn, Massachusetts, July.

Golder Associates Inc., 1991a. Pre-Design Investigation, Task A-1, Baseline Air Survey, Interim Final Report, Industri-Plex Site, Woburn, Massachusetts, May.

Golder Associates Inc., 1991b. Pre-Design Investigation, Site Monitoring Plan, Interim Final Report, Industri-Plex Site, Woburn, Massachusetts, April.

Roux Associates Inc., 1991. Groundwater/Surface Water Investigation Plan, Vol. 1, Industri-Plex Site, Woburn, Massachusetts.

Thompson, D.Q., R.L. Stucky, and E.B. Thompson, 1987. Spread, Impact and Control of Purple Loosestrife (*Lythrum Salicaria*) in North American Wetlands. US Fish and Wildlife Service, Fish Wildl. Res. 2. 55 p.

TABLE 19-1 SUMMARY OF MAINTENANCE AND CONTINGENCY ACTIONS FOR ACHIEVING DYNAMIC PERFORMANCE STANDARDS IN WETLAND MITIGATION AREAS OF THE INDUSTRI-PLEX SITE

POTENTIAL PERFORMANCE DEFICIENCY	MAINTENANCE OR CONTINGENCY ACTIONS
Plant density below specifications (i.e., 75% cover in wet meadow)	Supplement seeding/planting, fertilize
<75% Survival of trees or shrubs	Remove dead plant and replace
<50% Hydrophytic plants in wetlands in wetlands	Supplement seeding/planting/adjust outlet invert
Plant depredation by wildlife	Mechanical frightening devices or animal relocation
Species diversity decreases over time	Supplement seeding/planting
Marginal tree/shrub vigor	Spot fertilize
Presence of invasive weeds *(i.e., Phragmites, Lythrum)*	Manual removal/apply herbicides as needed/mow/adjust outlet invert/ supplement seeding/planting
Recruitment of woody vegetation on soil caps	Manual removal, periodic mowing in the fall
Erosion or siltation problems	Repair, replace, or initiate appropriate erosion control
Inadequate soil saturation/ inundation	Adjust outlet invert as necessary

APPENDIX 19-A

Cost Estimate for Annual Operation and Maintenance

Remedy for Contaminated Soils, Air Remedy for the East Hide Pile, and Groundwater Recharge System

1.0 INTRODUCTION

For the purpose of the cost estimate for Operation and Maintenance of the Remedy for Contaminated Soils, the Air Remedy for the East Hide Pile, and the groundwater recharge system, it was assumed that annual maintenance would be required for each of the components of the remedial design. Specifically, the following inspection, maintenance, and monitoring items were assumed:

1. Permeable and impermeable covers inspection and maintenance, including paved areas and associated drainage structures,
2. Gas collection system inspection and maintenance,
3. Gas treatment system inspection, operation, maintenance, and monitoring,
4. Wetlands vegetation inspection and maintenance, and environmental monitoring,
5. Groundwater recharge system inspection and maintenance, and
6. Preparation of quarterly and annual reports to the Agencies.

All costs are based upon 1991 dollars. Inflation has not been included in the cost estimate. Additional assumptions are presented for each of these items below.

2.0 INSPECTION AND MAINTENANCE OF THE PERMEABLE AND IMPERMEABLE COVERS

Permeable Covers

Inspections of permeable cover will be performed quarterly for the first three years following remedial construction, and annually thereafter. Given the relatively large area of the permeable cover, it was assumed that inspection of the cover would take three man-days to complete.

It is anticipated that some minor erosion of the cover will take place due to intense storm events or other natural phenomenon. The rate of erosion of cover materials was assumed to be 60 cubic yards per year. Repair of these areas was developed at an in-place unit price of fill of $25 per cubic yard. Reseeding of these areas will also be necessary. It was assumed that additional minor grade adjustments and reseeding would be performed and that two days of backhoe work per year would be required together with a two-man crew to effect repairs. In addition to replacement of permeable cover materials, it was assumed that some geotextile in spot areas would need maintenance. Accordingly, a 10 square yard per year rate of replacement was assumed together with a replacement cost of $20 per square yard to reflect the small quantity of the repairs and placement in several locations.

Impermeable Cover

Inspection of the impermeable cover was considered to coincide with the inspection of permeable cover areas. A time allotment of one man-day was assumed for inspection of the impermeable cover. Based on the relatively small area of the impermeable cover, replacement of vegetative cover materials at a rate of 10 cubic yards per year and a unit price of $25 per cubic yard was assumed. It was further assumed that no geosynthetics would require replacement. The same crew used for the permeable cover was assumed for impermeable cover maintenance and one work day allotted for slope regrading and placement of erosion control materials.

Associated Drainage Structures

Stream inspection and maintenance will consist of inspection of erosion control materials placed in new and remediated channels. It has been assumed that the inspection of the streams will require two man-days to complete. The maintenance will include replacement/relocation of existing gravel/cobble materials and other channel erosion control materials. Inspection will include

culverts, concrete channels, and catch basins. It is assumed that sediment removal from the detention basins will not be necessary.

Paved Areas

Paved areas must be inspected where they function as cover equivalent. Routine repair of pavement is a normal maintenance item which will be undertaken by facilities owners/operators. For financial assurance purposes, costs are included here for 5,000 square yards of patching of paved areas over 10 years and an allowance for crack sealing. It was also assumed that annual inspection would require two work days for an engineer.

CAPS AND DRAINAGE STRUCTURES--FIRST THREE YEARS

Item	Unit	Unit Cost	Quantity	Total
Inspection	man-hr	$50	240	$12,000
Cover soil	cu. yard	$25(*)	60	$1,500
Geotextile	sq. yard	$20(*)	10	$200
Pickup Truck	day	$100	3	$300
Backhoe	hour	$50	30	$1,500
Labor	hour	$30	60	$1,800
Erosion repair	lump sum	$6,000(**)	1	$6,000
Seeding	sq. yard	$10	60	$600

(*) installed
(**) estimate, for drainage structures only

CAP SUBTOTAL--FIRST THREE YEARS $23,900

CAPS AND DRAINAGE STRUCTURES--AFTER THIRD YEAR

Item	Unit	Unit Cost	Quantity	Total
Inspection	man-hr	$50	60	$3,000
Cover soil	cu. yard	$25(*)	60	$1,500
Geotextile	sq. yard	$20(*)	10	$200
Pickup Truck	day	$100	3	$300
Backhoe	hour	$50	30	$1,500
Labor	hour	$30	60	$1,800
Erosion repair	lump sum	$6,000(**)	1	$6,000
Seeding	sq. yard	$10	60	$600

(*) installed
(**) estimate, for drainage structures only

CAP SUBTOTAL--AFTER THIRD YEAR $14,900

PAVEMENT

Item	Unit	Unit Cost	Quantity	Total
Patching	sq. yard	$18(*)	5,000	$90,000
Sealing	sq. yard	$0.92	34,000	$31,280
Manholes/catch basins	each	$125	65	$8,125

(*) installed

10 YEAR PAVEMENT SUBTOTAL $129,405

Annual Pavement Cost $12,940

Inspection	man-hr	$50	20	$1,000

ANNUAL PAVEMENT SUBTOTAL $13,940

COVER ANNUAL TOTAL--FIRST THREE YEARS $37,840

COVER ANNUAL TOTAL--AFTER THIRD YEAR $28,840

3.0 INSPECTION AND MAINTENANCE OF THE GAS COLLECTION SYSTEM

Estimates for annual inspection, operation, and maintenance costs of the gas collection system was calculated as 3 percent of the total cost, for a total of $3,923.

4.0 INSPECTION, OPERATION, MAINTENANCE, AND MONITORING OF THE GAS TREATMENT SYSTEM

Estimates for annual inspection, operation, and maintenance, costs of the gas treatment system was calculated as 3 percent of the total cost, for a subtotal of $13,000. Monitoring of the gas treatment system effluent is calculated separately:

Item	Unit	Unit Cost	Quantity	Total
Sampling Team	team-hr	$300(*)	10	$3,000
Laboratory	test suite	$1,000(*)	2	$2,000
Mob/demob	event	$2,000(*)	1	$2,000

(*) estimate

Monitoring Subtotal $7,000

ANNUAL TOTAL COST $20,000

5.0 INSPECTION AND MAINTENANCE OF WETLANDS VEGETATION AND WETLANDS ENVIRONMENTAL MONITORING

Wetlands vegetation inspection and maintenance has been estimated for a five-year period following remediation. Inspection will consist of visual observation of the remediated and created wetland areas. The cost for wetlands inspection and maintenance has been developed as a per-acre unit price based on Normandeau Associates' experience of similar wetlands in Massachusetts.

Inspection and maintenance of wetlands vegetation is for the five year period following construction.

Vegetation Inspection/Maintenance -
estimate 43,000 sq. yards @ $2.40/sq. yard: $103,200(*)

(*) annual cost for each of initial five years only

The cost of wetlands environmental monitoring has been estimated for a five year period following remediation.

Item	Unit	Unit Cost	Quantity	Total
Sampling	event	$3,300	2	$6,600
Laboratory Chemistry	test suite	$13,800	2	$27,600
Laboratory Macroinvertebrates	test suite	$10,500	2	$21,000
			ANNUAL TOTAL COST	$55,200(*)

(*) annual cost for each of initial five years only.

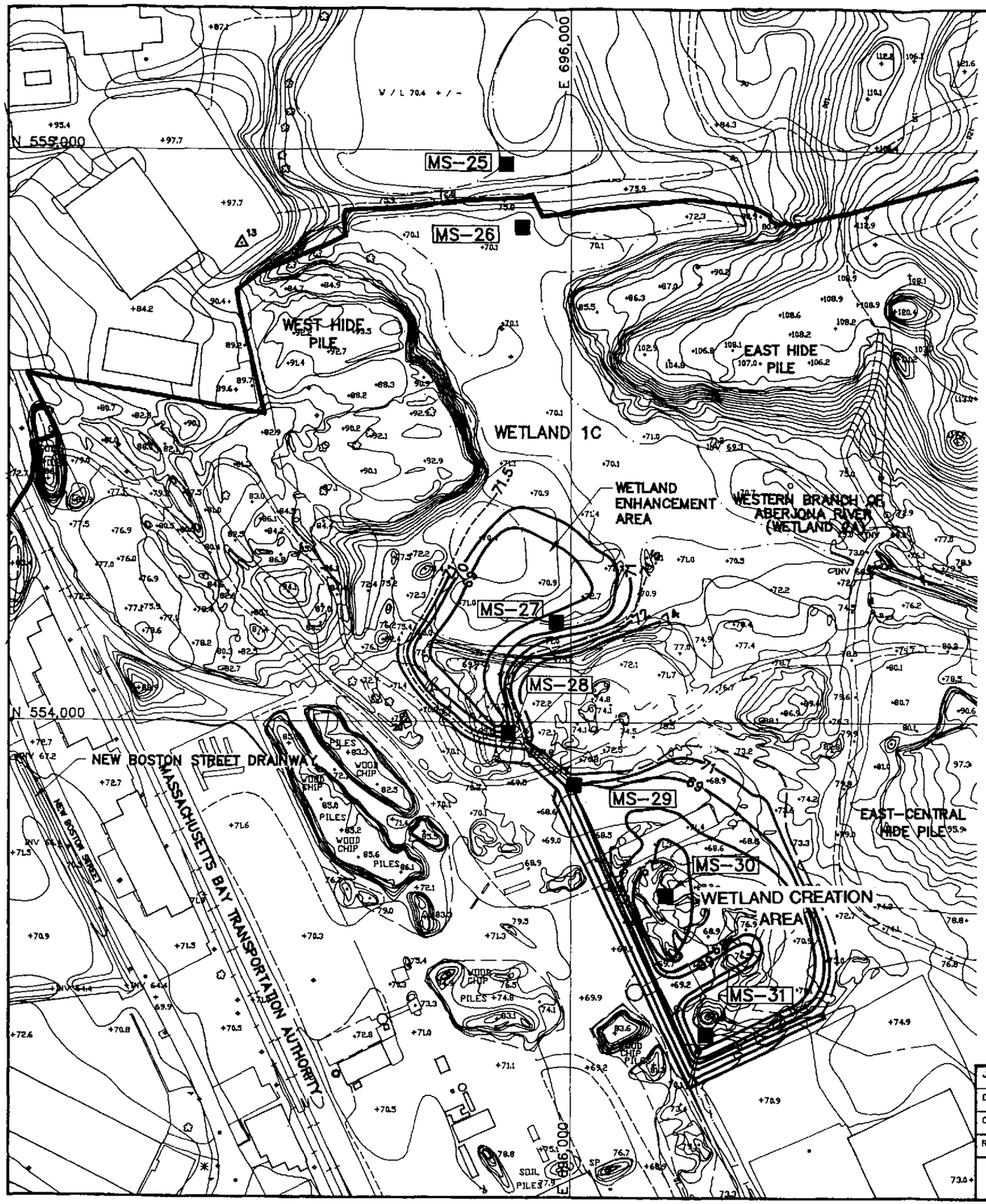
WETLANDS ANNUAL TOTAL (FIRST FIVE YEARS ONLY) $158,400

6.0 INSPECTION AND MAINTENANCE OF THE GROUNDWATER RECHARGE SYSTEM

Inspection and maintenance of the groundwater recharge system involves inspection of the basin for erosion of the rip-rap banks and removal of vegetation and floating matter which could impede passage of flood waters. These activities have been estimated to require two man-days per year, at a cost of $1,000.

7.0 REPORTING

It is assumed that once the initial quarterly and annual reports are prepared, the cost to prepare subsequent reports will be minimal because the format will have been defined. It is assumed that annual reporting costs are $2,000.



LEGEND

MS-25 ■ WETLAND MONITORING STATION

NOTES

1) MONITORING STATION LOCATIONS:
   - MS-25 – SHALLOW MARSH ON THE EAST SIDE OF NORTH POND.
   - MS-26 – NORTH END OF WETLAND 1C IN THE REVITALIZED WETLAND.
   - MS-27 – VEGETATED MARSH OF THE ENHANCEMENT AREA SOUTHEAST SIDE.
   - MS-28 – ADJACENT TO THE OUTLET STREAM IN THE ENHANCEMENT AREA.
   - MS-29 – CREATED WETLAND AT THE MOUTH OF THE INLET STREAM.
   - MS-30 – LOWEST ELEVATION WITHIN THE CREATED WETLAND.
   - MS-31 – CREATED WETLAND AT THE OUTLET STREAM.

2) MONITORING PARAMETERS AND METHODS ARE PROVIDED IN SECTION 19.5 AND 19.6.

3) MONITORING FREQUENCY:
   SURFACE WATER SAMPLES WILL BE TAKEN AT ALL STATIONS IN MAY, AUGUST, AND OCTOBER FOR 5 YEARS FOLLOWING CONSTRUCTION OF THE CREATED WETLAND.

   SEDIMENT SAMPLES WILL BE COLLECTED BIANNUALLY IN MAY AND OCTOBER FOR 5 YEARS AT ALL RELEVANT MONITORING STATIONS.

   MACROINVERTEBRATES WILL BE SAMPLED BIANNUALLY IN MAY AND OCTOBER AT ALL STATIONS.

   WATER LEVEL AND FLOW DATA WILL BE COLLECTED WEEKLY DURING THE FIRST TWO GROWING SEASONS AFTER CONSTRUCTION OF THE CREATED WETLAND AT STATION MS-29, MS-30, AND MS-31.

200 0 200
scale feet

JOB No.:	903-6400	SCALE:	AS SHOWN
DR BY:	CDS	DATE:	04/23/93
CHK BY:		FILE No.:	MA10-002
REV BY:		DR SUBTITLE:	00

NORMANDEAU ASSOCIATES INC.
ENVIRONMENTAL CONSULTANTS

WETLAND MONITORING STATION

INDUSTRI-PLEX SITE REMEDIAL TRUST

FIGURE 19-1

8.0 SUMMARY

First Three Years

Permeable/impermeable covers, drainage structures	$ 37,840
Gas collection system	$ 3,923
Gas treatment system	$ 20,000
Wetlands	$158,400
Groundwater recharge basin	$ 1,000
Reporting	$ 2,000
GRAND TOTAL	$223,163/YR

Fourth and Fifth Years

Permeable/impermeable covers, drainage structures	$ 28,840
Gas collection system	$ 3,923
Gas treatment system	$ 20,000
Wetlands	$158,400
Groundwater recharge basin	$ 1,000
Reporting	$ 2,000
GRAND TOTAL	$214,163/YR

After Four Years

Permeable/impermeable covers, drainage structures	$ 28,840
Gas collection system	$ 3,923
Gas treatment system	$ 20,000
Groundwater recharge basin	$ 1,000
Reporting	$ 2,000
GRAND TOTAL	$ 55,763/YR

APPENDIX 19-B

Health and Safety Specifications for Operation and Maintenance

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LIST OF ATTACHMENTS

Attachment 1 References

1.0 INTRODUCTION

1.1 Purpose

The purpose of these Health and Safety Specifications for Operation and Maintenance (O&M) is to establish minimum health and safety requirements for the O&M contractor during implementation of the Remedy for Contaminated Soils and the Air Remedy for the East Hide Pile (the remedies) at the Industri-Plex Site in Woburn, Massachusetts.

1.2 Applicability

These requirements should be used by the Contractor's Health and Safety Officer to assist in preparation of the Contractor's Health and Safety Plans. These requirements shall not relieve any party from compliance with any applicable State, Federal, or other health and/or safety requirements and safe construction practices which are not identified in these requirements.

2.0 SITE BACKGROUND/REMEDIES

The Industri-Plex Site, which covers approximately 248 acres in the northern part of Woburn, Massachusetts, is a CERCLA site. Certain chemicals known to be present at the Site may cause adverse health effects under certain circumstances. Various chemical hazards are identified below, based upon Site data presented in the Record of Decision (ROD), Remedial Investigation (RI), and Pre-Design Investigation (PDI) reports. These reports, which are identified in Attachment 1, should be consulted for more detail. These reports are contained in the Administrative Record for the Industri-Plex Site, and can be reviewed at the City of Reading Public Library and USEPA Region 1 in Boston, MA.

Potentially impacted media include air, soil and water. Potential exposure pathways include, but are not necessarily limited to, ingestion, inhalation of vapors and particulates, and dermal contact. Materials of greatest concern include:

1. Animal hide residues in above-grade piles or buried in soil and stream/pond sediments which give off a noxious odor (hydrogen sulfide and methyl mercaptan) and methane;

2. Soils and sediments containing metals and certain organic compounds; and

3. Groundwater containing benzene, toluene, hydrogen sulfide, cyanide, metals, ammonia, and other inorganic and organic species.

Many of these materials are known or suspected human carcinogens and might cause adverse health effects under certain circumstances. In accordance with the ROD, three remedies will been instituted at various parts of the Site in order to protect public health and the environment from the above chemical hazards. The three remedies comprise:

1. Remedy for Contaminated Soils, Sediments and Sludges,

2. Groundwater Remedy, and

3. Air Remedy for the East Hide Pile.

The soil and sediment remedy is intended to prevent physical contact with soil and sediment containing arsenic, lead, and/or chromium above ROD Action Levels of 300 ppm, 600 ppm, and 1000 ppm, respectively. Physical contact is prevented using either pre-existing structures (such as buildings and paved roadways), or a permeable soil cover or cover equivalent.

The groundwater remedy is intended to extract and remove constituents of concern from the Site groundwater.

A gas collection and treatment system constitutes the Air Remedy for the East Hide Pile.

Institutional Controls are an integral part of the remedies and are intended to protect the integrity of the remedies in perpetuity.

3.0 HEALTH AND SAFETY PLANS

The Contractor shall prepare and implement Project Health and Safety Plans. The Health and Safety Plans shall conform with the requirements of 29 CFR 1910.120 and shall be prepared by the Contractor's Health and Safety Officer. The Contractor's Health and Safety Officer shall be a Certified Industrial Hygienist and shall have experience with establishing and implementing health and safety plans and programs for hazardous waste site operations. The Contractor's Health and Safety Plans shall incorporate the requirements contained herein and shall describe all actions to be taken to protect worker health and safety. These plans shall identify all tasks to be undertaken by the Contractor and shall establish Health and Safety procedures for each task. The Contractors's Health and Safety Plans shall be approved by the Contractor's Health and Safety Officer, the USEPA, and MDEP prior to the initiation of any fieldwork. Any modifications to the Plans shall be approved by the USEPA and MDEP.

4.0 RECORD KEEPING

All parties engaged in on-Site activities must read the Contractor's Health and Safety Plans for the relevant tasks. Documentation demonstrating compliance with this requirement shall be maintained on-Site by the Contractor. Written evidence of compliance with 29 CFR 1910.120 shall also be maintained on-Site in the Contractor's files. Copies of such documentation shall be provided to the Trust Representative.

ATTACHMENT 1

References

ATTACHMENT 1

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