file copy

Conceptual Site Model Report
Union Chemical Company Site
214 Main Street
South Hope, Maine
Second Revision

Submitted to:
United States Environmental Protection Agency - Region I
and
Maine Department of Environmental Protection

September 10, 2004

ENGINEERS • SCIENTISTS • PLANNERS

RIZZO
ASSOCIATES
A TETRA TECH COMPANY

One Grant Street
Framingham, MA 01701-9005
(508) 903-2000
(508) 903-2001 *fax*
www.rizzo.com

September 10, 2004

Mr. Terry Connelly
U.S. Environmental Protection Agency
Region I
1 Congress Street, Suite 1100 (HBT)
Boston, MA 02114-2023

Ms. Rebecca Hewett
Maine Department of Environmental Protection
State House Station 17
Augusta, ME 04333

Re: Conceptual Site Model Report
Union Chemical Company Site
214 Main Street
South Hope, Maine

Dear Mr. Connelly and Ms. Hewett:

Attached is Rizzo Associates, Inc. (Rizzo) Conceptual Site Model Report summarizing the environmental investigations, remedial activities, and monitoring activities that have taken place on the Site, and providing opinions on the current and projected environmental conditions at the Site.

If you have any questions regarding this report please contact Bob Ankstitus at 508-903-2415.

Very truly yours,

Christopher K. Nitchie
Environmental Engineer

William C. Phelps
Senior Project Geologist

Robert J. Ankstitus, P.E.
Senior Project Manager

Raymond C. Johnson
Senior Vice President

P:\2000\2420\SITE_CONCEPT_MOD_RPT\CONCEPTUAL SITE MODEL_JUNE 04 DOC

Table of Contents

List of Tables

List of Figures

List of Appendices

Executive Summary

Rizzo Associates, on behalf of American Environmental Consultants, has prepared this Conceptual Site Model (CSM) Report for the Union Chemical Company Superfund Site in South Hope Maine.

Site History

Union Chemical Company (UCC), located on Route 17 (Main Street) in a rural, residential area of South Hope, Maine, was founded in 1967 as a commercial operation to produce and distribute a patented solvent for the removal of furniture finishes. The predominant operations performed at UCC during most of the operating life of the facility were handling, storage, recycling, repacking, and destruction of industrial solvents and other organic chemicals.

In 1979, the Maine Department of Environmental Protection (MEDEP) discovered that groundwater below the Site and surface water in Quiggle Brook were impacted by volatile organic chemicals. Subsequently, investigations were conducted to assess the source, nature and extent of volatile organic chemicals in soils and groundwater at the Site. A study conducted for the Union Chemical Company in 1981 found that two contaminated groundwater plumes were present in the area between the UCC facilities and Quiggle Brook. Volatile organic compounds (VOCs), similar to those processed by Union Chemical Company, were the principal contaminants observed in the plumes and Quiggle Brook.

Following the identification of the release of VOCs an evaluation of the conditions at the Site was performed and remedial technologies were aggressively implemented over the course of 20 years as described in Section 2.0 of this report. Approximately $15.1 million has been spent on remedial efforts at the UCC Site. The decontamination and off-site disposal of approximately 2,500 55-gallon drums and 28 tanks and their contents (1984) represent the most significant volume of hazardous materials removed from the Site (approximately 1.5 million pounds of contaminants). Large volumes of hazardous materials were also removed during the decontamination, demolition and off-site disposal of the original Site buildings (approximately 2-million pounds).

A soil and groundwater treatment plant operated at the Site from 1996 until 2000 which removed approximately 9,500 pounds of VOCs from the UCC Site (IT, Treatment Plant VOC Removal Figure). In 1998, following nearly two years of treatment system operation, sufficient contaminant mass reduction had been demonstrated by IT to achieve closure and the

Performance Standards for the unsaturated and upper saturated zone soils at the UCC Site.

It is estimated that approximately 139 pounds of VOCs and SVOCs remain in the subsurface of the Site. This residual VOC and SVOC volume represents only a fraction of the approximately 10,000 pounds that have been removed from the Site groundwater and soils and the nearly 3.5 million pounds of chemicals and contaminated media that were removed from the Site surface.

Site Description

The UCC Site is located within the Quiggle Brook watershed, and topography of the Site slopes from west to east, with a steep slope down to Quiggle Brook on the eastern flank of the Site. Quiggle Brook represents the primary potential receptor for the Site. Quiggle Brook is the outflow of nearby Fish Pond. Fish Pond is a man-made feature resulting from a dam constructed at its outflow. The Fish Pond dam is located approximately 400 feet northeast of the Site. Quiggle Brook flows to the south-southwest eventually discharging to Crawford Pond in the town of South Union, Maine, approximately 3 miles downstream of the UCC Site. Crawford Pond is used as a drinking water source and a recreational area and is considered a secondary potential receptor.

Based on surficial geology maps and soil boring logs, the surficial deposits at the Site consist primarily of till. The till is glacial deposit and likely has a marine origin. The till is generally a heterogeneous mixture of sand, silt, clay and stones. The till thickness varies from 80 feet in proximity to Quiggle Brook, to less than 25 feet in the western portion of the UCC Site, and is directly underlain by bedrock.

Groundwater exists in both the till and bedrock at the Site. Due to the regional topography, overburden groundwater west of Quiggle Brook is presumed to flow east toward Quiggle Brook, and groundwater east of Quiggle Brook flows west toward Quiggle Brook (Canonie, 1990). Depth to groundwater varies from 15 to 20 feet below the ground surface and artesian conditions were observed to exist in some wells located adjacent to Quiggle Brook. The potentiometric surface maps generated for the overburden and bedrock units at the UCC Site suggest that much of the groundwater beneath the UCC Site ultimately discharges to Quiggle Brook. Piezometric heads in the till suggest that the overburden unit acts as a single layered aquifer (Canonie, 1990).

For the purposes of this conceptual site model, bedrock at the Site has been classified into three categories: weathered bedrock, shallow bedrock and deep bedrock. This classification is based largely on the evaluation of bedrock cores and geophysical logging of the boreholes. The break between shallow and deep bedrock occurs at a structural unconformity (change in orientation of the strike and dip of fractures in the bedrock) which was observed at a depth of approximately 110 feet below the ground surface and approximately 30-50 feet below the bedrock surface.

Core logs and observations made during monitoring well installation have indicated that the weathered bedrock comprises up to the top 5 feet of the bedrock surface. The weathered bedrock at the Site is likely the most significant migration pathway for groundwater and the VOC contamination. The highly weathered horizon has been categorized as a fine to medium sand in some of the boring logs, providing a comparatively more porous and transmissive layer relative to the overlying till and the underlying competent bedrock. VOC contaminants may migrate from the till into the weathered bedrock on the western and central portions of the Site. Downward hydraulic gradients have been observed in these areas, however, the effect of the negative gradients is likely dampened by the tight till formation in the overburden and the sorptive nature of these soils. Additional contaminant migration may occur through monitoring wells with screened intervals set in the overburden and upper portions of the weathered rock in areas where downward gradients exist. Groundwater flow in the weathered rock is anticipated to follow the slope of the bedrock surface and migrate east and southeasterly towards Quiggle Brook. The upward gradient on the eastern portion of the Site likely causes a corresponding upward migration of contaminants from the weathered bedrock to the till, and ultimately discharge to Quiggle Brook.

Shallow bedrock is defined as being below the weathered bedrock and approximately 5 to 50-feet into bedrock. Core logs from several of the shallow bedrock wells indicate that the upper 15 to 25 feet of the bedrock is moderately fractured. Numerous horizontal to subhorizontal fractures were noted in the upper cores, with a general decrease in fracture frequency and aperture with depth. Steeper dipping fractures and joints were observed in deeper core samples, such that groundwater migrating under downward gradients on the western and central portions of the Site would likely move through the weathered bedrock layer and would flow down dip, deeper into the formation and to a lesser degree along the strike of the fractures. Evidence of this migration is observed in the elevated contaminant concentrations detected in shallow bedrock wells B-6A-D and B-8A-D. As with the overburden and weathered bedrock, the upward gradients that occur along the eastern portion of the Site, adjacent to Quiggle Brook, will limit the downward and eastward migration of the contaminants in the shallow bedrock. Evidence of artesian conditions is commonly observed in shallow bedrock monitoring well B-12A-D, located adjacent to Quiggle Brook. These artesian conditions are likely the result of the steep gradient in the weathered portion of the bedrock and the confining nature of the clayey till overlying the bedrock. An additional factor is a possible hydraulic connection with Fish Pond, where large areas of bedrock outcrop exist at the upgradient and northern end of the pond. Water from the pond may be hydraulically connected with the bedrock at the Site via the same small aperture fractures observed in the Site bedrock and may result in further dilution of the contaminants as they discharge and are diluted in the brook.

Deep or competent bedrock generally occurs at depths greater than 110 feet below the ground surface. Limited data is available regarding the lithology and structure of the deep bedrock at the Site. Only 5 of the wells at the Site can be classified as being screened in the deep bedrock: NBW-L, ODW-U, ODW-L, OPW and ITW-1.

For the CSM, deep bedrock is defined as bedrock greater than 110-feet below the ground surface. Very limited migration of contaminants is likely to occur in the deep bedrock. As with the competent shallow bedrock, contaminants are anticipated to migrate in the direction of dip (southeast) until they encounter the unconformity and associated change in the direction of the strike and dip of the fractures. Geophysical logging of the wells has indicated that fractures below 110 feet dip to the southwest. Groundwater is anticipated to migrate down dip towards the southwest. However, at this depth, decreasing fracture frequency and aperture will likely result in "pinching out" of the contaminant plume. In addition, the effects of continued sorption, dilution and natural degradation of the contaminants in the overburden and weathered bedrock will serve to further limit the volume of contaminants available for deeper migration.

Water Quality Indicator Parameters

Measurements of water quality indicator parameters including pH, specific conductance, dissolved oxygen (DO), turbidity, oxidation/reduction potential (ORP), and temperature have been collected and recorded during the low-flow purging of Site wells during each of the semi-annual sampling events since the MOM/SC treatment system was shut down in 2000. Ranges of values recorded for each parameter between Q30 and Q35, indicate that the Site is returning to static conditions with respect to physical parameters following the implementation of the MOM/SC remedy.

Temperature readings for the groundwater and surface water at the Site have been observed to fluctuate seasonally. The pH readings observed during Q30 through Q35 sampling events were similar to those reported from the Q11 (January, 1995) and the Q12 (April 1995) sampling events with pH readings generally between 5 and 8. Elevated (basic) pH readings have been consistently observed in some wells over the history of the Site. For example, monitoring well MW-15D has reported pH values greater than 11 both prior to MOM/SC system start up and after the MOM/SC system was shut down. Due to the recent lactate additions, specific conductance values were generally higher during Q35 than during the pre-remediation groundwater sampling events. Pre-remediation specific conductance values in the groundwater were generally between 40 and 500 uS/cm, however individual wells had elevated conductivity values reported as high as 1,990 uS/cm (MW-15D, Q11). The anomalies represent effects of remedial additives (permanganate and lactate) as well as potential contaminant impacts. Overall, the water quality indicator parameters have been at or approaching expected background conditions since the termination of the active remediation activity at the Site (Year 2000).

Site Hydrology

Based on the conditions described in the historical Site documents and available laboratory analytical data, Rizzo Associates has divided the overburden into five zones of approximately similar subsurface conditions. These five zones were used to characterize and make predictions regarding contaminant plume migration at the Site as well as identifying overburden areas that will likely retain contaminant concentrations for a prolonged period of time. Figure CSM-8 presents the five overburden zones that have been established for the CSM to describe subsurface units of the Site with similar geologic and contaminant transport characteristics. The properties of each zone are described in this report.

The overburden at the Site has been divided into five distinct zones based on geology and contaminant distribution, with the till matrix becoming more dense to the east. The results of numerous gauging rounds at the Site have demonstrated that groundwater in the till generally flows from northwest to southeast across the Site. As such, groundwater flowing onto the Site first enters Zone 1 where groundwater generally flows through the sandy till matrix. Downward vertical gradients in this portion of the Site may cause portions of the groundwater to migrate into the weathered bedrock layer. As groundwater migrates east across the Site into Zone 2, groundwater flow is retarded by the increasingly fine-grained and dense nature of the till, but may follow preferential pathways associated with observed boulders and/or cobbles within the till or migrate downward into the weathered bedrock layer. Downward gradients in this area may cause migration of contaminants deeper into the till and/or bedrock at the Site. Further eastward migration of groundwater (and contamination) is likely further retarded by the clayey nature of the till in Zone 3, and migration through the weathered bedrock likely becomes the primary transport pathway. Preferred pathways also may exist in Zone 3 due to the existence of numerous boulders and cobble along the eastern side of Zone 3. Due to the fine-grained nature of the till in this zone, contaminants are likely to remain, in part, sorbed to the till matrix. Upward gradients observed in some monitoring wells in this zone likely reflect the confining nature of the till and the head provided by the western ridge and Fish Pond. Fish Pond's hydraulic effects will likely be limited by available fractures and hydraulic connections to the Site through the bedrock and till.

The hydraulic connection to Fish Pond is expected affect the hydrology of a portion of the Site, even though this connection is expected to be limited by the dense nature of the subsurface materials. During the operation of the pump and treat system, and following achievement of the dewatering of the Site, pumping was reduced from 29 wells to 4 wells to maintain hydraulic control. Three of these four wells (each screened into weathered bedrock) were within Zone 3. Continued pumping from these four wells maintained the de-watered subsurface at a pumping rate of approximately 5-6 gallons per minute. The potential hydraulic connection between Fish Pond and the bedrock at the Site is expected to be through fractures that are limited in size and number such that despite the hydraulic head present at Fish Pond a limited number of pumping locations were capable of keeping the Site dewatered. Additionally, when the pump and treat system was shut down, the time necessary for groundwater to return to pre-pumping conditions in the overburden was substantial, reinforcing the theory that the expected high density of the till matrix does not readily transmit water even though substantial head was available to move groundwater through the Site's overburden.

Upward gradients, coupled with the tight till at the Site, have effectively limited further migration of contaminants eastward past Quiggle Brook. Westerly groundwater flow was observed in the wells that were located on the eastern side of the brook, which serves to limit migration of the VOC contaminants beyond the brook area. Although this model concludes that discharge of contaminated groundwater occurs to the brook, laboratory analysis has not detected contaminants at concentrations above the Performance Standards in the surface water samples. This non-detect condition is likely due to the low volume discharge of contaminated groundwater into the brook and the rapid dilution/aeration provided by the brook.

Groundwater Analytical Data

Groundwater analytical data for the sampling rounds conducted since the November 2000 MOM/SC treatment system shut down provide evidence that concentrations of VOC contaminants above the Performance Standards still exist at the Site.

During the most recent sampling round (Q35), 16 VOC analytes and one semi-volatile organic compound (DMF) were reported to be present in groundwater at concentrations above their respective Performance Standards. Contaminant distribution discussions in this report focus on the four compounds that are the most prevalent on the Site: 1,1 dichloroethane (DCA), cis-1,2 dichloroethene (DCE), trichloroethene (TCE), and dimethylformamide (DMF). For the purposes of discussing the contaminant distribution, the Site has been separated into three geologic units: overburden, shallow/weathered bedrock and deep bedrock.

Detected concentrations of the target analytes within the overburden contaminant plume suggest that concentrations of DCA continue to represent the largest plume area for the four selected analytes in the overburden aquifer. The Q35 (Spring 2004) data suggests that the DCA contaminant plume in the overburden aquifer extends through the central, south and east portions of the Site cap area and to the south/southeast of the Site cap. A large portion of the TCE plume covers a smaller area within the DCA plume located in the central and southeast areas of the Site cap and extending east of the capped area toward Quiggle Brook. The TCE plume extends farther to the north (MW-14-S) in the Site cap area than the DCA plume. The 1,2-DCE plume is limited to the central and eastern portion of the Site cap and east of the capped area toward Quiggle Brook and is located entirely within the DCA and TCE plumes. A comparatively smaller DMF plume area in the overburden aquifer was observed to the southeast of the capped area in the B-12 well couplet.

VOC contaminant concentrations in the overburden are declining as a trend and have been substantially reduced by the MOM/SC. The overburden aquifer VOC contaminant plumes are expected to gradually migrate in the downgradient (east/southeast) direction, however the plume migration appears to be occurring at a very slow rate such that little change or shift in the plume locations has been observed over the recent two and a half year time frame (Q30 and Q35 sampling events). Due to the apparent low flow velocity of the Site groundwater through the till, sorption of VOC contaminants to the till matrix is believed to be retarding the migration of the VOC plumes. In the areas of the Site with the lowest groundwater flow velocities (till with clays and silts), sorption may be strong enough to negate advective transport entirely and slow the diffusion and partitioning of the VOCs into the groundwater from the soil matrix. Though this Site condition mitigates the migration of the contaminant plumes these sorptive properties will likely extend the amount of time required to flush the contaminants from the overburden aquifer and thereby reduce their concentrations to meet the Performance Standards for the Site. Dilution and localized areas of microbial degradation of the contaminants are expected to further reduce the contaminant concentrations at a slow rate in the overburden.

Detected concentrations of the selected analytes within the shallow bedrock contaminant plume suggest that the DCA plume extends from well B-12A-D on the eastern fringe of the Site to well B-8A-D, which is located in the south-central portion of the Site, with the majority of the contaminant mass located between wells B-6A-D and well B-8A-D. DCA was also reported in shallow bedrock wells B-5C-D and NBW-U at concentrations below the Performance Standards indicating that these wells are located on the fringe of the DCA plume area. The detected concentrations of TCE, 1,2-DCE and DMF suggest that their respective groundwater plume areas cover a comparatively smaller area and are generally contained within the larger DCA plume area.

The shallow bedrock contaminant plume inferred from the Q35 sampling data is almost identical in size and location to shallow bedrock plumes inferred from the Q30 through Q34 sample events covering the last two and a half years. Observed increases in the DCA plume area over this time are attributed to the addition of a new monitoring point (NBW-U) and not likely the result of the expansion of the actual plume. With the exception of well B-6A-D, the Site wide trend dating back to Q30 and Q31 indicates that VOC concentrations are gradually decreasing in the shallow bedrock and have been substantially reduced by the remediation activities at the Site. Reported VOC concentrations in well B-6A-D have been observed to remain relatively stable over this period with some indication of a gradual increase in concentrations. Migration of the VOC contaminant plume(s) within the shallow bedrock is expected to primarily occur within the weathered strata at the bedrock surface, and to a lesser degree, through the fractures observed in the more competent shallow bedrock. Contaminant migration and groundwater flow in the shallow/weathered bedrock is anticipated to be towards Quiggle Brook (east/southeast) along the strike and dip of the bedrock with and upward component in the area of Quiggle Brook. Impacts to Quiggle Brook and/or downgradient receptors have not been identified by biannual sampling rounds conducted to date. While preferred pathways in the fractures may provide conduits for small volumes of contaminated groundwater to migrate deeper within the bedrock, the Q30 through Q35 data does not indicate that the shallow bedrock aquifer contaminant plume(s) as a whole have migrated horizontally beyond their respective inferred plume area(s) over the two and a half year time period since Q30. The gradual increase in contaminant concentrations in well B-6A-D may be an indication that contaminants are migrating into the shallow bedrock in this area of the Site, however the increase might also be the result of this location being slower to return to equilibrium following treatment than the other zones at the Site due to non-transmissive subsurface conditions and their associated very slow groundwater flow velocities (near stagnant).

Monitoring well ODW-L is the only deep bedrock monitoring well that has been sampled consistently as part of the bi-annual sampling rounds since the November 2000 treatment system shut down. An additional deep bedrock monitoring well, monitoring well NBW-L, was installed in November 2003 and has been sampled on two occasions since its installation. One comprehensive round of deep bedrock sampling was performed by Rizzo Associates as a part of a bedrock conditions analysis in October 2002. The deep bedrock aquifer contaminant plume inferred from the November 2002 deep bedrock sampling round and available Q35 data (ODW-L and NBW-L) is presented in the CSM. DCA is the only VOC that has been reported at concentrations greater than its Performance Standard in the deep bedrock. DCA has only been reported above its Performance Standard in wells ODW-U and ODW-L at concentrations typically in the 20 ug/L range. Well ODW served as the water supply well for the former UCC facility. VOC contaminants were detected in well ODW in the mid-1980's. Based on Site subsurface conditions, it is believed that the VOC's were drawn to well ODW under pumping conditions and not as a result of VOC migration from the source area under static conditions.

The potential for migration of VOCs into or through the deep bedrock at the Site is expected to be limited to flow through the zones where a sufficient number of small aperture fractures exist within the rock. Monitoring wells ODW (now ODW-L and ODW-U) and NBW-L are the only deep bedrock sampling locations downgradient of the source area. Monitoring well ODW is the only deep bedrock sampling location at the Site with reported concentrations that exceed the Performance Standards. Due to the significant space between these well locations, the installation of a new well down-strike and down-dip from well B-8A-D and between well ODW and well NBW may be necessary to close an apparent coverage gap for the south section of the Site.

The NBW well couplet contains a deep bedrock point (NBW-L) downgradient of the Site source area where VOC concentrations have not been detected. According to the geophysical data collected by Hagar GeoScience during the installation of the NBW well couplet, the NBW-L well is located in the down-dip direction from the source area at the Site. DMF, an SVOC, was detected in well NBW-L during the Q34 (November 2003) sampling round at a concentration below the Performance Standard. The presence of VOCs in well ODW-L and SVOCs in well NBW-L indicates that the deep bedrock is hydraulically connected to the source area at the Site.

Under non-pumping conditions migration of the VOC contaminant plume to or from the deep bedrock aquifer appears to be minimal. This is likely due to the small size and number of fractures available to transmit groundwater. This Site condition was observed during the logging of the deep wells at and adjacent to the Site. Granitic intrusions in the deep bedrock may also cause the fractures to be discontinuous and not interconnected, and thus limit the ability of the rock to transmit significant volumes of groundwater. A tracer test performed at well ODW indicated that groundwater flows at a rate of 4.9 feet per year in the shallow bedrock and 2.1 feet per year in the deep bedrock.

The extent of the DCA plume in the deep bedrock south of the ODW well couplet has not been fully defined. The aperture size, orientation, strike and dip of the fractures at the Site would likely place the ODW well in a cross gradient location from the contaminant plumes. However, DCA concentrations above the Performance Standard have been identified in ODW-L. Based on the ODW well having been used as a production well for the former chemical recycling/manufacturing facility on the property it is likely that the detected VOC concentrations were pulled to the ODW well via the pumping activities. The concentrations of DCA in ODW-L have declined over time but currently remain nearly 5-times the Performance Standard. It is likely that the DCA plume does not extend significantly (far enough to reach potential receptors) beyond ODW to the south due to the low transmissive nature of the bedrock and small number fractures available for groundwater flow. Measurable impacts to potential receptors, including surrounding drinking water supply wells, have not been identified downgradient of the Site. It is expected that under non-pumping conditions further downgradient migration of VOCs will not occur in significant volumes and distances beyond well ODW within the deep bedrock due to the limiting properties of the deep bedrock which include low groundwater velocities, small fracture aperture, and small number of available fractures to transmit water.

Surface Water Analytical Data

VOCs have not been detected at concentrations above the laboratory method detection limits in the surface water samples collected from

Quiggle Brook since the Site treatment system and permanganate addition program was completed in the Fall of 2000.

Treatment System Effectiveness

Comparing the average and maximum VOC values between Q12 and Q35 provides an approximate assessment of how effective the MOM/SC remedy combined with oxidant and/or carbon source additions have been to date. From the reported data, DCA was the VOC with the greatest observed concentration rebound following the treatment system shut down and is currently the contaminant of primary concern at the Site. Despite observed rebound in the average concentration of DCA since the treatment system shutdown, the reduction in the average DCA concentrations in the overburden was from 2,865 ug/L to 487 ug/L between Q12 and Q35; and the reduction in the average DCA concentrations in the bedrock was from 1,144 ug/L to 405 ug/L. Between Q12 and Q35 the maximum reported concentration of DCA in the overburden was reduced from 13,000 ug/L (Q12, B-12C-S) to 3,100 ug/L (Q35, B-9A-I), and the maximum reported DCA concentration in the bedrock was reduced from 11,000 ug/L (Q12, B-6A-D) to 3,300 ug/L (Q35, B-6A-D).

Contaminants other than DCA generally showed greater reductions in their concentrations. Of the 13 VOCs reported at concentrations above the Site Performance Standards in Q12, six were no longer reported at concentrations above their Performance Standards for Q35, bis(2-ethylhexyl)phthalate, methylene chloride, toluene, total xylenes, 1,1,1-trichloroethane, and trans-1,2-dichloroethene).

While the operation of the MOM/SC remedy did not achieve the remedial action goal for all of the contaminant Performance Standards, it was nevertheless effective in reducing the VOC and DMF concentrations in the soil and groundwater at the Site.

Future Monitoring and Time to Reach Performance Standards

At this time it is estimated that approximately 140 pounds of the four primary contaminants (DCA, DCE, TCE, and DMF) remain in the subsurface at the Site. Attempts to further reduce VOC contaminant concentrations at the remaining hot spots via chemical oxidation could not achieve the target cleanup levels due to resistant contaminants (DCA) and the limited permeability of the overburden and weathered bedrock formations. Carbon source additions proved successful in creating and/or returning the Site to a reducing environment; however, evidence that this reducing environment is accelerating the biodegradation of the primary contaminants, to the extent that this technology could achieve a timely cleanup of the Site, have not been observed at this time. To the extent practicable the feasible chemical, physical and mechanical technologies for remediating the Site to achieve the Performance Standards have been implemented and VOC concentrations have been reduced by these technologies . Further reductions in the VOC concentrations by alternative commercially available technologies are believed to be infeasible due to the dense units, low permeability, and low transmisivity exhibited by the subsurface material at the Site.

The Site conditions indicate that the most feasible technology to implement may be long term monitoring and monitored natural attenuation (MNA). The MNA and long term monitoring phase should provide sufficient monitoring data to demonstrate that the groundwater contaminant plume(s) is not migrating beyond the Site limits and that downgradient receptors are not being negatively impacted. The implementation of a long term monitroing program will also assess the progress of natural processes such as biodegradation, dispersion and dilution to reduce the VOC concentrations and achieve the Performance Standards.

The CSM provides a more thorough explanation of the monitored natural attenuation process at the Site and the currently projected amount of time that it will take for the Site to reach the Performance Standards using natural attenuation. Currently projected times for 5 specific wells on the Site to reach the Performance Standards through natural attenuation range from 11 to 122 years.

Conceptual Site Model Conclusions

Water quality, geological and hydrological data collected during the numerous subsurface investigations have been utilized to develop a conceptual site model for the former UCC Site. Active remediation by the MOM/SC remedy has effectively remediated the unsaturated soils at the Site that were the source area for the groundwater contamination observed in the overburden and bedrock units at the Site. This CSM demonstrates that Site conditions have essentially reached equilibrium, and that migration of contaminants at detectable concentrations beyond the limits currently defined has not been observed in two and a half years. We conclude the following:

- **Source Area Removal** Initial response actions implemented at the Site included the removal of 2,000-2,500 55-gallon drums and 28 liquid storage tanks. Asbestos containing Site-related buildings and structures have been demolished and removed from the Site.

As a result of the source area removal, no ongoing and active sources of contamination are known to exist at the former UCC Site.

- **Successful MOM/SC Remedial Activities** Remedial activities, including the operation of the SVE and groundwater pump and treat systems, have reportedly removed approximately 10,000 lbs of VOCs from the subsurface at the Site. The SVE treatment of the soils has been performed successfully such that unsaturated soils at the Site are no longer considered an ongoing source of the dissolved phase VOC contamination. The operation of the groundwater treatment system and subsequent use of remedial additives has resulted in a substantial reduction in dissolved phase VOC contaminant concentrations at the Site. Successful Remediation of the unsaturated soils has reduced the primary source of the dissolved phase contaminants. In the absence of the unsaturated zone soil contaminants, conditions at the Site have appeared to stabilize and reach equilibrium. Some residual VOC contaminants are likely sorbed to the fine-grained matrix of the till at the Site. However, based on the low groundwater transport velocities estimated for the till and bedrock, evidence of significant migration of the VOC contaminants has not been observed and is not anticipated to occur.

- **Stable Contaminant Distribution** VOC contaminant plume maps generated for the overburden and shallow bedrock units at the Site suggest that conditions at the Site have achieved equilibrium. Evidence of contaminant concentration "spiking" has not been generally observed in wells on the downgradient portion of the Site. The inferred VOC plume areas have stabilized or have been observed to be shrinking. Data generated from the most current semi-annual monitoring events has suggested that VOC contaminant concentrations in the overburden and bedrock units are slowly declining.

- **Low Contaminant Migration Potential** Much of the discussion in this conceptual site model has focused on the migration of dissolved phase VOC contamination in the till and underlying bedrock. The overall conclusion of these discussions is that conditions at the Site are not conducive to significant migration of contaminants beyond the limits of the Site. The till at the Site has been shown to produce very little water under pumping conditions and, therefore, is expected to transmit very little water. Yields for wells screened in the till were observed to be only fractions of a gallon per minute. Similar low yields are generally observed in the bedrock. Contaminants that do migrate downgradient at the Site will be limted in volume and concentration due to the successful source removal/reductions achieved at the Site. The limited quantity of VOC contaminants that migrate will likely flow in a east/southeast direction where they will eventually discharge to Quiggle Brook and be diluted to below detectable levels upon discharge via the assimilative capacity of the brook. Contaminant migration into deeper bedrock is not considered to be significant due to the low VOC concentrations detected and the limited pathways available to the VOC contaminants in the deep bedrock.

Little migration beyond the source area of Site contaminants has been documented by the groundwater data collected during 35 rounds of sampling conducted since the initiation of assessment and response activities in 1987. Recent approximations of the extent of the contaminant plumes in the overburden and bedrock are generally similar to those previously generated for the Site and significant reductions in the VOC contaminant concentrations have been observed.

The same subsurface conditions that limit the VOC contaminant migration potential at the Site also make removal of the residual contaminants difficult. The low influent flow rates into the MOM system (less than 8 gpm total from approximately 30 separate recovery wells with less than 1000 pounds of VOCs removed) have demonstrated that active remediation of the dissolved phase contamination through conventional means is not feasible. Similar difficulties with permeabilities and transmissivity were observed during the implimentation of the remedial additive technologies. Other than localized decreases in the wells, influence on contaminant concentrations Site wide and beyond the wells was generally not observed. To the extent practicable, the feasible remedial technologies have been successfully implemented at the Site. Further reduction of VOC concentrations via alternative technologies is not considered feasible at this time. As a result, the implementation of comprehensive, long term monitoring program is proposed for the Site. In general the existing monitoring well network at the Site provides adequate coverage of the contaminant plumes, and offers the ability to monitor for downgradient migration of dissolved-phase contamination. The long term monitoring program may require modification or inclusion of additional monitoring points or a new well(s) to provide the environmental data necessary to evaluate future Site conditions. During periodic 5-year reviews, the long term monitoring data should be analyzed to evaluate the overall Site conditions and to evaluate any feasible new technologies that have the potential to decrease the time and costs to achieve the Performance Standards.

1.0 Introduction

Rizzo Associates, on behalf of Union Chemical RD/RA Trust, has prepared this Conceptual Site Model (CSM) Report for the Union Chemical Company Superfund Site in South Hope Maine. This CSM is intended to provide a concise summary of the environmental and regulatory history of the Site including the release of hazardous chemicals at the Site, the cleanup actions that have been performed at the Site, the subsurface conditions that affect fate and transport of chemicals at the Site, the estimated volume of residual chemicals remaining at the Site and the expected time period before the Site will reach the established Performance Standards and cleanup goals. The information provided here is based on previous environmental reports, submittals to regulatory agencies, completion report documents for remedial efforts at the Site, reported periodic environmental monitoring data, and observations by Rizzo Associates personnel at the Site.

2.0 Site History

The following Site history was compiled primarily from previous environmental documents, submittals to the U.S. Environmental Protection Agency (USEPA) and the State of Maine Department of Environmental Protection (DEP) and reports for the Site and provides a summary of the Site location, the discovery of a release of hazardous chemicals on the Site and the remedial actions that have been performed on the Site. Table 7 presents a chronological list of events that have taken place on the Site.

2.1 Site Location

The Site is located on Route 17 (Main Street) in a rural, residential area of South Hope, Maine. The Site occupies approximately 12.5 acres along the south side of Route 17.

The Site is in close proximity to several residential dwellings, 150 feet to the north along Route 17 and within 400 feet to the west along the south side of Route 17. Additional residential properties are located further to the east and southeast of the Site.

2.2 Site Background and Initial Cleanup Actions

Union Chemical Company (UCC) was founded in 1967 as a commercial operation to produce and distribute a patented solvent for the removal of furniture finishes. Distillation equipment and a small solvent recovery unit were installed at the Site in 1969. Distillation capacity was later expanded to provide solvent reclamation and recycling services for other companies. These services subsequently developed into UCC's primary business. Several additional facilities and operations to support the solvent reclamation services were constructed at the Site between 1967 and 1983, including: a chemical processing and solvent recovery building; an incinerator used for destruction of product residuals and still bottoms; a warehouse used for drum storage; and numerous storage tanks. The predominant operations performed at UCC during most of the operating life of the facility were handling, storage, recycling, repacking, and destruction of industrial solvents and other organic chemicals.

2.2.1 Release Description

In 1979, the Maine Department of Environmental Protection (MEDEP) discovered that groundwater below the Site and surface water in Quiggle Brook were impacted by volatile organic chemicals. Subsequently, site investigations were conducted to assess the source, nature and extent of volatile organic chemicals in soils and groundwater at the Site. A study conducted for the Union Chemical Company in 1981 found that two contaminated groundwater plumes were present in the area between the UCC facilities and Quiggle Brook. Volatile organic compounds (VOCs), similar to those processed by Union Chemical Company, were the principal contaminants observed in the plumes and Quiggle Brook.

Figure CSM-10 shows the approximate locations of former Site features relative to current Site features. This figure also shows the overburden zone designations which are described in Section 4.2 of this report. Releases of VOCs are expected to have occurred at multiple locations from the former UCC facilities at the Site. Large quantities of VOCs were stored and released in the area of the Site designated as Zone 1 which included several drum storage areas as well as the majority of the former processing plant operations. The concrete dike wall near the boundary between Zone 1 and Zone 5 was also used to contain VOC tanks and vessels where fluid transfers and storage subject to spills were located. The surface of Zone 5, near current monitoring well B-9A-I, is likely to have been heavily impacted by release(s) from these features. A leach field in the southwestern portion of Zone 5 is also expected to have been impacted and overlies this area of the Site. Likewise a leach field was located in Zone 2 near current monitoring well P-20. An interceptor trench was installed northeast of this leach field to reduce migration of a spill of VOCs towards Quiggle Brook. It is also likely that VOC impacted materials that collected in this leach field may have been free to flow to the southeast along the ground surface or in the very shallow overburden of the Site. In this manner it is expected that Zone 2 between the leach field and the B-6 series wells, as well as portions of Zone 3, may have been directly impacted by the VOC laden materials released in to the leach field.

2.2.2 EPA Actions

The Maine DEP closed the hazardous waste treatment operations at the Site in June 1984, at which time approximately 2,000 – 2,500 55-gallon drums and thirty liquid storage tanks were found on the Site. All of these drums and all but two of the tanks and their contents (approximately 100,000 gallons) were removed by USEPA and Maine DEP by the end of November 1984 as a removal action under CERCLA. (USEPA Interim Remedial Action Report, September 28, 2001.) The completed removal actions removed approximately 1.8 million pounds of contaminants from the UCC Site at a total cost of approximately $1.6 million.

2.3 Additional Site Assessment and Remedial Actions

A Remedial Investigation/Feasibility Study (RI/FS) and Human Health Risk Assessment were performed by Canonie Environmental in 1990 on behalf of Union Chemical Company RD/RA Trust (UCC Trust). The RI/FS established the applicable regulations for the selected remedy and formulated the remedial action goals for the Site. The remedial action goals for the Sites soil and groundwater as described in the RI/FS are to remediate the impacted groundwater to concentrations that are safe for potential users and environmental receptors, or to background levels (for metals), and to prevent the migration of volatile organics from unsaturated soils into the groundwater that would result in groundwater impacts inconsistent with the groundwater remedial action objectives. The RI/FS determined that impacts to surface water and sediment in Quiggle brook were not sufficient to pose a risk to human health or the environment. The RI/FS did, however, identify a potential risk to future Site employees with respect to an exposure to impacted UCC chemical residues if the Site were to be redeveloped. The RI/FS set the remedial action goal to prevent ingestion or absorption of UCC chemical residues which would result in excess cancer risks greater than 10^{-4} to 10^{-6}; prevent inhalation of asbestos from the Still Building; remove existing structures to allow remediation of impacted soils beneath the structures, and remove impacted facilities materials so that the UCC Site will be suitable for future human and animal habitation.

Following the establishment of the Site remedial action goals, the RI/FS evaluated potential remedial alternatives to eliminate, reduce, or control potential health and environmental risks posed by the Site and meet the goals. Potential feasible response actions evaluated in the RI/FS for groundwater included containment of impacted groundwater; collection, treatment, and discharge of impacted groundwater; and in-situ groundwater treatment. Potential feasible response actions evaluated in the RI/FS for impacted soil included limiting the exposure potential by access restrictions; containment of the soils; excavation and disposal of the impacted soils; excavation, treatment, and disposal of the impacted soils; and in-situ treatment. Potential feasible response actions evaluated in the RI/FS for the UCC facilities and surrounding structures included limiting the exposure potential by access restrictions; containment actions, in which exposure to impacted facilities residues would be prevented by containment of the residues; demolition and disposal of the impacted facilities; demolition, treatment or processing, and disposal of the impacted facilities; and in place treatment of the facilities.

The potential feasible response actions were evaluated in detail in the RI/FS along with the applicable technologies to perform these response actions providing a list of alternatives suitable to meet the remedial action goals. The alternatives were developed to address the impacted soils in the source area (source control), the impacted groundwater (management of migration), the facilities process residuals, and the off-site surface soil.

Based on the information provided in the RI/FS, the EPA selected a source control alternative, a management of migration alternative, a facilities management alternative, and an off-site surface soil alternative for implementation. The EPA provided a period for public comment on the proposed remedial approach and issued a Record of Decision which specified the alternatives to be implemented.

The Record of Decision (ROD) for the Site was signed on December 27, 1990. The ROD describes a comprehensive multi-component remedy to address the contaminated on-Site soils, groundwater and facilities. The ROD specified soil excavation with low temperature thermal treatment and aeration, vacuum enhanced groundwater extraction, facilities demolition and limited action for off-Site soils as the Site remedy.

In June 1994, a proposed change in technology from low-temperature thermal aeration to soil vapor extraction (SVE) was approved, and an

Explanation of Significant Differences was submitted by the EPA for the Site.

2.3.1 Groundwater Monitoring

During the initial phase of the remedial design, the UCC Trust designed and implemented a surface water and groundwater monitoring plan. This plan was reviewed and modified slightly during the subsequent management of migration design process and approved by the USEPA and MEDEP. Subsequent quarterly monitoring was conducted at the Site between 1992 and 1998 and biannual (spring/fall) monitoring has been performed since 1998, as outlined in the UCC monitoring plans.

IT Corporation (IT; formerly Fluor Daniel GTI and Groundwater Technology) was retained by the UCC Trust in 1995 to perform the source control / management of migration (SC/MOM) remedial activities at the UCC Site. The remediation system design and remediation program were implemented and developed by IT on behalf of the UCC Trust.

IT conducted the periodic sampling until the Fall 2001 sampling event (Q30). Beginning in Spring 2002 (Q31), sampling, monitoring and related activities were conducted by Rizzo Associates, Inc.

2.3.2 Facilities Demolition

The ROD called for the facilities to be decontaminated, concrete structures demolished, asbestos in the still building containerized, and then all material to be disposed off-Site at CERCLA approved facilities. Approximately 2-million pounds of contaminated demolition debris and asbestos containing materials were removed from the Site during the facilities demolition. The UCC facilities decontamination and demolition activities were completed in May, 1994 at a cost of approximately $1.2 million. The layout of the Site prior to these activities is shown on Figure CSM-10.

2.3.3 Soil Consolidation and Clay Cap Installation

Construction activities for the UCC source control (SC) remediation and management of migration (MOM) system began in October, 1994. Approximately 2,260 cubic yards of impacted soil was excavated from outlying hotspots and consolidated into the SVE treatment area. A soil cap, consisting of eighteen inches of clay overlain by six inches of gravel, was installed over the entire SVE treatment system area. The clay cap was completed in May, 1995 with the exception of a small area for the placement of soil cuttings from drilling activities during the instillation of SVE and injection wells. At the conclusion of the drilling operations, the final portion of the treatment area cap was completed.

2.3.4 Soil Vapor Extraction and Groundwater Extraction System Installations

Using a RotaSonic drilling method, 28 groundwater recovery wells, 33 SVE wells and 91 hot air injection points were installed between June 4, 1995 and July 30, 1995. The Site treatment building construction was completed in September 1995. Installation of the treatment equipment for the SVE, hot air injection and groundwater extraction systems were completed in the fall of 1995.

The SVE system consisted of an 1200 CFM rotary vane extraction blower, a propane-fired thermal oxidizer for off-gas treatment, and a heat exchange unit which heated clean air from a second 1100 CFM rotary vane blower for the hot air injection system. The groundwater treatment system consisted of sand filters, an equalization tank, a tray-type air stripper, an advanced oxidation unit, two granulated activated carbon (GAC) filters, an ion exchange unit, and a 500-gallon effluent tank.

Interior and exterior piping construction was completed in November 1995 and the SC/MOM system passed a final inspection on January 15, 1996.

2.3.5 Soil Vapor Extraction and Groundwater Extraction System Operation.

The SVE and groundwater extraction system was started in February 1996 and was certified operational and functional by the agencies on April 28, 1997. The hot air injection points complemented the SVE system by accelerating the in-situ volatilization process and promoting removal of the more recalcitrant compounds. Also the groundwater withdrawal, provided by the 28 pumping wells, lowered the water table exposing a greater thickness of VOC contaminated soils to the SVE and hot air injection remedial technologies. The treatment system was operated intermittently from January 1996 to October 1996 during the equipment testing and start-up period. After October 1996 the system operated nearly continuously through March 1998.

The MOM portion of the remediation system continued operating through 1999. However an evaluation of the pump and treat system performed by IT and presented in an informal meeting revealed that the system was minimally effective for remediating groundwater. IT estimated that the system was likely to remediate only 10-20 pounds of VOC's over approximately 20 years of operation and potassium permanganate additions were proposed to supplement the system.

2.3.6 Final Closure Action Plan for Soils

During the period between August 30, 1998 through September 10, 1998, IT supervised the collection of 42 soil samples from the Site to determine if the soil closure goals had been met. Reported analytical results from this sampling indicated that the soil closure goals had been met, and that more than 9,440 pounds of VOCs had been removed from the unsaturated soils and more than 1,113,600,000 cubic feet of air was treated by the SVE system. (IT, Final Closure Action Plan for Soils Findings and Summary, October 1999) The USEPA and MEDEP approved the closure of the SC portion of the cleanup in EPA correspondence dated December 17, 1999. In addition to the soil treatment, approximately 600 lbs of VOCs were removed from the Site groundwater.

The soil and groundwater cleanup costs for the SC/MOM remedial activities were approximately $9.5 million with an additional $2 million expended in site assessment and system design costs.

2.3.7 Permanganate Additions

In order to supplement the operation of the MOM treatment system on the Site and in an attempt to accelerate the overall objectives of the MOM, the remedial program incorporated field application of sodium and potassium permanganate solutions, as well as potassium permanganate in crystal form in well B-8A-D. The permanganate solutions and crystals were added to groundwater at the Site to oxidize chemical constituents adsorbed to the saturated soils in the dissolved phase. A summary of the permanganate addition activities conducted at the Site between 1997 and 2000 includes:

- A small pilot test of a dilute permanganate solution conducted in the Fall 1997;
- Wider application of permanganate within the source area conducted from June through August 1998;
- Re-treatment and expanded permanganate additions conducted during the Summer and early Fall of 1999;

- Treatment of additional areas identified during the Q26 and Q27 sampling event conducted during the Summer and Fall of 2000.

The permanganate addition programs are expected to have significantly contributed to the groundwater VOC concentration reductions observed between 1997 and 2000. Prior to permanganate additions reported DCE and TCE concentrations from wells within the capped area were typically between 1,000 ug/L and 10,000 ug/L. Current concentrations for these compounds within the capped area range from less than 2 ug/L to 3,300 ug/L. The permangate addition program removed an estimated 35 lbs of VOCs from the groundwater and 310 lbs from saturated soils in the treated areas at a cost of approximately $600,000. Permanganate additions have not been conducted at the Site since the Fall of 2000 (Q28).

2.3.8 Carbon Source Additions

With the dense till overburden limiting the effectiveness of the groundwater pump and treat component of the MOM system, and the 1,1 dichloroethane (1,1 DCA) the primary groundwater contaminant being resistant to oxidation via the permanganate addition program, enhanced natural attenuation was proposed as an alternative to further reduce VOC and SVOC concentrations at the UCC Site. In an attempt to optimize Site groundwater conditions for anaerobic reductive dechlorination, the addition of carbon source solutions to groundwater was proposed and conducted in 2001 and 2002. The carbon source additions provided a reduced substrate to assist in the depletion of residual permanganate and as an electron donor and carbon source to enhance anaerobic, reductive dechlorination of 1,1DCA along with remaining chlorinated ethenes and ethanes in the groundwater. The carbon source activities that were conducted at the Site included:

- Approximately 200 gallons of molasses was added to four wells located within the eastern portion of the Site during two separate events in August and November 2001;

- Approximately 23 gallons of sodium lactate was added to three wells located within the south central portion of the Site in August/November 2001;

- The potential impact of carbon additions was evaluated during the Q31 sampling and analysis of target wells for VOCs and monitored natural attenuation (MNA) parameters and comparison to previous reported concentrations and levels observed during Q28 through Q30;

- Sodium lactate was selected as the preferred carbon source addition program at the UCC Site based on an evaluation performed following the Q31 monitoring event.

- Sodium lactate additions to designated pumping wells and monitoring wells was conducted throughout the Site in August 2002. Stoichiometric requirements previously calculated by IT in the 2001 work plan were used to determine the ability of carbon source material to deplete dissolved oxygen, react with any residual permanganate, and provide at least a 25- to 100- fold excess of carbon source concentration in the groundwater, versus detected VOC concentrations in each selected individual well at the UCC Site.

- Initial results of the carbon source addition program indicated that though conditions were amenable to have reductive dechlorination occur in the Site groundwater, the achieved reduction in VOC concentration was minimal and localized to various wells and sections of the Site. As part of the carbon source addition program, an assessment of the indigenous microorganisms was also conducted in select wells. The results of the study indicated that the presence of microorganisms capable of degrading VOCs, and specifically, 1,1 DCA, at the Site was well specific, with the growth of the microorganism populations evaluated as very slow where the microorganism populations were present in the groundwater. The complete Bioremediation Consulting Inc (BCI) report is included in Appendix D. Based on the results of BCI report and the minimal and localized reductions in VOCs that have been observed following the carbon source addition program to date, biodegradation of the VOC plumes does not appear to be a feasible technology for further reducing the residual contamination of VOCs at the UCC Site. The approximate cost of the carbon addition program was $125,000. The carbon source addition program was suspended following the August 2002 addition event.

2.4 Remedial Action Impact Summary

The remedial technologies described above have been aggressively implemented at the Site over the past 20 years. Approximately $15.1 million has been spent on remedial efforts at the UCC Site. The decontamination and off-site disposal of approximately 2,500 55-gallon drums and 28 tanks and their contents (1984) represent the most significant volume of hazardous materials removed from the Site (approximately 1.5 million pounds of contaminants). Large volumes of hazardous materials were also removed during the decontamination, demolition and off-site disposal of the original Site buildings (approximately 2-million pounds).

According to IT, the operation of the soil and groundwater treatment plant (1996-2000) in conjunction with potassium permanganate additions removed approximately 9,500 pounds of VOCs from the UCC Site (IT, Treatment Plant VOC Removal Figure) which includes approximately 950 pounds of total VOCs from the groundwater. In 1998, following nearly two years of treatment system operation, sufficient contaminant mass reduction had been demonstrated by IT to achieve closure and the Performance Standards for the unsaturated and upper saturated soil at the UCC Site. When the MOM/SC treatment system was shut down in November 2000, significant reductions in contaminant concentrations in groundwater had also been achieved; however, VOC contaminant concentration rebound was observed and provided evidence that residual VOCs and SVOCs existed in the saturated subsurface soils that partition slowly into groundwater.

The technologies described above were effective in significantly reducing the volume of hazardous materials on the Site, however, the technologies were not able to achieve all of the remedial action goals since residual VOC concentrations in the groundwater remain above the Performance Standards established for the Site. It is expected that the residual volumes of VOC and SVOC contaminants in the saturated soils and groundwater that are not technically feasible to remove via further Site remediation will be attenuated naturally over time, primarily through reductive dechlorination, dispersion and dilution. In order to aid in the naturally occurring reductive dechlorination process, a reducing environment has been created via the carbon source additions to the subsurface (2001 and 2002). It is estimated that approximately 139 pounds of VOCs and SVOCs remain in the subsurface of the Site. The volume of VOCs and SVOCs remaining on the Site is based on the plume extent maps presented as Figures CSM-5 through CSM-7, and the calculations for this estimate are presented in Appendix B. This residual VOC and SVOC volume represents only a fraction of the approximately 10,000 pounds that have been removed from the Site groundwater and soils and the nearly 3.5 million pounds of chemicals and contaminated media that were removed from the Site surface.

3.0 Site Conditions

The Site is located in a rural, residential area of South Hope, Maine. The Site and surrounding area are generally hilly and un-improved areas are generally wooded or swampy. Lakes, ponds, rivers, and brooks exist throughout the area surrounding the Site. Specific details of the Site conditions are described below.

3.1 Topography and Watershed

The elevation of the UCC Site is approximately 380 feet above mean sea level (MSL). Northwest and northeast of the Site land surface rises to 480 feet. These highlands mark the drainage divide for Alford Lake/Lermond Pond to the northwest, and Grassy Pond to the southeast. There is approximately 100 feet of elevation rise between the surrounding surface water divides. The UCC Site is located within the Quiggle Brook watershed, and topography of the Site slopes from west to east, with a steep slope down to Quiggle Brook on the eastern flank of the Site. Quiggle Brook is the outflow of nearby Fish Pond. Fish Pond is a man-made feature resulting from a dam constructed at its outflow. The Fish Pond dam is located approximately 400 feet northeast of the Site. Quiggle Brook flows to the south-southwest eventually discharging to Crawford Pond in the town of South Union, Maine, approximately 3 miles downstream of the UCC Site.

The UCC Site is located at a localized discharge point within the Quiggle Brook watershed. To the east of Quiggle Brook (and the Site), a ridge separates the Quiggle Brook and Grassy Pond watersheds. The ridge creates a westerly hydraulic gradient toward Quiggle Brook that opposes the easterly gradient observed at the UCC Site. As groundwater from the UCC Site flows from west to east/southeast towards Quiggle Brook, it encounters and merges with groundwater flowing in the opposite direction caused by the drainage from the eastern ridge. The merging of groundwater contributes to a resultant upwelling flow into Quiggle Brook and its associated wetlands.

3.2 Potential Receptors

The resultant upwelling condition for regional groundwater described in Section 3.1 is expected to cause both overburden and shallow bedrock groundwater at the UCC Site to discharge to Quiggle Brook to the southeast. Quiggle Brook is therefore the primary potential environmental receptor for the residual dissolved phase VOCs from the UCC Site. No in-use drinking water wells are known to exist between the Site and the potential discharge at Quiggle Brook. Quiggle Brook eventually discharges into Crawford Pond, which is located approximately 3 miles southwest of the Site. Crawford Pond is used as a drinking water source and a recreational area. Therefore, Crawford Pond is considered a potential receptor for VOC contaminated groundwater from the UCC Site.

Potential impacts to Quiggle Brook associated with the discharge of VOC contaminated groundwater are likely to be minimized via the rough stream channel , flow mixing rate and vigorous aeration of the surface water in the vicinity of the UCC Site. Monitoring data collected during the Site remediation activities indicate that no VOCs have been detected in the surface water samples collected from Quiggle Brook since the treatment system shut down in 1999.

3.3 Overburden

The overburden soil and groundwater at the Site represent important units affecting the UCC Site conditions. It is necessary to understand these units since we believe the majority of the residual contaminant volume is located in the overburden groundwater units. This will be demonstrated by the description below of the geological and hydrogeological conditions that play a major role in the fate and transport of the residual contaminants at the Site.

3.3.1 Surficial Geology

The surficial geology at the site, as shown on the Surficial Geology of the West Rockport Quadrangle (Open-File No. 74-19), is mapped as till. The till is a glacial deposit and likely has a marine origin, The till is defined on the map as a heterogeneous mixture of sand, silt, clay and stones and stratification is noted to be rare.

The till thickness varyies from 80 feet in proximity to Quiggle Brook, to less than 25 feet in the western portion of the UCC Site, and is directly underlain by bedrock. Soil boring logs completed during the installation of monitoring wells at the UCC Site confirms the presence of till at the Site. The overburden at the UCC Site has been described by previous consultants to consist of shallow fill overlying poorly conductive, dense, glacial till. Boring logs also indicate the presence of gravel, cobbles and boulders in some areas of the Site. The presence of peat at a depth of 5-10 feet along the west side of the Site (near monitoring well B-1A), is an indication of a former topographic low area. With the exception of the limited area of peat, the till tends to be more sandy in the western portion of the Site, silty in the central portion, and clayey in the eastern portion. The soil boring program that was conducted over the years at the UCC Site did not detect the presence of any continuous silt or clay layers that could act as aquicludes or aquitards, or create distinct contaminant migration pathways. Overall, the overburden soil at the UCC Site consisted of poorly graded sands and silts that appear to be connected as one hydrologic unit (Canonie, 1990).

3.3.2 Overburden Hydrogeology

Groundwater exists in both the till and bedrock at the Site. Due to the regional topography, groundwater west of Quiggle Brook is presumed to flow east toward Quiggle Brook, and groundwater east of Quiggle Brook flows west toward Quiggle Brook (Canonie, 1990). Depth to groundwater varies from 15 to 20 feet below the ground surface and artesian conditions were observed to exist in some wells located adjacent to Quiggle Brook. The potentiometric surface maps generated for the overburden and bedrock units at the UCC Site suggest that much of the groundwater beneath the UCC Site ultimately discharges to Quiggle Brook. Piezometric heads in the till suggest that the overburden unit acts as a single layered aquifer (Canonie, 1990).

The pumping conditions that were achieved during the operation of the MOM/SC treatment system depressed the overburden water table. The change in heads from pumping may have increased the rate of flow along the preferred pathways. As observed by IT, the primary flow and yield of groundwater occurred through the weathered bedrock immediately below the till and above the competent bedrock, characterized by IT as a sand layer. The sand layer identified by IT may actually be a horizon of highly weathered granite that can resemble a coarse sand when viewed in a split-spoon. Groundwater flow directions observed in the overburden during the most recent gauging event (Q35) are very similar to overburden flow directions reported in historical quarterly reports prepared prior to the start up of the MOM/SC treatment system (1987 through 1994). A review of the groundwater elevation data for individual wells at the Site during the MOM/SC operation show that current groundwater elevations are also within the range of observed seasonal groundwater elevations that were observed prior to the MOM/SC treatment system start up. This is an indication that the Site groundwater table has returned to pre-remediation conditions and that the impact of the groundwater depression caused by MOM/SC treatment system at the Site has abated. As a part of the closure of the SC component potential recontamination of the soil by the rising water table was evaluated and the conclusion reached by that evaluation was that any contamination partitioning from groundwater to soil would not sufficiently affect the soil so as to create soil concentrations above the soil clean up standards.

The results of the completed monitoring well gauging and elevation surveys have been utilized historically to generate the groundwater potentiometric surface maps for the overburden unit at the Site. Hydraulic gradients for the Site were estimated from these inferred maps. Canonie calculated that the average horizontal gradient in overburden east of Quiggle Brook ranged from 0.027 to 0.05 feet/foot. At the UCC Site (west of Quiggle Brook) the horizontal hydraulic gradient in the till has been estimated to range from 0.016 to 0.048 feet/foot. Based on gauging rounds performed by Rizzo Associates, we have estimated the hydraulic gradients to be 0.032 to 0.062 feet/foot in the overburden. Potentiometric surface maps constructed from the recent Q35 groundwater elevation data in the overburden (Figure CSM-3) indicate that groundwater along the east side of the UCC Site continues to discharge to Quiggle Brook. Along the central portion of the UCC Site the overburden groundwater appears to flow in a more southerly direction, but is expected to ultimately discharge to Quiggle Brook within the UCC property and eventually discharge to Crawford Pond.

3.3.3 Preferential Pathways in the Till

A review of historical boring logs and reported drilling rates collected during the advancement of the borings/wells in the overburden at the UCC Site indicate that the till is generally very dense. Logs for several of the borings/wells indicate difficult and slow drilling conditions due to large cobbles and boulders. Although hydrogeologic models developed by Balsam utilized an average groundwater flow velocity of 15 ft/yr (½-inch/day) for groundwater flow through the till layer, this value likely varies considerably across the UCC Site due to the heterogeneity of the till. The average groundwater velocity in the till was estimated using average hydraulic conductivities generated during slug testing of various overburden monitoring wells at the Site. However, preferential pathways may provide conduits for groundwater to travel more quickly through some localized areas of the till. Densely compacted till areas with limited preferential pathways may have negligible groundwater velocities under non-pumping conditions at the Site, while the more sandy areas of till identified on the western portion of the UCC Site may have groundwater velocities greater than 15 ft/year. Evidence of the heterogeneity of the till was observed during the installation of some of the overburden monitoring wells at the UCC Site. Localized short circuiting of the drilling water was observed during one event where the drilling water was observed coming out of the ground at a location other than the point of entry of the drilling rods. The apparent cause of the short-circuiting was attributed to either available preferred pathways within the till, or an interconnected conduit within the till unit that was comprised of cobbles and boulders.

Although localized preferential pathways may provide isolated areas of higher groundwater velocity within the till, groundwater monitoring data collected at the Site suggest that overall, the groundwater flow and the resultant contaminant migration through the till occur at a very slow rate. Groundwater monitoring in the overburden has been performed at the

UCC Site since 1987 and has included the collection of 35 rounds of quarterly/biannual data. The results of the 35 rounds of completed groundwater sampling and analysis show little evidence of downgradient migration of the VOC contaminants within their respective plume areas at the Site. This conclusion is derived from an analysis of successive increases and decreases in VOC type and concentrations in downgradient wells. Typically, the migration of VOC contaminants in groundwater can be observed within groundwater monitoring wells that are spaced closely together. As VOC contaminants migrate through advection to downgradient areas of a site, VOC concentrations increase in the most proximate downgradient wells and decrease in wells near the up-gradient end of the plume. This typical increasing and decreasing concentration condition has not been observed on a regular basis in the groundwater data collected during the 35 rounds of groundwater sampling at the Site and slugs of contaminants have rarely been observed progressing from one well to the next through the till.

Due to these observations, we conclude that though preferential pathways may exist in the overburden it is apparent from the quarterly monitoring data that these pathways are likely limited in number and location and not interconnected across the Site. Site wide groundwater flow is generally restricted by these dense tills.

3.3.4 Groundwater Velocity

Estimates of the groundwater velocity through the till have been calculated by different consultants and have been reported to vary greatly across the Site. Since these groundwater flow velocity estimates are based on the results of slug tests performed on individual wells, much of this variation is attributed to the localized soil conditions encountered at each boring location. Acheron conducted slug tests at several overburden monitoring wells to evaluate the hydraulic conductivity of the till. The estimated hydraulic conductivity (K) values ranged from 1.1E-3 to 4.1E-5 cm/sec (1,138 feet/year to 42 feet/year). Wright-Pierce (W-P) conducted slug tests on several wells and found K values to range from 2.09E-4 cm/sec (300 feet/year) in sandy till to 1.16E-5 cm/sec (12 feet/year) in dense silty till (Canonie, 1990).

In their draft Conceptual Site Model, the MEDEP assumed a matrix porosity of 15 percent, and used the range of hydraulic conductivities calculated from the previously completed slug testing to estimate the groundwater velocity in the till. The MEDEP groundwater velocity estimates ranged from 4.45 feet/year to 413 feet/year. The variability in groundwater flow velocity reflects the heterogeneous nature of the till described above and the limitations of the slug test method. During operation of the MOM/SC treatment system on the Site, IT observed initial flow rates from the 28 pumping wells and reported that a total of 8.37 gallons per minute could be pumped from the 28 wells combined, with 26 of the 28 wells producing 0.6 gallons per minute or less (IT Memo, November 19, 1997). Subsequent pumping rates and yields were reduced once the Site dewatered with observed yields as low as 5 gallons per minute during the operation of the groundwater pump and treat system. Most of the recharge to the pumping wells was also attributed to the groundwater flow within the relatively more permeable weathered bedrock and not groundwater flow within the till. A groundwater velocity of 28.7 feet per year under pumping conditions was calculated by IT using their pumping rates. Groundwater flow velocities are anticipated to be much lower across the Site under non-pumping conditions. The Site wide pumping rates reported by IT indicate that the groundwater flow velocity at the Site is likely to be on the low end of the MEDEP calculated range of 4.45 feet/year to 413 feet/year. The wide range of groundwater flow velocity reflects the heterogeneous nature of the till. Based on the above calculated values, the groundwater velocity in the till can be assumed to be 15 ft/yr with the exception of soil zones at the Site that have been identified as either low permeability/low groundwater velocity zones (groundwater flow velocity less than 15 ft/yr), or high permeability/high groundwater velocity zones (groundwater flow velocity greater than 15 ft/yr).

3.4 Bedrock

An evaluation of the bedrock lithology, structure, and hydrology has been performed based on a review of available maps and literature from the USGS and the Maine Geological Survey, available boring logs from wells installed at the Site, geophysical evaluations including seismic refraction surveys, borehole logging and the results of previous environmental evaluations of groundwater flow and quality.

3.4.1 Bedrock Classification

For the purposes of this conceptual site model, bedrock at the Site has been classified into three categories: weathered bedrock, shallow bedrock and deep bedrock. This classification is based largely on the evaluation of bedrock cores and geophysical logging of the boreholes. As discussed below, the break between shallow and deep bedrock occurs at a structural unconformity (change in the orientation of the strike and dip of fractures in the bedrock) which was observed at a depth of approximately 110 feet below the ground surface and approximately 30 to 50 feet below the bedrock surface.

Core logs and observations made during monitoring well installation have indicated that the weathered bedrock comprises up to the top 5 feet of the bedrock surface. The weathered rock includes 1 to 2 foot layer of highly weathered rock overlying a few feet of moderately weathered and fractured rock.

Shallow bedrock at the Site is classified as bedrock within 110 feet of the ground surface and includes the thin layer of weathered rock encountered at the bedrock surface in many of the borings. The majority of the bedrock wells and borings installed at the Site were completed in the shallow bedrock, with the screened intervals set an average of 5 feet below the encountered bedrock surface.

Deep or competent bedrock generally occurs at depths greater than 110 feet below the ground surface. Some data is available regarding the lithology and structure of the deep bedrock at the Site. Only 5 of the wells at the Site can be classified as being screened in the deep bedrock: NBW-L, ODW-U, ODW-L, OPW and ITW-1. However, well ITW-1 was installed for purposes of providing a clean water source for decontamination activities at the Site. Bedrock in the ITW-1 well was encountered at approximately 20 feet below the ground surface and ITW-1 is an open borehole from a depth of 26 feet to 500 feet below the ground surface. As a result, this well intersects the shallow and deep bedrock units. Table 6 presents depth to bedrock and well screen interval information for the Shallow and Deep Bedrock wells.

3.4.2 Bedrock Geology

Lithology - A review of the Bedrock Geology Map of Maine (1985) indicates that bedrock underlying the Site is mapped as an Ordovician-Cambrian age sulfidic/carbonaceous pelite (mudstone) of the Penobscot Formation that has experienced moderate to high-grade metamorphism, resulting in schist and gneiss at the Site. A more detailed bedrock map, included as Plate 2 in the report *Physical Resources of Knox County, Maine* (1974), indicates that the Site is underlain by rusty schist and gneiss and that Quiggle Brook marks an approximate stratigraphic boundary between rusty and non-rusty schist. On the east side of Quiggle Brook, the bedrock is mapped as non-rusty schist. Locally, the schist and gneiss are intruded by granite/pegmatite. The high iron sulfide contributes to the rustiness and results in a high degree of weathering (Canonie, 1990).

Rock cores collected during the advancement of selected bedrock wells at the Site revealed that bedrock underlying the Site is comprised of schist and gneiss, with granite and granite pegmatite intrusions. Granite/pegmatite is noted in the core log for borings B-13A, SB-1-1D, SB-3-1D and SB-3-4D. A thin layer of granite was noted overlying the schist in the cores from boring SB-3-1D. Gneiss was noted in the boring log for well MW-10, and many of the core samples contained intruded granite.

Structure - The Site is mapped within the Coastal LithoTectonic block of Maine. Rocks in this region are characterized by folding, faulting and thrusting associated with ancient mountain building (orogenic) events. Locally, these mountain building events have resulted in moderate to high grade metamorphism and folding of the mudstone (pelite) deposits to form the bedrock observed at the Site. A geologic cross section (designated as E – E') on the Bedrock Map indicates that the bedrock at the Site is in an area of intense recumbent (overturned) folding of the rocks of the Penobscot and Megunticook Formations. Orientation of local bedrock structural features generally strike northeast, which is consistent with regional deformation associated with the past orogenic events.

Bedrock Profile Wright-Pierce (W-P) conducted a seismic refraction survey in 1980 to determine the bedrock profile at the Site. The seismic results indicated that the bedrock high (in elevation) was located near the northwest corner of the Site with a bedrock low (in elevation) being near Quiggle Brook (Canonie, 1990). Subsequent soil borings installed across the Site confirmed these findings. The depth to bedrock is approximately 25 feet below the ground surface in the northwestern corner of the Site, and increases to 80 feet below the ground surface along the eastern portion of the Site at well B-13A(D). The bedrock surface generally follows the surface topography, although the slope of the bedrock is steeper approaching Quiggle Brook (Canonie, 1990). These results are generally consistent with the thickness of overburden mapped by the Maine DEC in 1974, as shown on Plate 6 from the *Physical Resources of Knox County* report.

Bedrock Competency The upper 5 feet of the bedrock at the Site generally shows a moderate to high degree of weathering. Borings advanced to refusal at the Site were typically able to penetrate the first few feet of the bedrock through the use of a roller bit or by simply driving a split spoon with a 300 lb hammer. Weathered rock in some borings was characterized by Balsam as a fine to medium sand, evidence of highly weathered granite and/or schist.

Cores of the upper 5 feet of bedrock obtained by W-P from five borings (B-1 – B-5) were described as thoroughly fractured. The rock quality designation (RQD) that is used to describe bedrock is a measure of the competency of the rock and represents the percentage of the number of bedrock core sections greater than 4-inches in length divided by the total length of the bedrock core. Competent bedrock yields higher RQD values, while weathered or highly fractured rock will yield lower RQD values. In the RI/FS, Canonie reported that RQD values for rock cores retrieved during various bedrock boring installations at the UCC Site ranged from 17% to 98% with the average RQD for rock cores retrieved from the upper 5-feet of the bedrock being 17%. Average RQD for deeper rock cores was found to be 70%. The coring data indicated, as is common in fractured rock, that the fracture density decreased with depth and that the fracture joints were closely spaced and dipping 35 to 75 degrees (Canonie, 1990). Cores obtained from the first 10 to 15 feet into the bedrock by Balsam had RQDs that ranged from 76%-97% in boring SB-1-1D, where the bedrock was categorized as fresh to only slightly weathered; from 10% to 60% in boring SB-3-4D where the bedrock was categorized as highly weathered; and from 32% to 37% in boring SB-3-1D where the bedrock ranged from fresh to moderately weathered.

Only two bedrock borings were completed on the east side of Quiggle Brook (borings B-11A and B-7A). The core logs from these borings do not present RQD values, and do not explicitly indicate the presence of non-rusty schist, as shown on the *Physical Resources of Knox County* map.

Borehole geophysical logging was conducted on four bedrock wells: NBW, ODW, OPW and a residential well owned by Gus Johnson. Natural gamma logging conducted in the four wells indicated varied stratigraphy, which was evident in bedrock core samples. The results are further summarized in Section 3.4.3.

3.4.3 Bedrock Fracture Occurrence and Orientation

The geophysical logging suite performed on the deep bedrock wells also included use of an acoustic televiewer (ATV). The ATV has the ability to identify the orientation of fractures and fracture-like features within a bedrock borehole. The logging that was performed within the bedrock boreholes at/near the UCC Site showed that the observed fractures that were located less than 110 feet deep generally had a strike of northeast-southwest and were dipping to the southeast. Deeper fractures (>110 feet deep) were found to strike northwest-southeast and dip to the southwest. Figure CSM-9 shows the approximate strike and dip of the bedrock fractures in the shallow and deep bedrock based on the geophysical logging performed by Hager GeoScience Inc. and Technos Inc. The reason for the apparent change in strike and dip observed at a depth of approximately 110 feet is unknown, but may be an indication of an unmapped stratigraphic and/or structural unconformity (MEDEP). The ATV-derived average fracture dip angle was reported by Technos as 47 degrees, and the average frequency of fracture occurrence was 7.3 fractures per 100 feet of borehole.

Bedding and foliation plane fractures are likely to occur in the schist and gneiss bedrock found at the UCC Site. Bedding planes represent horizontal variations in grain size that define the stratification within sedimentary rocks, while foliation refers to planes that develop due to the alignment of platy minerals (muscovite and biotite) within the rock during metamorphism. Stresses related to mountain building events can cause fractures in the zones of rock with preferential weakness that can develop along the bedding planes and foliation in the rock. These zones of weakness are commonly along the horizontal folding of the bedrock, (that has been assumed at the Site), and can result in varying orientation of the fractures. Based on the available bedrock resource data, the strike of the fractures will generally be northeast to southwest, coincident with the regional structural fabric. Axial plane cleavage is also likely to be found in folded rock structures. These fractures develop along the "hinge" of the folds in the rock and will have a similar strike to bedding plane fractures, however, their dip will be in the opposite direction. The occurrence of the variance in the fractures results in a variable groundwater flow direction in a bedrock unit.

Core logs from borings SB-1-1D, SB-3-1D and SB-3-4D indicate numerous horizontal fractures in the first 5 feet of core from each location. According to the core logs, granite was the primary rock type encountered at the bedrock surface in each of these borings. The fracturing of the granite is likely associated with the weathering of the bedrock surface and "unloading" of the granite. Since granites generally form deep within the crust of the earth, stresses are imparted into the rock due to the weight of the overlying rock. When exposed at or near the surface due to uplift and/or erosion, these embedded stresses cause the rock to expand and fracture. Commonly, these fractures form in horizontal layers or sheets. As expansion continues, vertical joints can develop within the sheets of rock. Core logs from borings SB-1-1D, SB-3-1D and SB-3-4D indicate numerous horizontal fractures in the first 5 feet of core from each location, suggesting that a weathering process is occurring to some degree at the Site. Although coring was performed at additional locations at the Site, the descriptions of the cores presented in the logs are generalized, and do not quantify the frequency or orientation of fractures.

Additional fractures can form due to the intrusion of granite into the existing "country" rock (schist). Due to the high temperatures of the granite and differential cooling of the two rock types, fractures can form at the contact areas between the schist and the intruded granite. These fractures are generally poorly connected and discontinuous due to the variable orientation of the intrusions, and the intruded rock can truncate to fracture traces that may be present within the schist.

All of these factors result in a complex fracture network within the bedrock at the Site. The complex fracture network will likely result in a bedrock groundwater flow system(s) with preferential pathways and directions of groundwater flow that vary from expected or measured gradients which is an anisotropic condition. The anisotropic conditions were observed during a 48-hour pump test that was performed by Canonie on the shallow bedrock well B-6A-D. Well B-6A-D was pumped at rate of 0.6 gallons per minute and resulted in a measured drawdown of 42 feet within well B-6A-D. Nearby, overburden well B-6B-I had little measured in-well drawdown (0.25 feet). Shallow bedrock wells had drawdown measurements ranging from 1.7 feet to 4.15 feet with some wells proximate to B-6A-D showing little drawdown. Some shallow bedrock wells much further away and upgradient/cross-gradient, or shallow bedrock wells downgradient and closer to Quiggle Brook, had greater drawdown (up to 4.15 feet) during the pump test. These observed conditions differed from expectations based on proximity to well B-6A-D, Site topography/bedrock contours and groundwater elevations. The pump test indicated the presence of preferential pathways in the fractures within the bedrock and a weak hydraulic connection between overburden and shallow bedrock in this area. As drawn by the MEDEP in their draft conceptual site model, the hydraulic anisotropy created by this somewhat random fracture network (i.e., because of the intrusions) is evidenced by the inferred drawdown contour map of the well B-6A-D pumping test (Figure CSM-11).

3.4.4 Bedrock Hydrogeology

Weathered Bedrock Groundwater flow in the upper weathered portion of the bedrock is likely similar to that of a well sorted unconsolidated granular deposit. Highly weathered granite can have porosities of up to 50% and may act as a reservoir, storing infiltrated water and releasing it to wells with intersecting fractures in the underlying rock (Fetter, 1994). This porosity generally decreases with depth, and likely decreases to less than 10% in the area immediately above fresh bedrock (Davis and DeWeist, 1991). Site data corroborate this hypothesis in that the number of fractures observed in the bedrock cores decreased significantly with depth.

Shallow Bedrock Groundwater flow in the shallow bedrock is likely influenced by several factors including the thickness of the weathered bedrock horizon, the type of bedrock at the surface, and nature of the shallow fractures. Reported values for primary porosity in unfractured rock are generally less than 2%; however, fracturing of the rock can increase porosity by as much as 5% (Freeze and Cherry, 1979). Groundwater gauging results suggest that groundwater flow in the shallow bedrock at the UCC Site generally follows the topography of the bedrock surface and flows in a easterly and southeasterly direction towards Quiggle Brook. Recently constructed (Q35, Spring 2004) potentiometric surface maps of the bedrock (Figure CSM-4) indicate that groundwater along the east side of the UCC Site continues to discharge to Quiggle Brook. Along the south/central side of the Site, groundwater flows in a more southerly direction in the shallow bedrock. Figure CSM-12 shows the approximate contour of the bedrock surface based on the soil boring logs provided in previous Site documents.

The boring logs indicate that the granite and schist encountered at the bedrock surface in several of the borings showed varying degrees of weathering. This differential weathering likely results in zones of higher and lower conductivity within the shallow weathered bedrock at the Site.

Deep Bedrock Groundwater flow in the deeper bedrock at the Site is predominantly via facture flow. As a result, bedrock structure plays an important role in the transmission of groundwater. Logging of the deeper bedrock wells at the Site identified a pronounced change in the strike and dip of the factures at depths below 110 feet, resulting in an anticipated southwesterly groundwater flow direction in bedrock below that depth (>110 feet below the ground surface). This direction is consistent with the local bedrock groundwater flow direction shown on Plate 7 – *Piezometric Surface of Bedrock Wells in Knox County* (1974), which was based on static water level readings collected from wells throughout the Knox County.

Based on the geology of the Site, the primary method of groundwater flow in the deep bedrock at the Site is anticipated to be along bedding plane and foliation fractures within the schist at the Site. It is well established in literature that the average permeability of metamorphic and plutonic igneous rocks decreases rapidly with depth (Davis and DeWeist, 1991). Thus, although fractures were observed during the logging of the deeper bedrock wells, the ability of these deep bedrock fractures to transmit water is uncertain and may be minimal due to the fractures not being connected (dead end) and/or the compressive weight of the overlying rock and overburden that tends to decrease fracture aperture and yield.

3.4.5 Bedrock Groundwater Velocity

Groundwater velocity in bedrock is difficult to determine because it is dependent on the aperture size and number and connectivity of available fractures within the rock. Assuming a bulk K of 8.2E-5 cm/sec, a matrix porosity of 0.01, and a hydraulic gradient of 0.057, the groundwater velocity in the bedrock is estimated (assuming the bedrock behaves as an equivalent porous media) to be 5.0E-4 cm/sec (1.42 ft/day) or approximately 520 feet/year.

However, the previous shallow bedrock well B-6A-D pumping test demonstrated that water is transmitted almost entirely through the network of bedrock fractures and not through the bedrock matrix. The cubic law is commonly used to describe flow through fractured media, and takes into account the fracture aperture and fracture density. Using the same bulk K and hydraulic gradient, a fracture frequency of 0.073 fractures/ft (determined from ATV logging) and a fracture aperture of 200 microns, the calculated seepage velocity in bedrock is approximately 300 feet/day. Tracer testing performed at well ODW in the shallow bedrock and deep bedrock resulted in calculated groundwater velocities of 4.9 feet/year in the shallow bedrock and 2.1 feet/year in the deep bedrock, with corresponding low volume yields of less than 10 gallons/year.

Though the unfractured bedrock matrix is relatively impermeable, the small aperture fractures within the (deeper) bedrock can result in a calculated high velocity "conduit" flow of several hundred feet per day due to the small area (micron size) of the apertures over which a small volume of water may flow. Using the aperture size (200 microns) and the calculated seepage velocity above, the yield of the fracture would be 22 gallons/year. Therefore the potential migration of significant volumes of VOC contaminated groundwater is likely to be minimal. Possible evidence of the low yield of the deeper bedrock was observed during the geophysical logging performed on deep well NPW. Television and caliper logs identified intervals in NPW where dynamite had been used to artificially enhance the yield of the well, suggesting that natural fractures in the rock at that depth did not transmit a sufficient amount of water. In contrast, the near surface bedrock is sufficiently fractured for groundwater to move at a flow rate that can range between the flow rate of groundwater moving through the till and the flowrate of the deeper bedrock fractures. It is likely that the near surface fractures are relatively transmissive. Comparatively, these fractures are capable of transmitting a larger volume of groundwater at a rate that is faster than the till (which is very slow to transmit groundwater) and the deep bedrock due to the smaller number and size of fractures in the deep bedrock.

3.5 Bedrock/Overburden Interaction

The results of monitoring well gauging, pump testing and the distribution of VOCs at the Site, suggest that the shallow bedrock and overburden aquifers at the UCC Site are connected to some degree. The potential for a hydraulic connection between the overburden and bedrock is best evaluated through a review of the hydraulic gradient information and the results of hydrogeologic testing conducted at the Site.

3.5.1 Vertical Hydraulic Gradients

The most recent groundwater elevation gauging data collected at the Site (Q35, Spring 2004) identified downward vertical gradients in the majority of monitoring well couplets/triplets at the UCC Site. The downward gradients transitioned to upward gradients along Quiggle Brook (B-12 well series). Based on historical groundwater elevation gauging at the Site, the transition from downward to upward vertical gradients as you move east across the Site is almost always observed during average groundwater elevation (non-pumping and non-drought) conditions. Vertical groundwater gradients have also been observed from the shallow bedrock to the till on the east side of Quiggle Brook. The upward vertical gradient near Quiggle Brook may be caused by preferred pathways through or beneath the till in the eastern portion of the Site, as discussed further in Section 4.2.3. The upward flow of groundwater from bedrock into the till may also be related to the water stored in Fish Pond (Canonie, 1990). A review of the Surficial Geology of the West Rockport Quadrangle (1974) map indicates that a large area of bedrock outcrops exist at the north end of Fish Pond, thus providing a potential hydraulic connection and recharge area for the local shallow bedrock. Drought conditions, caused by lack of rainfall and/or improper management of the Fish Pond Dam, may cause a reversal in the direction of gradients at the Site (from upward to downward) due to diminished available recharge from the pond and/or from Quiggle Brook. The downward vertical gradient observed during drought and/or pumping conditions may cause some migration of contaminants into deep bedrock fractures, however the number and size of fractures within the deep bedrock is believed to significantly limit the volume of VOCs migrating downward beyond the shallow bedrock.

3.5.2 Pump Test and Slug Test Results

Slug test and pumping tests were conducted on monitoring wells at the UCC Site as part of previous investigations to evaluate the physical parameters of the overburden and bedrock aquifers. During the initial stages of the subsurface investigations at the Site, W-P conducted a 2-month long pumping test of deep bedrock well OPW at a continuous rate of 10 gallons per minute. Records of groundwater elevations in the overburden monitoring wells at the Site indicated that the measured groundwater elevations in the shallow overburden wells changed very little during operation of the OPW pump test. This condition resulted in a conclusion that little connection between the shallow overburden and the deep bedrock existed at the Site. Groundwater elevations in the intermediate and deeper overburden wells at the Site showed a comparatively more significant drawdown, such that the inferred groundwater flow direction under pumping conditions changed from southeast (static conditions) to a southerly direction (pumping conditions). This change may be due to a weak connection between the deep till and weathered bedrock. Shallow bedrock groundwater elevations that normally showed inferred groundwater flow directions easterly or southeasterly toward Quiggle Brook under non-pumping conditions, had a change in the inferred groundwater flow direction to northerly and toward well OPW during pumping, especially in the vicinity of monitoring wells B-2A-D, B-4B-I and B-5A-D (Canonie, 1990).

A 48-hour pumping test was conducted by Canonie in shallow bedrock well B-6A-D. The measured drawdown within well B-6A-D at a pumping rate of 0.6 gallons per minute was 42 feet at the end of the test. The results of the pump test suggested a weak hydrologic connection between the surrounding overburden and the bedrock. Overburden wells B-9A-I, B-6B-I and B-3B-I showed 0.4, 0.3 and 0.2 feet of drawdown, respectively. Transmissivity values derived by the distance-drawdown and time-drawdown methods yielded values of 79 gallons per day (gpd)/ft and 67 gpd/ft respectively. Storativity values derived by the same methods yielded values of 0.00027 and 0.00015 respectively. These data indicated that the till would be difficult to fully dewater and would retain a substantial volume of water and VOCs due to the low permeability and soil type (clayey till). Downward vertical gradients are expected to exist throughout the eastern portion of the Site, however the pump tests indicate a very limited volume of water is likely to be transferred from the till to the shallow bedrock.

The various pumping tests performed at the Site demonstrated a weak hydraulic connection between the till and bedrock units. As discussed above, 42 feet of drawdown was observed as a result of pumping well B-6A-D at a rate of less than one gallon per minute, while the drawdown in the adjacent overburden well B-6B-1, was only 0.3 feet. The connection between the till and overburden is weak enough such that the vertical migration downward of dissolved phase VOCs at the Site has historically been minimal. The apparent anisotropy evident in the observed drawdown data from the observation wells indicates that the bedrock aquifer behaves more like a discrete fracture flow system than as an equivalent porous media. Areas of the Site where the bedrock fracture system is hydraulically connected to the overburden groundwater system have provided pathways for VOC contaminants to enter the bedrock fracture flow system. However, based on the available Site environmental data for groundwater, higher concentrations of VOCs (more contaminant mass) are bound up in the overburden aquifer due to its low characterized permeability and the clay/till soil types than the lower bedrock aquifers.

3.6 Water Quality Indicator Parameters

Measurements of water quality indicator parameters including pH, specific conductance, dissolved oxygen (DO), turbidity, oxidation/reduction potential (ORP), and temperature have been collected and recorded during the low-flow purging of Site wells during each of the quarterly sampling events since the MOM/SC treatment system was shut down in 1999. The following ranges of values were recorded for each parameter between Q30 and Q35.

pH	4.97 to 12.44
Specific Conductance	7.2 uS/cm to 28,960 uS/cm
Oxygen Reduction Potential	-499.5 mV to 617 mV
Dissolved Oxygen	0.01 mg/L to 12.5 mg/L
Turbidity	0.2 NTU to 633 NTU
Turbidity (Q31 – Q33)	0.2 NTU to 47 NTU

Bias was created in the water quality indicator parameters at localized wells by the permanganate and lactate additions at the Site. Elevated conductivity, pH, ORP and DO readings have typically been observed in permanganate addition wells, specifically those with residual un-reacted permanganate. Elevated conductivity, negative ORP values, and depressed dissolved oxygen values have typically been observed in the carbon source addition wells. Additionally expected dissolved oxygen/ORP interference was observed in well B-8C-S. The following sections provide a brief summary of the observed trends in the water quality indicator parameters at the Site. It should be noted that prior to Rizzo Associates assuming the role of lead consultant, IT corporation and the agencies assessed the water quality parameters discussed in this section. While there appeared to be some general trends at that time, there were many exceptions to the trends. Ultimately, the agencies concluded that explanations of Site dynamics should not rest solely on level one field screening data and monitoring equipment.

3.6.1 pH

The trend in pH readings in recent quarters (Q30 through Q35) has been towards more neutral (pH 7) groundwater conditions. This trend in pH may be attributable to the Site slowly returning to its static conditions observed prior to the permanganate injections that were conducted in 1999 and 2000. Use of permanganate has created elevated pH values in wells with permanganate residuals.

3.6.2 Oxygen Reduction Potential

A site wide decreasing trend in ORP concentrations was observed during Q32 and Q33 sampling at which time the majority of intermediate and bedrock wells on the Site had reported negative ORP readings. Observed ORP values in the majority of the intermediate and bedrock wells remained negative through Q35 however the majority of the ORP values indicate that the decreasing trend in the ORP values observed during the Q32 and Q33 sampling rounds has ceased and ORP values are likely returning to pre-treatment levels. Historical ORP measurements prior to permanganate additions at the Site were typically less than a positive 150 mV. The only wells at the Site not observed to be below positive 150 mV in the Q35 sampling were shallow wells and wells with unreacted permanganate remaining in them.

3.6.3 Conductivity

Observed conductivity values at the Site increased in most lactate addition wells following the August 2002 carbon source additions. Observed conductivity values have generally fallen gradually since then. As a reference, the conductivity of the approximate 6 % lactate solution that was used for carbon source additions at the Site was approximately 30,000 μS/cm. Therefore, current elevated (versus historical conductivities) specific conductivities in a given well (lactate addition well) may be more an indication of the presence of residual concentrations of lactate in the well rather than VOC contaminants. Elevated conductivities (versus historical conductivities) in lactate addition wells during the most recent Q35 sampling round suggest that residual lactate remains present and are an indication that that well is likely within a low permeability/low groundwater velocity area of the Site where there is little groundwater movement to dilute the lactate concentrations. Conductivity values in non-lactate addition wells have also shown generally decreasing trends as the Site wide conditions gradually return to pre-treatment conditions. Isolated wells have shown consistent conductivity values since 2002, indicating that these individual wells may have returned to pre-treatment conditions, however the majority of the Site is expected to still be approaching pre-treatment conditions.

3.6.4 Dissolved Oxygen

Observed DO readings at the Site have primarily decreased over recent sampling rounds (Q30 through Q35) and the decreases in DO readings in the Site groundwater have been primarily attributed to three factors; the spring 2002 reduction in the sampling tubing diameter that decreased the potential for aeration of the groundwater samples during sampling; the carbon source additions which promote biological activity and as a result deplete the dissolved oxygen; and the gradual return of the dissolved oxygen levels in the groundwater to the pre-remediation activity (pre-1996) reducing conditions at the Site. Fluctuations in DO readings have been observed, primarily in wells screened within the shallow overburden and in wells with un-reacted permanganate or other expected interferences. As the Site approaches pre-treatment conditions DO readings in the intermediate overburden and bedrock wells are expected to continue to stabilize at concentrations around or below 1 mg/L.

3.6.5 Turbidity

Higher turbidity values were reported by IT in groundwater sampling rounds prior to the low flow sampling method implementation and prior to the Spring 2002 reduction in the sampling tubing diameter. Otherwise turbidity readings have stayed relatively consistent for the wells throughout the Site for pre- remediation (1996) and current Site groundwater conditions. Turbidity values in recently installed monitoring wells (NBW wells and B-5 series wells) have been observed to be elevated relative to the rest of the Site however this values are expected to decrease and stabilize over time.

3.7 Pre-Remediation Water Quality Indicator Parameters.

Water quality indicator parameters were recorded during quarterly sampling events at the Site prior to the start-up of the Site MOM/SC treatment system in February 1996, however only temperature, pH and specific conductivity were recorded at that time. Our research of historical Site groundwater sampling documents indicates that the water quality parameters used currently to evaluate the UCC Site aerobic/anaerobic conditions, such as dissolved oxygen and oxidation reduction potential, were not measured or recorded prior to 1996 and the start-up of the MOM/SC treatment system.

Temperature readings for the groundwater and surface water at the Site fluctuated seasonally. The pH readings observed during Q30 through Q35 sampling events were similar to those reported from the Q11 (January, 1995) and the Q12 (April 1995) sampling events with pH readings generally between 5 and 8. Elevated (basic) pH readings have been consistently observed in some wells over the history of the Site. For example, monitoring well MW-15D has reported pH values greater than 11 both prior to MOM/SC system start up and after the MOM/SC system was shut down. Due to the recent lactate additions, specific conductance values were generally higher during Q35 than during the pre-remediation groundwater sampling events. Pre-remediation specific conductance values in the groundwater were generally between 40 and 500 uS/cm, however individual wells had elevated conductivity values reported as high as 1,990 uS/cm (MW-15D, Q11). The anomalies represent effects of remedial additives (permanganate and lactate) as well as potential contaminant impacts. Overall, the water quality indicator parameters have been at or approaching expected background conditions.

4.0 Contaminant Distribution

Groundwater analytical data for the groundwater sampling rounds conducted since the November 2000 MOM/SC treatment system shut down provide evidence that concentrations of VOC contaminants above the Performance Standards still exist at the Site.

During the most recent sampling round (Q35), 16 VOC analytes and one semi-volatile organic compound (DMF) were reported to be present in groundwater at concentrations above their respective Performance Standards. The following contaminant distribution discussion focuses on the four compounds that are the most prevalent on the Site: 1,1 dichloroethane (DCA), cis-1,2 dichloroethene (DCE), trichloroethene (TCE), and dimethylformamide (DMF).

For the purposes of discussing the contaminant distribution, the Site has been separated into three units of subsurface geology: overburden, shallow/weathered bedrock and deep bedrock.

4.1 Overburden Contaminant Distribution

The overburden contaminant plume that was inferred from the Q35 data is presented as Figure CSM-5. Detected concentrations of the target analytes suggest that concentrations of DCA continue to represent the largest plume area for the four selected analytes in the overburden aquifer. The Q35 (Spring 2004) data suggests that the DCA contaminant plume in the overburden aquifer extends through the central, south and east portions of the Site cap area and to the south/southeast of the Site cap. A large portion of the TCE plume covers a smaller area within the DCA plume located in the central and southeast areas of the Site cap and extending east of the capped area toward Quiggle Brook. The TCE plume extends farther to the north (MW-14-S) in the Site cap area than the DCA plume. The 1,2-DCE plume is limited to the central and eastern portion of the Site cap and east of the capped area toward Quiggle Brook and is located entirely within the DCA and TCE plumes. A comparatively smaller DMF plume area in the overburden aquifer was observed to the southeast of the capped area in the B-12 well couplet.

4.1.1 Overburden Plume Migration

The overburden contaminant plume extent inferred from the Q35 data is similar to previous overburden contaminant plumes inferred from the Q30 (Fall 2001) through Q34 (Fall 2003) data. Prior to Q30, detected VOC contaminant concentrations were influenced by the operation of the MOM/SC treatment system at the Site, the completion of the permanganate addition program and the observed gradual rebound of VOC contaminant concentrations following the MOM/SC treatment system shut down and completion of the permanganate addition program. While some rebound of VOC contaminant concentrations was observed in isolated areas of the Site as late as the Q32 sampling round, the Site-wide trend for most of the Site monitoring wells dating back to Q30 and Q31 sampling events indicate that VOC concentrations in the overburden wells are substantially reduced when compared to their pre-remediation concentrations in 1996, and are gradually decreasing across the Site. The detected VOC and DMF concentrations reported during the Q35 sampling event for most wells are less than the detected VOC and DMF concentrations reported for the Q31 sampling round. The overburden aquifer VOC contaminant plumes are expected to gradually migrate in the downgradient (south/southeast) direction, however the plume migration appears to be occurring at a slow enough rate such that little change or shift in the plume locations can be observed over the two and a half year time frame (Q30 and Q35 sampling events). Due to the apparent low groundwater flow velocity through the till, sorption of VOC contaminants to the till matrix is believed to be retarding the migration of the VOC plumes. In the areas of the Site with the lowest groundwater flow velocities (till with clays and silts), sorption may be strong enough to negate advective transport entirely and slow the diffusion and partitioning of the VOCs into the groundwater from the soil matrix. Though this Site condition mitigates the migration of the contaminant plumes these sorptive properties will likely extend the amount of time required to flush the contaminants through the overburden aquifer and thereby reduce the concentrations to meet the Performance Standards for the Site. Dilution and localized areas of microbial degradation of the contaminants are expected to further reduce the contaminant concentrations at a slow rate in the overburden.

4.2 Overburden Areas of Similar Subsurface Conditions

Based on the conditions described in the historical Site documents and available laboratory analytical data, Rizzo Associates has divided the overburden into five zones of approximately similar subsurface conditions. These five zones were used to characterize and and make predictions regarding contaminant plume migration at the Site as well as identifying overburden areas that will likely retain contaminant concentrations for a prolonged period of time. Figure CSM-8 presents the five overburden zones that have been established for the CSM to describe subsurface units of the Site with similar geologic and contaminant transport characteristics. A brief description of each zone is described below.

4.2.1 Zone 1 – Northern Zone

Zone 1 is the northernmost overburden zone at the Site and is expected to be located hydraulically up-gradient of Zones 2 and 3 and cross gradient to Zone 4. Zone 1 is approximately 94,000 square feet in area and is estimated to contain 139,200 cubic yards of overburden soils. Subsurface soils in this zone contain dense silty sands, however the soils in this zone are believed to be less dense than the zones closer to Quiggle Brook.

Zone 1 underlies an area of the Site that formerly contained several source areas from the former UCC facility when the Site cleanup began in 1984. Former source areas located within Zone 1 included drum storage areas, an abandoned storage tank farm, the welding shop, the incinerator and a portion of the UCC facility process buildings. However the source removal actions, and the MOM/SC treatment system that was operated at the Site, provided high density remedial asset coverage of this area and VOC contaminant rebound concentrations in the Zone 1 groundwater has been limited compared to other zones at the Site. Contaminants remaining in the overburden in Zone 1 are located primarily in the northeastern portion of the zone around well MW-14-S. VOCs in Zone 1 may be migrating gradually towards Zone 2. However, MOM/SC treatment system pumping rates from wells within Zone 2 ranged from 0.02 to 0.60 gallons per minute which indicates that groundwater flow (recharge) through this overburden zone and the weathered bedrock is very slow. Therefore, contaminant migration from this zone is also expected to be slow. VOC concentrations in this overburden zone show a declining trend, and most of the wells within this zone are at or below the Performance Standards.

4.2.2 Zone 2 – Central Zone

Zone 2 is located in the central portion of the Site and is expected to be located hydraulically downgradient of Zone 1 and up-gradient of Zone 3. Zone 2 also lies beneath former UCC facility source areas where cleanup activities have been conducted. Zone 2 lies beneath a portion of the diked AST farm, a leach field, an interceptor trench, used for containment of a release(s) of VOCs and a portion of the UCC facility process plant buildings. Zone 2 is approximately 31,900 square feet in area and is estimated to contain 78,100 cubic yards of overburden soils. Source removal actions and operation of the MOM/SC treatment system have significantly reduced the VOC concentrations in the soil and groundwater within this zone. In comparison to other zones, Zone 2 can be characterized as the third most contaminated zone at the Site.

Soils in this zone contain more dense silt and clay than Zone 1, with lower hydraulic conductivities for the subsurface. Based on the observed heads at the B-6 well couplet, the vertical hydraulic gradient within this zone is believed to be downward. The overburden in this zone may be contributing VOC contaminants to the underlying weathered bedrock zone. The dense soils with sorptive clays in Zone 2 are believed to be the source of the VOC contaminant concentration rebound observed in the wells within this zone following the MOM/SC treatment system shut down and completion of the permanganate program as groundwater concentrations returned to equilibrium. Reported concentrations of total DCE in well P-20 rebounded from 210 ug/L (Q28) to 2,480 ug/L (Q33) following the MOM/SC treatment system shut down and completion of the permanganate program. Under equilibrium conditions the dense soils with sorptive clays, however, are also likely to be retarding significant VOC plume migration throughout this zone via reduced groundwater velocities, and the effects of sorption. This zone may be receiving some VOC contaminants from Zone 1 and could potentially contribute contaminants to Zone 3.

Reported MOM/SC treatment system pumping rates for wells within Zone 2 ranged from 0.05 to 0.42 gallons per minute, indicating that groundwater flow and recharge through this zone is very slow and significant contaminant migration is not expected to occur horizontally through this overburden zone. In addition, evidence of VOC contaminant plume migration in the form of increases in the VOC concentrations or plume area shifts to Zone 3, and specifically to wells GT-16 through GT-18 and/or B-12B-I and B-12C-S, have not been observed, indicating that the overburden VOC plume migration from Zone 2 into Zone 3 is minimal. Given the number of sand packed wells within this zone there is the potential for some contaminant migration vertically downward along the sand packs to the weathered bedrock zone. Based on the vertical gradients observed at normal (non-pumping, non-drought) conditions it is considered unlikely that large volumes of contaminants will migrate from the weathered bedrock into Zone 2.

4.2.3 Zone 3 – Eastern Zone

Zone 3 is located on the eastern portion of the Site and adjacent to Quiggle Brook. This zone is expected to be located hydraulically downgradient from Zone 1 and Zone 2, and is the source of groundwater discharge into Quiggle Brook, the identified primary receptor for the Site VOC plumes. Zone 3 is approximately 45,900 square feet in area and is estimated to contain 118,900 cubic yards of overburden soils. By comparison, Zone 3 is the most contaminated overburden zone at the Site. Though Zone 3 was not overlain by former UCC facility structures, Zone 3 is directly downgradient of the leach field and spill interceptor trench adjacent to the former UCC process buildings and diked tank farm.

Subsurface soils in this zone contain large amounts of dense clayey till that may act as a confining layer. Due to the low groundwater velocities and the effects of sorption and biodegradation, horizontal migration of VOCs through this zone is believed to be very limited. The vertical hydraulic gradient in this zone has been observed to vary seasonally and may be impacted by the western ridge on the Site, by Fish Pond that is located approximately 400 feet upstream of the zone and Quiggle Brook. Based on the data gathered for well couplets B-12 and B-5, the vertical hydraulic gradient in this zone is upward to Quiggle Brook for much of the year through the overburden and from the weathered bedrock. The upward gradient in Zone 3 indicates that contaminants may be migrating into this zone from the weathered bedrock, particularly along conduits created by the sand pack around wells and/or cobbles and boulders. The dense clayey tills in Zone 3 with their sorptive nature are believed to be retarding the horizontal migration of residual VOC contaminant concentrations within the saturated overburden soils.

Zone 3 is located primarily outside of the capped area of the Site and the MOM/SC treatment system was less effective in reducing groundwater contaminant concentrations in this area of the Site due to a reliance on the pump and treat technology and limited application of permanganate due to the nearby presence of a sensitive receptor (Quiggle Brook). Reported DCA concentrations in well B-12B-I have remained consistently between 2,200 ug/L and 3,200 ug/L during the quarterly sampling events from Q28 to Q35 without a discernable increasing or decreasing trend. The dense soils that have sorbed the VOC contaminant concentrations in Zone 3 are most likely retarding significant groundwater plume migration throughout this zone. This zone could potentially be receiving some contaminant migration horizontally from Zone 2. The slope of the weathered bedrock and overburden topography results in a step gradient in Zone 2 and likely is a primary pathway for contaminant migration to Zone 3. however evidence of significant horizontal contaminant migration into this zone has not yet been observed.

Reported MOM/SC treatment system pumping rates from wells within Zone 3 were greater than those observed in other Site zones ranging from 0.29 to 2.25 gallons per minute. However, these pumping rates are likely biased by the screened interval locations in the weathered bedrock and the hydraulic connection between Zone 3 and Fish Pond. Based on the soil characterization, we do not believe that the reported pump rates represent the groundwater flow and recharge, under non-pumping conditions, through the dense and less permeable overburden soils in Zone 3. Given the dense, low permeability nature of the Zone 3 soils, the weathered bedrock beneath Zone 3 most likely provided the recharge and groundwater flow for these pumping wells.

Discharge of VOCs from this zone to Quiggle Brook is likely due to the close proximity of Quiggle Brook and the upward vertical gradient observed in the overburden and shallow bedrock units in this zone. The upward gradient for the groundwater in this zone would also be affected by the westerly flow and drainage contribution from the off-site eastern ridge. Surface water samples collected from Quiggle Brook during the 33 quarterly sampling rounds have not reported concentrations of VOCs above the laboratory method detection limits. Groundwater modeling performed by IT estimated that the rate of groundwater discharge to Quiggle Brook from the UCC Site is approximately 0.039 gallons per minute. This calculated discharge rate indicates that the impact of VOC contaminated groundwater from the Site migrating into Quiggle Brook from Zone 3 is limited by the low rate of contaminated groundwater discharge to the brook and the effects of dilution, vigorous aeration and dispersion within the brook that would quickly reduce the discharged groundwater VOC concentrations from this zone.

4.2.4 Zone 4 – Western Zone

Zone 4 is located on the southwestern portion of the Site and is expected to be located hydraulically cross gradient from the other overburden zones. Zone 4 is approximately 138,200 square feet in area and is estimated to contain 302,000 cubic yards of overburden soils. Subsurface soils in this zone were described as dense silty sands on the western portion of the zone to dense silt and clay on the eastern portion of the zone. Zone 4 was overlain by a former leach field for the UCC processing facility and is immediately downgradient of former satellite drum storage areas located in Zone 1.

Based on the groundwater elevation data gathered for the B-2 and B-8 well couplets, horizontal groundwater flow across Zone 4 is expected to be from the northwest to the southeast toward Quiggle Brook. The vertical hydraulic gradient in this zone is downward. Reported contaminant concentrations in the overburden of Zone 4 during the recent groundwater sampling round (Q35) were limited to slightly elevated DCA concentrations (12 ug/L to 34 ug/L) in the B-2 series wells. Due to the dense silt and clay reported in the overburden of Zone 4 and the relatively low reported VOC concentrations, the comparatively small portion of the Site VOC plume in Zone 4 is expected to be reduced to non-detectable concentrations prior to migrating out of Zone 4 through the overburden aquifer. Some migration of VOC concentrations may be occurring from the Zone 4 overburden into the weathered bedrock below, potentially through the sand pack around wells, as evidenced by the B-8 well couplet.

4.2.5 Zone 5 - Low Permeability/ Low Groundwater Velocity Zone-

Zone 5 is located along the southwestern edge of Zone 2 and has been identified as an area of low permeability soil and low groundwater velocity. Zone 5 is approximately 12,700 square feet in area and is estimated to contain 27,400 cubic yards of overburden soils. Soils in Zone 5 are also characterized as very dense clayey tills with very low permeability. Zone 5 is comprised of various wells with VOC concentrations above the Performance Standards and can be characterized as the second most contaminated zone at the Site. Zone 5 was partially overlain by the diked AST farm for the former UCC facility. Spills from the former AST farm are the likely source for the VOCs in Zone 5.

Lactate addition rate information and post-lactate water quality indicator parameter (WQIP) monitoring have been used to characterize the groundwater flow within Zone 5. Lactate was gravity fed into the majority of the wells at the Site during the Summer of 2002 as a part of the carbon source additions. During lactate additions the falling head rate was measured to calculate each well's expected addition rate. The three Zone 5 overburden wells with the lowest addition rates were OW-1-2M (0.006 gpm), B-9A-I (<0.010 gpm) and EW-1 (0.085 gpm). These wells were identified as being within a low soil permeability/low groundwater velocity zone. As a comparison to the Zone 5 overburden wells, addition rates in bedrock wells where flows are restricted to available fractures ranged from 0.006 gpm (B-12A-D) to 0.2 gpm (B-6A-D), with an average addition rate of 0.099 gpm. Average addition rates in the overburden wells outside of Zone 5 ranged from 0.08 gpm (B-12C-S) to 0.8 gpm (B-8B-I), with an average addition rate of 0.230 gpm. The soils in Zone 5 are believed to be a more dense till material than the majority of the Site and this area appears to exhibit groundwater flow properties closer to that of the Site bedrock than those of the Site till. Zone 5 may be characterized as a stagnant zone with little groundwater movement.

Post-lactate WQIP monitoring also provided evidence of a low permeability soils and low groundwater velocity zone in the central portion of Zone 5. The specific conductance of the 6% lactate solution injected into the ground in 2002 was approximately 30,000 uS/cm. By the Spring 2003 (Q33) sampling round, specific conductance readings in the majority of the lactate addition wells outside of Zone 5 had returned to readings comparable with those observed prior to the lactate additions (Q31); however, specific conductance reading for wells in Zone 5 remained elevated. Recorded specific conductance readings for wells OW-1-2M, B-9A-I and EW-1 prior to the lactate additions were 814 uS/cm (Q30), 6840 uS/cm (Q31) and 1120 uS/cm (Q31) respectively. Recorded specific conductance readings for these three wells spiked following the lactate additions and have been observed to decrease in each sampling round since the additions. However, the observed measurements have not yet returned to pre-lactate addition levels with reported specific conductance readings in Q35 of 10,504 uS/cm, 9315 uS/cm and 3885 uS/cm respectively for these wells. These elevated conductivity readings during post lactate addition monitoring events indicate that high concentrations of residual lactate remain in the wells and that microbial activity had not been sufficient to reduce the lactate concentrations; these observations of little dilution of lactate by the Zone 5 groundwater demonstrate that the rate of groundwater flow through this area is relatively minimal.

Contaminant concentrations in the Zone 5 overburden wells rebounded following the MOM/SC treatment system shut down and completion of permanganate addition activities, and while overall decreases in the contaminant concentrations were observed in this area following the lactate additions, the observed decreases in VOC concentrations may be attributed to dilution via the volume of lactate solution remaining in the wells. Hot spot well B-9A-I that is located within Zone 5 consistently has the most elevated concentration of reported DCA in the overburden and concentrations of DCA were also observed to be elevated in wells OW-1-1M and EW-1 during the last sampling round in which these wells were sampled (Q33).

Sorption is expected to retard contaminant plume migration significantly in this zone and while some VOC mass may be entering this zone from upgradient Zone 1, there is little evidence to suggest that the VOCs in Zone 5 will begin to migrate from Zone 5 into downgradient Zone 2 or the more cross gradient Zone 4 in the overburden. The observed vertical gradient in Zone 5 may be influenced by a preferred pathway to a more permeable weathered bedrock layer provided by the existing monitoring wells and sand pack around the monitoring wells. Based on the groundwater elevation data gathered for the OW-1-1 well couplet, the vertical hydraulic gradient in Zone 5 is downward, however evidence that VOC contaminants from the overburden in Zone 5 are migrating downward into the bedrock of Zone 5 have not been observed. This potential condition is likely being mitigated by the properties of the dense soils with very low permeability, the low volume of groundwater that can move through this Zone and the high sorptive capacity in Zone 5.

4.2.6 Overburden Contaminant Volume

Based on the available analytical data from Q35, and assuming uniform groundwater contaminant distribution between monitoring points, we estimate that approximately 43 pounds of the primary VOCs (DCA, DCE, TCE) and SVOCs (DMF) remain in the overburden groundwater at the Site. This estimate is based on the plume areas presented as Figure CSM-5, standard sorption rates for the VOCs and SVOC in soil dominated by fines, and an assumption that 15% of the overall volume within the overburden layer is comprised of groundwater. In addition, based on literature values, an estimated 87 pounds of VOCs may be sorbed to the saturated soils and bound up in the overburden soil matrix. Appendix B presents Rizzo Associates' calculations for the volume of remaining VOCs and SVOCs on the Site. In descending order the majority of VOC contamination is found in Zone 3, Zone 5, Zone 2, Zone 4 and Zone 1 in the overburden.

4.3 Shallow/Weathered Bedrock Contaminant Distribution

The shallow bedrock contaminant plume that was inferred from the Q35 data is presented as Figure CSM-6. Detected concentrations of the selected analytes suggest that the DCA plume extends from well B-12A-D on the eastern fringe of the Site to well B-8A-D, which is located in the south-central portion of the Site, with the majority of the contaminant mass located between wells B-6A-D and well B-8A-D. DCA was also reported in shallow bedrock wells B-5C-D and NBW-U at concentrations below the Performance Standard indicating that these wells are located on the fringe of the DCA plume area. The detected concentrations of TCE, 1,2-DCE and DMF suggest that their respective groundwater plume areas cover a comparatively smaller area that is generally contained within the larger DCA plume area. The contaminant plumes may also be influenced by the construction of the monitoring wells. Several of the shallow bedrock wells are screened within the weathered portions of the bedrock, which could potentially provide a hydraulic connection with the overburden. Furthermore, the annular space above the well screen in several of the bedrock wells, including B-6A-D, B-8A-D and B-12A-D, was not sealed with grout to limit the potential for vertical migration of contaminants within the borehole. Rather, these wells were fitted with two-foot bentonite seals and the remainder of the annular space was backfilled with sand. Shallow bedrock well NBW-U was installed in November 2003 and has been sampled on only two occasions since its installation.

4.3.1 Shallow/Weathered Bedrock Plume Migration

The shallow bedrock contaminant plume inferred from the Q35 sampling data is almost identical in size and location to shallow bedrock plumes inferred from the Q30 through Q34 sample events covering the last two and a half years. Observed increases in the DCA plume area over this time are attributed to the addition of a new monitoring point (NBW-U) and not likely the result of the expansion of the actual plume. With the exception of well B-6A-D, the Site wide trend dating back to Q30 and Q31 indicates that VOC concentrations are gradually decreasing in the shallow bedrock and have been substantially reduced by the remediation activities at the Site. Reported VOC concentrations in well B-6A-D have been observed to remain relatively stable over this period with some indications of a gradual increase in concentrations. The detected VOC and DMF concentrations for Q35 in shallow bedrock wells other than B-6A-D are below the detected VOC and DMF concentrations for Q31. Migration of the VOC contaminant plume(s) within the shallow bedrock is expected to primarily occur within the weathered strata at the bedrock surface, and to a lesser degree, through the fractures observed in the more competent shallow bedrock. Due to the vertical connection provided by a number of monitoring wells, former pumping wells and the substantial hydraulic head on the western section of the Site, contaminant migration and groundwater flow in the shallow/weathered bedrock is anticipated to be towards Quiggle Brook (east/southeast) along the strike and dip of the bedrock with an upward component in the area of Quiggle Brook. However, the upward vertical gradients observed on the eastern portion of the Site, combined with the westerly flow direction observed on the eastern side of the Brook, will likely limit further easterly migration of the VOC plume in the shallow/weathered bedrock beyond Quiggle Brook. Measurable impacts to Quiggle Brook and/or downgradient receptors have not been identified by biannual sampling rounds conducted to date. While preferred pathways in the fractures may provide conduits for small volumes of contaminated groundwater to migrate deeper within the bedrock, the Q30 through Q35 data does not indicate that the shallow bedrock aquifer contaminant plume(s) as a whole have migrated horizontally beyond their respective inferred plume area(s) over the two and a half year time period since Q30. The gradual increase in contaminant concentrations in well B-6A-D may be an indication that contaminants are migrating into the shallow bedrock in this area of the Site, however the increase might also be the result of this Site location being slower to return to equilibrium following treatment then other zones at the Site due to non-transmissive subsurface conditions and their associated very slow groundwater flow velocities (near stagnant).

VOCs have not been reported at concentrations above the Performance Standards in newly installed (November 2003) bedrock well NBW-U. However, concentrations of DCA below the Performance Standard have been reported in this well. The presence of relatively low concentrations of VOCs in well NBW-U, which is located in a cross gradient direction to the source area, overburden and shallow bedrock VOC plumes at the Site, has been attributed to limited VOC volumes migrating along the strike and dip of the shallow bedrock fractures and/or possibly along the slope(s) or folding of the shallow bedrock and weathered bedrock at the bedrock overburden interface.

4.3.2 Shallow/Weathered Bedrock Contaminant Volume

Based on the analytical data available from Q35 and assuming uniform contaminant distribution between monitoring points, we estimate that approximately 8.8 pounds of the primary VOCs (DCA, DCE, TCE) and SVOCs (DMF) remain in the shallow bedrock at the Site. This estimate is based on the contaminant plume areas shown on the shallow bedrock plume map (Figure CSM-6), the assumptions that 10% of the overall volume within this layer is comprised of groundwater and that no VOCs or SVOCs are sorbed to the shallow bedrock. Appendix B shows Rizzo Associates calculations of the total remaining VOCs and SVOCs on the Site.

4.4 Deep Bedrock Contaminant Distribution

Monitoring well ODW-L is the only deep bedrock monitoring well that has been sampled consistently as part of the bi-annual sampling rounds since the November 2000 treatment system shut down. An additional deep bedrock monitoring well, monitoring well NBW-L, was installed in November 2003 and has been sampled on two occasions since its installation. One, comprehensive round of deep bedrock sampling was performed by Rizzo Associates as a part of a bedrock conditions analysis in October 2002.

The deep bedrock aquifer contaminant plume inferred from the October 2002 deep bedrock sampling round and available Q35 data (ODW-L and NBW-L) is presented as Figure CSM-7. DCA is the only VOC that has been reported at concentrations greater than its Performance Standard in the deep bedrock. DCA has only been reported above its Performance Standard in wells ODW-U and ODW-L at concentrations typically in the 20 ug/L range. Well ODW served as the water supply well for the former UCC facility. VOC concentrations were detected in well ODW in the mid-1980's. Based on the Site subsurface conditions, it is believed that the VOC's were drawn to well ODW under pumping conditions and not as a result of VOC migration from the source area under static conditions.

4.4.1 Deep Bedrock Plume Migration

The potential for migration of VOCs into or through the deep bedrock layer at the Site is expected to be limited to flow through the zones where a sufficient number of the small aperture fractures exist within the rock. Monitoring wells ODW (now ODW-L and ODW-U) and NBW-L are the only deep bedrock sampling locations downgradient of the source area. Monitoring well ODW is the only deep bedrock sampling location at the Site with reported concentrations that exceed the Performance Standards. Due to the significant space between these well locations, the installation of a new bedrock well down-strike and down-dip from well B-8A-D and between well ODW and well NBW may be necessary to close an apparent coverage gap for the south section of the Site. Monitoring well ODW was reported to have been used as a production well for the former chemical recycling/manufacturing facility on the property. Pumping water from the ODW well by the UCC Site operations is believed to have contributed to the migration of VOC contaminants from the source area(s) into the deep bedrock in this area of the Site. Since that time, the VOC contaminant concentrations detected in the ODW well have remained relatively stable and exhibited a declining trend with VOC concentrations typically in the 20 ug/L range.

The presence of VOCs in well ODW indicates that there is some hydraulic connection between the Site overburden, shallow bedrock and the deep bedrock. Most likely the fracture network in the deep bedrock provides a sufficient connection for water to migrate from the shallow bedrock area between wells B-6A-D and B-8A-D to the area around well ODW. The volume of contaminated water transmitted through the fracture network that comprises the hydraulic connection is assumed to be minimal based on the following observation. Following the pumping of the ODW well by the UCC facility, which would have greatly exaggerated groundwater flow rate relative to non-pumping conditions, concentrations of DCA in this well did not exceed 50 ug/L and VOC concentrations have steadly declined since that time. Calculated groundwater flow volumes and velocities through the deep bedrock were less than 3 feet/year and less than 10 gallons/year.

The NBW well couplet contains a deep bedrock point (NBW-L) downgradient of the Site source area where VOC concentrations have not been detected. According to the geophysical data collected by Hagar GeoScience during the installation of the NBW well couplet, the NBW well is located in the down-dip direction from the source area at the Site. DMF, an SVOC was observed in well NBW-L during the Q34 (November 2003) sampling round, indicating that the deep bedrock in this area is also hydraulically connected to the contaminated areas of the Site. VOCs have not been observed in well NBW-L at concentrations greater than the laboratory detection limits however, indicating that the fractures in the deep bedrock at NBW-L appear to be small enough that, under non-pumping conditions, the fractures by convection do not transmit sufficient volumes of contaminants to elevate groundwater concentrations above the performance standards.

Under non-pumping conditions migration of the VOC contaminant plume to or from this area of the deep bedrock aquifer appears to be minimal. This is likely due to the small size and number of fractures available to transmit groundwater. This Site condition was observed during the logging of the deep wells at and adjacent to the Site. Granitic intrusions in the deep bedrock may also cause the fractures to be discontinuous and not interconnected, and thus limit the ability of the rock to transmit significant volumes of groundwater. A tracer test performed at well ODW, indicated that groundwater flows at a rate of 4.9 feet per year in the shallow bedrock and 2.1 feet per year in the deep bedrock.

The extent of the DCA plume in the deep bedrock south of the ODW well couplet has not been fully defined. The aperture, orientation, strike and dip of the fractures at the Site would likely place the ODW well in a cross gradient location from the contaminant plumes. However, DCA concentrations above the Performance Standard have been identified in ODW-L. Based on the ODW well having been used as a production well for the former chemical recycling/manufacturing facility on the property it is likely that the detected VOC concentrations were induced toward the ODW well via pumping. The concentrations of DCA in ODW-L have declined over time but currently remain nearly 5-times the Performance Standard. It is likely that the DCA plume does not extend significantly (far enough to reach potential receptors) beyond ODW to the south due to the low transmissive nature of the bedrock and small number of small size fractures available for groundwater flow. Measurable impacts to potential receptors, including surrounding drinking water supply wells, have not been identified downgradient of the Site. It is expected that under non-pumping conditions further downgradient migration of VOCs will not occur to significant distances beyond well ODW within the deep bedrock. due to the limiting properties of the deep bedrock which include low groundwater velocities, small fracture aperture, and small number of available fractures to transmit water.

4.4.2 Deep Bedrock Contaminant Volume

Based on the analytical data available from the October 2002 deep bedrock sampling round and Q35 (ODW-L and NBW-L), we estimate that less than 0.3 pounds of VOCs and SVOCs (DMF) remain in the deep bedrock at the Site. This estimate is based on the plume areas shown on the deep bedrock plume map (Figure CSM-7) and the assumption that no DCA is sorbed to the bedrock within this aquifer. The plume map that this estimate is based on does not account for any undetected trail of VOCs and SVOCs that may remain between the Site source area and well ODW. The hydraulic connection to well ODW is most likely from the shallow bedrock area between wells B-6A-D and B-8A-D. Based on this assumption, the trail of VOC's and SVOCs in the deep bedrock may double or triple from the estimate provided above and, therefore, for the purposes of this model, a conservative estimate of 1 pound of VOCs and SVOCs in the deep bedrock aquifer will be used. Appendix B shows Rizzo Associates calculations of the total remaining VOCs and SVOCs on the Site.

4.5 Surface Water Contaminant Distribution

VOCs have not been detected at concentrations above the laboratory method detection limits in any of the surface water samples collected from Quiggle Brook since the Site treatment system and permanganate addition program was completed in the Fall of 2000.

4.6 Effectiveness of the Treatment System

The treatment system at the Site was in operation between February 1996 and November 2000. During this time significant reductions were reported for VOC and SVOC concentrations in groundwater collected from the majority of wells within the plume area. Since the treatment system shut down and the permanganate addition program was completed in November 2000, some rebound in VOC and SVOC concentrations has been observed. The rebound in VOC contaminant concentrations has been observed primarily in the areas that had the greatest reported concentrations of VOCs and SVOCs prior to the treatment system and permanganate addition program start up, and the most significant reductions in the VOC contaminant concentrations while the MOM/SC was fully operational. The historical VOC contaminant distribution at the Site is discussed here to provide background for evaluating the effectiveness of the Site treatment system.

4.6.1 Average Pre and Post Remediation Contaminant Concentrations

Tables 2, 3 and 4 show a comparison of the average and maximum reported concentrations of some VOCs and DMF for groundwater samples collected from overburden and bedrock groundwater wells prior to the treatment system startup, after the treatment system shut down, and in the most recent sampling round. The Q12 (April 1995) sampling round was chosen as a sampling round representative of pre-treatment conditions at the Site, the Q31 (April 2002) sampling was chosen to represent the post-treatment system sampling with sufficient time for contaminant rebound but prior to the lactate additions at the Site in August 2002 and the most recent sampling round at the time of preparation of this report is the Q35 (April 2004) sampling.

The Site wide average concentrations of reported VOCs during the Q12 sampling event ranged from 520 ug/L to 4,641 ug/L with a maximum reported VOC concentration of 48,000 ug/L (total xylenes, PZ-C-02). The average DMF concentration on the Site during Q12 was 2,581 ug/L with a maximum DMF concentration of 26,000 ug/L (B-12C-S).

The Site wide average concentrations of reported VOCs during the Q31 sampling event ranged from 5 ug/L to 729 ug/L with a maximum reported VOC concentration of 3,800 ug/L (DCA, B-9A-I). The average DMF concentration on the Site during Q31 was 733 ug/L with a maximum reported DMF concentration of 2,600 ug/L in well B-8A-D.

The average concentrations of reported VOCs during the Q35 sampling event ranged from 3 ug/L to 448 ug/L with a maximum reported VOC concentration of 3,300 ug/L (DCA, B6A-D). The average DMF concentration on the Site during Q35 was 332 ug/L with a maximum reported DMF concentration of 1,400 in well B-12B-I.

4.6.2 Contaminant Reductions

Isolated contaminant rebounding may still be occurring in areas of the Site with the densest soils or where geologic anomalies might be impacting contaminant concentrations. However, reductions in most of the average and maximum VOC and DMF concentrations have been reported between Q31 and Q35 indicating that the Site as a whole is likely to be nearing equilibrium and may have ceased concentration rebounding.

Comparing the average and maximum VOC values between Q12 (pre-remediation) and Q35 (post-remediation) provides an approximate assessment of how effective the MOM/SC remedy combined with oxidant and/or carbon source additions have been at the Site. From the reported data, DCA was the VOC with the greatest observed concentration rebound following the treatment system shut down and is currently the contaminant of primary concern at the Site. Despite observed rebound in the average concentration of DCA since the treatment system shutdown, the reduction in the average DCA concentrations in the overburden was from 2,865 ug/L to 487 ug/L between Q12 and Q35; and the reduction in the average DCA concentration in the bedrock was from 1,144 ug/L to 405 ug/L. Between Q12 and Q35 the maximum reported concentration of DCA in the overburden was reduced from 13,000 ug/L (Q12, B-12C-S) to 3,100 ug/L (Q35, B-9A-I), and the maximum reported DCA concentration in the bedrock was reduced from 11,000 ug/L (Q12, B-6A-D) to 3,300 ug/L (Q35, B-6A-D).

Contaminants other than DCA generally showed greater reductions in their concentrations. Of the 13 VOCs reported at concentrations above the Site Performance Standards in Q12, six were no longer reported at concentrations above their Performance Standards for Q35, bis(2-ethylhexyl)phthalate, methylene chloride, toluene, total xylenes, 1,1,1-trichloroethane, and trans-1,2-dichloroethene).

While the operation of the MOM/SC remedy did not achieve the remedial action goal for all of the contaminant Performance Standards it was nevertheless effective in reducing the VOC and DMF concentrations in the soil and groundwater at the Site.

4.6.3 Impact of Treatment System on the Deep Bedrock

Monitoring wells ODW-U and ODW-L are the only deep bedrock monitoring wells with historical VOC concentrations greater than their respective Performance Standards. The primary VOC with reported concentrations consistently above its respective action level in these wells is DCA. The treatment system was not designed to impact groundwater in the deep bedrock layer; however, between 1995 and the most recent sampling data DCA concentrations in monitoring wells ODW-L and ODW-U were reduced from 53 ug/L and 46 ug/L (Q12, April 1995) to 23 ug/L (Q35, April 2004) and 19 ug/L (October 2002, Bedrock Conditions Summary Sampling), respectively. These reductions are attributed to natural degradation, dilution and/or dispersion mechanisms and to a lesser degree the reduction of VOC concentrations within the source area.

5.0 Groundwater Target Cleanup Levels

The Record of Decision (ROD) signed December 27, 1990, defines a list of 19 chemicals of concern for the groundwater at the Site. The chemicals of concern for the groundwater and their respective target cleanup levels are presented in Table 1.

6.0 Additional Remedial Action Evaluation

A number of remedial technologies have been aggressively implemented at the Site over the past 20 years including the decontamination and off-Site disposal of approximately 2,500 55-gallon drums and 28 tanks and their contents; the decontamination, demolition and off-site disposal of the original Site buildings; and the operation of a soil and groundwater treatment plant that removed approximately 9,500 pounds of VOCs from the Site's subsurface. The most recently applied technologies at the Site were chemical oxidation treatment using permanganate (1998-2000) followed by an attempt to enhance the reducing environment via carbon additions to the subsurface (2001-2002). Sufficient VOC contaminant mass reduction has been achieved for closure of the unsaturated and upper saturated soil at the Site, and significant reductions in VOC contaminant concentrations in groundwater have been achieved.

At this time it is estimated that approximately 140 pounds of the four primary contaminants (DCA, DCE, TCE, and DMF) remain in the subsurface at the Site. Attempts to further reduce VOC contaminant concentrations at the remaining hot spots via chemical oxidation could not achieve the target cleanup levels due to oxidant resistant contaminants (DCA) and the limited permeability of the overburden and weathered bedrock formations. Carbon source additions proved successful in creating and/or returning the Site to a reducing environment; however, evidence that this reducing environment is accelerating the biodegradation of the primary contaminants, to the extent that this technology could achieve a timely cleanup of the Site, have not been observed at this time. To the extent practicable the the feasible chemical, physical and mechanical technologies for remediating the Site to achieve the Performance Standards have been implemented at the Site and VOC concentrations have been reduced by these technologies . Further reductions in the VOC concentrations by alternative commercially available technologies are believed to be infeasible due to the dense units, low permeability, and low transmisivity of the subsurface materials at the Site.

Some rebound of the reported contaminant concentrations was reported at the Site after the treatment plant was shut down. Biannual monitoring events between 2001 and 2004 (Q30 –Q35) indicate that additional rebound of VOC concentrations has slowed, with the exception of rebound associated with dilution following carbon source additions to low permeability wells. The VOC contaminant concentrations appear to have stabilized at the Site; however, seasonal patterns in the contaminant concentrations in individual wells has also been observed. VOC concentrations have generally been observed to be comparatively higher in most areas of the Site during time periods when the groundwater table is depressed (during the fall season) and lower when the groundwater table is elevated (during the spring season). This well specific trend indicates that the overall volume of VOC contaminants present in the groundwater and sorbed to the saturated soils is likely to be stable. The changes in the reported contaminant concentrations during the spring and fall seasons can be attributed to changes in the available volume of water within the subsurface which has a fixed volume of contaminants.

Additionally, vertical groundwater gradients have been observed to shift in several areas of the Site depending on the seasonal groundwater elevations. These changes in vertical groundwater gradients are likely to induce movement of VOCs vertically, causing variable contaminant concentrations in individual wells. Seasonal fluctuations in the VOC concentrations in some locations of the Site may be the result of VOCs migrating vertically through the sand pack around the monitoring wells while horizontal migration through the till and/or bedrock remains extremely limited due to the low permeability soils and limited number and size of fractures available to transmit water.

Based on the observed declining trends in the contaminant concentrations at the Site the contaminant plume appears to have stabilized. The low permeability formations with low groundwater velocities will also further limit or retard the movement of the residual VOCs at the Site. The limited VOC plume migration that has been observed at the Site over the past three years, as well as over the history of the Site, indicates that such factors as advection and hydrodynamic dispersion are likely being retarded by the low permeability and low transmisivity of the clay, till, and bedrock formations at the Site. These subsurface properties will also result in a much greater time period required for the Site contaminants to reach Quiggle Brook, the receptor of primary concern, and will also result in additional time for natural attenuation of the contaminants to occur at the Site.

The Site conditions indicate that the most feasible technology to implement may be long term monitoring and monitored natural attenuation (MNA). The long term monitoring phase should provide sufficient monitoring data to demonstrate that the groundwater contaminant plume(s) is not migrating beyond the Site limits and that downgradient receptors are not being negatively impacted. The implementation of a long term monitroing program will also assess the progress of natural processes such as biodegradation, dispersion and dilution to reduce the VOC concentrations and achieve the Performance Standards.

7.0 Monitored Natural Attenuation

Monitored natural attenuation (MNA) is the process of monitoring contaminant concentrations and groundwater movement at a Site while allowing natural chemical and biological processes to reduce the volume of contaminants at the Site though transformation or removal. Two of the processes that often play the largest roles in the rate at which a Site attenuates are reductive dechlorination and dilution/dispersion.

7.1.1 Reductive Dechlorination

One manner that chlorinated ethenes can be degraded is through a process of aerobic degradation, which is a method of natural ethene destruction. The "natural" conditions at the Site were changed during 1998 through 2000 when permanganate was added as an oxidant to break the VOC chemical bonds and oxidize the VOC components via an aerobic process. Chemical Oxidation, however, has not been effective to eliminate chlorinated ethane compounds at the Site. During natural attenuation, the primary mechanism for reduction of both chlorinated ethenes and ethanes is anaerobic biodegradation via reductive dechlorination. During reductive dechlorination, chlorine atoms are sequentially removed via microbial activity and replaced by hydrogen atoms. This process results in the formation of a series of lesser-chlorinated daughter products with the release of inorganic chloride. For example, tetrachloroethene (PCE) is typically dechlorinated to sequentially form trichloroethene (TCE), cis-1,2-dichloroethene (DCE) with some trans-1,2-DCE, vinyl chloride, and ethene. The reductive series and daughter products of 1,1,1-trichloroethane (TCA) are typically 1,1-dichloroethane (DCA), chloroethane and ethane. Ultimate end products of the reductive dechlorination process are carbon dioxide, methane, water and inorganic chloride.

7.1.1.1 Conditions for Anerobic Biodegredation

The subsurface conditions necessary for anerobic biodegradation to take place include a reduced oxygen state, and available microbial activity to degrade the desired contaminants. Key MNA parameters that were measured at the UCC Site including low DO and negative ORP values suggest that prerequisite groundwater conditions for reductive dechlorination are present in the majority of the Site wells across the central, southern and eastern sections of the Site.

An evaluation of microbial activity in two groundwater samples collected from the Site during the Q33 sampling round was performed by Bioremediation Consulting Inc. (BCI) and produced mixed results. The BCI report, available in Appendix D, reports that dechlorination was observed to take place in the sample collected from monitoring well B-12B-I (overburden well) over an 88 day test period, however evidence of dechlorination was not observed in the sample collected from groundwater monitoring well B-8A-D (bedrock well) over a 95 day test period.

Based on the groundwater data collected during Q35, DCA continues to exist as the primary contaminant at the Site. As a result, recent remedial and monitoring efforts in 2002 and 2003 primarily focused on the degradation/reduction of the DCA concentrations. The results of the bioremediation analysis indicate that limited microbial activity suitable to dechlorinate DCA is present in some areas of the Site, but is not consistent throughout the Site.

7.1.1.2 Chloroethane and Vinyl Chloride Concentrations

Since DCA degrades to chloroethane, increased concentrations of chloroethane in areas where elevated concentrations of DCA were previously detected would suggest that DCA is being degraded in that area of the Site. Likewise, increased concentrations of vinyl chloride in areas where elevated concentrations of TCE and/or DCE were previously detected would suggest that TCE and DCE are being degraded.

Evidence that a gradual increase of chloroethane concentrations may be occurring across the southeast portion of the VOC contaminant plume is beginning to be observed. Following lactate additions at the Site the number of wells with reported concentrations of chloroethane increased from 1 out of 26 in Q30 to 13 out of 41 in Q33. The average reported chloroethane concentration at the Site increased from 7 ug/L in Q30 to 111 ug/L over the same time period, with the majority of the increases being observed along the eastern edge of the Site in Zone 3. Since Q33, the percentage of wells with reported concentrations of chloroethane has dropped slightly to 5 out of 19 wells in Q35 with an average reported chloroethane concentration of 17 ug/L. The B-12 series wells represent the most consistently sampled well couplet southeast of the capped area of the Site, and these wells suggest an increase in the chloroethane concentrations in this area. None of the three wells had reported chloroethane concentrations above the laboratory method detection limit during Q30 and each of these wells had reported chloroethane concentrations during Q35. Despite the reported decreases in chloroethane concentrations since Q33, the increased number of wells since Q30 exhibiting some elevated chloroethane concentrations may be evidence that the Zone 3 area of the Site is being minimally affected by anaerobic dechlorination which will reduce some of the contaminant mass that will eventually be discharged to Quiggle Brook.

Unlike chloroethane, which has been observed almost exclusively in the Zone 3 area of the Site since the treatment system shut down, vinyl chloride concentrations have been reported in wells throughout the Site. Neither the average vinyl chloride concentration per semi-annual sampling event nor the number of wells where vinyl chloride has been observed have shown a consistent increasing or decreasing trend at the Site. Average vinyl chloride concentrations have ranged from 10ug/L (Q34) to a high of 22ug/L (Q33).

7.1.1.3 Carbon Source Additions Impact on Reductive Dechlorination

The chloroethane and vinyl chloride results suggest that the carbon additions may have improved the reductive dechlorination process at the

Site. Four of the five wells exhibiting the highest chloroethane concentrations during Q33 received carbon source additions in 2001 (molasses) and in 2002 (lactate). Additionally 24 of the 25 wells with observed vinyl chloride concentrations during Q33 were lactate addition wells in 2002. Conditions amenable to reductive dechlorination in the area around these wells may be attributed to the carbon source additions returning the Site to anaerobic conditions, and it is possible that the carbon source additions may have enhanced to some degree the indigenous reductive dechlorination process. While evidence of reductive dechlorination at Site wide rates that might reduce VOC concentrations at the Site in a timely manner have not been observed following the carbon source additions, anaerobic conditions continue to be observed over the majority of the Site indicating that a slow reductive dechlorination process might continue to occur at the Site into the future.

7.1.2 Dispersion

In addition to reductive dechlorination, dispersion can in some cases, play a major role in the natural attenuation of groundwater contaminants. Dispersion is the "spreading" of a fixed volume of contaminants over a larger area within the soil profile or groundwater unit by groundwater flow, gradient diffusion or both. The addition of precipitation and seasonal increases in available groundwater can, therefore, reduce detected contaminant concentrations by dilution and dispersion. Dilution and dispersion, however, do not remove any contaminant mass from the subsurface.

In tight clays and tills that are present at the UCC Site the effects of dilution and dispersion are greatly reduced. The presence of the clay cap at the Site also limits the effects of dilution and dispersion since, by design, the clay cap sheds precipitation limiting infiltration into the overburden. Precipitation that falls on the surface is more likely to run-off on or near the surface as opposed to infiltrating through the clay and till formations. Likewise the rate of groundwater flow through the tight clays and tills of the overburden unit has been shown to be slow. At the reduced rates of groundwater flow observed at the Site the effects of sorption, ion-exchange and biodegradation can further retard the migration of the contaminant plume and reduce the affects of dispersion to nearly negligible. Contaminant dispersion through the weathered bedrock layer, which is the primary conduit for dispersion at the Site, will also be influenced by the factors affecting the till since the reduced rates at which VOCs partion and migrate into the weathered bedrock from the till unit will remain minimal. The minimal amount of apparent horizontal and vertical contaminant plume migration at the Site provides evidence that dispersion is not likely to play a major role in a short term reduction of contaminant concentrations at the Site in the future. In the long term dispersion will eventually result in reduction of VOC concentrations as the VOCsmove through the currently impacted areas at limited rates and volumes.

7.2 Retardation Factors and Contaminant Velocities

The five zones of the Site described in Sections 4.2.1 through 4.2.5 will each have individual groundwater velocities as well as individual retardation factors. The retardation factor is an approximate measure of the effects of particle size, pore space, and sorption on contaminant molecules as they migrate though the subsurface. Based on the soil descriptions provided in previous Site reports and boring logs for the Site, the calculated retardation factors for DCA, DCE, TCE, and DMF are estimated to be 25, 28, 127, and 8.5 respectively (Appendix C). These retardation factors do not take into account additional retardation that may result from biodegradation of contaminants. If biodegradation is occurring at the Site then the effective particle size of the contaminants will be larger and retardation factors will be greater. These retardation factors can be divided into the groundwater velocities in a given area of the Site to obtain the velocities at which the contaminants may migrate through the subsurface.

The velocity of the groundwater through the subsurface varies greatly within Zones 1 through 5, and between the overburden and bedrock units. Section 3.3.4 of this report indicates that the groundwater velocity in the till is expected to range from 4.45 to 413 feet/year; however given the data derived from Site observations and pumping rates the comparative velocities are expected to be at the low end of the range across the Site and nearly stagnant in some areas (Zone 5). A site-wide groundwater velocity of 15 ft/yr in the till was used in previous groundwater modeling at the Site, which we believe is a conservative (high) estimate given the Site data. Based on the 15 feet/year groundwater velocity and the retardation calculations presented in Appendix C, the migration of DCA, DCE, TCE, and DMF at the Site should occur no faster than between 0.12 ft/yr and 1.8 ft/yr. Based on the inferred VOC contaminant plume maps generated from the Q30 through Q35 sampling rounds, the rate of plume movement laterally across the Site cannot be discerned, therefore, the calculated values may be applicable to the Site.

The areas of the Site that have shown the most significant rebounding following the treatment system shut down have been the areas of denser tills and clays that are likely to not only have lower groundwater velocities than 15 ft/yr, but to also have greater retardation factors. Contaminant migration of less than 5 ft/yr is likely since little or no contaminant migration has been observed at the Site since the treatment system ceased operation in 2000. Low permeability/low groundwater velocity areas of the Site such as overburden Zone 3 and Zone 5 are expected to have contaminant migration velocities of less than 2 ft/yr, or possibly less in areas where biological degradation activity is taking place.

7.3 Contaminant Concentration Hot Spots

In addition to establishing the overburden subsurface condition zones at the Site, our review of the data generated by recent monitoring events has identified wells with elevated contaminant concentrations (hot spots). These hot spots are areas where contaminant concentrations are at least one order of magnitude greater than observed within adjacent areas of the Site, and they exist in both the overburden and shallow bedrock units. The following is a brief description of each of these areas and what geological and hydraulic features may be contributing to the elevated contaminant concentrations in each area.

7.3.1 Zone 5 - Wells B-9A-I, OW-1-1M, EW-1, and OW-1-2M.

As described in Section 7.2 above, Zone 5 is considered an area of low permeability soil and low groundwater velocity. The low permeability of the soils is believed to have increased the effects of sorption in this zone which in turn made the treatment system less effective in this area leading to VOC rebounding following the treatment system shut down. The increased effects of sorption in this area are also expected to dramatically limit migration of contaminants from Zone 5, therefore the contaminants within this zone are expected to be essentially immobile. DCA is the VOC of primary concern in Zone 5 and reported DCA concentrations in well B-9A-I decreased from 4,400 ug/L (Q30) to 1,700 ug/L (Q33) following lactate additions. These declining trends did not continue however, with DCA concentrations rebounding to 3,100 ug/L (Q35) in the most recent sampling round. The recent rebounding in this well is expected to be related to initial dilution caused by the lactate additions. Dilution within the well column may account for the majority of the apparent VOC contaminant concentration reductions observed in this area. As residual lactate in the Zone 5 wells disperses into the subsurface around the wells, we anticipate that VOC concentrations in the Zone 5 wells will continue to increase, possibly returning to the approximate concentrations observed in these wells prior to the 2002 lactate additions.

Reductive dechlorination is anticipated to be the primary mechanism that will attenuate the hot spot in Zone 5. Vinyl chloride has been detected in the Zone 5 wells since the treatment system shut down, indicating possible reductive dechlorination of DCE and TCE in this area. Alternatively, chloroethane concentrations above the laboratory method detection limits have not been reported in the Zone 5 wells since treatment system shut down indicating that DCA is likely to be the slowest contaminant to attenuate from Zone 5 through reductive dechlorination.

7.3.2 Shallow Bedrock Wells B-6A-D and B-8A-D

The groundwater contaminant plume in the shallow bedrock is defined almost exclusively by reported VOC and DMF concentrations in monitoring wells B-6A-D and B-8A-D. Each of these two bedrock wells is screened, at least in part, into the weathered bedrock layer. The top of the well screen for B-6A-D extends to within 3 feet of the bedrock surface while the top of the well screen for B-8A-D extends to within 4 feet of the bedrock surface. The measured lactate addition rates for wells B-6A-D and B-8A-D were 0.2 gallons per minute (gpm) and 0.09 gpm, respectively. The lactate addition rates for these wells offer additional evidence that these wells are likely to be hydraulically connected to fractures or the weathered bedrock layer. Based on the orientation of the VOC contaminant plume in the shallow bedrock it is expected that fractures and/or the weathered bedrock layer may be a preferred pathway for VOC contaminants to migrate cross gradient at the Site, from the B-6A-D area towards the B-8A-D area. This migration direction is consistent with the strike of the fractures identified in the boreholes at the Site. Evidence has also been observed that the weathered bedrock layer may be the preferred pathway for VOC contaminants migrating out of the Zone 2 overburden. It is believed that at approximately the boundary between Zones 2 and 3, the till becomes more dense and clayey, creating a confining layer for horizontal groundwater migration. Vertical hydraulic gradients in Zone 2 are primarily downward, indicating that contaminants in the overburden might potentially migrate into the weathered bedrock instead of migrating horizontally into Zone 3.

The extent of the bedrock contaminant plume along the northeast to southwest fracture line has not been fully defined since no shallow/deep bedrock monitoring point exists to the southwest of well B-8A-D. The reported results from the sampling of monitoring wells NBW-U and NBW-L, which is located in the down-dip location from the majority of the shallow bedrock contaminant plume, provides some evidence that significant volumes of contaminants are not likely to be migrating in the fractures from the shallow bedrock to the deep bedrock in this area.

7.3.3 P-20/P-24

The area around monitoring wells P-20 and P-24 has been identified as a TCE and DCE hot spot within the Zone 2 overburden. Well P-20 had represented the maximum reported TCE (1,300 ug/L) and total-DCE (2,480 ug/L) concentrations at the Site during the Q33 sampling event. These two wells have not been sampled on a regular basis since the treatment system shut down and, therefore, it is not possible to analyze trends in the VOC contaminant concentration in these wells at this time. It is important to note however that a hot spot does exist in this area and periodic monitoring may be required to assess migration of this hot spot through Zone 2.

7.3.4 B-12B-I, B-12C-S and GT-18

The final hot spot on the Site is the center of the VOC contaminant plume within the overburden in Zone 3. The rebound in VOC concentrations in Zone 3 is being attributed to the dense till and clay overburden soils in this area that promote the sorption of contaminants to soils. After well B-9A-I, monitoring well B-12B-I represented the maximum reported DCA concentration (2,300 ug/L) in the Site overburden during the Q35 sampling event. Well B-12B-I also represented the Site wide maximum DMF concentrations (1,400 ug/L) during the Q35 sampling event. Despite the elevated VOC concentrations in wells in Zone 3 and the close proximity of these wells to Quiggle Brook, VOC concentrations have not been identified at concentrations above the laboratory method detection limits in the surface water samples collected from the brook.

7.4 CVOC Half Lives

Rizzo Associates has estimated the half lives of contaminants in key monitoring wells on the Site in an attempt to estimate how long it will take for reductive dechlorination and other natural attenuation processes to reduce contaminant concentrations at the Site to levels necessary to meet the Site Performance Standards. Reported analytical data from recent quarterly sampling events indicates that contaminant concentrations in the majority of the wells on the Site did not reach equilibrium from the operation of the treatment system on the Site until the Q30 or Q31 sampling rounds. This leaves a very limited amount of data from which to analyze trends. Additionally many of the Site monitoring wells had observed contaminant concentration rebounding. Many of these wells were screened within the dense till and clay formations and had lactate additions performed in the summer of 2002 (between Q31 and Q32) which served to dilute the contaminant concentrations in these wells creating potentially "false" reductions in the reported data. The calculated half lives should be considered inaccurate for monitoring wells B-9A-I and B-6A-D due to continued rebounding over the past three years in these wells. Half life calculations are presented in Table 5 and further discussed in Section 7.5.

7.5 Projected Timeline to Meet Target Cleanup Levels

Half lives for contaminants in wells B-6A-D, B-9A-I, B-12A-D, B-12B-I, B-12C-S, B-8A-D and MW-14-S were calculated using the reduction in contaminant concentrations from the peak concentration recorded following the treatment system shut down (Q30 or Q31) to the most recent sampling of the well (Q35). Table 5 shows the calculated half lives and projected time to reach the Performance Standards for the four primary contaminants on the Site for each of these wells. Concentrations appear to be continuing to rebound in wells B-6A-D and B-9A-I biasing the calculations for these wells. In the remaining five wells, DCA is projected to take the longest to reach the action level of 5 ug/L in four of the five wells (it has already been achieved in well MW-14-S) with projected times ranging from approximately 11 to 122 years. The half-life calculations for these four wells are based on a limited time frame of three years of data. Many of the wells that are screened in the tightest tills and clays on the Site such as Zones 2 and 5 are expected to take longer than these five wells to fully attenuate. More accurate half life calculations and projected timelines will require subsurface conditions at the Site to remain undisturbed until all wells have fully equilibrated and remedial additives (lactate and permanganate) can no longer be detected in monitoring wells, followed by several events of contaminant concentration monitoring that can be used to calculate Site specific half life information.

8.0 Conceptual Hydrogeologic Model

The conceptual hydrogeolgic model has been developed using the contaminant distribution and hydrogeologic data collected at the Site in addition to the results of literature research. The model is divided into four separate units: overburden, weathered bedrock, shallow bedrock and deep bedrock.

8.1 Overburden - Till

As discussed in Section 7.2, the overburden at the Site has been divided into five distinct zones based on geology and contaminant distribution, with the till matrix becoming more dense to the east. The results of numerous gauging rounds at the Site have demonstrated that groundwater in the till generally flows from northwest to southeast across the Site. As such, groundwater flowing onto the Site first enters Zone 1 where groundwater generally flows through the sandy till matrix. Downward vertical gradients in this portion of the Site may cause portions of the groundwater to migrate into the weathered bedrock layer. As groundwater migrates east across the Site into Zone 2, groundwater flow is retarded by the increasingly fine-grained and consolidated nature of the till, but may follow preferential pathways associated with observed boulders and/or cobbles within the till or migrate downward into the weathered bedrock layer. Downward gradients in this area may cause migration of contaminants deeper into the till and/or bedrock at the Site. Further eastward migration in the overburden of groundwater (and contamination) is likely further retarded by the clayey nature of the till in Zone 3, and migration through the weathered bedrock likely becomes the primary transport pathway for flow of contaminated groundwater. Due to the fine-grained nature of the till in this area, contaminants are likely to remain, in part, sorbed to the till matrix. Upward gradients observed in monitoring wells in this area likely reflect the confining nature of the till and the head provided by the western ridge and Fish Pond. Fish Pond's hydraulic effects will likely be limited by available fractures and hydraulic connections to the Site through the bedrock and till.

The hydraulic connection to Fish Pond is expected to affect the hydrology of a portion of the Site even though this connection is expected to be limited by the dense nature of the subsurface material. During the operation of the pump and treat system, and following achievement of the dewatering of the Site, pumping was reduced from 29 wells to 4 wells to maintain hydraulic control. Three of these four wells (each screened into weathered bedrock) were within Zone 3. Continued pumping from these four wells maintained the de-watered subsurface at a pumping rate of approximately 5-6 gallons per minute. The potential hydraulic connection between Fish Pond and the bedrock at the Site is expected to be through fractures that are limited in size and number, such that despite the hydraulic head present at Fish Pond a limited number of pumping locations were capable of keeping the Site dewatered. Additionally, when the pump and treat system was shut down, the time necessary for groundwater to return to pre-pumping conditions in the overburden was substantial, reinforcing the theory that the expected high density of the till matrix does not readily transmit water even though substantial head was available to move groundwater through the Site's overburden.

As is evidenced by the groundwater data, these upward gradients, coupled with the tight till, have effectively limited further migration of contaminants eastward past Quiggle Brook. Westerly groundwater flow was observed in the wells that were located on the eastern side of the brook, which creates a hydraulic barrier and, therefore, serves to limit migration of the VOC contaminants beyond the brook area. Although this model results in discharge of contaminated groundwater to the brook, laboratory analysis of surface water samples has not detected contaminants at concentrations above the Performance Standards in the surface water samples. This non-detect condition is likely due to the low volume discharge of contaminated groundwater into the brook and the rapid dilution/aeration provided by the brook.

8.2 Weathered Bedrock

Weathered bedrock is defined as up to the top 5-feet of bedrock. Compared to the overburden, the weathered bedrock at the Site is likely the most significant migration pathway for groundwater and the VOC contamination. The highly weathered horizon has been categorized as a fine to medium sand in some of the boring logs, providing a comparatively more porous and transport pathway relative to the overlying till and the underlying competent bedrock. VOC contaminants may migrate from the till into the weathered bedrock on the western and central portions of the Site. Though downward gradients were observed in these areas, the effects of these negative gradients are likely dampened by the tight till formation in the overburden and the sorptive nature of these soils. Additional contaminant migration may occur through monitoring wells with screened intervals set in the overburden and upper portions of the weathered rock in areas where downward gradients exist. Groundwater flow in the weathered rock is anticipated to follow the slope of the bedrock surface and migrate east and southeast towards Quiggle Brook. The upward gradient conditions observed on the eastern portion of the Site likely cause a corresponding upward migration of contaminants from the weathered bedrock to the till, and ultimately discharge to Quiggle Brook.

8.3 Shallow Bedrock

Shallow bedrock is defined as being below the weathered bedrock and approximately 5 to 50-feet into bedrock. Core logs from several of the shallow bedrock wells indicate that the upper 15 to 25 feet of the bedrock is moderately fractured. Numerous horizontal to subhorizontal fractures were noted in the upper cores, with a general decrease in fracture frequency and aperture with depth. Steeper dips and joints were observed in deeper core samples, such that groundwater migrating under downward gradients on the western and central portions of the Site would likely move through the weathered bedrock layer and would likely flow down dip, deeper into the formation and to a lesser degree along the strike of the fractures. Evidence of this migration is observed in the elevated contaminant concentrations detected in shallow bedrock wells B-6A-D and B-8A-D. As with the overburden and weathered bedrock, the upward gradients that occur along the eastern portion of the Site, adjacent to Quiggle Brook, will limit the downward and eastward migration of the contaminants in the shallow bedrock. Evidence of artesian conditions is commonly observed in shallow bedrock monitoring well B-12A-D, located adjacent to the brook. These artesian conditions are likely the result of the steep hydraulic gradient in the weathered portion of the bedrock and the confining nature of the clayey till overlying the bedrock. An additional factor is a possible hydraulic connection with Fish Pond, where large areas of bedrock outcrop exist at the upgradient and northern end of the pond. Water from the pond may be hydraulically connected with the bedrock at the Site via the same small aperture fractures observed in the Site bedrock and may result in further dilution of the contaminants as they discharge to Quiggle Brook.

8.4 Deep Bedrock

Deep bedrock is defined as the bedrock located greater than 110-feet below the ground surface. Very limited migration of contaminants is likely to occur in the deep bedrock. As with the competent shallow bedrock, contaminants are anticipated to migrate in the direction of dip (southeast) until they encounter the unconformity and associated change in the direction of the strike and dip of the fractures. Geophysical logging of the wells has indicated that fractures below 110 feet dip to the southwest. Groundwater is anticipated to migrate down dip towards the southwest. However, at this depth, decreasing fracture frequency and aperture size due to overlying lithostatic pressures will likely result in "pinching out" of the contaminant plume. In addition, the effects of continued sorption, dilution and natural degradation of the contaminants in the overburden and weathered bedrock units will serve to further limit the volume of contaminants available for potential deeper migration to the shallow bedrock and ultimately to the deep bedrock.

8.5 Conclusions

Water quality, geological and hydrological data collected during the numerous subsurface investigations have been utilized to develop a conceptual site model for the former UCC Site. Active remediation by the MOM/SC remedy has effectively remediated the unsaturated soils at the Site that were the source area for the groundwater contamination observed in the overburden and bedrock units at the Site. This CSM demonstrates that site conditions have essentially reached equilibrium, and that migration of contaminants at detectable concentrations beyond the limits currently defined has not been observed in two and a half years. We conclude the following:

- **Source Area Removal** Initial response actions implemented at the Site included the removal of 2,000-2,500 55-gallon drums and 28 liquid storage tanks. Asbestos containing Site-related buildings and structures have been demolished and removed from the Site. As a result of the source area removal, no ongoing and active sources of contamination are known to exist at the former UCC Site.

- **Successful MOM/SC Remedial Activities** Remedial activities, including the operation of the SVE and groundwater pump and treat systems, have reportedly removed approximately 10,000 lbs of VOCs from the subsurface at the Site. The SVE treatment of the soils has been performed successfully such that unsaturated soils at the Site are no longer considered an ongoing source of the dissolved phase VOC contamination. The operation of the groundwater treatment system and subsequent use of remedial additives has resulted in a substantial reduction in dissolved phase VOC contaminant concentrations at the Site. Successful Remediation of the unsaturated soils has reduced the primary source of the dissolved phase contaminants. In the absence of the unsaturated zone soil contaminants, conditions at the Site have appeared to stabilize and reach equilibrium. Some residual VOC contaminants are likely sorbed to the fine-grained matrix of the till at the Site. However, based on the low groundwater transport velocities estimated for the till and bedrock, evidence of significant migration of the VOC contaminants has not been observed and is not anticipated to occur.

- **Stable Contaminant Distribution** VOC contaminant plume maps generated for the overburden and shallow bedrock units at the Site suggest that conditions at the Site have achieved equilibrium. Evidence of contaminant concentration "spiking" has not been generally observed in wells on the downgradient portion of the Site. The inferred VOC plume areas have stabilized or have been observed to be shrinking. Data generated from the most current semi-annual monitoring events has suggested that VOC contaminant concentrations in the overburden and bedrock units are slowly declining.

- **Low Contaminant Migration Potential** Much of the discussion in this conceptual site model has focused on the migration of dissolved phase VOC contamination in the till and underlying bedrock. The overall conclusion of these discussions is that conditions at the Site are not conducive to significant migration of contaminants beyond the limits of the Site. The till at the Site has been shown to produce very little water under pumping conditions and, therefore, is expected to transmit very little water. Yields for wells screened in the till were observed to be only fractions of a gallon per minute. Similar low yields are generally observed in the bedrock. Contaminants that do migrate downgradient at the Site will be limted in volume and concentration due to the successful source removal/reductions achieved at the Site. The limited quantitiy of VOC contaminants that migrate will likely flow in a east/southeast direction where they will eventually discharge to Quiggle Brook, and be diluted to below detectable levels upon discharge via the assimilative capacity of the brook. Contaminant migration into deeper bedrock is not considered to be significant due to the low VOC concentrations detected and the limited pathways available to the VOC contaminants in the deep bedrock.

Little migration of contaminants beyond the source area has been documented by the groundwater data collected during 35 rounds of sampling conducted since the initiation of assessment and response activities 1987. Recent approximations of the extent of the contaminant plumes in the overburden and bedrock are generally similar to those previously generated for the Site and significant reductions in the VOC contaminant concentrations have been observed.

The same subsurface conditions that limit the VOC contaminant migration potential at the Site also make removal of the residual contaminants difficult. The low influent flow rates into the MOM system (less than 8 gpm total from approximately 30 separate recovery wells with less than 1000 pounds of VOCs removed) have demonstrated that active remediation of the dissolved phase contamination through conventional means is not feasible. Similar difficulties associated with the permeability and transmissivity of the subsurface interface were observed during the implementation of the remedial additive technologies. Other than localized decreases in the wells, influence on contaminant concentrations Site wide and beyond the wells was generally not observed. To the extent practicable, the feasible remedial technologies have been successfully implemented at the Site. Further reduction of VOC concentrations via alternative technologies is not considered feasible at this time. As a result, the implementation of comprehensive, long term monitoring program is proposed for the Site. In general the existing monitoring well network at the Site provides adequate coverage of the contaminant plumes, and offers the ability to monitor for downgradient migration of dissolved-phase contamination. The long term monitoring program may require modification or inclusion of additional monitoring points or a new well(s) to provide the environmental data necessary to evaluate future Site conditions. During periodic 5-year reviews, the long term monitoring data should be analyzed to evaluate the overall Site conditions and to evaluate any feasible new technologies that have the potential to decrease the time and costs to achieve the Performance Standards.

9.0 References

Balsam Environmental Consultants Inc, Conceptual Ground Water Flow Model Letter Report, May 20, 1993.

Canonie Environmental, Remedial Investigation/Feasibility Study Union Chemical Company Superfund Site.

Davis, Stanley N and DeWiest, Roger J.M., Hydrogeology, Krieger Publishing Company, 1991.

Fetter, C.W. Applied Hydrogeology, Third Edition, Prentice Hall, 1994.

Fluor Daniel GTI, Closure Action Plan (CAP) – Groundwater, November 1997.

Fluor Daniel GTI, Construction Completion Report Management of Migration/Source Control, 1997.

Fluor Daniel GTI, Interim Test Report for the Potassium Permanginate Addition Activities Performed During the Summer of 1998, November 30, 1998.

Groundwater Technology, Management of Migration/Source Control Final 100% Design Union Chemical Company Site South Hope, Maine, Revised February 1995.

IT Corporation, Final Closure Action Plan for Soils Findings and Summary, October 4, 1999.

IT Corporation, Union Chemical Meeting Data Package, September 14, 1999.

Maine Department of Conservation, Maine Geological Survey, Physical Resources of Knox County, Maine, 1974.

Maine Department of Environmental Protection, Conceptual Hydrogeologic Model (Draft), July 22, 2003.

Identity and Physical/Chemical Properties, N,N-Dimethylformamide, http://www.inchem.org/documents/cicads/cicads/cicad31.htm.

Rizzo Associates, 2001 Carbon Source Addition Report Union Chemical Trust, June 16, 2003.

Rizzo Associates, IT Corporation, Fluor Daniel GTI, and GEI Consultants Inc. Quarterly Surface Water and Ground water Monitoring Reports Q1 through Q35, 1992 -2004.

Rizzo Associates. Bedrock Well Installation and Geophysical Evaluation Union Chemical Company Site. April 30, 2004.

Tetra Tech NUS, Inc, Union Chemical Company Superfund Site Five Year Review, September 2002.

Weiner, Eugene R, Applications of Environmental Chemistry, Lewis Publishers, 2000.

United States Environmental Protection Agency, Union Chemical Company Superfund Site Interim Remedial Action Report, September 28, 2001.

TABLE 1 - GROUNDWATER PERFORMANCE STANDARDS
Site Conceptual Model Report
Union Chemical Company Superfund Site
Hope, Maine

Constituent	Performance Standard (ug/L)
bis (2-ethylhexyl) phthalate	4
carbon tetrachloride	5
chloroform (as Total THM)	100
methylene chloride	5
1,1-dichloroethene	7
trans-1,2-dichloroethene	100
1,1-dichloroethane	5
1,2-dichloroethane	5
2-butanone (MEK)	170
cis-1,2-dichloroethene	70
tetrahydrofuran (THF)	70
1,1,1-trichloroethane	200
trichloroethene	5
vinyl chloride	2
toluene	70
tetrachloroethene	5
ethylbenzene	700
total xylenes	10000
Dimethylformamide	390

NOTES:

TABLE 2 - OVERBURDEN GROUNDWATER CONTAMINANT REDUCTIONS
Site Conceptual Model Report
Union Chemical Company Superfund Site
Hope, Maine

Constituent	Overburden Q12 Average Concentration[1] (ug/L)	Overburden Q12 Maximum Reported Concentration (ug/L)	Overburden Q12 Location of Maximum	Overburden Q31 Average Concentration[1] (ug/L)	Overburden Q31 Maximum Reported Concentration (ug/L)	Overburden Q31 Location of Maximum	Overburden Q35 Average Concentration[1] (ug/L)	Overburden Q35 Maximum Reported Concentration (ug/L)	Overburden Q35 Location of Maximum	Performance Standard (ug/L)
1,1-dichloroethene	868	3,200	B-12C-S	73	320	B-12B-I	241	2300	B-12B-I	7
trans-1,2-dichloroethene	3579 (total)	16,000 (total)	PZ-C-02	9	42	GT-16	6	8	MW-14-S	100
1,1-dichloroethane	2865	13,000	B-12C-S	873	3800	B-9A-I	487	3100	B-9A-I	5
2-butanone (MEK)	3863	12,000	B-12C-S	191	1700	B-9A-I	360	2900	B-9A-I	170
cis-1,2-dichloroethene	3579 (total)	16,000 (total)	PZ-C-02	289	1800	B-9A-I	120	740	B-12B-I	70
tetrahydrofuran (THF)	NA	NA	NA	30	40	B-5B-I	27	100U	B-9A-I	70
1,1,1-trichloroethane	2756	24,000	B-6B-I	9	33	B-6B-I	6	12	B-2B-S	200
trichloroethene	1056	8,200	B-6B-I	76	460	MW-14S	17	95	MW-14-S	5
vinyl chloride	NA	NA	NA	28	240	B-9A-I	12	50	B-12B-I	2
4-methyl-2-pentanone (MIBK)	1095	3,100	B-9A-I	66	320	B-12B-I	58	310	B-12B-I	NA
toluene	1710	12,000	PZ-B-01	8	30	GT-17/B-12B-I	18	80	B-9A-I	70
tetrachloroethene	1910	1,200	PZ-B-01	7	30	EW-1	5	20U	B-9A-I	5
ethylbenzene	8046	7,700	PZ-C-02	85	720	GT-17	88	500	B-12C-S	700
total xylenes	619	48,000	PZ-C-02	88	920	GT-17	113	550	B-12C-S	10000
Dimethylformamide	4491	26,000	B-12C-S	600	1900	B-12B-I	353	1400	B-12B-I	390

NOTES:
ND-not detected above method detection limits
NA-not available or not established
U - The analite was not detected above the laborotory reporting limit
[1]Average Concentration calculated using the typical detection limit if the compound tested was not detected.

TABLE 3 - BEDROCK GROUNDWATER CONTAMINANT REDUCTIONS
Site Conceptual Model Report
Union Chemical Company Superfund Site
Hope, Maine

Constituent	Bedrock Q12 Average Concentration[1] (ug/L)	Bedrock Q12 Maximum Reported Concentration (ug/L)	Bedrock Q12 Location of Maximum	Bedrock Q31 Average Concentration[1] (ug/L)	Bedrock Q31 Maximum Reported Concentration (ug/L)	Bedrock Q31 Location of Maximum	Bedrock Q35 Average Concentration[1] (ug/L)	Bedrock Q35 Maximum Reported Concentration (ug/L)	Bedrock Q35 Location of Maximum	Performance Standard (ug/L)
1,1-dichloroethene	68	630	B-6A-D	58	220	B-8A-D	56	370	B-6A-D	7
1,1-dichloroethane	1144	11,000	B-6A-D	420	2000	B-6A-D	405	3300	B-6A-D	5
2-butanone (MEK)	218	ND	ND	NA	NA	NA	134	1000	B-12A-D	170
cis-1,2-dichloroethene	176 (total)	1700(total)	B-6A-D	152	1000	B-6A-D	252	2200	B-6A-D	70
tetrahydrofuran (THF)	NA	NA	NA	41	130	B-8A-D	29	50	B-12A-D/B-8A-D	70
trichloroethene	116	1,100	B-6A-D	10	40	B-6A-D	10	60	B-6A-D	5
vinyl chloride	NA	NA	NA	6	20	B-6A-D	11	70	B-6A-D	2
4-methyl-2-pentanone (MIBK)	55	39	ODW-U	321	2100	B-8A-D	158	810	B-8A-D	NA
toluene	165	1,600	B-6A-D	9	20	B-8A-D	8	20	B-6A-D	70
tetrachloroethene	55	ND	ND	NA	NA	NA	6	20U	B-6A-D	5
ethylbenzene	215	2,100	B-6A-D	24	140	B-6A-D	148	1300	B-6A-D	700
total xylenes	725	7,200	B-6A-D	19	60	B-6A-D	104	870	B-6A-D	10000
Dimethylformamide	98	710	B-6A-D	1000	2600	B-8A-D	290	770	B-8A-D	390

NOTES:
ND-not detected above method detection limits
NA-not available or not established
U - The analite was not detected above the laborotory reporting limit
[1]Average Concentration calculated using the typical detection limit if the compound tested was not detected.

TABLE 4 - SITE WIDE GROUNDWATER CONTAMINANT REDUCTIONS
Site Conceptual Model Report
Union Chemical Company Superfund Site
Hope, Maine

Constituent	Site Wide Q12 Average Concentration[1] (ug/L)	Site Wide Q12 Maximum Reported Concentration (ug/L)	Site Wide Q12 Location of Maximum	Site Wide Q31 Average Concentration[1] (ug/L)	Site Wide Q31 Maximum Reported Concentration (ug/L)	Site Wide Q31 Location of Maximum	Site Wide Q35 Average Concentration[1] (ug/L)	Site Wide Q35 Maximum Reported Concentration (ug/L)	Site Wide Q35 Location of Maximum	Performance Standard (ug/L)
1,1-dichloroethene	520	3,200	B-12C-S	68	320	B-12B-I	153	2300	B-12B-I	7
trans-1,2-dichloroethene	2099	16,000 (total)	PZ-C-02	6	42	GT-16	3	8	MW-14-S	100
1,1-dichloroethane	2117	13,000	B-12C-S	729	3800	B-9A-I	448	3300	B-6A-D	5
2-butanone (MEK)	2278	12,000	B-12C-S	130	1700	B-9A-I	253	2900	B-9A-I	170
cis-1,2-dichloroethene	2099	16,000 (total)	PZ-C-02	245	1800	B-9A-I	183	2200	B-6A-D	70
tetrahydrofuran (THF)	NA	NA	NA	34	130	B-8A-D	28	100U	B-9A-I	70
1,1,1-trichloroethane	1582	24,000	B-6B-I	6	33	B-6B-I	3	12	B-2B-S	200
trichloroethene	647	8,200	B-6B-I	55	460	MW-14S	14	95	MW-14-S	5
vinyl chloride	NA	NA	NA	21	240	B-9A-I	12	70	B-6A-D	2
4-methyl-2-pentanone (MIBK)	643	3,100	B-9A-I	147	2100	B-8A-D	105	810	B-8A-D	NA
toluene	1038	12,000	PZ-B-01	8	30	GT-17/B-12B-I	13	80	B-9A-I	70
tetrachloroethene	1103	1,200	PZ-B-01	5	30	EW-1	5	20U	B-9A-I/B-6A-D	5
ethylbenzene	4641	7,700	PZ-C-02	66	720	GT-17	116	1300	B-6A-D	700
total xylenes	665	48,000	PZ-C-02	66	920	GT-17	109	870	B-6A-D	10000
Dimethylformamide	2581	26,000	B-12C-S	733	2600	B-8A-D	332	1400	B-12B-I	390

NOTES:
ND-not detected above method detection limits
NA-not available or not established
U - The analite was not detected above the laborotory reporting limit
[1]Average Concentration calculated using the typical detection limit if the compound tested was not detected.

TABLE 5 - CALCULATED HALF LIVES AND PROJECTED TIMES TO REACH PERFORMANCE STANDARDS
Site Conceptual Model Report
Union Chemical Company Superfund Site
Hope, Maine

B-12A-D Fully rebounded in Q31 most receint spring data compaired to Q31

Compound	Fall 2001 Q30	Spring 2002 Q31	Fall 2002 Q32	Spring 2003 Q33	Fall 2003 Q34	Spring 2004 Q35	reduction	over time in years	k	half life years	cleanup target	time to reach target (years)
DCA	380	13	300	30	10	10	3	2	-0.13118	-5.283854	5	13.65856339
DCE	150	4	78	10	10	10	-6	2	0.458145	1.512942	70	4.247364033
DMF	100	100	240	50	50	50	50	2	-0.34657	-2	390	achieved
TCE	6	2	2	10	10	10	-8	2	0.804719	0.861353	5	-0.861353116

B-12B-I Fully rebounded in Q31 most receint spring data compaired to Q31

Compound	Fall 2001 Q30	Spring 2002 Q31	Fall 2002 Q32	Spring 2003 Q33	Fall 2003 Q34	Spring 2004 Q35	reduction	over time in years	k	half life years	cleanup target	time to reach target (years)
DCA	2200	3000	2800	2300	2300	2300	700	2	-0.13285	-5.217455	5	46.15094798
DCE	760	1100	890	580	640	740	360	2	-0.19821	-3.497076	70	10.66827142
DMF	1300	2000	470	1200	1400	1400	600	2	-0.17834	-3.886716	390	6.302265498
TCE	40	50	40	30	30	30	20	2	-0.25541	-2.713831	5	7.015151104

B-12C-S Fully rebounded in Q31 most receint spring data compaired to Q31

Compound	Fall 2001 Q30	Spring 2002 Q31	Fall 2002 Q32	Spring 2003 Q33	Fall 2003 Q34	Spring 2004 Q35	reduction	over time in years	k	half life years	cleanup target	time to reach target (years)
DCA	1000	1200	1100	1000	1000	1100	100	2	-0.04351	-15.93233	5	121.7844735
DCE	540	730	520	480	330	370	360	2	-0.33977	-2.040044	70	5.666440625
DMF	380	700	200	540	520	460	240	2	-0.20993	-3.30185	390	1.550169917
TCE	110	40	20	10	20	10	30	2	-0.69315	-1	5	1

TABLE 5 - CALCULATED HALF LIVES AND PROJECTED TIMES TO REACH PERFORMANCE STANDARDS
Site Conceptual Model Report
Union Chemical Company Superfund Site
Hope, Maine

B-6A-D Appears to be continuing to rebound or contaminants are migrating from other parts of the Site to this location

Compound	Fall 2001 Q30	Spring 2002 Q31	Fall 2002 Q32	Spring 2003 Q33	Fall 2003 Q34	Spring 2004 Q35	reduction	over time in years	k	half life years	cleanup target	time to reach target (years)
DCA	3000	2000	NA	2200	4000	3300	-1000	2	0.143841	4.818842	5	-42.31598219
DCE	1600	1000	NA	1300	2500	2200	-900	2	0.223144	3.106284	70	-13.09302592
TCE	39	40	NA	40	60	60	-21	2	0.215391	3.218081	5	-9.654243304

NA - Not Available

B-8A-D Fully rebounded in Q31or Q32 most receint spring data compaired to Q31

Compound	Fall 2001 Q30	Spring 2002 Q31	Fall 2002 Q32	Spring 2003 Q33	Fall 2003 Q34	Spring 2004 Q35	reduction	over time in years	k	half life years	cleanup target	time to reach target (years)
DCA	590	690	690	420	510	300	390	2	-0.41645	-1.664401	5	10.63937632
DCE	45	40	60	40	40	30	10	2	-0.14384	-4.818842	70	achieved
DMF	3300	2600	1400	1300	1800	770	1830	2	-0.60844	-1.139224	390	1.978792576
TCE	19	20	20	10	20	10	10	2	-0.34657	-2	5	2

B-9A-I Apperas to be rebounding from the effects of dilution from lactate additions. Bio may have pushed DCE and TCE to near or below standards.

Compound	Fall 2001 Q30	Spring 2002 Q31	Fall 2002 Q32	Spring 2003 Q33	Fall 2003 Q34	Spring 2004 Q35	reduction	over time in years	k	half life years	cleanup target	time to reach target (years)
DCA	4400	3800	1300	1700	2200	3100	1300	2.5	-0.14008	-4.948189	5	39.69619543
DCE	2000	1800	400	420	10	20	1980	2.5	-1.84207	-0.376287	70	0.946202439
TCE	280	200	80	50	20	20	260	2.5	-1.05562	-0.656624	5	2.62649535

TABLE 5 - CALCULATED HALF LIVES AND PROJECTED TIMES TO REACH PERFORMANCE STANDARDS
Site Conceptual Model Report
Union Chemical Company Superfund Site
Hope, Maine

MW-14S Fully rebounded in Q30 most receint spring data compaired to Q31

Compound	Fall 2001 Q30	Spring 2002 Q31	Fall 2002 Q32	Spring 2003 Q33	Fall 2003 Q34	Spring 2004 Q35	reduction	over time in years	k	half life years	cleanup target	time to reach target (years)
DCA	4	3	2	2	2	2	1	2	-0.20273	-3.419023	5	achieved
DCE	210	150	200	150	170	61	89	2	-0.44988	-1.540735	70	1.694093627
TCE	470	460	310	360	370	95	365	2	-0.78867	-0.878876	5	5.42259766

NA - Not Available

TABLE 6 - BEDROCK GROUNDWATER WELL DESCRIPTION
Site Conceptual Model Report
Union Chemical Company Superfund Site
Hope, Maine

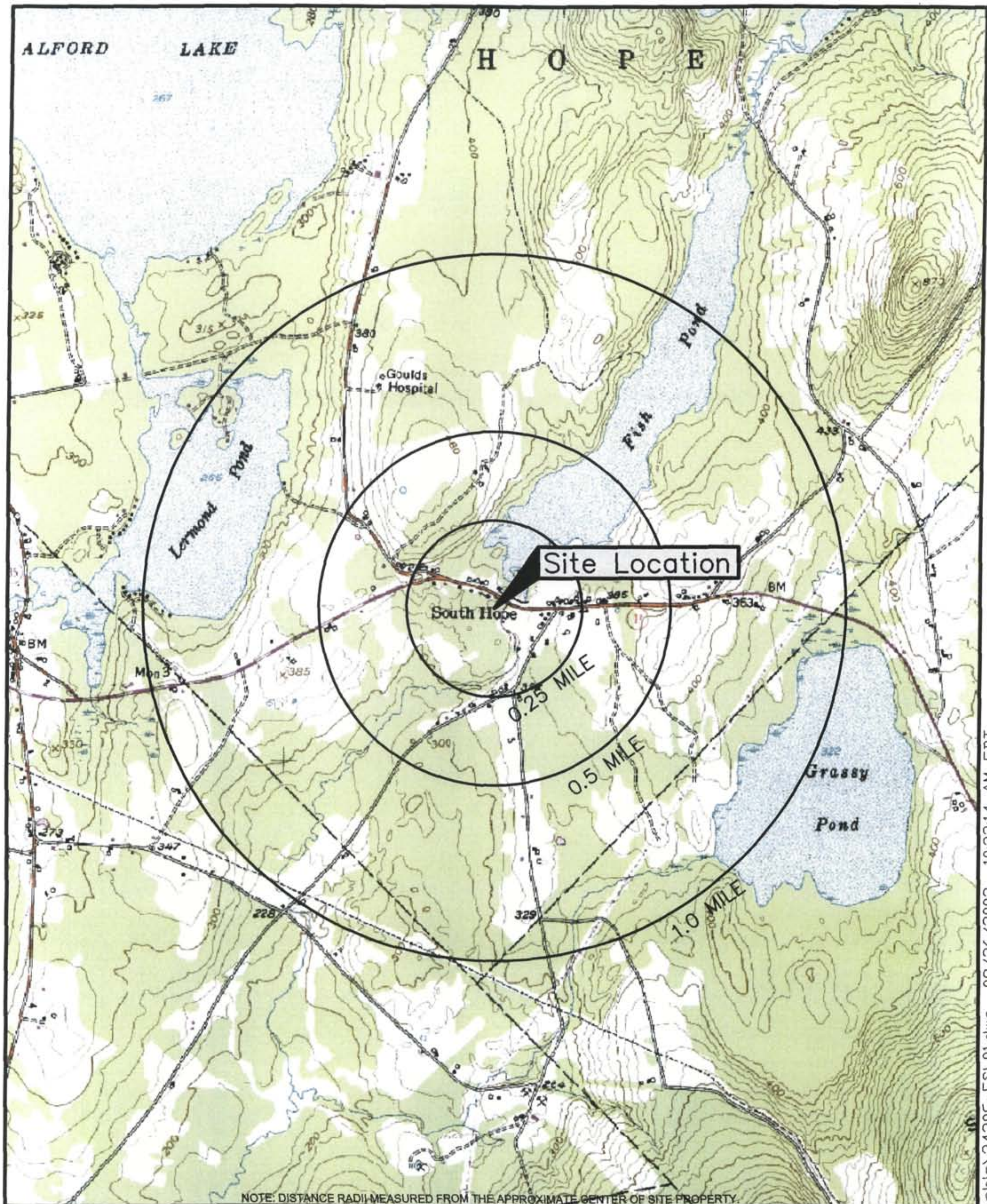
Well Identification	Depth to Bedrock	Well Screen Interval	Well Screen Elevations	Notes
B-1A(D)	30.5	34-37	331-228	Up-gradient, broken at 15 feet, unusable
B-2A(D)	54.5	57.5-59.5	303.5-301.5	Broken at 10 feet, unusable
B-3A(D)	70.3	73-75	273.5-271.5	Bedrock well couplet with B-3B(D), east near Quiggle Brook
B-3B(D)	61.2	67-68	279.8-278.8	Bedrock well couplet with B-3B(D)
B-4B(D)	63.7	66.7-68.7	288.6-286.6	Well broken at 30 feet, unusable
B-5A(D)	61.6	66-68	283.7-281.7	Downgradient, southeast, bedrock well adjacent to Quiggle Brook
B-6A(D)	75	78-88	274.5-264.5	Bedrock well in south center with highest contaminant concentrations
B-8A(D)	64	68-78	289.3-279.3	Downgradient, south of Site
B-12A(D)	69	76-86	271.5-261.5	Downgradient and east, bedrock well adjacent to Quiggle Brook
B-13A(D)	78	80-90	266.3-256.3	Northeast corner near Quiggle brook
B-14A(D)	54	58-68	299.5-289.5	Downgradient, southwest of Site
ITW-1	20	26-500	--	Up-gradient, Site water source, west of site, historically clean well
MW-3(D)	71	76-86	270.2-260.2	Northeast portion of Site
MW-10(D)	67	72-82	276-266	Downgradient, and cross gradient to ODW
MW-13A(D)	--	84.5-127.5	282-239	South center of site, well screened across shallow and deep bedrock aquifer

TABLE 6 - BEDROCK GROUNDWATER WELL DESCRIPTION
Site Conceptual Model Report
Union Chemical Company Superfund Site
Hope, Maine

MW-15(D)	60	63-73	304.7-294.7	Up-gradient, north and center - furthest usable bedrock well north
NBW-L	53	115-120	243.6-238.6	Down Dip/Strike from source area
NBW-U	53	56-66	302.6-292.6	Down Dip/Strike from source area
OW-1-1D	58	66-81	293.7-278.7	Downgradient, south-center
OW-3-1D	65	71-81	279.6-269.6	Northeast corner near Quiggle Brook
ODW(L)	--	225-245	130.79-110.79	Downgradient, furthest well south
ODW(U)	--	154-174	201.79-181.79	Downgradient, furthest well south
OPW	--	102-150	270-222	Up-gradient, center of site

TABLE 7 - CHRONOLOGY OF SITE EVENTS
Site Conceptual Model Report
Union Chemical Company Superfund Site
Hope, Maine

Union Chemical Company produces and recycles solvents at the Site	1967 - 1983
MEDEP discovers organic chemicals in groundwater below the Site	1979
UCC funded studies of soil and groundwater contamination	1981
Hazardous waste treatment operations at the Site closed by MEDEP	June, 1984
2,000-2,500 55-gallon drums and 30 liquid storage tanks and contents removed from the Site by the USEPA and the MEDEP	November 1984
UCC evicted from the Site by state court order; MEDEP appointed as receiver of the property	1986
Under two Administrative Orders by Consent, the PRPs agree to reimburse EPA and MEDEP for response costs incurred prior to May 22, 1987 and perform an RI/FS	Fall 1987
Additional PRPs sign Consent Decree reimbursing EPA for past response costs	August 7, 1989
Final listing of the Site on NPL	October 4, 1989
Canonie performs Remedial Investigation/Feasibility Study	1990
Record of Decision signed	December 27, 1990
Focused Feasibility Study completed demonstrating SVE is a viable soil treatment technology	April 1993
EPA approval of Facilities Remedial Design	October 23, 1993
EPA approval of Facilities Remedial Action Work Plan	November 5, 1993
ESD signed changing source control from excavation and low-thermal aeration to SVE	June 24, 1994
Source Control soil consolidation and site capping	October 1994-May1995
EPA approves 100% SVE/MOM Remedail Design and Remedial Action Work Plan	April 5, 1995
Wells Installed for SVE/MOM Treatment System	June 1995 - July 1995
Construction of Treatment Plan	July 1995 - September 1995
Final Section of Clay Cap Completed	September 1995
SVE/MOM treatment system equipment installation	September 1995 - November 1995
Equipment Testing	November 1995 - December 1995
SVE/MOM treatment system start-up period	Januray 1996 - June 1996
Extended SVE/MOM start up-period	June 1996 - Februarly 1997
Off-Site Soils Investigation	October 1996
O&F Final design Inspection for SVE/MOM systems	April 28, 1997
ESD signed documenting change to off-Site soils remedy and certification of completion	September 1997
Permanginate pilot study	November 1, 1997
EPA approval of Construction Completion Report for SVE/MOM systems	December 19, 1997
Compliance sampling for soil performance standards	August 1998-September 1998
First permanginate full scale implementation	Summer 1998
second permanginate full scale implementation	Summer - Fall 1999
EPA approval of final close actoin plan for soils, findings and summary	December 17, 1999
Third permanganate full-scale implementation	Summer-Fall 2000
ESD signed documenting permanganate and carbon source additions	September 27, 2001
Carbon souce pilot study	Fall 2001
First carbon source full scale implementation	August 1, 2002
EPA First Five Year Review	September 2002



Project No. 2420.13

Union Chemical Company
Hope, Maine

Information obtained from
USGS Map of West Rockport, Massachusetts
Quadrangle dated 1988

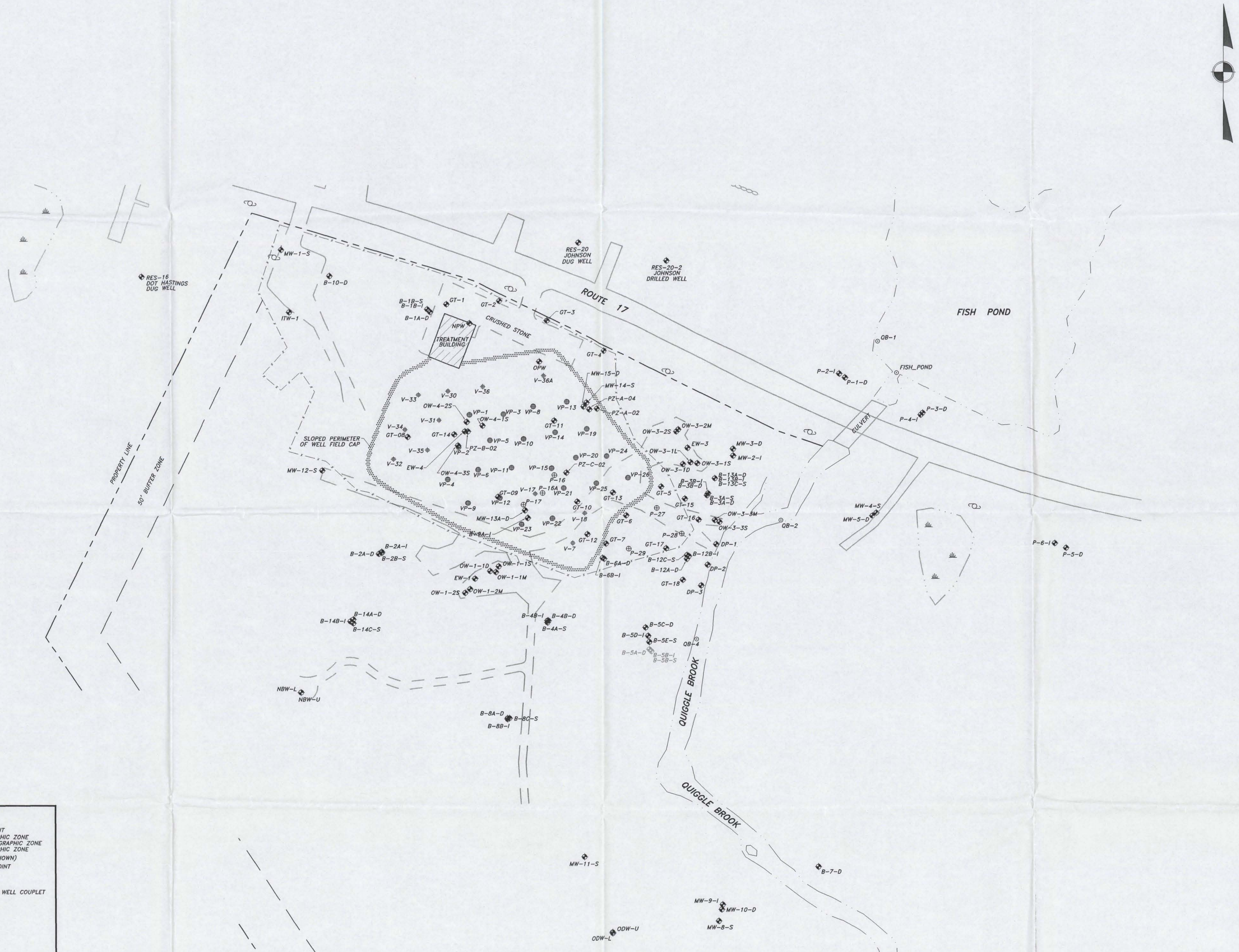
RIZZO ASSOCIATES
A TETRA TECH COMPANY

Figure

Site Locus Plan

CSM-1

J:\Project\2420\Graphic\2420G-ESL01.dwg 08/26/2003 10:32:14 AM EDT



LEGEND

B-8A-D B-8B-I B-8C-S	GROUNDWATER QUALITY MONITORING POINT (D) WELL SET IN BEDROCK STRATIGRAPHIC ZONE (I) WELL SET IN INTERMEDIATE STRATIGRAPHIC ZONE (S) WELL SET IN SHALLOW STRATIGRAPHIC ZONE (NOT ALL SITE RELATED WELLS ARE SHOWN)
QB-1	SURFACE WATER QUALITY MONITORING POINT
V-33	SOIL VAPOR EXTRACTION WELL
P-16	PUMPING WELL
VP-3	PUMPING WELL/SOIL VAPOR EXTRACTION WELL COUPLET
	WETLAND
	UTILITY POLE
	STONE WALL
	FENCE
	GRAVEL ROAD
	PROPERTY LINE

NOTES:

1. ALL WELLS LOCATED IN ACCORDANCE WITH SURVEY CONDUCTED BY MAINE COAST SURVEYING NOV. 9, 1995 (EXCEPT WELLS P-5-D & P-6-I, GT-15 THROUGH GT-18; DP-1 THROUGH DP-3).

SOURCE:

AutoCAD SITE PLAN PREPARED FOR UNION CHEMICAL COMPANY RDRA TRUST BY MAINE COAST SURVEYING, ELM STREET, DAMARISCOTTA, MAINE, LAST REVISED NOVEMBER 4, 1992; 2] "MONITORING WELL AND PIEZOMETER LOCATION PLAN" PREPARED FOR UNION CHEMICAL TRUSTESS BY CANONIE ENVIRONMENTAL, FIGURE 4, 9/27/88.

NOT FOR CONSTRUCTION

THESE PLANS WERE PREPARED FOR THE PURPOSE OF OBTAINING STATE AND LOCAL APPROVALS AND ARE NOT INTENDED TO BE USED AS CONSTRUCTION DOCUMENTS.

No.	Date	Description

Revisions

Drawn By | Designed By | Checked By | Approved By

RIZZO ASSOCIATES
A TETRA TECH COMPANY
One Grant Street
Framingham, MA 01701-9005
508.903.2000
www.rizzo.com

Project Title

Union Chemical Company Hope, Maine

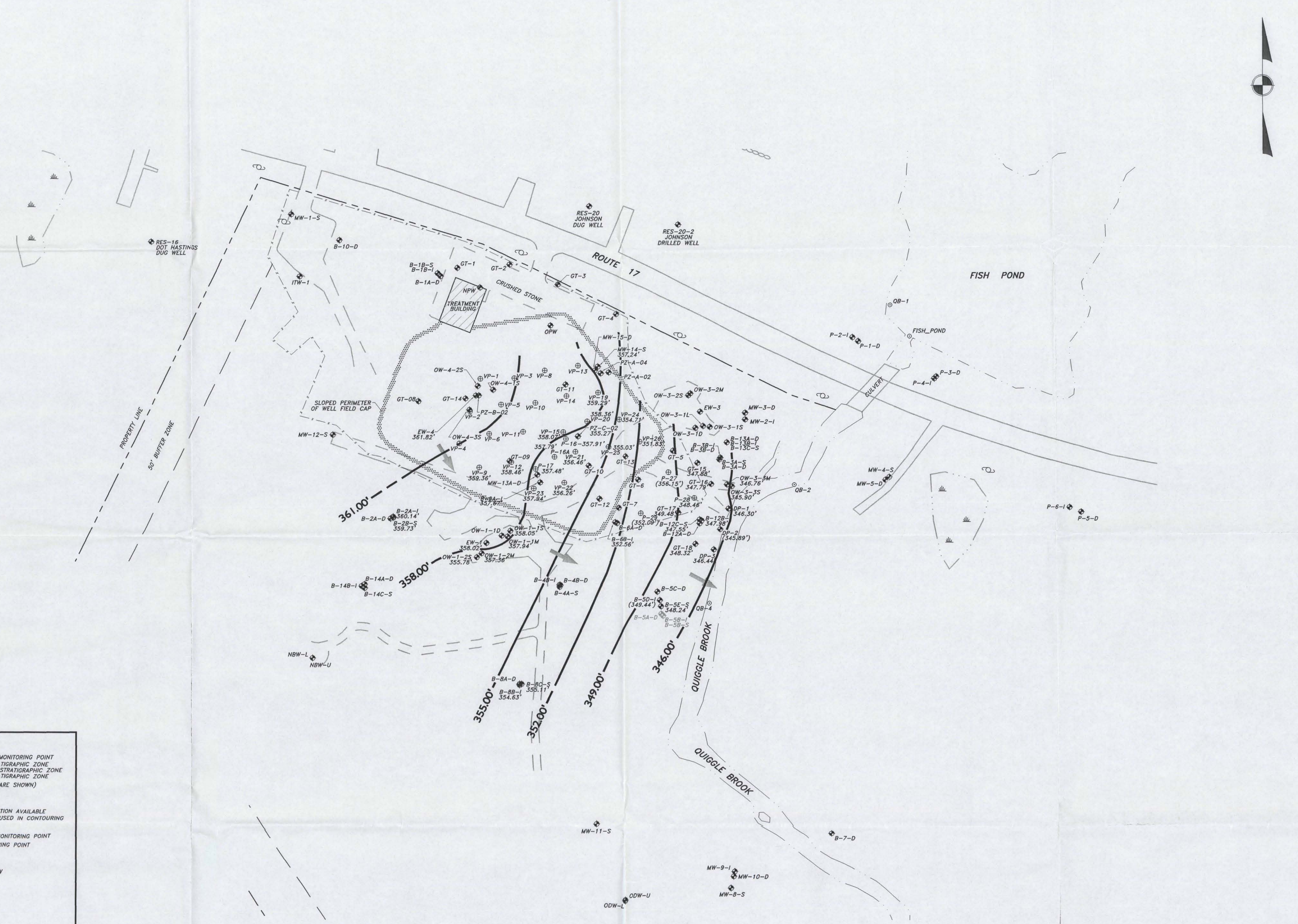
Sheet Title

Site Plan
DRAFT

Scale: 1"=50'
Job No.: 2420.13
File Name: ESP01
Date: 07/02/04

Sheet No.
CSM-2

J:\Project\2420\Plot\Q35\SitePlans\2420P-ESP02.dwg 07/02/2004 12:52:54 PM EDT



LEGEND

B-8A-D B-8B-I B-8C-S	EXISTING GROUNDWATER QUALITY MONITORING POINT (D) WELL SET IN BEDROCK STRATIGRAPHIC ZONE (I) WELL SET IN INTERMEDIATE STRATIGRAPHIC ZONE (S) WELL SET IN SHALLOW STRATIGRAPHIC ZONE (NOT ALL SITE RELATED WELLS ARE SHOWN)
P-16 ⊕	PUMPING WELL
353.90'	GROUNDWATER ELEVATION (FEET) NA INDICATES NO CASING ELEVATION AVAILABLE ( ) INDICATES WELL DATA NOT USED IN CONTOURING
B-5B-I	FORMER GROUNDWATER QUALITY MONITORING POINT
QB-1 ⊙	SURFACE WATER QUALITY MONITORING POINT
	WETLAND
	UTILITY POLE
	DIRECTION OF GROUNDWATER FLOW
358.00'	GROUNDWATER CONTOUR (FEET) (DASHED WHERE INFERRED)
	STONE WALL
	FENCE
	GRAVEL ROAD
	PROPERTY LINE

NOTES:

1. ALL WELLS LOCATED IN ACCORDANCE WITH SURVEY CONDUCTED BY MAINE COAST SURVEYING NOV. 9, 1995 (EXCEPT WELLS P-5-D & P-6-I, GT-15 THROUGH GT-18; DP-1 THROUGH DP-3).
2. FLUCTUATIONS IN THE GROUNDWATER LEVEL MAY OCCUR DUE TO FACTORS NOT ACCOUNTED FOR AT THE TIME MEASUREMENTS WERE MADE.
3. GROUNDWATER CONTOURS AND FLOW DIRECTIONS ASSUME HOMOGENEOUS, ISOTROPIC AQUIFER CONDITIONS AND HORIZONTAL FLOW.
4. GROUNDWATER CONTOURS ARE INTERPOLATED BETWEEN DATA POINTS AND INFERRED IN OTHER AREAS.

SOURCE:

AutoCAD SITE PLAN PREPARED FOR UNION CHEMICAL COMPANY RDRA TRUST BY MAINE COAST SURVEYING, ELM STREET, DAMARISCOTTA, MAINE, LAST REVISED NOVEMBER 4, 1992; 2] "MONITORING WELL AND PIEZOMETER LOCATION PLAN" PREPARED FOR UNION CHEMICAL TRUSTESS BY CANONIE ENVIRONMENTAL, FIGURE 4, 9/27/88.

NOT FOR CONSTRUCTION

THESE PLANS WERE PREPARED FOR THE PURPOSE OF OBTAINING STATE AND LOCAL APPROVALS AND ARE NOT INTENDED TO BE USED AS CONSTRUCTION DOCUMENTS.

No.	Date	Description

Revisions

Drawn By Designed By Checked By Approved By

RIZZO ASSOCIATES
A TETRA TECH COMPANY
One Grant Street
Framingham, MA 01701-9005
508.903.2000
www.rizzo.com

Project Title

Union Chemical Company Hope, Maine

Sheet Title

Overburden Groundwater Table Elevation Contours April 13, 2004

Scale: 1"=50'
Job No.: 2420.13
File Name: EOGW01
Date: 07/02/04

Sheet No. CSM-3

J:\Project\2420\Plot\035\overburden\2420P-EOGW02.dwg 07/02/2004 12:54:52 PM EDT

LEGEND

- SURFACE WATER QUALITY MONITORING POINT
- GROUNDWATER QUALITY MONITORING POINT
  - (D) WELL SET IN BEDROCK STRATIGRAPHIC ZONE
  - (I) WELL SET IN INTERMEDIATE STRATIGRAPHIC ZONE
  - (S) WELL SET IN SHALLOW STRATIGRAPHIC ZONE

NOT ALL SITE RELATED WELLS ARE SHOWN

SAMPLING DATES: 4/13/04 – 4/14/04

EX.: B-12C-S – WELL IDENTIFICATION
1100 – 1,1-DICHLOROETHANE (µg/L)
20 – TRICHLOROETHENE (µg/L)
530 – CIS 1,2-DICHLOROETHENE (µg/L)
200 – DIMETHYLFORMAMIDE (µg/L)

NOTE: ISOCONCENTRATION CONTOURS BASED ON ALL GROUNDWATER SAMPLES COLLECTED DURING Q35. ONLY DATA FROM WELLS IN FSP FOR QUARTERLY SAMPLING ARE POSTED.

< or U	– LESS THAN METHOD DETECTION LIMIT
-------	– INFERRED ISOCONCENTRATION CONTOUR (µg/L)
J	– ASSOCIATED NUMERICAL VALUE IS AN ESTIMATED QUANTITY
D	– CONSTITUENT IDENTIFIED IN DILUTED SAMPLE
B	– CONSTITUENT IDENTIFIED IN TRIP BLANK
( )	– CONCENTRATION NOT USED IN CONTOURING
NA	– NOT ANALYZED
NS	– NOT SAMPLED
	STONE WALL
	WETLAND
	UTILITY POLE
	FENCE

MAP SOURCE: 1] AUTOCAD SITE PLAN PREPARED FOR UNION CHEMICAL COMPANY RDRA TRUST BY MAINE COAST SURVEYING, ELM STREET, DAMARISCOTTA, MAINE, LAST REVISED NOVEMBER 4, 1992; 2] "MONITORING WELL AND PIEZOMETER LOCATION PLAN" PREPARED FOR UNION CHEMICAL TRUSTESS BY CANONIE ENVIRONMENTAL, FIGURE 4, 9/27/88.

ALL WELLS LOCATED IN ACCORDANCE WITH SURVEY CONDUCTED BY MAINE COAST SURVEYING NOV. 9, 1995 (EXCEPT WELLS GT-15 THROUGH GT-18; DP-1, DP-2, DP-3, B-5C-D, B-5D-I, B-5E-S, NBW-U, NBW-L).

GRAPHIC SCALE

50 0 25 50 100 200

(IN FEET)
1 inch = 50 ft.

NOT FOR CONSTRUCTION
THESE PLANS WERE PREPARED FOR THE PURPOSE OF OBTAINING STATE AND LOCAL APPROVALS AND ARE NOT INTENDED TO BE USED AS CONSTRUCTION DOCUMENTS.

No.	Date	Description

Revisions

Drawn By	Designed By	Checked By	Approved By

RIZZO ASSOCIATES
A TETRA TECH COMPANY
One Grant Street
Framingham, MA 01701-9005
508.903.2000
www.rizzo.com

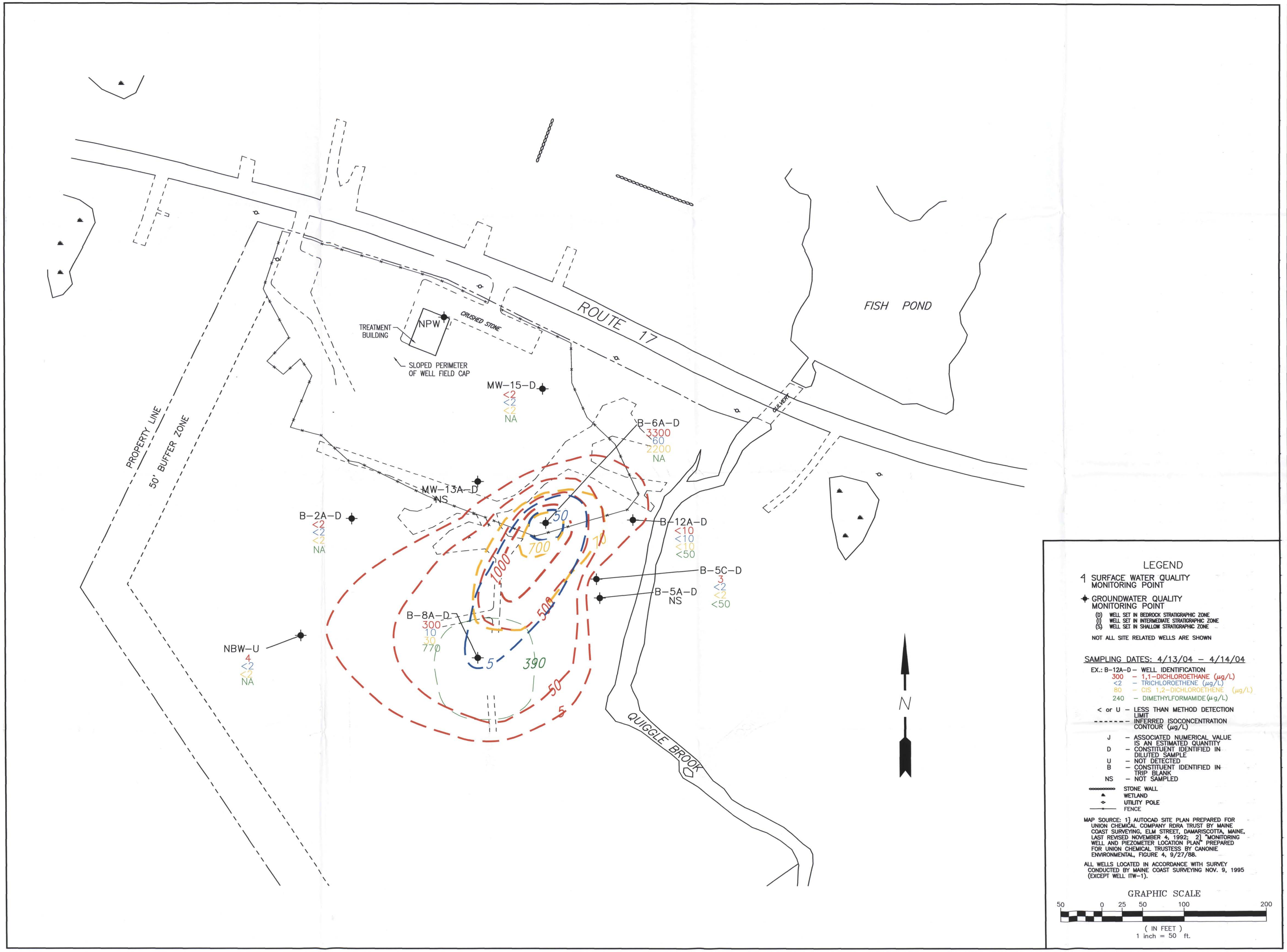
Project Title
Union Chemical Company Hope, Maine

Sheet Title
Overburden Plume Extents April 2004 DRAFT

Scale: 1"=50'
Job No.: 2420.13
File Name: EOPM02
Date: 07/02/04

Sheet No.
CSM-5

J:\Project\2420\Plot\Q35\overburden\2420P-EOPM02.dwg 07/02/2004 01:03:28 PM EDT



LEGEND

4 SURFACE WATER QUALITY MONITORING POINT

✦ GROUNDWATER QUALITY MONITORING POINT

- (D) WELL SET IN BEDROCK STRATIGRAPHIC ZONE
- (I) WELL SET IN INTERMEDIATE STRATIGRAPHIC ZONE
- (S) WELL SET IN SHALLOW STRATIGRAPHIC ZONE

NOT ALL SITE RELATED WELLS ARE SHOWN

SAMPLING DATES: 4/13/04 – 4/14/04

EX.: B-12A-D – WELL IDENTIFICATION
- 300 – 1,1-DICHLOROETHANE (μg/L)
- <2 – TRICHLOROETHENE (μg/L)
- 80 – CIS 1,2-DICHLOROETHENE (μg/L)
- 240 – DIMETHYLFORMAMIDE (μg/L)

< or U – LESS THAN METHOD DETECTION LIMIT

------- – INFERRED ISOCONCENTRATION CONTOUR (μg/L)

J – ASSOCIATED NUMERICAL VALUE IS AN ESTIMATED QUANTITY

D – CONSTITUENT IDENTIFIED IN DILUTED SAMPLE

U – NOT DETECTED

B – CONSTITUENT IDENTIFIED IN TRIP BLANK

NS – NOT SAMPLED

STONE WALL

WETLAND

UTILITY POLE

FENCE

MAP SOURCE: 1] AUTOCAD SITE PLAN PREPARED FOR UNION CHEMICAL COMPANY RDRA TRUST BY MAINE COAST SURVEYING, ELM STREET, DAMARISCOTTA, MAINE, LAST REVISED NOVEMBER 4, 1992; 2] "MONITORING WELL AND PIEZOMETER LOCATION PLAN" PREPARED FOR UNION CHEMICAL TRUSTESS BY CANONIE ENVIRONMENTAL, FIGURE 4, 9/27/88.

ALL WELLS LOCATED IN ACCORDANCE WITH SURVEY CONDUCTED BY MAINE COAST SURVEYING NOV. 9, 1995 (EXCEPT WELL ITW-1).

GRAPHIC SCALE

50 0 25 50 100 200

(IN FEET)
1 inch = 50 ft.

NOT FOR CONSTRUCTION

THESE PLANS WERE PREPARED FOR THE PURPOSE OF OBTAINING STATE AND LOCAL APPROVALS AND ARE NOT INTENDED TO BE USED AS CONSTRUCTION DOCUMENTS.

No.	Date	Description

Revisions

Drawn By	Designed By	Checked By	Approved By

RIZZO ASSOCIATES
A TETRA TECH COMPANY
One Grant Street
Framingham, MA 01701-9005
508.903.2000
www.rizzo.com

Project Title

Union Chemical Company Hope, Maine

Sheet Title

Shallow Bedrock Plume Extents April 2004 DRAFT

Scale: 1"=50'

Job No.: 2420.13

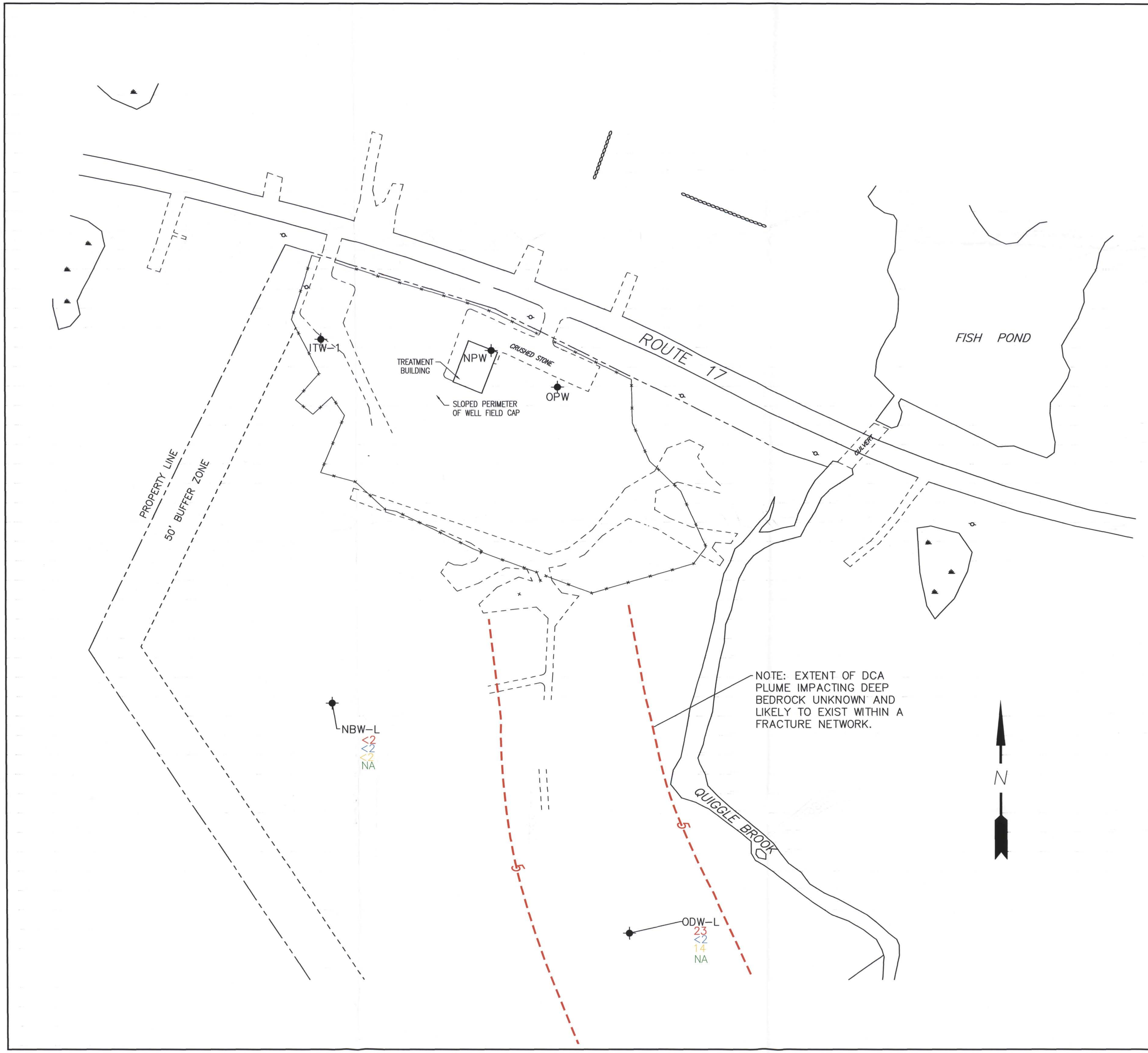
File Name: EBGW602

Date: 07/02/04

Sheet No.

CSM-6

J:\Project\2420\Plot\Q35\Bedrock\2420P-EBGW602.dwg 07/02/2004 01:18:49 PM EDT



LEGEND

4 SURFACE WATER QUALITY MONITORING POINT

GROUNDWATER QUALITY MONITORING POINT

(D) WELL SET IN BEDROCK STRATIGRAPHIC ZONE
(I) WELL SET IN INTERMEDIATE STRATIGRAPHIC ZONE
(S) WELL SET IN SHALLOW STRATIGRAPHIC ZONE

NOT ALL SITE RELATED WELLS ARE SHOWN

SAMPLING DATES: 4/13/04 – 4/14/04

EX.: B-12A-D – WELL IDENTIFICATION
300 – 1,1-DICHLOROETHANE (μg/L)
<2 – TRICHLOROETHENE (μg/L)
80 – CIS 1,2-DICHLOROETHENE (μg/L)
240 – DIMETHYLFORMAMIDE (μg/L)

< or U – LESS THAN METHOD DETECTION LIMIT
------- – INFERRED ISOCONCENTRATION CONTOUR (μg/L)

J – ASSOCIATED NUMERICAL VALUE IS AN ESTIMATED QUANTITY
D – CONSTITUENT IDENTIFIED IN DILUTED SAMPLE
U – NOT DETECTED
B – CONSTITUENT IDENTIFIED IN TRIP BLANK
NS – NOT SAMPLED

STONE WALL
WETLAND
UTILITY POLE
FENCE

MAP SOURCE: 1] AUTOCAD SITE PLAN PREPARED FOR UNION CHEMICAL COMPANY RDRA TRUST BY MAINE COAST SURVEYING, ELM STREET, DAMARISCOTTA, MAINE, LAST REVISED NOVEMBER 4, 1992; 2] "MONITORING WELL AND PIEZOMETER LOCATION PLAN" PREPARED FOR UNION CHEMICAL TRUSTESS BY CANONIE ENVIRONMENTAL, FIGURE 4, 9/27/88.

ALL WELLS LOCATED IN ACCORDANCE WITH SURVEY CONDUCTED BY MAINE COAST SURVEYING NOV. 9, 1995 (EXCEPT WELL ITW-1).

GRAPHIC SCALE

50 0 25 50 100 200

(IN FEET)
1 inch = 50 ft.

NOT FOR CONSTRUCTION

THESE PLANS WERE PREPARED FOR THE PURPOSE OF OBTAINING STATE AND LOCAL APPROVALS AND ARE NOT INTENDED TO BE USED AS CONSTRUCTION DOCUMENTS.

No.	Date	Description

Revisions

Drawn By Designed By Checked By Approved By

RIZZO ASSOCIATES
A TETRA TECH COMPANY
One Grant Street
Framingham, MA 01701-9005
508.903.2000
www.rizzo.com

Project Title

Union Chemical Company Hope, Maine

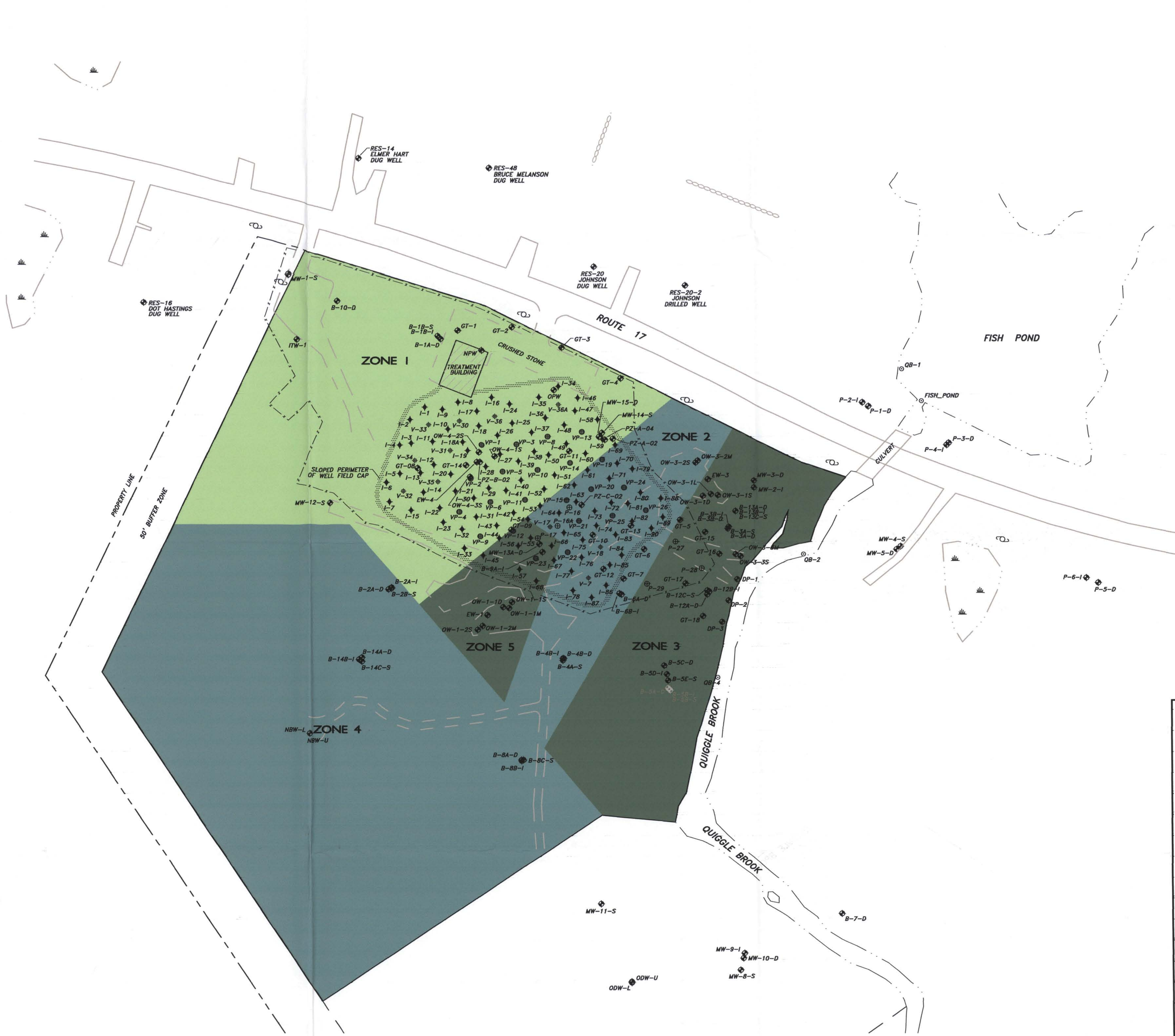
Sheet Title

Deep Bedrock Plume Extents April 2004 DRAFT

Scale: 1"=50'
Job No.: 2420.13
File Name: EBGW702
Date: 07/02/04

Sheet No.
CSM-7

J:\Project\2420\Plot\Q35\Bedrock\2420P-EBGW702.dwg 07/02/2004 01:19:20 PM EDT



NOT FOR CONSTRUCTION

THESE PLANS WERE PREPARED FOR THE PURPOSE OF OBTAINING STATE AND LOCAL APPROVALS AND ARE NOT INTENDED TO BE USED AS CONSTRUCTION DOCUMENTS.

No.	Date	Description

Revisions

Drawn By | Designed By | Checked By | Approved By

LEGEND

SITE PERMEABILITY VELOCITY ZONE
- RELATIVE MEDIUM PERMEABILITY
- RELATIVE LOW PERMEABILITY
- RELATIVE EXTREMELY LOW PERMEABILITY

B-13A-D / B-13B-I / B-13C-S — GROUNDWATER QUALITY MONITORING POINT
- (D) WELL SET IN BEDROCK STRATIGRAPHIC ZONE
- (I) WELL SET IN INTERMEDIATE STRATIGRAPHIC ZONE
- (S) WELL SET IN SHALLOW STRATIGRAPHIC ZONE

(NOT ALL SITE RELATED WELLS ARE SHOWN)

- QB-1 — SURFACE WATER QUALITY MONITORING POINT
- V-33 — SOIL VAPOR EXTRACTION WELL
- P-16 — PUMPING WELL
- VP-3 — PUMPING WELL/SOIL VAPOR EXTRACTION WELL COUPLET
- I-33 — HOT AIR INJECTION WELL
- WETLAND
- UTILITY POLE
- STONE WALL
- FENCE
- GRAVEL ROAD
- PROPERTY LINE
- ZONE LINE

NOTES:

1. ALL WELLS LOCATED IN ACCORDANCE WITH SURVEY CONDUCTED BY MAINE COAST SURVEYING NOV. 9, 1995 (EXCEPT WELLS P-5-D & P-6-I, GT-15 THROUGH GT-18; DP-1 THROUGH DP-3).

SOURCE:

AutoCAD SITE PLAN PREPARED FOR UNION CHEMICAL COMPANY RDRA TRUST BY MAINE COAST SURVEYING, ELM STREET, DAMARISCOTTA, MAINE, LAST REVISED NOVEMBER 4, 1992; 2] "MONITORING WELL AND PIEZOMETER LOCATION PLAN" PREPARED FOR UNION CHEMICAL TRUSTESS BY CANONIE ENVIRONMENTAL, FIGURE 4, 9/27/88.

GRAPHIC SCALE

50 0 25 50 100 200

(IN FEET)
1 inch = 50 ft.

RIZZO ASSOCIATES
A TETRA TECH COMPANY
One Grant Street
Framingham, MA 01701-9005
508.903.2000
www.rizzo.com

Project Title

Union Chemical Company Hope, Maine

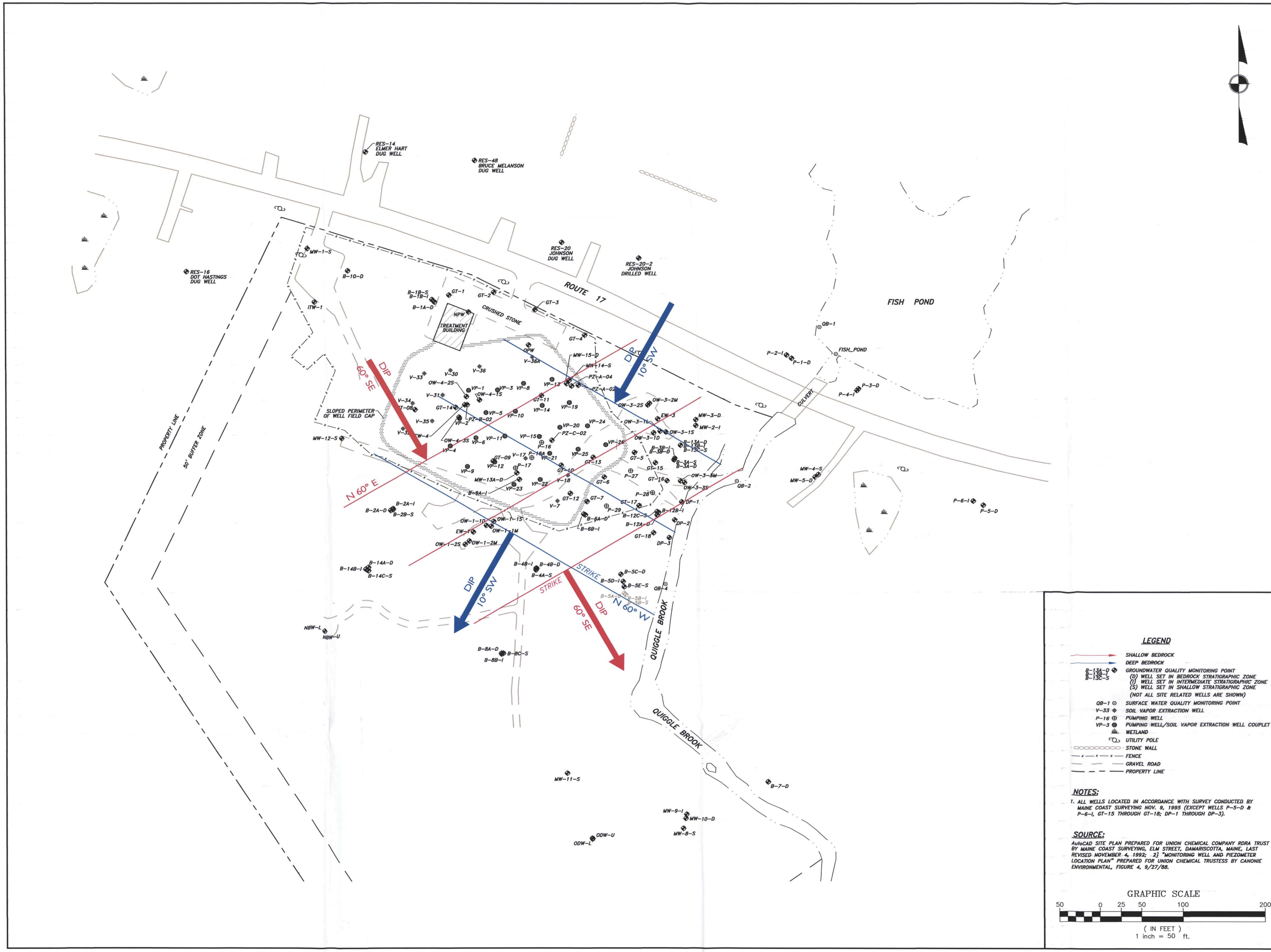
Sheet Title

Overburden Zones of Similar Subsurface Conditions DRAFT

Scale: 1"=50'
Job No.: 2420.13
File Name: EOZP01
Date: 07/02/04

Sheet No.
CSM-8

J:\Project\2420\Plat\Q35\overburden\2420P-EOZP01.dwg 07/02/2004 01:22:55 PM EDT



NOTES:

1. ALL WELLS LOCATED IN ACCORDANCE WITH SURVEY CONDUCTED BY MAINE COAST SURVEYING NOV. 9, 1995 (EXCEPT WELLS P-5-D & P-6-I, GT-15 THROUGH GT-18; DP-1 THROUGH DP-3).

SOURCE:

AutoCAD SITE PLAN PREPARED FOR UNION CHEMICAL COMPANY RDRA TRUST BY MAINE COAST SURVEYING, ELM STREET, DAMARISCOTTA, MAINE, LAST REVISED NOVEMBER 4, 1992; 2] "MONITORING WELL AND PIEZOMETER LOCATION PLAN" PREPARED FOR UNION CHEMICAL TRUSTESS BY CANONIE ENVIRONMENTAL, FIGURE 4, 9/27/88.

NOT FOR CONSTRUCTION

THESE PLANS WERE PREPARED FOR THE PURPOSE OF OBTAINING STATE AND LOCAL APPROVALS AND ARE NOT INTENDED TO BE USED AS CONSTRUCTION DOCUMENTS.

No.	Date	Description

Revisions

Drawn By | Designed By | Checked By | Approved By

RIZZO ASSOCIATES
A TETRA TECH COMPANY
One Grant Street
Framingham, MA 01701-9005
508.903.2000
www.rizzo.com

Project Title
Union Chemical Company Hope, Maine

Sheet Title
Site Plan with Strike and Dip Lines DRAFT

Scale: 1"=50'
Job No.: 2420.13
File Name: ESD01
Date: 07/02/04

Sheet No.
CSM-9

J:\Project\2420\Plot\035\SitePlans\2420P-ESD01.dwg 07/02/2004 01:23:25 PM EDT

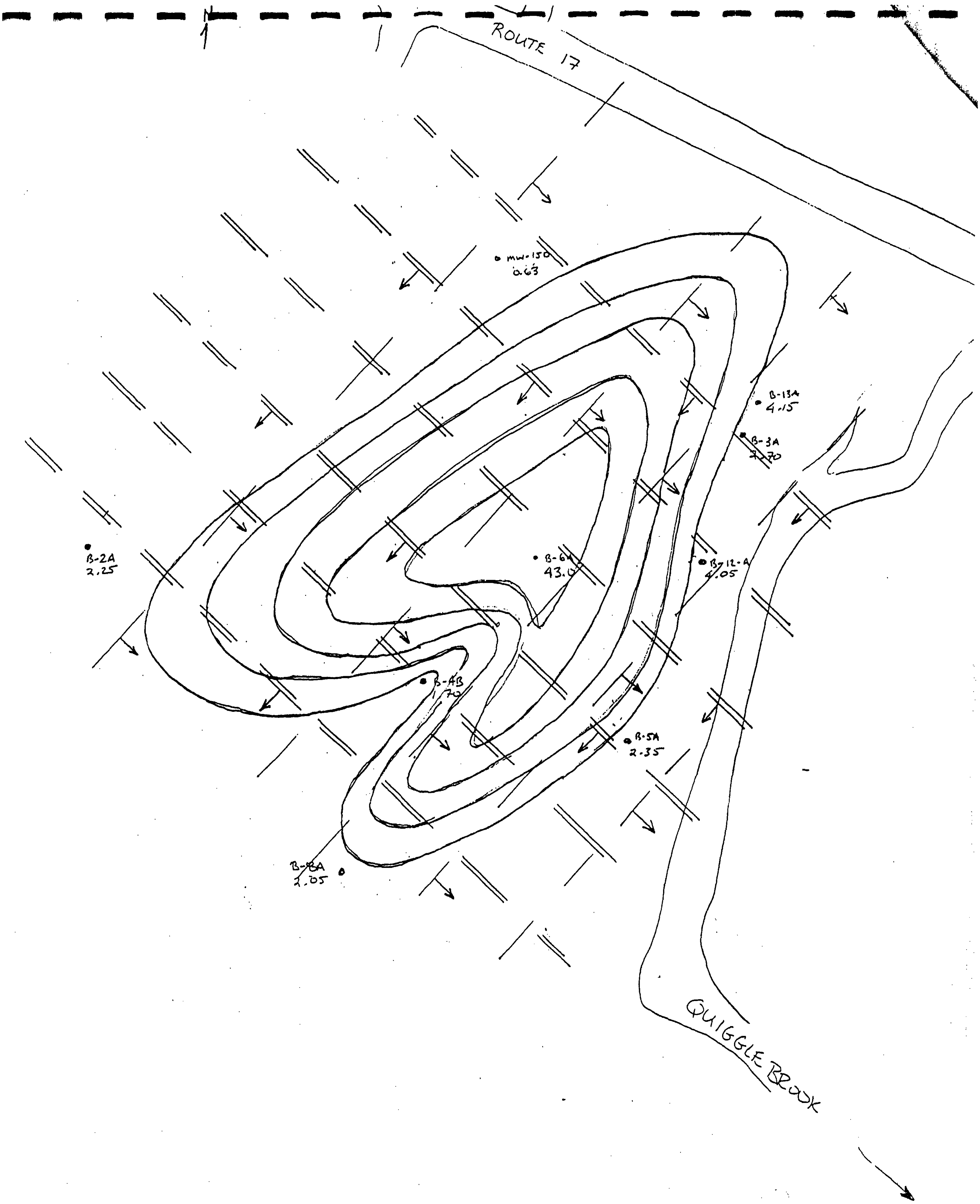


FIGURE CSM - 11

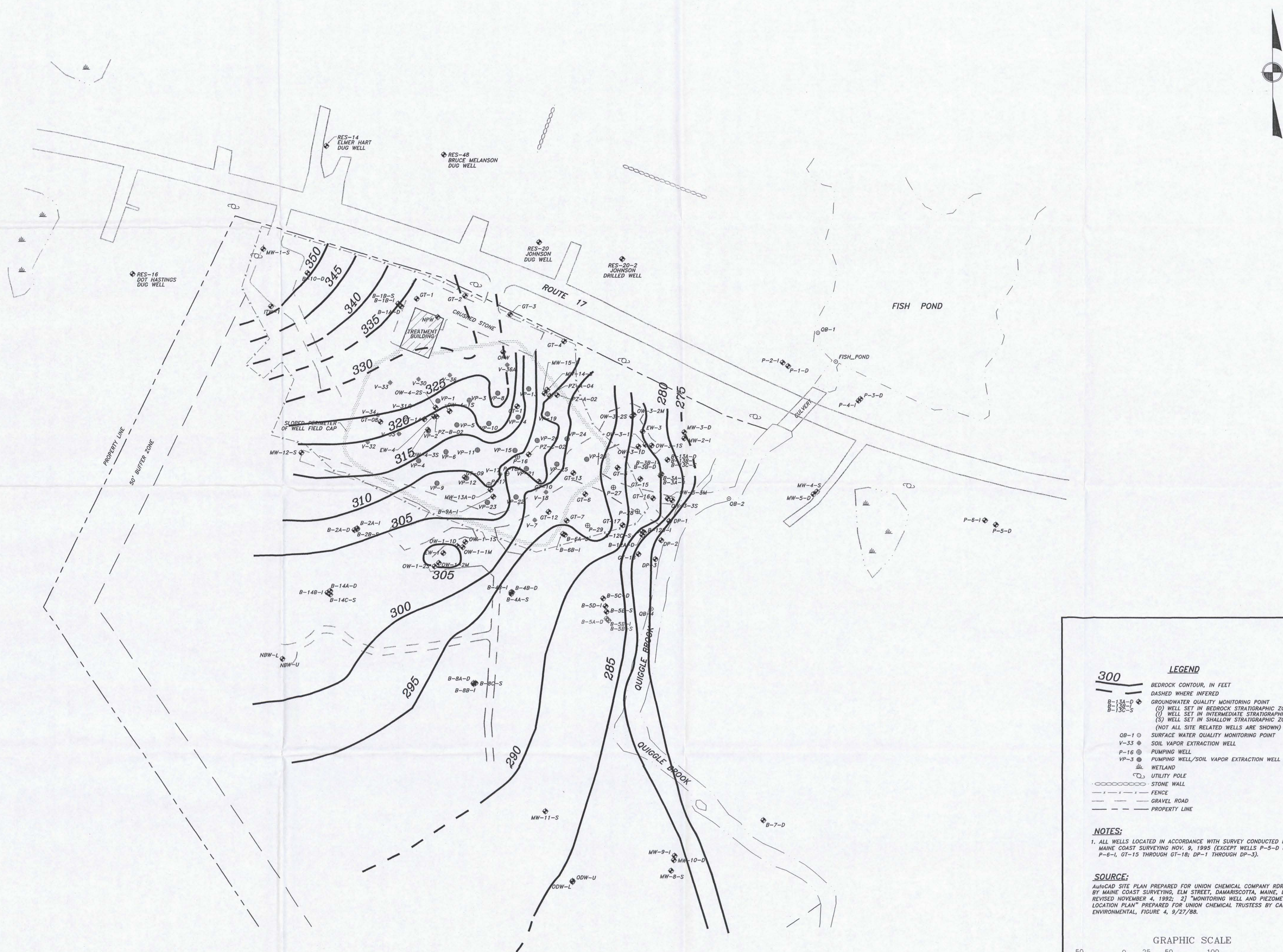
CONTOURS OF RELATIVE DRAWDOWN

@ 1000 minutes ΔS =

B-2A(D) - 2.25
B-3A(D) - 2.70
B-4B(D) - 1.70
B-5A(D) - 2.35
B-8A(D) - 2.05
B-12A(D) - 4.05
B-13A(D) - 4.15
MW-15(D) - 0.63

STRIKE & DIP OF FRACTURES >110FT

STRIKE & DIP OF FRACTURES <110 FT



LEGEND

300	BEDROCK CONTOUR, IN FEET
	DASHED WHERE INFERED
B-13A-D B-13B-I B-13C-S	GROUNDWATER QUALITY MONITORING POINT (D) WELL SET IN BEDROCK STRATIGRAPHIC ZONE (I) WELL SET IN INTERMEDIATE STRATIGRAPHIC ZONE (S) WELL SET IN SHALLOW STRATIGRAPHIC ZONE (NOT ALL SITE RELATED WELLS ARE SHOWN)
QB-1	SURFACE WATER QUALITY MONITORING POINT
V-33	SOIL VAPOR EXTRACTION WELL
P-16	PUMPING WELL
VP-3	PUMPING WELL/SOIL VAPOR EXTRACTION WELL COUPLET
	WETLAND
	UTILITY POLE
	STONE WALL
	FENCE
	GRAVEL ROAD
	PROPERTY LINE

NOTES:

1. ALL WELLS LOCATED IN ACCORDANCE WITH SURVEY CONDUCTED BY MAINE COAST SURVEYING NOV. 9, 1995 (EXCEPT WELLS P-5-D & P-6-I, GT-15 THROUGH GT-18; DP-1 THROUGH DP-3).

SOURCE:

AutoCAD SITE PLAN PREPARED FOR UNION CHEMICAL COMPANY RDRA TRUST BY MAINE COAST SURVEYING, ELM STREET, DAMARISCOTTA, MAINE, LAST REVISED NOVEMBER 4, 1992; 2] "MONITORING WELL AND PIEZOMETER LOCATION PLAN" PREPARED FOR UNION CHEMICAL TRUSTESS BY CANONIE ENVIRONMENTAL, FIGURE 4, 9/27/88.

GRAPHIC SCALE

50 0 25 50 100 200

(IN FEET)
1 inch = 50 ft.

NOT FOR CONSTRUCTION

THESE PLANS WERE PREPARED FOR THE PURPOSE OF OBTAINING STATE AND LOCAL APPROVALS AND ARE NOT INTENDED TO BE USED AS CONSTRUCTION DOCUMENTS.

No.	Date	Description

Revisions

Drawn By | Designed By | Checked By | Approved By

RIZZO ASSOCIATES
A TETRA TECH COMPANY
One Grant Street
Framingham, MA 01701-9005
508.903.2000
www.rizzo.com

Project Title

Union Chemical Company Hope, Maine

Sheet Title

Site Plan with Bedrock Surface Contours

Scale: 1"=50'
Job No.: 2420.13
File Name: 2420P_EBSC01
Date: 09/09/04

Sheet No.
CSM-12

J:\Project\2420\Plot\Q35\Bedrock\2420P-EBSC01.dwg 09/09/2004 01:56:02 PM EDT

Appendix A

Limitations

Appendix A: Limitations

1. The observations described in this report were made under the conditions stated therein. The conclusions presented in the report were based solely upon the services described therein, and not on scientific tasks or procedures beyond the scope of described services or the time and budgetary constraints imposed by CLIENT. The work described in this report was carried out in accordance with the Terms and Conditions in our contract.

2. In preparing this report, Rizzo Associates has relied on certain information provided by state and local officials and other parties referenced therein, and information contained in the files of state and/or local agencies available to Rizzo Associates at the time of the site assessment. Although there may have been some degree of overlap in the information provided by these various sources, Rizzo Associates did not attempt to independently verify the accuracy or completeness of all information reviewed or received during the course of this site assessment.

3. Observations were made of the Site and structures on the Site as indicated within the report. Where access to portions of the Site, or to structures on the Site, was unavailable or limited, Rizzo Associates renders no opinion as to the presence of hazardous materials or oil, or to the presence of indirect evidence relating to hazardous material or oil, in that portion of the Site or structure. In addition, Rizzo Associates renders no opinion as to the presence of hazardous material or oil, or the presence of indirect evidence relating to hazardous material or oil, where direct observation of the interior walls, floor, or ceiling of a structure on a Site was obstructed by objects or coverings on or over these surfaces.

4. Rizzo Associates did not perform testing or analyses to determine the presence or concentration of asbestos at the Site or in the environment at the Site.

5. It is ENGINEER's understanding that the purpose of this report is to assess the physical characteristics of the subject Site with respect to the presence on the Site of hazardous material or oil. This stated purpose has been a significant factor in determining the scope and level of services provided for in the Agreement. Should the purpose

for which the report is to be used or the proposed use of the site(s) change, this report is no longer valid and use of this report by CLIENT or others without ENGINEER's review and written authorization shall be at the user's sole risk. Should ENGINEER be required to review the report after its date of submission, ENGINEER shall be entitled to additional compensation at then existing rates or such other terms as agreed between ENGINEER and CLIENT.

6. The conclusions and recommendations contained in this report are based in part, where noted, upon the data obtained from a limited number of soil samples obtained from widely spaced subsurface explorations. The nature and extent of variations between these explorations may not become evident until further exploration. If variations or other latent conditions then appear evident, it will be necessary to reevaluate the conclusions and recommendations of this report.

7. Any water level readings made in test pits, borings, and/or observation wells were made at the times and under the conditions stated in the report. However, it must be noted that fluctuations in the level of groundwater may occur due to variations in rainfall and other factors different from those prevailing when the measurements were made.

8. Except as noted within the text of the report, no quantitative laboratory testing was performed as part of the site assessment. Where such analyses have been conducted by an outside laboratory, Rizzo Associates has relied upon the data provided and has not conducted an independent evaluation of the reliability of these data.

9. The conclusions and recommendations contained in this report are based in part, where noted, upon various types of chemical data and are contingent upon their validity. These data have been reviewed, and interpretations made, in the report. As indicated within the report, some of these data may be preliminary "screening" level data and should be confirmed with quantitative analyses if more specific information is necessary. Moreover, it should be noted that variations in the types and concentrations of contaminants and variations in their flow paths may occur due to seasonal water table fluctuations, past disposal practices, the passage of time, and other factors. Should additional chemical data become available in the future, these data should be reviewed, and the conclusions and recommendations presented herein modified accordingly.

10. Chemical analyses have been performed for specific constituents during the course of this site assessment, as described in the text. However, it should be noted that additional chemical constituents not searched for during the current study may be present in soil and/or groundwater at the Site.

11. This report was prepared for the exclusive use of CLIENT. No other party is entitled to rely on the conclusions, observations, specifications, or data contained therein without the express written consent of ENGINEER.

12. The observations and conclusions described in this report are based solely on the Scope of Services provided pursuant to the Agreement. ENGINEER has not performed any additional observations, investigations, studies, or testing not specifically stated therein. ENGINEER shall not be liable for the existence of any condition, the discovery of which required the performance of services not authorized under the Agreement.

13. The passage of time may result in significant changes in technology, economic conditions, or site variations, which would render the report inaccurate. Accordingly, neither CLIENT, nor any other party, shall rely on the information or conclusions contained in this report after six months from its date of submission without the express written consent of ENGINEER. Reliance on the report after such period of time shall be at the user's sole risk. Should ENGINEER be required to review the report after six months from its date of submission, ENGINEER shall be entitled to additional compensation at then existing rates or such other terms as may be agreed upon between ENGINEER and CLIENT.

14. ENGINEER has endeavored to perform services based upon engineering practices accepted at the time they were performed. ENGINEER makes no other representations, express or implied, regarding the information, data, analysis, calculations, and conclusions contained herein.

APPENDIX B

Appendix B

Volume of VOC Calculations

Appendix B

Volume of Contaminants in Soil

Conceptual Site Model

Union Chemical Company Superfund Site

Hope, Maine

Volume of contaminants in soil $V_c = C_s * V_s$ (Weiner p89)

Where : V_s = Volume of soil

C_s = Concentration of sorbed organic compound in solid phase

Soil water partition coeficient $k_d = K_{oc} * f_{oc} = C_s/C_w$ (Weiner p89)

Where : k_d = Partition coefficient for sorption

K_{oc} = Partion coeficient in terms of soil organic carbon

f_{oc} = Fraction of organic carbon

C_w = Concentration of dissolved organic compound in water phase

And: K_{oc} = Organic Carbon Partition Coeficient Values

$K_{oc\ DCA}$ =	31.6		(Weiner P93)
$K_{oc\ DCE}$ =	35.5		(Weiner P93)
$K_{oc\ TCE}$ =	166		(Weiner P95)
$K_{oc\ DMF}$ =	9.84	(calculated based on log K_{ow} of DMF)	(Weiner P95 and Identity and Physical)

Assume: weight fraction of organic carbon f_{oc} for coarse soil = 0.04 (Weiner p89)

Conversion Factor: 125 lbs/ft^3 * 1kg/1,000,000,000ug = 0.000000125 lb kg/ug ft^3

Formula: $V_c = K_{oc} * f_{oc} * C_w * V_s$

$$V_c\,(lbs) = K_{oc}\,(L/kg) * f_{oc} * C_w\,(ug/L) * V_s\,(ft^3) * 0.000000125\,(lb\ kg/\ ug\ ft^3)$$

Appendix B
Volume of Contaminants in Soil
Conceptual Site Model
Union Chemical Company Superfund Site
Hope, Maine

DMF K_{oc} Calculation

For Semi-volitals: $\text{Log } K_{oc} = 0.983 \text{ Log } K_{ow} + 0.00028$ (Cicad 31 Long, Meek)

Where: $\text{Log } K_{ow} =$ 1.01

For DMF: $\text{Log } K_{oc} =$ 0.983 * 1.01 + 0.00028

$K_{oc} = 9.8426$

Appendix B
Volume of Contaminants in Soil
Conceptual Site Model
Union Chemical Company Superfund Site
Hope, Maine

CSM Groundwater plume maps where used when calculating the volume of soil within an area that is expected to be impacted by a given contaminant concnetration. The average of two representitive plume radai were used when calculating plume areas, and the average of the two representitive depths were used for each layer to calculate volume. Representitive depths are based on soil boring logs and previous environmental reports for the Site. The average concentration for a given contaminant was assumed to be the median value of the plume concentration lines as shown on the groundwater plume maps. The percentage of water in a given medium is based on values presented on p. 100, Weiner.

DCA Plume overburden

Plume conc. Area	avg conc (ug/L)	total area (sq feet)	inner area (sq feet)	area (sq feet)	d1 (feet)	d2 (feet)	avg depth (feet)	volume of soil (cu feet)	dtw 1 (feet)	dtw 2 (feet)	avg dtw (feet)	volume of soil under water (cu feet)	percentage of water (%)	volume of water (cu feet)	volume of water (liters)	volume of contaminants in gw (kg)	volume of contaminants in gw (lb)	soil water partition coefficient-Kd	volume of contaminants in soil (lb)	Total Volume of VOC in subsurface
5 to 50	27.5	112145	60552	51593	54.5	60	57.25	2953699.25	1.1	16.22	8.66	2506903.87	0.15	376035.58	10647088	0.292794919	0.645495679	0.1264	1.283382324	1.928878003
50 to 500	275	60552	29486	31066	58	69	63.5	1972691	4.5	1.53	3.015	1879027.01	0.15	281854.05	7980428.02	2.194617704	4.838254191	0.1264	8.571342395	13.40959659
500 to 3100	1800	29486	0	29486	78	69	73.5	2167221	12	1.53	6.765	1967748.21	0.15	295162.23	8357236.41	15.04302554	33.1638541	0.1264	61.63576524	94.79961934
																total (lbs)	38.64760397		71.49048996	110.1380939

DCE Plume overburden

Plume conc. Area	avg conc (ug/L)	total area (sq feet)	inner area (sq feet)	area (sq feet)	d1 (feet)	d2 (feet)	avg depth (feet)	volume of soil (cu feet)	dtw 1 (feet)	dtw 2 (feet)	avg dtw (feet)	volume of soil under water (cu feet)	percentage of water (%)	volume of water (cu feet)	volume of water (liters)	volume of contaminants (kg)	volume of contaminants (lb)	soil water partition coefficient-Kd	volume of contaminants in soil (lb)	Total Volume of VOC in subsurface
70 to 700	385	11320	95	11225	60	69	64.5	724013	16.22	1.53	8.875	624390.625	0.15	93658.594	2651853.54	1.020963615	2.250816385	0.142	4.947720422	7.198536807
700 to 740	720	95	0	95	69	69	69	6555	1.53	1.53	1.53	6409.65	0.15	961.4475	27222.4668	0.019600176	0.043210548	0.142	0.0837729	0.126983448
																total (lbs)	2.294026933		5.031493322	7.325520255

TCE Plume Overburden

Plume conc. Area	avg conc (ug/L)	total area (sq feet)	inner area (sq feet)	area (sq feet)	d1 (feet)	d2 (feet)	avg depth (feet)	volume of soil (cu feet)	dtw 1 (feet)	dtw 2 (feet)	avg dtw (feet)	volume of soil under water (cu feet)	percentage of water (%)	volume of water (cu feet)	volume of water (liters)	volume of contaminants (kg)	volume of contaminants (lb)	soil water partition coefficient-Kd	volume of contaminants in soil (lb)	Total Volume of VOC in subsurface
5 to 50	27.5	47868	8887	38981	69	60	64.5	2514275	1.53	16.22	8.875	2168318.125	0.15	325247.72	9209078.22	0.253249651	0.558314181	0.664	5.738831546	6.297145727
50 to 95	72.5	8887	0	8887	60	60	60	533220	16.22	16.22	16.22	389072.86	0.15	58360.929	1652433.91	0.119801459	0.264114296	0.664	3.20865135	3.472765646
																total (lbs)	0.822428476		8.947482896	9.769911373

DMF Plume Overburden

Plume conc. Area	avg conc (ug/L)	total area (sq feet)	inner area (sq feet)	area (sq feet)	d1 (feet)	d2 (feet)	avg depth (feet)	volume of soil (cu feet)	dtw 1 (feet)	dtw 2 (feet)	avg dtw (feet)	volume of soil under water (cu feet)	percentage of water (%)	volume of water (cu feet)	volume of water (liters)	volume of contaminants (kg)	volume of contaminants (lb)	soil water partition coefficient-Kd	volume of contaminants in soil (lb)	Total Volume of VOC in subsurface
390 to 1400	895	2597	0	2597	69	69	69	179193	1.53	1.53	1.53	175219.59	0.15	26282.939	744176.277	0.666037768	1.468346863	0.0394	0.789860345	2.258207208
																total (lbs)	1.468346863		0.789860345	2.258207208

Total volume of primary contaminants in groundwater (lbs) 43.23

Estimated volume of primary contaminants in overburden 129.4917328

DCA plume shallow bedrock

Plume conc. Area			avg conc (ug/L)	total area (sq feet)	inner area (sq feet)	area (sq feet)	d1 (feet)	d2 (feet)	avg depth (feet)	volume of soil under water (cu feet)	percentage of water (%)	volume of water (cu feet)	volume of water (liters)	volume of contaminants (kg)	volume of contaminants (lbs)
5	to	50	27.5	82924	38797	44127	20	20	20	882540	0.1	88254	2498827.6	0.06871776	0.151495174
50	to	500	275	49361	14396	34965	20	20	20	699300	0.1	69930	1980001.1	0.544500302	1.200405365
500	to	1000	750	14396	6029	8367	20	20	20	167340	0.1	16734	473807.21	0.355355409	0.783416535
1000	to	3300	2150	6029	0	6029	20	20	20	120580	0.1	12058	341410.74	0.734033096	1.618249365

total (lbs) 3.753566439

TCE plume shallow bedrock

Plume conc. Area			avg conc (ug/L)	total area (sq feet)	inner area (sq feet)	area (sq feet)	d1 (feet)	d2 (feet)	avg depth (feet)	volume of soil under water (cu feet)	percentage of water (%)	volume of water (cu feet)	volume of water (liters)	volume of contaminants (kg)	volume of contaminants (lbs)
5	to	50	27.5	17147	1260	15887	20	20	20	317740	0.1	31774	899650.43	0.024740387	0.054542657
50	to	60	55	1260	0	1260	20	20	20	25200	0.1	2520	71351.391	0.003924326	0.00865157

total (lbs) 0.063194227

DCE plume shallow bedrock

Plume conc. Area			avg conc (ug/L)	total area (sq feet)	inner area (sq feet)	area (sq feet)	d1 (feet)	d2 (feet)	avg depth (feet)	volume of soil under water (cu feet)	percentage of water (%)	volume of water (cu feet)	volume of water (liters)	volume of contaminants (kg)	volume of contaminants (lbs)
70	to	700	385	17533	2064	15469	20	20	20	309380	0.1	30938	875979.89	0.337252259	0.74350633
700	to	2200	1450	2064	0	2064	20	20	20	41280	0.1	4128	116880.37	0.169476542	0.373627984

total (lbs) 1.117134314

DMF plume shallow bedrock

Plume conc. Area			avg conc (ug/L)	total area (sq feet)	inner area (sq feet)	area (sq feet)	d1 (feet)	d2 (feet)	avg depth (feet)	volume of soil under water (cu feet)	percentage of water (%)	volume of water (cu feet)	volume of water (liters)	volume of contaminants (kg)	volume of contaminants (lbs)
390	to	770	580	60000	0	60000	20	20	20	1200000	0.1	120000	3397685.3	1.970657462	4.344511442

total (lbs) 4.344511442

total contaminants in shallow bedrock groundwater 9.278406421

Sorption factor 1

Estimated volume of primary contaminants in shallow bedrock 9.278406421

DCA plume deep bedrock

Plume conc. Area			avg conc (ug/L)	total area (sq feet)	inner area (sq feet)	area (sq feet)	d1 (feet)	d2 (feet)	avg depth (feet)	volume of soil under water (cu feet)	percentage of water (%)	volume of water (cu feet)	volume of water (liters)	volume of contaminants (kg)	volume of contaminants (lbs)
5	to	23	14	31482	0	31482	175	175	175	5509350	0.05	275467.5	7799598.9	0.109194385	0.24072994

total (lbs) 0.24072994

Total contaminants in shallow bedrock groundwater 0.24072994

Sorption factor 1

Estimated volume of primary contaminants in deep bedrock 0.24072994

This volume may be 2 to 3 times larger if a path of contaminants remains from well ODW to the source area in the shallow bedrock.
For the purposes of the Site Conceptual Model a conservitave estimate of 1 pound of contaminats in the deep bedrock will be used.

APPENDIX C

Appendix C

Migration Retardation due to Sorption Calculations

Appendix C
Migration Retardation Due to Sorption Calculations
Conceptual Site Model
Union Chemical Company Superfund Site
Hope, Maine

Retardation Factor $R = 1 + (r * k_d) / h$

Where : r = Dry bulk density, asumed to be 1.9 g/cm^3
typical r values are 1.5 to 1.9 g/cm^3 (Weiner p97)

h = Effective porosity of soil, assumed to be 0.10
typical h values for silt range from 0.01 to 0.20 (Weiner p100)

Soil water partition coeficient $k_d = K_{oc} * f_{oc}$

Where: K_{oc} = Organic Carbon Partition Coeficient

$K_{oc\ DCA}$ = 31.6 (Weiner P93)
$K_{oc\ DCE}$ = 35.5 (Weiner P93)
$K_{oc\ TCE}$ = 166 (Weiner P95)
$K_{oc\ DMF}$ = 9.84 (calculated based on log K_{ow} of DMF) (Weiner P95 and Identity and Physical)

Assume: weight fraction of organic carbon f_{oc} for coarse soil = 0.04 (Weiner p89)

Contaminant	K_{oc} (L/kg)	f_{oc} (wt. fraction)	k_d (L/kg)	r (g/cm^3)	h (%)	R
DCA	31.6	0.04	1.264	1.9	0.1	25.0
DCE	35.5	0.04	1.42	1.9	0.1	28.0
TCE	166	0.04	6.64	1.9	0.1	127.2
DMF	9.84	0.04	0.3936	1.9	0.1	8.5

Note: The above calculation does not account for Biodegredation

Calculatoin for contaminant flow across the Site

Contaminant	R	Estimated GW Flow Rate Across Site ft/yr	Estimated Contaminat Flow Rate Across Site ft/yr
DCA	25.0	15	0.600
DCE	28.0	15	0.536
TCE	127.2	15	0.118
DMF	8.5	15	1.769

APPENDIX D

Appendix D

Bioremediation Consulting Inc Report

AMENDED JULY 22, '03

Report

Ground Water Analysis
and
Presence / Absence Tests
for
Nitrate Reducers, Sulfate Reducers, Methanogens, and Dechlorinators

Samples Collected in Maine on 4/4/'03
Wells B-8A-D and B-12B-I

Prepared for:
Bob Ankstitus, RAnkstitus@rizzo.com
Rizzo Associates
One Grant Street
Framingham MA 01701

Prepared by:
Bioremediation Consulting Inc
39 Clarendon St Watertown MA 02472
phone 617-923-0976 bioremediation@bciLabs.com

Groundwater Analysis and Presence / Absence Tests: Maine B-8A-D and B-12B-I

Summary

Groundwater Characteristics.

Well B-12B-I had a pH of 9.9, whereas that of B-8A-D was 7.5. B-12B-I contained cDCE, 1,1-DCA, and 1,1-DCE, and small amounts of their dechlorination products VC, ethene, and ethane. B-8A-D contained 1,1-DCA and 1,1-DCE and traces of dechlorination products. Both wells also contained freon and its dechlorination products. Well B-8A-D had no nitrate or sulfate, whereas B-12B-I had small amounts of these anions. Acetate was also present in both wells.

Genetic Test (PCR) for Dehalococcoides ethenogenes. The genetic test showed that the sample from B-8A-D was negative, and that from B-12B-I was positive. (This test recognizes genetic material, and does not distinguish between live and dead bacteria.)

Presence / Absence Tests for Anaerobic Bacteria.

- For each well sample, four anaerobic microcosm tests were set up, one for each of the microbial types to be determined, and amended with appropriate electron donors, as well as small amounts of nitrogen and phosphate. (As a result of adding amendments and providing CO_2 to the headspace of the microcosm bottles, the pH of B-12B-I decreased from 9.9 to 7.6).

- Microcosms were monitored by removing small samples and analyzing for chlorinated organics, methane and ethene by gas chromatography, organic acids and sulfate by capillary ion electrophoresis, and molecular H_2 by reduction gas analyzer.

- Both wells were shown to contain nitrate reducers, sulfate reducers and methanogens.

- ***Well B-12B-I showed dechlorination of cDCE to VC within the 88 day test period.***
- ***Well B-8A-D did not show evidence of dechlorination during a 95 day test period..***

- Because the dechlorinator test for B-12B-I was conducted at a pH not similar to the field pH, this test is being repeated at pH 9.9. If the result is different from that stated here, an addendum to this report will be submitted.

Methods.

Sampling and shipping. Groundwater was sampled on April 4, 2003. 1 Liter bottles of groundwater to be used for methanogens, sulfate-reducers and dechlorinators contained Argon and reducing agent to give 0.4 mM FeS. Upon arrival at BCI, these bottles contained a black precipitate, indicating that reducing conditions had been maintained during sampling and shipping. Groundwater to be used for the nitrate-reducer test did not contain the reducing agent.

PCR Genetic Test for D. ethenogens.

Bacteria in groundwater samples (not treated with reducing agent) were concentrated by vacuum filtration through a sterile filter with a 0.2 μm pore size. The UltraClean Soil DNA Kit from Mo Bio Laboratories was used to extract and purify DNA from bacteria on the filter while removing substances that could interfere with PCR. The Purified DNA was subjected to a PCR reaction using a protocol and primers described by Fennell *et al.* (*Environ. Sci. Technol.* 2001, 35, p1830), modified by BCI. PCR products were electrophoresed on a 1% agarose gel containing 0.005% ethidium bromide. DNA banding was visualized using a Foto/UV15 trans-illuminator, and photodocumented with a FCR-10 Polaroid Camera. Controls were subjected to the same procedure as samples, and were conducted with each sample. Positive Control consisted of Ethenogen culture (shown to produce ethene from PCE) added to the groundwater to be tested. The negative control was performed to test for contamination in the PCR reagents, and involved carrying out the PCR reaction without adding DNA.

Microcosm Construction, Maintenance and Monitoring.

Microcosms were constructed on Apr 17, '03. Microcosm bottles (160 ml) were given 100 ml of ground water using anoxic transfer procedures involving flushing of the 1L groundwater sample and of the microcosm bottle with Argon, then were sealed with Teflon-lined septa, flushed to replace argon with 30% CO_2 in N_2 , slightly over-pressurized, and (except for nitrate-reducers) given 0.2 mM additional sulfide reducing agent.

The microcosms for nitrate reducers were amended with nitrate, nutrient broth, methanol, and phosphate. Those for the sulfate-reducer test were amended with sulfate, ammonia, phosphate, organic acids, and yeast extract. For methanogens, the bottles received ammonia, phosphate, organic acids, methanol, and H_2. For dechlorinators, amendments were ammonia, phosphate, organic acids, yeast extract and vitamin B_{12} . The dechlorinator microcosms were given an additional 1.7 ppm cDCE. Microcosms were maintained in darkness at 22°C, with the aqueous portion in contact with the septa, and shaken briefly three times per week.

Methane, ethene, and chlorinated compounds were monitored by removing 100 μL samples of microcosm headspace and injecting into a HP 5890 gas chromatograph. Standards were prepared similarly, and analyzed in the same manner as samples. ChemStation software was used to calculate response factors and quantitate sample results. Concentrations reported are those that would be present if each compound were completely in the aqueous phase.

Dissolved molecular H_2 was monitored by removing 100 μL headspace samples and injecting into a Hamilton dilution syringe containing 10 cc ultra-pure Argon. The dilution was then analyzed by injecting into a Trace Analytical Instrument. The instrument was calibrated using a 4.11 ppmv H_2 standard (Messer Industries). Concentrations reported are those that were actually in the aqueous phase (approximately 1/50 of the headspace concentration).

Sulfate and organic acids were determined by removing 100 μL aqueous samples and analyzing according to EPA Method 6500. Compounds were identified by retention time ratio in comparison with standards analyzed with each batch. Response factors were calculated and results quantified by Millennium software. pH was determined by removing 150 μL aqueous samples and measured with a ThermoOrion model 290A pH meter and an 8175BN electrode.

Results for Ground Water Analysis

Groundwater Sampled 4/9/03. **pH and Capillary Ion Electrophoresis Results mg/L**								
	pH	Cl	SO_4	NO_3	formate	acetate	propionate	butyrate
B-8A-D	7.5	89	0	0	0	16	11	0
B-12B-I	9.9	76	7	4	6	35	0	0

The electrophoresis method does not distinguish between lactate and propionate.

Groundwater Sampled 4/9/03. **GC/FID Results µg /L**											
	meth-ane	ethene	ethane	FM	DFM (or CM)	VC	CA	1,1-DCE	1,1-DCA	cis-DCE	Freon
B-8A-D	610	2	1	+	+	2	< 0.5	100	290	< 50	11
B-12B-I	474	144	10	+++	+++	31	170	150	400	500	85

The GC method does not distinguish between DFM and CM, between CA and butyne

Abbreviations: FM fluoromethane DFM difluoromethane CM chloromethane
VC vinyl chloride CA chloroethane DCE dichloroethene DCA dichloroethane

Groundwater Sampled 4/9/03. **PCR and Presence/Absence Test Results after 88 Days**					
	PCR *D.ethenogenes*	Nitrate Reducers	Sulfate Reducers	Methano-gens	Dechlor-inators
B-8A-D	negative	+++	+	+	**neg**
B-12B-I	+++ positive	+	+	+	**positive**

Raw Data

Nitrate-Reducers ppm $_{NO3}$		
	B-8A-D	B-12B-I
day 0	228	220
day 11	0	210
day 27		110
day 55		60

Sulfate-Reducers ppm SO_4		
	B-8A-D	B-12B-I
day 0	190	190
day 27	150	190
day 55	10	40

Methanogens μM $_{CH4}$		
	B-8A-D	B-12B-I
day 0	30	4
day 27	60	4
day 55	140	110

B-8A-D Dechlorinator Test μM					
	ethene	VC	CA	1,1-DCA	c-DCE
day 0	.07	< dl	< dl	2 (1)	23
day 27	.07	< dl	< dl	2	23
day 55	.07	< dl	< dl	1.7	23
day 95	.05	< dl	< dl	1.3	17

(1) day 0 estimate 1,1-DCA

B-12B-I Dechlorinator Test μM					
	ethene	VC	CA	1,1-DCA	c-DCE
day 0	4	0.5	1.7	9(1)	22
day 27	3	0.4	1.3	9	22
day 55	4	0.6	1.6	11	26
day 88	6	**6.5**	1.4	11	**10**

(1) day 0 estimate 1,1-DCA

X-ClientAddr: 209.235.30.103
From: "Sami Fam" <S.Fam@IESIonline.com>
To: "Margaret Findlay" <mfindlay@bcilabs.com>
Cc: "Kidd, Don" <d.kidd@IESIonline.com>
Subject: Re: Nampa setup ?
Date: Tue, 22 Jul 2003 11:23:09 -0400
X-Priority: 3
Status:

1. Aerobic plus ZVI at 300 ppb
2. Anaerobic dechlorination at 300 ppb plus NJ bioaugmentation
3. Anaerobic at 300 ppb plus ZVI after the sulfate and nitrate have been reduced- shake well
4. Anaerobic at 300 ppb plus NJ bioaugmentation and ZVI (after NO3 and SO4 reduction (do not confirm activity of ethenogens))- add ZVI 3-7 days after ethenogens
5. Anaerobic at 300 ppb plus NJ bioaugmentation (after NO3, SO4 reduction), confirm ethenogen activity- then add ZVI to see if works simultaneously and/or causes any inhibition- add the ZVI halfway (at 150 ppb) if possible-

Don will tell you the ZVI dose.

Thanks

----- Original Message -----
From: "Margaret Findlay" <mfindlay@bcilabs.com>
To: <s.fam@iesionline.com>
Sent: Tuesday, July 22, 2003 10:45 AM
Subject: Nampa setup ?

>

AMENDED JULY 22, '03

Report

Ground Water Analysis
and
Presence / Absence Tests
for
Nitrate Reducers, Sulfate Reducers, Methanogens, and Dechlorinators

Samples Collected in Maine on 4/4/'03
Wells B-8A-D and B-12B-I

Prepared for:
Bob Ankstitus, RAnkstitus@rizzo.com
Rizzo Associates
One Grant Street
Framingham MA 01701

Prepared by:
Bioremediation Consulting Inc
39 Clarendon St Watertown MA 02472
phone 617-923-0976 bioremediation@bciLabs.com

Groundwater Analysis and Presence / Absence Tests: Maine B-8A-D and B-12B-I

Summary

Groundwater Characteristics.

Well B-12B-I had a pH of 9.9, whereas that of B-8A-D was 7.5. B-12B-I contained cDCE, 1,1-DCA, and 1,1-DCE, and small amounts of their dechlorination products VC, ethene, and ethane. B-8A-D contained 1,1-DCA and 1,1-DCE and traces of dechlorination products. Both wells also contained freon and its dechlorination products. Well B-8A-D had no nitrate or sulfate, whereas B-12B-I had small amounts of these anions. Acetate was also present in both wells.

Genetic Test (PCR) for Dehalococcoides ethenogenes. The genetic test showed that the sample from B-8A-D was negative, and that from B-12B-I was positive. (This test recognizes genetic material, and does not distinguish between live and dead bacteria.)

Presence / Absence Tests for Anaerobic Bacteria.

- For each well sample, four anaerobic microcosm tests were set up, one for each of the microbial types to be determined, and amended with appropriate electron donors, as well as small amounts of nitrogen and phosphate. (As a result of adding amendments and providing CO_2 to the headspace of the microcosm bottles, the pH of B-12B-I decreased from 9.9 to 7.6).

- Microcosms were monitored by removing small samples and analyzing for chlorinated organics, methane and ethene by gas chromatography, organic acids and sulfate by capillary ion electrophoresis, and molecular H_2 by reduction gas analyzer.

- Both wells were shown to contain nitrate reducers, sulfate reducers and methanogens.

- ***Well B-12B-I showed dechlorination of cDCE to VC within the 88 day test period.***
- ***Well B-8A-D did not show evidence of dechlorination during a 95 day test period..***

- Because the dechlorinator test for B-12B-I was conducted at a pH not similar to the field pH, this test is being repeated at pH 9.9. If the result is different from that stated here, an addendum to this report will be submitted.

Methods.

Sampling and shipping. Groundwater was sampled on April 4, 2003. 1 Liter bottles of groundwater to be used for methanogens, sulfate-reducers and dechlorinators contained Argon and reducing agent to give 0.4 mM FeS. Upon arrival at BCI, these bottles contained a black precipitate, indicating that reducing conditions had been maintained during sampling and shipping. Groundwater to be used for the nitrate-reducer test did not contain the reducing agent.

PCR Genetic Test for D. ethenogens.

Bacteria in groundwater samples (not treated with reducing agent) were concentrated by vacuum filtration through a sterile filter with a 0.2 μm pore size. The UltraClean Soil DNA Kit from Mo Bio Laboratories was used to extract and purify DNA from bacteria on the filter while removing substances that could interfere with PCR. The Purified DNA was subjected to a PCR reaction using a protocol and primers described by Fennell *et al.* (*Environ. Sci. Technol.* 2001, 35, p1830), modified by BCI. PCR products were electrophoresed on a 1% agarose gel containing 0.005% ethidium bromide. DNA banding was visualized using a Foto/UV15 trans-illuminator, and photodocumented with a FCR-10 Polaroid Camera. Controls were subjected to the same procedure as samples, and were conducted with each sample. Positive Control consisted of Ethenogen culture (shown to produce ethene from PCE) added to the groundwater to be tested. The negative control was performed to test for contamination in the PCR reagents, and involved carrying out the PCR reaction without adding DNA.

Microcosm Construction, Maintenance and Monitoring.

Microcosms were constructed on Apr 17, '03. Microcosm bottles (160 ml) were given 100 ml of ground water using anoxic transfer procedures involving flushing of the 1L groundwater sample and of the microcosm bottle with Argon, then were sealed with Teflon-lined septa, flushed to replace argon with 30% CO_2 in N_2 , slightly over-pressurized, and (except for nitrate-reducers) given 0.2 mM additional sulfide reducing agent.

The microcosms for nitrate reducers were amended with nitrate, nutrient broth, methanol, and phosphate. Those for the sulfate-reducer test were amended with sulfate, ammonia, phosphate, organic acids, and yeast extract. For methanogens, the bottles received ammonia, phosphate, organic acids, methanol, and H_2. For dechlorinators, amendments were ammonia, phosphate, organic acids, yeast extract and vitamin B_{12} . The dechlorinator microcosms were given an additional 1.7 ppm cDCE. Microcosms were maintained in darkness at 22°C, with the aqueous portion in contact with the septa, and shaken briefly three times per week.

Methane, ethene, and chlorinated compounds were monitored by removing 100 μL samples of microcosm headspace and injecting into a HP 5890 gas chromatograph. Standards were prepared similarly, and analyzed in the same manner as samples. ChemStation software was used to calculate response factors and quantitate sample results. Concentrations reported are those that would be present if each compound were completely in the aqueous phase.

Dissolved molecular H_2 was monitored by removing 100 μL headspace samples and injecting into a Hamilton dilution syringe containing 10 cc ultra-pure Argon. The dilution was then analyzed by injecting into a Trace Analytical Instrument. The instrument was calibrated using a 4.11 ppmv H_2 standard (Messer Industries). Concentrations reported are those that were actually in the aqueous phase (approximately 1/50 of the headspace concentration).

Sulfate and organic acids were determined by removing 100 μL aqueous samples and analyzing according to EPA Method 6500. Compounds were identified by retention time ratio in comparison with standards analyzed with each batch. Response factors were calculated and results quantified by Millennium software. pH was determined by removing 150 μL aqueous samples and measured with a ThermoOrion model 290A pH meter and an 8175BN electrode.

Results for Ground Water Analysis

Groundwater Sampled 4/9/03. **pH and Capillary Ion Electrophoresis Results mg/L**								
	pH	Cl	SO_4	NO_3	formate	acetate	propionate	butyrate
B-8A-D	7.5	89	0	0	0	16	11	0
B-12B-I	9.9	76	7	4	6	35	0	0

The electrophoresis method does not distinguish between lactate and propionate.

Groundwater Sampled 4/9/03. **GC/FID Results μg /L**											
	meth-ane	ethene	ethane	FM	DFM (or CM)	VC	CA	1,1-DCE	1,1-DCA	cis-DCE	Freon
B-8A-D	610	2	1	+	+	2	< 0.5	100	290	< 50	11
B-12B-I	474	144	10	+++	+++	31	170	150	400	500	85

The GC method does not distinguish between DFM and CM, between CA and butyne

Abbreviations: FM fluoromethane DFM difluoromethane CM chloromethane
VC vinyl chloride CA chloroethane DCE dichloroethene DCA dichloroethane

Groundwater Sampled 4/9/03. **PCR and Presence/Absence Test Results after 88 Days**					
	PCR *D.ethenogenes*	Nitrate Reducers	Sulfate Reducers	Methano-gens	Dechlor-inators
B-8A-D	negative	+++	+	+	**neg**
B-12B-I	+++ positive	+	+	+	**positive**

Raw Data

Nitrate-Reducers ppm $_{NO3}$		
	B-8A-D	B-12B-I
day 0	228	220
day 11	0	210
day 27		110
day 55		60

Sulfate-Reducers ppm SO_4		
	B-8A-D	B-12B-I
day 0	190	190
day 27	150	190
day 55	10	40

Methanogens µM $_{CH4}$		
	B-8A-D	B-12B-I
day 0	30	4
day 27	60	4
day 55	140	110

B-8A-D Dechlorinator Test µM					
	ethene	VC	CA	1,1-DCA	c-DCE
day 0	.07	< dl	< dl	2 (1)	23
day 27	.07	< dl	< dl	2	23
day 55	.07	< dl	< dl	1.7	23
day 95	.05	< dl	< dl	1.3	17

(1) day 0 estimate 1,1-DCA

B-12B-I Dechlorinator Test µM					
	ethene	VC	CA	1,1-DCA	c-DCE
day 0	4	0.5	1.7	9 (1)	22
day 27	3	0.4	1.3	9	22
day 55	4	0.6	1.6	11	26
day 88	6	**6.5**	1.4	11	**10**

(1) day 0 estimate 1,1-DCA