CIVIL/SANITARY/ENVIRONMENTAL ENGINEERS
SOLID WASTE MANAGEMENT

Municipal Services

Engineering Company, P.A.

SITE PLANNING/SUBDIVISIONS
SUBSURFACE UTILITY ENGINEERING (SUE)

February 13, 2009

Mr. Brian Wootton, Hydrogeologist Permitting Branch
Solid Waste Section
Division of Waste Management
North Carolina Department of Environmental and Natural Resources
401 Oberlin Road, Suite 150
Raleigh, NC 27605

Re: Corrective Action Plan
City of Albemarle C&D Permit #84-01

Dear Mr. Wootton:

Enclosed you will find the Corrective Action Plan for the City of Albemarle C&D Landfill, permit #84-01. An electronic copy is also provided. Please contact us by phone at (919) 772-5393, should you have any questions or comments regarding this report.

Sincerely,
MUNICIPAL ENGINEERING SERVICES CO., P.A.

Sean K. Patrick, P.G.
Professional Geologist

Attachments

Received
Wr &
Hazardous W

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Corrective Action Plan

Prepared for

City of Albemarle Landfill - Permit #84-01
Albemarle, Stanly County, North Carolina

MESCO Project Number: G07059.0

Completed on 2/13/2009

Municipal Engineering Services Company, P.A.
Garner, Boone and Morehead City, North Carolina

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1 INTRODUCTION

1.1 Site Background

The City of Albemarle landfill is located off Stony Gap Road (SR 1720), in Stanly County, North Carolina. The City of Albemarle landfill operates under permit #84-01. Prior to operating as a C&D landfill the site operated as a Municipal Solid Waste (MSW) unlined sanitary landfill that consisted of two units. One unit was closed prior to October 1991; this unit was closed with a 24-inch final soil cover. The second unit was closed with a cohesive cap of 18 inches of soil with a permeability of 1 x 10^{-5} cm/sec, and 18 inches of erosive layer. This unit was closed by June 1999 as part of the *Transition Plan*.[9] The C&D landfill is constructed and operating on top of the MSW landfill. Adjacent to the C&D landfill, across the unnamed tributary of Jacobs Creek and utilizing the same scale house, is the existing Subtitle D MSW landfill, which operates also under permit #84-01. The site in monitored under 15A NCAC 13B .1630. A topographic map showing the location of the site is included as **Plate 1**. A facility map showing the locations of both permitted facilities is included as **Plate 2**.

1.2 Aquifer Characteristics

The site lies within the Carolina Slate Belt, a subdivision of the Appalachian Piedmont geologic and physiographic province. The Carolina Slate Belt is characterized by low, generally rolling hills with gentle to moderately steep slopes. Total relief across the facility is approximately 110 feet. An unnamed tributary of Jacobs Creek divides the facility, separating the C&D landfill on the west part of the facility from the lined Subtitle D landfill to the east. The unnamed creek flows southeast and joins another unnamed tributary south of the Subtitle D landfill. These tributaries join Jacobs Creek to the south before exiting the property. Jacobs Creek empties into Lake Tillery (Pee Dee River) approximately 2.5 miles southeast of the landfill. Surface drainage at the landfill generally flows towards the southeast. Natural vegetation of disturbed lowland with pine and hardwood trees lines the various drainage features at the facility. Pine and hardwood forest exist beyond the extent of the landfill operation.

The stratigraphic sequence in the Albemarle-Asheboro region has mapped as a thick, primarily felsic volcanic unit (Uwharrie Formation) overlain by a dominantly volcanic-sedimentary package (Albemarle Group), with various metagabbro and metabasalt intrusions.[2] Lithologies are fairly uniform, and consist of brown to gray sandy silt/sandy clay transitioning into a sandy silt/sandy clay layer with gravel and finally the highly fractured gray to greenish argillite of the Cid Formation. A regional geologic map is provided as **Plate 3**.

Regionally, Stanly County is located in the Piedmont groundwater region of the United States.[6] The aquifer typically consists of two hydrogeologic units- the uppermost unconsolidated regolith, and the fractured crystalline bedrock. The two units are hydrogeologically connected by fractures and faults in the bedrock. Groundwater in the unconfined aquifer typically occurs at depths of 5 to 25 feet below ground surface (bgs), with the shallowest depths occurring in draws and near drainage features. Groundwater depths in the monitoring wells have been generally consistent over time, and generally occur in the following depth ranges:

- ≤ 10 ft. bgs: *MW-9, MW-10, MW-11*
- 10 to 20 ft. bgs: *MW-1, MW-2, MW-3, MW-5R, MW-7*
- > 20 ft. bgs: *MW-4R, MW-6, MW –12, MW-24, MW-25*
- > 50 ft. bgs: *MW-8D*

Historical groundwater elevations are provided in **Table 2**. Groundwater exhibits flow dynamics that are primarily controlled by the topographical high and local drainage features. Groundwater flow at the site is in a general westerly direction, with southwesterly and northwesterly flow away from the waste limits. A single-day potentiometric map depicting groundwater flow conditions on January 16, 2008 is provided as **Plate 4**.

Hydraulic conductivities, hydraulic gradients, and average linear groundwater velocities are summarized in **Table 3**. Hydraulic conductivity values, as determined from slug testing, ranged from 6.02 x 10^{-7} cm/sec (MW-8D) to 3.40 x 10^{-4} cm/sec (MW-3), with a geometric mean of 3.79 x 10^{-5} cm/sec. Hydraulic gradient at the site is fairly uniform with an average value of 0.031 ft/ft. Average linear velocities (v_x) were calculated using the following equation:

$$v_x = \frac{K * i}{n_e}$$

where

v_x is the average linear velocity [length/time]

K is the hydraulic conductivity [length/time]

n_e is the effective porosity [unitless]

i is the horizontal hydraulic gradient in the direction of groundwater flow, taken as the difference in head elevation between two points divided by the distance between those points [unitless, or length/length]

The calculated average linear velocities were found to have a median value of 39.4 ft/yr.

1.3 Contaminant Distribution

Groundwater contamination at the site consists of dissolved-phase volatile organic compounds (VOCs) in concentrations exceeding established 15A NCAC 2L groundwater standards. Groundwater contaminants are distributed in two (2) plumes that extend toward the drainage areas. Groundwater contaminants of concern (as identified in the *ACM*) are: benzene, methylene chloride (dichloromethane- DCM), tetrachloroethene (tetrachloroethylene, perchloroethene- PCE), chlorobenzene, *cis*-1,2-dichloroethene (*cis*-1,2-DCE), and trichlorofluoromethane. Benzene and chlorobenzene are aromatic hydrocarbons. Methylene chloride, tetrachloroethene, *cis*-1,2-DCE, and trichlorofluoromethane are halogenated aliphatic hydrocarbons.[12] Historic organic results of detected constituents are shown on **Table 4**.

The two (2) contaminant plumes identified in the *Assessment of Corrective Measures* are:

- **Eastern Plume:** The plume associated with MW-3, MW-9, and MW-10 consists of benzene, methylene chloride, and tetrachloroethene. Groundwater contaminants are in the unconfined surficial aquifer

- **Western Plume:** The plume associated with MW-2, MW-6, and MW-7 consists of benzene, chlorobenzene, methylene chloride, *cis*-1,2-DCE, tetrachloroethene, and trichlorofluoromethane. Groundwater contaminants are in the unconfined surficial aquifer and upper bedrock aquifer.

Groundwater contamination has not been detected at the relative point of compliance.

1.4 Site Conceptual Models

Site conceptual and analytical models were developed in the ACM. The models consisted of conceptual cross sections and analytical modeling using MODFLOW with MT3D[96]. The conceptual cross sections are provided as **Plate 5**.

Physical Process

The primary mechanism of physical plume movement is through advection. Advective flow with applied sorption (retardation) typically slows plume migration. The retardation coefficient (R) used to calculate the expected migration rates for the constituents can be calculated from the following equation:

$$R = 1 + \frac{\rho_d}{n} K_d$$

where

R is the retardation coefficient
ρ_d is dry bulk density of the soil (g/cm^3)
n is the porosity (unit less)
K_d is the distribution coefficient (mL/g)

The average dry bulk density utilized in the *ACM* report, which was calculated from laboratory dry unit weights collected during the Phase 2 Design Hydrogeological Study, was 1.21 g/cm^3. The distribution coefficient (K_d) can be estimated as the Soil – Water Partitioning Coefficient K_{oc} times the fraction of organic carbon in the soil.[5] Based on boring logs and field observations there is little evidence to suggest any significant soil organic carbon. An overly conservative value for soil organic carbon was estimated to be 1%. "Soils vary in the amount of soil organic carbon they contain, ranging from less than 1 percent in many sandy soils to greater than 20 percent in soils found in wetlands and bogs."[8]

Coefficients of Retardation	
Constituent	**R**
Benzene	1.23
Methylene Chloride	1.06
Tetrachloroethene	1.73
Chlorobenzene	1.77
Trichlorofluoromethane	2.15

The above table suggests there is limited retardation. Contamination has the potential to travel at or near the seepage velocities as identified in the *ACM*.

The eastern groundwater plume is mixing with stream water as evidenced by low levels of VOC concentrations below groundwater standards. Groundwater mixing results in stream dilution and volatilization. In the case of the eastern plume the distance from the point of mixing to where the stream exits the facility is 4,700 feet. Additional dilution occurs through surfacewater contributions from downstream tributaries. Stream dilutions were calculated in the *ACM*.

Chemical/Biochemical Process

Chemical degradation processes, primarily that of half life decay, are typically expressed based on surfacewater measurements. The identified contamination consists of constituents dissolved in groundwater. Benzene, methylene chloride, tetrachloroethene, chlorobenzene, *cis*-1,2-DCE, and trichlorofluoromethane all undergo volatilization from soil when released near the surface and volatilization when released to

surfacewaters. Half-life reactions in groundwater vary greatly. A summary of published half life reactions in groundwater is included below.

Half-Life in Groundwater[7]		
Constituent	**Half-Life (high)**	**Half-Life (low)**
Benzene	24 Months	10 Days
Methylene Chloride	8 weeks	14 Days
Tetrachloroethene	2 years	12 Months
Chlorobenzene	300 Days	136 Days
cis-1,2-Dichloroethylene	95 Months	8 Weeks
Trichlorofluoromethane	2 Years	12 Months

Biotransformation of most chlorinated solvents, including halogenated aliphatic hydrocarbons, occurs through reductive dechlorination.[4] The reductive dechlorination process utilizes the chlorinated solvents as the electron acceptor. Through reductive dechlorination, carbon is utilized as the electron donor for microbial growth, with the hydrocarbon contaminants acting as the potential carbon source.

1.5 Regulatory Status

The City of Albemarle Landfill operates as a C&D landfill over a MSWLF landfill under permit #84-01. Assessment monitoring is currently performed on a semi-annual basis at the site.

2 CONTAMINATION CHARACTERIZATION

2.1 Contaminants of Concern

The following chemical compounds, based upon either exceedance of 2L standards or statistically significance, were identified in the *ACM* as being contaminants of concern (COCs):

- benzene, chlorobenzene – *aromatic hydrocarbons*
- *cis*-1,2-DCE; tetrachloroethene; methylene chloride, trichlorofluoromethane – *chlorinated aliphatic hydrocarbons*

2.2 Contaminant Source Confirmation

The groundwater contaminant source is the former MSW landfill cell. The mechanism for the presence of this contamination is precipitation that has percolated through the landfill waste, allowing VOCs to partition from solid/liquid phases into a dissolved phase, and that has subsequently migrated downwards to mix with groundwater. To limit water percolation, the MSW unit was closed with a cohesive cap of 18 inches of soil

with a permeability of 1 x 10^{-5} cm/sec, and 18 inches of erosive layer. Landfill drainage flows southeast towards an unnamed creek, which is a tributary of Jacobs Creek.

The receptor survey, performed during the *Transition Plan*, identified 44 private water supply wells within 2,000 feet of the facility. The majority of these water supply wells are located upgradient of the sanitary landfill along Stony Gap Road. The private water supply well nearest the sanitary landfill is located approximately 1,500 feet west of the waste limit. A non-potable water supply well is located at the shop immediately north of the sanitary landfill. A well tag indicated that the well was installed in 1974 by Whitley Well Drilling. The well is cased to 47 feet with a total depth of 305 feet. The well is used as a non-potable source of water for toilets and machine washing. Community water is not available to the surrounding area.

2.3 Source Control Measures

The first unit of the landfill stopped receiving MSW by October 1991 and was closed with a 24 inch final soil cover. The second unit was closed with a cohesive cap of 18 inches of soil liner with permeability of 1 x 10^{-5} cm/sec, and 18 inches of erosive layer. The surrounding property is owned and controlled by the City of Albemarle or Stanly County and is used as the Subtitle D Landfill or current/future borrow site for daily cover in the Subtitle D landfill. The property southwest of the landfill is currently being negotiated for purchase.

A gas venting system for methane extraction/collection was installed as part of the transition plan. The permanent probes were to be installed by October 1994, and are monitored quarterly.

2.4 Risk Assessment

Risk assessment was performed as part of the *ACM*, and assumed direct contact with the identified contamination. Exposure pathways are limited to onsite contact with groundwater. Monitoring wells are cased and secured with locking well caps. Access to the site is limited during operational hours. A passive horizontal gas venting system for methane extraction/collection was installed as part of the transition plan. Both adult and child hazard index values for contaminants of concern were less than 1 from inhalation, dermal and oral ingestion exposure.

2.5 Contaminant Concentrations

2.5.1 Background Concentrations

Groundwater sampling and monitoring has been conducted at the site since 1994. Background water quality data has historically been collected from monitoring well MW-1. Historical background results are shown on **Table 5**. Groundwater results for the January 2008 sampling event are summarized in **Table 6**.

2.5.2 Exceedances of Groundwater Quality Standards

Groundwater contaminants that have exceeded 2L standards are: benzene (MW-7, MW-10); chloroethene (MW-7); methylene chloride (MW-1, MW-3, MW-6, MW-7); and tetrachloroethene (MW-9, SHOP well). Lead, cadmium, and nickel concentrations in some samples were found to exceed 2L standards. However, these compounds were identified in the *ACM* as naturally occurring and are not of concern in this study. It must also be noted that chloroethene was not identified as a COC in the *ACM*.

2.5.3 Exceedances of Surfacewater Quality Standards

Laboratory analysis of surfacewater samples have not detected contaminant concentrations in excess of established NCAC 2B water quality standards. Surfacewater results (July 2007) for SW-1 and SW-6 are shown on **Table 7**.

2.6 Media of Concern

Groundwater is the primary media of concern at the site since it acts as the primary mechanism of transport for environmental contaminants emanating from the landfill. Dissolved-phase contaminants can potentially be transported via groundwater and discharged to surfacewater.

Landfill gas is a secondary media of concern since it can transport VOCs that have partitioned into the vapor phase, allowing them to re-partition into the dissolved phase into groundwater. A passive horizontal gas venting system for methane extraction/collection was installed as part of the *Transition Plan*.

3 SELECTED AND APPROVED REMEDY / TECHNICAL APPROACH

A number of factors influence the selection of remediation alternatives:

- Groundwater contamination exists in both the surficial (unconfined) and upper bedrock aquifers.
- Contamination is below risk exposure levels.
- The western plume has the potential to migrate off site.

Remediation of relatively low level contamination in the 100 ppb range can be difficult, expensive and may not be achievable. A multi-phase remedial approach is, therefore, necessary to address contamination across the site.

3.1 Technical Approach

3.1.1 Eastern Plume (Monitored Natural Attenuation)

Groundwater contaminants exist within the unconfined aquifer. Biochlor was initially run for the eastern plume to assess the potential effectiveness of MNA. Biochlor utilized site specific data for tetrachloroethene, trichloroethene and vinyl chloride. Dual modeling was utilized based on high half-life and low half-life. High half life results show a 5.7% decrease for tetrachloroethene, a 4% decrease for trichloroethene and a 9.4% decrease for vinyl chloride in 5 years through biotransformation modeling. Low half life results show a 52.7% decrease for tetrachloroethene, a 45.1% decrease for trichloroethene and a 68.8% decrease for vinyl chloride in 5 years through biotransformation modeling. Biochlor results are provided in **Appendix A**.

Groundwater sampling will be performed semi-annually on monitoring wells MW-3, MW-9, and MW-10. Baseline sampling for the suite of MNA performance parameters listed in **Section 4** and **Appendix B** shall be performed for two years following. Monitoring of stream quality in the adjacent stream will be achieved through surfacewater sampling at sampling points SW-1 and SW-6 (see **Plate 2**). Surfacewater sampling parameters will include Appendix I VOCs and metals.

3.1.2 Western Plume (Monitored Natural Attenuation w/ HRC Injection & Phytoremediation)

Unconfined Aquifer

Based on the ACM observations, the most cost effective and practical approach for remediation of the western plume may be to purchase the all, or a portion, of the adjacent property towards which the western plume may potentially migrate. While not imperative, acquisition of the adjacent property would establish a new

compliance boundary for the site. Modeling indicates through pure advection flow, without natural decay, the western plume may reach the relevant point of compliance by 2025. Until the adjacent property is acquired, MNA with phytoremediation is one cost-effective remedial approach.

Phytoremediation procedures will be implemented to enhance remediation by monitored natural attenuation of low level contaminants. To accelerate the natural evapotranspiration process and to allow for hydraulic containment (plume control), the area will be thinned of juvenile trees (those trees with a diameter of less than 3 inches) and pines, and planted with hybrid willows of the genus *Salix*. Hybrid willows have been recognized as being phreatophytic (water-loving) trees with root systems that can extend up to 40 feet bgs[11]. Phytoremediation is expected to occur through several processes: the release of enzymes from the root system that break down hydrocarbons (phytodegradation), limitation of infiltration by increasing evapotranspiration, and eventual uptake of hydrocarbons (phytoextraction). Available literature (e.g. Schnoor, 1997 [11]) indicates an initial planting density of 1,000-2,000 trees/acre (~43 ft^2/tree). As the trees become established over time (1-2 years) competition between plants will reduce this density to ~600-800 trees/acre. The proposed phytoremediation area comprises approximately 7.5 acres. At the aforementioned planting density a minimum of 7,500 hybrid willow seedlings will need to be planted at the onset of corrective action. Planting of seedlings will likely be performed by mechanical methods to reduce installation costs, and is tentatively scheduled to occur during May-June 2009. Protective fencing to prevent damage to the seedlings by wildlife (e.g. deer) shall be constructed around the area of planting. The proposed phytoremediation area is depicted in **Plate 5**.

Groundwater sampling will be performed semi-annually on monitoring wells MW-2, MW-6, MW-7, MW-24, and MW-25. Baseline sampling for the suite of MNA performance parameters listed in **Section 4** and **Appendix B** shall be performed for two years following planting of hybrid willow trees. Soil sampling may also be conducted to monitor potential salt accumulation in the root zone. Phytoremediation sampling and monitoring results, in addition to information on tree growth and health, shall be included as a separate section within the semi-annual monitoring reports.

Water levels in MW-2, MW-6, MW-7, MW-24, and MW-25 will be monitored daily with pressure transducer data loggers that will be installed in the wells prior to planting of the hybrid willow trees. Water levels should show a decrease in water level, particularly in conjunction with spring growing season, once the trees begin to establish. Water level readings will be recorded twice daily, and the water level data downloaded from the data loggers on a monthly basis by MESCO field personnel. Once the trees are semi-established (1-2 years) water levels in these wells are expected to decrease, particularly in conjunction with the spring growing season.

Upper Bedrock Aquifer

Because groundwater contaminants exist within the upper bedrock aquifer, a remedial technology to supplement MNA within the bedrock aquifer is required. Natural attenuation of VOCs can be enhanced through the introduction of hydrogen release compound (HRC) into the subsurface. HRC enhances processes such as the reductive dechlorination of chlorinated hydrocarbons including the COCs identified in **Section 2** (e.g. PCE, *cis*-1,2-DCE). One such brand of commercially-available HRC is 3DMe™ which is manufactured by Regenesis (San Clemente, CA). According to Regenesis, HRC 3DMe™ "is composed of free lactic acid, controlled-release lactic acid (polylactate) and certain fatty acid components which are esterified to a carbon backbone molecule of glycerin. HRC 3DMe™ produces a sequential, staged release of its electron donor components. The immediately available, free lactic acid is fermented rapidly while the controlled release lactic acid is metabolized at a more controlled rate. The fatty acids are converted to hydrogen over a mid to long-range timeline giving HRC 3DMe an exceptionally long electron donor release profile. This staged fermentation provides an immediate, mid-range and very long-term, controlled-release supply of hydrogen (electron donor) to fuel the reductive dechlorination process." Prior to injection HRC 3DMe™ is mixed with water in a 1:10 ratio. Regenesis recommends a minimum quantity of 22 gals. of HRC per injection point (~242 gals. total liquid). HRC can remain resident in the subsurface for over one year. A material safety data sheet for HRC 3DMe™ is included in **Appendix C**.

HRC will be injected into monitoring wells MW-6 and MW-7. Since groundwater flow in bedrock occurs within interconnected discontinuities such as fractures, joints, and faults within the rock mass (secondary porosity), the HRC mixture will necessarily permeate only those areas impacted by groundwater contaminants. The HRC will, therefore, travel downgradient through the contaminant plume. Typical injection rates are on the order of 4 gallons per minute (gpm) at a pressure of 10 pounds per square inch (psi). Actual injection rates are contingent upon the permeability of the formation material at the injection points, and care should be taken during injection so as not to compromise monitoring well integrity. Since HRC can remain resident in the subsurface for over one year after introduction, a single injection only will be needed to implement this form of corrective action. An injection permit will be required from the NCDENR Underground Injection Control Section prior to implementation.

Baseline sampling will be instated as part of the monitoring protocol, and will incorporate the full suite of MNA parameters. Sampling will be performed semi-annually on monitoring wells MW-2, MW-6, MW-7, MW-24, and MW-25. Baseline sampling for the suite of MNA performance parameters listed in **Section 4** and **Appendix B** shall be performed for two years following implementation of corrective action. *It must be*

noted that due to the persistence of HRC in the subsurface after initial injection, groundwater in the injection wells may not be of adequate quality to sample for 30-60 days after injection.

3.1.3 Additional Measures

The SHOP well will be abandoned to limit exposure potential. The methane detection system will be monitored quarterly in accordance with the operation plan to ensure the concentration of methane gas does not exceed 25 percent of the lower explosive limit for methane in landfill structures and does not exceed 100 percent of the lower explosive limit at the property boundary. A passive methane trench may be warranted if methane continues to be detected.

4 GROUNDWATER AND SURFACEWATER MONITORING PLAN

4.1 Groundwater Sampling and Monitoring

Data with which to monitor and evaluate the performance of remediation shall be obtained through a groundwater sampling and monitoring program. All groundwater samples collected from the monitoring wells will be analyzed for Appendix I VOC concentrations by EPA method 8260, and for Appendix I metals concentrations by EPA method 6010. Additionally, groundwater samples collected from monitoring wells in the areas subject to MNA, phytoremediation, and HRC injection will be analyzed for the following MNA performance parameters:

MNA Performance Parameters		
Parameter	**Analysis Type**	**Analytical Method**
Dissolved Oxygen (DO)	Field Reading	Multi-parameter Field Instrument w/ flow-through cell
pH	Field Reading	
Oxidation-Reduction Potential (ORP)	Field Reading	
Turbidity	Field Reading	
Conductivity	Field Reading	
Temperature	Field Reading	
Dissolved CO_2	Field Reading	Field Instrument / Hach Kit
Alkalinity (Total as $CaCO_3$)*	Laboratory/Field*	EPA 310.2
Chloride*	Laboratory/Field*	SM 4500-CLB
Iron	Laboratory	SM3111B
Nitrate*	Laboratory/Field*	EPA 353.2 / SM 2320B
Sulfate*	Laboratory/Field*	EPA 375.4 / SM 4500-SO4E
Sulfide*	Laboratory/Field*	EPA 376.1 or SM 4500SE
TOC/BOD/COD	Laboratory	EPA 415.1 / EPA 405.1 / EPA 410.1
Methane	Laboratory	RSK 175
Ethane, Ethene	Laboratory	RSK 175
Hydrogen	Laboratory	AM19GA
Volatile Fatty Acids	Laboratory	AM23G
*For budgetary considerations these analyses may be performed in the field using Hach® brand color wheel test kits. Historical iron concentrations have exceeded Hach kit quantitation limits.		

4.2 Surfacewater Sampling and Monitoring

Surfacewater sampling will be conducted to monitor COC concentrations in the adjacent stream areas. To date (January 2009) COC concentrations have been below respective NCAC 2B and 2L standards. Surfacewater locations SW-3 and SW-4 are downstream of the landfill and have been dry since 2002. Surfacewater location SW-5 is downstream of the landfill on the tributary of Jacobs Creek where it flows past the landfill on the southwestern side. Surfacewater SW-5 has been dry since 2003. Surfacewater collected as part of the Existing Subtitle D Landfill is performed on the creek separating the two landfills. SW-1 is collected prior to the creek entering the facility and SW-6 is collected downstream of the landfill prior to the creek exiting the facility. Additional sampling point SW-7 has been initiated along the tributary of Jacobs Creek. All surfacewater samples will be analyzed for Appendix I VOC and metals concentrations by EPA methods 8260

and 6010, respectively. The complete *Ground and Surfacewater Sampling and Analysis Plan* is presented as **Appendix B**.

5 EVALUATION OF EFFECTIVENESS AND REPORT SUBMITTAL

5.1 Evaluation of Effectiveness

As remediation progresses at the site certain changes in the physical and chemical characteristics of the contaminant plumes should occur. In all areas contaminant concentrations are expected to decrease over the period of remediation, thus resulting in a decrease in the physical extent of the plume. The various methods for evaluating the effectiveness of remediation are discussed in the sections below.

5.1.1 Qualitative and Quantitative Evaluation

Qualitative Evaluation

Qualitative methods include graphical analysis of groundwater analytical data over time in order to visualize changing trends in groundwater chemistry that are expected to occur over time as a result of the various remedial mechanisms/processes that are occurring at the site (e.g. biodegradation, phytoremediation, HRC injection). Examples of graphical analyses that will be used include, but are not be limited to, time-series graphs of contaminant concentrations and groundwater levels, distance-concentration graphs of analytical data, and mapping of the contaminant plumes over time. Specific biodegradation plume parameters (e.g. point attenuation rate, bulk attenuation rate, biodegradation rate) will be determined for the individual plume areas. For the western plume, tree growth (height and girth) will be monitored monthly to bi-monthly for the first two years following planting. Correlation of contaminant plume size and migration with hybrid willow growth may be used to further evaluate the progress of phytoremediation.

Quantitative Evaluation

Quantitative evaluation will be conducted through annual revision of Bioscreen models, and through analysis of groundwater analytical data using statistical tests for significance. Statistical significance tests can be grouped into two types, *inter-well* and *intra-well*. *Inter-well* methods determine statistical significance by examining trends in contaminant concentrations from performance wells with respect to those from background wells, which are used as a control group. As remediation progresses, the performance well data is expected to exhibit decreases in contaminant concentrations, while contaminant concentrations in the background wells are expected to remain relatively stable. Background wells are selected on the basis of location (typically upgradient) and analytical history (non-impacted wells are best). *Intra-well* methods determine statistical significance within individual performance wells by examining historical analytical

results (time series) for a given well, thus indicating if changing contaminant concentrations at a given well location result from either remedial activity or natural fluctuation. Comparisons of background well data with sentinel and compliance well data will also be performed to monitor groundwater contaminant movement over time.

Various types of significance tests have been developed to analyze differing types of data populations based upon characteristics such as distribution type (normal vs. non-normal), trend type (changing vs. non-changing), percentage of "non-detect" results for a given population, and the sample population size. This allows for the selection of particular methods that are appropriate for a given situation. For the remedial activity at the subject facility the following statistical tests are proposed for use, although others may be used as the course of remediation progresses:

- Wilcoxon Rank-Sum (Inter-well) - *normal or non-normal data, invariant trends, < 90% non-detects, >3 samples/per well.*
- Parametric Prediction Limit (Inter-well) – *normal data, varying trends,< 15% non-detects.*
- Parametric Prediction Limit (Intra-well) – *normal data, varying trends,≥ 4 samples/well, < 15% non-detects.*
- Non-Parametric Prediction Limit (Inter-Well & Intra-Well) – *normal or non-normal data, can tolerate high percentage of non-detects, compares recent to historical data.*

As indicated by the list above, it is important to note that prior to conducting any test of statistical significance a baseline of analytical data must first be established. For the MNA parameters listed in **Section 4.0** this baseline will consist of the four (4) semi-annual sampling events mentioned previously. *Since some plume areas do not have upgradient wells that are suitable for use as background wells, non-impacted compliance wells may be used if necessary for inter-well statistical analyses.*

5.1.2 Evaluation of Plume Areas

Eastern Plume Area

Monitoring well MW-1 will be used as a background well for inter-well statistical analysis of MNA data from this area. Monitoring wells MW-3, MW-9, and MW-10 will be used as performance wells. Existing monitoring well MW-11 will be used as a sentinel well. Qualitative evaluation of phytoremediation will include the methods discussed in **Section 5.1.1.** Significant changes in groundwater chemistry and contaminant concentrations are not expected to occur until 3-5 years after initiation of corrective action in this area.

Western Plume Area

Monitoring well MW-1 will be used as a background well for inter-well statistical analysis of MNA data from this area. Monitoring wells MW-2, MW-6, and MW-7 will be used as performance wells. Monitoring wells MW-24 and MW-25 will be used as sentinel/compliance wells.

Within 1-3 months of HRC injection, decreases in groundwater contaminant concentrations on the order of a few ppb are expected to occur at wells MW-6 and MW-7. Increases in acetone, total organic carbon, and VFAs are expected to occur as the process of reductive dechlorination breaks down chlorinated hydrocarbons. Consequently, end products such as ethane, ethene, and chloride are also expected to increase as COC concentrations decrease. Follow-up sampling at 30-day, 60-day, and 90-day intervals will be required by the NCDENR Underground Injection Control Section as part of their injection permit requirements. Reduction in contaminant concentrations should be observed in the monitoring wells within 6 to 12 months after HRC injection.

5.2 Refining the Site Conceptual Model

Over the course of corrective action the site conceptual model will be refined in order to determine the appropriate course of remediation. Additional information on groundwater chemistry, site lithology, plume characteristics, etc. will be used to further improve understanding of contaminant fate and transport at the site, and to determine any changes to the approved remedial measures if necessary.

5.3 Report Submittals

Remediation Status Reports will be submitted on a semi-annual basis, within 30 days of receiving all complete laboratory analytical reports. An *Initial Status Report* will be submitted upon implementation of the selected remedial approach, and will detail all activities performed to initiate corrective action. All reports submitted shall include complete laboratory analytical reports, data tables, contaminant concentration trend graphs, groundwater flow maps, contaminant plume maps, and cross-sections, as per NCDENR-SWS guidelines. A separate section detailing the status of phytoremediation (tree health, growth, appearance, rainfall, etc.) will be included with each report.

Injection reports for the areas where HRC injection is proposed will be submitted in accordance with the injection permits to be issued for the site by the NCDENR Underground Injection Control Section. These reports typically consist of an *Injection Event Record* report detailing the actual event, and subsequent monitoring reports submitted at semi-annual intervals.

6 CONTINGENCY PLAN

6.1 Contingency Plan

Should the selected remedial approaches not perform as expected and/or the constituent concentrations do not decrease, contingency plans will be needed for each respective plume. These are discussed in detail in the sections below.

Eastern Plume Area

Should MNA fail to significantly reduce contaminant concentrations within five years of implementation a more aggressive remedial approach may be necessary. HRC injection as discussed previously for the western plume area is one option, and would require the installation of injection wells and injection via direct push. The cost estimate of HRC application over the subject area is beyond the scope of this report. An injection permit would be required from the NCDENR Underground Injection Control Section should this contingency plan be implemented. This approach could, therefore, not be applied until at least 60 days after initiation of this option.

Western Plume Area

Should MNA, phytoremediation, and the introduction of HRC fail to significantly reduce contaminant concentrations within two years of implementation, substrates other than HRC may need to be injected. One such substrate that has also been shown to effectively reduce contaminant concentrations is oxygen-release compound (ORC). ORC as manufactured by Regenesis, Ltd. consists of a dry mixture of calcium hydroxides with potassium phosphates that is injected with water as a slurry. Issues to consider prior to its use are its high pH (11-13), and its insolubility which may lead to settlement during mixing and handling. Air sparging with vapor extraction is also an option but would require the design, construction, operation, and maintenance of a remediation system, the scope of which is beyond this CAP report.

6.2 Safeguard Measures and Site Security

Exposure pathways are limited to onsite contact with groundwater. Monitoring wells are cased and secured with locking well caps. Access to the site is limited during operational hours. Heavy vegetation limits access from other areas. The City of Albemarle County owns the majority of the property surrounding the facility. Public water is available to the surrounding area. A passive horizontal gas venting system for methane extraction/collection was installed as part of the *Transition Plan*. [9]

Prior to the facility becoming a C&D landfill, the western unit of the sanitary landfill was closed with a 24 inch soil cap and vegetative cover. The vegetative cover acts as an erosion control measure and also aides in the evapotranspiration process to reduce infiltration. "(T)he natural evapotranspiration process of vegetation has been recognized and harnessed as an alternative cover method to reduce landfill infiltration."[11][page 392] As with the western unit, side slopes of the eastern unit were closed with a 24 inch soil cap and vegetative cover. The top of the eastern unit was closed with a cohesive cap of 18 inches of soil with a permeability of 1 x 10^{-5} cm/sec, and 18 inches of erosive layer. Surfacewater is diverted from the landfill and is not impounded on the landfill property.

6.3 Revisions

Requests for modification of the approved corrective action and implementation schedule will be submitted in writing to the Solid Waste Section. No actions regarding modification will be implemented until written approval is received from the Division of Waste Management. Approval of changes to HRC injection will be required by the NCDENR Underground Injection Control Section prior to implementation.

7 SCHEDULE AND MAINTENANCE

7.1 Operations & Maintenance

The City of Albemarle will oversee day-to-day operation and upkeep of the remediation technology. Any equipment required for remediation will be the responsibility of the City of Albemarle. If problems with the remediation system arise, the Solid Waste Section will be notified and a written report will be issued. The City of Albemarle Department of Solid Waste can be contacted at (704) 984-9667 regarding daily activities.

7.2 Timeline

Implementation of corrective action will begin within 30 days of CAP approval. Initial activities will consist primarily of administrative tasks including scheduling of drilling and remediation subcontractors, permit preparation/submittal, and materials purchasing. HRC injection will be performed after the July 2009 semi-annual sampling and monitoring, during which the MNA performance parameter baseline will be established. A timeline estimate for sampling events and performance evaluation is presented in **Table 9**.

8 FINANCIAL ASSURANCE REQUIREMENTS

In general accordance with 15A NCAC 13B .0546, demonstration of financial assurance was achieved through the local government financial test. Due to uncertainty of the acquisition of the property through private cost negotiation, costs associated with corrective action were estimated. The estimated cost includes acquisition of

additional property, installation of an active methane system, purchase and planting of hybrid willow trees, one HRC injection event, additional monitoring of water levels, additional sampling parameters, and methane monitoring. A breakdown of estimated costs for initiation of proposed corrective action, as well as operation and maintenance costs over a 5-year period, is as follows:

Purchase of Adjacent Property - $385,000
Phytoremediation (seedlings) - $25,000
Phytoremediation + HRC Injection (planting & maintenance; one injection event) - $35,000
MNA Sampling & Monitoring - $55,000
Estimated Total Costs – $500,000 (based upon ACM)

9 COMPLETENESS OF CORRECTIVE ACTION

Results indicate that reduction of the low level contamination can be achieved through natural attenuation, HRC injection, active methane extraction, and phytoremediation. The purchase of the property associated with the western plume will allow for the expansion of the relevant point of compliance. As per 15A NCAC 13B .1631(a)(2)(A) the new compliance boundary would be established no more than 250 feet from the waste limit, and be at least 50 feet within the facility property boundary. Prior to establishing the new compliance boundary a petition would have to be submitted to the SWS Permitting Branch. For the City of Albemarle County to control all property associated with the plume migration patterns would also eliminate the need for off-site access permits. There is no indication that the contamination would reach the new relative point of compliance within a reasonable time period. Institutional controls limit access to the site. The source area has been capped to limit infiltration. The on-site, non-potable water supply well (SHOP) located near the scale house will be abandoned to eliminate both a possible exposure hazard, and a potential contaminant migration pathway.

Respectfully submitted
MUNICIPAL ENGINEERING SERVICES COMPANY, P.A.

NORTH CAROLINA LICENSED SEAL 1776 2/13/09 GEOLOGIST SEAN K. PATRICK

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TABLES

Table 1: Well Construction Details

Monitoring Well	Date Installed	Ground Elevation	TOC Elevation	Northing	Easting	Well Diameter	Boring Diameter	Screen Interval (BGS)	TOR	Status
MW-1	03/20/1991	445.60	447.21	569161.7600	1655967.3800	2"	6"	3-18	430.10	Background Well
MW-2	03/21/1991	429.87	431.85	567560.0300	1655560.0000	2"	6"	2.5-17.5	413.87	Performance Well
MW-3	03/20/1991	393.93	396.11	568269.0500	1657132.7400	2"	6"	7.5-22.5	382.43	Performance Well
MW-4	03/25/1991	394.27	396.19	566897.9510	1657520.6150	2"	6"	3.5-18.5	377.77	Decomissioned
MW-4R	09/08/1994	412.83	415.36	566905.2600	1657249.8300	2"	6"	19.4-34.4	409.83	Replaced MW-4
MW-5	09/08/1994	413.13	415.73	566907.2600	1657250.8300	2"	6"	4.9-19.9	-	Abandoned
MW-5R	02/24/1999	413.13	416.06	566701.8300	1656958.2800	2"	6"	15-25	-	Replaced MW-5
MW-6	09/08/1994	437.65	439.63	567044.7000	1655827.7700	2"	6"	20.5-35.5	430.65	Performance Well
MW-7	09/08/1994	429.42	431.30	567967.4500	1655267.8800	2"	6"	12.92-27.92	411.42	Performance Well
MW-8	09/08/1994	484.79	486.34	568832.1400	1655475.7600	2"	6"	20.5-35.5	-	Decomissioned
MW-8D	06/25/2007	488.81*	491.38*	568820.5800	1655494.2092	2"	6"	60.9-75.9	488.81*	Monitoring Point
MW-9	09/08/1994	389.11	392.64	569199.1700	1656883.0200	2"	6"	1.1-16.1	386.11	Performance Well
MW-10	09/08/1994	385.38	388.01	568679.6600	1657073.4700	2"	6"	2.1-17.7	382.38	Performance Well
MW-11	09/08/1994	384.40	386.78	567971.5200	1657356.3600	2"	6"	2.24-17.24	374.90	Sentinel Well
MW-12	09/08/1994	398.07	399.47	567474.4220	1657534.6800	2"	6"	6.96-21.96	-	Sampling Plan
MW-24	07/04/2007	429.19*	432.19*	567922.4680	1655228.8793	2"	6"	6.25-21.25	423.44*	Sentinel/Compliance Well
MW-25	07/04/2007	422.32*	425.22*	567504.0292	1655499.7712	2"	6"	6.2-18.2	417.32*	Sentinel/Compliance Well

NOTE:
1. Ground, TOC, and TOR elevations are in feet above mean sea level (amsl); well and boring diameter are in units of inches.
2. * Survey data suspect due to differences in elevations of adjacent monitoring wells.
3. TOC = top-of-casing
4. TOR = top-of-rock

Table 2: Historical Groundwater Elevation Data

WELL	9/15/1994	11/29/1994	2/25/1995	10/30/1995	4/29/1996	10/24/1996	5/28/1997	10/23/1997	4/22/1998	10/27/1998	4/14/1999
MW-1	438.71	444.51	444.08	442.61	442.06	441.21	439.72	442.11	442.28	433.20	440.86
MW-2	419.85	429.55	428.82	426.13	426.60	424.20	424.53	423.90	427.13	420.27	424.49
MW-3	384.91	385.26	385.21	383.11	383.74	382.41	382.47	382.63	383.13	382.01	382.57
MW-4R	398.56	396.98	400.42	398.76	396.63	395.96	394.81	394.76	398.78	391.51	393.65
MW-5	401.26	398.71	412.88	410.81	409.28	408.91	408.31	409.96	410.91	-	-
MW-5R	-	-	-	-	-	-	-	-	-	-	407.50
MW-6	417.96	417.61	420.53	418.43	419.48	417.33	417.57	415.06	421.12	414.29	417.61
MW-7	421.15	423.30	428.50	426.35	427.02	425.30	424.10	421.44	427.30	416.58	425.82
MW-8	-	-	-	-	-	-	-	-	-	-	-
MW-9	378.34	391.29	390.54	388.09	-	386.39	386.37	387.14	387.20	385.72	386.35
MW-10	372.41	386.81	386.41	384.18	384.76	384.01	383.74	383.59	384.03	382.66	383.05
MW-11	374.78	382.88	383.88	380.73	381.18	379.92	379.92	380.01	381.60	379.62	380.27
MW-12	378.97	389.97	392.54	390.45	387.69	386.87	386.19	385.27	389.22	384.29	384.11

WELL	2/7/2000	6/2/2000	12/5/2000	7/11/2001	1/9/2002	6/25/2002	12/16/2002	6/18/2003	1/6/2004	6/23/2004	1/6/2005
MW-1	443.13	-	-	434.16	429.30	-	442.76	442.25	441.76	431.71	436.89
MW-2	427.70	421.90	419.87	422.14	416.51	416.48	426.85	427.23	425.02	419.74	423.14
MW-3	383.52	381.74	382.04	382.11	382.23	380.96	383.63	383.73	382.73	381.92	382.64
MW-4R	397.95	392.21	390.65	392.39	389.51	389.48	399.10	400.11	396.41	392.91	394.48
MW-5	-	-	-	-	-	-	-	-	-	-	-
MW-5R	409.47	405.92	406.19	406.90	405.81	401.58	409.61	410.21	408.41	406.27	407.42
MW-6	418.31	415.63	413.21	414.93	411.85	412.48	417.80	420.82	418.58	415.61	417.49
MW-7	426.77	419.98	417.27	419.73	414.11	414.88	425.97	426.58	427.20	418.78	426.90
MW-8	-	-	-	-	-	-	-	-	-	-	-
MW-9	387.51	385.79	386.13	386.06	386.91	383.23	387.64	387.55	386.70	385.37	386.61
MW-10	384.11	382.11	383.19	382.59	383.58	381.09	384.22	384.13	383.71	382.39	383.99
MW-11	381.82	379.00	379.53	379.33	379.78	378.43	381.74	381.67	380.41	379.26	380.27
MW-12	389.37	387.42	-	383.94	383.53	381.49	388.72	389.16	385.16	383.98	384.26

Table 2: Historical Groundwater Elevation Data

WELL	6/16/2005	1/26/2006	7/13/2006	1/25/2007	7/3/2007	1/16/2008	7/16/2008	Observed High	Observed Low	Difference	Average
MW-1	437.22	442.84	432.91	442.90	432.14	427.69	-	444.51	427.69	16.82	438.76
MW-2	424.00	426.91	421.64	426.66	419.53	419.31	417.23	429.55	416.48	13.07	423.36
MW-3	382.45	383.66	381.31	383.61	382.11	381.85	381.34	385.26	380.96	4.30	382.79
MW-4R	397.12	399.38	394.42	399.81	393.89	393.31	391.06	400.42	389.48	10.94	395.35
MW-5	-	-	-	-	-	-	-	412.88	398.71	14.17	407.89
MW-5R	408.54	409.45	407.47	409.91	407.12	405.15	405.15	410.21	401.58	8.63	407.27
MW-6	418.13	419.49	416.06	419.89	415.83	412.40	413.73	421.12	411.85	9.27	416.87
MW-7	424.60	427.13	420.69	427.58	419.47	414.39	415.00	428.50	414.11	14.39	422.55
MW-8	-	-	-	-	-	-	-	-	-	-	-
MW-8D	-	-	-	-	439.68	434.68	435.44	439.68	434.68	5.00	392.78
MW-9	385.85	387.47	386.16	387.33	384.99	385.86	384.01	391.29	378.34	12.95	383.88
MW-10	382.79	384.26	383.01	384.43	382.06	382.96	381.40	386.81	372.41	14.40	380.93
MW-11	379.97	382.23	379.59	382.30	379.27	-	-	383.88	374.78	9.10	385.23
MW-12	385.06	389.18	385.56	389.09	385.22	382.79	383.56	392.54	378.97	13.57	385.78
MW-24	-	-	-	-	419.21	415.83	416.10	419.21	415.83	3.38	417.05
MW-25	-	-	-	-	414.17	413.66	413.02	414.17	413.02	1.15	413.62

Table 3: Summary of Slug Test Results

Well	Screen Interval (BGS)	Initial DTW (BTOC)	Initial Head Change	K (cm/sec)	Lithology
MW-1	3-18	15.10	15.10	1.40E-04	Argillite
MW-2	2.5-17.5	9.00	9.00	6.60E-05	Sandy Silt with Gravel
MW-3	7.5-22.5	14.40	14.40	3.40E-04	Argillite
MW-4R	19.4-34.4	23.05	23.05	1.40E-05	Argillite
MW-5	4.9-19.9	9.30	9.30	5.05E-05	Argillite
MW-6	20.5-35.5	24.20	24.20	4.15E-05	Argillite
MW-7	12.92-27.92	13.00	13.00	2.20E-05	Silty Clay with Gravel
MW-8	20.5-35.5	37.60	37.60	1.00E-04	Argillite
MW-8D	60.9-75.9	51.90	9.90	6.02E-07	Argillite
MW-9	1.1-16.1	6.90	6.90	8.30E-05	Argillite
MW-10	2.1-17.7	5.40	5.40	7.10E-05	Argillite
MW-11	2.24-17.24	7.55	7.55	2.40E-04	Sandy Clay with Gravel
MW-12	6.96-21.96	15.20	15.20	7.40E-05	Sandy Silt
MW-24	6.25-21.25	12.98	5.51	1.32E-05	Argillite
MW-25	6.2-18.2	10.92	5.85	2.82E-06	Argillite

Summary Statistics			
GeometricMean	3.79E-05	Maximum	3.40E-04
Geo. Std. Deviation (σ_{GSD})	5.31	Minimum	6.02E-07
GM / GSD (-1σ_{GSD})	7.13E-06	Median	6.60E-05
GM * GSD (+1σ_{GSD})	2.01E-04	Count	15

Unconsolidated/Residual Soils			
Geometric Mean (GM)	7.13E-05	Maximum	2.40E-04
Geo. Std. Deviation (σ_{GSD})	2.66	Minimum	2.20E-05
GM / GSD (-1σ_{GSD})	2.68E-05	Median	7.00E-05
GM * GSD (+1σ_{GSD})	1.89E-04	Count	4

Gneiss			
Geometric Mean (GM)	3.01E-05	Maximum	3.40E-04
Geo. Std. Deviation (σ_{GSD})	6.32	Minimum	6.02E-07
GM / GSD (-1σ_{GSD})	4.76E-06	Median	5.05E-05
GM * GSD (+1σ_{GSD})	1.90E-04	Count	11

Notes: BGS = Below Ground Surface
BTOC = Below Top-of-Casing
Information obtained from Responses to Review Comments dated April 28, 1995

Table 4: Summary of Historical Organic Results

Well ID	Parameter Name [1]	Sample Date	Result	Unit	Qual Code	PQL [2]	NCGW2L [3]	Exceedance
EB	Acetone	12/16/2002	11	ug/l		10	700	
EB	Carbon disulfide	06/02/2000	22	ug/l		5	700	
EB	Chloroform	01/15/2008	18	ug/l		0.16	70	
EB	Chloroform	10/24/1996	6.4	ug/l		5	70	
EB	Chloroform	10/31/1995	8	ug/l		5	70	
FB	Chloroform	01/15/2008	18	ug/l		0.16	70	
MW-1	Chloride	07/03/2007	3.1	mg/l		0	250	
MW-1	Chloride	01/25/2007	4	mg/l		1	250	
MW-1	**Methylene chloride**	**04/22/1998**	**5.3**	**ug/l**		**5**	**4.6**	**0.7**
MW-1	Toluene	07/03/2007	3.1	ug/l		1	1000	
MW-10	**Benzene**	**05/28/1997**	**5.5**	**ug/l**		**5**	**1**	**4.5**
MW-10	Carbon disulfide	06/02/2000	14	ug/l		5	700	
MW-10	Carbon disulfide	01/09/2002	1	ug/l		1	700	
MW-10	Carbon disulfide	12/05/2000	75	ug/l		5	700	
MW-10	Chloride	01/25/2007	250	mg/l		1	250	
MW-10	**Chloride**	**07/03/2007**	**290**	**mg/l**		**0**	**250**	**40**
MW-10	Chlorobenzene	05/28/1997	11	ug/l		5	50	
MW-10	Chlorobenzene	04/30/1996	6	ug/l		5	50	
MW-10	Chlorobenzene	10/24/1996	6.3	ug/l		5	50	
MW-10	Chlorobenzene	04/22/1998	8.1	ug/l		5	50	
MW-10	Chlorobenzene	10/23/1997	5.3	ug/l		5	50	
MW-10	Toluene	07/12/2001	12	ug/l		5	1000	
MW-11	1,1-Dichloroethane	01/16/2008	11	ug/l		0.09	70	
MW-11	1,1-Dichloroethane	01/09/2002	1.7	ug/l		1	70	
MW-11	Carbon disulfide	01/09/2002	1.4	ug/l		1	700	
MW-11	Chloride	01/25/2007	5	mg/l		1	250	
MW-12	Carbon disulfide	07/12/2001	6.4	ug/l		5	700	
MW-12	Chloride	01/25/2007	7	mg/l		1	250	
MW-12	Chloroethane	01/25/2007	1.5	ug/l		0.4	2800	
MW-12	Toluene	01/10/2002	1.5	ug/l		1	1000	
MW-12	Toluene	07/13/2006	6.7	ug/l		5	1000	
MW-12	Toluene	07/12/2001	74	ug/l		5	1000	
MW-2	Chloride	01/25/2007	100	mg/l		1	250	
MW-2	Chloride	07/03/2007	49	mg/l		0	250	
MW-24	Chloride	07/13/2007	11	mg/l		0.64	250	
MW-24	Chloride	07/13/2007	11	mg/l		0.64	250	
MW-25	Chloride	07/13/2007	23	mg/l		0.64	250	
MW-25	Chloride	07/13/2007	23	mg/l		0.64	250	
MW-3	1,1-Dichloroethane	01/25/2007	1.7	ug/l		0.09	70	
MW-3	1,1-Dichloroethane	01/09/2002	1.5	ug/l		1	70	
MW-3	**1,4-Dichlorobenzene**	**08/22/2007**	**1.7**	**ug/l**		**0.33**	**1.4**	**0.3**
MW-3	**1,4-Dichlorobenzene**	**01/16/2008**	**1.6**	**ug/l**		**0.15**	**1.4**	**0.2**
MW-3	Carbon disulfide	12/05/2000	9.1	ug/l		5	700	
MW-3	Chloride	07/03/2007	34	mg/l		0	250	
MW-3	Chloride	01/25/2007	79	mg/l		1	250	
MW-3	Chlorobenzene	08/22/2007	8.2	ug/l		0.27	50	
MW-3	Chlorobenzene	01/25/2007	3.5	ug/l		0.16	50	
MW-3	Chlorobenzene	01/16/2008	7	ug/l		0.16	50	
MW-3	Chlorobenzene	01/09/2002	2.1	ug/l		1	50	
MW-3	Chlorobenzene	06/23/2004	5.9	ug/l		5	50	

Table 4: Summary of Historical Organic Results

Well ID	Parameter Name [1]	Sample Date	Result	Unit	Qual Code	PQL [2]	NCGW2L [3]	Exceedance
MW-3	Chlorobenzene	01/06/2004	5.2	ug/l		5	50	
MW-3	Chlorobenzene	06/18/2003	5.2	ug/l		5	50	
MW-3	Chlorobenzene	01/06/2005	6	ug/l		5	50	
MW-3	Chlorobenzene	06/17/2005	7	ug/l		5	50	
MW-3	Chlorobenzene	07/13/2006	7.8	ug/l		5	50	
MW-3	**Methylene chloride**	**04/14/1999**	**11**	**ug/l**		**5**	**4.6**	**6.4**
MW-3	Trichloroethylene	08/22/2007	1.1	ug/l		0.26	2.8	
MW-4R	Carbon disulfide	01/09/2002	1.4	ug/l		1	700	
MW-4R	Carbon disulfide	12/05/2000	12	ug/l		5	700	
MW-5R	Carbon disulfide	12/05/2000	20	ug/l		5	700	
MW-5R	Carbon disulfide	01/09/2002	8.2	ug/l		1	700	
MW-5R	Methyl ethyl ketone	04/14/1999	510	ug/l		100	4200	
MW-6	Carbon disulfide	10/23/1997	9.1	ug/l		5	700	
MW-6	Carbon disulfide	01/09/2002	1.6	ug/l		1	700	
MW-6	Chloride	07/03/2007	7.8	mg/l		0	250	
MW-6	Chloride	01/25/2007	12	mg/l		1	250	
MW-6	**Methylene chloride**	**08/22/2007**	**14**	**ug/l**		**0.19**	**4.6**	**9.4**
MW-6	**Methylene chloride**	**07/03/2007**	**8.7**	**ug/l**		**1**	**4.6**	**4.1**
MW-6	**Methylene chloride**	**07/13/2006**	**13.1**	**ug/l**		**10**	**4.6**	**8.5**
MW-6	**Methylene chloride**	**01/06/2005**	**12**	**ug/l**		**10**	**4.6**	**7.4**
MW-6	**Tetrachloroethylene**	**08/22/2007**	**1.9**	**ug/l**		**0.47**	**0.7**	**1.2**
MW-6	Trichlorofluoromethane	06/23/2004	8.1	ug/l		5	2100	
MW-6	Trichlorofluoromethane	01/16/2008	7.3	ug/l		0.16	2100	
MW-6	Trichlorofluoromethane	01/06/2005	10	ug/l		5	2100	
MW-6	Trichlorofluoromethane	01/09/2002	2.5	ug/l		1	2100	
MW-6	Trichlorofluoromethane	06/16/2005	5	ug/l		5	2100	
MW-6	Trichlorofluoromethane	01/06/2004	7.4	ug/l		5	2100	
MW-6	Trichlorofluoromethane	08/22/2007	17	ug/l		0.45	2100	
MW-6	Trichlorofluoromethane	07/03/2007	9.2	ug/l		1	2100	
MW-6	Trichlorofluoromethane	07/13/2006	26.1	ug/l		5	2100	
MW-7	1,1-Dichloroethane	06/25/2002	5.2	ug/l		5	70	
MW-7	1,1-Dichloroethane	01/25/2007	2.9	ug/l		0.09	70	
MW-7	1,1-Dichloroethane	07/11/2001	5.2	ug/l		5	70	
MW-7	1,1-Dichloroethane	02/07/2000	5.8	ug/l		5	70	
MW-7	1,1-Dichloroethane	06/02/2000	6.4	ug/l		5	70	
MW-7	1,4-Dichlorobenzene	08/22/2007	1.2	ug/l		0.33	1.4	
MW-7	1,4-Dichlorobenzene	07/03/2007	1	ug/l		1	1.4	
MW-7	**Benzene**	**01/16/2008**	**2.4**	**ug/l**		**0.12**	**1**	**1.4**
MW-7	**Benzene**	**08/22/2007**	**2.4**	**ug/l**		**0.32**	**1**	**1.4**
MW-7	**Benzene**	**01/25/2007**	**1.3**	**ug/l**		**0.12**	**1**	**0.3**
MW-7	**Benzene**	**07/03/2007**	**2.7**	**ug/l**		**1**	**1**	**1.7**
MW-7	Carbon disulfide	07/11/2001	6.3	ug/l		5	700	
MW-7	Carbon disulfide	12/05/2000	5.6	ug/l		5	700	
MW-7	Chloride	07/03/2007	100	mg/l		0	250	
MW-7	Chloride	01/25/2007	110	mg/l		1	250	
MW-7	Chlorobenzene	01/16/2008	4	ug/l		0.16	50	
MW-7	Chlorobenzene	08/22/2007	4.3	ug/l		0.27	50	
MW-7	Chlorobenzene	01/25/2007	2.1	ug/l		0.16	50	
MW-7	cis-1,2-Dichloroethene	01/25/2007	1.3	ug/l		0.14	70	
MW-7	**Methylene chloride**	**04/22/1998**	**8.1**	**ug/l**		**5**	**4.6**	**3.5**

Table 4: Summary of Historical Organic Results

Well ID	Parameter Name [1]	Sample Date	Result	Unit	Qual Code	PQL [2]	NCGW2L [3]	Exceedance
MW-7	Trichlorofluoromethane	07/03/2007	1.1	ug/l		1	2100	
MW-9	1,1-Dichloroethane	01/09/2002	1.7	ug/l		1	70	
MW-9	1,4-Dichlorobenzene	08/22/2007	1	ug/l		0.33	1.4	
MW-9	Chloride	07/03/2007	72	mg/l		0	250	
MW-9	Chloride	01/25/2007	43	mg/l		1	250	
MW-9	cis-1,2-Dichloroethene	01/09/2002	1.3	ug/l		1	70	
MW-9	cis-1,2-Dichloroethene	08/22/2007	5.6	ug/l		0.18	70	
MW-9	**Tetrachloroethylene**	**08/22/2007**	**4.4**	**ug/l**		**0.47**	**0.7**	**3.7**
MW-9	**Tetrachloroethylene**	**07/03/2007**	**1.1**	**ug/l**		**1**	**0.7**	**0.4**
MW-9	Toluene	06/05/2000	23	ug/l		5	1000	
MW-9	Trichloroethylene	07/03/2007	1.5	ug/l		1	2.8	
MW-9	**Trichloroethylene**	**08/22/2007**	**4.7**	**ug/l**		**0.26**	**2.8**	**1.9**
MW-9	**Vinyl chloride**	**08/22/2007**	**1.4**	**ug/l**		**0.91**	**0.015**	**1.385**
SHOP	1,1-Dichloroethane	01/25/2007	5.6	ug/l		0.09	70	
SHOP	1,1-Dichloroethane	07/13/2006	6.5	ug/l		5	70	
SHOP	1,1-Dichloroethane	01/26/2006	7	ug/l		5	70	
SHOP	1,1-Dichloroethane	01/16/2008	6.7	ug/l		0.09	70	
SHOP	cis-1,2-Dichloroethene	01/25/2007	5.5	ug/l		0.14	70	
SHOP	cis-1,2-Dichloroethene	01/16/2008	6.4	ug/l		0.14	70	
SHOP	**Tetrachloroethylene**	**07/03/2007**	**1.5**	**ug/l**		**1**	**0.7**	**0.8**
SHOP	**Tetrachloroethylene**	**01/25/2007**	**10**	**ug/l**		**0.25**	**0.7**	**9.3**
SHOP	**Tetrachloroethylene**	**07/13/2006**	**15.9**	**ug/l**		**5**	**0.7**	**15.2**
SHOP	**Tetrachloroethylene**	**01/16/2008**	**8.6**	**ug/l**		**0.25**	**0.7**	**7.9**
SHOP	**Tetrachloroethylene**	**01/26/2006**	**8**	**ug/l**		**5**	**0.7**	**7.3**
SHOP	**Trichloroethylene**	**01/26/2006**	**6**	**ug/l**		**5**	**2.8**	**3.2**
SHOP	**Trichloroethylene**	**01/25/2007**	**6.4**	**ug/l**		**0.23**	**2.8**	**3.6**
SHOP	**Trichloroethylene**	**07/13/2006**	**6.9**	**ug/l**		**5**	**2.8**	**4.1**
SHOP	Trichloroethylene	07/03/2007	2.2	ug/l		1	2.8	
SHOP	**Trichloroethylene**	**01/16/2008**	**6**	**ug/l**		**0.23**	**2.8**	**3.2**
SHOP	**Vinyl chloride**	**01/16/2008**	**1.4**	**ug/l**		**0.15**	**0.015**	**1.385**
SHOP	**Vinyl chloride**	**01/25/2007**	**1.3**	**ug/l**		**0.15**	**0.015**	**1.285**
SW-3	Toluene	04/22/1998	10	ug/l		5	1000	
SW-5	Acetone	01/09/2002	20	ug/l		5	700	
TB	**Methylene chloride**	**06/02/2000**	**8.6**	**ug/l**		**5**	**4.6**	**4**
EB	Acetone	01/15/2008	14	ug/l	J	0.9	700	
EB	Toluene	07/17/2007	0.39	ug/l	J	1	1000	
FB	Acetone	01/15/2008	13	ug/l	J	0.9	700	
FB	Toluene	07/17/2007	0.32	ug/l	J	1	1000	
MW-1	Acetone	01/16/2008	4.6	ug/l	J	0.9	700	
MW-1	Acetone	07/03/2007	1	ug/l	J	100	700	
MW-1	DEHP	08/22/2007	2.4	ug/l	J	1.9	2.5	
MW-10	Toluene	07/03/2007	0.46	ug/l	J	1	1000	
MW-11	1,1-Dichloroethane	07/03/2007	0.37	ug/l	J	5	70	
MW-11	Chloroethane	01/16/2008	4	ug/l	J	0.4	2800	
MW-11	cis-1,2-Dichloroethene	01/16/2008	3	ug/l	J	0.14	70	
MW-11	Toluene	07/03/2007	0.51	ug/l	J	1	1000	
MW-12	Acetone	01/16/2008	19	ug/l	J	0.9	700	
MW-12	Acetone	07/03/2007	11	ug/l	J	100	700	
MW-2	1,4-Dichlorobenzene	01/25/2007	0.35	ug/l	J	0.15	1.4	
MW-2	1,4-Dichlorobenzene	07/03/2007	0.64	ug/l	J	1	1.4	

Table 4: Summary of Historical Organic Results

Well ID	Parameter Name [1]	Sample Date	Result	Unit	Qual Code	PQL [2]	NCGW2L [3]	Exceedance
MW-2	1,4-Dichlorobenzene	08/22/2007	0.98	ug/l	J	0.33	1.4	
MW-2	Acetone	07/03/2007	19	ug/l	J	100	700	
MW-2	Benzene	07/03/2007	0.45	ug/l	J	1	1	
MW-2	Chlorobenzene	01/25/2007	0.42	ug/l	J	0.16	50	
MW-2	Chlorobenzene	08/22/2007	1.2	ug/l	J	0.27	50	
MW-2	Chlorobenzene	07/03/2007	1	ug/l	J	3	50	
MW-2	Methyl ethyl ketone	07/03/2007	2.9	ug/l	J	100	4200	
MW-25	1,1-Dichloroethane	07/13/2007	1.6	ug/l	J	0.09	70	
MW-25	1,1-Dichloroethane	07/13/2007	1.6	ug/l	J	0.09	70	
MW-3	1,1-Dichloroethane	01/16/2008	3.3	ug/l	J	0.09	70	
MW-3	1,1-Dichloroethane	08/22/2007	2.6	ug/l	J	0.28	70	
MW-3	1,4-Dichlorobenzene	01/25/2007	0.84	ug/l	J	0.15	1.4	
MW-3	Chlorobenzene	07/03/2007	0.39	ug/l	J	3	50	
MW-3	cis-1,2-Dichloroethene	01/16/2008	1.1	ug/l	J	0.14	70	
MW-3	cis-1,2-Dichloroethene	01/25/2007	0.63	ug/l	J	0.14	70	
MW-3	cis-1,2-Dichloroethene	08/22/2007	1.1	ug/l	J	0.18	70	
MW-3	Dichlorodifluoromethane	08/22/2007	4.2	ug/l	J	0.63	1400	
MW-3	**Tetrachloroethylene**	**01/16/2008**	**0.71**	**ug/l**	J	**0.25**	**0.7**	**0.01**
MW-3	**Tetrachloroethylene**	**08/22/2007**	**0.87**	**ug/l**	J	**0.47**	**0.7**	**0.17**
MW-3	Tetrachloroethylene	01/25/2007	0.43	ug/l	J	0.25	0.7	
MW-3	Toluene	08/22/2007	0.88	ug/l	J	0.35	1000	
MW-3	Toluene	07/03/2007	0.39	ug/l	J	1	1000	
MW-3	Trichloroethylene	01/16/2008	0.82	ug/l	J	0.23	2.8	
MW-3	Trichloroethylene	01/25/2007	0.45	ug/l	J	0.23	2.8	
MW-4R	1,1-Dichloroethane	07/03/2007	0.39	ug/l	J	5	70	
MW-4R	1,1-Dichloroethane	01/16/2008	1.1	ug/l	J	0.09	70	
MW-4R	Chlorobenzene	01/16/2008	0.42	ug/l	J	0.16	50	
MW-4R	cis-1,2-Dichloroethene	01/16/2008	0.43	ug/l	J	0.14	70	
MW-4R	Toluene	07/03/2007	0.31	ug/l	J	1	1000	
MW-6	1,1-Dichloroethane	01/16/2008	2	ug/l	J	0.09	70	
MW-6	1,1-Dichloroethane	08/22/2007	2.5	ug/l	J	0.28	70	
MW-6	1,1-Dichloroethane	07/03/2007	2.2	ug/l	J	5	70	
MW-6	1,1-dichloroEthene	08/22/2007	1.1	ug/l	J	0.4	7	
MW-6	1,1-dichloroEthene	07/03/2007	0.58	ug/l	J	5	7	
MW-6	1,4-Dichlorobenzene	07/03/2007	0.44	ug/l	J	1	1.4	
MW-6	1,4-Dichlorobenzene	08/22/2007	0.4	ug/l	J	0.33	1.4	
MW-6	Benzene	07/03/2007	0.55	ug/l	J	1	1	
MW-6	Benzene	08/22/2007	0.54	ug/l	J	0.32	1	
MW-6	Chlorobenzene	08/22/2007	0.76	ug/l	J	0.27	50	
MW-6	DEHP	08/22/2007	3.2	ug/l	J	1.9	2.5	
MW-6	Dichlorodifluoromethane	08/22/2007	4.5	ug/l	J	0.63	1400	
MW-6	Methylene chloride	01/16/2008	0.67	ug/l	J	0.088	4.6	
MW-6	**Tetrachloroethylene**	**07/03/2007**	**0.92**	**ug/l**	**J**	**1**	**0.7**	**0.22**
MW-6	**Tetrachloroethylene**	**01/16/2008**	**0.92**	**ug/l**	**J**	**0.25**	**0.7**	**0.22**
MW-6	Toluene	07/03/2007	0.46	ug/l	J	1	1000	
MW-6	Trichloroethylene	08/22/2007	0.47	ug/l	J	0.26	2.8	
MW-6	Trichlorofluoromethane	01/25/2007	0.41	ug/l	J	0.16	2100	
MW-7	1,1-Dichloroethane	07/03/2007	4.2	ug/l	J	5	70	
MW-7	1,1-Dichloroethane	08/22/2007	2.8	ug/l	J	0.28	70	
MW-7	1,1-Dichloroethane	01/16/2008	3.9	ug/l	J	0.09	70	

Table 4: Summary of Historical Organic Results

Well ID	Parameter Name [1]	Sample Date	Result	Unit	Qual Code	PQL [2]	NCGW2L [3]	Exceedance
MW-7	1,1-dichloroEthene	07/03/2007	0.49	ug/l	J	5	7	
MW-7	1,4-Dichlorobenzene	01/25/2007	0.98	ug/l	J	0.15	1.4	
MW-7	cis-1,2-Dichloroethene	01/16/2008	1.8	ug/l	J	0.14	70	
MW-7	cis-1,2-Dichloroethene	08/22/2007	1.4	ug/l	J	0.18	70	
MW-7	cis-1,2-Dichloroethene	07/03/2007	1.8	ug/l	J	5	70	
MW-7	Dichlorodifluoromethane	08/22/2007	3.2	ug/l	J	0.63	1400	
MW-7	Methylene chloride	01/16/2008	0.42	ug/l	J	0.088	4.6	
MW-7	o-Dichlorobenzene	07/03/2007	0.31	ug/l	J	5	620	
MW-7	**Tetrachloroethylene**	**08/22/2007**	**0.81**	**ug/l**	J	**0.47**	**0.7**	**0.11**
MW-7	Tetrachloroethylene	01/16/2008	0.47	ug/l	J	0.25	0.7	
MW-7	Tetrachloroethylene	01/25/2007	0.6	ug/l	J	0.25	0.7	
MW-7	**Tetrachloroethylene**	**07/03/2007**	**0.9**	**ug/l**	J	**1**	**0.7**	**0.2**
MW-7	Toluene	07/03/2007	0.45	ug/l	J	1	1000	
MW-7	Trichloroethylene	07/03/2007	0.48	ug/l	J	1	2.8	
MW-7	Trichloroethylene	08/22/2007	0.41	ug/l	J	0.26	2.8	
MW-7	Trichlorofluoromethane	01/16/2008	0.51	ug/l	J	0.16	2100	
MW-7	Trichlorofluoromethane	08/22/2007	0.96	ug/l	J	0.45	2100	
MW-7	Trichlorofluoromethane	01/25/2007	0.36	ug/l	J	0.16	2100	
MW-7	**Vinyl chloride**	**01/25/2007**	**0.31**	**ug/l**	J	**0.15**	**0.015**	**0.295**
MW-7	**Vinyl chloride**	**07/03/2007**	**0.71**	**ug/l**	J	**1**	**0.015**	**0.695**
MW-8D	Toluene	07/03/2007	0.99	ug/l	J	1	1000	
MW-9	1,1-Dichloroethane	07/03/2007	2.4	ug/l	J	5	70	
MW-9	1,1-Dichloroethane	08/22/2007	4.4	ug/l	J	0.28	70	
MW-9	1,4-Dichlorobenzene	07/03/2007	0.43	ug/l	J	1	1.4	
MW-9	Benzene	07/03/2007	0.4	ug/l	J	1	1	
MW-9	Benzene	08/22/2007	0.58	ug/l	J	0.32	1	
MW-9	Chlorobenzene	08/22/2007	2	ug/l	J	0.27	50	
MW-9	cis-1,2-Dichloroethene	07/03/2007	2.5	ug/l	J	5	70	
MW-9	DEHP	08/22/2007	2.2	ug/l	J	1.9	2.5	
MW-9	Dichlorodifluoromethane	08/22/2007	1.5	ug/l	J	0.63	1400	
MW-9	Ethylene dichloride	08/22/2007	0.21	ug/l	J	0.18	0.38	
MW-9	Tetrachloroethylene	01/16/2008	0.42	ug/l	J	0.25	0.7	
MW-9	Toluene	07/03/2007	0.86	ug/l	J	1	1000	
MW-9	**Vinyl chloride**	**07/03/2007**	**0.67**	**ug/l**	**J**	**1**	**0.015**	**0.655**
SHOP	1,1-Dichloroethane	07/03/2007	4	ug/l	J	5	70	
SHOP	1,1-dichloroEthene	01/25/2007	0.72	ug/l	J	0.14	7	
SHOP	1,1-dichloroEthene	01/16/2008	0.89	ug/l	J	0.14	7	
SHOP	Benzene	01/25/2007	0.74	ug/l	J	0.12	1	
SHOP	Benzene	07/03/2007	0.47	ug/l	J	1	1	
SHOP	Chloroethane	01/25/2007	0.48	ug/l	J	0.4	2800	
SHOP	cis-1,2-Dichloroethene	07/03/2007	2.7	ug/l	J	5	70	
SHOP	Methylene chloride	01/16/2008	0.87	ug/l	J	0.088	4.6	
SHOP	Methylene chloride	01/25/2007	0.6	ug/l	J	0.088	4.6	
SHOP	trans-1,2-Dichloroethene	01/16/2008	0.4	ug/l	J	0.1	100	
SHOP	**Vinyl chloride**	**07/03/2007**	**0.65**	**ug/l**	**J**	**1**	**0.015**	**0.635**
TB	**Methylene chloride**	**01/26/2006**	**10**	**ug/l**	**J**	**10**	**4.6**	**5.4**
TB	Toluene	07/17/2007	0.59	ug/l	J	1	1000	

[1] Table only contains detected constituents.

[2] PQL = Practical Quantitation Limit

[3] NCGW2L = North Carolina Ground Water 2L Standard

Table 5: Summary of Historical Background Results

Well ID	Parameter Name [1]	Sample Date	Result	Unit	Qual Code	PQL [2]	NCGW2L [3]	Exceedance
MW-1	Acetone	07/03/2007	1	ug/l	J	100	700	
MW-1	Acetone	01/16/2008	4.6	ug/l	J	0.9	700	
MW-1	Antimony, total	01/16/2008	1.5	ug/l	J	0.68	1.4*	
MW-1	Arsenic	09/16/1994	0.025	mg/l		0.01	0.05	
MW-1	Arsenic	05/28/1997	0.007	mg/l		0.005	0.05	
MW-1	Arsenic	10/27/1998	0.012	mg/l		0.005	0.05	
MW-1	Arsenic	01/25/2007	4.1	ug/l	J	2	50	
MW-1	Arsenic	07/03/2007	4.2	ug/l	J	10	50	
MW-1	Arsenic	01/16/2008	6.2	ug/l	J	2	50	
MW-1	Barium, total	09/16/1994	0.25	mg/l		0.1	2	
MW-1	Barium, total	10/24/1996	0.043	mg/l		0.01	2	
MW-1	Barium, total	05/28/1997	0.064	mg/l		0.01	2	
MW-1	Barium, total	10/23/1997	0.045	mg/l		0.01	2	
MW-1	Barium, total	04/22/1998	0.026	mg/l		0.01	2	
MW-1	Barium, total	10/27/1998	0.13	mg/l		0.01	2	
MW-1	Barium, total	04/14/1999	0.032	mg/l		0.005	2	
MW-1	Barium, total	02/07/2000	0.029	mg/l		0.005	2	
MW-1	Barium, total	07/13/2001	0.061	mg/l		0.005	2	
MW-1	Barium, total	01/10/2002	0.16	mg/l		0.005	2	
MW-1	Barium, total	12/16/2002	0.046	mg/l		0.005	2	
MW-1	Barium, total	06/18/2003	0.067	mg/l		0.005	2	
MW-1	Barium, total	01/25/2007	34	ug/l		0.2	2000	
MW-1	Barium, total	07/03/2007	124	ug/l		100	2000	
MW-1	Barium, total	08/22/2007	158	ug/l		1	2000	
MW-1	Barium, total	01/16/2008	177	ug/l		0.2	2000	
MW-1	Beryllium, total	10/27/1998	0.0024	mg/l		0.002	4*	
MW-1	Beryllium, total	01/10/2002	0.0012	mg/l		0.001	4*	
MW-1	Beryllium, total	07/03/2007	0.3	ug/l	J	1	4*	
MW-1	Beryllium, total	08/22/2007	0.9	ug/l	J	0.7	4*	
MW-1	Cadmium, total	09/16/1994	0.001	mg/l		0.001	0.0018	
MW-1	Cadmium, total	04/29/1996	0.001	mg/l		0.001	0.0018	
MW-1	Cadmium, total	08/22/2007	1.4	ug/l		0.5	1.75	
MW-1	Chloride	01/25/2007	4	mg/l		1	250	
MW-1	Chloride	07/03/2007	3.1	mg/l		0	250	
MW-1	**Chromium, total**	**09/16/1994**	**0.06**	**mg/l**		**0.005**	**0.05**	**0.01**
MW-1	Chromium, total	05/28/1997	0.006	mg/l		0.002	0.05	
MW-1	Chromium, total	10/23/1997	0.004	mg/l		0.002	0.05	
MW-1	Chromium, total	04/22/1998	0.011	mg/l		0.002	0.05	
MW-1	Chromium, total	10/27/1998	0.024	mg/l		0.002	0.05	
MW-1	Chromium, total	07/13/2001	0.003	mg/l		0.002	0.05	
MW-1	Chromium, total	01/10/2002	0.0061	mg/l		0.002	0.05	
MW-1	Chromium, total	12/16/2002	0.002	mg/l		0.002	0.05	
MW-1	Chromium, total	06/18/2003	0.0021	mg/l		0.002	0.05	
MW-1	Chromium, total	07/03/2007	4.6	ug/l	J	10	50	
MW-1	Chromium, total	08/22/2007	8.1	ug/l	J	3	50	
MW-1	Chromium, total	01/16/2008	14.2	ug/l		2	50	
MW-1	Cobalt, total	02/07/1995	0.018	mg/l		0.01	70*	
MW-1	Cobalt, total	02/27/1995	0.018	mg/l		0.01	70*	
MW-1	Cobalt, total	10/30/1995	0.01	mg/l		0.01	70*	
MW-1	Cobalt, total	04/29/1996	0.015	mg/l		0.01	70*	

Table 5: Summary of Historical Background Results

Well ID	Parameter Name [1]	Sample Date	Result	Unit	Qual Code	PQL [2]	NCGW2L [3]	Exceedance
MW-1	Cobalt, total	10/24/1996	0.005	mg/l		0.002	70*	
MW-1	Cobalt, total	05/28/1997	0.015	mg/l		0.003	70*	
MW-1	Cobalt, total	10/23/1997	0.017	mg/l		0.003	70*	
MW-1	Cobalt, total	04/22/1998	0.008	mg/l		0.002	70*	
MW-1	Cobalt, total	10/27/1998	0.042	mg/l		0.002	70*	
MW-1	Cobalt, total	04/14/1999	0.013	mg/l		0.005	70*	
MW-1	Cobalt, total	07/13/2001	0.0096	mg/l		0.005	70*	
MW-1	Cobalt, total	01/10/2002	0.05	mg/l		0.005	70*	
MW-1	Cobalt, total	06/18/2003	0.01	mg/l		0.005	70*	
MW-1	Cobalt, total	01/06/2004	0.018	mg/l		0.01	70*	
MW-1	Cobalt, total	06/23/2004	0.014	mg/l		0.01	70*	
MW-1	Cobalt, total	01/06/2005	0.017	mg/l		0.01	70*	
MW-1	Cobalt, total	06/17/2005	0.012	mg/l		0.01	70*	
MW-1	Cobalt, total	01/26/2006	0.0128	mg/l		0.01	70*	
MW-1	Cobalt, total	07/13/2006	0.0151	mg/l		0.01	70*	
MW-1	Cobalt, total	01/25/2007	8.9	ug/l	J	2	70*	
MW-1	Cobalt, total	07/03/2007	16.1	ug/l		10	70*	
MW-1	Cobalt, total	08/22/2007	23.7	ug/l		2	70*	
MW-1	Cobalt, total	01/16/2008	66.8	ug/l		2	70*	
MW-1	Copper	09/16/1994	0.2	mg/l		0.01	1	
MW-1	Copper	10/24/1996	0.024	mg/l		0.01	1	
MW-1	Copper	05/28/1997	0.045	mg/l		0.01	1	
MW-1	Copper	10/23/1997	0.027	mg/l		0.01	1	
MW-1	Copper	04/22/1998	0.024	mg/l		0.01	1	
MW-1	Copper	10/27/1998	0.12	mg/l		0.01	1	
MW-1	Copper	04/14/1999	0.029	mg/l		0.002	1	
MW-1	Copper	02/07/2000	0.0034	mg/l		0.002	1	
MW-1	Copper	07/13/2001	0.017	mg/l		0.002	1	
MW-1	Copper	01/10/2002	0.038	mg/l		0.002	1	
MW-1	Copper	12/16/2002	0.0064	mg/l		0.002	1	
MW-1	Copper	06/18/2003	0.0064	mg/l		0.002	1	
MW-1	Copper	01/25/2007	8.5	ug/l	J	0.6	1000	
MW-1	Copper	07/03/2007	42.5	ug/l		10	1000	
MW-1	Copper	08/22/2007	59	ug/l		3	1000	
MW-1	Copper	01/16/2008	55.1	ug/l		0.6	1000	
MW-1	DEHP	08/22/2007	2.4	ug/l	J	1.9	2.5	
MW-1	**Iron**	**01/25/2007**	**1090**	**ug/l**		**20**	**300**	**790**
MW-1	**Lead, total**	**09/16/1994**	**0.093**	**mg/l**		**0.01**	**0.015**	**0.078**
MW-1	**Lead, total**	**02/07/1995**	**0.016**	**mg/l**		**0.01**	**0.015**	**0.001**
MW-1	**Lead, total**	**05/28/1997**	**0.2**	**mg/l**		**0.005**	**0.015**	**0.185**
MW-1	Lead, total	10/23/1997	0.013	mg/l		0.005	0.015	
MW-1	Lead, total	04/22/1998	0.007	mg/l		0.005	0.015	
MW-1	**Lead, total**	**10/27/1998**	**0.074**	**mg/l**		**0.005**	**0.015**	**0.059**
MW-1	Lead, total	04/14/1999	0.008	mg/l		0.005	0.015	
MW-1	Lead, total	07/13/2001	0.0077	mg/l		0.003	0.015	
MW-1	**Lead, total**	**01/10/2002**	**0.016**	**mg/l**		**0.003**	**0.015**	**0.001**
MW-1	Lead, total	06/23/2004	0.011	mg/l		0.01	0.015	
MW-1	Lead, total	06/17/2005	0.012	mg/l		0.01	0.015	
MW-1	**Lead, total**	**07/03/2007**	**31.3**	**ug/l**		**10**	**15**	**16.3**
MW-1	**Lead, total**	**08/22/2007**	**37**	**ug/l**		**2**	**15**	**22**

Table 5: Summary of Historical Background Results

Well ID	Parameter Name [1]	Sample Date	Result	Unit	Qual Code	PQL [2]	NCGW2L [3]	Exceedance
MW-1	**Lead, total**	**01/16/2008**	**37.8**	**ug/l**		**2**	**15**	**22.8**
MW-1	**Manganese**	**01/25/2007**	**407**	**ug/l**		**1.4**	**50**	**357**
MW-1	**Methylene chloride**	**04/22/1998**	**5.3**	**ug/l**		**5**	**4.6**	**0.7**
MW-1	**Nickel, total**	**09/16/1994**	**0.14**	**mg/l**		**0.1**	**0.1**	**0.04**
MW-1	Nickel, total	11/30/1994	0.057	mg/l		0.05	0.1	
MW-1	Nickel, total	10/27/1998	0.096	mg/l		0.05	0.1	
MW-1	Nickel, total	04/14/1999	0.015	mg/l		0.005	0.1	
MW-1	Nickel, total	07/13/2001	0.014	mg/l		0.005	0.1	
MW-1	**Nickel, total**	**01/10/2002**	**0.17**	**mg/l**		**0.005**	**0.1**	**0.07**
MW-1	Nickel, total	06/18/2003	0.0059	mg/l		0.005	0.1	
MW-1	Nickel, total	01/25/2007	4.8	ug/l	J	2	100	
MW-1	Nickel, total	07/03/2007	26.4	ug/l	J	50	100	
MW-1	Nickel, total	08/22/2007	25	ug/l	J	2	100	
MW-1	Nickel, total	01/16/2008	76.1	ug/l		2	100	
MW-1	Sulfate, total	01/25/2007	9.9	mg/l		0.6	250	
MW-1	Sulfate, total	07/03/2007	7.5	mg/l		0	250	
MW-1	Thallium	07/03/2007	0.105	ug/l	J	5.5	0.28*	
MW-1	Thallium	08/22/2007	0.053	ug/l	J	0.036	0.28*	
MW-1	Thallium	01/16/2008	0.097	ug/l	J	0.036	0.28*	
MW-1	Toluene	07/03/2007	3.1	ug/l		1	1000	
MW-1	Total Alkalinity	01/25/2007	42	mg/l		2	NE	
MW-1	Total Alkalinity	07/03/2007	21	mg/l		0	NE	
MW-1	Total Dissolved Solids	01/25/2007	78	mg/l		10	500000	
MW-1	Total Dissolved Solids	07/03/2007	68	mg/l		0	500000	
MW-1	Vanadium	09/16/1994	0.07	mg/l		0.05	3.5*	
MW-1	Vanadium	05/28/1997	0.019	mg/l		0.005	3.5*	
MW-1	Vanadium	10/27/1998	0.046	mg/l		0.005	3.5*	
MW-1	Vanadium	01/10/2002	0.0074	mg/l		0.005	3.5*	
MW-1	Vanadium	08/22/2007	9.1	ug/l	J	1	3.5*	
MW-1	Vanadium	01/16/2008	13.3	ug/l	J	1	3.5*	
MW-1	Zinc	09/16/1994	0.36	mg/l		0.05	1.05	
MW-1	Zinc	11/30/1994	0.076	mg/l		0.05	1.05	
MW-1	Zinc	02/27/1995	0.089	mg/l		0.05	1.05	
MW-1	Zinc	04/29/1996	0.078	mg/l		0.05	1.05	
MW-1	Zinc	10/24/1996	0.045	mg/l		0.01	1.05	
MW-1	Zinc	05/28/1997	0.081	mg/l		0.01	1.05	
MW-1	Zinc	10/23/1997	0.093	mg/l		0.01	1.05	
MW-1	Zinc	04/22/1998	0.033	mg/l		0.01	1.05	
MW-1	Zinc	10/27/1998	0.21	mg/l		0.01	1.05	
MW-1	Zinc	04/14/1999	0.034	mg/l		0.01	1.05	
MW-1	Zinc	02/07/2000	0.017	mg/l		0.01	1.05	
MW-1	Zinc	07/13/2001	0.042	mg/l		0.01	1.05	
MW-1	Zinc	01/10/2002	0.22	mg/l		0.01	1.05	
MW-1	Zinc	12/16/2002	0.036	mg/l		0.01	1.05	
MW-1	Zinc	06/18/2003	0.057	mg/l		0.01	1.05	
MW-1	Zinc	06/23/2004	0.05	mg/l		0.05	1.05	
MW-1	Zinc	06/17/2005	0.05	mg/l		0.05	1.05	
MW-1	Zinc	01/25/2007	21.7	ug/l		1	1050	
MW-1	Zinc	07/03/2007	88.3	ug/l		10	1050	
MW-1	Zinc	08/22/2007	123	ug/l		3	1050	

Table 5: Summary of Historical Background Results

Well ID	Parameter Name [1]	Sample Date	Result	Unit	Qual Code	PQL [2]	NCGW2L [3]	Exceedance
MW-1	Zinc	01/16/2008	173	ug/l		1	1050	
MW-8D	Antimony, total	07/03/2007	0.85	ug/l	J	6	1.4*	
MW-8D	Antimony, total	01/16/2008	1.17	ug/l	J	0.68	1.4*	
MW-8D	Arsenic	01/16/2008	2	ug/l	J	2	50	
MW-8D	Barium, total	07/03/2007	30.7	ug/l	J	100	2000	
MW-8D	Barium, total	01/16/2008	24.2	ug/l	J	0.2	2000	
MW-8D	Cadmium, total	07/03/2007	1.2	ug/l		1	1.75	
MW-8D	Cobalt, total	07/03/2007	4.1	ug/l	J	10	70*	
MW-8D	Cobalt, total	01/16/2008	4.8	ug/l	J	2	70*	
MW-8D	Copper	07/03/2007	2.7	ug/l	J	10	1000	
MW-8D	Copper	01/16/2008	4.5	ug/l	J	0.6	1000	
MW-8D	Nickel, total	07/03/2007	2.8	ug/l	J	50	100	
MW-8D	Nickel, total	01/16/2008	4.9	ug/l	J	2	100	
MW-8D	Thallium	07/03/2007	0.036	ug/l	J	5.5	0.28*	
MW-8D	Thallium	01/16/2008	0.037	ug/l	J	0.036	0.28*	
MW-8D	Toluene	07/03/2007	0.99	ug/l	J	1	1000	
MW-8D	Zinc	07/03/2007	5.9	ug/l	J	10	1050	
MW-8D	Zinc	01/16/2008	15.7	ug/l		1	1050	

[1] Table only contains detected constituents.
[2] PQL = Practical Quantitation Limit
[3] NCGW2L = North Carolina Ground Water 2L Standard
* Groundwater Protection Standard

Table 6: Summary of Current Groundwater Results

Well ID	Parameter Name [1]	Sample Date	Result	Unit	Qual Code	PQL [2]	NCGW2L [3]	Exceedance
EB	Chloroform	01/15/2008	18	ug/l		0.16	70	
FB	Chloroform	01/15/2008	18	ug/l		0.16	70	
MW-1	Barium, total	01/16/2008	177	ug/l		0.2	2000	
MW-1	Chromium, total	01/16/2008	14.2	ug/l		2	50	
MW-1	Cobalt, total	01/16/2008	66.8	ug/l		2	70*	
MW-1	Copper	01/16/2008	55.1	ug/l		0.6	1000	
MW-1	**Lead, total**	**01/16/2008**	**37.8**	**ug/l**		**2**	**15**	**22.8**
MW-1	Nickel, total	01/16/2008	76.1	ug/l		2	100	
MW-1	Zinc	01/16/2008	173	ug/l		1	1050	
MW-11	1,1-Dichloroethane	01/16/2008	11	ug/l		0.09	70	
MW-12	Arsenic	01/16/2008	33.2	ug/l		2	50	
MW-12	Barium, total	01/16/2008	138	ug/l		0.2	2000	
MW-12	**Cadmium, total**	**01/16/2008**	**2.2**	**ug/l**		**0.5**	**1.75**	**0.45**
MW-12	Cobalt, total	01/16/2008	73.4	ug/l		2	70*	
MW-12	Copper	01/16/2008	40.1	ug/l		0.6	1000	
MW-12	**Nickel, total**	**01/16/2008**	**111**	**ug/l**		**2**	**100**	**11**
MW-12	Zinc	01/16/2008	30.9	ug/l		1	1050	
MW-2	Cobalt, total	01/16/2008	930	ug/l		2	70*	
MW-2	Copper	01/16/2008	16.9	ug/l		0.6	1000	
MW-2	Lead, total	01/16/2008	13.6	ug/l		2	15	
MW-2	**Nickel, total**	**01/16/2008**	**861**	**ug/l**		**2**	**100**	**761**
MW-2	Zinc	01/16/2008	603	ug/l		1	1050	
MW-24	Arsenic	01/16/2008	17.5	ug/l		2	50	
MW-24	Chromium, total	01/16/2008	13.8	ug/l		2	50	
MW-24	Cobalt, total	01/16/2008	12.4	ug/l		2	70*	
MW-24	Copper	01/16/2008	33.7	ug/l		0.6	1000	
MW-24	Lead, total	01/16/2008	10.1	ug/l		2	15	
MW-24	Zinc	01/16/2008	17.3	ug/l		1	1050	
MW-25	Chromium, total	01/16/2008	25.9	ug/l		2	50	
MW-25	Copper	01/16/2008	35.5	ug/l		0.6	1000	
MW-25	**Lead, total**	**01/16/2008**	**16.3**	**ug/l**		**2**	**15**	**1.3**
MW-25	Vanadium	01/16/2008	28.7	ug/l		1	3.5*	
MW-25	Zinc	01/16/2008	37.7	ug/l		1	1050	
MW-3	**1,4-Dichlorobenzene**	**01/16/2008**	**1.6**	**ug/l**		**0.15**	**1.4**	**0.2**
MW-3	Chlorobenzene	01/16/2008	7	ug/l		0.16	50	
MW-4R	Cadmium, total	01/16/2008	1	ug/l		0.5	1.75	
MW-4R	Cobalt, total	01/16/2008	22	ug/l		2	70*	
MW-5R	Arsenic	01/16/2008	14.4	ug/l		2	50	
MW-5R	Cobalt, total	01/16/2008	62.2	ug/l		2	70*	
MW-5R	Copper	01/16/2008	62.4	ug/l		0.6	1000	
MW-5R	Lead, total	01/16/2008	12.6	ug/l		2	15	
MW-5R	Zinc	01/16/2008	34.4	ug/l		1	1050	
MW-6	Trichlorofluoromethane	01/16/2008	7.3	ug/l		0.16	2100	
MW-6	Zinc	01/16/2008	4.6	ug/l		1	1050	
MW-7	**Benzene**	**01/16/2008**	**2.4**	**ug/l**		**0.12**	**1**	**1.4**
MW-7	Cadmium, total	01/16/2008	1	ug/l		0.5	1.75	
MW-7	Chlorobenzene	01/16/2008	4	ug/l		0.16	50	
MW-8D	Zinc	01/16/2008	15.7	ug/l		1	1050	
MW-9	Zinc	01/16/2008	11	ug/l		1	1050	
SHOP	1,1-Dichloroethane	01/16/2008	6.7	ug/l		0.09	70	

Table 6: Summary of Current Groundwater Results

Well ID	Parameter Name [1]	Sample Date	Result	Unit	Qual Code	PQL [2]	NCGW2L [3]	Exceedance
SHOP	cis-1,2-Dichloroethene	01/16/2008	6.4	ug/l		0.14	70	
SHOP	Copper	01/16/2008	22.7	ug/l		0.6	1000	
SHOP	**Tetrachloroethylene**	**01/16/2008**	**8.6**	**ug/l**		**0.25**	**0.7**	**7.9**
SHOP	**Trichloroethylene**	**01/16/2008**	**6**	**ug/l**		**0.23**	**2.8**	**3.2**
SHOP	**Vinyl chloride**	**01/16/2008**	**1.4**	**ug/l**		**0.15**	**0.015**	**1.385**
SHOP	Zinc	01/16/2008	22.3	ug/l		1	1050	
EB	Acetone	01/15/2008	14	ug/l	J	0.9	700	
FB	Acetone	01/15/2008	13	ug/l	J	0.9	700	
MW-1	Acetone	01/16/2008	4.6	ug/l	J	0.9	700	
MW-1	Antimony, total	01/16/2008	1.5	ug/l	J	0.68	1.4*	
MW-1	Arsenic	01/16/2008	6.2	ug/l	J	2	50	
MW-1	Thallium	01/16/2008	0.097	ug/l	J	0.036	0.28*	
MW-1	Vanadium	01/16/2008	13.3	ug/l	J	1	3.5*	
MW-10	Barium, total	01/16/2008	69.4	ug/l	J	0.2	2000	
MW-10	Cobalt, total	01/16/2008	3.5	ug/l	J	2	70*	
MW-10	Copper	01/16/2008	1.7	ug/l	J	0.6	1000	
MW-10	Nickel, total	01/16/2008	13	ug/l	J	2	100	
MW-10	Silver, total	01/16/2008	2	ug/l	J	2	18	
MW-11	Arsenic	01/16/2008	2.2	ug/l	J	2	50	
MW-11	Barium, total	01/16/2008	32.6	ug/l	J	0.2	2000	
MW-11	Chloroethane	01/16/2008	4	ug/l	J	0.4	2800	
MW-11	cis-1,2-Dichloroethene	01/16/2008	3	ug/l	J	0.14	70	
MW-11	Cobalt, total	01/16/2008	8.9	ug/l	J	2	70*	
MW-11	Copper	01/16/2008	2	ug/l	J	0.6	1000	
MW-11	Nickel, total	01/16/2008	47.7	ug/l	J	2	100	
MW-11	Zinc	01/16/2008	3.4	ug/l	J	1	1050	
MW-12	Acetone	01/16/2008	19	ug/l	J	0.9	700	
MW-12	Chromium, total	01/16/2008	7.8	ug/l	J	2	50	
MW-12	Thallium	01/16/2008	0.099	ug/l	J	0.036	0.28*	
MW-2	Barium, total	01/16/2008	45.4	ug/l	J	0.2	2000	
MW-2	Cadmium, total	01/16/2008	0.8	ug/l	J	0.5	1.75	
MW-2	Thallium	01/16/2008	0.043	ug/l	J	0.036	0.28*	
MW-24	Barium, total	01/16/2008	18.5	ug/l	J	0.2	2000	
MW-24	Nickel, total	01/16/2008	11	ug/l	J	2	100	
MW-24	Thallium	01/16/2008	0.049	ug/l	J	0.036	0.28*	
MW-24	Vanadium	01/16/2008	15.9	ug/l	J	1	3.5*	
MW-25	Arsenic	01/16/2008	7.6	ug/l	J	2	50	
MW-25	Barium, total	01/16/2008	33.8	ug/l	J	0.2	2000	
MW-25	Cobalt, total	01/16/2008	9.5	ug/l	J	2	70*	
MW-25	Nickel, total	01/16/2008	22	ug/l	J	2	100	
MW-25	Thallium	01/16/2008	0.07	ug/l	J	0.036	0.28*	
MW-3	1,1-Dichloroethane	01/16/2008	3.3	ug/l	J	0.09	70	
MW-3	Arsenic	01/16/2008	5.4	ug/l	J	2	50	
MW-3	Barium, total	01/16/2008	15.4	ug/l	J	0.2	2000	
MW-3	cis-1,2-Dichloroethene	01/16/2008	1.1	ug/l	J	0.14	70	
MW-3	Cobalt, total	01/16/2008	6.6	ug/l	J	2	70*	
MW-3	Copper	01/16/2008	1.3	ug/l	J	0.6	1000	
MW-3	Nickel, total	01/16/2008	2.5	ug/l	J	2	100	
MW-3	**Tetrachloroethylene**	**01/16/2008**	**0.71**	**ug/l**	**J**	**0.25**	**0.7**	**0.01**
MW-3	Trichloroethylene	01/16/2008	0.82	ug/l	J	0.23	2.8	

Table 6: Summary of Current Groundwater Results

Well ID	Parameter Name [1]	Sample Date	Result	Unit	Qual Code	PQL [2]	NCGW2L [3]	Exceedance
MW-4R	1,1-Dichloroethane	01/16/2008	1.1	ug/l	J	0.09	70	
MW-4R	Antimony, total	01/16/2008	0.89	ug/l	J	0.68	1.4*	
MW-4R	Arsenic	01/16/2008	3.7	ug/l	J	2	50	
MW-4R	Barium, total	01/16/2008	4.2	ug/l	J	0.2	2000	
MW-4R	Chlorobenzene	01/16/2008	0.42	ug/l	J	0.16	50	
MW-4R	cis-1,2-Dichloroethene	01/16/2008	0.43	ug/l	J	0.14	70	
MW-4R	Copper	01/16/2008	8.6	ug/l	J	0.6	1000	
MW-4R	Nickel, total	01/16/2008	16.9	ug/l	J	2	100	
MW-4R	Zinc	01/16/2008	8.9	ug/l	J	1	1050	
MW-5R	Barium, total	01/16/2008	34.1	ug/l	J	0.2	2000	
MW-5R	Chromium, total	01/16/2008	5.2	ug/l	J	2	50	
MW-5R	Nickel, total	01/16/2008	13.6	ug/l	J	2	100	
MW-5R	Vanadium	01/16/2008	5.5	ug/l	J	1	3.5*	
MW-6	1,1-Dichloroethane	01/16/2008	2	ug/l	J	0.09	70	
MW-6	Barium, total	01/16/2008	3.8	ug/l	J	0.2	2000	
MW-6	Copper	01/16/2008	3	ug/l	J	0.6	1000	
MW-6	Methylene chloride	01/16/2008	0.67	ug/l	J	0.088	4.6	
MW-6	Nickel, total	01/16/2008	2.7	ug/l	J	2	100	
MW-6	Selenium	01/16/2008	2.8	ug/l	J	2	50	
MW-6	**Tetrachloroethylene**	**01/16/2008**	**0.92**	**ug/l**	**J**	**0.25**	**0.7**	**0.22**
MW-7	1,1-Dichloroethane	01/16/2008	3.9	ug/l	J	0.09	70	
MW-7	Arsenic	01/16/2008	8.7	ug/l	J	2	50	
MW-7	Barium, total	01/16/2008	16.2	ug/l	J	0.2	2000	
MW-7	cis-1,2-Dichloroethene	01/16/2008	1.8	ug/l	J	0.14	70	
MW-7	Cobalt, total	01/16/2008	3.3	ug/l	J	2	70*	
MW-7	Copper	01/16/2008	4.7	ug/l	J	0.6	1000	
MW-7	Methylene chloride	01/16/2008	0.42	ug/l	J	0.088	4.6	
MW-7	Nickel, total	01/16/2008	4.7	ug/l	J	2	100	
MW-7	Tetrachloroethylene	01/16/2008	0.47	ug/l	J	0.25	0.7	
MW-7	Trichlorofluoromethane	01/16/2008	0.51	ug/l	J	0.16	2100	
MW-7	Zinc	01/16/2008	7.1	ug/l	J	1	1050	
MW-8D	Antimony, total	01/16/2008	1.17	ug/l	J	0.68	1.4*	
MW-8D	Arsenic	01/16/2008	2	ug/l	J	2	50	
MW-8D	Barium, total	01/16/2008	24.2	ug/l	J	0.2	2000	
MW-8D	Cobalt, total	01/16/2008	4.8	ug/l	J	2	70*	
MW-8D	Copper	01/16/2008	4.5	ug/l	J	0.6	1000	
MW-8D	Nickel, total	01/16/2008	4.9	ug/l	J	2	100	
MW-8D	Thallium	01/16/2008	0.037	ug/l	J	0.036	0.28*	
MW-9	Arsenic	01/16/2008	3.1	ug/l	J	2	50	
MW-9	Barium, total	01/16/2008	12	ug/l	J	0.2	2000	
MW-9	Chromium, total	01/16/2008	6.5	ug/l	J	2	50	
MW-9	Copper	01/16/2008	5.2	ug/l	J	0.6	1000	
MW-9	Nickel, total	01/16/2008	5.9	ug/l	J	2	100	
MW-9	Tetrachloroethylene	01/16/2008	0.42	ug/l	J	0.25	0.7	
MW-9	Vanadium	01/16/2008	7.3	ug/l	J	1	3.5*	
SHOP	1,1-dichloroEthene	01/16/2008	0.89	ug/l	J	0.14	7	
SHOP	Arsenic	01/16/2008	5.7	ug/l	J	2	50	
SHOP	Barium, total	01/16/2008	1.4	ug/l	J	0.2	2000	
SHOP	Cobalt, total	01/16/2008	3	ug/l	J	2	70*	
SHOP	Methylene chloride	01/16/2008	0.87	ug/l	J	0.088	4.6	

Table 6: Summary of Current Groundwater Results

Well ID	Parameter Name [1]	Sample Date	Result	Unit	Qual Code	PQL [2]	NCGW2L [3]	Exceedance
SHOP	Nickel, total	01/16/2008	2.9	ug/l	J	2	100	
SHOP	trans-1,2-Dichloroethene	01/16/2008	0.4	ug/l	J	0.1	100	
SHOP	Vanadium	01/16/2008	1.4	ug/l	J	1	3.5*	

[1] Table only contains detected constituents.

[2] PQL = Practical Quantitation Limit

[3] NCGW2L = North Carolina Ground Water 2L Standard

* Groundwater Protection Standard

Table 7: Summary of Current Surface Water Results

Well ID	Parameter Name [1]	Sample Date	Result	Unit	PQL [2]	NCAC 2B STD[3]	Exceedance
SW-1	Barium, total	07/17/2007	16.8	ug/l	0.2	1,000	
SW-1	Zinc	07/17/2007	1	ug/l	1	50	
SW-2	Barium, total	07/17/2007	10.7	ug/l	0.2	1,000	
SW-2	Zinc	07/17/2007	1	ug/l	1	50	
SW-6	Barium, total	07/17/2007	16	ug/l	0.2	1,000	
SW-6	Zinc	07/17/2007	1	ug/l	1	50	

[1] Table only contains detected constituents.

[2] PQL = Practical Quantitation Limit

[3] NCAC 2B STD = North Carolina Surface Water Standard Class C or Class IV as applicable

Table 8A: Carcinogenic Toxicity Values for Oral Ingestion

Contaminant	Well	Reference Dose	Maximum Concentration (ug/L)	LADD Maximum		Concentration July 2007 (ug/L)	LADD July 2007		HI Risk Maximum		Hi Risk July 2007	
		Oral Sfo (ug/kg-day)		Adult (ug/kg-day)	Child (ug/kg-day)		Adult (ug/kg-day)	Child (ug/kg-day)	Adult	Child	Adult	Child
Benzene	MW-7	55	2.70	0.03	0.01	2.70	0.03	0.01	6.01E-04	1.99E-04	6.01E-04	1.99E-04
	MW-10	55	5.50	0.07	0.02	-	-	-	1.22E-03	4.05E-04	-	-

NOTE:
1. LADD is lifetime average daily dose from ingested groundwater at the specified concentration.
2. Sfo values taken from the Region 9 Risk Based Concentration Table. These values represent a cancer slope factor.
3. During July 2007 sampling "-" designates none of this constituent was detected.
4. Formula used for calculations:

LADD = (C*IR*ED)/(BW*AT)

C = constituent concentration (ug/L)

IR = Ingestion Rate (L/day)	An ingestion rate of 2L/day was used for adults 1L/day for children
ED = Exposure Duration (days)	An exposure duration of 30 years was used for adults, 8 for children
BW = Body weight (kg)	An average weight of 70 kg was used for adults, 28.2 kg for children
AT = Average Time (days)	A time of 70 years for adults and children was used

Table 8B: Carcinogenic Toxicity Values for Inhalation Exposure

Contaminant	Well	Reference Dose	Maximum Concentration	LADD Maximum		Concentration July 2007	LADD July 2007		HI Risk Maximum		HI Risk July 2007	
		Inhalation Sfi (ug/kg-day)	(ug/m^3)	Adult (ug/kg-day)	Child (ug/kg-day)	(ug/m^3)	Adult (ug/kg-day)	Child (ug/kg-day)	Adult	Child	Adult	Child
Benzene	MW-7	27	2.70	0.17	0.07	2.70	0.17	0.07	6.12E-03	2.43E-03	6.12E-03	2.43E-03
	MW-10	27	5.50	0.34	0.13	-	-	-	0.01	0.00	-	-

NOTE:
1. LADD is lifetime average daily dose inhaled at the specified concentration.
2. Sfi values taken from the Region 9 Risk Based Concentration Table. These values represent a cancer slope factor.
3. During July 2007 sampling "-" designates none of this constituent was detected.
4. HI is the Hazzard Index Risk = LADD/RfD
5. Formula used for calculations:

LADD = (C*IR*ED*K)/(BW*AT)

C = constituent concentration (ug/m^3)

K = Volatilization factor (L/m^3)	A Volatilization factor of 0.5 L/m^3 was used based on EPA published values
IR = Inhalation Rate (m^3/day)	An inhalation rate of 20 m^3/day was used for adults and 12m^3/day for children
ED = Exposure Duration (days)	An exposure duration of 30 years was used for adults, 8 for children
BW = Body weight (kg)	An average weight of 70 kg was used for adults, 28.2 kg for children
AT = Average Time (days)	A times of 70 years for adults and children was used

Table 8C: Carcinogenic Toxicity Values from Dermal Exposure

Contaminant	Well	Reference Dose	Maximum Concentration (ug/L)	LADD Maximum		Concentration 2007 (ug/L)	LADD 2007		HI Risk Maximum		HI Risk 1/25/2007	
		Oral Sfo (ug/kg-day)		Adult (ug/kg-day)	Child (ug/kg-day)		Adult (ug/kg-day)	Child (ug/kg-day)	Adult	Child	Adult	Child
Benzene	MW-7	55	2.70	1.73E-04	5.37E-05	2.70	1.73E-04	5.37E-05	3.15E-06	9.76E-07	3.15E-06	9.76E-07
	MW-10	55	5.50	3.53E-04	1.09E-04	-	-	-	6.42E-06	1.99E-06	-	-

NOTE:
1. LADD is lifetime average daily dose from dermal contact with contaminated groundwater at the specified concentration.
2. Sfo values taken from the Region 9 Risk Based Concentration Table. These values represent a cancer slope factor.
3. During July2007 sampling "-" designates none of this constituent was detected.
4. Dermal Values used the same RfD values as those used for Oral.
5. HI is the Hazard Index Risk = LADD/RfD
6. Formula used for calculations:

LADD = (C*K*EV*ED*EF*SA)/(BW*AT)

C = constituent concentration (ug/L)	
K = permeability coefficient (cm/day)	contaminant dependent
EV = event frequency	15 min/day
ED = Exposure Duration (years)	30 years for an adult, 8 years for a child
EF = Exposure Frequency (days/year)	365 days per year
SA = skin surface area (cm^2)	20,000cm^2 for adults and 9360 cm^2 for children
BW = Body weight (kg)	70 kg was used for adults, 28.2 kg for children
AT = Average Time (days)	70 years for adults and children

Table 8D: Non-Carcinogenic Toxicity Values for Oral Ingestion

Contaminant	Well	Reference Dose	Maximum Concentration (ug/L)	LADD Maximum		Concentration July 2007 (ug/L)	LADD July 2007		HI Risk Maximum		Hi Risk July 2007	
		Oral RfD (ug/kg-day)		Adult (ug/kg-day)	Child (ug/kg-day)		Adult (ug/kg-day)	Child (ug/kg-day)	Adult	Child	Adult	Child
Chlorobenzene	MW-2	20	0.42	0.01	0.01	-	-	-	6.00E-04	7.45E-04	-	-
	MW-3	20	7.80	0.22	0.28	-	-	-	1.11E-02	1.38E-02	-	-
	MW-7	20	2.10	0.06	0.07	-	-	-	3.00E-03	3.72E-03	-	-
	MW-10	20	11.00	0.31	0.39	-	-	-	1.57E-02	1.95E-02	-	-
cis-1,2-dichloroethylene	MW-3	10	0.63	0.02	0.02	-	-	-	1.80E-03	2.23E-03	-	-
	MW-7	10	1.30	0.04	0.05	-	-	-	3.71E-03	4.61E-03	-	-
	MW-9	10	1.30	0.04	0.05	-	-	-	3.71E-03	4.61E-03	-	-
Trichlorofluoromethane	MW-6	300	26.10	0.75	0.93	9.20	0.26	0.33	2.49E-03	3.09E-03	8.76E-04	1.09E-03
	MW-7	300	1.10	0.03	0.04	1.10	0.03	0.04	1.05E-04	1.30E-04	1.05E-04	1.30E-04
Benzene	MW-7	4	2.70	0.08	0.10	2.70	0.08	0.10	0.02	0.02	0.02	0.02
	MW-10	4	5.50	0.16	0.20	-	-	-	0.04	0.05	-	-
Methylene Chloride	MW-1	60	5.30	0.15	0.19	-	-	-	2.52E-03	3.13E-03	-	-
	MW-3	60	11.00	0.31	0.39	-	-	-	0.01	0.01	-	-
	MW-6	60	13.10	0.37	0.46	8.70	0.25	0.31	0.01	0.01	4.14E-03	0.01
	MW-7	60	8.10	0.23	0.29	-	-	-	3.86E-03	4.79E-03	-	-
Tetrachloroethene	MW-3	10	0.43	0.01	0.02	-	-	-	1.23E-03	1.52E-03	-	-
	MW-7	10	0.60	0.02	0.02	-	-	-	1.71E-03	2.13E-03	-	-
	MW-9	10	1.10	0.03	0.04	1.10	0.03	0.04	3.14E-03	3.90E-03	3.14E-03	3.90E-03
	SHOP	10	1.50	0.04	0.05	1.50	0.04	0.05	4.29E-03	0.01	4.29E-03	0.01

NOTE:
1. LADD is lifetime average daily dose from ingested groundwater at the specified concentration.
2. RfD values taken from the Region 9 Risk Based Concentration Table. These values represent a daily exposure level that is not harmful to human health, over a lifetime.
3. During July 2007 sampling "-" designates none of this constituent was detected.
4. Formula used for calculations:

LADD = (C*IR*ED)/(BW*AT)

C = constituent concentration (ug/L)

IR = Ingestion Rate (L/day)	An ingestion rate of 2L/day was used for adults 1L/day for children
ED = Exposure Duration (days)	An exposure duration of 30 years was used for adults, 8 for children
BW = Body weight (kg)	An average weight of 70 kg was used for adults, 28.2 kg for children
AT = Average Time (days)	Times of 30 years for adults and 8 for children were used

Table 8E: Non-Carcinogenic Toxicity Values for Inhalation Exposure

Contaminant	Well	Reference Dose Inhalation RfD (ug/kg-day)	Maximum Concentration (ug/L)	LADD Maximum Adult (ug/kg-day)	LADD Maximum Child (ug/kg-day)	Concentration July 2007 (ug/L)	LADD July 2007 Adult (ug/kg-day)	LADD July 2007 Child (ug/kg-day)	HI Risk Maximum Adult	HI Risk Maximum Child	HI Risk July 2007 Adult	HI Risk July 2007 Child
Chlorobenzene	MW-2	17	0.42	0.06	0.09	-	-	-	3.53E-03	0.01	-	-
	MW-3	17	7.80	1.11	1.66	-	-	-	0.07	0.10	-	-
	MW-7	17	2.10	0.30	0.45	-	-	-	0.02	0.03	-	-
	MW-10	17	11.00	1.57	2.34	-	-	-	0.09	0.14	-	-
cis-1,2-dichloroethylene	MW-3	10	0.63	0.09	0.13	-	-	-	0.01	0.01	-	-
	MW-7	10	1.30	0.19	0.28	-	-	-	0.02	0.03	-	-
	MW-9	10	1.30	0.19	0.28	-	-	-	0.02	0.03	-	-
Trichlorofluoromethane	MW-6	200	26.10	3.73	5.55	9.20	1.31	1.96	0.02	0.03	6.57E-03	9.79E-03
	MW-7	200	1.10	0.16	0.23	1.10	0.16	0.23	7.86E-04	1.17E-03	7.86E-04	1.17E-03
Benzene	MW-7	8.6	2.70	0.39	0.57	2.70	0.39	0.57	0.04	0.07	0.04	0.07
	MW-10	8.6	5.50	0.79	1.17	-	-	-	0.09	0.14	-	-
Methylene Chloride	MW-1	860	5.30	0.76	1.13	-	-	-	8.80E-04	1.31E-03	-	-
	MW-3	860	11.00	1.57	2.34	-	-	-	1.83E-03	2.72E-03	-	-
	MW-6	860	13.10	1.87	2.79	8.70	1.24	1.85	2.18E-03	3.24E-03	1.45E-03	2.15E-03
	MW-7	860	8.10	1.16	1.72	-	-	-	1.35E-03	2.00E-03	-	-
Tetrachloroethene	MW-3	10	0.43	0.06	0.09	-	-	-	0.01	0.01	-	-
	MW-7	10	0.60	0.09	0.13	-	-	-	0.01	0.01	-	-
	MW-9	10	1.10	0.16	0.23	1.10	0.16	0.23	0.02	0.02	0.02	0.02
	SHOP	10	1.50	0.21	0.32	1.50	0.21	0.32	0.02	0.03	0.02	0.03

NOTE:
1. LADD is lifetime average daily dose inhaled at the specified concentration.
2. RfD values taken from the Region 9 Risk Based Concentration Table. These values represent a daily exposure level that is not harmful to human health, over a lifetime.
3. During July 2007 sampling "-" designates none of this constituent was detected.
4. HI is the Hazzard Index Risk = LADD/RfD
5. Formula used for calculations:

LADD = (C*IR*ED*K)/(BW*AT)

C = constituent concentration (ug/L)

K = Volatilization factor (L/m^3)	A Volatilization factor of 0.5 L/m^3 was used based on EPA published values
IR = Inhalation Rate (m^3/day)	An inhalation rate of 20 m^3/day was used for adults and 12m^3/day for children
ED = Exposure Duration (days)	An exposure duration of 30 years was used for adults, 8 for children
BW = Body weight (kg)	An average weight of 70 kg was used for adults, 28.2 kg for children
AT = Average Time (days)	Times of 30 years for adults and 8 for children were used

Table 9: Timeline / Schedule of Corrective Action

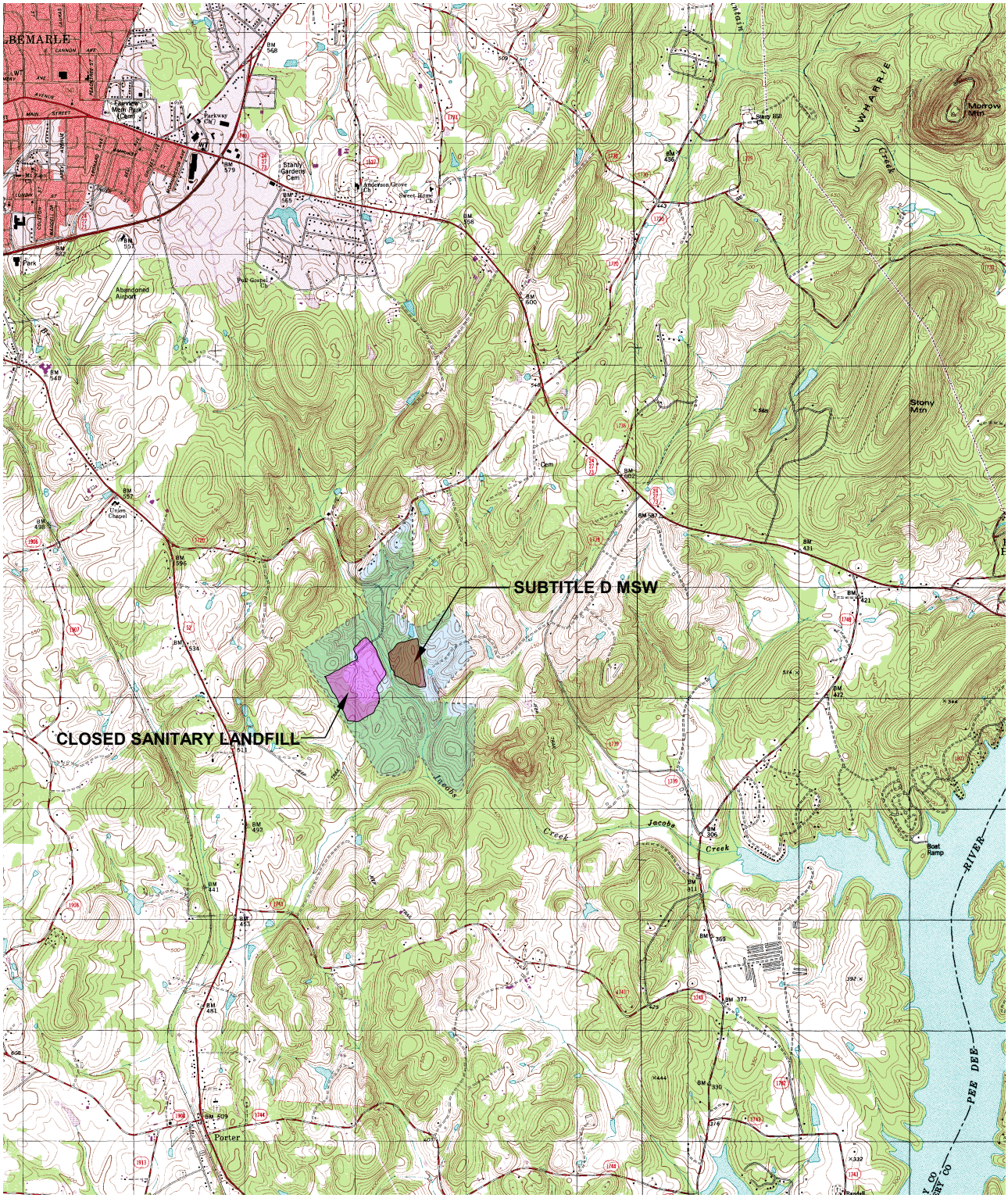
Date after CAP Approval	Description of Event
March - April 2009	Preparation and submittal of HRC injection permits. Scheduling of HRC injection events and tree thinning for phytoremediation.
May 2009	Begin tree thinning for phytoremediation & hybrid willow planting.
July 2009	Semi-Annual Assessment Sampling & Monitoring w/ implementation of full suite of MNA performance parameters. HRC injection event. Planting of hybrid willow trees. Begin daily logging of water levels in MW-2, MW-6, MW-7, MW-24, & MW-25 using transducer probes.
August 2009	Submit HRC Injection Event Report (~30 days after injection)
January 2010	Semi-Annual Assessment Sampling & Monitoring.
July 2010	Semi-Annual Assessment Sampling & Monitoring. HRC injection event.
August 2010	Submit HRC Injection Event Report (~30 days after injection)
December 2010	Semi-Annual Assessment Sampling & Monitoring.
March 2011	Initial Summary Report.
July 2011	Semi-Annual Assessment Sampling & Monitoring. Evaluation of effectiveness for MNA with HRC Injection.
August 2011	Cease HRC injection if Evaluation of Effectiveness indicates and if SWS agrees.
January 2011	Semi-Annual Assessment Sampling & Monitoring.
January 2012 to January 2015	Semi-Annual Assessment Sampling & Monitoring; reduction of MNA analytical requirements as determined through Evaluation of Effectiveness Report and SWS approval.
March 2015	Phytoremediation Evaluation of Effectiveness Report
April 2015	Cease phytoremediation activities if Evaluation of Effectiveness indicates and if SWS agrees.

PLATES

Topographic Map with Landfill Location

City of Albemarle Landfill

PLATE 1



QUADRANGLE LEGEND

ROAD CLASSIFICATION

Primary highway, hard surface

Light-duty road, hard or improved surface

Secondary highway, hard surface

Unimproved road

Interstate Route

U. S. Route

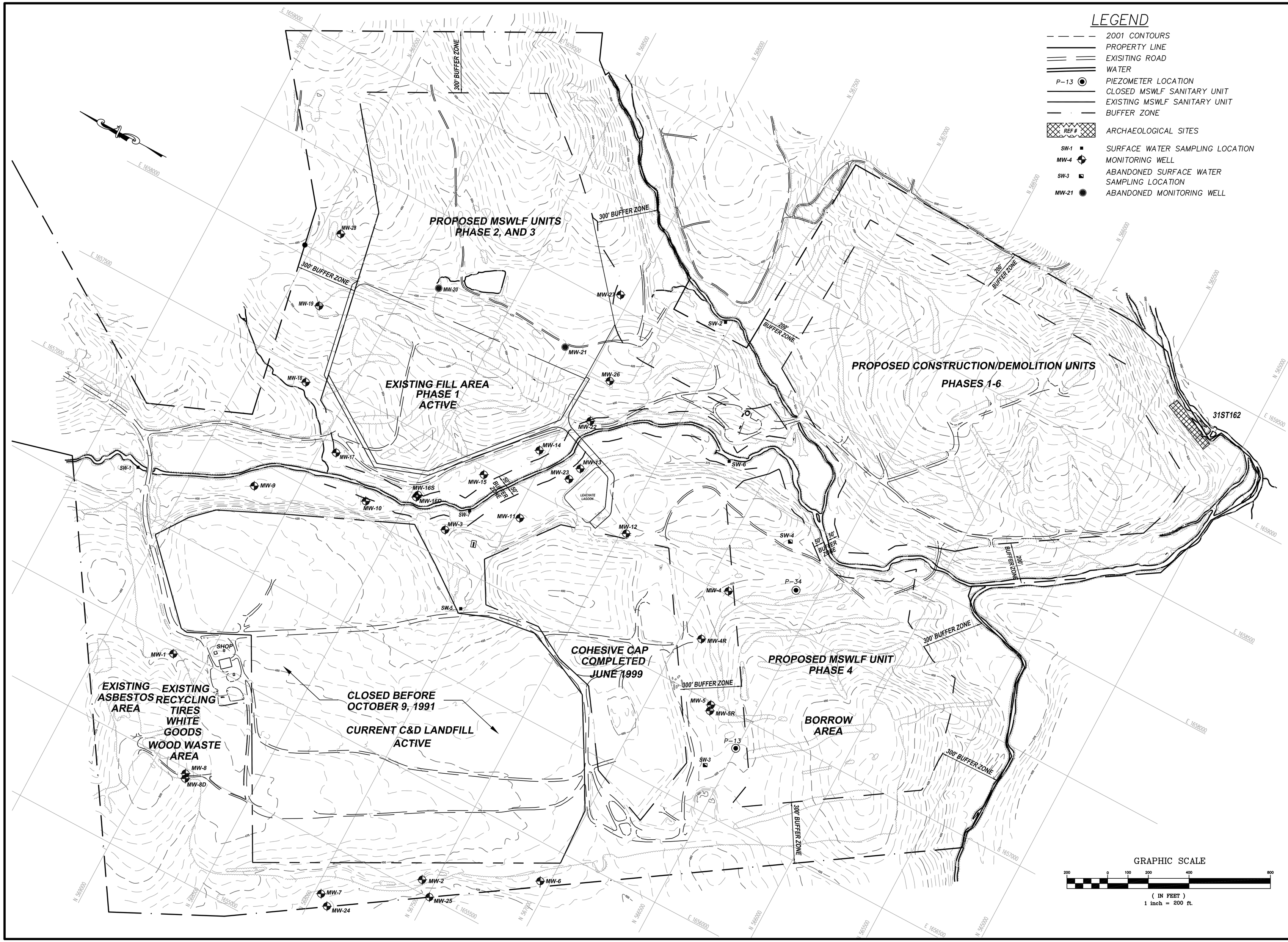
State Route

NOTE: Topographical map assembled from corresponding USGS 7.5-min. quadrangles of the subject region.

Date Completed	06/24/2008
Created By	M. German
Project Name	Corrective Action Plan
Site Name	City of Albemarle Landfill
Project Number	G07059.0

Municipal Engineering Services Company, PA

1 0 1 MILE



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CLOSED MSWLF AND ACTIVE C&D LANDFILL FACILITY
CITY OF ALBEMARLE NORTH CAROLINA

DATE	BY	REV.	DESCRIPTION

SITE MAP W/ SAMPLING LOCATIONS

SCALE:	1"=200'
DATE:	6/30/2008
DRWN. BY:	E. CALDWELL
CHKD. BY:	S. PATRICK
PROJECT NUMBER	G07059.0
DRAWING NO.	PLATE 2
SHEET NO.	1 of 1

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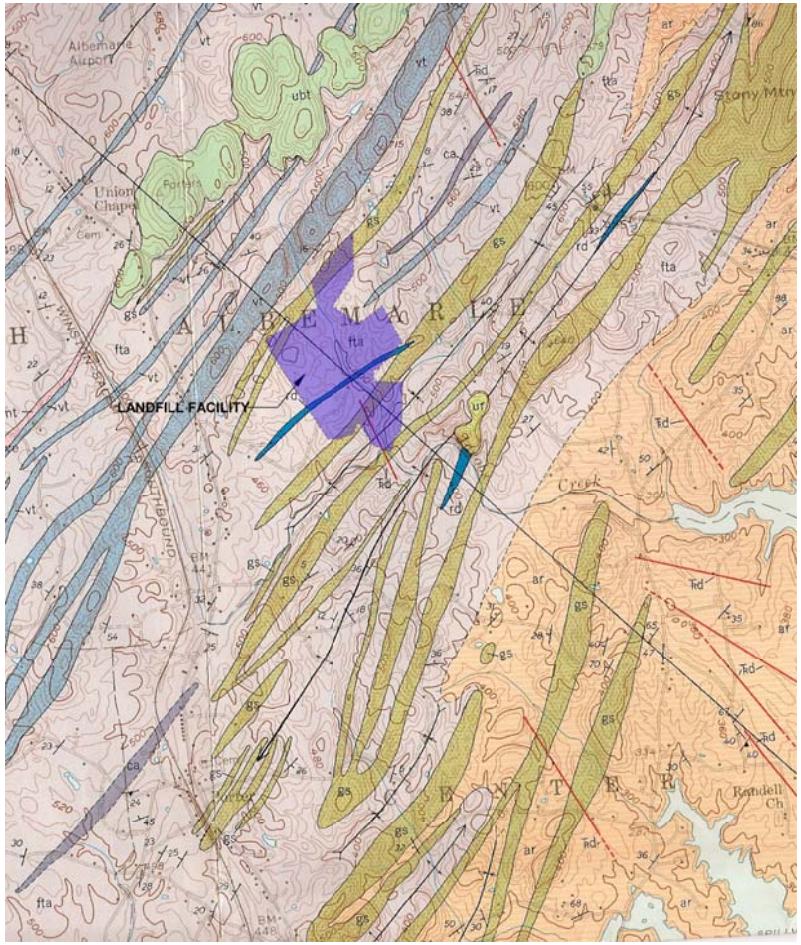
Geologic Map

Assessment of Corrective Measures - City of Albemarle Landfill



FORMATION DESCRIPTION

UPPER VOLCANIC SEQUENCE: The Upper Volcanic sequence is approximately 450' thick comprised of andesitic tuff, basaltic tuff, and rhyolite (from base to top) and unconformibly lies on both the Lower Volcanic sequence and the Volcanic Sedimentary sequence.

ur: Rhyollite-Rhyollite and porphyritic rhyollite containing prominent flow banding with basal lithic tuff occasionally present. 200' thick and appears to only cap the highest hills.

ubt: Basaltic Tuffs –Overlying unit to the argillite and the tuffaceous argillite approximately 200' thick. Very well jointed containing rare basaltic flows and lithic and lithic crystal tuffs exhibiting faint bedding. Chlorite, hornblende, feldspar, and pyroxene are present within the matrix and flow rock.

VOLCANIC SEDIMENTARY SEQUENCE: Composed of an argillite unit, a tuffaceous argillite unit and a greywacky unit, the entire sequence is thought to be 10,000 ' thick and Ordovician in age. Unconformibly overlain by the Upper Volcanic and conformibly overlays the Lower Volcanic.

TUFFACEOUS ARGILLITE UNIT: Separated from argillite unit by an arbitrary line based on predominance of thick bedded, water laid, fine grained tuffs over argillite exhibiting graded bedding. Variable thickness throughout the unit indicates volcanism's affect on sedimentation.

fta: Felsic Tuffaceous Argillite – Major rock of the Tuffaceous Argillite Unit, well sorted, coarsely bedded, with beds ranging from 6”-24” thick. Water laid volcanic ash with interspersed crystal fragments and relic glass shards.

ca: Felsic Crystal Tuff- Rounded crystal fragments in a matrix of felsic tuff.

vt : Vitric Tuff – Devitrified felsic tuff exhibiting flow banding, indicating a welded flow tuff. Very resistant to erosion, forming northeast trending hills, key horizons traceable over wide areas.

mt: Mafic Tuff – Lithic crystal tuffs of basaltic composition

ARGILLITE UNIT: Grades into the Tuffaceous Argillite unit, averaging 500' thick. Overlays the Lower Volcanic Sequence by a gradational boundary.

ar: Argillite – Exhibits fine graded bedding composed of alternating silt and clay layers, well developed plane cleavage, and contains lithic fragmented beds near base, indicating volcanism at the time of deposition.

INTRUSIVE ROCK

trd: Triassic Dikes - Diabase dikes composed predominantly of augite and calcic plagioclase, trending in the Northwest direction, ranging from 3'-10' thick, with narrow baked zones, not altering the country rock

rd: Rhyolite dikes- Porphyritic rhyolite composed predominantly of phenocrysts of orthoclase, oglioclase, and beta quartz in an aphanitic groundmass.

gs: Gabbro Sills - Northeastern trending, of variable grain size, and extent. The baked zones are comparable to sill size noticeable only when weathered. Composed of hornblende gabbro, sometimes amygdaloidal.

Taken From: Conley, J.F., Geologic Map of the Albemarle Quadrangle, NC, & Geology of the Albemarle Quadrangle, NC, 1962.

GEOLOGIC MAP LEGEND

10 — Strike and dip of bedding (inclined)

Formation boundary

40 — Strike and Dip of folliation

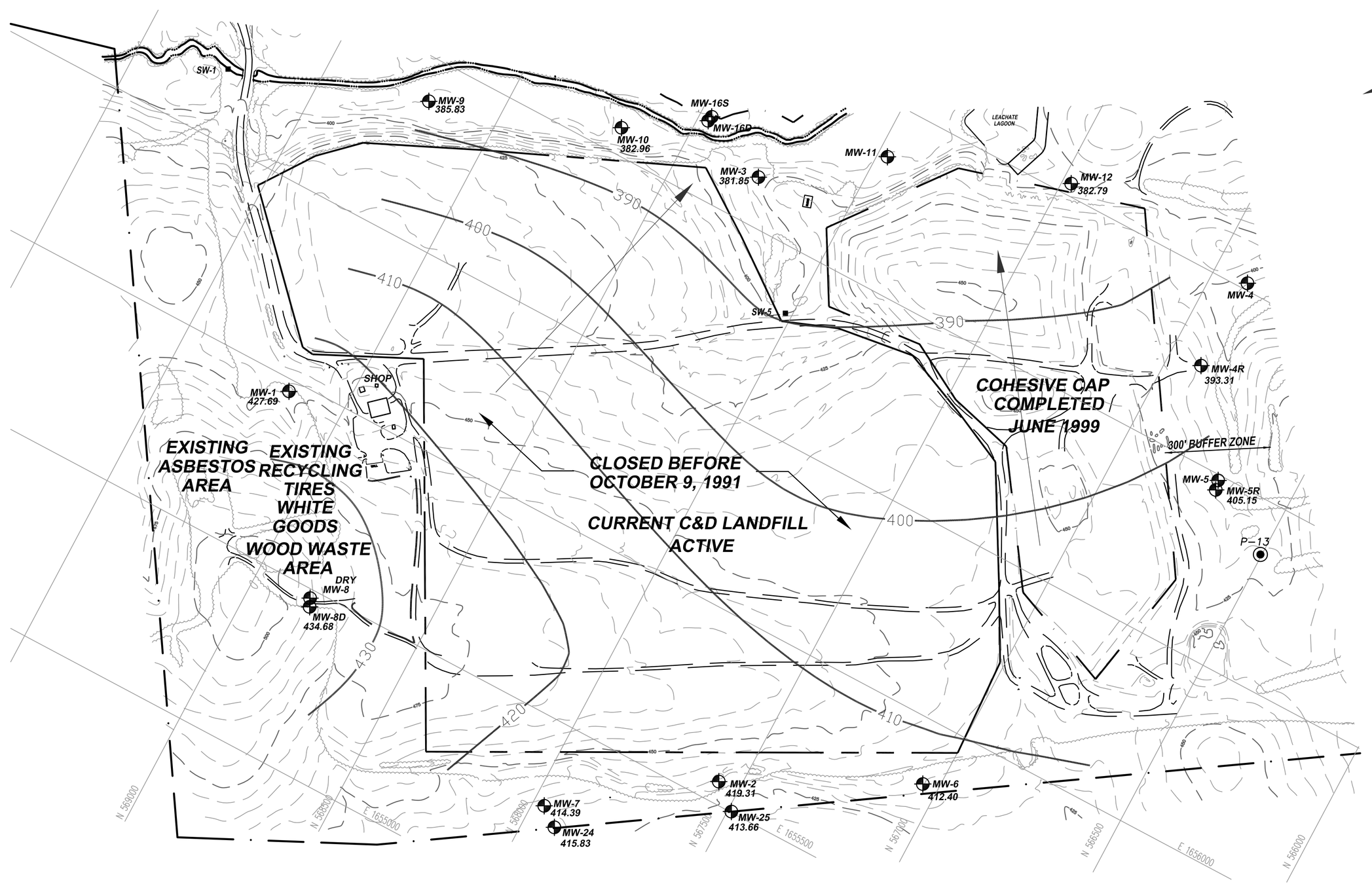
Syncline

Anticline

Date Completed	8/24/2006
Created By	M. Clement
Project Name	Assessment of Corrective Measures
Site Name	City of Albemarle Landfill
Project Number	G07059.0

Municipal Engineering Services Company, PA

PLATE 3



LEGEND

- 2001 CONTOURS
- PROPERTY LINE
- EXISITING ROAD
- WATER
- P-13 PIEZOMETER LOCATION
- CLOSED MSWLF SANITARY UNIT
- EXISTING MSWLF SANITARY UNIT
- BUFFER ZONE
- SW-1 SURFACE WATER SAMPLING LOCATION
- MW-5 MONITORING WELL
- 382.79 SINGLE DAY ELEVATION (1-16-2008)
- 400 SINGLE DAY CONTOUR
- GROUNDWATER FLOW DIRECTION

GROUNDWATER READINGS COLLECTED ON JANUARY 16, 2008

WELL	SINGLE DAY GROUNDWATER ELEVATION (FT AMSL)
MW-1	427.69
MW-2	419.31
MW-3	381.85
MW-4R	393.31
MW-5R	405.15
MW-6	412.40
MW-7	414.39
MW-8D	434.68
MW-9	385.86
MW-10	382.96
MW-12	382.79
MW-24	415.83
MW-25	413.66

GRAPHIC SCALE

200 0 100 200 400 800

(IN FEET)
1 inch = 200 ft.

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CLOSED MSWLF AND ACTIVE C&D LANDFILL FACILITY
CITY OF ALBEMARLE NORTH CAROLINA

DATE	BY	REV.	DESCRIPTION

SINGLE DAY POTENTIOMETRIC SURFACE MAP

SCALE: 1"=200'
DATE: 6/24/2008
DRWN. BY: M. GERMAN
CHKD. BY: S. PATRICK
PROJECT NUMBER G07059.0
DRAWING NO. PLATE 4
SHEET NO. 1 of 1

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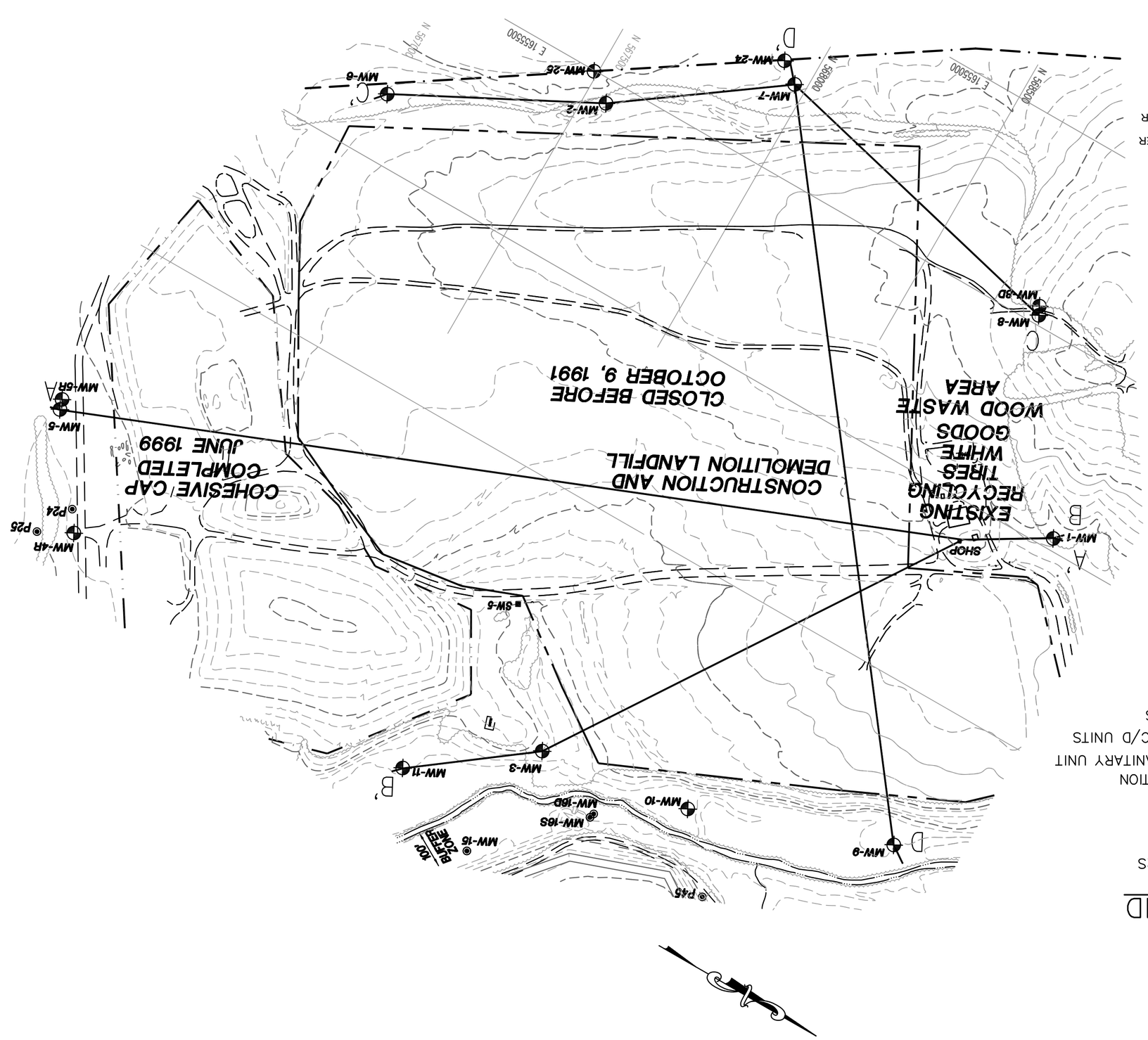
NOTE:
- NUMBERS SHOWN IN THIS PLATE ARE IN UNITS OF FEET UNLESS INDICATED OTHERWISE.
- SOIL PROFILES SHOWN HEREIN ARE INTERPOLATED FROM AVAILABLE BORING RECORDS.
- SOIL PROFILE BOUNDARIES DO NOT NECESSARILY INDICATE AN ABRUPT CHANGE IN SOIL TEXTURES.



MAP LEGEND

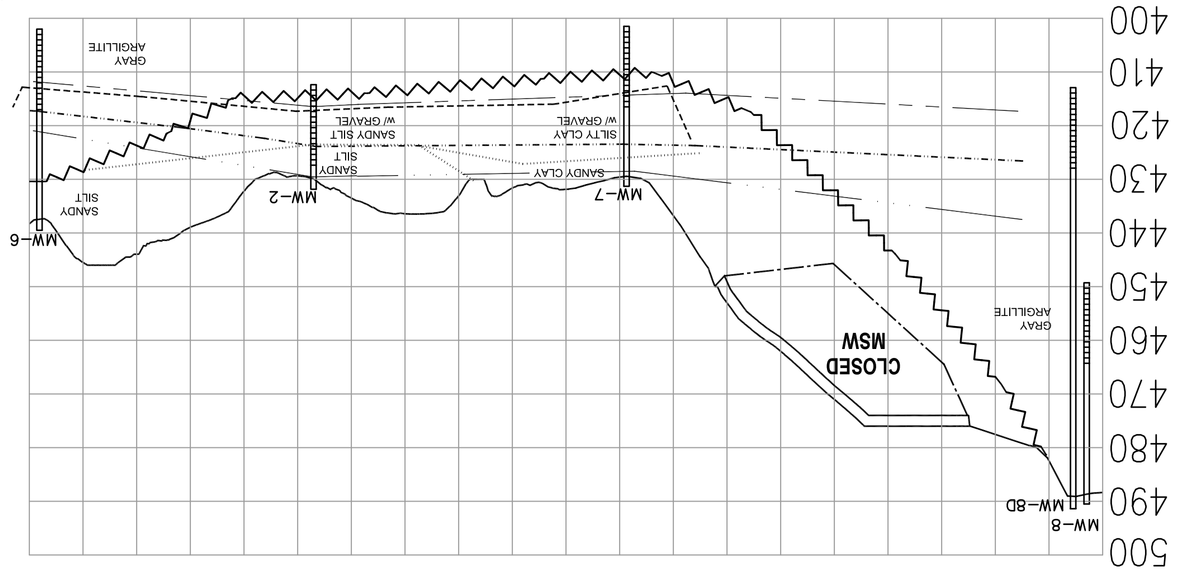
- EXISTING CONTOURS (400)
- PROPERTY LINE
- EXISTING ROAD
- WATER
- PIEZOMETER LOCATION (P13)
- CLOSED MSWLF SANITARY UNIT
- NEW MSWLF AND C/D UNITS
- MONITORING WELLS (MW-1)

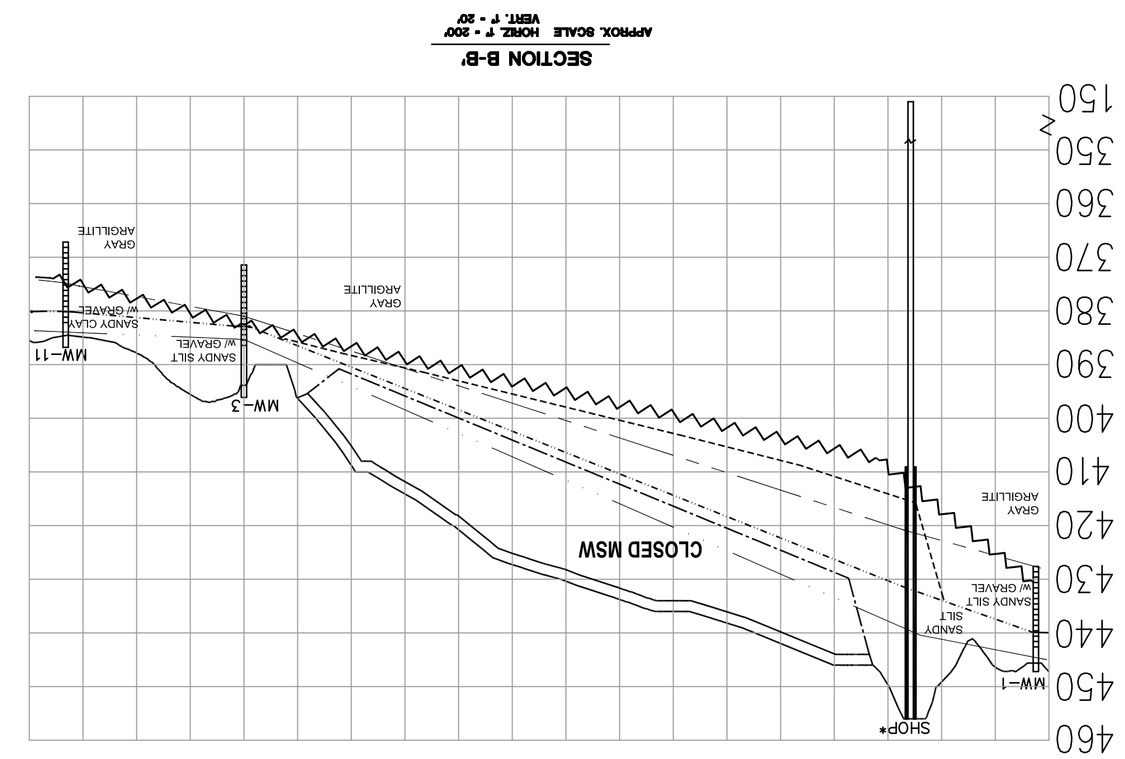
MW-1 MONITORING WELL

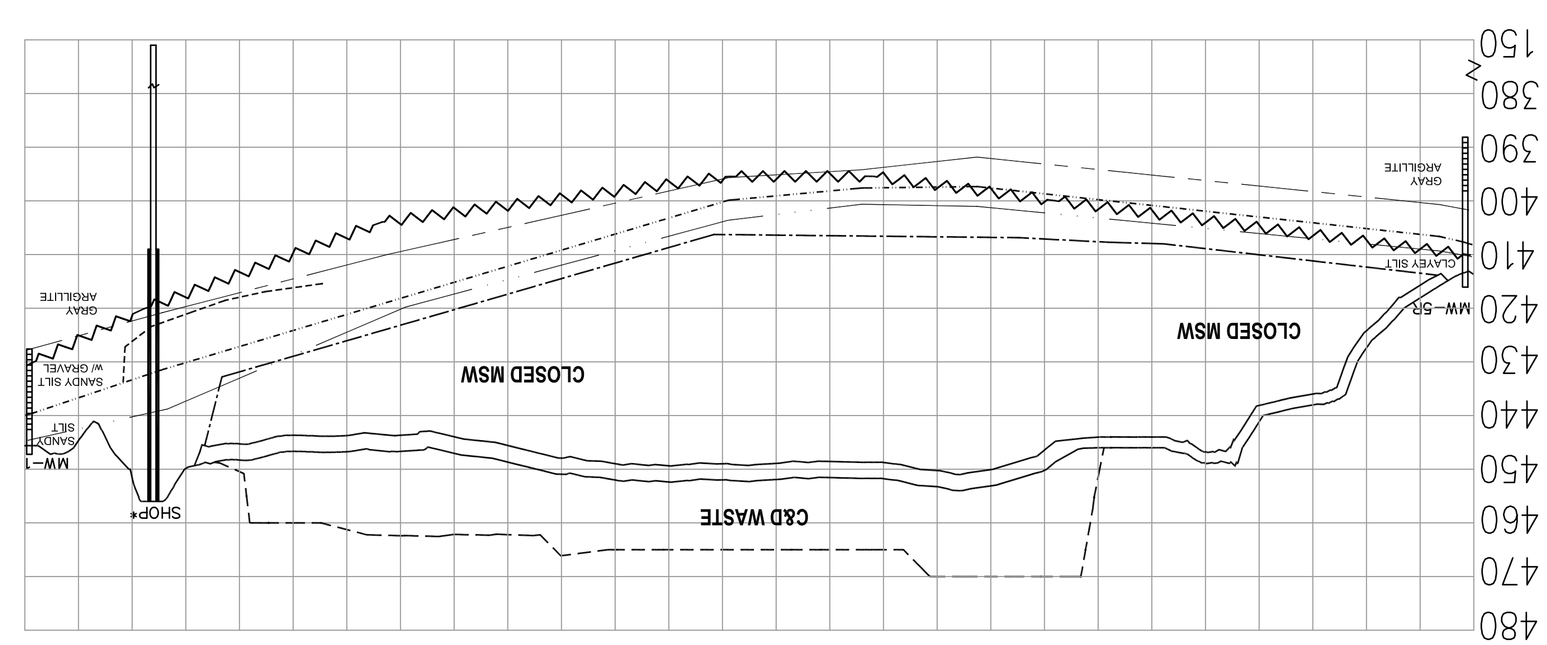
SCREENED SECTION

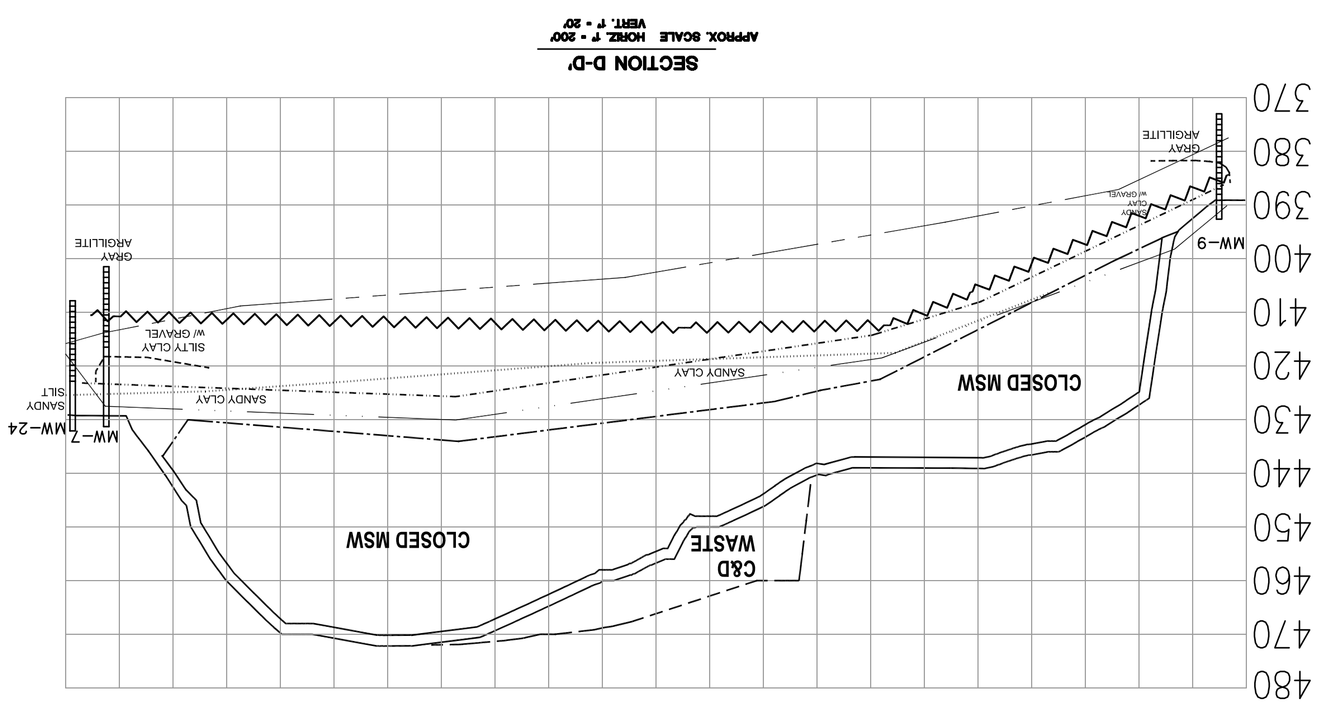
CROSS-SECTION LEGEND:
- NEW C&D WASTE
- TOP OF MSW WITH COVER
- ESTIMATED BASE OF MSW
- AVERAGE GROUNDWATER
- SEASONAL HIGH GROUNDWATER
- SEASONAL LOW GROUNDWATER
- ESTIMATED STRATIGRAPHIC CONTACT
- TOP OF COMPETENT ROCK
- ESTIMATED EXTENT OF VOC CONTAMINATION

* NOTE: SHOP WELL EXTENDS TO A TOTAL DEPTH OF 305'









CLOSED MSWLF AND ACTIVE C&D LANDFILL FACILITY
CITY OF ALBEMARLE
NORTH CAROLINA

REV.	DATE	BY	DESCRIPTION
1	7/22/2008	MMG	ADDED SEASONAL HIGH AND SEASONAL LOW

CROSS-SECTIONS

SCALE: AS SHOWN
DATE: 2/12/09
DRWN. BY: M. GERMAN
CHKD. BY: S. PATRICK
PROJECT NUMBER: G07059.0
DRAWING NO.: PLATE 5
SHEET NO.: 1 OF 1

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P.O. BOX 278 MOREHEAD CITY, N.C. 28557 (252) 726-4481

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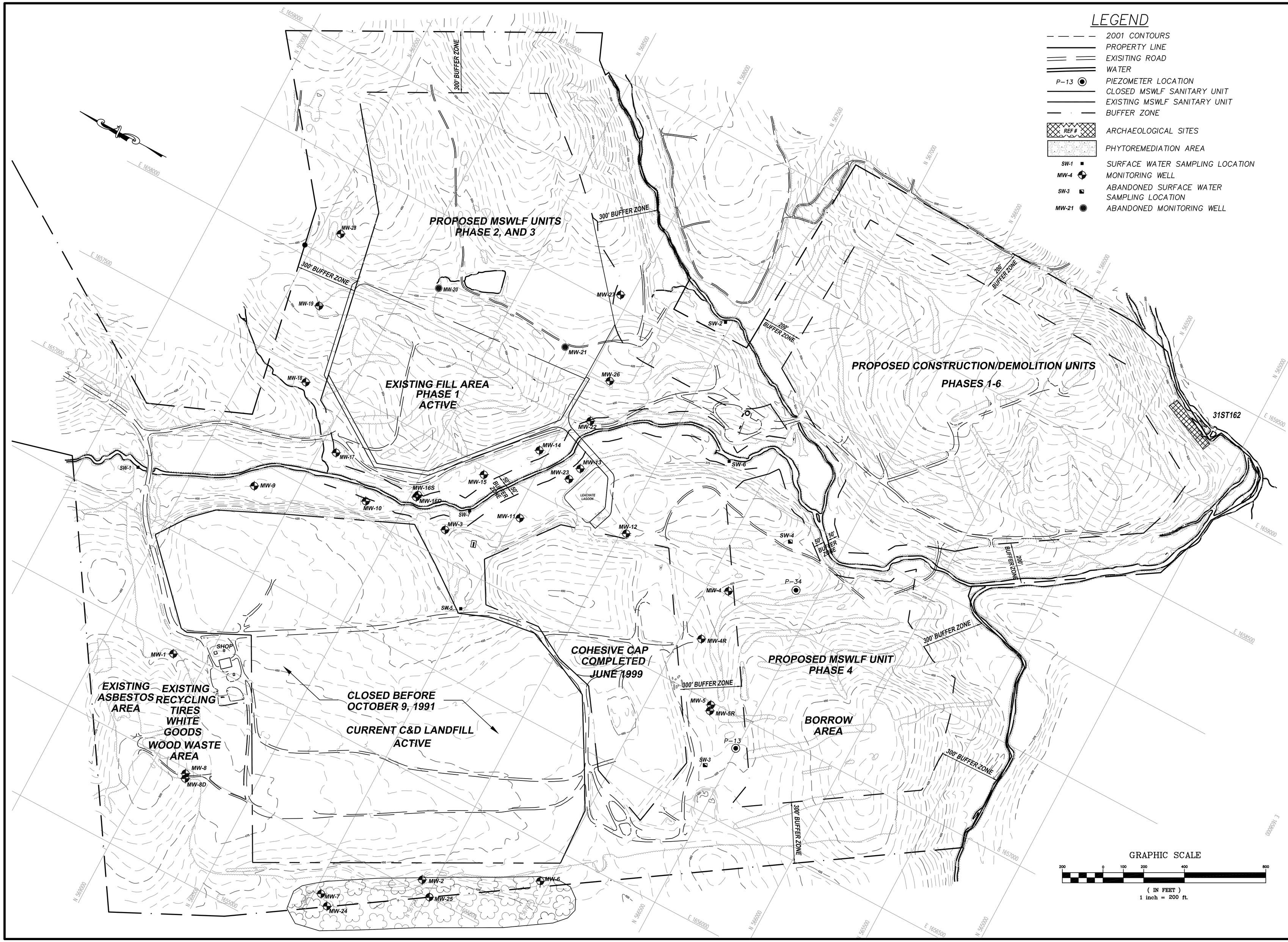

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P.O. BOX 349 BOONE, N.C. 28607 (828) 262-1767

CLOSED MSWLF AND ACTIVE C&D LANDFILL FACILITY
CITY OF ALBEMARLE NORTH CAROLINA

DATE	BY	REV.	DESCRIPTION

PHYTOREMEDIATION AREA

SCALE:	1"=200'
DATE:	6/30/2008
DRWN. BY:	M. GERMAN
CHKD. BY:	S. PATRICK
PROJECT NUMBER	G07059.0
DRAWING NO.	PLATE 6
SHEET NO.	1 of 1

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APPENDIX A

BIOCHLOR Natural Attenuation Decision Support System

Version 2.2
Excel 2000

City of Albemarle
Eastern Plume
Run Name

Data Input Instructions:

115 → 1. Enter value directly....or
↑ *or* 2. Calculate by filling in gray
0.02 cells. Press Enter, then C
(To restore formulas, hit "Restore Formulas" button)
Variable* → Data used directly in model.

Test if Biotransformation is Occurring → Natural Attenuation Screening Protocol

TYPE OF CHLORINATED SOLVENT: Ethenes ◉ Ethanes ○

1. ADVECTION

Seepage Velocity*	Vs	54.2	(ft/yr)
or			
Hydraulic Conductivity	K	1.7E-04	(cm/sec)
Hydraulic Gradient	i	0.0476	(ft/ft)
Effective Porosity	n	0.15	(-)

2. DISPERSION

Alpha x*	47.5	(ft)
(Alpha y) / (Alpha x)*	0.1	(-)
(Alpha z) / (Alpha x)*	1.E-99	(-)

Calc. Alpha x

3. ADSORPTION

Retardation Factor* → R

or

Soil Bulk Density, rho	1.7	(kg/L)		
FractionOrganicCarbon, foc	1.0E-3	(-)		
Partition Coefficient	Koc			
PCE	426	(L/kg)	5.83	(-)
TCE	130	(L/kg)	2.47	(-)
DCE	125	(L/kg)	2.42	(-)
VC	30	(L/kg)	1.34	(-)
ETH	0	(L/kg)	1.00	(-)
Common R (used in model)* =			**2.42**	

4. BIOTRANSFORMATION

-1st Order Decay Coefficient*

	λ (1/yr)	half-life (yrs)	Yield
Zone 1			
PCE → TCE	0.070	9.90	0.79
TCE → DCE	0.050	13.90	0.74
DCE → VC	0.000		0.64
VC → ETH	0.119	5.80	0.45
Zone 2	λ (1/yr)	half-life (yrs)	
PCE → TCE	0.000		
TCE → DCE	0.000		
DCE → VC	0.000		
VC → ETH	0.000		

λ HELP

5. GENERAL

Simulation Time*	5	(yr)
Modeled Area Width*	1200	(ft)
Modeled Area Length*	475	(ft)
Zone 1 Length*	475	(ft)
Zone 2 Length*	0	(ft)

L, W

Zone 2= L - Zone 1

6. SOURCE DATA

TYPE: Decaying Single Planar

Source Options

Source Thickness in Sat. Zone* 10 (ft)

Vertical Plane Source: Determine Source Well Location and Input Solvent Concentrations

	Y1
Width* (ft)	1200
Conc. (mg/L)*	C1
PCE	.01
TCE	.5
DCE	.0
VC	.01
ETH	0

k_s* (1/yr)

View of Plume Looking Down

Observed Centerline Conc. at Monitoring Wells

7. FIELD DATA FOR COMPARISON

PCE Conc. (mg/L)	1.1E-03										
TCE Conc. (mg/L)	4.7E-03										
DCE Conc. (mg/L)	0.0										
VC Conc. (mg/L)	6.7E-04										
ETH Conc. (mg/L)	0.0										
Distance from Source (ft)	50										
Date Data Collected	2008										

8. CHOOSE TYPE OF OUTPUT TO SEE:

RUN CENTERLINE | RUN ARRAY | Help | Restore Formulas | RESET | SEE OUTPUT | Paste Example

Start Here → ◉ PCE ○ TCE ○ DCE ○ VC ○ ETH

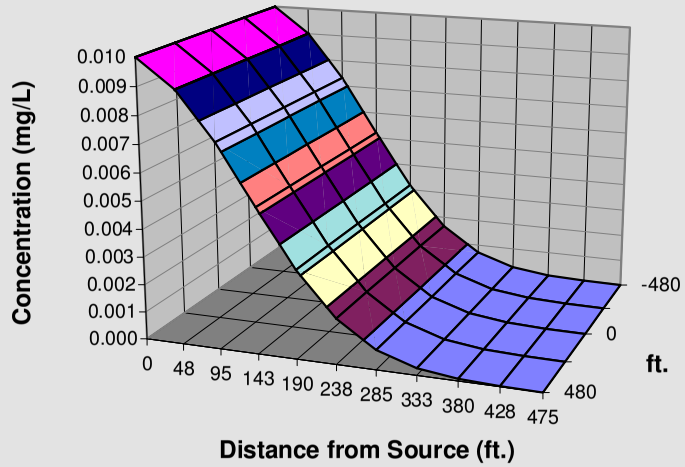
DISSOLVED SOLVENT CONCENTRATIONS IN PLUME

Transverse Distance (ft)	Distance from Source (ft) 0	48	95	143	190	238	285	333	380	428	475
480	0.010	0.009	0.007	0.005	0.003	0.002	0.001	0.000	0.000	0.000	0.000
240	0.010	0.009	0.007	0.005	0.003	0.002	0.001	0.000	0.000	0.000	0.000
0	0.010	0.009	0.007	0.005	0.003	0.002	0.001	0.000	0.000	0.000	0.000
-240	0.010	0.009	0.007	0.005	0.003	0.002	0.001	0.000	0.000	0.000	0.000
-480	0.010	0.009	0.007	0.005	0.003	0.002	0.001	0.000	0.000	0.000	0.000
MASS RATE (mg/day)	7.6E+1	6.8E+1	5.5E+1	3.9E+1	2.4E+1	1.2E+1	5.3E+0	1.9E+0	5.6E-1	1.4E-1	2.7E-2

Show No Degradation

Show Biotransformation

Time: 5 yr Target Level: 0.005 mg/L Displayed Model: No Degradation Displayed Compound: PCE



Plume Mass (Order-of-Magnitude Accuracy)

See Gallons

Plume Mass If No Degradation	1.9E-01	(Kg)
- Plume Mass If Biotransformation/Production	1.8E-01	(Kg)
Mass Removed	1.1E-02	(Kg)
% Biotransformed =	+5.7%	
% Change in Mass Rate =	100.0 % (source to edge)	

If "Can't Calc.", make model area longer

See acre-ft

Current Volume of Ground Water in Plume	2.56	MGal
Flow Rate of Water Through Source Area	0.002	MGD

Compare to Pump and Treat

Pumping Rate		(gpm)
# Pore Volumes Removed Per Yr.	0.00	
# Pore Volumes to Clean-Up		
Clean-Up Time		(yr)

Plot All Data Plot Data > Target Mass HELP To Centerline Return to Input

DISSOLVED SOLVENT CONCENTRATIONS IN PLUME

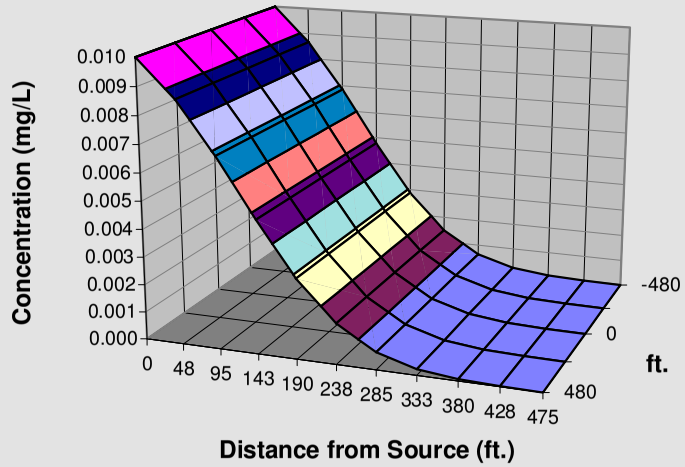
Start Here → PCE / TCE / DCE / VC / ETH

Transverse Distance (ft)	Distance from Source (ft) 0	48	95	143	190	238	285	333	380	428	475
480	0.010	0.009	0.007	0.005	0.003	0.001	0.001	0.000	0.000	0.000	0.000
240	0.010	0.009	0.007	0.005	0.003	0.001	0.001	0.000	0.000	0.000	0.000
0	0.010	0.009	0.007	0.005	0.003	0.001	0.001	0.000	0.000	0.000	0.000
-240	0.010	0.009	0.007	0.005	0.003	0.001	0.001	0.000	0.000	0.000	0.000
-480	0.010	0.009	0.007	0.005	0.003	0.001	0.001	0.000	0.000	0.000	0.000
MASS RATE (mg/day)	7.6E+1	6.5E+1	5.2E+1	3.6E+1	2.2E+1	1.1E+1	4.7E+0	1.7E+0	4.9E-1	1.2E-1	2.3E-2

Show No Degradation

Show Biotransformation

Time: 5 yr Target Level: 0.005 mg/L Displayed Model: Biotransformation Displayed Compound: PCE



Plume Mass (Order-of-Magnitude Accuracy)

See Gallons

Plume Mass If No Degradation	1.9E-01	(Kg)
- Plume Mass If Biotransformation/Production	1.8E-01	(Kg)
Mass Removed	1.1E-02	(Kg)
% Biotransformed =	+5.7%	
% Change in Mass Rate =	100.0 % (source to edge)	

If "Can't Calc.", make model area longer

See acre-ft

Current Volume of Ground Water in Plume	1.92	MGal
Flow Rate of Water Through Source Area	0.002	MGD

Compare to Pump and Treat

Pumping Rate		(gpm)
# Pore Volumes Removed Per Yr.	0.00	
# Pore Volumes to Clean-Up		
Clean-Up Time		(yr)

Plot All Data Plot Data > Target Mass HELP To Centerline Return to Input

Start Here → ○ PCE ◉ TCE ○ DCE ○ VC ○ ETH

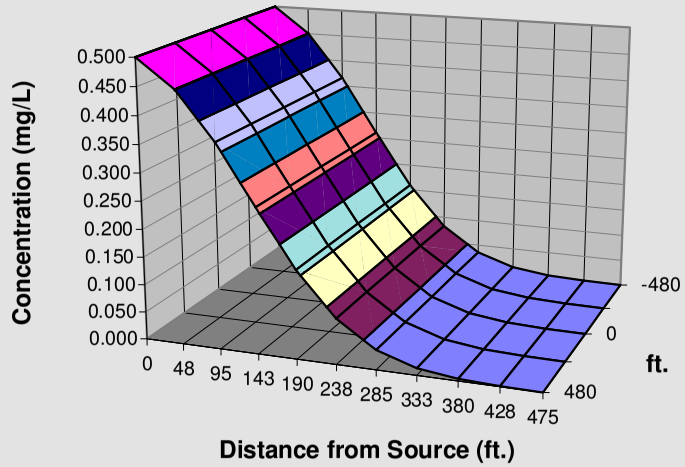
DISSOLVED SOLVENT CONCENTRATIONS IN PLUME

Transverse Distance (ft)	Distance from Source (ft) 0	48	95	143	190	238	285	333	380	428	475
480	0.500	0.450	0.366	0.260	0.159	0.082	0.035	0.012	0.004	0.001	0.000
240	0.500	0.450	0.366	0.260	0.159	0.082	0.035	0.013	0.004	0.001	0.000
0	0.500	0.450	0.366	0.260	0.159	0.082	0.035	0.013	0.004	0.001	0.000
-240	0.500	0.450	0.366	0.260	0.159	0.082	0.035	0.013	0.004	0.001	0.000
-480	0.500	0.450	0.366	0.260	0.159	0.082	0.035	0.012	0.004	0.001	0.000
MASS RATE (mg/day)	3.8E+3	3.4E+3	2.8E+3	2.0E+3	1.2E+3	6.2E+2	2.7E+2	9.5E+1	2.8E+1	6.8E+0	1.3E+0

Show No Degradation

Show Biotransformation

Time: 5 yr Target Level: 0.005 mg/L Displayed Model: No Degradation Displayed Compound: TCE



Plume Mass (Order-of-Magnitude Accuracy)

See Gallons

Plume Mass If No Degradation	9.5E+00	(Kg)
- Plume Mass If Biotransformation/Production	9.1E+00	(Kg)
Mass Removed	3.8E-01	(Kg)
% Biotransformed =	+4.0%	
% Change in Mass Rate =	100.0 % (source to edge)	

If "Can't Calc.", make model area longer

See acre-ft

Current Volume of Ground Water in Plume	5.12	MGal
Flow Rate of Water Through Source Area	0.002	MGD

Compare to Pump and Treat

Pumping Rate		(gpm)
# Pore Volumes Removed Per Yr.	0.00	
# Pore Volumes to Clean-Up		
Clean-Up Time		(yr)

Plot All Data Plot Data > Target Mass HELP To Centerline Return to Input

Start Here → ○ PCE ◉ TCE ○ DCE ○ VC ○ ETH

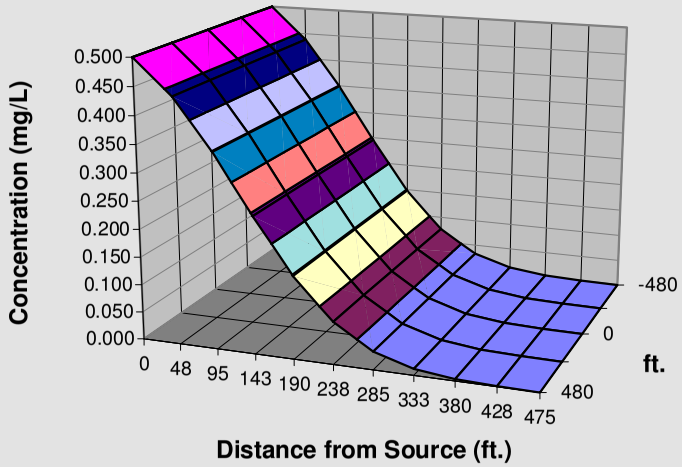
DISSOLVED SOLVENT CONCENTRATIONS IN PLUME

Transverse Distance (ft)	Distance from Source (ft) 0	48	95	143	190	238	285	333	380	428	475
480	0.500	0.438	0.349	0.245	0.148	0.076	0.032	0.011	0.003	0.001	0.000
240	0.500	0.438	0.349	0.245	0.148	0.076	0.033	0.012	0.003	0.001	0.000
0	0.500	0.438	0.349	0.245	0.148	0.076	0.033	0.012	0.003	0.001	0.000
-240	0.500	0.438	0.349	0.245	0.148	0.076	0.033	0.012	0.003	0.001	0.000
-480	0.500	0.438	0.349	0.245	0.148	0.076	0.032	0.011	0.003	0.001	0.000
MASS RATE (mg/day)	3.8E+3	3.3E+3	2.6E+3	1.9E+3	1.1E+3	5.7E+2	2.5E+2	8.7E+1	2.6E+1	6.2E+0	1.2E+0

Show No Degradation

Show Biotransformation

Time: 5 yr Target Level: 0.005 mg/L Displayed Model: Biotransformation Displayed Compound: TCE



Plume Mass (Order-of-Magnitude Accuracy)

See Gallons

Plume Mass If No Degradation	9.5E+00	(Kg)
- Plume Mass If Biotransformation/Production	9.1E+00	(Kg)
Mass Removed	3.8E-01	(Kg)
% Biotransformed =	+4.0%	
% Change in Mass Rate =	100.0 % (source to edge)	

If "Can't Calc.", make model area longer

See acre-ft

Current Volume of Ground Water in Plume	5.12	MGal
Flow Rate of Water Through Source Area	0.002	MGD

Compare to Pump and Treat

Pumping Rate		(gpm)
# Pore Volumes Removed Per Yr.	0.00	
# Pore Volumes to Clean-Up		
Clean-Up Time		(yr)

Plot All Data Plot Data > Target Mass HELP To Centerline Return to Input

Start Here → ○ PCE ○ TCE ○ DCE ◉ VC ○ ETH

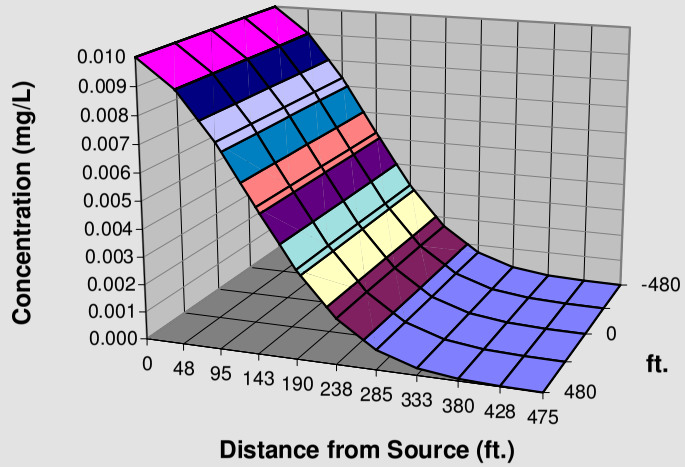
DISSOLVED SOLVENT CONCENTRATIONS IN PLUME

Transverse Distance (ft)	Distance from Source (ft) 0	48	95	143	190	238	285	333	380	428	475
480	0.010	0.009	0.007	0.005	0.003	0.002	0.001	0.000	0.000	0.000	0.000
240	0.010	0.009	0.007	0.005	0.003	0.002	0.001	0.000	0.000	0.000	0.000
0	0.010	0.009	0.007	0.005	0.003	0.002	0.001	0.000	0.000	0.000	0.000
-240	0.010	0.009	0.007	0.005	0.003	0.002	0.001	0.000	0.000	0.000	0.000
-480	0.010	0.009	0.007	0.005	0.003	0.002	0.001	0.000	0.000	0.000	0.000
MASS RATE (mg/day)	7.6E+1	6.8E+1	5.5E+1	3.9E+1	2.4E+1	1.2E+1	5.3E+0	1.9E+0	5.6E-1	1.4E-1	2.7E-2

Show No Degradation

Show Biotransformation

Time: 5 yr Target Level: 0.002 mg/L Displayed Model: No Degradation Displayed Compound: VC



Plume Mass (Order-of-Magnitude Accuracy)

See Gallons

Plume Mass If No Degradation	1.9E-01	(Kg)
- Plume Mass If Biotransformation/Production	1.7E-01	(Kg)
Mass Removed	1.8E-02	(Kg)
% Biotransformed =	+9.4%	
% Change in Mass Rate =	100.0 % (source to edge)	

If "Can't Calc.", make model area longer

See acre-ft

Current Volume of Ground Water in Plume	2.56	MGal
Flow Rate of Water Through Source Area	0.002	MGD

Compare to Pump and Treat

Pumping Rate		(gpm)
# Pore Volumes Removed Per Yr.	0.00	
# Pore Volumes to Clean-Up		
Clean-Up Time		(yr)

Plot All Data Plot Data > Target Mass HELP To Centerline Return to Input

DISSOLVED SOLVENT CONCENTRATIONS IN PLUME

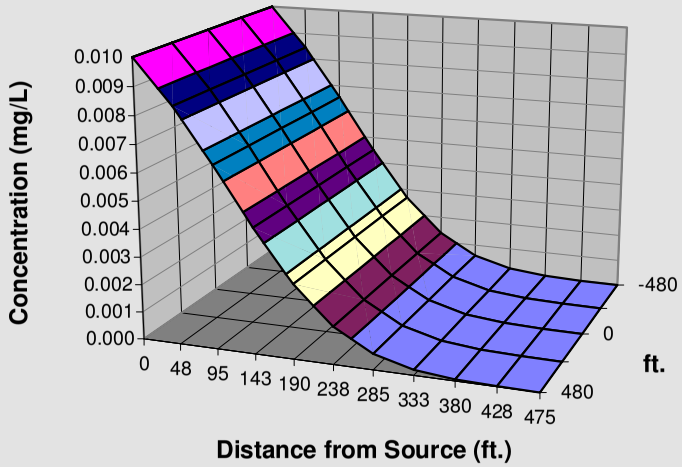
Start Here → PCE / TCE / DCE / VC / ETH

Transverse Distance (ft)	Distance from Source (ft) 0	48	95	143	190	238	285	333	380	428	475
480	0.010	0.008	0.007	0.004	0.003	0.001	0.001	0.000	0.000	0.000	0.000
240	0.010	0.008	0.007	0.004	0.003	0.001	0.001	0.000	0.000	0.000	0.000
0	0.010	0.008	0.007	0.004	0.003	0.001	0.001	0.000	0.000	0.000	0.000
-240	0.010	0.008	0.007	0.004	0.003	0.001	0.001	0.000	0.000	0.000	0.000
-480	0.010	0.008	0.007	0.004	0.003	0.001	0.001	0.000	0.000	0.000	0.000
MASS RATE (mg/day)	7.6E+1	6.4E+1	4.9E+1	3.4E+1	2.0E+1	1.0E+1	4.4E+0	1.5E+0	4.5E-1	1.1E-1	2.1E-2

Show No Degradation

Show Biotransformation

Time: 5 yr Target Level: 0.002 mg/L Displayed Model: Biotransformation Displayed Compound: VC



Plume Mass (Order-of-Magnitude Accuracy)

See Gallons

Plume Mass If No Degradation	1.9E-01	(Kg)
- Plume Mass If Biotransformation/Production	1.7E-01	(Kg)
Mass Removed	1.8E-02	(Kg)
% Biotransformed =	+9.4%	
% Change in Mass Rate =	100.0 %	(source to edge)

If "Can't Calc.", make model area longer

See acre-ft

Current Volume of Ground Water in Plume	1.92	MGal
Flow Rate of Water Through Source Area	0.002	MGD

Compare to Pump and Treat

Pumping Rate		(gpm)
# Pore Volumes Removed Per Yr.	0.00	
# Pore Volumes to Clean-Up		
Clean-Up Time		(yr)

Plot All Data Plot Data > Target Mass HELP To Centerline Return to Input

BIOCHLOR Natural Attenuation Decision Support System

Version 2.2
Excel 2000

City of Albemarle
Eastern Plume
Run Name

Data Input Instructions:

115 → 1. Enter value directly....or
↑ *or* 2. Calculate by filling in gray
0.02 cells. Press Enter, then (C)
(To restore formulas, hit "Restore Formulas" button)
Variable* → Data used directly in model.

Test if Biotransformation is Occurring → Natural Attenuation Screening Protocol

TYPE OF CHLORINATED SOLVENT: Ethenes ◉ Ethanes ○

1. ADVECTION

Seepage Velocity*	Vs	54.2	(ft/yr)
or			
Hydraulic Conductivity	K	1.7E-04	(cm/sec)
Hydraulic Gradient	i	0.0476	(ft/ft)
Effective Porosity	n	0.15	(-)

2. DISPERSION

Alpha x*	47.5	(ft)
(Alpha y) / (Alpha x)*	0.1	(-)
(Alpha z) / (Alpha x)*	1.E-99	(-)

Calc. Alpha x

3. ADSORPTION

Retardation Factor* → R

or

Soil Bulk Density, rho	1.7	(kg/L)		
FractionOrganicCarbon, foc	1.0E-3	(-)		
Partition Coefficient	Koc			
PCE	426	(L/kg)	5.83	(-)
TCE	130	(L/kg)	2.47	(-)
DCE	125	(L/kg)	2.42	(-)
VC	30	(L/kg)	1.34	(-)
ETH	0	(L/kg)	1.00	(-)
Common R (used in model)* =			**2.42**	

4. BIOTRANSFORMATION **-1st Order Decay Coefficient***

	λ (1/yr)	half-life (yrs)	Yield
Zone 1			
PCE → TCE	1.195	0.58	0.79
TCE → DCE	0.900	0.77	0.74
DCE → VC	0.000		0.64
VC → ETH	2.567	0.27	0.45
Zone 2	λ (1/yr)	half-life (yrs)	
PCE → TCE	0.000		
TCE → DCE	0.000		
DCE → VC	0.000		
VC → ETH	0.000		

λ HELP

5. GENERAL

Simulation Time*	5	(yr)
Modeled Area Width*	1200	(ft)
Modeled Area Length*	475	(ft)
Zone 1 Length*	475	(ft)
Zone 2 Length*	0	(ft)

L, W

Zone 2= L - Zone 1

6. SOURCE DATA TYPE: Decaying Single Planar

Source Options

Source Thickness in Sat. Zone* 10 (ft)

Width* (ft) Y1 1200

Conc. (mg/L)*	C1	k_s* (1/yr)
PCE	.01	
TCE	.5	
DCE	.0	
VC	.01	
ETH	0	

Vertical Plane Source: Determine Source Well Location and Input Solvent Concentrations

View of Plume Looking Down

Observed Centerline Conc. at Monitoring Wells

7. FIELD DATA FOR COMPARISON

PCE Conc. (mg/L)	1.1E-03										
TCE Conc. (mg/L)	4.7E-03										
DCE Conc. (mg/L)	0.0										
VC Conc. (mg/L)	6.7E-04										
ETH Conc. (mg/L)	0.0										
Distance from Source (ft)	50										
Date Data Collected	2008										

8. CHOOSE TYPE OF OUTPUT TO SEE:

RUN CENTERLINE | RUN ARRAY | Help | Restore Formulas | RESET | SEE OUTPUT | Paste Example

DISSOLVED SOLVENT CONCENTRATIONS IN PLUME

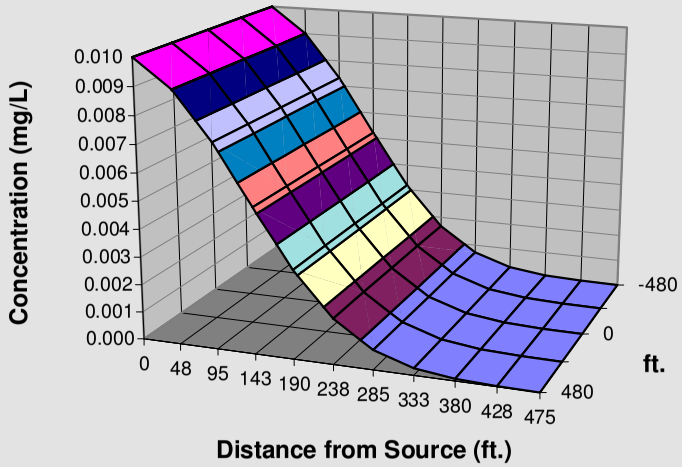
Start Here → (•) PCE ( ) TCE ( ) DCE ( ) VC ( ) ETH

Transverse Distance (ft)	Distance from Source (ft) 0	48	95	143	190	238	285	333	380	428	475
480	0.010	0.009	0.007	0.005	0.003	0.002	0.001	0.000	0.000	0.000	0.000
240	0.010	0.009	0.007	0.005	0.003	0.002	0.001	0.000	0.000	0.000	0.000
0	0.010	0.009	0.007	0.005	0.003	0.002	0.001	0.000	0.000	0.000	0.000
-240	0.010	0.009	0.007	0.005	0.003	0.002	0.001	0.000	0.000	0.000	0.000
-480	0.010	0.009	0.007	0.005	0.003	0.002	0.001	0.000	0.000	0.000	0.000
MASS RATE (mg/day)	7.6E+1	6.8E+1	5.5E+1	3.9E+1	2.4E+1	1.2E+1	5.3E+0	1.9E+0	5.6E-1	1.4E-1	2.7E-2

Show No Degradation

Show Biotransformation

Time: 5 yr Target Level: 0.005 mg/L Displayed Model: No Degradation Displayed Compound: PCE



Plume Mass (Order-of-Magnitude Accuracy)

See Gallons

Plume Mass If No Degradation	1.9E-01	(Kg)
- Plume Mass If Biotransformation/Production	9.0E-02	(Kg)
Mass Removed	1.0E-01	(Kg)
% Biotransformed =	+52.7%	
% Change in Mass Rate =	100.0 % (source to edge)	

If "Can't Calc.", make model area longer

See acre-ft

Current Volume of Ground Water in Plume	2.56	MGal
Flow Rate of Water Through Source Area	0.002	MGD

Compare to Pump and Treat

Pumping Rate		(gpm)
# Pore Volumes Removed Per Yr.	0.00	
# Pore Volumes to Clean-Up		
Clean-Up Time		(yr)

Plot All Data Plot Data > Target Mass HELP To Centerline Return to Input

Start Here → ◉ PCE ○ TCE ○ DCE ○ VC ○ ETH

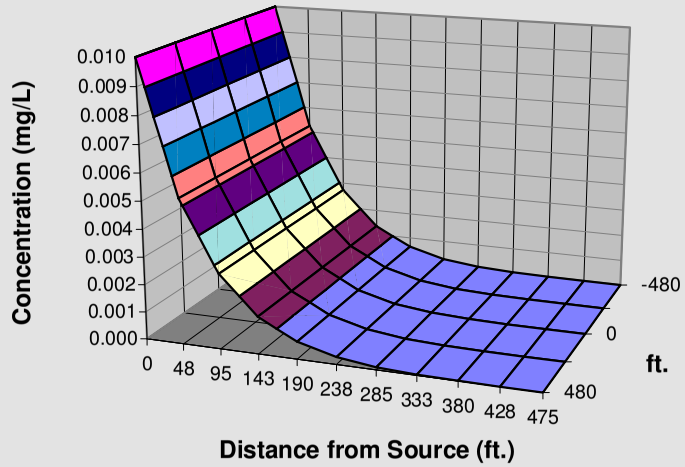
DISSOLVED SOLVENT CONCENTRATIONS IN PLUME

Transverse Distance (ft)	Distance from Source (ft) 0	48	95	143	190	238	285	333	380	428	475
480	0.010	0.005	0.003	0.001	0.001	0.000	0.000	0.000	0.000	0.000	0.000
240	0.010	0.005	0.003	0.001	0.001	0.000	0.000	0.000	0.000	0.000	0.000
0	0.010	0.005	0.003	0.001	0.001	0.000	0.000	0.000	0.000	0.000	0.000
-240	0.010	0.005	0.003	0.001	0.001	0.000	0.000	0.000	0.000	0.000	0.000
-480	0.010	0.005	0.003	0.001	0.001	0.000	0.000	0.000	0.000	0.000	0.000
MASS RATE (mg/day)	7.6E+1	4.0E+1	2.0E+1	1.0E+1	4.7E+0	2.0E+0	7.4E-1	2.4E-1	6.5E-2	1.5E-2	2.8E-3

Show No Degradation

Show Biotransformation

Time: 5 yr Target Level: 0.005 mg/L Displayed Model: Biotransformation Displayed Compound: PCE



Plume Mass (Order-of-Magnitude Accuracy)

See Gallons

Plume Mass If No Degradation	1.9E-01	(Kg)
- Plume Mass If Biotransformation/Production	9.0E-02	(Kg)
Mass Removed	1.0E-01	(Kg)
% Biotransformed =	+52.7%	
% Change in Mass Rate =	100.0 % (source to edge)	

If "Can't Calc.", make model area longer

See acre-ft

Current Volume of Ground Water in Plume	1.28	MGal
Flow Rate of Water Through Source Area	0.002	MGD

Compare to Pump and Treat

Pumping Rate		(gpm)
# Pore Volumes Removed Per Yr.	0.00	
# Pore Volumes to Clean-Up		
Clean-Up Time		(yr)

Plot All Data Plot Data > Target Mass HELP To Centerline Return to Input

DISSOLVED SOLVENT CONCENTRATIONS IN PLUME

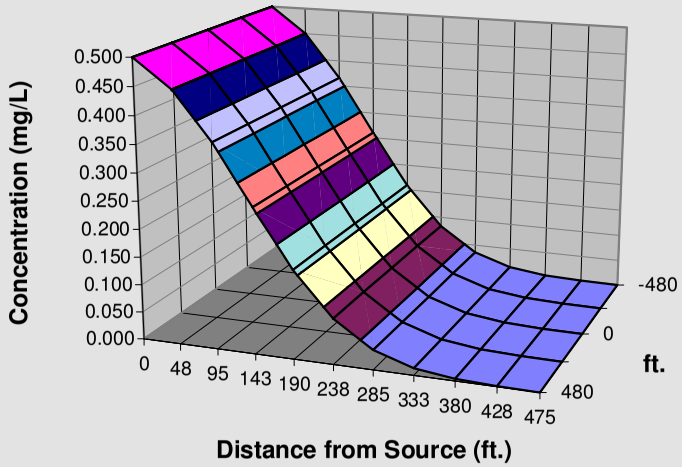
Start Here → ○ PCE ◉ TCE ○ DCE ○ VC ○ ETH

Transverse Distance (ft)	Distance from Source (ft) 0	48	95	143	190	238	285	333	380	428	475
480	0.500	0.450	0.366	0.260	0.159	0.082	0.035	0.012	0.004	0.001	0.000
240	0.500	0.450	0.366	0.260	0.159	0.082	0.035	0.013	0.004	0.001	0.000
0	0.500	0.450	0.366	0.260	0.159	0.082	0.035	0.013	0.004	0.001	0.000
-240	0.500	0.450	0.366	0.260	0.159	0.082	0.035	0.013	0.004	0.001	0.000
-480	0.500	0.450	0.366	0.260	0.159	0.082	0.035	0.012	0.004	0.001	0.000
MASS RATE (mg/day)	3.8E+3	3.4E+3	2.8E+3	2.0E+3	1.2E+3	6.2E+2	2.7E+2	9.5E+1	2.8E+1	6.8E+0	1.3E+0

Show No Degradation

Show Biotransformation

Time: 5 yr Target Level: 0.005 mg/L Displayed Model: No Degradation Displayed Compound: TCE



Plume Mass (Order-of-Magnitude Accuracy)

See Gallons

Plume Mass If No Degradation	9.5E+00	(Kg)
- Plume Mass If Biotransformation/Production	5.2E+00	(Kg)
Mass Removed	4.3E+00	(Kg)
% Biotransformed =	+45.1%	
% Change in Mass Rate =	100.0 % (source to edge)	

If "Can't Calc.", make model area longer

See acre-ft

Current Volume of Ground Water in Plume	5.12	MGal
Flow Rate of Water Through Source Area	0.002	MGD

Compare to Pump and Treat

Pumping Rate		(gpm)
# Pore Volumes Removed Per Yr.	0.00	
# Pore Volumes to Clean-Up		
Clean-Up Time		(yr)

Plot All Data Plot Data > Target Mass HELP To Centerline Return to Input

Start Here → ○ PCE ◉ TCE ○ DCE ○ VC ○ ETH

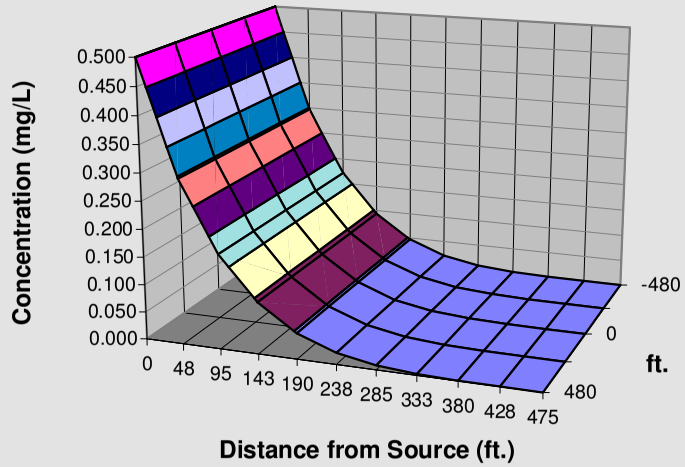
DISSOLVED SOLVENT CONCENTRATIONS IN PLUME

Transverse Distance (ft)	Distance from Source (ft) 0	48	95	143	190	238	285	333	380	428	475
480	0.500	0.296	0.171	0.093	0.047	0.021	0.008	0.003	0.001	0.000	0.000
240	0.500	0.296	0.171	0.093	0.047	0.021	0.008	0.003	0.001	0.000	0.000
0	0.500	0.296	0.171	0.093	0.047	0.021	0.008	0.003	0.001	0.000	0.000
-240	0.500	0.296	0.171	0.093	0.047	0.021	0.008	0.003	0.001	0.000	0.000
-480	0.500	0.296	0.171	0.093	0.047	0.021	0.008	0.003	0.001	0.000	0.000
MASS RATE (mg/day)	3.8E+3	2.2E+3	1.3E+3	7.0E+2	3.5E+2	1.6E+2	6.1E+1	2.0E+1	5.6E+0	1.3E+0	2.5E-1

Show No Degradation

Show Biotransformation

Time: 5 yr Target Level: 0.005 mg/L Displayed Model: Biotransformation Displayed Compound: TCE



Plume Mass (Order-of-Magnitude Accuracy)

See Gallons

Plume Mass If No Degradation	9.5E+00	(Kg)
- Plume Mass If Biotransformation/Production	5.2E+00	(Kg)
Mass Removed	4.3E+00	(Kg)
% Biotransformed =	+45.1%	
% Change in Mass Rate =	100.0 %	(source to edge)

If "Can't Calc.", make model area longer

See acre-ft

Current Volume of Ground Water in Plume	4.48	MGal
Flow Rate of Water Through Source Area	0.002	MGD

Compare to Pump and Treat

Pumping Rate		(gpm)
# Pore Volumes Removed Per Yr.	0.00	
# Pore Volumes to Clean-Up		
Clean-Up Time		(yr)

Plot All Data Plot Data > Target Mass HELP To Centerline Return to Input

DISSOLVED SOLVENT CONCENTRATIONS IN PLUME

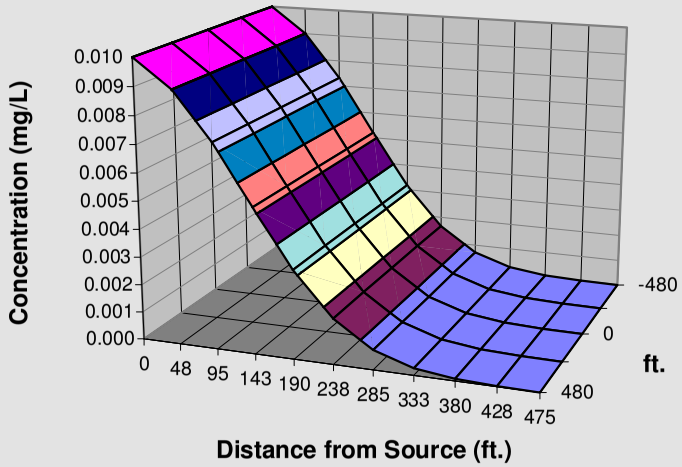
Start Here → PCE / TCE / DCE / VC / ETH

Transverse Distance (ft)	Distance from Source (ft) 0	48	95	143	190	238	285	333	380	428	475
480	0.010	0.009	0.007	0.005	0.003	0.002	0.001	0.000	0.000	0.000	0.000
240	0.010	0.009	0.007	0.005	0.003	0.002	0.001	0.000	0.000	0.000	0.000
0	0.010	0.009	0.007	0.005	0.003	0.002	0.001	0.000	0.000	0.000	0.000
-240	0.010	0.009	0.007	0.005	0.003	0.002	0.001	0.000	0.000	0.000	0.000
-480	0.010	0.009	0.007	0.005	0.003	0.002	0.001	0.000	0.000	0.000	0.000
MASS RATE (mg/day)	7.6E+1	6.8E+1	5.5E+1	3.9E+1	2.4E+1	1.2E+1	5.3E+0	1.9E+0	5.6E-1	1.4E-1	2.7E-2

Show No Degradation

Show Biotransformation

Time: 5 yr Target Level: 0.002 mg/L Displayed Model: No Degradation Displayed Compound: VC



Plume Mass (Order-of-Magnitude Accuracy)

See Gallons

Plume Mass If No Degradation	1.9E-01	(Kg)
- Plume Mass If Biotransformation/Production	5.9E-02	(Kg)
Mass Removed	1.3E-01	(Kg)
% Biotransformed =	+68.8%	
% Change in Mass Rate =	100.0 % (source to edge)	

If "Can't Calc.", make model area longer

See acre-ft

Current Volume of Ground Water in Plume	2.56	MGal
Flow Rate of Water Through Source Area	0.002	MGD

Compare to Pump and Treat

Pumping Rate		(gpm)
# Pore Volumes Removed Per Yr.	0.00	
# Pore Volumes to Clean-Up		
Clean-Up Time		(yr)

Plot All Data Plot Data > Target Mass HELP To Centerline Return to Input

Start Here → ○ PCE ○ TCE ○ DCE ◉ VC ○ ETH

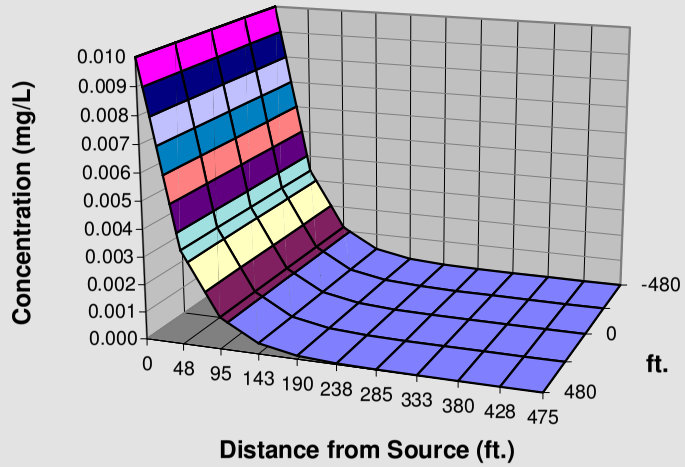
DISSOLVED SOLVENT CONCENTRATIONS IN PLUME

Transverse Distance (ft)	Distance from Source (ft) 0	48	95	143	190	238	285	333	380	428	475
480	0.010	0.003	0.001	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
240	0.010	0.003	0.001	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
0	0.010	0.003	0.001	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
-240	0.010	0.003	0.001	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
-480	0.010	0.003	0.001	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
MASS RATE (mg/day)	7.6E+1	2.6E+1	8.7E+0	2.9E+0	9.6E-1	3.1E-1	9.2E-2	2.5E-2	6.0E-3	1.2E-3	2.2E-4

Show No Degradation

Show Biotransformation

Time: 5 yr Target Level: 0.002 mg/L Displayed Model: Biotransformation Displayed Compound: VC



Plume Mass (Order-of-Magnitude Accuracy)

See Gallons

Plume Mass If No Degradation	1.9E-01	(Kg)
- Plume Mass If Biotransformation/Production	5.9E-02	(Kg)
Mass Removed	1.3E-01	(Kg)
% Biotransformed =	+68.8%	
% Change in Mass Rate =	100.0 % (source to edge)	

If "Can't Calc.", make model area longer

See acre-ft

Current Volume of Ground Water in Plume	0.64	MGal
Flow Rate of Water Through Source Area	0.002	MGD

Compare to Pump and Treat

Pumping Rate		(gpm)
# Pore Volumes Removed Per Yr.	0.00	
# Pore Volumes to Clean-Up		
Clean-Up Time		(yr)

Plot All Data Plot Data > Target Mass HELP To Centerline Return to Input

APPENDIX B

Ground and Surfacewater Sampling and Analysis Plan

Prepared for

City of Albemarle C&D Landfill
Albemarle, Stanly County, North Carolina

MESCO Project Number: G07059.0

This report is included as Appendix B the *Corrective Action Plan* completed for the City of Albemarle C&D Landfill.
Completed on 2/13/2009

Municipal Engineering Services Company, P.A.
Garner, Boone and Morehead City, North Carolina

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Attachment 1 ..... NCDENR Solid Waste Section Sampling & Monitoring Guidance

1 INTRODUCTION

1.1 Objective

The objective of the Ground and Surfacewater Sampling and Analysis Plan (SAP) is to provide clear guidelines and procedures for field and laboratory personnel when obtaining and testing ground and surface water samples. This plan is an update, and supersedes the November 1995 SAP for the Alexander County C&D landfill on top of MSW landfill. The sampling procedures outlined in this analysis plan are guidelines by which sampling will be performed. Deviation from the procedures may be warranted depending on facility conditions or unforeseen sampling variables. Alternative sampling procedures must conform to the N.C. Water Quality Monitoring Guidance Document for Solid Waste Facilities (Guidance Document). Copies of the NCDENR Solid Waste Section technical guidelines for sampling and monitoring are presented in the **Attachments**.

All groundwater and surface water monitoring points shall be sampled semi annually for the constituents listed in Appendix I. In addition to the Appendix I constituents, the eastern plume monitoring wells MW-3, MW-9, and MW-10, and the western plume monitoring wells, MW-2, MW-6, MW-7, MW-24, and MW-25 will be sampled for the following suite of Monitored Natural Attenuation (MNA) parameters.

MNA Performance Parameters		
Parameter	**Analysis Type**	**Analytical Method**
Dissolved Oxygen (DO)	Field Reading	Multi-parameter Field Instrument w/ flow-through cell
pH	Field Reading	
Oxidation-Reduction Potential (ORP)	Field Reading	
Turbidity	Field Reading	
Conductivity	Field Reading	
Temperature	Field Reading	
Dissolved CO_2	Field Reading	Field Instrument / Hach Kit
Alkalinity (Total as $CaCO_3$)*	Laboratory/Field*	EPA 310.2
Chloride*	Laboratory/Field*	SM 4500-CLB
Iron	Laboratory	SM3111B
Nitrate*	Laboratory/Field*	EPA 353.2 / SM 2320B
Sulfate*	Laboratory/Field*	EPA 375.4 / SM 4500-SO4E
Sulfide*	Laboratory/Field*	EPA 376.1 or SM 4500SE
TOC/BOD/COD	Laboratory	EPA 415.1 / EPA 405.1 / EPA 410.1
Methane	Laboratory	RSK 175
Ethane, Ethene	Laboratory	RSK 175
Hydrogen	Laboratory	AM19GA
Volatile Fatty Acids	Laboratory	AM23G
*For budgetary considerations these analyses may be performed in the field using Hach® brand color wheel test kits. Historical iron concentrations have exceeded Hach kit quantitation limits.		

1.2 Water Quality Monitoring Summary

The nature of the groundwater flow, geology, location of creeks, and close proximity of several drainage features will requires extensive monitoring for early detection of a release. The monitoring plan consists of 14 monitoring wells numbered MW-1, MW-2, MW-3, MW-4R, MW-5R, MW-6, MW-7, MW-8D, MW-9, MW-10, MW-11, MW-12, MW-24 and MW-25 and 2 surface monitoring points numbered SW-5, SW-7. Monitoring points included in this plan are summarized on Table E-1. A topographic map is provided as **Plate A**. Locations of monitoring points are shown on **Plate B**.

Monitoring well MW-1 is the background well located up gradient of the landfill. MW-2 is a down gradient monitoring well for the western portion and is designed to intersect groundwater flow from the northwestern portion prior to reaching the property line. MW-3 is a down gradient monitoring well in the northeastern portion of the landfill, selected based on the groundwater flow from the northern portion of the landfill in a southeastern direction. MW-4R is installed on the southeastern half of the landfill. MW-5R is a down gradient well utilized for the detection of a release from the southwestern portion of the landfill. MW-6 is a down gradient monitoring well located on the southwestern side of the landfill, positioned to detect a release flowing in the southwestern direction. MW-7 is the westernmost, down gradient monitoring well, designed to intersect the more southerly flow from the northern portion of both units, transported by advection. MW-8D is an additional up gradient monitoring well. MW-8D was installed to replace dry well MW-8. MW-9 is installed on the northern side of the landfill. MW-10 is a down gradient well utilized for the detection of a release from the southwestern portion of the landfill, including the center of the northern unit. MW-11 is a down gradient well designed to monitor the center of the closed side, before it reaches Jacobs Creek. MW-12 is a down gradient well monitoring groundwater flow in the northeasterly direction. Newly installed well MW-24 is a down gradient well, positioned below MW-7 on the property line. MW-25 is a newly installed down gradient well, positioned below MW-2 on the property line.

Surface water locations SW-1, SW-2 and SW-6 from the MSW landfill have been included for reference purposes. Over the past six years surface water locations SW-3 and SW-4 have been historically dry. Due to this, they will be removed from the Sampling and Analysis Plan. Surface water location SW-5 is downstream of the landfill on the tributary of Jacobs Creek where it flows past the landfill on the southwestern side. Additional sampling point, SW-7, has been initiated, located along the tributary of Jacobs Creek. Actual field locations are shown on **Plate A**.

Detection Monitoring

Detection monitoring will be performed on MW-1, MW-4R, MW-5R, MW-8D, MW-11 and MW-12. Detection monitoring will consist of the collection of groundwater for analysis for the complete list of Appendix I constituents. In addition field parameters including dissolved oxygen (DO), oxidation reduction potential (ORP), pH, temperature, turbidity, and conductivity will also be collected.

Assessment Monitoring

As identified in the Corrective Action Plan, Assessment Monitoring will be performed on eastern wells MW-3, MW-9, and MW-10, and western wells MW-2, MW-6, MW-7, MW-24, and MW-25.

1.3 Sampling Equipment

Groundwater purging and sampling will be performed using a submersible pump and disposable polyethylene bailers. A new bailer will be used to sample each individual well. *Under no circumstance will a disposable bailer used to sample a given well be used to sample any remaining well.* The following procedure will be used decontaminate the submersible pump:

1. Phosphate-free detergent & de-ionized or distilled water rinse.
2. De-ionized or distilled water rinse.
3. Isopropyl alcohol (isopropanol) rinse.
4. De-ionized or distilled water rinse.

At least one (1) equipment blank will be collected during pump decontamination procedures to ensure that cross-contamination has not occurred as a result of the decontamination process. The standard equipment necessary to conduct sampling for each well consists of sample containers (including trip blanks and equipment blanks), one wide-mouth container, at least one 100-ft spool of nylon twine, at least one box of disposable latex/nitrile gloves, temperature/pH/ORP/conductivity indicator, water level indicator, storage coolers, and ice. All equipment subject to damage and contamination will be transported in sealed, plastic bags or storage containers. The water level indicator will be decontaminated in accordance with Steps 2 and 3 described above prior to placement in a clean plastic bag or storage container.

1.4 Sampling Containers

Ground and surfacewater monitoring will include organic (volatile organic compounds- VOCs) and inorganic (metals) analyses. Samples will be collected for the various analyses in laboratory supplied containers.

1. Each sample container will be clearly labeled providing the following information: site name, county location, sample identification number, parameters to be analyzed, preservative added, date and time of sampling, and initials of the sampler.
2. Samples to be analyzed for VOC concentrations will be collected first in three 40-ml glass vials with Teflon septa caps. The sample vials will be completely filled to create zero headspace in the vials.
3. Samples to be analyzed for inorganic contamination will be collected second in a quart/1-liter polyethylene container.

All sample containers will be obtained from an independent laboratory in a sterilized condition and with the appropriate, method-specific preservative. Care will be taken by the field technician to not allow the preservative to wash out of the sample containers during sampling.

Appendix I Sampling Containers

Samples to be analyzed for VOC concentrations will be collected into three 40-ml glass vials with Teflon septa caps. The sample vials will be completely filled with zero headspace in the vials. Samples to be analyzed for inorganic compound concentrations will be collected into 1-liter polyethylene containers, with ½ inch space for air permitted. All sample containers will be obtained from an independent laboratory in a sterilized condition. Some of the containers will have a pre-measured amount of preservative in them as necessary. In this event, care will be taken not to rinse the container or to allow the preservative to wash out during sampling.

MNA Sampling Containers

Groundwater samples to be analyzed for MNA performance parameters will be collected into the container types listed in the table below.

MNA Parameter	Volume	Bottle Type	Preservative
Alkalinity	250 mL	Plastic	none; cool to 4°C
Chloride	125 mL	Plastic	none; cool to 4°C
TOC/COD	250 mL	Glass	Sulfuric acid (H_2SO_4)
BOD	500 mL	Polyethylene	none; cool to 4°C
Iron	125 mL	Plastic	Nitric acid (HNO_3)
Nitrate	125 mL	Plastic	Sulfuric acid (H_2SO_4)
Sulfate	125 mL	Plastic	none; cool to 4°C
Sulfide	250 mL	Glass	Sodium hydroxide (NaOH)
Methane/Ethane/Ethene	125 mL	Plastic	none; cool to 4°C
Hydrogen	-	-	proprietary lab sampler
Volatile Fatty Acids	40 mL	Glass	Hydrochloric Acid (HC1)

2 SAMPLING

Wells will be sampled from upgradient to downgradient; or when previous analytical data is available, from least to greatest contamination. This procedure is required to limit the potential of cross contamination between sampling points.

2.1 Set-Up

A clean sheet of plastic will be placed around the well to provide a clean surface for sampling equipment. The total well depth read from the well tag and the measured depth to water, determined using the water level indicator, will be used to compute the depth of water in the well. The total well depth will be measured and compared to the depth indicated on the well tag as a check for silt buildup or blockage at depth.

All meters used to monitor purge parameters will be calibrated immediately prior to purging and sampling, and those readings recorded in a field logbook. Entries will always include pre- and post- calibration readings as well as the model and serial number of the equipment and the date, time, and person performing the calibration(s). Two standards, which bracket the average or suspected measurements for pH and specific conductance, will be used at the site. Since natural waters (including those impacted by environmental contaminants) tend to have pH values less than 7.0, pH buffers of 4.0 and 7.0 will typically be used for instrument calibration.

Disposable nitrile gloves will be worn by the field technician during sampling to minimize the risk of personal exposure to potentially harmful chemical substances and to minimize the risk of sample cross-contamination.

Fresh pairs of nitrile gloves will be worn during each purge and sampling event. The groundwater samples will be transferred from the bailers into method-specific and appropriately preserved containers and placed into a clean cooler containing ice to chill the samples to a temperature of approximately 4°C.

Indicator parameters such as pH, temperature and specific conductance will be measured during purging as an indication that groundwater representative of the formation surrounding a given well is being sampled. Purging is considered complete when at least three well volumes have been purged and indicator parameters have stabilized such that three successive readings vary by no more than 10%. Purging may need to be continued beyond five well volumes if indicator parameters have not stabilized. All information will be recorded on a field data sheet or in a field logbook with copies submitted to the Division of Waste Management with the analytical results.

2.2 Purging

Each well will be purged of approximately three (3) to five (5) volumes of standing water and allowed to settle prior to collection of groundwater samples. If the well should go dry and not recharge before the requisite well volumes are removed, the well will be allowed to recharge and a sample will be collected within 24 hours of the initial purging. The amount of standing water will be calculated by first subtracting the depth-to-water from total well depth. The amount of water in the well (in gallons) will then be determined by using the chart on **Plate C**. For example, a two-inch well that is 29 feet deep and contains 19 feet of standing water will have a well volume of ~3.3 gallons.

After determination of the amount of water to be purged from a given well, the equipment necessary for purging will be assembled at the well. The disposable bailer will be maintained in a stable, upright position while the upper portion of the plastic wrapping will be pulled away to expose only the eyelet used for securing twine to the bailer. After the twine has been secured to the bailer with gloved hands, the bailer will be suspended as the remaining plastic is removed. The bailer will be lowered slowly into the well until the bailer contacts groundwater. The bailer twine will then be cut to an adequate length and secured to prevent loss of the bailer in the well. At no time during purging will the bailer twine be allowed to touch the ground. In order to not allow the twine to touch the ground during purging, the twine will be collected when raising the bailer either by loops gathered in one hand or by alternating hand-to-hand as the bailer is pulled from the well. When purging deep wells (in excess of 40 feet), the ground and the well head may be covered with a clean plastic bag or sheet of plastic with a slit cut to allow the plastic to slide over the well head. This will be a separate sheet of plastic from the one used for the sampling equipment.

2.3 Groundwater Sample Collection

The bailer will be lowered slowly into the well to avoid volatilization of any dissolved-phase compounds that may be present in the groundwater. Once full, the bailer will be retrieved and containers filled by emptying the water through the hole at the bottom of the bailer. Glass 40-mL vials for VOC analyses will be filled in such a manner as to produce zero headspace in the vials. Polyethylene containers for metals analyses will be filled and sealed with the cap, leaving about ½-inch of airspace at the top. In addition to collecting the samples, water will be collected in the wide-mouth container for pH, temperature, and conductivity measurements. Upon completion of sampling, all groundwater samples, including equipment and trip blanks, will be placed in labeled and sealed plastic bags and stored in ice-filled coolers to chill the samples to 4°C pending transport to a NCDENR-certified analytical laboratory. Contaminated nitrile gloves and twine will be discarded.

2.4 Surface Water Sample Collection

Surfacewater sampling will be taken with given consideration to minimize turbulence and aeration. As during groundwater sampling, surfacewater samples will be collected by a field technician wearing disposable gloves. Containers will be dipped at sampling location points by gently dipping the sample container into surfacewater and allowing surfacewater to flow over the mouth of container so as not to displace any preservative within the sample container. If there is little current movement, the container will be moved slowly through the water laterally. During times of low water, if the water is not deep enough to allow filling of sample containers, an appropriately decontaminated sampling cup will be used to retrieve the sample. All containers will be treated in the same manner as the groundwater samples. The samples will be sealed in labeled, plastic bags, and stored in an ice-filled cooler to chill the samples to 4°C pending transport to a NCDENR-certified analytical laboratory.

2.5 Chain of Custody

Chain-of-custody forms will be used to document the handling of all samples collected and listing all individuals who have taken possession of a given set of samples, including field personnel, laboratory couriers, and laboratory personnel. Trip blanks, equipment blanks, and sample containers will all travel and be stored together. Trip blanks will remain in the condition they are received from the laboratory and will not be opened or tampered with during the sampling. A chain-of-custody record will be completed for each day's samples, indicating the date and time, sample location, sample matrix (soil, water, etc.), and laboratory analyses to be conducted.

3 ANALYSIS

When the water samples reach the laboratory, they will be transferred to a sample custodian who will sign the chain of custody documentation as receipt of the samples. Internal control of the water samples in the laboratory will be in accordance with QA/QC procedures for the laboratory. Copies of QA/QC manuals for approved laboratories are on file at the Division of Solid Waste.

Groundwater and surface water samples will be analyzed for the Appendix I list of constituents; QA/QC procedures utilized during the testing will be in conformance with the laboratory QA/QC manual. Monitoring wells MW-1, MW-2, MW-3, MW-4R, MW-5R, MW-6, MW-7, MW-8D, MW-9, MW-10, MW-11, MW-12, MW-24, and MW-25 will be sampled for the Appendix I constituent list. Additionally, monitoring wells MW-2, MW-3, MW-6, MW-7, MW-9, MW-10, MW-24, and MW-25 will be sampled for the aforementioned MNA performance parameters.

4 CONCLUSION

This report is included as part of the Corrective Action Plan for the City of Albemarle C&D Landfill. The ground and surfacewater monitoring plan is designed to be effective in the early detection of any possible release of hazardous constituents to the unconfined surficial and upper bedrock aquifers, and to provide indicator parameters of the natural degradation, HRC injection, and phytoremediation processes.

MUNICIPAL ENGINEERING SERVICES COMPANY, P.A.

NORTH CAROLINA LICENSED SEAL 1776 GEOLOGIST SEAN K. PATRICK 2/13/09

Sean K. Patrick, P.G.
Professional Geologist

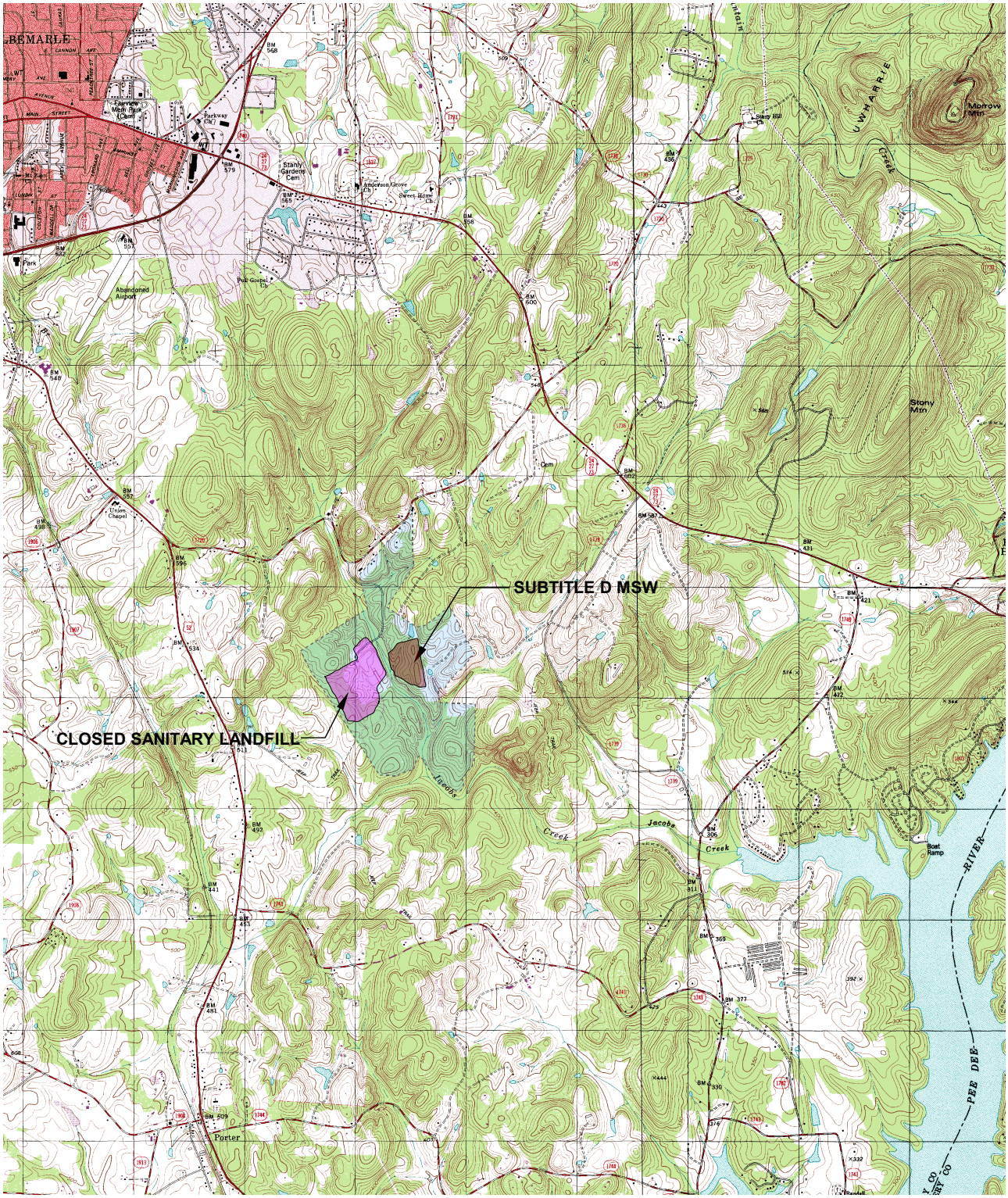
Table E-1. Summary of Ground and Surfacewater Monitoring Points

Sampling Point	Type	Gradient	Total Depth (ft)	Designation
MW-1	Monitoring Well	Upgradient	18	Background Well
MW-2	Monitoring Well	Down	17.5	Performance Well
MW-3	Monitoring Well	Down	22.5	Performance Well
MW-4R	Monitoring Well	Down	34.4	Monitoring Well
MW-5R	Monitoring Well	Down	25	Monitoring Well
MW-6	Monitoring Well	Down	35.5	Performance Well
MW-7	Monitoring Well	Down	27.9	Performance Well
MW-8D	Monitoring Well	Down	75.9	Monitoring Well
MW-9	Monitoring Well	Down	16.1	Performance Well
MW-10	Monitoring Well	Down	17.7	Performance Well
MW-11	Monitoring Well	Down	17.24	Sentinel Well
MW-12	Monitoring Well	Down	21.96	Performance Well
MW-24	Monitoring Well	Down	21.25	Sentinel/Compliance Well
MW-25	Monitoring Well	Down	18.2	Sentinel/Compliance Well
SW-1	Surface Water	Upstream	-	Tributary – MSW landfill
SW-2	Surface Water	Upstream	-	Tributary – MSW landfill
SW-3	Surface Water	Upstream	*dry*	Tributary - C&D landfill
SW-4	Surface Water	Upstream	*dry*	Tributary - C&D landfill
SW-5	Surface Water	Downstream	-	Tributary - C&D landfill
SW-6	Surface Water	Downstream	-	Tributary – MSW landfill
SW-7	Surface Water	Midstream	-	Tributary – MSW landfill

Topographic Map with Landfill Location

City of Albemarle Landfill

PLATE A



QUADRANGLE LEGEND

ROAD CLASSIFICATION

Primary highway, hard surface

Light-duty road, hard or improved surface

Secondary highway, hard surface

Unimproved road

Interstate Route

U. S. Route

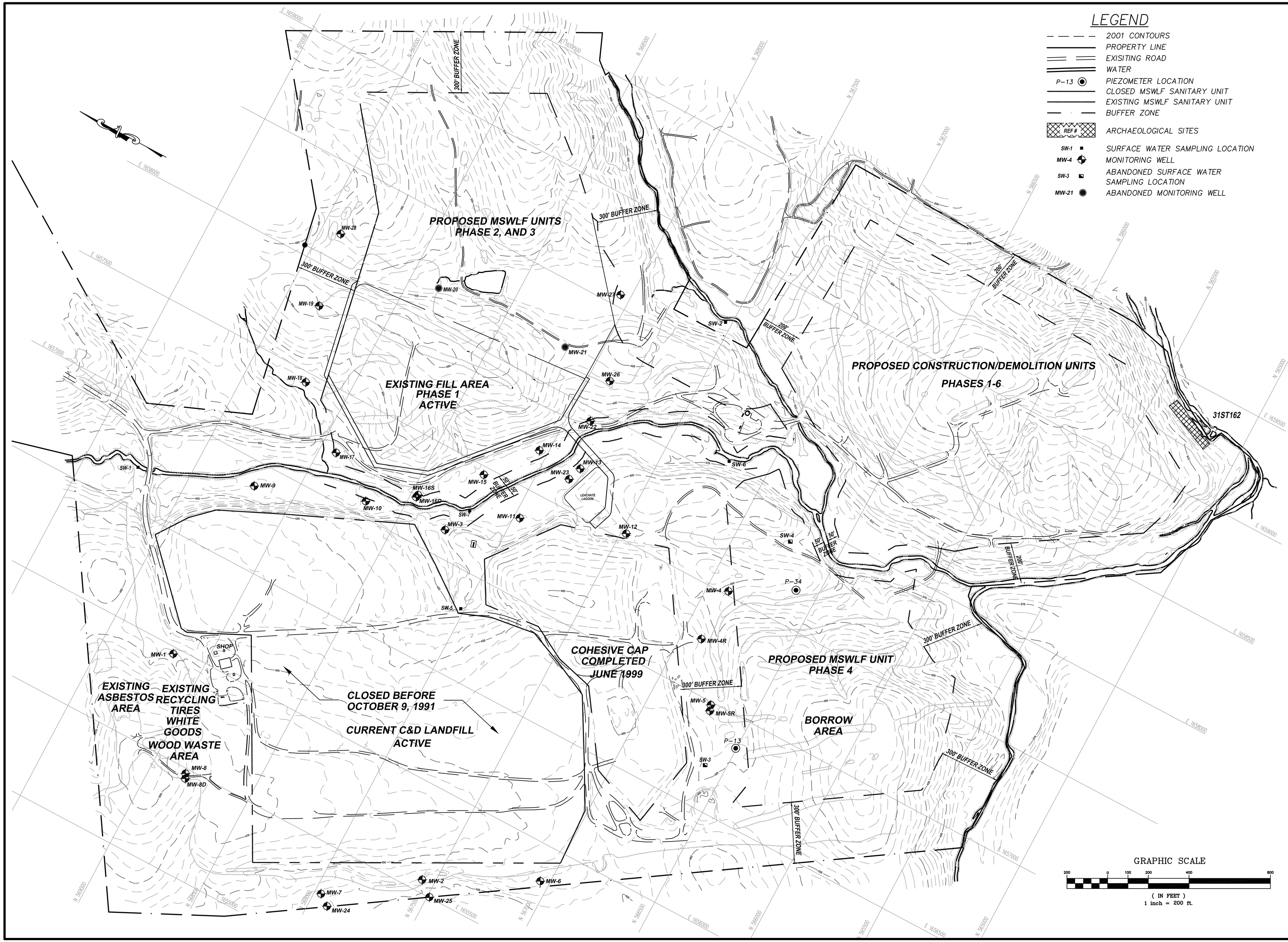
State Route

NOTE: Topographical map assembled from corresponding USGS 7.5-min. quadrangles of the subject region.

Date Completed	06/24/2008
Created By	M. German
Project Name	Sampling and Analysis Plan
Site Name	City of Albemarle Landfill
Project Number	G07059.0

Municipal Engineering Services Company, PA

1 0 1 MILE



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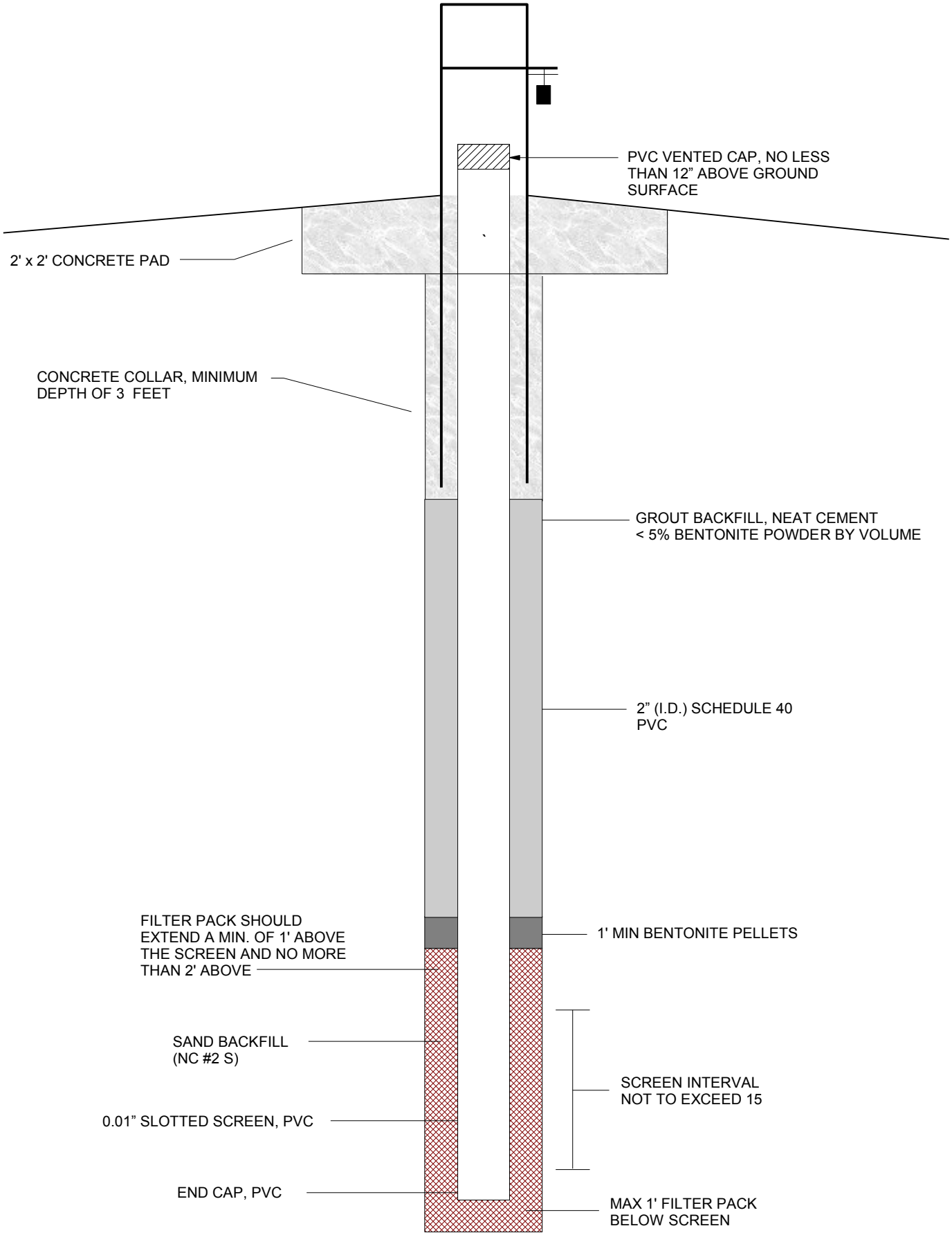
CLOSED MSWLF AND ACTIVE C&D LANDFILL FACILITY
CITY OF ALBEMARLE NORTH CAROLINA

DATE	BY	REV.	DESCRIPTION

SITE MAP W/ SAMPLING LOCATIONS

SCALE:	1"=200'
DATE:	6/30/2008
DRWN. BY:	E. CALDWELL
CHKD. BY:	S. PATRICK
PROJECT NUMBER	G07059.0
DRAWING NO.	PLATE B
SHEET NO.	1 of 1

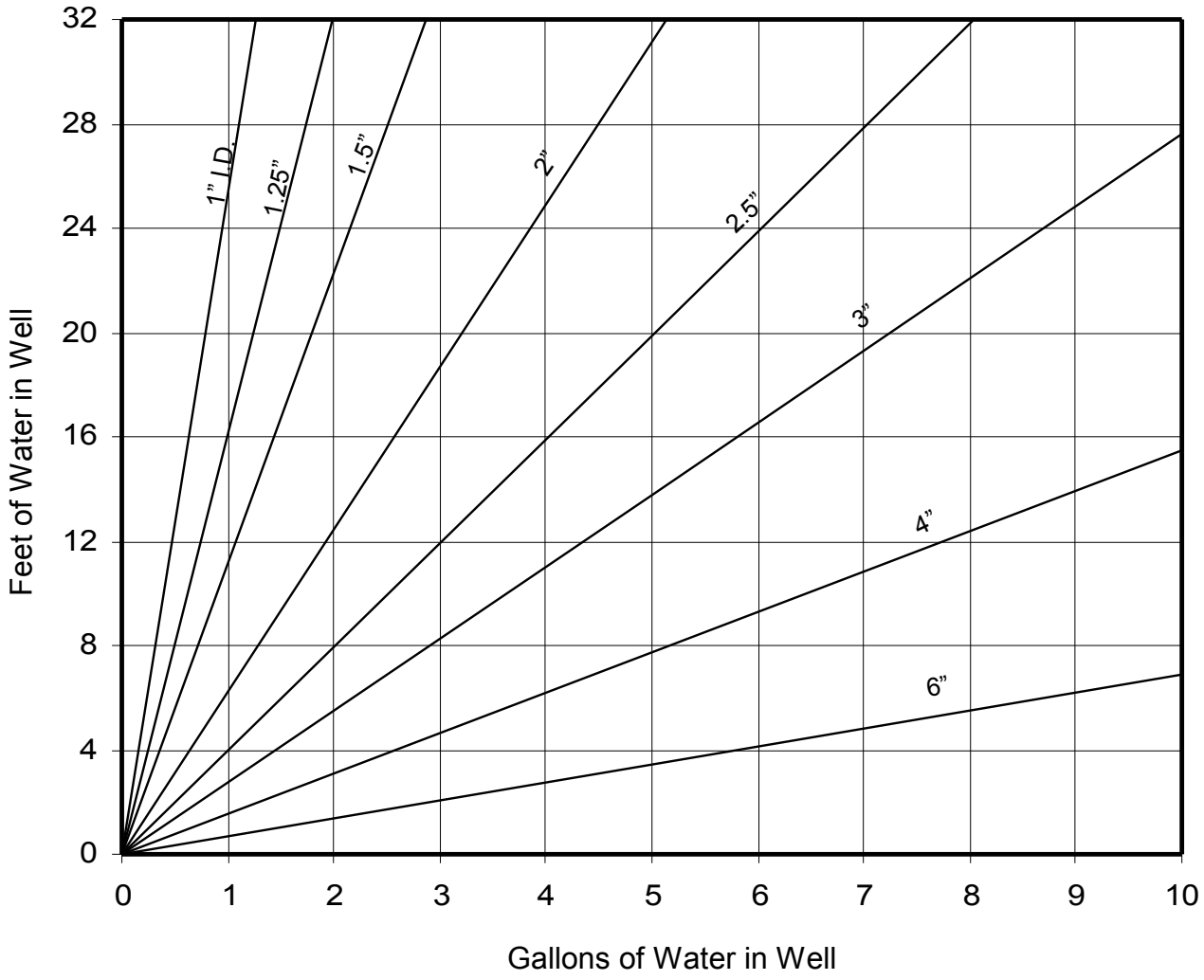
H:\C&D CAP\City of Albemarle\Albemarle CAP - Revised\CAD\Plate B - SAP Facility Map.dwg, 2/12/2009 2:31:07 PM, SKP,SKP



NOTE: SHALLOW WELLS REQUIRE A MINIMUM OF 5' COMBINED THICKNESS OF GROUT AND BENTONITE.

TYPICAL MONITORING WELL

PLATE C



GRAPHICAL PLOT OF STANDING VOLUMES OF WATER

PLATE D

NCDENR SOLID WASTE SECTION
SAMPLING GUIDANCE

Solid Waste Section
Guidelines for Groundwater, Soil, and Surface Water Sampling

STATE OF NORTH CAROLINA
DEPARTMENT OF ENVIRONMENT AND NATURAL RESOURCES
DIVISION OF WASTE MANAGEMENT
SOLID WASTE SECTION

General Sampling Procedures

The following guidance is provided to insure a consistent sampling approach so that sample collection activities at solid waste management facilities provide reliable data. Sampling must begin with an evaluation of facility information, historical environmental data and site geologic and hydrogeologic conditions. General sampling procedures are described in this document.

Planning

Begin sampling activities with planning and coordination. The party contracting with the laboratory is responsible for effectively communicating reporting requirements and evaluating data reliability as it relates to specific monitoring activities.

Sample Collection

<u>Contamination Prevention</u>

a.) Take special effort to prevent cross contamination or environmental contamination when collecting samples.
    1. If possible, collect samples from the least contaminated sampling location (or background sampling location, if applicable) to the most contaminated sampling location.
    2. Collect the ambient or background samples first, and store them in separate ice chests or separate shipping containers within the same ice chest (e.g. untreated plastic bags).
    3. Collect samples in flowing water at designated locations from upstream to downstream.

b.) Do not store or ship highly contaminated samples (concentrated wastes, free product, etc.) or samples suspect of containing high concentrations of contaminants in the same ice chest or shipping containers with other environmental samples.
    1. Isolate these sample containers by sealing them in separate, untreated plastic bags immediately after collecting, preserving, labeling, etc.
    2. Use a clean, untreated plastic bag to line the ice chest or shipping container.

c.) All sampling equipment should be thoroughly decontaminated and transported in a manner that does not allow it to become contaminated. Arrangements should be made ahead of time to decontaminate any sampling or measuring equipment that will be reused when taking samples from more than one well. Field decontamination of

sampling equipment will be necessary before sampling each well to minimize the risk of cross contamination. Decontamination procedures should be included in reports as necessary. Certified pre-cleaned sampling equipment and containers may be used. When collecting aqueous samples, rinse the sample collection equipment with a portion of the sample water before taking the actual sample. Sample containers do not need to be rinsed. In the case of petroleum hydrocarbons, oil and grease, or containers with pre-measured preservatives, the sample containers cannot be rinsed.

d.) Place all fuel-powered equipment away from, and downwind of, any site activities (e.g., purging, sampling, decontamination).

1. If field conditions preclude such placement (i.e., the wind is from the upstream direction in a boat), place the fuel source(s) as far away as possible from the sampling activities and describe the conditions in the field notes.
2. Handle fuel (i.e., filling vehicles and equipment) prior to the sampling day. If such activities must be performed during sampling, the personnel must wear disposable gloves.
3. Dispense all fuels downwind. Dispose of gloves well away from the sampling activities.

<u>Filling Out Sample Labels</u>

Fill out label, adhere to vial and collect sample. Print legibly with indelible ink. At a minimum, the label or tag should identify the sample with the following information:

1. Sample location and/or well number
2. Sample identification number
3. Date and time of collection
4. Analysis required/requested
5. Sampler's initials
6. Preservative(s) used, if any [i.e., HCl, $Na_2S_2O_3$, NO_3, ice, etc.]
7. Any other pertinent information for sample identification

<u>Sample Collection Order</u>

Unless field conditions justify other sampling regimens, collect samples in the following order:

1. Volatile Organics and Volatile Inorganics
2. Extractable Organics, Petroleum Hydrocarbons, Aggregate Organics and Oil and Grease
3. Total Metals
4. Inorganic Nonmetallics, Physical and Aggregate Properties, and Biologicals
5. Microbiological

NOTE: *If the pump used to collect groundwater samples cannot be used to collect volatile or extractable organics then collect all other parameters and withdraw the pump and tubing. Then collect the volatile and extractable organics.*

Health and Safety

Implement all local, state, and federal requirements relating to health and safety. Follow all local, state and federal requirements pertaining to the storage and disposal of any hazardous or investigation derived wastes.

a.) The Solid Waste Section recommends wearing protective gloves when conducting all sampling activities.

1. Gloves serve to protect the sample collector from potential exposure to sample constituents, minimize accidental contamination of samples by the collector, and preserve accurate tare weights on preweighed sample containers.
2. Do not let gloves come into contact with the sample or with the interior or lip of the sample container. Use clean, new, unpowdered and disposable gloves. Various types of gloves may be used as long as the construction materials do not contaminate the sample or if internal safety protocols require greater protection.
3. Note that certain materials that may potentially be present in concentrated effluent can pass through certain glove types and be absorbed in the skin. Many vendor catalogs provide information about the permeability of different gloves and the circumstances under which the glove material might be applicable. The powder in powdered gloves can contribute significant contamination. Powdered gloves are not recommended unless it can be demonstrated that the powder does not interfere with the sample analysis.
4. Change gloves after preliminary activities, after collecting all the samples at a single sampling point, if torn or used to handle extremely dirty or highly contaminated surfaces. Properly dispose of all used gloves as investigation derived wastes.

b.) Properly manage all investigation derived waste (IDW).

5. To prevent contamination into previously uncontaminated areas, properly manage all IDW. This includes all water, soil, drilling mud, decontamination wastes, discarded personal protective equipment (PPE), etc. from site investigations, exploratory borings, piezometer and monitoring well installation, refurbishment, abandonment, and other investigative activities. Manage all IDW that is determined to be RCRA-regulated hazardous waste according to the local, state and federal requirements.
6. Properly dispose of IDW that is not a RCRA-regulated hazardous waste but is contaminated above the Department's Soil Cleanup Target Levels or the state standards and/or minimum criteria for ground water quality. If the drill cuttings/mud orpurged well water is contaminated with hazardous waste, contact the DWM Hazardous Waste Section (919-508-8400) for disposal options. Maintain all containers holding IDW in good condition. Periodically inspect the containers for damage and ensure that all required labeling (DOT, RCRA, etc.) are clearly visible.

Sample Storage and Transport

Store samples for transport carefully. Pack samples to prevent from breaking and to maintain a temperature of approximately 4 degrees Celsius (°C), adding ice if necessary. Transport samples to a North Carolina-certified laboratory as soon as possible. Avoid unnecessary handling of sample containers. Avoid heating (room temperature or above, including exposure to sunlight) or freezing of the sample containers. Reduce the time between sample collection and delivery to a laboratory whenever possible and be sure that the analytical holding times of your samples can be met by the laboratory.

a.) A complete chain-of-custody (COC) form must be maintained to document all transfers and receipts of the samples. Be sure that the sample containers are labeled with the sample location and/or well number, sample identification, the date and time of collection, the analysis to be performed, the preservative added (if any), the sampler's initials, and any other pertinent information for sample identification. The labels should contain a unique identifier (i.e., unique well numbers) that can be traced to the COC form. The details of sample collection must be documented on the COC. The COC must include the following:

1. Description of each sample (including QA/QC samples) and the number of containers (sample location and identification)
2. Signature of the sampler
3. Date and time of sample collection
4. Analytical method to be performed
5. Sample type (i.e., water or soil)
6. Regulatory agency (i.e., NCDENR/DWM – SW Section)
7. Signatures of all persons relinquishing and receiving custody of the samples
8. Dates and times of custody transfers

b.) Pack samples so that they are segregated by site, sampling location or by sample analysis type. When COC samples are involved, segregate samples in coolers by site. If samples from multiple sites will fit in one cooler, they may be packed in the same cooler with the associated field sheets and a single COC form for all. Coolers should not exceed a maximum weight of 50 lbs. Use additional coolers as necessary. All sample containers should be placed in plastic bags (segregated by analysis and location) and completely surrounded by ice.

1. Prepare and place trip blanks in an ice filled cooler before leaving for the field.
2. Segregate samples by analysis and place in sealable plastic bags.
3. Pack samples carefully in the cooler placing ice around the samples.
4. Review the COC. The COC form must accompany the samples to the laboratory. The trip blank(s) must also be recorded on the COC form.
5. Place completed COC form in a waterproof bag, sealed and taped under the lid of the cooler.
6. Secure shipping containers with strapping tape to avoid accidental opening.
7. For COC samples, a tamper-proof seal may also be placed over the cooler lid or over a bag or container containing the samples inside the shipping cooler.

8. "COC" or "EMERG" should be written in indelible ink on the cooler seal to alert sample receipt technicians to priority or special handling samples.
9. The date and sample handler's signature must also be written on the COC seal.
10. Deliver the samples to the laboratory or ship by commercial courier.
    NOTE*: If transport time to the laboratory is not long enough to allow samples to be cooled to 4° C, a temperature reading of the sample source must be documented as the field temperature on the COC form. A downward trend in temperature will be adequate even if cooling to 4° C is not achieved. The field temperature should always be documented if there is any question as to whether samples will have time to cool to 4° C during shipment. Thermometers must be calibrated annually against an NIST traceable thermometer and documentation must be retained.*

Appendix A - Decontamination of Field Equipment

Decontamination of personnel, sampling equipment, and containers - before and after sampling - must be used to ensure collection of representative samples and to prevent the potential spread of contamination. Decontamination of personnel prevents ingestion and absorption of contaminants. It must be done with a soap and water wash and deionized or distilled water rinse. Certified pre-cleaned sampling equipment and containers may also be used.

All previously used sampling equipment must be properly decontaminated before sampling and between sampling locations. This prevents the introduction of contamination into uncontaminated samples and avoids cross-contamination of samples. Cross-contamination can be a significant problem when attempting to characterize extremely low concentrations of organic compounds or when working with soils that are highly contaminated.

Clean, solvent-resistant gloves and appropriate protective equipment must be worn by persons decontaminating tools and equipment.

Cleaning Reagents

Recommendations for the types and grades of various cleaning supplies are outlined below. The recommended reagent types or grades were selected to ensure that the cleaned equipment is free from any detectable contamination.

a.) Detergents: Use Liqui-Nox (or a non-phosphate equivalent) or Alconox (or equivalent). Liqui-Nox (or equivalent) is recommended by EPA, although Alconox (or equivalent) may be substituted if the sampling equipment will not be used to collect phosphorus or phosphorus containing compounds.

b.) Solvents: Use pesticide grade isopropanol as the rinse solvent in routine equipment cleaning procedures. This grade of alcohol must be purchased from a laboratory supply vendor. Rubbing alcohol or other commonly available sources of isopropanol **are not acceptable**. Other solvents, such as acetone or methanol, may be used as the final rinse solvent if they are pesticide grade. However, methanol is more toxic to the environment and acetone may be an analyte of interest for volatile organics.

1. **Do not** use acetone if volatile organics are of interest
2. Containerize all methanol wastes (including rinses) and dispose as a hazardous waste.

Pre-clean equipment that is heavily contaminated with organic analytes. Use reagent grade acetone and hexane or other suitable solvents. Use pesticide grade methylene chloride when cleaning sample containers. Store all solvents away from potential sources of contamination.

c.) Analyte-Free Water Sources: Analyte-free water is water in which all analytes of interest and all interferences are below method detection limits. Maintain documentation (such as results from equipment blanks) to demonstrate the reliability and purity of analyte-free water source(s). The source of the water must meet the requirements of the analytical method and must be free from the analytes of interest. In general, the following water types are associated with specific analyte groups:

1. *Milli-Q (or equivalent polished water)*: suitable for all analyses.

2. *Organic-free*: suitable for volatile and extractable organics.
3. *Deionized water*: may not be suitable for volatile and extractable organics.
4. *Distilled water*: not suitable for volatile and extractable organics, metals or ultratrace metals.

Use analyte-free water for blank preparation and the final decontamination water rinse. In order to minimize long-term storage and potential leaching problems, obtain or purchase analyte-free water just prior to the sampling event. If obtained from a source (such as a laboratory), fill the transport containers and use the contents for a single sampling event. Empty the transport container(s) at the end of the sampling event. Discard any analyte-free water that is transferred to a dispensing container (such as a wash bottle or pump sprayer) at the end of each sampling day.

d.) Acids:

1. *Reagent Grade Nitric Acid*: 10 - 15% (one volume concentrated nitric acid and five volumes deionized water). Use for the acid rinse unless nitrogen components (e.g., nitrate, nitrite, etc.) are to be sampled. If sampling for ultra-trace levels of metals, use an ultra-pure grade acid.
2. *Reagent Grade Hydrochloric Acid*: 10% hydrochloric acid (one volume concentrated hydrochloric and three volumes deionized water). Use when nitrogen components are to be sampled.
3. If samples for both metals and the nitrogen-containing components are collected with the equipment, use the hydrochloric acid rinse, or thoroughly rinse with hydrochloric acid after a nitric acid rinse. If sampling for ultra trace levels of metals, use an ultra-pure grade acid.
4. Freshly prepared acid solutions may be recycled during the sampling event or cleaning process. Dispose of any unused acids according to local ordinances.

Reagent Storage Containers

The contents of all containers must be clearly marked.

a.) Detergents:

1. Store in the original container or in a HDPE or PP container.

b.) Solvents:

1. Store solvents to be used for cleaning or decontamination in the original container until use in the field. If transferred to another container for field use, use either a glass or Teflon container.
2. Use dispensing containers constructed of glass, Teflon or stainless steel. Note: If stainless steel sprayers are used, any gaskets that contact the solvents must be constructed of inert materials.

c.) Analyte-Free Water:

1. Transport in containers appropriate for the type of water stored. If the water is commercially purchased (e.g., grocery store), use the original containers when transporting the water to the field. Containers made of glass, Teflon, polypropylene or HDPE are acceptable.
2. Use glass or Teflon to transport organic-free sources of water on-site. Polypropylene or HDPE may be used, but are not recommended.

3. Dispense water from containers made of glass, Teflon, HDPE or polypropylene.
4. Do not store water in transport containers for more than three days before beginning a sampling event.
5. If working on a project that has oversight from EPA Region 4, use glass containers for the transport and storage of all water.
6. Store and dispense acids using containers made of glass, Teflon or plastic.

General Requirements

a.) Prior to use, clean/decontaminate all sampling equipment (pumps, tubing, lanyards, split spoons, etc.) that will be exposed to the sample.

b.) Before installing, clean (or obtain as certified pre-cleaned) all equipment that is dedicated to a single sampling point and remains in contact with the sample medium (e.g., permanently installed groundwater pump). If you use certified pre-cleaned equipment no cleaning is necessary.

1. Clean this equipment any time it is removed for maintenance or repair.
2. Replace dedicated tubing if discolored or damaged.

c.) Clean all equipment in a designated area having a controlled environment (house, laboratory, or base of field operations) and transport it to the field, pre-cleaned and ready to use, unless otherwise justified.

d.) Rinse all equipment with water after use, even if it is to be field-cleaned for other sites. Rinse equipment used at contaminated sites or used to collect in-process (e.g., untreated or partially treated wastewater) samples immediately with water.

e.) Whenever possible, transport sufficient clean equipment to the field so that an entire sampling event can be conducted without the need for cleaning equipment in the field.

f.) Segregate equipment that is only used once (i.e., not cleaned in the field) from clean equipment and return to the in-house cleaning facility to be cleaned in a controlled environment.

g.) Protect decontaminated field equipment from environmental contamination by securely wrapping and sealing with one of the following:

1. Aluminum foil (commercial grade is acceptable)
2. Untreated butcher paper
3. Clean, untreated, disposable plastic bags. Plastic bags may be used for all analyte groups except volatile and extractable organics. Plastic bags may be used for volatile and extractable organics, if the equipment is first wrapped in foil or butcher paper, or if the equipment is completely dry.

Cleaning Sample Collection Equipment

a.) <u>On-Site/In-Field Cleaning</u> – Cleaning equipment on-site is not recommended because environmental conditions cannot be controlled and wastes (solvents and acids) must be containerized for proper disposal.

1. Ambient temperature water may be substituted in the hot, sudsy water bath and hot water rinses.

NOTE: Properly dispose of all solvents and acids.

2. Rinse all equipment with water after use, even if it is to be field-cleaned for other sites.
3. Immediately rinse equipment used at contaminated sites or used to collect in-process (e.g., untreated or partially treated wastewater) samples with water.

b.) Heavily Contaminated Equipment - In order to avoid contaminating other samples, isolate heavily contaminated equipment from other equipment and thoroughly decontaminate the equipment before further use. Equipment is considered heavily contaminated if it:

1. Has been used to collect samples from a source known to contain significantly higher levels than background.
2. Has been used to collect free product.
3. Has been used to collect industrial products (e.g., pesticides or solvents) or their byproducts.

NOTE: *Cleaning heavily contaminated equipment in the field is not recommended.*

c.) On-Site Procedures:

1. Protect all other equipment, personnel and samples from exposure by isolating the equipment immediately after use.
2. At a minimum, place the equipment in a tightly sealed, untreated, plastic bag.
3. Do not store or ship the contaminated equipment next to clean, decontaminated equipment, unused sample containers, or filled sample containers.
4. Transport the equipment back to the base of operations for thorough decontamination.
5. If cleaning must occur in the field, document the effectiveness of the procedure, collect and analyze blanks on the cleaned equipment.

d.) Cleaning Procedures:

1. If organic contamination cannot be readily removed with scrubbing and a detergent solution, pre-rinse equipment by thoroughly rinsing or soaking the equipment in acetone.
2. Use hexane only if preceded and followed by acetone.
3. In extreme cases, it may be necessary to steam clean the field equipment before proceeding with routine cleaning procedures.
4. After the solvent rinses (and/or steam cleaning), use the appropriate cleaning procedure. Scrub, rather than soak, all equipment with sudsy water. If high levels of metals are suspected and the equipment cannot be cleaned without acid rinsing, soak the equipment in the appropriate acid. Since stainless steel equipment should not be exposed to acid rinses, do not use stainless steel equipment when heavy metal contamination is suspected or present.
5. If the field equipment cannot be cleaned utilizing these procedures, discard unless further cleaning with stronger solvents and/or oxidizing solutions is effective as evidenced by visual observation and blanks.
6. Clearly mark or disable all discarded equipment to discourage use.

e.) General Cleaning - Follow these procedures when cleaning equipment under controlled conditions. Check manufacturer's instructions for cleaning restrictions and/or recommendations.

1. *Procedure for Teflon, stainless steel and glass sampling equipment*: This procedure must be used when sampling for ALL analyte groups. (Extractable organics, metals, nutrients, etc. or if a single decontamination protocol is desired to clean all Teflon, stainless steel and glass equipment.) Rinse equipment with hot tap water. Soak equipment in a hot, sudsy water solution (Liqui-Nox or equivalent). If necessary, use a brush to remove particulate matter or surface film. Rinse thoroughly with hot tap water. If samples for trace metals or inorganic analytes will be collected with the equipment that is not stainless steel, thoroughly rinse (wet all surfaces) with the appropriate acid solution. Rinse thoroughly with analyte-free water. Make sure that all equipment surfaces are thoroughly flushed with water. If samples for volatile or extractable organics will be collected, rinse with isopropanol. Wet equipment surfaces thoroughly with free-flowing solvent. Rinse thoroughly with analyte-free water. Allow to air dry. Wrap and seal as soon as the equipment has air-dried. If isopropanol is used, the equipment may be air-dried without the final analyte-free water rinse; however, the equipment must be completely dry before wrapping or use. Wrap clean sampling equipment according to the procedure described above.
2. *General Cleaning Procedure for Plastic Sampling Equipment*: Rinse equipment with hot tap water. Soak equipment in a hot, sudsy water solution (Liqui-Nox or equivalent). If necessary, use a brush to remove particulate matter or surface film. Rinse thoroughly with hot tap water. Thoroughly rinse (wet all surfaces) with the appropriate acid solution. Check manufacturer's instructions for cleaning restrictions and/or recommendations. Rinse thoroughly with analyte-free water. Be sure that all equipment surfaces are thoroughly flushed. Allow to air dry as long as possible. Wrap clean sampling equipment according to the procedure described above.

Appendix B - Collecting Soil Samples

Soil samples are collected for a variety of purposes. A methodical sampling approach must be used to assure that sample collection activities provide reliable data. Sampling must begin with an evaluation of background information, historical data and site conditions.

Soil Field Screening Procedures

Field screening is the use of portable devices capable of detecting petroleum contaminants on a real-time basis or by a rapid field analytical technique. Field screening should be used to help assess locations where contamination is most likely to be present.

When possible, field-screening samples should be collected directly from the excavation or from the excavation equipment's bucket. If field screening is conducted only from the equipment's bucket, then a minimum of one field screening sample should be collected from each 10 cubic yards of excavated soil. If instruments or other observations indicate contamination, soil should be separated into stockpiles based on apparent degrees of contamination. At a minimum, soil suspected of contamination must be segregated from soil observed to be free of contamination.

a.) Field screening devices – Many field screen instruments are available for detecting contaminants in the field on a rapid or real-time basis. Acceptable field screening instruments must be suitable for the contaminant being screened. The procdedure for field screening using photoionization detectors (PIDs) and flame ionization detectors (FIDs) is described below. If other instruments are used, a description of the instrument or method and its intended use must be provided to the Solid Waste Section. Whichever field screening method is chosen, its accuracy must be verified throughout the sampling process. Use appropriate standards that match the use intended for the data. Unless the Solid Waste Section indicates otherwise, wherever field screening is recommended in this document, instrumental or analytical methods of detection must be used, not olfactory or visual screening methods.

b.) Headspace analytical screening procedure for filed screening (semi-quantitative field screening) - The most commonly used field instruments for Solid Waste Section site assessments are FIDs and PIDs. When using FIDs and PIDs, use the following headspace screening procedure to obtain and analyze field-screening samples:

1. Partially fill (one-third to one-half) a clean jar or clean ziplock bag with the sample to be analyzed. The total capacity of the jar or bag may not be less than eight ounces (app. 250 ml), but the container should not be so large as to allow vapor diffusion and stratification effects to significantly affect the sample.
2. If the sample is collected from a spilt-spoon, it must be transferred to the jar or bag for headspace analysis immediately after opening the split-spoon. If the sample is collected from an excavation or soil pile, it must be collected from freshly uncovered soil.

3. If a jar is used, it must be quickly covered with clean aluminum foil or a jar lid; screw tops or thick rubber bands must be used to tightly seal the jar. If a zip lock bag is used, it must be quickly sealed shut.
4. Headspace vapors must be allowed to develop in the container for at least 10 minutes but no longer than one hour. Containers must be shaken or agitated for 15 seconds at the beginning and the end of the headspace development period to assist volatilization. Temperatures of the headspace must be warmed to at least 5° C (approximately 40° F) with instruments calibrated for the temperature used.
5. After headspace development, the instrument sampling probe must be inserted to a point about one-half the headspace depth. The container opening must be minimized and care must be taken to avoid the uptake of water droplets and soil particulates.
6. After probe insertion, the highest meter reading must be taken and recorded. This will normally occur between two and five seconds after probe insertion. If erratic meter response occurs at high organic vapor concentrations or conditions of elevated headspace moisture, a note to that effect must accompany the headspace data.
7. All field screening results must be documented in the field record or log book.

Soil Sample Collection Procedures for Laboratory Samples

The number and type of laboratory samples collected depends on the purpose of the sampling activity. Samples analyzed with field screening devices may not be substituted for required laboratory samples.

a.) General Sample Collection - When collecting samples from potentially contaminated soil, care should be taken to reduce contact with skin or other parts of the body. Disposable gloves should be worn by the sample collector and should be changed between samples to avoid cross-contamination. Soil samples should be collected in a manner that causes the least disturbance to the internal structure of the sample and reduces its exposure to heat, sunlight and open air. Likewise, care should be taken to keep the samples from being contaminated by other materials or other samples collected at the site. When sampling is to occur over an extended period of time, it is necessary to insure that the samples are collected in a comparable manner. All samples must be collected with disposable or clean tools that have been decontaminated. Disposable gloves must be worn and changed between sample collections. Sample containers must be filled quickly. Soil samples must be placed in containers in the order of volatility, for example, volatile organic aromatic samples must be taken first, organics next, then heavier range organics, and finally soil classification samples. Containers must be quickly and adequately sealed, and rims must be cleaned before tightening lids. Tape may be used only if known not to affect sample analysis. Sample containers must be clearly labeled. Containers must immediately be preserved according to procedures in this Section. Unless specified

otherwise, at a minimum, the samples must be immediately cooled to 4 ± 2°C and this temperature must be maintained throughout delivery to the laboratory.

b.) Surface Soil Sampling - Surface soil is generally classified as soil between the ground surface and 6-12 inches below ground surface. Remove leaves, grass and surface debris from the area to be sampled. Select an appropriate, pre-cleaned sampling device and collect the sample. Transfer the sample to the appropriate sample container. Clean the outside of the sample container to remove excess soil. Label the sample container, place on wet ice to preserve at 4°C, and complete the field notes.

c.) Subsurface Soil Sampling – The interval begins at approximately 12 inches below ground surface. Collect samples for volatile organic analyses. For other analyses, select an appropriate, pre-cleaned sampling device and collect the sample. Transfer the sample to the appropriate sample container. Clean the outside of the sample container to remove excess soil. Label the sample container, place on wet ice to preserve at 4°C, and complete field notes.

d.) Equipment for Reaching the Appropriate Soil Sampling Depth - Samples may be collected using a hollow stem soil auger, direct push, Shelby tube, split-spoon sampler, or core barrel. These sampling devices may be used as long as an effort is made to reduce the loss of contaminants through volatilization. In these situations, obtain a sufficient volume of so the samples can be collected without volatilization and disturbance to the internal structure of the samples. Samples should be collected from cores of the soil. Non-disposable sampling equipment must be decontaminated between each sample location. **NOTE:** *If a confining layer has been breached during sampling, grout the hole to land.*

e.) Equipment to Collect Soil Samples - Equipment and materials that may be used to collect soil samples include disposable plastic syringes and other "industry-standard" equipment and materials that are contaminant-free. Non-disposable sampling equipment must be decontaminated between each sample location.

Appendix C - Collecting Groundwater Samples

Groundwater samples are collected to identify, investigate, assess and monitor the concentration of dissolved contaminant constituents. To properly assess groundwater contamination, first install sampling points (monitoring wells, etc.) to collect groundwater samples and then perform specific laboratory analyses. All monitoring wells should be constructed in accordance with 15A NCAC 2C .0100 and sampled as outlined in this section. Groundwater monitoring is conducted using one of two methods:

1. Portable Monitoring: Monitoring that is conducted using sampling equipment that is discarded between sampling locations. Equipment used to collect a groundwater sample from a well such as bailers, tubing, gloves, and etc. are disposed of after sample collection. A new set of sampling equipment is used to collect a groundwater sample at the next monitor well.

2. Dedicated Monitoring: Monitoring that utilizes permanently affixed down-well and well head components that are capped after initial set-up. Most dedicated monitoring systems are comprised of an in-well submersible bladder pump, with air supply and sample discharge tubing, and an above-ground driver/controller for regulation of flow rates and volumes. The pump and all tubing housed within the well should be composed of Teflon or stainless steel components. This includes seals inside the pump, the pump body, and fittings used to connect tubing to the pump. Because ground water will not be in contact with incompatible constituents and because the well is sealed from the surface, virtually no contamination is possible from intrinsic sources during sampling and between sampling intervals. All dedicated monitoring systems must be approved by the Solid Waste Section before installation.

Groundwater samples may be collected from a number of different configurations. Each configuration is associated with a unique set of sampling equipment requirements and techniques:

1. Wells without Plumbing: These wells require equipment to be brought to the well to purge and sample unless dedicated equipment is placed in the well.

2. Wells with In-Place Plumbing: Wells with in-place plumbing do not require equipment to be brought to the well to purge and sample. In-place plumbing is generally considered permanent equipment routinely used for purposes other than purging and sampling, such as for water supply.

3. Air Strippers or Remedial Systems: These types of systems are installed as remediation devices.

Groundwater Sample Preparation

The type of sample containers used depends on the type of analysis performed. First, determine the type(s) of contaminants expected and the proper analytical method(s). Be sure to consult your selected laboratory for its specific needs and requirements prior to sampling.

Next, prepare the storage and transport containers (ice chest, etc.) before taking any samples so that each sample can be placed in a chilled environment immediately after collection.

Use groundwater purging and sampling equipment constructed of only non-reactive, non-leachable materials that are compatible with the environment and the selected analytes. In selecting groundwater purging and sampling equipment, give consideration to the depth of the well, the depth to groundwater, the volume of water to be evacuated, the sampling and purging technique, and the analytes of interest. Additional supplies, such as reagents and preservatives, may be necessary.

All sampling equipment (bailers, tubing, containers, etc.) must be selected based on its chemical compatibility with the source being sampled (e.g., water supply well, monitoring well) and the contaminants potentially present.

a.) Pumps - All pumps or pump tubing must be lowered and retrieved from the well slowly and carefully to minimize disturbance to the formation water. This is especially critical at the air/water interface.

1. *Above-Ground Pumps*
   - Variable Speed Peristaltic Pump: Use a variable speed peristaltic pump to purge groundwater from wells when the static water level in the well is no greater than 20- 25 feet below land surface (BLS). If the water levels are deeper than 18-20 feet BLS, the pumping velocity will decrease. A variable speed peristaltic pump can be used for normal purging and sampling, and sampling low permeability aquifers or formations. Most analyte groups can be sampled with a peristaltic pump if the tubing and pump configurations are appropriate.
   - Variable Speed Centrifugal Pump: A variable speed centrifugal pump can be used to purge groundwater from 2-inch and larger internal diameter wells. **Do not use** this type of pump to collect groundwater samples. When purging is complete, do not allow the water that remains in the tubing to fall back into the well. Install a check valve at the end of the purge tubing.
2. *Submersible Pumps*
   - Variable Speed Electric Submersible Pump: A variable speed submersible pump can be used to purge and sample groundwater from 2-inch and larger internal diameter wells. A variable speed submersible pump can be used for normal purging and sampling, and sampling low permeability aquifers or formations. The pump housing, fittings, check valves and associated hardware must be constructed of stainless steel. All other materials must be

compatible with the analytes of interest. Install a check valve at the output side of the pump to prevent backflow. If purging **and** sampling for organics, the entire length of the delivery tube must be Teflon, polyethylene or polypropylene (PP) tubing; the electrical cord must be sealed in Teflon, polyethylene or PP and any cabling must be sealed in Teflon, polyethylene or PP, or be constructed of stainless steel; and all interior components that contact the sample water (impeller, seals, gaskets, etc.) must be constructed of stainless steel or Teflon.

3. *Variable Speed Bladder Pump*: A variable speed, positive displacement, bladder pump can be used to purge and sample groundwater from 3/4-inch and larger internal diameter wells.
    - A variable speed bladder pump can be used for normal purging and sampling, and sampling low permeability aquifers or formations.
    - The bladder pump system is composed of the pump, the compressed air tubing, the water discharge tubing, the controller and a compressor, or a compressed gas supply.
    - The pump consists of a bladder and an exterior casing or pump body that surrounds the bladder and two (2) check valves. These parts can be composed of various materials, usually combinations of polyvinyl chloride (PVC), Teflon, polyethylene, PP and stainless steel. Other materials must be compatible with the analytes of interest.
    - If purging and sampling for organics, the pump body must be constructed of stainless steel. The valves and bladder must be Teflon, polyethylene or PP; the entire length of the delivery tube must be Teflon, polyethylene or PP; and any cabling must be sealed in Teflon, polyethylene or PP, or be constructed of stainless steel.
    - Permanently installed pumps may have a PVC pump body as long as the pump remains in contact with the water in the well.

b.) <u>Bailers</u>

1. *Purging*: Bailers must be used with caution because improper bailing can cause changes in the chemistry of the water due to aeration and loosening particulate matter in the space around the well screen. Use a bailer if there is non-aqueous phase liquid (free product) in the well or if non-aqueous phase liquid is suspected to be in the well.
2. *Sampling*: Bailers must be used with caution.
3. *Construction and Type*: Bailers must be constructed of materials compatible with the analytes of interest. Stainless steel, Teflon, rigid medical grade PVC, polyethylene and PP bailers may be used to sample all analytes. Use disposable bailers when sampling grossly contaminated sample sources. NCDENR recommends using dual check valve bailers when collecting samples. Use bailers with a controlled flow bottom to collect volatile organic samples.

4. *Contamination Prevention*: Keep the bailer wrapped (foil, butcher paper, etc.) until just before use. Use protective gloves to handle the bailer once it is removed from its wrapping. Handle the bailer by the lanyard to minimize contact with the bailer surface.

c.) Lanyards

1. Lanyards must be made of non-reactive, non-leachable material. They may be cotton twine, nylon, stainless steel, or may be coated with Teflon, polyethylene or PP.
2. Discard cotton twine, nylon, and non-stainless steel braided lanyards after sampling each monitoring well.
3. Decontaminate stainless steel, coated Teflon, polyethylene and PP lanyards between monitoring wells. They do not need to be decontaminated between purging and sampling operations.

Water Level and Purge Volume Determination

The amount of water that must be purged from a well is determined by the volume of water and/or field parameter stabilization.

a.) General Equipment Considerations - Selection of appropriate purging equipment depends on the analytes of interest, the well diameter, transmissivity of the aquifer, the depth to groundwater, and other site conditions.

1. Use of a pump to purge the well is recommended unless no other equipment can be used or there is non-aqueous phase liquid in the well, or non-aqueous phase liquid is suspected to be in the well.
2. Bailers must be used with caution because improper bailing:
    - Introduces atmospheric oxygen, which may precipitate metals (i.e., iron) or cause other changes in the chemistry of the water in the sample (i.e., pH).
    - Agitates groundwater, which may bias volatile and semi-volatile organic analyses due to volatilization.
    - Agitates the water in the aquifer and resuspends fine particulate matter.
    - Surges the well, loosening particulate matter in the annular space around the well screen.
    - May introduce dirt into the water column if the sides of the casing wall are scraped.

NOTE: *It is critical for bailers to be slowly and gently immersed into the top of the water column, particularly during the final stages of purging. This minimizes turbidity and disturbance of volatile organic constituents.*

b.) Initial Inspection

1. Remove the well cover and remove all standing water around the top of the well casing (manhole) before opening the well.
2. Inspect the exterior protective casing of the monitoring well for damage. Document the results of the inspection if there is a problem.
3. It is recommended that you place a protective covering around the well head. Replace the covering if it becomes soiled or ripped.

4. Inspect the well lock and determine whether the cap fits tightly. Replace the cap if necessary.

c.) Water Level Measurements - Use an electronic probe or chalked tape to determine the water level. Decontaminate all equipment before use. Measure the depth to groundwater from the top of the well casing to the nearest 0.01 foot. Always measure from the same reference point or survey mark on the well casing. Record the measurement.

1. *Electronic Probe*: Decontaminate all equipment before use. Follow the manufacturer's instructions for use. Record the measurement.
2. *Chalked Line Method*: Decontaminate all equipment before use. Lower chalked tape into the well until the lower end is in the water. This is usually determined by the sound of the weight hitting the water. Record the length of the tape relative to the reference point. Remove the tape and note the length of the wetted portion. Record the length. Determine the depth to water by subtracting the length of the wetted portion from the total length. Record the result.

d.) Water Column Determination - To determine the length of the water column, subtract the depth to the top of the water column from the total well depth (or gauged well depth if silting has occurred). The total well depth depends on the well construction. If gauged well depth is used due to silting, report total well depth also. Some wells may be drilled in areas of sinkhole, karst formations or rock leaving an open borehole. Attempt to find the total borehole depth in cases where there is an open borehole below the cased portion.

e.) Well Water Volume - Calculate the total volume of water, in gallons, in the well using the following equation:

$$V = (0.041)d \times d \times h$$

Where:

V = volume in gallons
d = well diameter in inches
h = height of the water column in feet

The total volume of water in the well may also be determined with the following equation by using a casing volume per foot factor (Gallons per Foot of Water) for the appropriate diameter well:

$$V = [\text{Gallons per Foot of Water}] \times h$$

Where:

V = volume in gallons
h = height of the water column in feet

Record all measurements and calculations in the field records.

f.) Purging Equipment Volume - Calculate the total volume of the pump, associated tubing and flow cell (if used), using the following equation:

$$V = p + ((0.041)d \times d \times l) + fc$$

Where:

V = volume in gallons
p = volume of pump in gallons
d = tubing diameter in inches
l = length of tubing in feet

fc = volume of flow cell in gallons

g.) If the groundwater elevation data are to be used to construct groundwater elevation contour maps, all water level measurements must be taken within the same 24 hour time interval when collecting samples from multiple wells on a site, unless a shorter time period is required. If the site is tidally influenced, complete the water level measurements within the time frame of an incoming or outgoing tide.

Well Purging Techniques

The selection of the purging technique and equipment is dependent on the hydrogeologic properties of the aquifer, especially depth to groundwater and hydraulic conductivity.

a.) Measuring the Purge Volume - The volume of water that is removed during purging must be recorded. Therefore, you must measure the volume during the purging operation.

1. Collect the water in a graduated container and multiply the number of times the container was emptied by the volume of the container, OR
2. Estimate the volume based on pumping rate. This technique may be used only if the pumping rate is constant. Determine the pumping rate by measuring the amount of water that is pumped for a fixed period of time, or use a flow meter.
    - Calculate the amount of water that is discharged per minute: D = Measured Amount/Total Time In Minutes
    - Calculate the time needed to purge one (1) well volume or one (1) purging equipment volume: Time = V/D
      Where: V = well volume or purging equipment volume
      D = discharge rate
    - Make new measurements each time the pumping rate is changed.
3. Use a totalizing flow meter.
    - Record the reading on the totalizer prior to purging.
    - Record the reading on the totalizer at the end of purging.
    - To obtain the volume purged, subtract the reading on the totalizer prior to purging from the reading on the totalizer at the end of purging.
    - Record the times that purging begins and ends in the field records.

b.) Purging Measurement Frequency - When purging a well that has the well screen fully submerged and the pump or intake tubing is placed within the well casing above the well screen or open hole, purge a minimum of one (1) well volume prior to collecting measurements of the field parameters. Allow at least one quarter (1/4) well volume to purge between subsequent measurements. When purging a well that has the pump or intake tubing placed within a fully submerged well screen or open hole, purge until the water level has stabilized (well recovery rate equals the purge rate), then purge a minimum of one (1) volume of the pump, associated tubing and flow cell (if used) prior to collecting measurements of the field parameters. Take measurements of the field parameters no sooner than two (2) to three (3) minutes apart. Purge at least

three (3) volumes of the pump, associated tubing and flow cell, if used, prior to collecting a sample. When purging a well that has a partially submerged well screen, purge a minimum of one (1) well volume prior to collecting measurements of the field parameters. Take measurements of the field parameters no sooner than two (2) to three (3) minutes apart.

c.) Purging Completion - Wells must be adequately purged prior to sample collection to ensure representation of the aquifer formation water, rather than stagnant well water. This may be achieved by purging three volumes from the well or by satisfying any one of the following three purge completion criteria:

1.) Three (3) consecutive measurements in which the three (3) parameters listed below are within the stated limits, dissolved oxygen is no greater than 20 percent of saturation at the field measured temperature, and turbidity is no greater than 20 Nephelometric Turbidity Units (NTUs).

- Temperature: + 0.2° C
- pH: + 0.2 Standard Units
- Specific Conductance: + 5.0% of reading

Document and report the following, as applicable. The last four items only need to be submitted once:

- Purging rate.
- Drawdown in the well, if any.
- A description of the process and the data used to design the well.
- The equipment and procedure used to install the well.
- The well development procedure.
- Pertinent lithologic or hydrogeologic information.

2.) If it is impossible to get dissolved oxygen at or below 20 percent of saturation at the field measured temperature or turbidity at or below 20 NTUs, then three (3) consecutive measurements of temperature, pH, specific conductance and the parameter(s) dissolved oxygen and/or turbidity that do not meet the requirements above must be within the limits below. The measurements are:

- Temperature: + 0.2° C
- pH: + 0.2 Standard Units
- Specific Conductance: + 5.0% of reading
- Dissolved Oxygen: + 0.2 mg/L or 10%, whichever is greater
- Turbidity: + 5 NTUs or 10%, whichever is greater

Additionally, document and report the following, as applicable, except that the last four(4) items only need to be submitted once:

- Purging rate.
- Drawdown in the well, if any.
- A description of conditions at the site that may cause the dissolved oxygen to be high and/or dissolved oxygen measurements made within the screened or open hole portion of the well with a downhole dissolved oxygen probe.

- A description of conditions at the site that may cause the turbidity to be high and any procedures that will be used to minimize turbidity in the future.
- A description of the process and the data used to design the well.
- The equipment and procedure used to install the well.
- The well development procedure.
- Pertinent lithologic or hydrogeologic information.

3.) If after five (5) well volumes, three (3) consecutive measurements of the field parameters temperature, pH, specific conductance, dissolved oxygen, and turbidity are not within the limits stated above, check the instrument condition and calibration, purging flow rate and all tubing connections to determine if they might be affecting the ability to achieve stable measurements. It is at the discretion of the consultant/contractor whether or not to collect a sample or to continue purging. Further, the report in which the data are submitted must include the following, as applicable. The last four (4) items only need to be submitted once.

- Purging rate.
- Drawdown in the well, if any.
- A description of conditions at the site that may cause the Dissolved Oxygen to be high and/or Dissolved Oxygen measurements made within the screened or open hole portion of the well with a downhole dissolved oxygen probe.
- A description of conditions at the site that may cause the turbidity to be high and any procedures that will be used to minimize turbidity in the future.
- A description of the process and the data used to design the well.
- The equipment and procedure used to install the well.
- The well development procedure.
- Pertinent lithologic or hydrogeologic information.

If wells have previously and consistently purged dry, and the current depth to groundwater indicates that the well will purge dry during the current sampling event, minimize the amount of water removed from the well by using the same pump to purge and collect the sample:

- Place the pump or tubing intake within the well screened interval.
- Use very small diameter Teflon, polyethylene or PP tubing and the smallest possible pump chamber volume. This will minimize the total volume of water pumped from the well and reduce drawdown.
- Select tubing that is thick enough to minimize oxygen transfer through the tubing walls while pumping.

- Pump at the lowest possible rate (100 mL/minute or less) to reduce drawdown to a minimum.
- Purge at least two (2) volumes of the pumping system (pump, tubing and flow cell, if used).
- Measure pH, specific conductance, temperature, dissolved oxygen and turbidity, then begin to collect the samples.

Collect samples immediately after purging is complete. The time period between completing the purge and sampling cannot exceed six hours. If sample collection does not occur within one hour of purging completion, re-measure the five field parameters: temperature, pH, specific conductance, dissolved oxygen and turbidity, just prior to collecting the sample. If the measured values are not within 10 percent of the previous measurements, re-purge the well. The exception is "dry" wells.

d.) Lanyards

1. Securely fasten lanyards, if used, to any downhole equipment (bailers, pumps, etc.).
2. Use bailer lanyards in such a way that they do not touch the ground surface.

Wells Without Plumbing

a.) Tubing/Pump Placement

1. If attempting to minimize the volume of purge water, position the intake hose or pump at the midpoint of the screened or open hole interval.
2. If monitoring well conditions do not allow minimizing of the purge water volume, position the pump or intake hose near the top of the water column. This will ensure that all stagnant water in the casing is removed.
3. If the well screen or borehole is partially submerged, and the pump will be used for both purging and sampling, position the pump midway between the measured water level and the bottom of the screen. Otherwise, position the pump or intake hose near the top of the water column.

b.) Non-dedicated (portable) pumps

1. *Variable Speed Peristaltic Pump*
    - Wear sampling gloves to position the decontaminated pump and tubing.
    - Attach a short section of tubing to the discharge side of the pump and into a graduated container.
    - Attach one end of a length of new or precleaned tubing to the pump head flexible hose.
    - Place the tubing as described in one of the options listed above.
    - Change gloves before beginning to purge.
    - Measure the depth to groundwater at frequent intervals.
    - Record these measurements.
    - Adjust the purging rate so that it is equivalent to the well recovery rate to minimize drawdown.

- If the purging rate exceeds the well recovery rate, reduce the pumping rate to balance the withdrawal rate with the recharge rate.
- If the water table continues to drop during pumping, lower the tubing at the approximate rate of drawdown so that water is removed from the top of the water column.
- Record the purging rate each time the rate changes.
- Measure the purge volume.
- Record this measurement.
- Decontaminate the pump and tubing between wells (see Appendix C) or if precleaned tubing is used for each well, only the pump.

2. *Variable Speed Centrifugal Pump*
    - Position fuel powered equipment downwind and at least 10 feet from the well head. Make sure that the exhaust faces downwind.
    - Wear sampling gloves to position the decontaminated pump and tubing.
    - Place the decontaminated suction hose so that water is always pumped from the top of the water column.
    - Change gloves before beginning to purge.
    - Equip the suction hose with a foot valve to prevent purge water from re-entering the well.
    - Measure the depth to groundwater at frequent intervals.
    - Record these measurements.
    - To minimize drawdown, adjust the purging rate so that it is equivalent to the well recovery rate.
    - If the purging rate exceeds the well recovery rate, reduce the pumping rate to balance the withdrawal rate with the recharge rate.
    - If the water table continues to drop during pumping, lower the tubing at the approximate rate of drawdown so that the water is removed from the top of the water column.
    - Record the purging rate each time the rate changes.
    - Measure the purge volume.
    - Record this measurement.
    - Decontaminate the pump and tubing between wells or if precleaned tubing is used for each well, only the pump.
3. *Variable Speed Electric Submersible Pump*
    - Position fuel powered equipment downwind and at least 10 feet from the well head. Make sure that the exhaust faces downwind.
    - Wear sampling gloves to position the decontaminated pump and tubing.
    - Carefully position the decontaminated pump.

- Change gloves before beginning to purge.
- Measure the depth to groundwater at frequent intervals.
- Record these measurements.
- To minimize drawdown, adjust the purging rate so that it is equivalent to the well recovery rate.
- If the purging rate exceeds the well recovery rate, reduce the pumping rate to balance the withdrawal rate with the recharge rate.
- If the water table continues to drop during pumping, lower the tubing or pump at the approximate rate of drawdown so that water is removed from the top of the water column.
- Record the purging rate each time the rate changes.
- Measure the purge volume.
- Record this measurement.
- Decontaminate the pump and tubing between wells or only the pump if precleaned tubing is used for each well.

4. *Variable Speed Bladder Pump*
    - Position fuel powered equipment downwind and at least 10 feet from the well head. Make sure that the exhaust faces downwind.
    - Wear sampling gloves to position the decontaminated pump and tubing.
    - Attach the tubing and carefully position the pump.
    - Change gloves before beginning purging.
    - Measure the depth to groundwater at frequent intervals.
    - Record these measurements.
    - To minimize drawdown, adjust the purging rate so that it is equivalent to the well recovery rate.
    - If the purging rate exceeds the well recovery rate, reduce the pumping rate to balance the withdrawal rate with the recharge rate.
    - If the water table continues to drop during pumping, lower the tubing or pump at the approximate rate of drawdown so that water is removed from the top of the water column.
    - Record the purging rate each time the rate changes.
    - Measure the purge volume.
    - Record this measurement.
    - Decontaminate the pump and tubing between wells or if precleaned tubing is used for each well, only the pump.

c.) <u>Dedicated Portable Pumps</u>

1. *Variable Speed Electric Submersible Pump*
    - Position fuel powered equipment downwind and at least 10 feet from the well head. Make sure that the exhaust faces downwind.
    - Wear sampling gloves.

- Measure the depth to groundwater at frequent intervals.
- Record these measurements.
- Adjust the purging rate so that it is equivalent to the well recovery rate to minimize drawdown.
- If the purging rate exceeds the well recovery rate, reduce the pumping rate to balance the withdraw with the recharge rate.
- Record the purging rate each time the rate changes.
- Measure the purge volume.
- Record this measurement.

2. *Variable Speed Bladder Pump*
    - Position fuel powered equipment downwind and at least 10 feet from the well head. Make sure that the exhaust faces downwind.
    - Wear sampling gloves.
    - Measure the depth to groundwater at frequent intervals.
    - Record these measurements.
    - Adjust the purging rate so that it is equivalent to the well recovery rate to minimize drawdown.
    - If the purging rate exceeds the well recovery rate, reduce the pumping rate to balance the withdraw with the recharge rate.
    - Record the purging rate each time the rate changes.
    - Measure the purge volume.
    - Record this measurement.
3. *Bailers* - Using bailers for purging is not recommended unless care is taken to use proper bailing technique, or if free product is present in the well or suspected to be in the well.
    - Minimize handling the bailer as much as possible.
    - Wear sampling gloves.
    - Remove the bailer from its protective wrapping just before use.
    - Attach a lanyard of appropriate material.
    - Use the lanyard to move and position the bailer.
    - Lower and retrieve the bailer slowly and smoothly.
    - Lower the bailer carefully into the well to a depth approximately a foot above the water column.
    - When the bailer is in position, lower the bailer into the water column at a rate of 2 cm/sec until the desired depth is reached.
    - Do not lower the top of the bailer more than one (1) foot below the top of the water table so that water is removed from the top of the water column.
    - Allow time for the bailer to fill with aquifer water as it descends into the water column.

- Carefully raise the bailer. Retrieve the bailer at the same rate of 2 cm/sec until the bottom of the bailer has cleared to top of the water column.
- Measure the purge volume.
- Record the volume of the bailer.
- Continue to carefully lower and retrieve the bailer as described above until the purging is considered complete, based on either the removal of 3 well volumes.
- Remove at least one (1) well volume before collecting measurements of the field parameters. Take each subsequent set of measurements after removing at least one quarter (1/4) well volume between measurements.

Groundwater Sampling Techniques

a.) Purge wells.

b.) Replace protective covering around the well if it is soiled or torn after completing purging operations.

c.) Equipment Considerations

1. The following pumps are approved to collect volatile organic samples:
    - Stainless steel and Teflon variable speed submersible pumps
    - Stainless steel and Teflon or polyethylene variable speed bladder pumps
    - Permanently installed PVC bodied pumps (As long as the pump remains in contact with the water in the well at all times)
2. Collect sample from the sampling device and store in sample container. Do not use intermediate containers.
3. To avoid contamination or loss of analytes from the sample, handle sampling equipment as little as possible and minimize equipment exposure to the sample.
4. To reduce chances of cross-contamination, use dedicated equipment whenever possible. "Dedicated" is defined as equipment that is to be used solely for one location for the life of that equipment (e.g., permanently mounted pump). Purchase dedicated equipment with the most sensitive analyte of interest in mind.
    - Clean or make sure dedicated pumps are clean before installation. They do not need to be cleaned prior to each use, but must be cleaned if they are withdrawn for repair or servicing.
    - Clean or make sure any permanently mounted tubing is clean before installation.
    - Change or clean tubing when the pump is withdrawn for servicing.
    - Clean any replaceable or temporary parts.

- Collect equipment blanks on dedicated pumping systems when the tubing is cleaned or replaced.
- Clean or make sure dedicated bailers are clean before placing them into the well.
- Collect an equipment blank on dedicated bailers before introducing them into the water column.
- Suspend dedicated bailers above the water column if they are stored in the well.

Sampling Wells Without Plumbing

a.) Sampling with Pumps – The following pumps may be used to sample for organics:

- Peristaltic pumps
- Stainless steel, Teflon or polyethylene bladder pumps
- Variable speed stainless steel and Tefloṇ submersible pumps

1. *Peristaltic Pump*

- Volatile Organics: One of three methods may be used.
  - Remove the drop tubing from the inlet side of the pump; submerge the drop tubing into the water column; prevent the water in the tubing from flowing back into the well; remove the drop tubing from the well; carefully allow the groundwater to drain into the sample vials; avoid turbulence; do not aerate the sample; repeat steps until enough vials are filled. OR
  - Use the pump to fill the drop tubing; quickly remove the tubing from the pump; prevent the water in the tubing from flowing back into the well; remove the drop tubing from the well; carefully allow the groundwater to drain into the sample vials; avoid turbulence; do not aerate the sample; repeat steps until enough vials are filled. OR
  - Use the pump to fill the drop tubing; withdraw the tubing from the well; reverse the flow on the peristaltic pumps to deliver the sample into the vials at a slow, steady rate; repeat steps until enough vials are filled.
- Extractable Organics: If delivery tubing is not polyethylene or PP, or is not Teflon lined, use pump and vacuum trap method. Connect the outflow tubing from the container to the influent side of the peristaltic pump. Turn pump on and reduce flow until smooth and even. Discard a

small portion of the sample to allow for air space. Preserve (if required), label, and complete field notes.

- Inorganic samples: These samples may be collected from the effluent tubing. If samples are collected from the pump, decontaminate all tubing (including the tubing in the head) or change it between wells. Preserve (if required), label, and complete field notes.

2. *Variable Speed Bladder Pump*
    - If sampling for organics, the pump body must be constructed of stainless steel and the valves and bladder must be Teflon. All tubing must be Teflon, polyethylene, or PP and any cabling must be sealed in Teflon, polyethylene or PP, or made of stainless steel.
    - After purging to a smooth even flow, reduce the flow rate.
    - When sampling for volatile organic compounds, reduce the flow rate to 100-200mL/minute, if possible.
3. *Variable Speed Submersible Pump*
    - The housing must be stainless steel.
    - If sampling for organics, the internal impellers, seals and gaskets must be constructed of stainless steel, Teflon, polyethylene or PP. The delivery tubing must be Teflon, polyethylene or PP; the electrical cord must be sealed in Teflon; any cabling must be sealed in Teflon or constructed of stainless steel.
    - After purging to a smooth even flow, reduce the flow rate.
    - When sampling for volatile organic compounds, reduce the flow rate to 100-200mL/minute, if possible.

b.) Sampling with Bailers - A high degree of skill and coordination are necessary to collect representative samples with a bailer.

1. *General Considerations*
    - Minimize handling of bailer as much as possible.
    - Wear sampling gloves.
    - Remove bailer from protective wrapping just before use.
    - Attach a lanyard of appropriate material.
    - Use the lanyard to move and position the bailers.
    - Do not allow bailer or lanyard to touch the ground.
    - If bailer is certified precleaned, no rinsing is necessary.
    - If both a pump and a bailer are to be used to collect samples, rinse the exterior and interior of the bailer with sample water from the pump before removing the pump.
    - If the purge pump is not appropriate for collecting samples (e.g., non-inert components), rinse the bailer by collecting a single bailer of the groundwater to be sampled.
    - Discard the water appropriately.

- Do not rinse the bailer if Oil and Grease samples are to be collected.

2. *Bailing Technique*
    - Collect all samples that are required to be collected with a pump before collecting samples with the bailer.
    - Raise and lower the bailer gently to minimize stirring up particulate matter in the well and the water column, which can increase sample turbidity.
    - Lower the bailer carefully into the well to a depth approximately a foot above the water column. When the bailer is in position, lower the bailer into the water column at a rate of 2 cm/sec until the desired depth is reached.
    - Do not lower the top of the bailer more than one foot below the top of the water table, so that water is removed from the top of the water column.
    - Allow time for the bailer to fill with aquifer water as it descends into the water column.
    - Do not allow the bailer to touch the bottom of the well or particulate matter will be incorporated into the sample. Carefully raise the bailer. Retrieve the bailer at the same rate of 2 cm/sec until the bottom of the bailer has cleared to top of the water column.
    - Lower the bailer to approximately the same depth each time.
    - Collect the sample. Install a device to control the flow from the bottom of the bailer and discard the first few inches of water. Fill the appropriate sample containers by allowing the sample to slowly flow down the side of the container. Discard the last few inches of water in the bailer.
    - Repeat steps for additional samples.
    - As a final step measure the DO, pH, temperature, turbidity and specific conductance after the final sample has been collected. Record all measurements and note the time that sampling was completed.

c.) <u>Sampling Low Permeability Aquifers or Wells that have Purged Dry</u>

1. Collect the sample(s) after the well has been purged. Minimize the amount of water removed from the well by using the same pump to purge and collect the sample. If the well has purged dry, collect samples as soon as sufficient sample water is available.
2. Measure the five field parameters temperature, pH, specific conductance, dissolved oxygen and turbidity at the time of sample collection.
3. Advise the analytical laboratory and the client that the usual amount of sample for analysis may not be available.

Appendix D - Collecting Samples from Wells with Plumbing in Place

In-place plumbing is generally considered permanent equipment routinely used for purposes other than purging and sampling, such as for water supply.

a.) Air Strippers or Remedial Systems - These types of systems are installed as remediation devices. Collect influent and effluent samples from air stripping units as described below.

1. Remove any tubing from the sampling port and flush for one to two minutes.
2. Remove all hoses, aerators and filters (if possible).
3. Open the spigot and purge sufficient volume to flush the spigot and lines and until the purging completion criteria have been met.
4. Reduce the flow rate to approximately 500 mL/minute (a 1/8" stream) or approximately 0.1 gal/minute before collecting samples.
5. Follow procedures for collecting samples from water supply wells as outlined below.

b.) Water Supply Wells – Water supply wells with in-place plumbing do not require equipment to be brought to the well to purge and sample. Water supply wells at UST facilities must be sampled for volatile organic compounds (VOCs) and semivolatile compounds (SVOCs).

1. *Procedures for Sampling Water Supply Wells*
   - Label sample containers prior to sample collection.
   - Prepare the storage and transport containers (ice chest, etc.) before taking any samples so each collected sample can be placed in a chilled environment immediately after collection.
   - You must choose the tap closest to the well, preferably at the wellhead. The tap must be before any holding or pressurization tank, water softener, ion exchange, disinfection process or before the water line enters the residence, office or building. If no tap fits the above conditions, a new tap that does must be installed.
   - The well pump must not be lubricated with oil, as that may contaminate the samples.
   - The sampling tap must be protected from exterior contamination associated with being too close to a sink bottom or to the ground. If the tap is too close to the ground for direct collection into the appropriate container, it is acceptable to use a smaller (clean) container to transfer the sample to a larger container.
   - Leaking taps that allow water to discharge from around the valve stem handle and down the outside of the faucet, or taps in which water tends to run up on the outside of the lip, are to be avoided as sampling locations.

- Disconnect any hoses, filters, or aerators attached to the tap before sampling.
- Do not sample from a tap close to a gas pump. The gas fumes could contaminate the sample.

2. *Collecting Volatile Organic Samples*
    - Equipment Needed: VOC sample vials [40 milliliters, glass, may contain 3 to 4 drops of hydrochloric acid (HCl) as preservative]; Disposable gloves and protective goggles; Ice chest/cooler; Ice; Packing materials (sealable plastic bags, bubble wrap, etc.); and Lab forms.
    - Sampling Procedure: Run water from the well for at least 15 minutes. If the well is deep, run water longer (purging three well volumes is best). If tap or spigot is located directly before a holding tank, open a tap after the holding tank to prevent any backflow into the tap where you will take your sample. This will ensure that the water you collect is "fresh" from the well and not from the holding tank. After running the water for at least 15 minutes, reduce the flow of water. The flow should be reduced to a trickle but not so slow that it begins to drip. A smooth flow of water will make collection easier and more accurate. Remove the cap of a VOC vial and hold the vial under the stream of water to fill it. Be careful not to spill any acid that is in the vial. For best results use a low flow of water and angle the vial slightly so that the water runs down the inside of the vial. This will help keep the sample from being agitated, aerated or splashed out of the vial. It will also increase the accuracy of the sample. As the vial fills and is almost full, turn the vial until it is straight up and down so the water won't spill out. Fill the vial until the water is just about to spill over the lip of the vial. The surface of the water sample should become mounded. It is a good idea not to overfill the vial, especially if an acid preservative is present in the vial. Carefully replace and screw the cap onto the vial. Some water may overflow as the cap is put on. After the cap is secure, turn the vial upside down and gently tap the vial to see if any bubbles are present. If bubbles are present in the vial, remove the cap, add more water and check again to see if bubbles are present. Repeat as necessary. After two samples without bubbles have been collected, the samples should be labeled and prepared for shipment. Store samples at 4° C.

3. *Collecting Extractable Organic and/or Metals Samples*

- Equipment Needed: SVOC sample bottle [1 liter, amber glass] and/or Metals sample bottle [0.5 liter, polyethylene or glass, 5 milliliters of nitric acid (HNO3) preservative]; Disposable gloves and protective goggles; Ice Chest/Cooler; Ice; Packing materials (sealable plastic bags, bubble wrap, etc.); and Lab forms.
- Sampling Procedure: Run water from the well for at least 15 minutes. If the well is deep, run the water longer (purging three well volumes is best). If tap or spigot is located directly before a holding tank, open a tap after the holding tank to prevent any backflow into the tap where you will take your sample. This will ensure that the water you collect is "fresh" from the well and not from the holding tank. After running the water for at least 15 minutes, reduce the flow. Low water flow makes collection easier and more accurate. Remove the cap of a SVOC or metals bottle and hold it under the stream of water to fill it. The bottle does not have to be completely filled (i.e., you can leave an inch or so of headspace in the bottle). After filling, screw on the cap, label the bottle and prepare for shipment. Store samples at 4° C.

Appendix E - Collecting Surface Water Samples

The following topics include 1.) acceptable equipment selection and equipment construction materials and 2.) standard grab, depth-specific and depth-composited surface water sampling techniques.

Facilities which contain or border small rivers, streams or branches should include surface water sampling as part of the monitoring program for each sampling event. A simple procedure for selecting surface water monitoring sites is to locate a point on a stream where drainage leaves the site. This provides detection of contamination through, and possibly downstream of, site via discharge of surface waters. The sampling points selected should be downstream from any waste areas. An upstream sample should be obtained in order to determine water quality upstream of the influence of the site.

a.) General Cautions
    1. When using watercraft take samples near the bow away and upwind from any gasoline outboard engine. Orient watercraft so that bow is positioned in the upstream direction.
    2. When wading, collect samples upstream from the body. Avoid disturbing sediments in the immediate area of sample collection.
    3. Collect water samples prior to taking sediment samples when obtaining both from the same area (site).
    4. Unless dictated by permit, program or order, sampling at or near man-made structures (e.g., dams, weirs or bridges) may not provide representative data because of unnatural flow patterns.
    5. Collect surface water samples from downstream towards upstream.

b.) Equipment and Supplies - Select equipment based on the analytes of interest, specific use, and availability.

c.) Surface Water Sampling Techniques - Adhere to all general protocols applicable to aqueous sampling when following the surface water sampling procedures addressed below.
    1. *Manual Sampling*: Use manual sampling for collecting grab samples for immediate in-situ field analyses. Use manual sampling in lieu of automatic equipment over extended periods of time for composite sampling, especially when it is necessary to observe and/or note unusual conditions.
        - Surface Grab Samples - Do not use sample containers containing premeasured amounts of preservatives to collect grab samples. If the sample matrix is homogeneous, then the grab method is a simple and effective technique for collection purposes. If homogeneity is not apparent, based on flow or vertical variations (and should never be assumed), then use other collection protocols. Where practical, use the actual sample container submitted to the laboratory for collecting samples to be analyzed for oil and grease, volatile organic compounds (VOCs), and microbiological samples. This procedure eliminates the possibility of contaminating the sample with an intermediate collection container. The use of

unpreserved sample containers as direct grab samplers is encouraged since the same container can be submitted for laboratory analysis after appropriate preservation. This procedure reduces sample handling and eliminates potential contamination from other sources (e.g., additional sampling equipment, environment, etc.).

1. Grab directly into sample container.
2. Slowly submerge the container, opening neck first, into the water.
3. Invert the bottle so the neck is upright and pointing towards the direction of water flow (if applicable). Allow water to run slowly into the container until filled.
4. Return the filled container quickly to the surface.
5. Pour out a few mL of sample away from and downstream of the sampling location. This procedure allows for the addition of preservatives and sample expansion. Do not use this step for volatile organics or other analytes where headspace is not allowed in the sample container.
6. Add preservatives, securely cap container, label, and complete field notes. If sample containers are attached to a pole via a clamp, submerge the container and follow steps 3 – 5 but omit steps 1 and 2.

- Sampling with an Intermediate Vessel or Container: If the sample cannot be collected directly into the sample container to be submitted to the laboratory, or if the laboratory provides prepreserved sample containers, use an unpreserved sample container or an intermediate vessel (e.g., beakers, buckets or dippers) to obtain the sample. These vessels must be constructed appropriately, including any poles or extension arms used to access the sample location.
    1. Rinse the intermediate vessel with ample amounts of site water prior to collecting the first sample.
    2. Collect the sample as outlined above using the intermediate vessel.
    3. Use pole mounted containers of appropriate construction to sample at distances away from shore, boat, etc. Follow the protocols above to collect samples.
- Peristaltic Pump and Tubing: The most portable pump for this technique is a 12 volt peristaltic pump. Use appropriately precleaned, silastic tubing in the pump head and attach polyethylene, Tygon, etc. tubing to the pump. This technique is not acceptable for Oil and Grease, EPH, VPH or VOCs. Extractable organics can be collected through the pump if flexible interior-wall Teflon, polyethylene or PP tubing is used in the pump head or if used with the organic trap setup.

1. Lower appropriately precleaned tubing to a depth of 6 – 12 inches below water surface, where possible.
2. Pump 3 – 5 tube volumes through the system to acclimate the tubing before collecting the first sample.
3. Fill individual sample bottles via the discharge tubing. Be careful not to remove the inlet tubing from the water.
4. Add preservatives, securely cap container, label, and complete field notes.

- Mid-Depth Grab Samples: Mid-depth samples or samples taken at a specific depth can approximate the conditions throughout the entire water column. The equipment that may be used for this type of sampling consists of the following depth-specific sampling devices: Kemmerer, Niskin, Van Dorn type, etc. You may also use pumps with tubing or double check-valve bailers. Certain construction material details may preclude its use for certain analytes. Many Kemmerer samplers are constructed of plastic and rubber that preclude their use for all volatile and extractable organic sampling. Some newer devices are constructed of stainless steel or are all Teflon or Teflon-coated. These are acceptable for all analyte groups without restriction.
    1. Measure the water column to determine maximum depth and sampling depth prior to lowering the sampling device.
    2. Mark the line attached to the sampler with depth increments so that the sampling depth can be accurately recorded.
    3. Lower the sampler slowly to the appropriate sampling depth, taking care not to disturb the sediments.
    4. At the desired depth, send the messenger weight down to trip the closure mechanism.
    5. Retrieve the sampler slowly.
    6. Rinse the sampling device with ample amounts of site water prior to collecting the first sample. Discard rinsate away from and downstream of the sampling location.
    7. Fill the individual sample bottles via the discharge tube.
- Double Check-Valve Bailers: Collect samples using double check-valve bailers if the data requirements do not necessitate a sample from a strictly discrete interval of the water column. Bailers with an upper and lower check-valve can be lowered through the water column. Water will continually be displaced through the bailer until the desired depth is reached, at which point the bailer is retrieved. Sampling with this type of bailer must follow the same protocols outlined above, except that a messenger weight is not applicable. Although not designed specifically for this kind of sampling, a bailer is acceptable when a mid-depth sample is required

1. As the bailer is dropped through the water column, water is displaced through the body of the bailer. The degree of displacement depends upon the check-valve ball movement to allow water to flow freely through the bailer body.
2. Slowly lower the bailer to the appropriate depth. Upon retrieval, the two check valves seat, preventing water from escaping or entering the bailer.
3. Rinse the sampling device with ample amounts of site water prior to collecting the first sample.
4. Fill the individual sample bottles via the discharge tube. Sample bottles must be handled as described above.

- Peristaltic Pump and Tubing: The most portable pump for this technique is a 12 volt peristaltic pump. Use appropriately precleaned, silastic tubing in the pump head and attach HDPE, Tygon, etc. tubing to the pump. This technique is not acceptable for Oil and Grease, EPH, VPH or VOCs. Extractable organics can be collected through the pump if flexible interior-wall Teflon, polyethylene or PP tubing is used in the pump head, or if used with an organic trap setup.
    1. Measure the water column to determine the maximum depth and the sampling depth.
    2. Tubing will need to be tied to a stiff pole or be weighted down so the tubing placement will be secure. Do not use a lead weight. Any dense, non-contaminating, non-interfering material will work (brick, stainless steel weight, etc.). Tie the weight with a lanyard (braided or monofilament nylon, etc.) so that it is located below the inlet of the tubing.
    3. Turn the pump on and allow several tubing volumes of water to be discharged before collecting the first sample.
    4. Fill the individual sample bottles via the discharge tube. Sample bottles must be handled as described above.

Leachate Sampling and Analysis

To maintain sample quality, leachate samples are to be taken as close to the sump as possible. Because of dubious results, pond and storage tank samples should be avoided. The leachate data is to be submitted with the semi-annual monitoring report. Leachate is to be analyzed for the Appendix I list of constituents plus the following required additional parameters: 1) biological oxygen demand (BOD), 2) chemical oxygen demand (COD), 3) phosphate, 4) nitrate, 5) sulfate, and 6) pH. Based upon sample results, compliance history and waste screening practices, additional parameters may be required.

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SaveWaterNC.org NC SWAP Info Source Water Protection nc ONE map Geographic State Data

Electronic Data need to be in the following format such that they can be uploaded into the Solid Waste Section database.
Please see the "Data Format Explanation" tab at the bottom of this sheet for an explanation of each column.

FACILITY PERMIT	WELL ID	CAS Number	SWS ID	PARAMETER	RESULT	UNITS	QUALIFIER	METHOD	MDL	SWSL	DILUTION FACTOR	COLLECT DATE	EXTRACTION DATE	ANALYSIS DATE
12-34	1234-MW3A	74-87-3	137	Chloromethane	BQL	ug/L	U	SW846 8260B	0.18	1	1	07/23/2007	07/24/2007	7/27/2007
12-34	1234-MW3A		325	Temperature	19.1	oC						07/23/2007		
12-34	1234-MW5	74-83-9	136	Bromomethane	35	ug/L		SW846 8260B	0.26	10	1	07/23/2007	07/24/2007	7/27/2007
12-34	1234-MW5	7440-39-3	15	Barium	50	ug/L	J	SW846 6020	0.04	100	1	07/23/2007		7/27/2007
12-34	1234-MW5		411	Total Well Depth	54.3	ft						07/23/2007		

ALL DATA SHOULD INCLUDE THE PERMIT NUMBER. If unsure, contact the operator/owner of the facility.
The unit of concentration should be ug/L for ALL constituents.

North Carolina Department of Environment and Natural Resources

Dexter R. Matthews, Director | Division of Waste Management | Michael F. Easley, Governor
William G. Ross Jr., Secretary

October 16, 2007

MEMORANDUM

To: Solid Waste Directors, Landfill Operators, North Carolina Certified Laboratories, and Consultants

From: North Carolina Division of Waste Management, Solid Waste Section

Re: **Environmental Monitoring Data for North Carolina Solid Waste Management Facilities**

The purpose of this memorandum is to provide a reiteration of the use of the Solid Waste Section Limits (SWSLs), provide new information on the Groundwater Protection Standards, and provide a reminder of formats for environmental monitoring data submittals.

The updated guidelines are in large part due to questions and concerns from laboratories, consultants, and the regulated community regarding the detection of constituents in groundwater at levels below the previous Practical Quantitation Limits (PQLs). The North Carolina Solid Waste Section solicited feedback from the regulated community, and, in conjunction with the regulated community, developed new limits. The primary purpose of these changes was to improve the protection of public health and the environment.

Data must be reported to the laboratory specific method detection limits and must be quantifiable at or below the SWSLs. The SWSLs must be used for both groundwater and surface water data reported to the North Carolina Solid Waste Section. The PQLs will no longer be used.

In June 2007, we received new information regarding changes to the Groundwater Protection Standards. If a North Carolina 2L Groundwater Standard does not exist, then a designated Groundwater Protection Standard is used pursuant to 15A NCAC 13B .1634. Toxicologists with the North Carolina Department of Health and Human Services calculated these new Groundwater Protection Standards. Questions regarding how the standards were calculated can be directed to the North Carolina Department of Health and Human Services.

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We have reviewed the new results from the North Carolina Department of Public Health and have updated our webpage accordingly. The list of Groundwater Protection Standards, North Carolina 2L Standards and SWSLs are subject to change and will be reviewed every year or sooner if new scientific and toxicological data become available. Please review our website periodically for any changes to the 2L NC Standards, Groundwater Protection Standards, or SWSLs. Specific updates will be noted on our website.

http://www.wastenotnc.org/sw/swenvmonitoringlist.asp

In addition, the following should be included with environmental monitoring data submittals:

1. Environmental Monitoring Data Form as a cover sheet:
http://www.wastenotnc.org/swhome/EnvMonitoring/NCEnvMonRptForm.pdf
2. Copy of original laboratory results.
3. Table of detections and discussion of 2L exceedances.
4. Electronic files on CD or sent by email. These files should include the written report as a Portable Document Format (PDF) file and the laboratory data as an excel file following the format of the updated Electronic Data Deliverable (EDD) template on our website:
http://www.wastenotnc.org/swhome/enviro_monitoring.asp

If you have any questions or concerns, please feel free to contact Donald Herndon (919-508-8502), Ervin Lane (919-508-8520) or Jaclynne Drummond (919-508-8500).

Thank you for your continued cooperation with these matters.

North Carolina Department of Environment and Natural Resources
Dexter R. Matthews, Director
Division of Waste Management
Michael F. Easley, Governor
William G. Ross Jr., Secretary

October 27, 2006

To: SW Director/County Manager/Consultant/Laboratory

From: NC DENR-DWM, Solid Waste Section

Re: New Guidelines for Electronic Submittal of Environmental Monitoring Data

The Solid Waste Section receives and reviews a wide variety of environmental monitoring data from permitted solid waste management facilities, including the results from groundwater and surface water analyses, leachate samples, methane gas readings, potentiometric measurements, and corrective action data. We are in the process of developing a database to capture the large volume of data submitted by facilities.

To maintain the integrity of the database, it is critical that facilities, consultants, and laboratories work with the Solid Waste Section to ensure that environmental samples are collected and analyzed properly with the resulting data transferred to the Solid Waste Section in an accurate manner.

In order to better serve the public and to expedite our review process, the Solid Waste Section is requesting specific formatting for environmental monitoring data submittals for all solid waste management facilities.

Effective, December 1, 2006, please submit a Solid Waste Environmental Monitoring Data Form in addition to your environmental monitoring data report. This form will be sent in lieu of your current cover letter to the Solid Waste Section. The Solid Waste Environmental Monitoring Data Form must be filled out completely, signed, and stamped with a Board Certified North Carolina Geologist License Seal.

The solid waste environmental monitoring data form will include the following:

1. Contact Information
2. Facility Name
3. Facility Permit Number
4. Facility Address
5. Monitoring Event Date (MM/DD/YYYY)
6. Water Quality Status: Monitoring, Detection Monitoring, or Assessment Monitoring
7. Type of Data Submitted: Groundwater Monitoring Wells, Groundwater Potable Wells, Leachate, Methane Gas, or Corrective Action Data
8. Notification of Exceedance of Groundwater, Surface Water, or Methane Gas (in table form)
9. Signature
10. North Carolina Geologist Seal

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Most of these criteria are already being included or can be added with little effort. The Solid Waste Environmental Monitoring Data Form can be downloaded from our website: http://www.wastenotnc.org/swhome/enviro_monitoring.asp.

The Solid Waste Section is also requesting a new format for monitoring wells, potable wells, surface water sampling locations, and methane probes. This format is essential in the development and maintenance of the database. The Solid Waste Section is requesting that each sampling location at all North Carolina solid waste management facilities have its own unique identification number. We are simply asking for the permit number to be placed directly in front of the sampling location number (example: 9901-MW1 = Permit Number 99-01 and Monitoring Well MW-1). No changes will need to be made to the well tags, etc. This unique identification system will enable us to accurately report data not only to NCDENR, but to the public as well. We understand that this new identification system will take some time to implement, but we feel that this will be beneficial to everyone involved in the long term.

Additionally, effective December 1, 2006, the Practical Quantitation Limits (PQLs) established in 1994 will change. The Solid Waste Section is requiring that all solid waste management facilities use the new Solid Waste Reporting Limits (SWRL) for all groundwater analyses by a North Carolina Certified Laboratory. Laboratories must also report any detection of a constituent even it is detected below the new SWRL (e.g., J values where the constituent was detected above the detection limit, but below the quantitation limit).

PQLs are technology-based analytical levels that are considered achievable using the referenced analytical method. The PQL is considered the lowest concentration of a contaminant that the lab can accurately detect and quantify. PQLs provided consistency and available numbers that were achievable by the given analytical method. However, PQLs are not health-based, and analytical instruments have improved over the years resulting in lower achievable PQLs for many of the constituents. As a result, the Solid Waste Section has established the SWRLs as the new reporting limits eliminating the use of the PQLs.

We would also like to take this opportunity to encourage electronic submittal of the reports. This option is intended to save resources for both the public and private sectors. The Solid Waste Section will accept the entire report including narrative text, figures, tables, and maps on CD-ROM. The CD-ROM submittal shall contain a CD-ROM case and both CD-ROM and the case shall be labeled with the site name, site address, permit number, and the monitoring event date (MM/DD/YYYY). The files may be a .pdf, .txt, .csv, .xls, or .doc type. Also, analytical lab data should be reported in an .xls file. We have a template for analytical lab data available on the web at the address listed above.

If you have any questions or concerns, please call (919) 508-8400. Thank you for your anticipated cooperation in this matter.

North Carolina Department of Environment and Natural Resources

Dexter R. Matthews, Director | Division of Waste Management | Michael F. Easley, Governor
William G. Ross Jr., Secretary

February 23, 2007

MEMORANDUM

To: Solid Waste Directors, Landfill Operators, North Carolina Certified Laboratories, and Consultants

From: North Carolina Division of Waste Management, Solid Waste Section

Re: Addendum to October 27, 2006, North Carolina Solid Waste Section Memorandum Regarding New Guidelines for Electronic Submittal of Environmental Data.

The purpose of this addendum memorandum is to provide further clarification to the October 27, 2006, North Carolina Solid Waste Section memo titled, "New Guidelines for Electronic Submittal of Environmental Data."

The updated guidelines is in large part due to questions and concerns from laboratories, consultants, and the regulated community regarding the detection of constituents in groundwater at levels below the previous practical quantitation limits (PQLs). The North Carolina Solid Waste Section solicited feedback from the regulated community, and, in conjunction with the regulated community, developed new limits. The primary purpose of these changes was to improve the protection of public health and the environment. The North Carolina Solid Waste Section is concerned about analytical data at these low levels because the earliest possible detection of toxic or potentially carcinogenic chemicals in the environment is paramount in the North Carolina Solid Waste Section's mission to protect human health and the environment. Low level analytical data are critical for making the correct choices when designing site remediation strategies, alerting the public to health threats, and protecting the environment from toxic contaminants. The revised limits were updated based on readily available laboratory analytical methodology and current health-based groundwater protection standards.

Definitions

Many definitions relating to detection limits and quantitation limits are used in the literature and by government agencies, and commonly accepted procedures for calculating these limits exist. Except for the Solid Waste Section Limit and the North Carolina 2L Standards, the definitions listed below are referenced from the Environmental Protection Agency (EPA). The definitions are also an attempt to clarify the meaning of these terms as used by the North Carolina Solid Waste Section.

Method Detection Limit (MDL) is the minimum concentration of a substance that can be measured and reported with 99% confidence that the analyte concentration is greater than zero.

Method Reporting Limit or Method Quantitation Limit (MRL or MQL) is the minimum concentration of a target analyte that can be accurately determined by the referenced method.

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Practical Quantitation Limit (PQL) is a quantitation limit that represents a practical and routinely achievable quantitation limit with a high degree of certainty (>99.9% confidence) in the results. Per EPA Publication Number SW-846, the PQL is the lowest concentration that can be reliably measured within specified limits of precision and accuracy for a specific laboratory analytical method during routine laboratory operating conditions in accordance with "Test Methods for Evaluating Solid Wastes, Physical/Chemical Methods. The PQL appears in older NCDENR literature; however, it is no longer being used by the North Carolina Solid Waste Section.

Solid Waste Section Limit (SWSL) is the lowest amount of analyte in a sample that can be quantitatively determined with suitable precision and accuracy. The SWSL is the concentration below which reported analytical results must be qualified as estimated. *The SWSL is the updated version of the PQL that appears in older North Carolina Solid Waste Section literature. The SWSL is the limit established by the laboratory survey conducted by the North Carolina Solid Waste Section. The nomenclature of the SWRL described in the October 27, 2006, memorandum has changed to the SWSL.*

North Carolina 2L Standards (2L) are water quality standards for the protection of groundwaters of North Carolina as specified in 15A NCAC 2L .0200, Classifications and Water Quality Standards Applicable to the Groundwaters of North Carolina.

Method Detection Limits (MDLs)

Clarification of detection limits referenced in the October 27, 2006, memorandum needed to be addressed because of concerns raised by the regulated community. The North Carolina Solid Waste Section is now requiring laboratories to report to the method detection limit.

Method detection limits are statistically determined values that define the concentration at which measurements of a substance by a specific analytical protocol can be distinguished from measurements of a blank (background noise). Method detection limits are matrix-specific and require a well defined analytical method. In the course of routine operations, laboratories generally report the highest method detection limit for all the instruments used for a specific method.

In many instances, the North Carolina Solid Waste Section gathers data from many sources prior to evaluating the data or making a compliance decision. Standardization in data reporting significantly enhances the ability to interpret and review data because the reporting formats are comparable. Reporting a method detection limit alerts data users of the known uncertainties and limitations associated with using the data. Data users must understand these limitations in order to minimize the risk of making poor environmental decisions. Censoring data below unspecified or non-statistical reporting limits severely biases data sets and restricts their usefulness.

Solid Waste Section Limits (SWSLs)

Due to comments from the regulated community, the North Carolina Solid Waste Section has changed the nomenclature of the new limits referenced on Page 2 of the October 27, 2006, memorandum, from the North Carolina Solid Waste Reporting Limits (SWRL) to the Solid Waste Section Limits (SWSL). Data must be reported to the laboratory specific method detection limits and must be quantifiable at or below the SWSL. The SWSLs must be used for both groundwater and surface water data reported to the North Carolina Solid Waste Section. The PQLs will no longer be used.

The North Carolina Solid Waste Section has considered further feedback from laboratories and the regulated community and has made some additional changes to the values of the SWSLs. These changes may be viewed on our webpage:
http://www.wastenotnc.org/sw/swenvmonitoringlist.asp

Analytical Data Reporting Requirements

The strategy for implementing the new analytical data reporting requirements involves reporting the actual laboratory method detection limit with all analytical laboratory results along with the following requirements:

1) Any analyte detected at a concentration greater than the MDL but less than the SWSL is known to be present, but the uncertainty in the value is higher than a value reported above the SWSL. As a result, the actual concentration is estimated. The estimated concentration is reported along with a qualifier ("J" flag) to alert data users that the result is between the MDL and the SWSL. Any analytical data below quantifiable levels should be examined closely to evaluate whether the analytical data should be included in any statistical analysis. A statistician should make this determination. If an analyte is detected below the North Carolina 2L Standards, even if it is a quantifiable concentration, compliance action may not be taken unless it is statistically significant increase over background.

These analytical results may require additional confirmation.

2) Any analyte detected at a concentration greater than the SWSL is present, and the quantitated value can be reported with a high degree of confidence. These analytes are reported without estimated qualification. The laboratory's MDL and SWSL must be included in the analytical laboratory report. Any reported concentration of an organic or inorganic constituent at or above the North Carolina 2L Standards will be used for compliance purposes, unless the inorganic constituent is not statistically significant). Exceedance of the North Carolina 2L Standards or a statistically significant increase over background concentrations define when a violation has occurred. Any reported concentration of an organic or inorganic constituent at or above the SWSL that is not above an North Carolina 2L Standard will be used as a tool to assess the integrity of the landfill system and predict the possibility that a constituent concentration may exceed the North Carolina 2L Standards in the future.

These analytical results may be used for compliance without further confirmation.

Failure to comply with the requirements described in the October 27, 2006, memorandum and this addendum to the October 27, 2006, memorandum will constitute a violation of 15A NCAC 13B .0601, .0602, or .1632(b), and the analytical data will be returned and deemed unacceptable. Submittal of unacceptable data may lead to enforcement action.

Electronic Data Deliverable (EDD) Submittal

The North Carolina Solid Waste Section would also like to take this opportunity to encourage electronic submittal of the reports in addition to the analytical laboratory data. This option is intended to save resources for both the public and private sectors.

The North Carolina Solid Waste Section will accept the entire report including narrative text, figures, tables, and maps on CD-ROM. Please separate the figures and tables from the report when saving in order to keep the

size of the files smaller. The CD-ROM submittal shall contain a CD-ROM case and both CD-ROM and the case shall be labeled with the site name, site address, permit number, and the monitoring event date (MM/DD/YYYY). The reporting files may be submitted as a .pdf, .txt, .csv, .xls,. or .doc type.

Also, analytical lab data and field data should be reported in .xls files. The North Carolina Solid Waste Section has a template for analytical lab data and field data. This template is available on our webpage: http://www.wastenotnc.org/swhome/enviro_monitoring.asp. Methane monitoring data may also be submitted electronically in this format.

Pursuant to the October 27, 2006, memorandum, please remember to submit a Solid Waste Section Environmental Monitoring Reporting Form in addition to your environmental monitoring data report. This form should be sealed by a geologist or engineer licensed in North Carolina if hydrogeologic or geologic calculations, maps, or interpretations are included with the report. Otherwise, any representative that the facility owner chooses may sign and submit the form. Also, if the concentration of methane generated by the facility exceeds 100% of the lower explosive limits (LEL) at the property boundary or exceeds 25% of the LEL in facility structures (excluding gas control or recovery system components), include the exceedance(s) on the North Carolina Solid Waste Section Environmental Monitoring Reporting Form.

If you have any questions or concerns, please feel free to contact Jaclynne Drummond (919-508-8500) or Ervin Lane (919-508-8520).

Thank you for your continued cooperation with this matter.

APPENDIX C

3-D MicroEmulsion™ HRC ADVANCED®

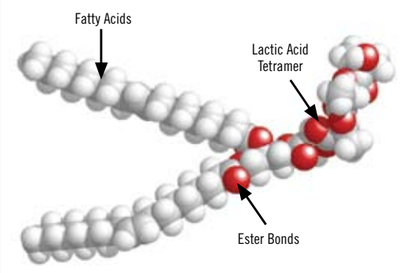
Achieve wide-area, rapid and sustai ned reductive dechlorination with continuous distribution and staged hydrogen release

3-D MicroEmulsion™ HRC ADVANCED®

PRODUCT FEATURES

- **Three Stage Electron Donor Release – Immediate, Mid-Range and Long-Term Hydrogen Production**
  - Provides free lactic acid, controlled-release lactic acid and long release fatty acids for effective hydrogen production for periods of up to 3 to 5 years.
- **Low-Cost**
  - 3-D Microemulsion is 25¢ to 42¢ per pound as applied
- **Maximum and Continuous Distribution via Micellar Transport**
  - Unlike oil products, 3DMe forms micelles which are mobile in groundwater and significantly enhance electron donor distribution after injection.
- **Wide-Area/High Volume Microemulsion Application**
  - High volume application increases contact with contaminants and reduces number of injection points required for treatment – minimizes overall project cost.

FIGURE 1: THE 3-D MICROEMULSION MOLECULAR STRUCTURE



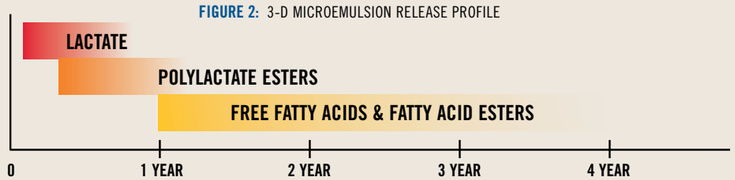
PRODUCT COMPOSITION

3-D Microemulsion (3DMe)™ is a form of HRC Advanced® and has a molecular structure specifically designed to maximize the cost-effective anaerobic treatment of contaminants in subsurface soils and groundwater. This structure (patent pending) is composed of free lactic acid, controlled-release lactic acid (polylactate) and certain fatty acid components which are esterified to a carbon backbone molecule of glycerin (Figure 1).

3DMe produces a sequential, staged release of its electron donor components. The immediately available free lactic acid is fermented rapidly while the controlled-release lactic acid is metabolized at a more controlled rate. The fatty acids are converted to hydrogen over a mid to long-range timeline giving 3DMe an exceptionally long electron donor release profile (Figure 2). This staged fermentation provides an immediate, mid-range and very long-term, controlled-release supply of hydrogen (electron donor) to fuel the reductive dechlorination process.

Typical 3DMe single application longevity is rated at periods of up to 3 to 5 years. With 5 years occurring under optimal conditions, e.g. low permeability, low consumption environments.

FIGURE 2: 3-D MICROEMULSION RELEASE PROFILE



APPLICATION AND DISTRIBUTION

3DMe applications can be configured in several different ways including: **grids, barriers** and **excavations**. The material itself can be applied to the subsurface through the use of **direct-push injection, hollow-stem auger, existing wells or re-injection wells**.

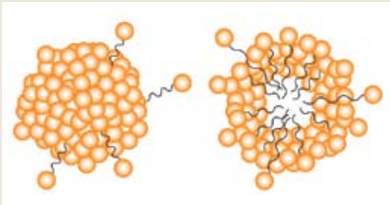
3DMe is typically applied in high-volumes as an emulsified, micellar suspension (microemulsion). The microemulsion is easily pumped into the subsurface and is produced on-site by mixing specified volumes of water and delivered 3DMe concentrate. Detailed preparation and installation instructions are available at www.regenesis.com.

3DMe is usually applied throughout the entire vertical thickness of the determined treatment area. Once injected, the emulsified material moves out into the subsurface pore spaces via micellar transport, eventually coating most all available surfaces. Over time the released soluble components of 3-D Microemulsion are distributed within the aquifer via the physical process of advection and the concentration driven forces of diffusion.

MORE ON MICELLES

Micelles (Figure 3) are groups (spheres) of molecules with the hydrophilic group facing out to the water and the "tails" or lipophilic moiety facing in. They are formed during the 3-D Microemulsion emulsification process and provide the added benefit of increased distribution via migration to areas of lower concentration.

FIGURE 3: MICELLE REPRESENTATION



MORE ON APPLICATIONS

3-D Microemulsion is delivered in 55 gallon drums, 300 gallon totes, tankers or buckets.

The microemulsion is easily prepared on-site and applied in high-volumes for maximum subsurface distribution.

3-D Microemulsion is typically applied through permanent wells or by using direct-push injection.

PERFORMANCE

Case Study #1

A site in Massachusetts showed high levels of PCE and its daughter products TCE and cis-DCE which had been consistently present for more than two years. 3DMe was applied in a grid configuration around monitoring well #16. In Figure 4, the contaminant concentration results indicate a rapid decrease in the parent product PCE and evidence of reductive dechlorination as demonstrated by the relative increases in daughter products TCE and cis-DCE.

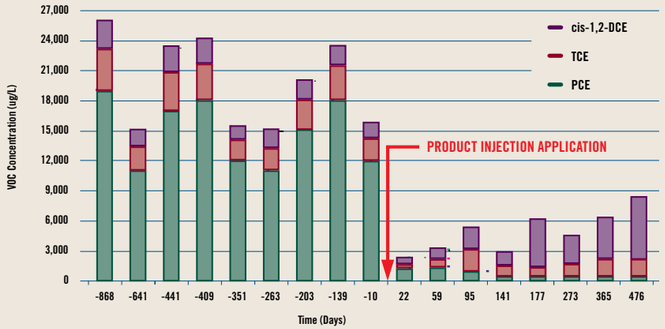


FIGURE 4: MW-16 CONTAMINANT CONCENTRATION DATA

Case Study #2

A site in Florida was characterized with PCE contamination approaching 225 ug/L A total of 1,080 pounds of 3DMe was applied via 16 direct-push injection points to reduce PCE concentrations. Monitoring results in well MW-103 indicated a PCE reduction of approximately 67% within 75 days of the 3DMe application. PCE concentrations continued to decline by 96% one year after application and daughter products remained at low levels. Total Organic Carbon (TOC) levels remained elevated at 17-19 mg/L after 275 days demonstrating the longevity of 3DMe (Figure 5).

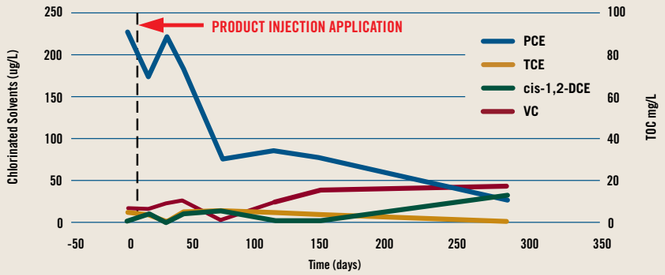


FIGURE 5: MW-103 CONTAMINANT CONCENTRATION DATA

3-D Microemulsion (3DMe)™
MATERIALS SAFETY DATA SHEET

Last Revised: March 26, 2007

Section 1 – Material Identification

Supplier:

REGENESIS

1011 Calle Sombra
San Clemente, CA 92673

Phone: **949.366.8000**

Fax: **949.366.8090**

E-mail: **info@regenesis.com**

Chemical Name(s):	• Glycerides, di-, mono [2-[2-[2-(2-hydroxy-1-oxopropoxy)-1-oxopropoxyl]-1-oxopropoxy]propanoates] • Propanoic acid, 2-[2-[2-(2-hydroxy-1-oxopropoxy)-1-oxopropoxy]-1-oxopropoxy]-1,2,3-propanetriyl ester • Glycerol
Chemical Family:	**Organic Chemical**
Trade Name:	**3-D Microemulsion (3DMe)™**
Synonyms:	**HRC Advanced™ HRC-PED (Hydrogen Release Compound – Partitioning Electron Donor)**
Product Use:	**Used to remediate contaminated groundwater (environmental applications)**

Section 2 – Chemical Identification

CAS#	Chemical
823190-10-9	**HRC-PED**
61790-12-3 or 112-80-1	**Fatty Acids (neutralized)**
201167-72-8	**Glycerol Tripolylactate**
56-81-5	**Glycerol**

Section 3 – Physical Data

Melting Point:	**Not Available (NA)**
Boiling Point:	**Not determined (ND)**
Flash Point:	**> 200 ºF using the Closed Cup method**
Density:	**0.9 -1.1 g/cc**
Solubility:	**Slightly soluble in acetone. Insoluble in water.**
Appearance:	**Amber semi-solid.**
Odor:	**Not detectable**
Vapor Pressure:	**None**

Section 4 – Fire and Explosion Hazard Data

Extinguishing Media:	**Use water spray, carbon dioxide, dry chemical powder or appropriate foam to extinguish fires.**

Water May be used to keep exposed containers cool.

For large quantities involved in a fire, one should wear full protective clothing and a NIOSH approved self contained breathing apparatus with full face piece operated in the pressure demand or positive pressure mode as for a situation where lack of oxygen and excess heat are present.

Section 5 – Toxicological Information

Acute Effects:	**May be harmful by inhalation, ingestion, or skin absorption. May cause irritation. To the best of our knowledge, the chemical, physical, and toxicological properties of the 3-D Microemulsion have not been investigated. Listed below are the toxicological information for glycerol, lactic acid and fatty acid.**	
RTECS#	**MA8050000**	
	Glycerol	
Irritation Data:	**SKN-RBT 500 MG/24H MLD**	**85JCAE-,207,1986**
	EYE-RBT 126 MG MLD	**BIOFX* 9-4/1970**
	EYE-RBT 500 MG/24H MLD	**85JCAE-,207,1986**

Section 5 – Toxicological Information (cont)

Toxicity Data:	**ORL-MUS LD50:4090 MG/KG**	**FRZKAP (6),56,1977**
	SCU-RBT LD50:100 MG/KG	**NIIRDN 6,215,1982**
	ORL-RAT LD50:12,600 MG/KG	**FEPRA7 4,142,1945**
	IHL-RAT LC50: >570 MG/M3/1H	**BIOFX* 9-4/1970**
	IPR-RAT LD50: 4,420 MG/KG	**RCOCB8 56,125,1987**
	IVN-RAT LD50:5,566 MG/KG	**ARZNAD 26,1581,1976**
	IPR-MUS LD50: 8,700 MG/KG	**ARZNAD 26,1579,1978**
	SCU-MUS LD50:91 MG/KG	**NIIRDN 6,215,1982**
	IVN-MUS LD50:4,250 MG/KG	**JAPMA8 39,583,1950**
	ORL-RBT LD50: 27 MG/KG	**DMDJAP 31,276,1959**
	SKN-RBT LD50: >10 MG/KG	**BIOFX* 9-4/1970**
	IVN-RBT LD50: 53 MG/KG	**NIIRDN 6,215,1982**
	ORL-GPG LD50: 7,750 MG/KG	**JIHTAB 23,259,1941**

Target Organ Data: **Behavioral (headache), gastrointestinal (nausea or vomiting), Paternal effects (spermatogenesis, testes, epididymis, sperm duct), effects of fertility (male fertility index, post-implantation mortality).**

Only selected registry of toxic effects of chemical substances (RTECS) data is presented here. See actual entry in RTECS for complete information on lactic acid and glycerol.

Fatty Acids

Acute oral (rat) LD50 value for fatty acids is 10000 mg/kg. Aspiration of liquid may cause pneumonitis. Repeated dermal contact may cause skin sensitization.

Section 6 – Health Hazard Data

One should anticipate the potential for eye irritation and skin irritation with large scale exposure or in sensitive individuals. Product is not considered to be combustible. However, after prolonged contact with highly porous materials in the presence of excess heat, this product may spontaneously combust.

Handling: **Avoid continued contact with skin. Avoid contact with eyes.**

In any case of any exposure which elicits a response, a physician should be consulted immediately.

First Aid Procedures

Inhalation: **Remove to fresh air. If not breathing give artificial respiration. In case of labored breathing give oxygen. Call a physician.**

Ingestion: **No effects expected. Do not give anything to an unconscious person. Call a**

physician immediately. DO NOT induce vomiting.

Section 6 – Health Hazard Data (cont)

Skin Contact:	**Flush with plenty of water. Contaminated clothing may be washed or dry cleaned normally.**
Eye Contact:	**Wash eyes with plenty of water for at least 15 minutes lifting both upper and lower lids. Call a physician.**

Section 7 – Reactivity Data

Conditions to Avoid:	**Strong oxidizing agents, bases and acids**
Hazardous Polymerization:	**Will not occur.**
Further Information:	**Hydrolyses in water to form lactic acid, glycerol and fatty acids.**
Hazardous Decomposition Products:	**Thermal decomposition or combustion may produce carbon monoxide and/or carbon dioxide.**

Section 8 – Spill, Leak or Accident Procedures

After Spillage or Leakage:	**Neutralization is not required. The material is very slippery. Spills should be covered with an inert absorbent and then be placed in a container. Wash area thoroughly with water. Repeat these steps if slipperiness remains.**
Disposal:	**Laws and regulations for disposal vary widely by locality. Observe all applicable regulations and laws. This material may be disposed of in solid waste. Material is readily degradable and hydrolyses in several hours.**

No requirement for a reportable quantity (CERCLA) of a spill is known.

Section 9 – Special Protection or Handling

Should be stored in plastic lined steel, plastic, glass, aluminum, stainless steel, or reinforced fiberglass containers.

Protective Gloves:	**Vinyl or Rubber**
Eyes:	**Splash Goggles or Full Face Shield. Area should have approved means of washing eyes.**
Ventilation:	**General exhaust.**
Storage:	**Store in cool, dry, ventilated area. Protect from incompatible materials.**

Section 10 – Other Information

This material will degrade in the environment by hydrolysis to lactic acid, glycerol and fatty acids. Materials containing reactive chemicals should be used only by personnel with appropriate chemical training.

The information contained in this document is the best available to the supplier as of the time of writing. Some possible hazards have been determined by analogy to similar classes of material. No separate tests have been performed on the toxicity of this material. The items in this document are subject to change and clarification as more information becomes available.

REGENESIS

Hydrogen Release Compound (HRC®) Installation Instructions

(HELPFUL HINTS)

Application in Cold Weather Settings:

The viscosity of HRC is directly related to the ambient temperature. As discussed in the Material Overview, Handling, and Safety section, cold weather tends to increase HRC viscosity and decrease ease of pumping. To maintain HRC at a temperature/viscosity at which it is easy to apply:

1. Raise and maintain HRC's temperature to at least 95°F (35°C) prior to pouring it into the pump hopper

2. Insulate the delivery hose and keep the pump and hot water bath inside an enclosed structure such as a cargo van or trailer

3. Periodically check the HRC temperature in the hopper

4. Occasionally re-circulate HRC through the pump and hose to maintain temperature and viscosity

5. The volume of HRC recirculated should not exceed the volume of HRC in the hopper

6. Do not constantly recirculate HRC through the pump and hoses, as this may adversely affect HRC's longevity.

HRC Bedrock Applications:

When contaminants are present in competent bedrock aquifers, the use of direct push technology as a delivery method is not possible. *Regenesis is in the process of developing methods for applying HRC via boreholes drilled using conventional rotary techniques.* To develop the best installation strategy for a particular bedrock site, it is critical that our customers call the technical support department at Regenesis early in the design process.

HRC can be applied into a bedrock aquifer in cased and uncased boreholes. HRC can be delivered by simply filling the borehole without pressure or by using a single or straddle packer system to inject HRC under pressure. Selection of the appropriate

delivery method is predicated on site-specific conditions. The following issues should be considered in developing an HRC delivery strategy:

Is the aquifers transmissivity controlled by fractures?

Backfilling may be the better delivery method in massive, un-fractured bedrock, this is particularly true in an aquifer setting with high permeability and little fracturing

Intervals greater than 10 feet will require a straddle packer system).

- such as found in massive sandstone

- Down-hole packer systems may be more advantageous in fractured bedrock aquifers

- In this case the fracture type, trends, and interconnections should be evaluated and identified

Is the injection and monitoring wells connected by the same fractures?

Determine if it is likely that the HRC injection zone is connected to the proposed monitoring points

If pressure injection via straddle packers is desired, consideration should be given to the well construction. Specific issues to be considered are:

- Diameter of the uncased borehole (*will casing diameter allow a packer system to be used*?)

- Diameter of the casing (same as above)

- Strength of the casing (can it withstand the delivery pressures?)

- Length of screened interval (screened intervals greater than 10 feet will require a straddle packer system).

For direct assistance or answers to any questions you may have regarding these instructions, contact Regenesis Technical Services at 949-366-8000.

REGENESIS, 2003
www.regenesis.com

HRC TECHNICAL BULLETIN #2.5.1

Plume Area Treatment Example

HRC injection grids are commonly employed at project sites where a localized plume of chlorinated solvent contamination exists. HRC injection grids are often applied to affect a very cost-effective remediation. The design process for this treatment strategy is described below for a hypothetical site. After the example, a description of the various spreadsheet input parameters is provided for reference.

Step 1: Gather Relevant Site Assessment Data

As with any remediation design, the first step is to gather the relevant site assessment data. For example, consider the following site:

Lithologic data: Groundwater is located 10 feet below the ground surface (bgs) and extends to a depth of 40 feet bgs at which point a clay aquitard is encountered. Aquifer sediments consist primarily of silty sands.

Contaminant concentrations: PCE concentration ranges from 0.1 to 5 mg/L. Daughter products of the biological degradation of PCE are identified at the following concentrations: TCE at 0.5 mg/L and cis-1,2-DCE at 0.5 mg/L.

Extent of impacted groundwater:

The aerial extent of the contaminant plume is estimated to be 50 feet wide by 100 feet long.

Most groundwater monitoring wells contain screen intervals that extend to a depth of 20 feet bgs. Vertical profiling of the contaminants is accomplished by (1) installing several groundwater wells with screened intervals located from 25 to 30 feet bgs and (2) by collecting groundwater samples using direct push equipment. This results in the conclusion that the contaminants are limited to the upper 15 feet of the aquifer.

Aquifer redox conditions: ORP = 100 mV, DO = 2 mg/L, nitrate = 1 mg/L, dissolved iron = 10 mg/L, sulfate = 50 mg/L

Additional aquifer parameters: The following parameters were collected through soil and groundwater investigations or estimated or calculated using industry standard procedures: fraction of organic carbon (0.005), porosity (0.3), hydraulic gradient (0.005 ft/ft), hydraulic conductivity (10 ft/day or 3.5x10-3 cm/sec), groundwater velocity (60 ft/yr).

Step 2: Evaluate Site Data and Specify HRC Grid Design and Cost

The next step is to determine the scope of the remediation. After evaluating health risks and groundwater quality thresholds, the designer specifies a cleanup goal and the extent of the contaminant plume requiring remediation. For this example, assume that the following decisions are made concerning the remediation design:

Aerial and vertical extent of aquifer requiring remediation: 50 feet x 100 feet x 15 feet

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Conservative estimate of contaminant concentrations to be bioremediated: 5 mg/L PCE, 0.5 mg/L TCE, and 0.5 mg/L cis-1,2-DCE

The presence of daughter products from the reductive dechlorination of PCE indicates that the biodegradation of PCE is occurring to a limited extent. Geochemical parameters (ORP, DO, etc.) indicate that the aquifer redox conditions are not yet in the optimum range for the reductive dechlorination of chlorinated hydrocarbons. Furthermore, there is no apparent electron donor (or hydrogen source) to stimulate further dechlorination. The remediation designer decides that HRC can be used to provide the aquifer with a consistent low level of hydrogen accelerating the reductive dechlorination of PCE and its daughter products.

The quantity of HRC needed to fuel the reductive dechlorination process is estimated using the site assessment data and general design guidelines. The HRC grid design process is simplified by using the HRC Grid Design worksheet found on the HRC Application Software (available from Regenesis) and consists of specifying the following design variables:

Site information: Plume dimensions, aquifer transport parameters, and contaminant and CEA concentrations are entered into the worksheet.

Demand factors: A microbial demand factor of 3x is used, and an additional demand factor of 3x is chosen since the entire source of the contaminant plume is targeted for remediation with one application of HRC.

HRC delivery point spacing: A delivery point spacing of 10 feet on center is selected to provide a reasonable distribution of HRC into the contaminant plume. This results in an HRC grid of 10 rows of 5 points per row, for a total of 50 delivery points.

HRC injection amounts: The contaminant and competing electron acceptor concentrations, adsorbed phase concentrations, and demand factors are used to estimate the required amount of hydrogen and corresponding HRC required for the reductive dechlorination reactions. For a 10 feet-on-center spacing (and 50 total injection points as determined above), a vertical HRC application rate of 6.8 lbs/ft is calculated by the software. Therefore, a total of 5,107 pounds of HRC are required (50 points with 15 feet of injection per point at 6.8 pounds of HRC per vertical foot).

Cost estimate: The HRC material cost for this example is $6/lb for a total of approximately $30,640. Costs of HRC product, shipping and applicable taxes vary from site to site and should be requested from Regenesis' sales or technical support staff if a detailed cost estimate is needed. HRC installation costs can be estimated using a daily rate for the injection subcontractor and an estimate of the production rate for the site. For this example, it is assumed that two injection points can be completed per hour and that a Geoprobe rig costs $2,000 per day and is mobilized for $1,000. The installation cost for 50 injection points to a depth of 25 feet is then $9,000, resulting in a total installation and HRC material cost of approximately $40,700.

To summarize, the following issues should be considered during the HRC grid design and cost estimation process:

Injection point spacing typically ranges from 5 to 15 feet-on-center, and its specification depends on groundwater velocity, sediment permeability, required HRC injection amounts, and HRC grid size.

The HRC injection rate for each point typically ranges from 4 to 10 lb/ft, and its specification depends on the contaminant concentrations, competing electron acceptor concentrations,

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competing microbial demand, and soil type. It should be noted that using fewer points and higher doses might not provide sufficient distribution of HRC and lactic acid throughout the contaminant plume.

For larger plumes and/or large ranges of contaminant concentrations, the HRC dose rate should be adjusted as appropriate (i.e., the plume can be divided into high-, medium-, and low-contaminant concentration areas, each with a specific HRC dose rate).

- The need for reapplication of HRC will depend on achievable biodegradation rates, remedial goals for the site, proximity of downgradient receptors, and other technical/regulatory issues. Some sites will require only one application of HRC, while others may require multiple reapplications (the reapplications typically will be done at lower HRC doses and in a smaller grid area).

Input and Output Parameters for HRC Applications Software

1) General Information on Software Use

User input parameters are shown in blue, whereas cells containing the results of calculations are shown in black. Red warnings or guiding comments may be generated in response to the spreadsheet calculations. Dialog boxes and point and click buttons are available to assist with data entry and to navigate the software.

2) Basic Site Characteristics

Basic site characteristic parameters are needed to specify the physical site characteristics. The width and depth of the contaminant plume refer to the planned treatment area, which can vary depending on remedial goals and cleanup strategy.

Thickness of the Contaminated Saturated Zone specifies the vertical thickness across which HRC will be delivered. The vertical thickness is dictated by the estimated thickness of the contaminant plume. For instance, if a site has a contaminant plume spanning the saturated zone above an aquitard, then the design should treat the aquifer down to the aquitard. If the contaminant plume is limited to a localized depth interval or lithologic layer, then HRC injection can be limited to the contaminated depth interval.

The HRC material cost is proportional to the thickness specification. Therefore, it is important to determine the vertical contaminant distribution as accurately as possible. If only moderate concentrations of contaminant are present, and no vertical profile of the plume has been done, Regenesis suggests that the user assume a thickness of approximately 20 feet. Porosity refers to the total porosity of the aquifer soil matrix. Using the above input parameters, the software will calculate the treatment zone pore volume.

Next, information regarding aquifer transport properties are requested. The hydraulic gradient and conductivity are used to calculate the groundwater seepage velocity, which can be used to select delivery point spacing and evaluate flow dynamics within the grid.

3) Dissolved-phase Groundwater Concentrations

Under this category of input parameters, representative contaminant concentrations are specified for the area where HRC will be delivered. Specifically, dissolved-phase concentrations that are determined by groundwater well sampling and analysis are entered here. While it is important to consider the most recent data available, the input values should represent the concentration that the user judges to be indicative of actual subsurface conditions over the course of an entire hydrogeologic cycle.

Regenesis has included input spaces for the most commonly encountered chlorinated solvents;

however, HRC will stimulate the degradation of a myriad of pollutants. If the contaminant the user is concerned with is not listed for input, please contact Regenesis directly. We will be glad to assist in determining the amount of HRC required to treat other less common contaminants.

4) Sorbed Phase Contaminant Mass

For HRC grid designs, there is usually a multiple of the total dissolved contaminant mass that is bound to the saturated soil zone matrix. This is called hydrophobically sorbed contamination and can be visualized as a thin layer of contaminant that is retained by clean aquifer materials when they come into contact with a dissolved contaminant flow. The mass of contaminant sorbed to the aquifer matrix is a function of the bulk density of the aquifer matrix, the fraction of organic carbon in the matrix (foc), and the contaminant-partitioning coefficient (Koc). An estimate of the mass of sorbed contamination is calculated in this section by entering the factors mentioned above. Input values for the soil, the bulk density, and the fraction of organic carbon (foc) can be measured or estimated based on soil type. The Koc value can be obtained for each contaminant from any number of published references.

5) Competing Electron Acceptor Concentrations

The concentrations of competing electron acceptors (CEAs) such as dissolved oxygen, nitrate, ferric iron, and sulfate have an effect on the amount of HRC required for enhancing in-situ bioremediation. Hydrogen from the HRC is used to reduce these CEAs to create redox conditions that are conducive to reductive dechlorination processes. As a result, the CEA demand for hydrogen (and consequently HRC) must be considered in the specification of the amount of HRC required for a project. Groundwater data indicating the actual site values for these parameters are important in determining an accurate final design for HRC application. However, in the absence of these data, reasonable estimates of these values can be made to generate a preliminary design and cost estimate.

6) Microbial Demand Factor

In addition to contaminant and CEA demand for HRC, subsurface microbes will use some of the lactic acid as a source of energy or structural carbon. Therefore, in designing an HRC application, these competing microbial processes must be taken into account. Regenesis' experience indicates that a value of 3 suffices under most conditions. However, if site-specific laboratory microcosm data are available, the designer can input the appropriate value directly.

7) Additional Demand Factor

Additional Demand Factor is used to account for uncertainty about the potential sinks for electron donor. This factor can be thought of as a contingency or safety factor, which is used to account for the many uncertainties inherent in a subsurface investigation and in situ remediation project. Potential sources of additional HRC demand include higher than expected contaminant mass (in the form of residual phase DNAPL and/or high concentration hot spots), microbial demand in excess of the estimated 3x, and uncertainty about the quantity of HRC required for the reduction of iron and manganese. The simple measurement of the concentrations of these competing electron acceptors in groundwater samples does not give an accurate representation of the iron and manganese reduction demand since these species may be present either as colloids or attached to the soil matrix. Regenesis recommends an additional demand factor of 2 to 3 for a first application at a site.

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8) Life Span for One Application (for barrier designs)

For HRC barrier designs, the life span for one application should be input in this field.

This value is used with the groundwater seepage velocity to estimate the flow of contaminant mass into the barrier during this period of time.

9) HRC Delivery Point Spacing and HRC Dosing Rate

For grid designs, the recommended spacing for HRC delivery points ranges from 5 feet-on-center to 15 feet-on-center. Spacing is a function of soil type, groundwater velocity, and necessary HRC dosing. Generally, the lower the hydraulic conductivity of the soil matrix, the closer the spacing. For sites with silts and clay, delivery point spacing should be 5 to 8 feet-on-center, while a site with sands and gravels may have a spacing up to 15 feet-on-center. The Delivery Point Spacing section of the Grid Design worksheet allows the designer to calculate the required number of points and HRC dose rate for a given plume size and spacing.

For barrier designs, a series of staggered HRC injection point rows are typically constructed. The effective spacing of delivery points perpendicular to the groundwater flow should be no more than 10 feet-on-center. The Delivery Point Spacing section of the Barrier Design worksheet allows the designer to estimate the required number of points and HRC dose rate for a given barrier length and contaminant flow rate.

10) Proposed HRC Grid Specifications

In this section of the worksheet, the designer may adjust the total number of injection points and the HRC dosing rate or leave it as calculated. The software will then calculate the cost of HRC material and estimate the cost of shipping and taxes for the given scope of the project (i.e., number of points, treatment thickness, and HRC dosing rate).

11) HRC Installation Cost Estimate and Total Project Cost

Although Regenesis does not perform installation services, our experience on many applications has given us an understanding of the costs associated with installing the HRC. This section offers the designer an opportunity to estimate how much the HRC grid or barrier application will cost. The suggested input parameters required are based on Regenesis' experience. The result of this section is an estimated subcontractor installation cost. This estimate should be adjusted based on local contractor costs. The Total Project Cost provided represents the sum of the HRC Installation Cost Estimate and the HRC Material Costs. It does not include the costs associated with groundwater monitoring, reporting, or consulting oversight.

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Hydrogen Release Compound HRC®

HRC Performance Characteristics - Longevity

General Background

Since Hydrogen Release Compound (HRC®) is a time-release product, one of the central issues in site design and one of the most frequently asked questions is "How long does it last"? The short answer is that the basic HRC now sold, specifically defined as a formulation of Glycerol Polylactate (GPL), diluted with glycerol to a viscosity of 20,000 centipoise (cP), is estimated to stimulate reductive dechlorination within the aquifer for about 12 months. The longevity is a function of basic product chemistry and certain biological and geochemical features of the aquifer. HRC has been shown to have a direct effect on contaminants resulting from the lactic acid release and other secondary effects, related to the formation of other organic acids that "borrow hydrogen" and recycled biomass, that have a more prolonged effect on aquifer conditions.

Theoretical Considerations

Longevity as a Function of HRC Chemical Characteristics

Hydrogen Release Compound is a specific article of commerce as described. The "active ingredient", Glycerol (tri) Polylactate (GPL), is one of a family of polylactate esters, defined by our patent, that upon hydration break down to release lactic acid. The exact chemical nature of a specific polylactate ester, such as GPL, is a major factor in product longevity. In essence, the structure and degree of esterification determine viscosity and viscosity is a critical factor in longevity.

Structurally, an ester is the product of a reaction between an organic acid (COOH group) and an alcohol (OH group). In this reaction as shown in Figure 1, the two groups react and water drops out forming the ester linkage, noting that the amount of water removed in esterification can affect viscosity. The example used shows methyl alcohol reacting with lactic acid to form a simple lactate ester (methyl lactate).

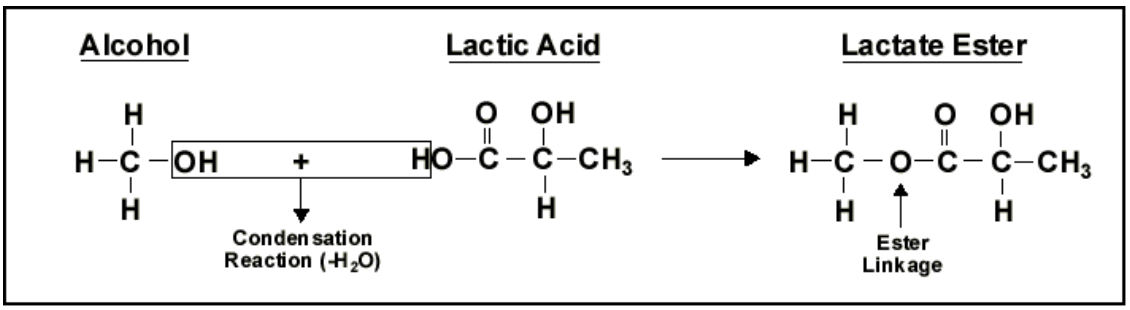

Figure 1. Formation of an Ester.

Polylactate esters are formed from the combination of certain alcohols with a unique lactic acid complex serving as the organic acid group. The alcohols used are compounds such as glycerol (3 OH groups), xylitol (5 OH groups) and sorbitol (6 OH groups). These "foundation" molecules are then esterified with a polylactic acid complex as illustrated in Figure 2.

One of the unique features of the polylactic acid complex is that lactic acid is esterified to itself. This is possible because lactic acid, as shown in Figure 1, has both an OH and a COOH group. As a result we can typically produce trimers or tetramers of lactic acid and create a "polylactic acid complex" or "polylactate complex", which is in turn esterified to the foundation OH donor as described.

The Glycerol (tri) Polylactate (GPL) component of the HRC in commerce is specifically the molecule in Figure 2. However, GPL itself can vary as a function of how many OH positions are actually esterified, so that one could have glycerol (tri) polylactate if all 3 are filled or glycerol (di)polylactate if just 2 are filled. The GPL in HRC is the Glycerol (tri) polylactate ester

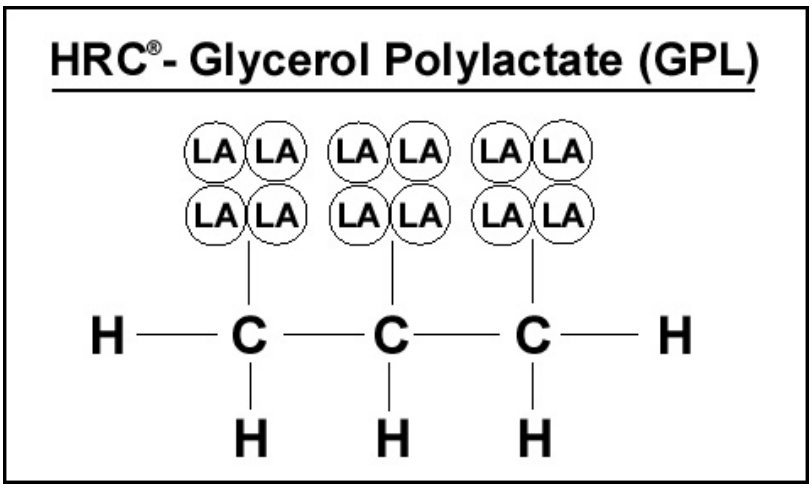

Figure 2. Structure of Glycerol (tri) Polylactate (GPL)

The point of this is to emphasize that the degree of complexity and esterification of the molecule control its viscosity and hence a major component of its reactivity. This in turn controls product longevity under a uniform set of conditions. For example, the (tri)polylactate form of GPL would be more viscous that the (di)polylactate form. Further, a molecule built with tetramers of lactic acid would be more viscous than one made with trimers. As a final example a sorbitol polylactate ester is more viscous than a glycerol polylactate ester, because it is based on 6 carbons rather than 3 carbons.

Viscosity becomes a dominant issue in longevity because it is a measurement of resistance to flow. As a result, viscosity controls the evolution of surface area over time and the speed at which HRC becomes soluble in water. Therefore, if a polylactate formulation becomes less viscous it will spread more, thus exposing more sites to chemical and biological attack. The latter case, involving the enzymatic action of microorganisms, is a particularly powerful mechanism and this will be expanded on later. In essence, "thicker lasts longer", which one would intuitively gather for the reaction of any solute with a solvent.

Returning to viscosity for a moment, we said that it is a measure of resistance to flow and can be measured in a viscometer. In a viscometer, the substance being tested is placed between two plates, one being stationary and one being movable. The amount of force applied to overcome resistance to the movement of the moveable plate is the key variable. Consequently, the units of viscosity in SI units are force-based, e.g., dyne-sec/cm^2 or Poise (P). Typically we measure the viscosity of HRC in centipoise (cP).

To be pumpable for push-point injection, HRC has to be about 20,000 cP (like honey). This is achieved by cutting raw GPL, which is about 200,000 cP (gel-like), with glycerol - by a factor of about 2, noting that the relationship between dilution and viscosity is non-linear. Therefore, we produce a form of HRC at 200,000 cP, as a function of the specific chemical structure, such that when it is cut about 50:50 with glycerol we achieve a pumpable 20,000 cP material.

Longevity as a Function of Aquifer Characteristics

The viscosity of the HRC is still only one side of the equation. The other important feature concerns the environment the HRC is placed into. An experimental model for the dynamics of HRC utilization in the bioremediation of TCE is published in Farone, Koenigsberg and Hughes (1999). Copies of this and other papers cited herein are available on request from Regenesis and it is convenient to use our web site at www.regenesis.com.

The model, which was calibrated with laboratory microcosm tests, clearly demonstrates that the nature and extent of microbial populations has a significant effect on the longevity of HRC. Simply put, most microbes - not just the kinds that ferment lactic acid into hydrogen or those that promote reductive dechlorination - will produce esterases and lipases that degrade HRC and release lactic acid.

Therefore, if an aquifer has a high microbial population it will metabolize a given mass of HRC at a faster rate than if the microbial counts are moderate to low. An example of this is presented in Figure 3 that shows a difference in lactic acid release rates at three different microbial concentrations. Note that this lab test represents a highly accelerated condition relative to field results, because everything is optimized and reacted in close proximity in the test tube environment.

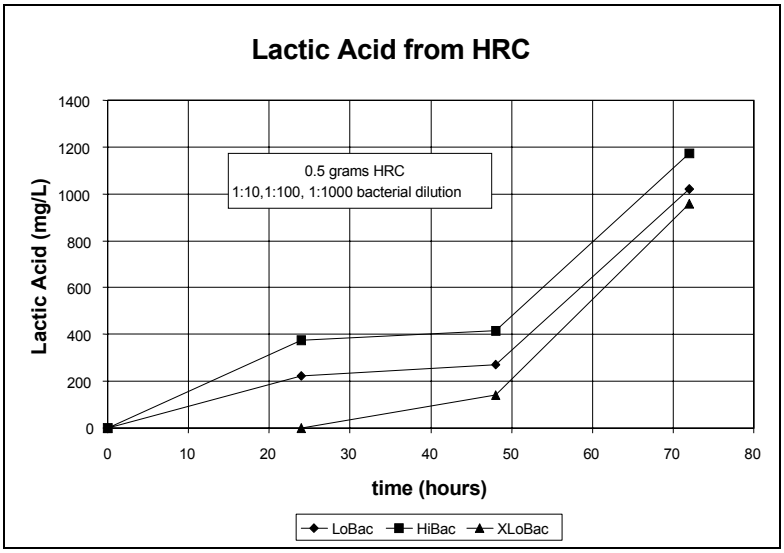

Figure 3. Lactic Acid Release Rates as a Function of Microbial Population.

Early Laboratory Work

Table 1 presents data that reflect a set of minimum times that standard HRC has lasted in the laboratory. Again, note that laboratory tests generally have high rates of activity relative to the field. The tests summarized below, were conducted to test the efficacy of HRC in remediating TCE and were not longevity tests per se. For economic reasons they were only run for about three months to collect the remediation rate data. Still, the tests supply some useful minimums for longevity. The tests were macrocosm studies conducted in Aquifer Simulation Vessels (ASVs) with a flow rate of about 1 ft/day. For a further discussion of the ASV type studies, please refer to TB 2.4.3.

Table 1. Macrocosm (ASV) Tests.

Product	Duration of Test	Presence of Product at Conclusion
GPL 52%/Glycerol 48%	84 days	Yes
GPL 52%/Glycerol 48%	80 days	Yes
GPL 52%/Glycerol 48%	80 days	Yes
GPL 52%/Glycerol 48%	94 days	Yes

Recent Laboratory Work

Recently an ASV study was established to specifically look at both longevity and diffusion issues regarding 20,000 cP HRC and 200,000 cP GPL. 15 g of each formulation was placed in the influent end of the ASV; there was no flow so that diffusion alone would be measured. While the main purpose of the test is covered in TB 2.4.3, it can be noted that, after 66 days, there is still considerable material left in the system of both products. The experiment will be continued until the product is exhausted. This is expected to be about one year for the 20,000 cP HRC and several years for the 200,000 GPL.

Field Results

<u>Data from the Oldest Trials</u>

The most powerful evidence for product longevity is of course the observations made in the field. As presented in Table 2 and graphically in Figure 4, the 20,000 cP HRC will last from 119 days to 580 days. It is important to note that this is a "living table" such that some of the applications are still in progress and the average longevity figures is getting larger. However, based on the range of this field experience and the fact that some tests are still in progress, we claim that 20,000 cP HRC degrades slowly, on average, for nine months (as modulated by certain features in the contaminated aquifer). However, just because the organic acids are gone does not mean the effects are over. Residual hydrogen will still be present and biomass accumulates which will later be available as fermentable carbon. The stimulated biomass is also more able to utilize native carbon as well. Therefore, ~20,000 cP HRC now sold is estimated to stimulate reductive dechlorination within the aquifer for at least 12 months.

Also, some work during the early phase of product development (not cited here) looked at the properties of a 1,000,000 cP sorbitol polylactate hard gel. In one test, the material physically lasted for at least two years at the point of application. In this experiment, which is presented in Dooley, Murray and Koenigsberg (1999), the SPL hard gel was placed in a canister with sufficient holes to allow it to ooze out slowly. It was placed in an injection well and the exposed surface was in contact with a fairly vigorous flow (relative to an aquifer velocity) of 0.25 gal/min. The active recirculation period ended at about 330 days, however, and the canister was retrieved after two years significant HRC was still present.

Regenesis is working on ways of delivering higher viscosity materials directly as "implants" using warmed GPL to lower the viscosity during application and special push-point injection and hollow stem auger techniques. These implants can be used as barriers or source treatments and can be expected to last for several years for very long-term plume management.

Table 2. Longevity Profile of GPL-HRC at 20,000 cP.

Site	Last Field Observation of Organic Acids- Lactic, Butyric, Propionic (in days)	Duration of Data Collection (in days)	Status
Site 1	150	364	Product exhausted before monitoring completed
Site 2	173	173	Product still present at conclusion of monitoring
Site 3	181	181	Product still present at conclusion of monitoring
Site 4	197	197	Product still present at conclusion of monitoring
Site 5	321	321	Product still present at conclusion of monitoring
Site 6	119	119	Product still present; monitoring on-going
Site 7	240	240	Product still present; monitoring on-going
Site 8	243	243	Product still present; monitoring on-going
Site 9	399	399	Product still present; monitoring on-going
Site 10	580	580	Product still present; monitoring on-going

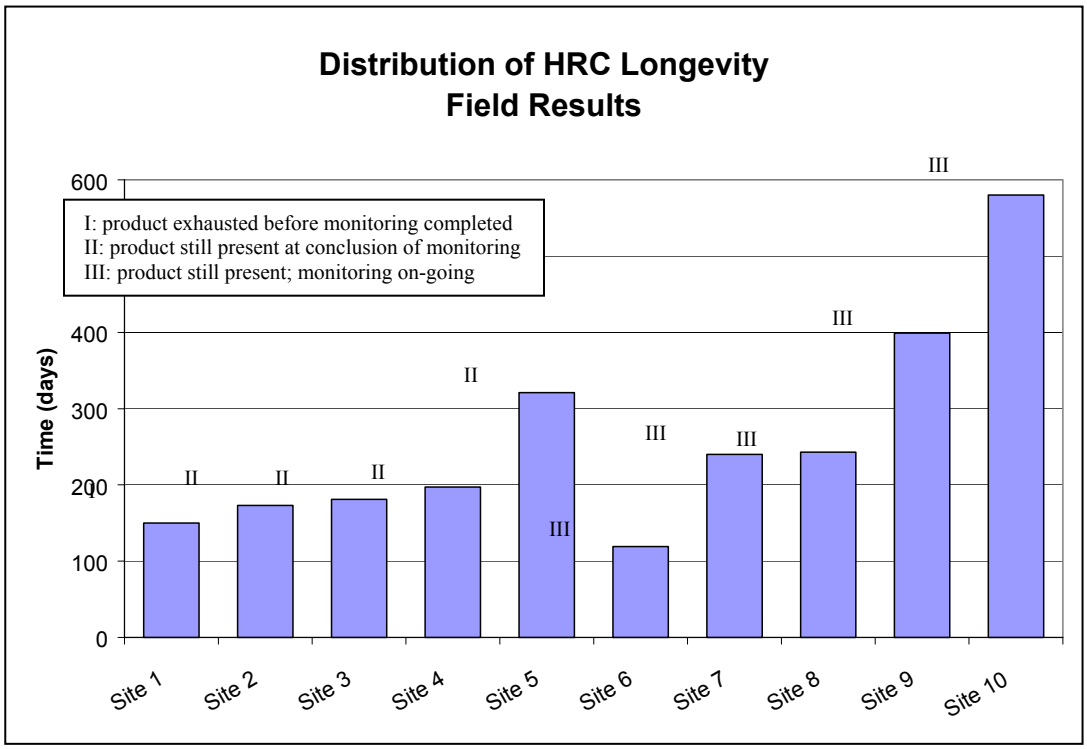

Figure 4.

Secondary Effects

Often we see remediation continuing after HRC breakdown products are no longer in the system. This observation led us to postulate that there may be more than one phase in the effect of adding HRC to the aquifer. Generally, we use the presence of elevated levels of organic acids as the metric, although we can also look at TOC data as well. However, sometimes after the footprint of the HRC is gone we can still see elevated rates of remediation. On further consideration we believe that the organic load to the aquifer that is provided by HRC is not a uni-directional event and that the biomass of microorganisms constructed from HRC can be recycled. This can cause an after effect as could native carbon in the system that might be more responsive to the elevated microbial population levels. While this is clearly not a dominant driver for reductive dechlorination relative to HRC, it apparently can have an impact. Lastly, at the formal exhaustion of the organic acids there is still hydrogen available.

To support this hypothesis we can look at an HRC injection as described in Sheldon, (1999). This experiment was a pilot test with a monitoring well (MW-8) that was clearly in the center of the HRC injection zone. Another well (MW-1) was in the experimental grid but was outside the migration zone for the HRC and its breakdown products during the course of the experiment. Figure 5 shows the nature of the organic acid profile over time and it should be noted that propionic acid is formed from lactic acid and then breaks down to release hydrogen. Acetic acid is generally considered to be a non-hydrogen evolving end point.

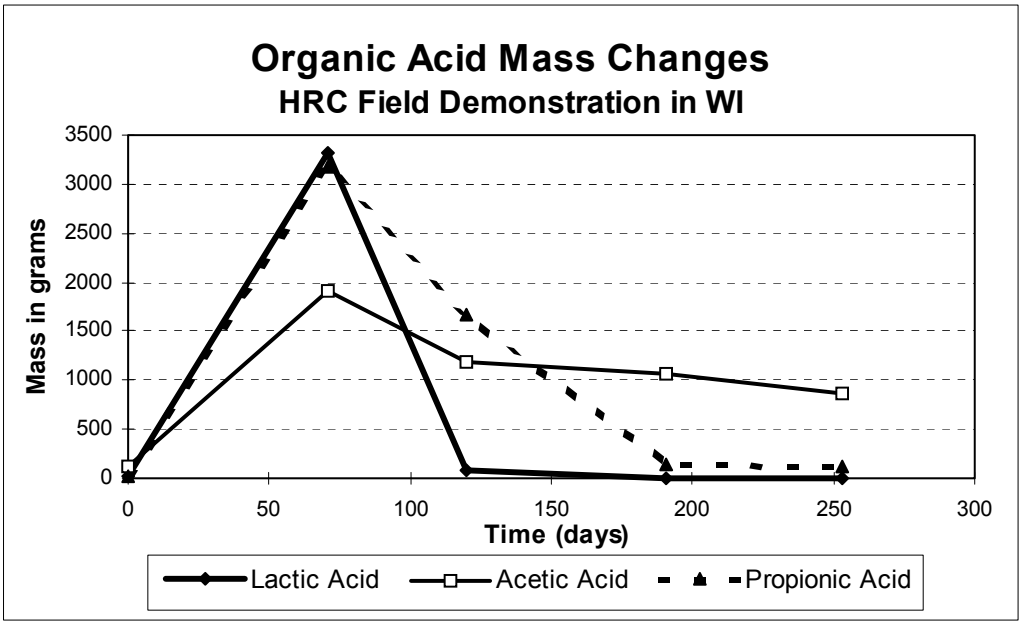

Figure 5.

The total mass of organic acids is calculated from a contouring exercise and the last appearance of lactic acid per se is between 70 and 120 days (the formulation was only about 10,000 cP in this early work). The disappearance of propionic acid between 120 and 190 days is further noted. With this background information we can now examine Table 3 and evaluate the remediation rate differences between the impacted and non-impacted wells (MW8 vs. MW1). It is clear that even after the organic acids are "gone" that there are still rate differences to be accounted for. At least two hypotheses can be presented.

- The HRC is still releasing slowly and is being consumed as fast as it is produced which would still allow remediation to proceed and cause a rate difference.

- The HRC is exhausted, but the organic material is being recycled and or native organic material is being mobilized by growing microbial populations - such that remediation continues.

Flow rates at this site are on the order of 0.5 ft/day and that is not sufficient to flush the system of HRC in the period involved in the study.

Table 3. TCE Degradation Rate Differentials at WI Site

Day	Half Life (d) Well TW01	Half Life (d) Well TW08	Ratio TW01/TW08
0-70	338	29	11.50
70-120	211	43	4.94
120-149	256	53	4.84
149-191	309	45	6.80
191-253	205	38	5.41

Summary

The main active ingredient in Hydrogen Release Compound is a polylactate ester called Glycerol (tri)Polylactate or GPL. Abiotic and microbially mediated hydrolysis of the ester linkage, between glycerol and the polylactate complex, releases the polylactate complex. The polylactate complex is a tetramer of lactic acid (4 lactic acid molecules esterified to themselves) and its degradation results in the release of individual lactic acid molecules which undergo fermentation to release hydrogen. These chemical features and the resultant viscosities, are an important component of longevity.

GPL is manufactured as a highly esterified thick gel and can be subsequently cut to a syrup-like consistency for injection. All other conditions being equal, product viscosity combined with the nature of microbial activity in the aquifer are the key determinants of product longevity. This is essentially a surface area argument. The thinner the material the more it will spread out and be exposed to chemical and biological degradation.

Based on the evidence presented in the laboratory and field, we can claim that ~20,000 cP HRC is estimated to stimulate reductive dechlorination within the aquifer for about 12 months. The longevity of this effect is a function of certain biological and geochemical features of the aquifer. HRC has been shown to promote reductive dechlorination resulting from the lactic acid release and possibly other indirect effects related in part to the formation of a nominal amount of recycling organic material that has a more prolonged effect on aquifer conditions. An “after effect” in the aquifer involving the recycling of carbon may extend the positive remediation effects beyond the formal longevity based on lactic acid release.

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for In Situ Bioremediation of Chlorinated Solvent Contamination, pp. 287-292. Battelle Press, Columbus, OH.

HRC Technical Bulletin 2.4.3. Aquifer Simulation Vessel (ASV) Studies.

Sheldon, J.K., S.S. Koenigsberg, K.J. Quinn and C.A. Sandefur. 1999. "Field Application of a Lactic Acid Ester for PCE Bioremediation". In: A. Leeson and B.C. Alleman (Eds.), *Engineered Approaches for In Situ Bioremediation of Chlorinated Solvent Contamination*, pp. 61-66. Battelle Press, Columbus, OH.

REGENESIS

Hydrogen Release Compound (HRC®) Installation Instructions

GENERAL GUIDELINES

The best method to deliver HRC into the subsurface is to inject the material through direct push rods using hydraulic equipment. This approach increases the spreading and mixing of HRC into the aquifer. This set of instructions is specific to direct push equipment.

Regenesis has found that very few pumps can adequately deliver HRC to the subsurface. Although other pumps may inject HRC, we have developed the following instructions specifically for use with an R.E. RUPE Company Model ORC/HRC 9-1500 mixing and pumping machine.

Note: We have strong evidence that the recently developed Geoprobe GS-2000 pump can effectively deliver HRC to the subsurface.

The installation of HRC should span the entire vertical contaminated saturated thickness. If the vertical extent of HRC application is confined to a limited interval, then the HRC material should be placed across a vertical zone extending a minimum of 2 feet above and below the screened Interval of monitoring wells to be used to evaluate the performance of the bioremediation project.

MATERIAL OVERVIEW, HANDLING, AND SAFETY

HRC is shipped in 4.25-gallon buckets and each bucket has a gross weight of approximately 32 pounds (net weight of HRC is 30 pounds). At room temperature HRC is a sticky gel with a viscosity of approximately 20,000 centipoise (roughly equivalent to cold honey). The HRC material has a nominal density of 1.3 grams/cubic centimeter or approximately 10.8 pounds per gallon. The viscosity of HRC is temperature sensitive, significant changes in HRC's viscosity are observed with large changes in product temperature. It should be noted that the temperature/viscosity relationship is not linear.

For ease of installation, HRC should be stored in a warm, dry place that is protected from direct sunlight. It is common for stored HRC to settle somewhat in a container. Care should be taken to mix the HRC into a relatively uniform fluid prior to installation. Product uniformity is most easily achieved by pre-heating HRC before pouring it into the pump hopper. Care should be taken to scrape any separated material from the bottom of each bucket. Do not use any "rocky material" in the bottom of the bucket because it could potentially clog the check valves in the machine. Use the Rupe pump's mixing and recirculation features to homogenize the HRC. Pre-heating HRC makes it easier to pour and remix the separated material. Although HRC is manufactured as a food-grade

material that is safe to ingest, field personnel should take precautions while handling and applying HRC. Field personnel should use appropriate safety equipment, including eye protection. The low pH when dissolved in water and the products viscosity make eye protection mandatory. Gloves should be used as appropriate based on the exposure duration and field conditions. A Material Safety Data Sheet is provided with each shipment. Personnel who operate field equipment during the installation process should have appropriate training, supervision, and experience

For direct assistance or answers to any questions you may have regarding these instructions, contact Regenesis Technical Services at 949-366-8000.

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Hydrogen Release Compound (HRC®) Installation Instructions

(Pump Information)

Regenesis has evaluated a number of pumps that are capable of delivering 20,000 centipoise HRC to the subsurface at a sufficient pressure and volumetric rate. Although a number of pumps may be capable of delivering the HRC to the subsurface at adequate pressures and volume, each pump has a set of practical issues that make it difficult to manage in a field setting. As a result of this evaluation, Regenesis has determined that the R.E. RUPE Company Model ORC/HRC 9-1500 meets the pressure and volume requirements needed to successfully inject HRC in the field. When applying measured volumes of HRC via probe boreholes, it is useful to know the volume of a single pump stroke and the associated delivery system lines. The following additional information is provided for reference

HRC Physical Characteristics:

Density	1.3 g/cc or 10.8 lbs./gal.
Viscosity	Approx. 20,000 centipoise

Equipment Volume and HRC Weight per length

Equipment	Volume	HRC weight
1 inch OD; 0.625 ID hose (10 feet long)	0.2 gallon	1.8 lbs.
1.25 inch OD; 0625 inch ID drive rod (3 feet length):	0.05 gallon	0.5 lbs.
1.25 inch OD; .625 inch ID drive rod (4 feet length):	0.06 gallon	0.7 lbs.

Before using the Rupe Pump, check the following:

- Fuel level prior to engaging in pumping activities (it's best to start with a full tank)

- Remote control/pump stroke counter LCD display; if no display is present, the electronic counter will need to be replaced (Grainger Stock No. 2A540)

- Monitor pump strokes by observing the proximity switches (these are located on the top of the piston)

Pump Cleaning after HRC Use:

For best results use a hot water (150-170 °F or 66-77 °C) pressure washer to clean equipment and rods periodically throughout the day. Internal pump mechanisms and hoses can be easily cleaned by circulating hot water and a biodegradable cleaner such as Simple Green through the pump and delivery hose. In order to maintain optimal pumping conditions, it is desirable to circulate pure glycerin through the pump after the pump has been thoroughly cleaned. A small volume of glycerin should be left in the pump works and hopper during storage or shipping. Further cleaning and decontamination (if necessary due to subsurface conditions) should be performed according to the equipment supplier's standard procedures and local regulatory requirements.

NOTE: The remote control/pump counter should be kept dry at all times, if it gets wet it will short-circuit and ill need to be replaced.

For direct assistance or answers to any questions you may have regarding these instructions, contact Regenesis Technical Services at 949-366-8000.

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REGENESIS

Hydrogen Release Compound (HRCâ)

INSTALLATION INSTRUCTIONS
Direct-Push Injection

GENERAL GUIDELINES

The best method to deliver HRC into the subsurface is to inject the material through direct push rods using hydraulic equipment. This approach increases the spreading and mixing of HRC into the aquifer. This set of instructions is specific to direct push equipment.

Regenesis has found that very few pumps can adequately deliver HRC to the subsurface. Although other pumps may be capable of injecting HRC, we have developed the following instructions specifically for use with an R.E. RUPE Company Model ORC/HRC 9-1500 mixing and pumping machine. There is also strong evidence that the Geoprobe GS-2000 pump can effectively deliver HRC to the subsurface. In general, Regenesis strongly recommends using a pump with a minimum pressure rating of 1,500 pounds per square inch (psi) and a minimum delivery rate of 3 gallons per minute.

The installation of HRC should span the entire vertical contaminated saturated thickness. If the vertical extent of HRC application is confined to a limited interval, then the HRC material should be placed across a vertical zone extending a minimum of 2 feet above and below the screened Interval of monitoring wells to be used to evaluate the performance of the bioremediation project.

MATERIAL OVERVIEW, HANDLING, AND SAFETY

HRC is shipped in 4.25-gallon buckets and each bucket has a gross weight of approximately 32 pounds (net weight of HRC is 30 pounds). At room temperature, HRC is a sticky gel with a viscosity of approximately 20,000 centipoise (roughly equivalent to cold honey). The HRC material has a nominal density of 1.3 grams/cubic centimeter or approximately 10.8 pounds per gallon. The viscosity of HRC is temperature sensitive. Significant changes in viscosity are observed with large changes in product temperature. It should be noted that the temperature/viscosity relationship is not linear. For ease of installation, HRC should be stored in a warm, dry place that is protected from direct sunlight. It is common for stored HRC to settle somewhat in a container. Pre-heating HRC makes it easier to work with the material. Although HRC is manufactured as a food-grade material that is safe to ingest, field personnel should take precautions while handling and applying HRC. Field personnel should use appropriate safety equipment, including eye protection. The low pH when dissolved in water and the viscosity of the product make eye protection mandatory. Gloves should be used as appropriate based on the exposure duration and field conditions. A Material Safety Data Sheet is provided with each shipment. Personnel who operate field equipment during the installation process should have appropriate training, supervision, and experience.

SPECIFIC INSTALLATION PROCEDURES

1) Prior to the installation of HRC, any surface or overhead impediments should be identified as well as the location of all underground structures. Underground structures include but are not limited to: utility lines, tanks, distribution piping, sewers, drains, and landscape irrigation systems.

2) The planned installation locations should be adjusted to account for all impediments and obstacles.

3) Regenesis recommends pre-heating HRC in a hot water bath. Place unopened buckets of HRC into an empty water tank. A Rubbermaid fiberglass Farm Trough Stock Tank (Model 4242-00-GRAY) is typically used for this application and can hold up to 16 buckets of HRC. Hot water (approximately 130-170°F or 54-77°C) should be added to the tank after the buckets of HRC have been placed inside. When the HRC reaches a minimum temperature of 95°F or 35°C (approximately 20-30 minutes) it is ready to be poured into the pump hopper.

4) Pre-mark the installation locations, noting any points that may have different vertical application requirements or total depth.

5) Set up the direct push unit over each specific point and follow the manufacturer standard operating procedures (SOP) for the direct push equipment. Care should be taken to assure that probe holes remain in the vertical.

6) For most applications, Regenesis suggests using 1.25-inch O.D./0.625-inch I.D Geoprobe brand drive rods. However, some applications may require the use of 2.125-inch O.D./1.5-inch I.D. drive rods.

7) The HRC delivery sub-assemblies that Regenesis currently uses are designed for 1.25-inch Geoprobe rods. Other brands of drive rods can also be used but require the fabrication of a sub-assembly (see Regenesis Website).

8) Advance drive rods through the surface pavement, as necessary, following SOP.

9) Push the drive rod assembly with an expendable tip to the desired maximum depth. Regenesis suggests pre-counting the number of drive rods needed to reach depth prior to starting injection activities.

10) After the drive rods have been pushed to the desired depth, the rod assembly should be withdrawn three to six inches. Then the expendable tip can be dropped from the drive rods, following SOP.

    a) If an injection tool was used instead of an expendable tip, the application of material can take place without any preliminary withdrawal of the rods.

11) In some cases, introduction of a large column of air may be problematic. This is particularly the case in deep injections (>50 ft) with large diameter rods (>1.5-inch O.D.). To prevent the injection of air into the aquifer during HRC application, fill the drive rods with water.

12) Pour the pre-heated HRC into the pump hopper (up to 40 gallons). Remove the separated HRC from the bucket bottom by tipping the bucket into the hopper and scraping out the smooth residual material. Use the pumps mixing and recirculation features to create a uniform consistency. This typically requires recirculation of approximately one hopper volume. NOTE: Do not attempt to mix HRC with water or other liquids to thin or decrease the viscosity of the material. This may adversely affect HRC longevity.

13) A volume check should be performed prior to injecting HRC. Determining the volume displaced per pump stroke can be accomplished in two easy steps.

    a) Determine the number of pump strokes needed to deliver 3 gallons of HRC (use a graduated bucket for this)

    b) Divide 3 gallons by the results from the first step to determine the number of gallons of HRC delivered by each pump stroke.

    c) Level indicators present in the hopper are in 3 gallon increments.

    d) The volume of HRC displaced should be confirmed using the HRC level indicators located inside the pump hopper.

14) Connect the 1.25-inch O.D., 1-inch I.D. delivery hose to the pump outlet and the provided HRC delivery sub-assembly. Circulate HRC though the hose and the delivery sub-assembly to displace air in the hose.

15) Connect the HRC sub-assembly to the drive rod. After confirming that all of the connections are secure, pump the HRC through the delivery system to displace the water/fluid in the rods. **NOTE:** Prior to pumping HRC into the aquifer, close the pump recirculation valve; failure to do so will allow material to short-circuit into the hopper and change the volume of HRC delivered per pump stroke.

16) The pump engine RPM and hydraulic settings should remain constant throughout the day. However, if the hydraulic system starts to “squeal”, the pump speed should be decreased until the noise is mitigated.

17) Use the pump’s stroke counter and the provided volume/weight conversions to apply the appropriate HRC volume per injection location (and per vertical foot of contaminated saturated zone). Table 1 shows typical HRC delivery information followed by an example calculation.

Table 1: Pump Volume Calculation

Example: For each injection location, install 60 pounds of HRC across 10 vertical feet of aquifer (an application rate of 6 pounds per vertical foot).

Solution:

- 60 pounds/10.8 pounds per gallon ≈ 5.6 gallons for the injection location
- 5.6 gallons/0.2 gallons per stroke ≈ 28 pump strokes for the injection location
- 28 pump strokes/10 vertical feet = 2.8 strokes per vertical foot
- 2.8 strokes per vertical foot = 8.4 strokes per 3 foot drive rod
- 2.8 strokes per vertical foot = 11.2 strokes per 4 foot drive rod

18) Slowly withdraw the drive rods using Geoprobe Rod Grip or Pull Plate Assembly (Part AT1222-For 1.25-inch drive rods). While slowly withdrawing single lengths of drive rod (3 or 4 feet), pump the pre-determined volume of HRC into the aquifer across the desired treatment interval (Step 13). Use the stroke counter and pump on/off switch to control volume of injection. See Helpful Hints at the end of this section.

19) Remove one section of the drive rod. The drive rod may contain some residual HRC. Place the HRC-filled rod in a clean, empty bucket and allow the HRC to drain. Eventually, the HRC should be returned to the HRC pump hopper for reuse.

20) Observe any indications of aquifer refusal. This is typically indicated by a high-pitched squeal in the pump's hydraulic system or (in the case of shallow applications) HRC "surfacing" around the injection rods or previously installed injection points. If aquifer acceptance appears to be low, allow enough time for the aquifer to equilibrate prior to removing the drive rod.

21) Repeat steps 15 through 20 until treatment of the entire contaminated vertical zone has been achieved.

22) Install an appropriate seal, such as bentonite, above the HRC material through the entire vadose zone. Depending on soil conditions and local regulations, use a bentonite seal via chips or pellets after the probe rods have been removed. This assures that the HRC remains properly placed and prevents contaminant migration from the surface. If HRC continues to "surface" up the direct push borehole, an appropriately sized (oversized) disposable drive tip or wood plug/stake can be used to plug the hole until the aquifer equilibrates and the HRC stops surfacing.

23) Remove and clean the drive rods as necessary.

24) Finish the borehole at the surface as appropriate (concrete or asphalt cap, if necessary).

25) Periodically compare the pre- and post-injection volumes of HRC in the pump hopper using the pre-marked volume levels. Volume level indicators are not on all pump hoppers. In this

case, volume level markings can be temporarily added using known amounts of water and a carpenter's grease pencil (Kiel crayon). We suggest marking the water levels in 3-gallon increments.

26) Move to the next probe point, repeating steps 8 through 25.

HELPFUL HINTS

1) *Application in Cold Weather Settings*

The viscosity of HRC is directly related to the ambient temperature. As discussed in the Material Overview, Handling, and Safety section, cold weather tends to increase HRC viscosity and decrease ease of pumping. To maintain HRC at a temperature/viscosity at which it is easy to apply:

Raise and maintain the temperature of the HRC to at least 95°F (35°C) prior to pouring it into the pump hopper.

Insulate the delivery hose and keep the pump and hot water bath inside an enclosed structure such as a cargo van or trailer.

Periodically check the HRC temperature in the hopper.

Occasionally re-circulate HRC through the pump and hose to maintain temperature and viscosity.

The volume of HRC recirculated should not exceed the volume of HRC in the hopper.

Do not constantly recirculate HRC through the pump and hoses, as this may adversely affect the longevity of HRC.

2) *HRC Pump Information*

Regenesis has evaluated a number of pumps that are capable of delivering 20,000 centipoise HRC to the subsurface at a sufficient pressure and volumetric rate. Although a number of pumps may be capable of delivering the HRC to the subsurface at adequate pressures and volume, each pump has a set of practical issues that make it difficult to manage in a field setting. As a result of this evaluation, Regenesis has determined that the R.E. RUPE Company Model ORC/HRC 9-1500 meets the pressure and volume requirements needed to successfully inject HRC in the field. In general, Regenesis strongly recommends using a pump with a minimum pressure rating of 1,500 pounds per square inch (psi) and a minimum delivery rate of 3 gallons per minute. When applying measured volumes of HRC via probe boreholes, it is useful to know the volume of a single pump stroke (Table 1 above) and the associated delivery system lines. The following additional information is provided for reference:

Table 2: HRC Physical Characteristics

Density	1.3 g/cc or 10.8 lbs/gal
Viscosity	Approx. 20,000 centipoise

Table 3: Equipment Volume and HRC Weight per length

Equipment	Volume	HRC weight
1-inch OD; 0.625-inch ID hose (10 feet long)	0.2 gallon	1.8 lbs.
1.25-inch OD; 0.625-inch ID drive rod (3 feet length):	0.05 gallon	0.5 lbs.
1.25-inch OD; 0.625-inch ID drive rod (4 feet length):	0.06 gallon	0.7 lbs.

3) *Pump Cleaning*

For best results, use a hot water pressure washer (150 - 170 °F or 66 - 77 °C) to clean equipment and rods periodically throughout the day. Internal pump mechanisms and hoses can be easily cleaned by circulating hot water and a biodegradable cleaner such as Simple Green through the pump and delivery hose. Further cleaning and decontamination (if necessary due to subsurface conditions) should be performed according to the equipment supplier's standard procedures and local regulatory requirements.

NOTE: The remote control/pump counter should be kept dry at all times. If it gets wet, it will short-circuit and will need to be replaced.

Before using the Rupe Pump, check the following:

- Fuel level prior to engaging in pumping activities (it would be best to start with a full tank)
- Remote control/pump stroke counter LCD display (if no display is present, the electronic counter will need to be replaced (Grainger Stock No. 2A540))

Monitor pump strokes by observing the proximity switches (these are located on the top of the piston).

4) *HRC Bedrock Applications*

When contaminants are present in competent bedrock aquifers, the use of direct push technology as a delivery method is not possible. *Regenesis is in the process of developing methods for applying HRC via boreholes drilled using conventional rotary techniques.* To develop the best installation strategy for a particular bedrock site, it is critical that our customers call the technical support department at Regenesis early in the design process.

HRC can be applied into a bedrock aquifer in cased and uncased boreholes. HRC can be delivered by simply filling the borehole without pressure or by using a single or straddle packer system to inject HRC under pressure. Selection of the appropriate delivery

method is predicated on site-specific conditions. The following issues should be considered in developing an HRC delivery strategy:

- Is the aquifer's transmissivity controlled by fractures?
- Backfilling may be the better delivery method in massive, unfractured bedrock. This is particularly true in an aquifer setting with high permeability and little fracturing (such as that found in massive sandstone).
- Down-hole packer systems may be more advantageous in fractured bedrock aquifers.
    - In this case the fracture type, trends, and interconnections should be evaluated and identified.
- Are the injection wells and monitoring wells connected by the same fractures?
- Determine if it is likely that the HRC injection zone is connected to the proposed monitoring points.
- If pressure injection via straddle packers is desired, consideration should be given to the well construction. Specific issues to be considered are:
    - Diameter of the uncased borehole (*will casing diameter allow a packer system to be used*?).
    - Diameter of the casing (*same as above*).
    - Strength of the casing (*can it withstand the delivery pressures?*).
    - Length of screened interval (*screened intervals greater than 10 feet will require a straddle packer system*).