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CONCEPTUAL SITE MODEL UPDATE
Disposal Specialists, Inc. Landfill
Rockingham, Vermont

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August 2012
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1.0   INTRODUCTION:

Remedial actions completed at the Disposal Specialists, Inc. (DSI) Landfill in Rockingham, Vermont to limit the migration of ground water quality impacts were developed based in part, on a hydrogeological Conceptual Site Model (CSM) presented in the Supplemental Remedial Investigation Report (Balsam, 1994a).   The remedial actions implemented included source control measures to reduce leachate generation within the landfill (placement of a multi-layer cover system), management of migration in overburden (Route 5 Slope Stabilization and Seepage Control System), Institutional Controls (supplying potable water, Site Security, Ground Water Reclassification) to restrict groundwater usage and semi-annual monitoring to assess the natural attenuation of constituents of concern in groundwater.

Following the third 5-year project review by the United States Environmental Protection Agency (EPA) in 2009, it was determined that although a number of monitoring locations had met Interim Groundwater Cleanup Levels (IGCLs) for bedrock ground water, several constituents of concern (mainly manganese, arsenic and some volatile organic compounds) in bedrock ground water continued to exceed IGCLs established in the 1994 Record of Decision (ROD) for the Site.

As stated in the Statement of Work contained in the ROD, should IGCLs not be met within 15 years of the ROD date, Browning Ferris Industries of Vermont (BFI) will be required to complete additional investigations or actions to address non-compliance with IGCLs.   An approach to addressing this was suggested by EPA at a March 7, 2011 meeting with BFI.   In an October 18, 2011 follow up letter, EPA requested that additional investigations discussed at the meeting be completed to verify the continued protection of the remedy.   BFI submitted an Investigation Plan dated January 12, 2012 that included a number of proposed actions including an update of the CSM.   EPA approved the Investigation Plan on February 16, 2012.

This CSM update has been prepared based upon ground water quality data collected since the ROD, as well as a review of technical publications related to progress of Monitored Natural Attenuation remedies at sites similar to the DSI Site.

1.1   Background

Landfill operations at the Disposal Specialists, Inc. (DSI) Landfill first started in 1968 (under the ownership of Harry K Shepard) following the removal of significant quantities of borrow material (fill) from the property for the construction of Interstate 91.   The Site was acquired by BFI in 1973. Neighbors began reporting potential groundwater quality impacts in 1977 and in 1979 samples collected from bedrock wells downgradient of the Site were found to contain some metals and volatile organic compounds (VOCs) consistent with a release from the DSI landfill. The State of Vermont required BFI to provide nearby residences with bottled water for potable use in 1979 and in 1980 BFI installed a water supply well and distribution system to serve an on-site residence (facility manager residence) and three off-site residences.   Landfilling activities at the Site ceased in November 1991.

Balsam Environmental Consultants, Inc. initiated a Remedial Investigation (RI) at the DSI Site in June 1991 (Balsam, 1992 and 1994a) followed by a Feasibility Study (FS; Balsam, 1994b) and the U.S. Environmental Protection Agency (EPA) subsequently issued a Record of Decision (ROD) in 1994. The selected site remedy included the following:

- The installation of a multilayer landfill cap to limit infiltration and reduce leachate generation;

- Operating and maintaining an active landfill gas extraction system to limit gas accumulation beneath the landfill cap;

- Operating and maintaining an existing leachate collection system located in the 1.5-acre lined ash monofill at the southeast corner of the landfill;

- Operating and maintaining a seepage control system along Route 5 to intercept shallow impacted groundwater originating from the area of the landfill and improve the stability of the slope along Route 5; and,

- Monitoring and natural attenuation of constituents of concern in groundwater downgradient of the landfill.

A Long Term Monitoring Plan (LTMP) was prepared and submitted to the EPA as part of the Site remedy and subsequently revised in April 1997 (Dames and Moore, 1997). Semiannual monitoring has occurred at the Site since 1994 and provides a significant database to assess groundwater quality changes over time at the Site. The most recent ground water monitoring report was submitted to EPA in June 2012 and presents the results of ground water quality monitoring from 2009 to 2011 (Summit, 2012a).

Note that the EPA-established IGCLs (cleanup criteria) were only specified for bedrock groundwater because the lacustrine overburden was not considered to be a viable water source. However, overburden monitoring wells have historically been sampled and analyzed for constituents of concern as part of the LTMP to evaluate the effectiveness of the site remedy and monitor the migration of impacted overburden groundwater.

2.0   DEVELOPMENT OF THE CONCEPTUAL SITE MODEL

The landfill occupies approximately 17 acres and is situated on a glacial terrace located along the west side of the Connecticut River. A Site Location Map and a Site Plan are included as Figures 1 and 2, respectively. The majority of the waste within the landfill is underlain by a relatively thin layer of sand deposits. Varved lacustrine deposits comprised of interbedded clay and silt underlies most of this sandy layer and impedes the vertical migration of water beneath the landfill resulting in predominantly horizontal flow within the overlying sand deposits.

In some areas, located along the west side of the landfill, waste may be situated in close proximity to bedrock and precipitation percolating through the waste mass in these areas may infiltrate into the fractured bedrock. The dominant fractures within the bedrock are near-vertical to steeply dipping and north-northeast trending. Bedrock ground water discharges to the Connecticut River valley located less than 1,000 feet to the east.

Prior to the installation of a multi-layer landfill cap completed in June 1995, the primary source of leachate generation within the landfill was infiltration of precipitation through the waste mass. Water level data collected from landfill gas extraction wells within the waste mass indicated that a groundwater mound had developed on top of the varved lacustrine deposits underlying the landfill in response to precipitation percolating through the waste. Conceptually, groundwater from the high point of the mound flows east towards the Route 5 Slope Stabilization and Seepage Control System and potentially a limited distance westward toward fractured bedrock underlying or adjacent to the west side of the landfill.

Several of the analytes for which IGCLs have been established are interpreted to have been present in waste material and migrated to the groundwater system. These analytes include VOCs, chromium, nickel and barium. Reducing conditions in groundwater that are likely attributable to the landfill are interpreted to have contributed to increased arsenic, iron and manganese concentrations observed in downgradient monitoring wells due to the mobilization of these naturally occurring metals found in fracture fillings in bedrock.

The CSM interpreted that geochemical conditions resulting from the presence and degradation of waste within the landfill are likely responsible for some of the manganese and effectively all of the arsenic present at elevated concentrations downgradient of the landfill area.   The CSM was based on the following conditions:

- Arsenic and manganese were not identified in appreciable quantities within the waste or waste-derived leachate, and lower but elevated concentrations had been detected in bedrock wells located hydraulically upgradient and cross gradient of the landfill.

- Under oxidizing conditions present in the near-surface bedrock groundwater under pre-landfill conditions, pyrite and other arsenic-bearing minerals present in bedrock will dissolve and release trace metals (e.g., arsenic) into groundwater. Simultaneously, oxidizing conditions tend to promote the formation of iron and manganese oxyhydroxide minerals on bedrock fracture surfaces. Upon encountering these oxyhydroxides, dissolved arsenic in the groundwater tends to adsorb onto the oxyhydroxide minerals.

- With the development of the landfill the oxygen influx to the underlying bedrock would be replaced by the infiltration of carbon-rich anaerobic discharges to groundwater in the underlying shallow bedrock. This change would create a relatively rapid transition to anaerobic and reducing conditions. In a strongly reducing environment the iron and manganese metallic oxides become unstable as a result of microbial mediated redox reactions and become soluble.

Based upon this conceptual model, it was assumed that oxidizing conditions likely existed in the bedrock groundwater system, especially under what is now the western portion of the landfill where waste was placed in close proximity to bedrock. These conditions would have facilitated the formation of arsenic- and manganese-containing oxyhydroxides in the bedrock beneath the landfill or would have maintained the stability of existing oxyhydroxides in hydraulically active fractures.

As a result of landfill operations, a reduced, anoxic environment in groundwater would develop resulting in dissolution and subsequent dissolved-phase transport of arsenic, manganese and iron to hydraulically downgradient areas. Following closure of the Site and placement of a multi-layer cover system, a transition back to oxidizing conditions as a result of reduced leachate generation was anticipated. Alternatively, as groundwater moves away from the landfill it was expected that interaction with a natural oxidizing environment, would re-stabilize metal oxyhydroxides over time and limit further solubility and migration of these metals. Distance, hydraulic gradients and hydraulic conductivities along flow paths in the bedrock and overburden groundwater were assessed to estimate the magnitude of flushing that would occur within the aquifer. Based on these data, the CSM interpreted that IGCLs would be achieved within a 15-year timeframe. Monitoring data collected over the last 15 years have shown that this has not occurred in all areas of the site for all parameters. Therefore, this updated CSM has been developed.

3.0   AQUIFER CHARACTERISTICS, GROUNDWATER FLOW AND RECHARGE CONDITIONS

Previous investigation (Balsam 1992a & 1994a) identified a perched overburden aquifer and a bedrock aquifer at the DSI site. The overburden aquifer consists of perched water bearing zones in varved lacustrine deposits with a shallow zone composed of a thin layer of sand overlying varved lacustrine silt and sand, and a deeper zone comprised of varved lacustrine clayey silt.

The subsurface geology of the DSI Site is shown on a map of the bedrock surface (Figure 3) and geological cross sections (Figures 4 and 5) completed as part of the Supplemental RI (Balsam, 1994b). Groundwater potentiometric surface contours for the shallow overburden, shallow bedrock and deeper bedrock based on water levels measurement collected in September 2011 are presented as Figures 6, 7 and 8, respectively. A summary of the known aquifer characteristics and an evaluation of the groundwater flow and recharge conditions is presented below.

3.1   Hydraulic Conductivity and Seepage Velocities

In-situ hydraulic conductivity measurements from wells representative of the range of geological conditions in the overburden and bedrock aquifers were presented in the RI (Balsam 1992a). The geometric mean and average in-situ hydraulic conductivity measurements from slug tests are summarized in the table below.

Aquifer Zone (# wells measured)	In-situ Hydraulic Conductivity (feet/day)	
	Average	Geometric Mean
Shallow Overburden (3)	0.23	0.20
Deeper Overburden (2)	0.02	0.02
Shallow Bedrock (4)	10.0	0.7
Deeper Bedrock (4)	1.38	0.15

The hydraulic conductivity of overburden decreases vertically by one order of magnitude from shallow to deep overburden. Given the lower hydraulic conductivity with depth and the horizontal deposition of the varved sand, silt and clay overburden, it was interpreted that flow is predominately horizontal with limited interconnectivity among perched water bearing zones in the overburden aquifer. The similarity between the averages and geometric means for overburden indicates that the hydraulic conductivity of overburden does not significantly vary in plan view (horizontally), which is consistent with geological conditions during the deposition of lacustrine sediments. Overburden groundwater seepage velocity calculations presented in the RI (Balsam, 1992) indicate that the horizontal component of flow ranges from 5 to 27 feet per year (ft/year) and the vertical (downward) component of flow ranges from 0.3 to 2 ft/yr.

The hydraulic conductivity of bedrock is generally higher than overburden although the hydraulic conductivity of bedrock significantly decreases with depth. The higher conductivity in shallow bedrock is interpreted to be the result of weathering and/or stresses that occurred during glacial events. Observations of exposed bedrock upgradient of the landfill support the interpretation of significant fracturing (and likely increased hydraulic conductivity) in shallow

bedrock. Nonetheless, the large difference between average and geometric means for shallow and deep bedrock indicates that the hydraulic conductivity of bedrock significantly varies both vertically and horizontally across the site, which is consistent with the presence of a fractured bedrock aquifer system. Groundwater seepage velocities in bedrock were estimated to be range from 38 to 1,750 ft/year (Balsam, 1992).

3.2 Groundwater Flow and Recharge Conditions

The LTMP required monitoring of groundwater elevations at monitoring wells and well couplets screened at discrete interval within the overburden and bedrock aquifers to provide a means for evaluating groundwater flow and recharge conditions within the vicinity of the landfill area. Groundwater flow and recharge conditions in the overburden and bedrock aquifers are summarized below.

3.2.1 Overburden Aquifer

Landfill refuse was placed in a former borrow pit. Data indicate that overburden underlying refuse consists of a thin layer of sand underlain by varved lacustrine deposits. The CSM assumes that the downward migration of water in overburden beneath the landfill is impeded by the presence of clay/silt layers resulting in predominately horizontal flow preferentially within sandy layers in shallow overburden. Furthermore, it was anticipated that fining of overburden deposits with depth and the resulting decrease in hydraulic conductivity would limit the downward migration of impacted groundwater into deeper overburden downgradient of the landfill area. While the downward migration of groundwater within overburden is limited by geological controls and some areas of the deeper overburden are dry (i.e.; MW-2, MW-B14), hydraulic head measurements from overburden well couplets indicate a component of downward flow in overburden.

Most of the impacted shallow overburden groundwater is currently intercepted by the Route 5 Seepage Control and Stabilization System (Route 5 System) located on the western side of Route 5. The Route 5 System is a trench drain constructed to collect seepage water formerly discharging to a drainage ditch along Route 5, reduce seepage beneath Route 5 and improve the slope stability along Route 5. The trench drain is approximately 315 foot long with a four inch diameter perforated pipe at the base that conveys water to a collection sump where it is pumped to a 10,000 gallon aboveground storage tank (AST) and disposed at an off-site disposal facility. The base of the trench intersects the geological transition from fine sands to laminated clayey silt at an elevation of 420 mean sea level (MSL) and terminates in laminated clayey silt, as schematically shown on Figure 5. From north to south, the base of the trench drain pitches from an elevation of 420 to 413.5 feet MSL. Hauling records for the Route 5 System AST from 1998 to 2011 indicate that the volume of overburden groundwater collected by the system is quite low and varies seasonally from 1.3 to 2.9 gallons per minute, with the highest flows reported in Spring (Summit 2012a).

North of the Route 5 System, a small component of the shallow overburden groundwater discharges to an active surface seep (Seep SW-6) located immediately east of Route 5 and/or potentially to a gravel underdrain below Route 5 and adjacent to Seep SW-6. Groundwater in

deeper overburden likely discharges to areas located along steep embankments between Route 5 and the Connecticut River.

Long-term monitoring has shown a significant improvement in shallow overburden groundwater quality following the construction of the Route 5 Seepage Control System in 1993 and the multi-layer landfill cap in 1995. Groundwater elevations along the eastern margin of the landfill at well couplet MW-B13S/MW-B13D (shallow/deep) screened in the uppermost overburden aquifer (refer to Figures 4 and 5) have dropped by 5-10 feet since 1995, and 28 of the 32 gas extraction wells that formerly contained water are currently dry, indicating that the multi-layer cap significantly reduces the volume of water percolating through the base of the landfill and into shallow overburden (or bedrock). At Seep SW-6 and shallow overburden well MW-B13D, many parameters including VOCs, barium and iron are reported at slightly higher concentrations in the Spring, which is likely the result of increased infiltration during wetter periods. Long-term monitoring of water quality at the Route 5 System AST, monitoring well MW-B13D, Seep SW-6 have shown significant improvement in water quality consistent with reduced leachate generation and subsequent contaminant loading to groundwater following landfill cap installation (Summit 2012a).

Deeper overburden water quality downgradient of the landfill is monitored at wells MW-J35 and MW-E22 which are screened in clayey silt at an elevation (380 to 390 feet MSL) approximately 25 feet deeper than the base of the Route 5 System. Trace VOCs were historically reported at deeper overburden wells MW-E22 and MW-J35 prior to 2001. However, since May 2002 some VOC analyte concentrations have notably increased at MW-J35, including ketones, 1,1-dichloroethane, chloroethane, cis-1,2-dichloroethene, trichloroethene, vinyl chloride, methylene chloride, toluene and ethylbenzene. Notably increased concentrations of some VOC analyte have also been reported at MW-E22 since May 2005, including methylene chloride, ketones, toluene and total xylenes. Concentrations of most VOCs detected at MW-E22 and MW-J35 began to increase significantly in 2008. In the mid- to late-1990's, these VOCs, as well as tetrachloroethene and trichloroethene, were reported present at higher concentrations in shallow overburden at well MW-B13D located along the downgradient margin of the landfill area. Conceptually, there are three potential scenarios that could explain how impacted groundwater migrated into deeper overburden.

1. The CSM hypothesized that impacted groundwater would migrate slowly from shallow to deeper overburden at a seepage velocity ranging from 0.3 to 2 ft/yr. This scenario is consistent with trends in deeper overburden water quality, since it would take approximately 15 to 100 years for shallow impacted groundwater to flow approximately 50 feet downward to the screened intervals at wells MW-J35 and MW-E22.

2. A component of impacted groundwater generated along the western portion of the landfill is migrating downward along the top of the bedrock surface and recharging the deeper overburden aquifer where sandy lenses are in direct contact with the bedrock surface. Based on the range of seepage velocities reported for shallow bedrock and deeper overburden this is considered to be a potential scenario.

In summary, trends in groundwater quality in shallow and deeper overburden and decreased water levels in shallow overburden are consistent with predicted response of the selected site

remedy proposed in the CSM. Seasonal variation of VOC concentrations in shallow overburden is consistent with increased infiltration during wetter periods, which is consistent with small seasonal variations in the volume of leachate collected by the ash-monofill leachate collection system.   Estimates of vertical seepage velocities in overburden and the delayed migration of VOCs to deeper overburden wells suggest that a "slug" of VOC impacted groundwater has slowly migrated downward though overburden deposits.   The observed improvements in shallow overburden groundwater quality at MW-B13D suggest that the landfill cover system has significantly reduced loading of contaminants to the shallow overburden resulting in groundwater quality improvement. A similar improvement in water quality is considered likely in deeper overburden.   However, improvement would be expected to be delayed due to the slow movement of groundwater in deeper overburden.   Further discussion of VOCs in overburden groundwater is provided in Section 5.0.

3.2.3   Bedrock Aquifer

Previous investigations (Balsam 1992a & 1994a) found that wastes were placed in close proximity to bedrock along the northeastern and western portions of the landfill. The CSM hypothesized that the infiltration of impacted groundwater into the bedrock aquifer in these areas is the most likely source of impacts in the bedrock aquifer.

Fractures in the bedrock are characterized by a strong, north-northeast trending foliation parallel fracture set and a less common cross-foliation fracture population oriented perpendicular to foliation that are much shorter in length than foliation-parallel fractures. Due to the orientation of primary fractures, groundwater flow in bedrock is likely dominated by flow south-southwesterly along the more pervasive foliation-parallel fractures until a hydraulically connected cross-foliation fracture is encountered. However, the actual flow pathways in the bedrock are likely more complex because flow in fractured bedrock is strongly controlled by the number, aperture (size), orientation and interconnectivity of bedrock fractures, as well as the tortuosity of flow paths within individual fractures.

Interpreted potentiometric surface contour maps constructed for shallow and deeper bedrock are included as Figures 7 and 8, respectively. Shallow bedrock is represented by monitoring wells generally screened within the upper 10 feet of bedrock, while deeper bedrock wells are generally screened greater than 50 feet from the bedrock surface. On a site-wide scale the horizontal component of groundwater flow in shallow and deeper bedrock flows is to the southeast toward the Connecticut River. However, while Figures 7 and 8 provide the general direction of groundwater flow, the actual flow pathway within individual bedrock fractures is more complex and local variability is difficult or impossible to characterize.

The spatial variations in the vertical component of groundwater flow and recharge conditions within the bedrock aquifer were evaluated using boring logs, well construction information and groundwater elevation measurements collected from ten well couplets screened in shallow and deeper bedrock zones within the vicinity of the landfill area. Consistent downward hydraulic gradients are present at well couplet (MW-G25/G26) located to the west of the landfill area and several couplets (MW-8/9, MW-J37/38 and MW-A11/A12) located to the east of the landfill area. A substantial vertical gradient is not present at upgradient well couplet (MW-H27/H28).

Spatially, the presence of downward hydraulic gradients correlates to areas where bedrock is shallow or to areas proximal to a prominent subsurface bedrock plateau located below the northern portion of the landfill extending south and east from MW-H27/H28 towards wells couplets MW-9/10 and MW-J37/38, as shown on Figure 3.   Consistent upward hydraulic gradients are present at the remaining well couplets (MW-2/3, MW-6/7, MW-C17/C18, MW-E23/E24 and MW-K39/K40), all of which are located cross-gradient or downgradient of the landfill area.   Potentiometric head elevations in bedrock well couplets MW-E23/E24, MW-C17/C18, MW-6/7 are higher than the elevation of the bedrock surface which indicates that a component of bedrock groundwater discharges to overburden deposits at these locations.

In summary, on a site-wide scale bedrock groundwater is recharged along the northern and western portion of the landfill area where the bedrock surface is exposed at the ground surface or covered by a thin layer of overburden. The Connecticut River controls groundwater discharge in the vicinity of the Site. As such, bedrock groundwater is interpreted to discharge to the River (or River valley). Many bedrock well couplets located cross and downgradient of the landfill exhibit upward gradients within bedrock. These data are consistent with the original interpretation in the CSM.

4.0   BEDROCK AQUIFER GEOCHEMISTRY

Data used to develop the fate and transport model presented in the CSM suggests that most of the manganese and iron, and effectively all of the arsenic present in bedrock groundwater within the hydraulic influence of the landfill area are attributable to the dissolution of naturally occurring iron/manganese/arsenic-bearing oxyhydroxide minerals, which were present in the bedrock aquifer prior to the construction of the landfill.   The CSM predicted that arsenic, manganese and iron concentrations in bedrock groundwater downgradient of the landfill area should decrease over time in response to increasing redox potentials (become more oxidizing) due to a reduction in the volume of carbon-rich anaerobic water released to the bedrock aquifer and as mixing with recharge waters occurs in downgradient areas. An evaluation of these two key elements of the CSM is presented below.

4.1   Background Concentrations of Iron, Manganese and Arsenic

Previous investigation (Balsam 1992a & 1994) demonstrated that iron, manganese and arsenic are naturally present in bedrock groundwater beyond the hydraulic influence of the landfill. The primary sources of iron, manganese and arsenic in non-impacted bedrock groundwater was attributed to the dissolution of iron sulfide (pyrite) and iron-oxyhydroxide minerals that were observed on bedrock fracture surfaces at and in the immediate vicinity of the DSI Site.

Summit compiled arsenic, iron and manganese concentrations reported in groundwater samples collected from fourteen (14) open-borehole bedrock wells monitored as part of the LTMP, including current or former open-borehole bedrock water supply wells serving the Greenwood, Hit or Miss Club, Allen, Benoit, Crawford, Facility, Falvey, Gayle, Murray, Potter, Tedesco, Washburn and Roberts properties, and one open-borehole well (Interceptor) located on the DSI site.   The Interceptor well is located to the west and hydraulically upgradient of the DSI landfill, while the remaining wells are located hydraulically cross-gradient to the south, east and southeast of the DSI landfill.   Dissolved and total (and commonly both) arsenic, iron and manganese concentrations were available for one or more grab samples periodically collected

from October 31, 1983 to September 27, 2011 as part of remedial investigations or the LTMP. Since there were significant variations in the reported laboratory detections limits over this time period, non-detect concentrations were removed from the dataset prior to calculating the minimum, maximum, average and median concentrations for each parameter. Estimated concentrations reported between the method detection limit and laboratory detection limits were not removed from the data set. The number of data points for each parameter used to calculate the statistics are as follows: arsenic (72 points), manganese (162 points) and iron (132 points). The results are summarized in the table below.

	Minimum	Maximum	Median	Average
Arsenic	0.51 ug/L	65.6 ug/L	8.2 ug/L	11.5 ug/L
Manganese	0.47 ug/L	2,300 ug/L	20 ug/L	143.7 ug/L
Iron	15.5 ug/L	3,600 ug/L	100.0 ug/L	221.13 ug/L

Consistent with the CSM, appreciable concentrations of arsenic, manganese and iron, are naturally present in the bedrock groundwater at and around the DSI site. This result is consistent with research (USGS 1999, 2009; Nelson et al. 2007) since the development of the CSM, which indicates that it is very common for ground water in the northeastern United States to contain appreciable concentrations of naturally-occurring arsenic, manganese and iron, and that local/regional variations in concentrations of these metals appears to be largely controlled by the redox state of groundwater and aquifer matrix mineralogy.

4.2   Bedrock Groundwater Geochemistry

The CSM predicted that arsenic, manganese and iron concentrations in groundwater downgradient of the landfill area should decrease over time in response to more oxidizing condition in groundwater due to a reduction in leachate generation and as mixing with recharge waters occurs in downgradient areas. Samples from fifteen (15) bedrock monitoring wells collected during the 2009/2010 semi-annual sampling events were analyzed for an expanded suite of parameters to further characterize the geochemical conditions in the bedrock aquifer and evaluate the fate and transport model presented in the CSM (Balsam, 1994a).

The expanded suite of water quality parameters included arsenic, chromium, iron, manganese, sodium, aluminum, calcium, magnesium, potassium, bicarbonate alkalinity, chloride, fluoride, sulfate, sulfide, ammonia, nitrate, total organic carbon (TOC) and methane (all samples were unfiltered). The samples were collected from shallow bedrock well MW-B3 and shallow/deeper bedrock well couplets MW-G25/G26 (shallow/deep), MW-H27/28, MW-K39/40, MW-J37/38, MW-3/4, MW-6/7 and MW-9/10. Well locations along with the shallow and deeper bedrock groundwater potentiometric surfaces are shown on Figures 7 and 8, respectively. Historical groundwater sampling results are included in the 2009 to 2011 Monitoring Report (Summit, 2012a) or presented in figures and tables referenced herein.

4.2.1   Distribution of Major Cations and Anions in Bedrock Groundwater

The relationships among the major cations and anions present in bedrock groundwater are shown on the scatter diagrams presented in Appendix A. The average concentrations of major cations and anions in bedrock groundwater are summarized in Table 1. A brief summary of the distribution of major cations and anions in bedrock groundwater is presented below.

Bedrock groundwater is monitored at five wells located to the west (generally upgradient) of the landfill including shallow bedrock well MW-B3 and well couplets MW-G25/G26 and MW-H27/H28. At these locations, with the exception of MW-B3 (discussed further below), calcium is the dominant cation with significantly lesser amounts of sodium, magnesium and potassium. Bicarbonate is the dominant anion, with lesser amount of sulfate, chloride and fluoride. Plots comparing milliequivalents of cations versus anions are consistent with the hydrolysis of silicate minerals being the major source of calcium, magnesium, sodium, potassium and bicarbonate in groundwater at upgradient wells; *[Note that these plots were prepared using a potassium detection limit of 5 mg/L if potassium was reported as not detected]*. The only other anion present at significant concentrations at these wells is sulfate (9 to 16 mg/L). Variations in sulfate do not correlate with variations in the major cations and iron; therefore, the most likely geochemical process that is consistent with the observed sulfate concentration is the dissolution of pyrite (iron sulfide) and the simultaneous precipitation of iron oxides onto fracture surfaces under oxidizing conditions.

The distribution of major cations and anions in groundwater at three of the five wells (i.e.; MW-H27/H28 and MW-G26) located along the west side of the landfill area are consistent with background geochemical conditions in the bedrock aquifer dominated by the weathering of silicate and sulfide minerals. The remaining two wells include shallow bedrock wells MW-B3 and MW-G25. At well MW-B3, sodium, potassium and pH (10 SU) are above background conditions, which, in the absence of elevated metals and total organic carbon, strongly suggest that water quality in MW-B3 is affected by base-cation exchange between a bentonite-based grout/cement used in well construction and non-impacted groundwater. At MW-G25, excess bicarbonate in groundwater correlates with elevated iron, manganese, total organic carbon and negative redox potentials, which is consistent with shallow bedrock impacts caused by the degradation of organic matter under reducing conditions. Impacts to groundwater quality to the west of the landfill are limited to shallow bedrock in the vicinity of MW-G25. The southwestward migration of impacted groundwater towards MW-G25 is attributed to localized groundwater mounding associated with the landfill.

Bedrock groundwater at downgradient wells located to the east (downgradient) of the landfill areas are preferentially enriched with sodium, potassium, chloride and bicarbonate. These parameters are highest in wells located directly downgradient of the center of the landfill area where the majority of the cleanup criteria exceedances occur (i.e.; MW-3, MW-4, MW-6, MW-9 and MW-10). At these wells, excess bicarbonate in groundwater also correlates with elevated iron, manganese, total organic carbon and negative redox potentials, which is consistent with impacts caused by the degradation of landfill derived organic matter under reducing conditions.

Bedrock groundwater at cross gradient well couplet MW-K39/K40 located north of the landfill area is slightly enriched in sodium, chloride and bicarbonate, which would suggest that slightly reducing conditions in the vicinity of this well couplet are attributable to the landfill.

4.2.2 *Redox Conditions in Bedrock Groundwater*

The primary constituents of concern in bedrock groundwater at the DSI Site are VOCs and the redox sensitive metals manganese and arsenic. The mobility/solubility of redox sensitive metals is controlled by a number of factors including the stability of solid mineral phases

(dissolution/precipitation) and adsorption of arsenic, iron and manganese to oxyhydroxide minerals (EPA, 2007a & 2007b) . However, in the presence of degradable organic carbon, the mobility of redox-sensitive metal in groundwater is principally controlled by the microbial mediated reduction of organic carbon. The biodegradation (reduction) of organic compounds in groundwater (i.e.; organic carbon, SVOCs and VOCs) results in observable changes in pH, redox potential, dissolved oxygen, redox sensitive metals, organic constituents, terminal electron acceptors (TEAs) and the byproducts of biodegradation (i.e.; methane, bicarbonate). Significant variation in these water quality parameters in bedrock groundwater at the DSI site indicates that microbial mediated redox reactions are an important process affecting bedrock aquifer geochemistry.

Microbial mediated redox reactions that degrade organic carbon sources in groundwater follow a progressive sequence from aerobic to anaerobic (and ultimately methanogenic) conditions that can be tracked based on the progressive usage of different TEAs (EPA, 2007a). The preferential usage of TEAs occurs along the following general sequence from aerobic to anaerobic conditions: oxygen-reducing, nitrate-reducing, manganese-reducing, iron-reducing, sulfate-reducing and ultimately carbon-reducing (methangenesis) in a strongly reducing/anaerobic environment. Ultimately, by characterizing the redox conditions in the bedrock aquifer the future effectiveness of the natural attenuation of the redox sensitive constituents of concern (VOCs, arsenic, iron and manganese) can be evaluated.

USGS Redox Model

A redox model (Jurgens, et al. 2009) published by the United States Geological Survey (USGS) was used to evaluate the spatial distribution of redox conditions in the shallow and deeper zones of the bedrock aquifer. The redox model identifies the primary redox processes/reactions occurring in groundwater by comparing established threshold values for dissolved oxygen, nitrate-nitrogen, iron (II), manganese (II) and sulfate to the actual concentrations in groundwater. Redox conditions at fifteen (15) bedrock wells were evaluated using the spreadsheet included with the USGS redox model and data from four (4) consecutive sampling rounds in 2009 and 2010. A copy of the spreadsheet is provided as Table 1.

The laboratory detection limit for sulfate (5 mg/L) is significantly higher than the established threshold for sulfate (<0.5 mg/L) the USGS redox model uses as an indicator for the onset of methanogenesis. Due to this limitation, the model will not assign methanogenesis as a dominant redox process; however, methanogenesis is clearly occurring at some locations on the DSI site, since methane was reported present at a wide range of concentrations in bedrock groundwater samples collected in 2009 and 2010. The occurrence of methane in bedrock groundwater will be used to further refine our evaluation of redox conditions beyond the constraints of the USGS redox model.

The redox conditions predicted by the USGS model are summarized in the table below. The redox conditions at well MW-3 were not determined using the redox model because the well is sampled with a bailer and the accuracy of dissolved oxygen values is uncertain. However, water quality at well MW-3 is similar to nearby well MW-6 and as a result MW-3 was assigned to the same redox category as MW-6.

Monitoring Wells	Dominant Redox Category	Dominant Redox Process
MW-H28, MW-10	Oxic/Suboxic	O_2
MW-B3, MW-G26, MW-H27	Oxic/Mixed (oxic-anoxic)	O_2 , O_2-Fe^{III}/SO_4
MW-K40	Mixed (oxic-anoxic)	O_2-Mn^{IV}
MW-K39	Mixed (oxic-anoxic)	O_2-Mn^{IV}, O_2-Fe^{III}/SO_4
MW-3*, MW-4, MW-6, MW-9, MW-G25	Mixed (oxic-anoxic)	O_2-Fe^{III}/SO_4
MW-7, MW-J37, MW-J38	Anoxic	Fe^{III}/SO_4

* Redox conditions at MW-3 were estimated by comparing water quality data to other wells.

Redox conditions at 7 of the 14 wells (excluding MW-3) were consistent for four consecutive sampling rounds, while redox conditions at the remaining 7 wells (i.e.; MW-6, MW-7, MW-10, MW-B3, MW-G26, MW-H27 and MW-K39) varied during one or more sampling rounds. Variations in redox conditions at wells MW-6, MW-7 and MW-10 appear to be controlled by small seasonal fluctuations in dissolved oxygen with respect to the 0.5 mg/L threshold value, with higher dissolved oxygen reported during Spring versus Fall sampling rounds. Variations in redox conditions at wells MW-B3, MW-G26 and MW-H27 are caused by fluctuations in iron concentrations with respect to the 100 ug/L threshold value; however, since dissolved oxygen concentrations are consistently >1.8 mg/L, total iron in groundwater is mostly in the form of colloidal hydrous ferric oxides, and the redox environment at wells MW-B3, MW-G26 and MW-H27 is more oxic than mixed (oxic-anoxic).   Variations in redox conditions at well MW-K39 are attributed to fluctuations in iron and dissolved oxygen with respect to the threshold values. Dissolved oxygen concentrations do not significantly vary at MW-K39; however, manganese and iron are higher in the Spring than the Fall suggesting a correlation between increased recharge and more reducing conditions.

Methane in Bedrock Groundwater

Methane in groundwater is an important indicator of redox conditions that was not directly incorporated into the USGS redox model (Jurgens, et al. 2009). The presence of methane in groundwater is indicative of methanogenesis, a process in which methane is produced by the microbial mediated degradation of organic compounds in a strongly (end-member) reducing/anaerobic environment in absence of TEAs other than carbon. Dissolved methane was detected in 12 of the 15 bedrock wells at a concentration ranging from just above the detection limit (0.001 mg/L) to 10 mg/L. Note that the solubility limit of methane in groundwater is 28 to 30 mg/L. A general outline of the methane concentrations reported in bedrock groundwater is presented below.

Bedrock Wells	Methane concentration
MW-4, MW-6, MW-7, MW-G25	High (>1 mg/L)
MW-3, MW-9, MW-K39	Moderate (0.1 to 1.0 mg/L)
MW-10, MW-G26, MW-J37, MW-J38, MW-K40	Low (0.001 - 0.1 mg/L)
MW-B3, MW-H27, MW-H28	Below detection limit (0.001 mg/L)

In general methane concentrations are expected to correlate with low sulfate concentrations since research has shown that effectively all of the TEAs should be depleted before the onset of methanogenesis (EPA 2007a). Sulfate was reported below the detection limit (< 5 mg/L) at

wells MW-7 and MW-J38, suggesting that the conditions suitable for methanogenesis may be present at MW-7 and MW-J38. However, at most wells where methane is reported present, appreciable concentrations of sulfate are also present (i.e., MW-4, MW-6, MW-9, MW-10, MW-G25, MW-G26, MW-J37, MW-K39 and MW-K40). This relationship suggests that strongly reducing (methanogenic) conditions are present in localized zones and that groundwater samples collected from bedrock wells represents a mixture of groundwater from more than one fracture zone where variable geochemical conditions are present.

<u>Trends in Redox Conditions:</u>

Historic trends in manganese and iron concentrations in bedrock groundwater were evaluated in the context of other redox-related parameters to establish where redox conditions are changing or stable. Tabulated iron and manganese water quality data and line graphs are included in Appendix B. Results of the evaluation are provided below:

- <u>MW-H27, MW-H28 and MW-G26:</u> Iron and manganese concentrations have decreased overall at upgradient shallow bedrock well MW-H27 and deep bedrock wells MW-G26 and MW-H28 and reported concentration are within the range of reported background concentrations presented in Section 4.1. Isolated peaks in iron and manganese at these wells are attributed to the presence of colloidal iron (III) and manganese (IV) under oxic conditions.   Stable oxic conditions are expected to persist at wells MW-H27, MW-H28 and MW-G26.

- <u>MW-G25:</u> Data from upgradient shallow bedrock well MW-G25 shows no substantial trend in iron concentration and an overall decreasing trend in manganese concentration. Iron- and manganese-reducing conditions are expected to persist at this location due to high TOC concentrations. A stable oxic environment at deep bedrock well MW-G26 in the presence of hydraulic gradients that support the downward migration of impacts suggests that vertical migration of impacts into the deeper bedrock at this location is limited.

- <u>MW-K39 and MW-K40:</u> Bedrock well couplet MW-K39/K40 (shallow/deep) is located hydraulically cross gradient (northeast) of the landfill area. An overall decreasing trend in iron concentration and an increasing trend in manganese concentration at shallow bedrock well MW-K39 suggests that a transition from an iron-reducing environment to a manganese-reducing environment is occurring and bedrock groundwater to the north of the landfill area is becoming more oxidizing. Similarly an overall decreasing trend in iron and manganese concentrations at deep bedrock well MW-K40 suggests a progressive trend toward more oxidizing conditions. This result suggests that a zone or area of reducing conditions in bedrock groundwater to the north of the landfill area is receding.

- <u>MW-3 and MW-4:</u> Bedrock well couplet MW-3/4 (shallow/deep) is located hydraulically downgradient (east) of the landfill area. An overall decreasing trend in iron and manganese concentration at both wells is apparent since 1994 indicating that redox conditions have improved (become less reducing) at both wells. However, iron and manganese concentrations continue to be elevated and the presence of appreciable

amounts of TOC in both wells indicates that a strongly reducing environment would be expected to persist at these locations.

- <u>MW-6 and MW-7:</u> Bedrock well couplet MW-6/7 (shallow/deep) is located hydraulically downgradient (east) of the landfill area. Iron and manganese concentrations at shallow bedrock well MW-6 have decreased overall and concentrations appear to be relatively stable at this time. Data from deeper bedrock well MW-7 shows no substantial trend in iron and an overall increasing trend in manganese concentrations from 1995 to 2006 that has stabilized since 2006. Manganese is slightly higher in shallow than deeper bedrock and total organic carbon is significantly higher in shallow than deeper bedrock. Iron is 10 times higher in shallow bedrock than deeper bedrock at this location and sulfate is depleted in shallow bedrock (<5 mg/L).   These relationships indicate redox conditions have improved (become less reducing) at both wells and that a stable sulfate-reducing environment is predominately present in shallow bedrock and a stable, less reducing, iron- and manganese-reducing environment is predominately present in deeper bedrock.

- <u>MW-9 and MW-10:</u>   Bedrock well couplet MW-9/10 (shallow/deep) is located hydraulically downgradient (east) of the landfill area. Substantial trends in iron and manganese are not present at shallow bedrock well MW-9; however, overall decreasing concentration trends in both metals are present at deeper bedrock well MW-10. Iron, manganese and methane concentrations are substantially lower in bedrock at this location as compared to other downgradient wells (MW-3, MW-4, MW-6 and MW-7). Sulfate concentrations in both wells are comparable to background. Total organic carbon was reported present at very low concentrations in shallow bedrock (<1 to 2.1 mg/L) and not reported above the detection limit (1 mg/L) in deeper bedrock. These relationships indicate the following: the stable iron- and manganese-reducing environment present in shallow bedrock will likely persist until total organic carbon concentrations decrease; and redox conditions have improved (become more oxidizing) in deeper bedrock indicating that stable oxic/suboxic environment will likely persist in deeper bedrock at this location.

- <u>MW-J37 and MW-J38:</u>   Bedrock well couplet MW-J37/J38 (shallow/deep) is located hydraulically downgradient (east) of the landfill area. Data from bedrock well couplet MW-J37/38 show no substantial trend in iron and an overall decreasing trend in manganese. Manganese, iron and TOC concentrations are significantly higher in shallow bedrock. Sulfate is depleted relative to background in deeper bedrock and enriched relative to background in shallow bedrock. Historically, sulfate concentrations greater than background have also been reported in nearby overburden wells MW-3, MW-A1-D, MW-A1-S, MW-A2-S and an open borehole bedrock well (Craigue) located to the east of the landfill area. Concentration of dissolved oxygen in shallow bedrock (MW-J37) are low, therefore it is likely that the elevated sulfate concentrations in shallow bedrock are attributed to the landfill, rather than the dissolution of pyrite under oxidizing conditions. These relationships indicate redox conditions are improving (becoming more oxidizing) at both wells and that until TOC concentrations decrease, a manganese- and iron-reducing environment will likely persist in shallow bedrock and a sulfate-reducing environment will likely persist in deeper bedrock groundwater.

4.2.3   Summary of Redox Conditions in Bedrock Groundwater

The dominant redox environments in bedrock groundwater within the hydraulic influence of the landfill area include manganese-reducing, iron-reducing, sulfate-reducing and carbon-reducing (methanogenesis).   Appreciable amounts of nitrate were not reported present in bedrock groundwater and as a result nitrate-reduction is not considered to be an important geochemical process in bedrock groundwater at the DSI Site.

The presence of "mixed" redox conditions at many bedrock wells, highlighted by the presence of methane and elevated sulfate concentrations in the same well, suggests that groundwater samples collected from bedrock wells represents a mixture of groundwater from more than one fracture zone where variable geochemical conditions are present.   Seasonal variations in ground water quality at several bedrock wells indicate that a more reducing environment is present in shallow bedrock during the Spring sampling events, which may correlate to higher recharge and subsequent changes to local flow patterns. The horizontal and vertical distribution of methane concentrations in bedrock ground water show that concentrations are decreasing away from the landfill area, which supports attenuation of constituents of concern via mixing within the bedrock aquifer.

Redox conditions in the bedrock aquifer have improved (become more oxidizing) at nearly all bedrock wells judged to be within the hydraulic influence of the landfill area.   A stable oxic environment is present in shallow and deeper bedrock groundwater west of the landfill area and variations in redox conditions in this portion of the Site appear to be limited to shallow bedrock near well MW-G25. The downward migration of reduced groundwater in the vicinity of MW-G25 appears to be limited; however, reducing conditions will persist at this location until TOC concentrations decrease. Redox conditions have improved (become more oxidizing) in shallow and deeper bedrock to the north of the landfill area (MW-K39/K40) indicating the zone of reducing groundwater to the north of the landfill area is receding towards the landfill. Redox conditions at most downgradient wells have improved overall (become more oxidizing) and a stable oxic/suboxic environment is present at one deeper bedrock well (MW-10); however, moderate to strongly reducing conditions at remaining downgradient wells (MW-3, MW-4, MW-6, MW-7, MW-9, MW-J37 and MW-J38) will likely persist due to elevated TOC concentrations that promote the observed reducing conditions.

4.2.4   Volatile Organic Compounds in Bedrock Groundwater

Remedial investigations in the early 1990's (Balsam 1992a and 1994a) reported the presence of several VOC analytes in twelve (12) of the nineteen (19) bedrock monitoring wells, including wells located conceptually upgradient (MW-G25, MW-G26, MW-B3 and MW-H28) cross gradient (MW-K40) and downgradient (MW-3, MW-4, MW-6, MW-9, MW-10, MW-E24, MW-J38) of the landfill area. VOCs were reported as not present in the remaining seven bedrock wells (MW-7, MW-C17, MW-C18, MW-E23, MW-H27, MW-K39 and MW-J37). Based on the results of a human health risk assessment (summarized in the ROD), cleanup criteria for bedrock groundwater (IGCLs) were established for benzene, methyl ethyl ketone (2-butanone), methylene chloride, trichloroethene (TCE), tetrachloroethene (PCE), vinyl chloride and total xylene. Note that the EPA-established IGCLs (cleanup criteria) for VOCs were only specified for bedrock groundwater because the lacustrine overburden deposits were not considered to be a viable water source.

It is worth noting that trace concentrations of semi-volatile organic compounds (SVOCs) were also reported present in some bedrock wells and IGLCs were also established for several analytes. However, SVOCs have limited mobility in groundwater and all bedrock wells (and overburden wells) have meet cleanup criteria, therefore further discussion of SVOCs is not warranted.

Samples from the nineteen bedrock wells included in the long-term monitoring program, collected during semi-annual monitoring events or 5-year monitoring events from April 2003 to September 2011 are summarized in Table 4, along with the results of a visual trend analysis. Results from the long-term monitoring program indicate significant improvements in bedrock groundwater quality and as of 2011, cleanup criteria for VOCs have been met at eight of the twelve monitoring wells where VOCs were historically reported present. VOCs reported present in bedrock groundwater above cleanup criteria during the September 2011 sampling event are limited to benzene (MW-3, MW-6), total xylenes (MW-3), methylene chloride (MW-3), and PCE (MW-9, MW-10). Additionally, it is worth noting that the reported concentrations of total xylenes and PCE are below the EPA Primary Drinking Water Standard Maximum Contaminant Level (MCL) and Vermont Department of Conservation Groundwater Quality Standards and the reported concentrations of benzene and methylene chloride only slightly exceed applicable standards.

5.0   NATURAL ATTENUATION OF IMPACTED GROUNDWATER

In the early 1990's most bedrock wells contained elevated concentrations of one or more constituents of concern including arsenic, barium, chromium, lead, manganese, nickel, benzene, 2-butanone, methylene chloride, PCE, TCE, total xylenes and three SVOC analytes (Balsam, 1992 & 1994a). Shortly following the construction of the Route 5 System in 1993 and the multi-layer landfill cap in 1995, groundwater quality in bedrock wells began to improve and many constituents of concern formerly found in wells above bedrock groundwater cleanup criteria (IGCLs) have decreased and now meet cleanup criteria. As of 2011, constituents of concern in bedrock groundwater above cleanup criteria are limited to arsenic, manganese, total xylenes, benzene and PCE.

Redox conditions in bedrock groundwater located in the vicinity of the landfill have improved (become more oxidizing) at nearly all monitoring wells. Improved redox conditions at shallow and deep bedrock well couplet MW-K39/K40 indicates the zone of reducing groundwater is receding southward. Groundwater at most downgradient wells (MW-3, MW-4, MW-6, MW-7, MW-9, MW-J37 and MW-J38) and cross-gradient well MW-G25 contains a detectable concentration of TOC and/or trace VOCs which indicates that reducing conditions will likely persist at these locations, and manganese, arsenic and iron concentrations will not decrease significantly until organic carbon sources are depleted allowing a more oxic environment to develop.

Arsenic concentrations in shallow bedrock groundwater exceed cleanup criteria at two downgradient wells (MW-3 and MW-6) where iron and/or sulfate reducing conditions occur in conjunction with elevated TOC concentrations. Based on trends in iron and manganese concentrations, redox conditions at these wells have improved since the early 1990's; however,

arsenic (as well as iron and manganese) concentrations continue to be elevated and will likely persist at concentrations above the cleanup criteria until organic carbon sources are depleted allowing a more oxic environment to develop.

Trends in VOC concentrations in shallow overburden (MW-B13D) and deeper overburden (MW-J35 and MW-E22), and downward hydraulic gradients between perched water-bearing zones in overburden indicate that impacted groundwater has slowly migrated into deeper overburden. Assuming groundwater impacts were present in shallow overburden in 1975, shortly following the opening of the landfill in 1968, it appears that approximately 25 to 30 year were required for significant amounts of impacted groundwater to migrate to these deeper overburden wells. These relationships are consistent with estimated downward seepage velocities (Balsam 1992a) in overburden ranging from 0.3 to 2 ft/yr and/or may indicate that a component of impacted groundwater present along western margins of the landfill area migrated downward along the top of the bedrock surface and recharged sandy lenses in deeper overburden that are in direct contact with the bedrock surface. Improvements in shallow overburden groundwater quality at MW-B13D suggest that deeper overburden ground water quality will likely improve in the future. Potentiometric heads in bedrock wells located physically below and to east of these wells indicate upward flow from bedrock to overburden which indicates that impacts will not migrate downward into bedrock.

Elevated concentrations of the 1,1-dichloroethane, chloroethane, cis-1,2-dichloroethene and vinyl chloride in deeper overburden (MW-J35) and shallow overburden (MW-B13D) indicate that anaerobic reductive dechlorination is an important process responsible for the attenuation of the chlorinated hydrocarbons in overburden groundwater. However, an aerobic environment is needed for the rapid degradation of some other VOCs analytes (i.e.; benzene, toluene, ethylbenzene, total xylene [BTEX], ketones and methylene chloride) reported present in deeper overburden and as a result the concentration of these VOCs are elevated relative to chlorinated VOC concentrations. Nonetheless, reported concentration of BTEX compounds are low and approach applicable standards, and ketones and methylene chloride will readily volatilize when exposed the atmosphere following discharge to the steep banking along the Connecticut River. The potential for VOCs in groundwater to present a vapor intrusion risk at enclosed structures located within the vicinity of the landfill area was evaluated in the Vapor Intrusion Evaluation report (Summit, 2012b) that was simultaneously submitted with this report to EPA under a separate cover.

From 2003 to 2011, VOCs have only been reported present at appreciable concentrations in shallow bedrock wells located within in a narrow zone to the east of the landfill area between MW-6 and MW-9. In this area upward hydraulic gradients in bedrock limit the downward migration of impacts into deeper bedrock, which is also supported by water quality sampling results from deeper bedrock well couplets (i.e.; MW-4, MW-7 and MW-10). In areas of the bedrock aquifer where VOCs are reported present, concentration are generally stable or decreasing and redox conditions suitable for the anaerobic degradation of VOCs have led to an environment where reductive dechlorination is an important process responsible for the attenuation of the chlorinated hydrocarbons in bedrock groundwater. Elevated concentration of BTEX compounds continue to be reported present at MW-3; however, significantly lower concentrations are reported at MW-6 suggesting that attenuation via mixing is occurring downgradient of the landfill area.

Consistent with the CSM/FS, spatial and temporal variations in redox sensitive parameters (manganese, iron, arsenic and methane) in bedrock groundwater provide strong evidence for attenuation via mixing and the contraction of the zone of impacted bedrock groundwater. Trends in bedrock groundwater quality indicate that the natural attenuation of constituents of concern has occurred by the mechanisms identified in the CSM (i.e.; biodegradation and change in redox state due to mixing with more oxic groundwater). However, the time frame predicted for cleanup goals to be achieved at some wells was greater than originally anticipated.

6.0   SITE CONCEPTUAL MODEL UPDATE

The observed trends in groundwater quality indicate improved groundwater quality in bedrock groundwater within the hydraulic influence of the landfill area. The geochemical processes by which groundwater quality in shallow overburden and bedrock groundwater improved and the migration rate for downward movement of groundwater in overburden is generally consistent with the CSM developed prior to issuance of the ROD. However, the time frame predicted for bedrock groundwater to meet cleanup criteria was underestimated.

Based on Summit's analysis and verification of the hydrogeological and geochemical conditions present at the DSI Site, the following mechanisms continue to affect ground water quality in the vicinity of the landfill area:

- **Continued dissipation of the groundwater mound within and beneath the landfill.** Based upon calculations of the hydraulic head decline of perched groundwater within and beneath the landfill, hydraulic head and resulting groundwater discharge from the perched groundwater mound was predicted to decline asymptotically following placement of the landfill cap. Water levels have declined consistent with the predicted response; however, the CSM also predicted that decreasing amounts of water would likely continue to discharge to the underlying bedrock over at least a period of 30 years. Groundwater quality data suggest that some discharge is likely continuing, although data also suggest an improvement in water quality over time that is consistent with a decline of a perched mound within the landfill and subsequent reduction in discharge of water from the landfill waste mass.

- **Residual infiltration through the multilayer cap and areas adjacent to the landfill.**   The purpose of the multilayer cap was to reduce direct infiltration of precipitation into the waste to the extent feasible. A large reduction in leachate generation has been observed indicating that the landfill cap is performing as anticipated. However, consistent with performance modeling of the landfill cap during design, minor infiltration is likely continuing through the cap and in areas proximal to the landfill waste boundary that might interact with the landfill. Hauling records for the UST associated with the lined leachate collection system for the ash mono-fill exhibit small seasonal fluctuations that support infiltration into the landfill. Additionally, seasonal variations in groundwater quality at shallow bedrock wells MW-3 and MW-K39 may be attributable to a seasonal variation in infiltration of water through the landfill. The carbonaceous waste in the landfill is the primary source of total organic carbon and methane detected in ground water samples and the primary cause of reducing conditions observed in ground water within the hydraulic influence of the landfill.

- **Bedrock groundwater seepage into waste adjacent to the western portion of the landfill and subsequent recharge to bedrock downslope of the point of influx.** For this to occur, shallow ground water (or water moving through near surface unsaturated bedrock) would discharge (or drain) toward the western portion of the landfill then subsequently recharge or infiltrate to underlying bedrock. This water could either interact directly with waste in proximity to discharging water or interact with water already present within the waste mass. Persistent groundwater quality impacts at well MW-G26 are consistent with this mechanism.

- **Limited hydraulic interconnectivity of bedrock fractures resulting slower than anticipated flushing rates.** Under pre-cap conditions, water interacting with the landfill was discharging to complexly-fractured bedrock beneath and downgradient of the landfill. Bedrock aquifer systems contain fractures with a wide range of transmissivities, including small aperture, low conductivity and "dead-end" fractures where flow may only occur in response to local hydrogeologic conditions such as during high recharge or high water table periods. It is likely that under post-cap conditions, the rate of recharge to many of these fractures was significantly reduced but not eliminated, resulting in less flushing of these fractures and more persistent reducing conditions compared to more transmissive fractures.

This report was prepared in accordance with the scope of work include in the Investigation Plan dated January 12, 2012, which was approved by the EPA in a letter dated February 16, 2012. Based on the result of this evaluation, the hydrogeological/geochemical conditions in the overburden and bedrock aquifers and the response to the site remedy are generally consistent with the CSM presented in the Supplemental Remedial Investigation Report (Balsam, 1994a). However, the time frame predicted for bedrock groundwater to meet cleanup criteria was underestimated due to the potential mechanism identified above. Based on the results of this evaluation, the relative contribution of each of these potential mechanisms and the time frame required for the natural attenuation of constituent of concern bedrock groundwater to meet cleanup criteria would be difficult to estimate; however, the results of this evaluation and long-term monitoring indicate that the selected site remedy has significantly reduced the volume of leachate discharged to groundwater resulting in significant improvement in groundwater quality downgradient of the DSI Landfill.

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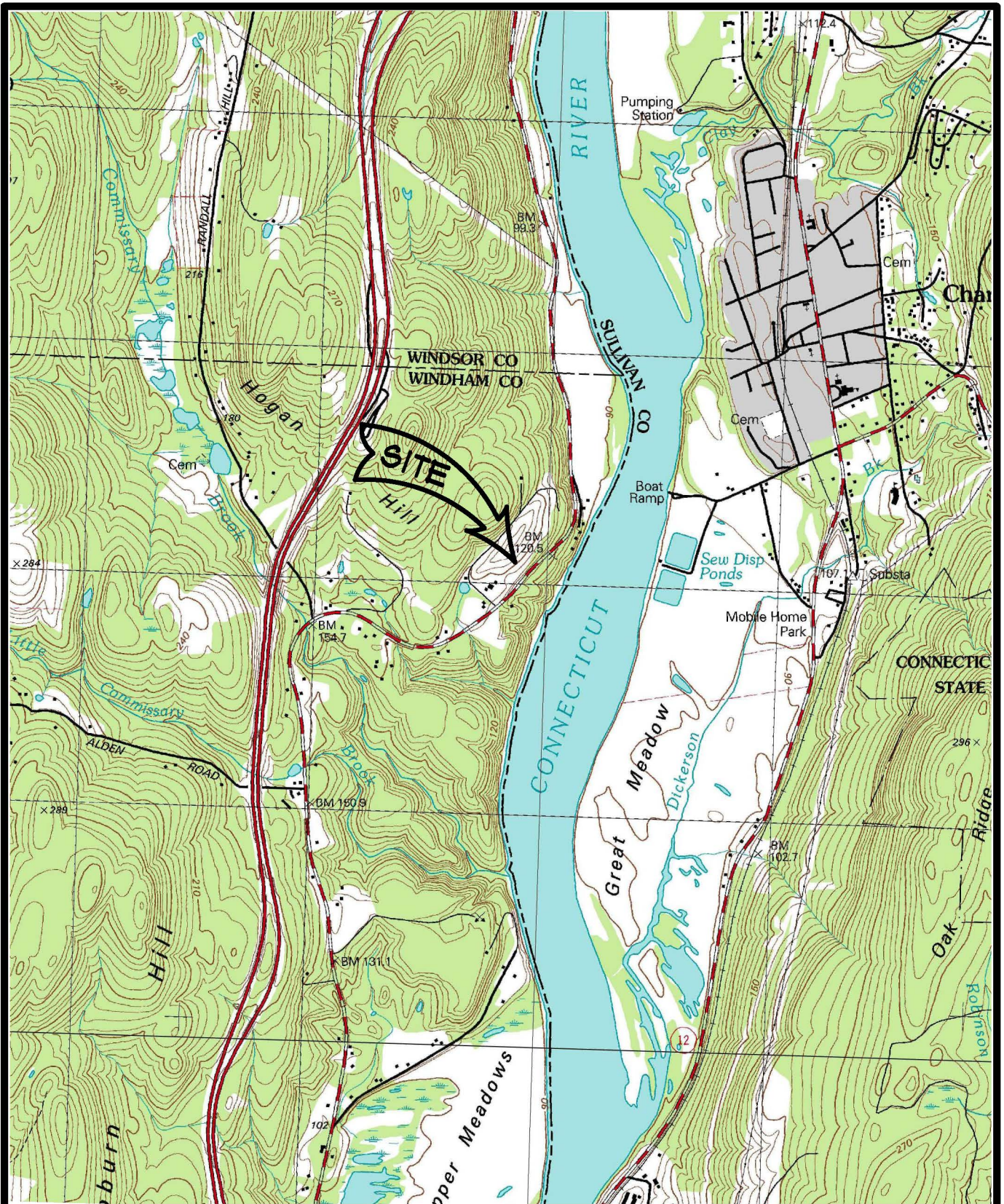
FIGURES 1-8

SITE

FIGURE 1
USGS TOPOGRAPHIC MAP
ROCKINGHAM, VERMONT
PREPARED FOR
DISPOSAL SPECIALIST, INC.

DATE: JAN. 2012 | DRAWN BY: KRF | CHECKED BY: MAD
JOB: 16819 | SCALE: 1" = 2000' | FILE: N/A

Summit
Environmental Consultants, Inc
640 MAIN ST.
LEWISTON, MAINE 04240
Tel.: (207) 795-6009
Fax: (207) 795-6128

SITE PLAN

DISPOSAL SPECIALIST, INC. LANDFILL

MISSING LINK ROAD - ROCKINGHAM, VT

FIGURE 2

INTERCEPTOR WELL

CROSS SECTION LINE

RUMRILL SPRING

EMS INFILTRATION GALLERY

DRAIN LAYER SAMPLE PORT

AREA NOT SURVEYED

BEDROCK OUTCROP AREA

PARCEL 4-505-949

LIMIT OF SOLID WASTE

PARCEL 4-505-894

APPROXIMATE ROW

PARCEL 4-107-008 (RUMRILL)

PARCEL 4-107-010 (GLYNN)

PARCEL 4-107-012 (JOHNSON)

PARCEL 4-107-014 (BANHOLZER)

PARCEL 4-107-032

CRAIGUE WELL

DANFORTH WELL

CONNECTICUT RIVER

ROUTE 5 SLOPE STABILIZATION & SEEPAGE CONTROL SYSTEM

HIT OR MISS CLUB WELL

PARCEL 4-505-891

BUILDING

PARCEL 4-505-890

LEACH FIELD

BLOWER BUILDING

FURNACE BUILDING

CONC PAD AND FLARE

POND

CROSS SECTION LINE

LEGEND

Symbol	Description
▬ ▬ ▬	LANDFILL SOLID WASTE BOUNDARY
— 380 —	EXISTING CONTOUR
⊕ MW-6	MONITORING WELL
⊕ MW-6	MONITORING WELL CURRENTLY SAMPLED
○ EW 11A	GAS EXTRACTION WELL
▲	FORMER WATER SUPPLY WELL (NOT IN USE)
— w —	WATER SUPPLY LINE

NOTES

1) WELLS A1-D, A1-S, A2-D AND A2-S ARE LOCATED IN THE VICINITY OF WELLS C-15, 16, 17 & 18 AND ARE NOT SHOWN FOR CLARITY.

2) CROSS SECTIONS A-A' & B-B' ARE INCLUDED AS FIGURES 4 & 5 RESPECTIVELY.

SCALE: 1" = 200'

0   100   200   400   600
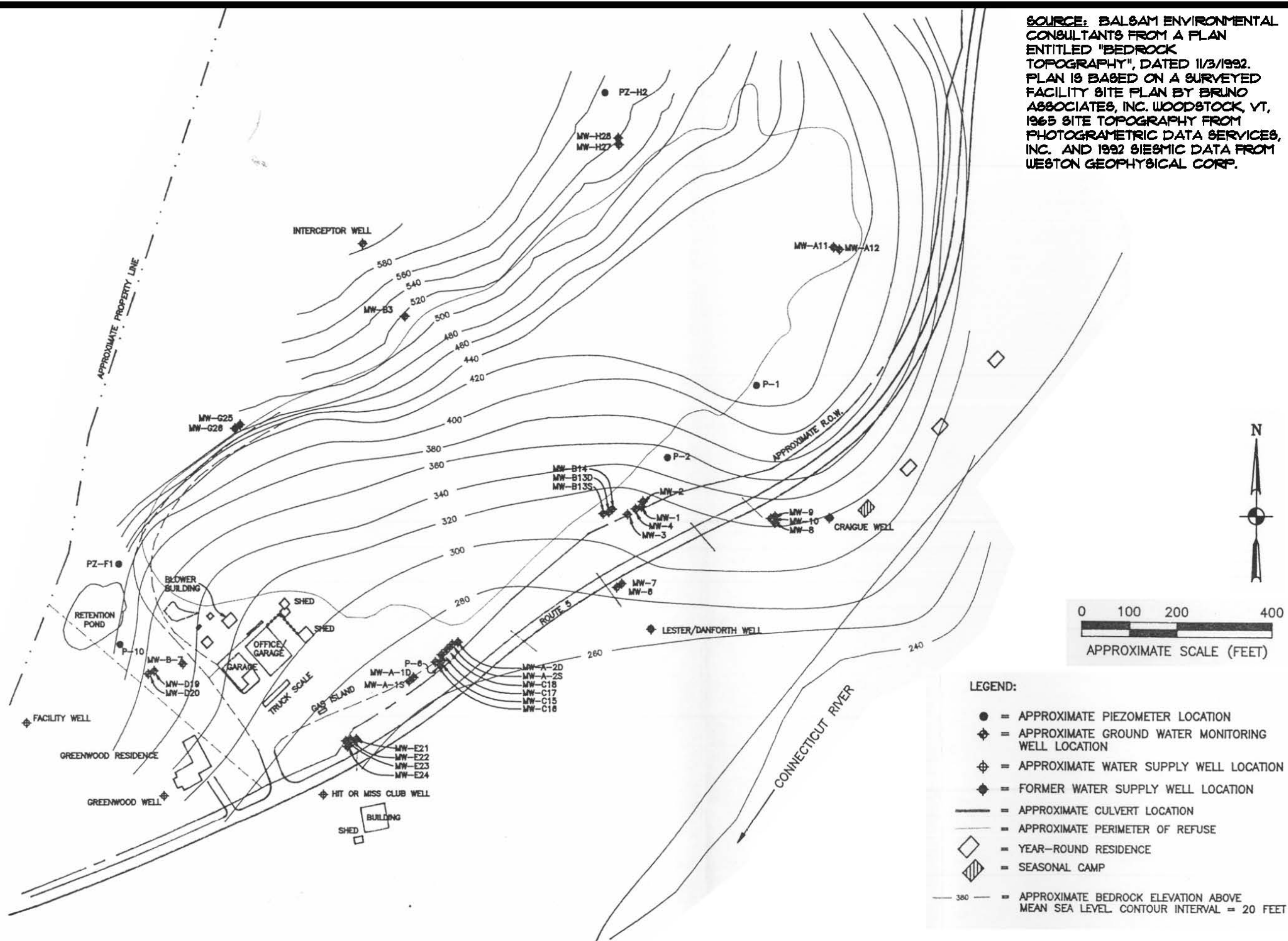
SOURCE: BALSAM ENVIRONMENTAL CONSULTANTS FROM A PLAN ENTITLED "BEDROCK TOPOGRAPHY", DATED 11/3/1992. PLAN IS BASED ON A SURVEYED FACILITY SITE PLAN BY BRUNO ASSOCIATES, INC. WOODSTOCK, VT, 1965 SITE TOPOGRAPHY FROM PHOTOGRAMETRIC DATA SERVICES, INC. AND 1992 SIESMIC DATA FROM WESTON GEOPHYSICAL CORP.

LEGEND:

● = APPROXIMATE PIEZOMETER LOCATION

⬦ = APPROXIMATE GROUND WATER MONITORING WELL LOCATION

⊕ = APPROXIMATE WATER SUPPLY WELL LOCATION

◆ = FORMER WATER SUPPLY WELL LOCATION

— = APPROXIMATE CULVERT LOCATION

— = APPROXIMATE PERIMETER OF REFUSE

◇ = YEAR-ROUND RESIDENCE

◨ = SEASONAL CAMP

——380—— = APPROXIMATE BEDROCK ELEVATION ABOVE MEAN SEA LEVEL. CONTOUR INTERVAL = 20 FEET
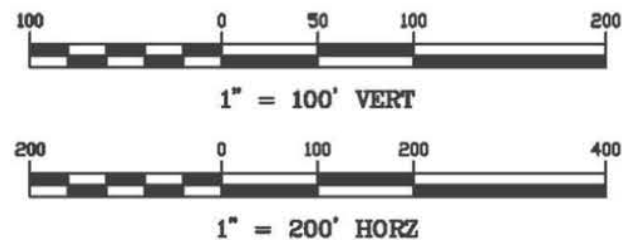
APPROXIMATE SCALE (FEET)
0   100   200   400

BEDROCK SURFACE
ELEVATION CONTOUR MAP
DISPOSAL SPECIALIST, INC.
LANDFILL

MISSING LINK ROAD - ROCKINGHAM, VT

FIGURE 3

LEGEND

- REFUSE
- SAND
- SILT WITH SAND (VARVED LACUSTRINE)
- CLAYEY SILT (VARVED LACUSTRINE)
- ROCK FRAGMENTS AND SILT (BASAL TILL)
- BEDROCK
- SCREENED INTERVAL
- PROJECTED MONITORING WELL DISTANCE ≥ 50 FEET FROM CROSS SECTION LINE

SOURCE: BALSAM ENVIRONMENTAL CONSULTANTS, FROM A PLAN ENTITLED "CONCENTRATION DISTRIBUTION OF TOTAL IRON IN GROUND WATER, CROSS SECTION 1-1'", DATED 4/18/94.

NOTES:

1) CONCEPTUALIZED STRATIGRAPHY BASED ON LIMITED SUBSURFACE DATA COLLECTED FROM BORINGS ADVANCED FROM 1977 THROUGH 1992. IN ADDITION, SEVERAL PRIVATE RESIDENTIAL WELL LOGS WERE INCLUDED.

2) SURFACE ELEVATION OF REFUSE REFLECTS CONDITIONS PRIOR TO REGRADE AND CAPPING.

1" = 100' VERT
1" = 200' HORZ

GREENWOOD WELL

MW-E21
MW-E22
MW-E23
MW-E24

MW-C16
MW-C15
MW-C17
MW-C18

INTERSECTION B-B'

MW-A11
MW-A12

MW-B13S
MW-B13D
MW-B14

MW-2
MW-1
MW-4
MW-3

LIMIT OF SOLID WASTE

U.S. ROUTE 5

ELEVATION IN FEET ABOVE MEAN SEA LEVEL

MW-E21
MW-C15
MW-B13S DRY
MW-1 DRY
MW-B13D

MW-E22
MW-C16
MW-C14 DRY
MW-2 DRY

MW-A11
MW-A12

MW-3

MW-E23
MW-C17

MW-4

GREENWOOD (OPEN HOLE)

MW-E24
MW-C18

DISTANCE (FEET)

GEOLOGICAL CROSS-SECTION A-A'
DISPOSAL SPECIALIST, INC. LANDFILL
MISSING LINK ROAD - ROCKINGHAM, VT

FIGURE 4

GEOLOGICAL CROSS-SECTION B-B'
DISPOSAL SPECIALIST, INC.
LANDFILL

MISSING LINK ROAD - ROCKINGHAM, VT

FIGURE 5

Summit
Environmental Consultants, Inc

640 MAIN ST.
LEWISTON, ME 04240

Tel.: (207) 795-6009
www.summitenv.com

SCALE: AS NOTED
CADD: FIG63-B.DWG

DRAWN BY: SEM
CHECKED BY: SEM

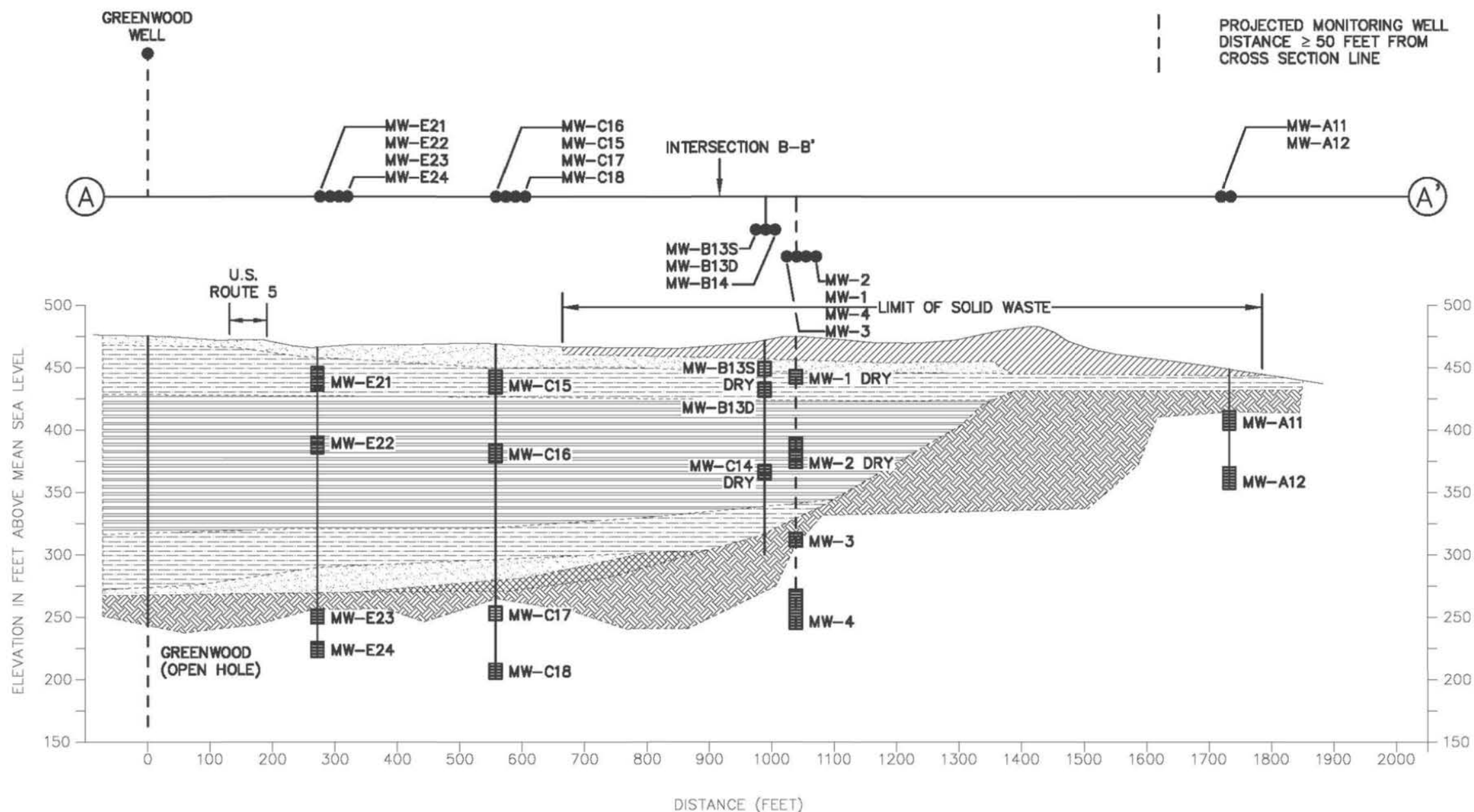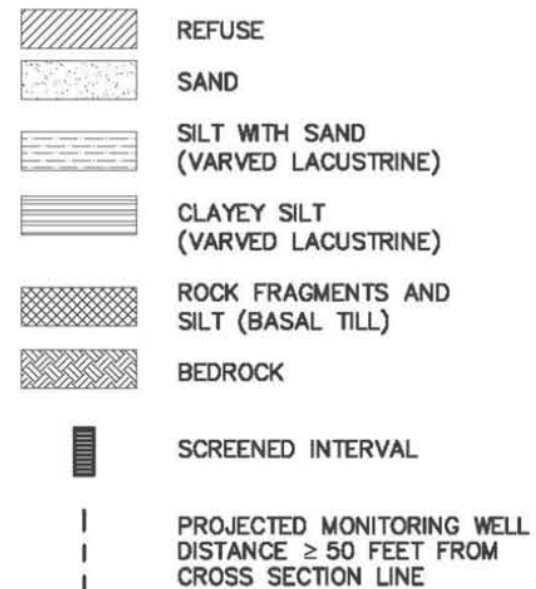DATE: JULY 2012
JOB NUMBER: 16515

SOURCE: BALSAM ENVIRONMENTAL CONSULTANTS, FROM A PLAN ENTITLED "CONCENTRATION DISTRIBUTION OF TOTAL IRON IN GROUND WATER, CROSS SECTION 2-2", DATED 4/18/94.

NOTES:

1) STRATIGRAPHY BASED ON LIMITED SUBSURFACE DATA COLLECTED FROM BORINGS ADVANCED FROM 1977 THROUGH 1992. IN ADDITION, SEVERAL PRIVATE RESIDENTIAL WELL LOGS WERE INCLUDED.

2) WELLS SHOWN ON SECTION LINE BUT NOT ON FIGURE HAVE BEEN DESTROYED, COVERED OR TAKEN OUT OF SERVICE.

3) SURFACE ELEVATION OF REFUSE REFLECTS CONDITIONS PRIOR TO REGRADE AND CAPPING.

LEGEND

REFUSE
SAND
SILT WITH SAND (VARVED LACUSTRINE)
CLAYEY SILT (VARVED LACUSTRINE)
ROCK FRAGMENTS AND SILT (BASAL TILL)
BEDROCK
SCREENED INTERVAL
PROJECTED MONITORING WELL DISTANCE ≥ 50 FEET FROM CROSS SECTION LINE

HORIZONTAL & VERTICAL SCALE: 1" = 120'

0   60'   120'   240'   360'

SHALLOW OVERBURDEN
GROUNDWATER POTENTIOMETRIC CONTOURS
SEPTEMBER 2011
DISPOSAL SPECIALIST, INC.
LANDFILL

FIGURE 6

NOTE

MONITORING WELLS USED TO DEVELOP THE SHALLOW OVERBURDEN GROUNDWATER POTENTIOMETRIC CONTOURS INCLUDE ALL GAS EXTRACTION WELLS (EW-1 THROUGH EW-39) AND WELLS B-13S, PZ-F1, D-19, E-21, C-15 & J-36.

SCALE: 1" = 200'

0 100 200 400 600

LEGEND

▪▪▪▪▪▪▪▪	LANDFILL SOLID WASTE BOUNDARY
----380----	EXISTING CONTOUR
◆ MW-6	MONITORING WELL
◆ MW-6	MONITORING WELL CURRENTLY SAMPLED
O EW 11A	GAS EXTRACTION WELL
(443.0)	SEPTEMBER 2011 GROUNDWATER ELEVATION
▲	FORMER WATER SUPPLY WELL (NOT IN USE)
←	INTERPRETED FLOW DIRECTION
-----	SHALLOW OVERBURDEN GROUNDWATER POTENTIOMETRIC CONTOUR (DASHED WHERE INTERPRETED)

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DRAWN BY: KRF
CHECKED BY: SBM

DATE: FEBRUARY 2012
JOB NUMBER: 16819

SCALE: 1" = 200'
CADD: 12201 FIG3 (8G6)

INTERCEPTOR WELL

CONNECTICUT RIVER

NOTE

MONITORING WELLS USED TO DEVELOP THE SHALLOW BEDROCK GROUNDWATER POTENTIOMETRIC CONTOURS INCLUDE WELLS C-17, E-23, G-25, H-27, J-37, PZ-H2, K-39, MW-3, MW-6, MW-9 & B-3

SCALE: 1" = 200'

0   100   200   400   600

LEGEND

▦▦▦▦	LANDFILL SOLID WASTE BOUNDARY
----380----	EXISTING CONTOUR
✛ MW-6	MONITORING WELL
✛ MW-6	MONITORING WELL CURRENTLY SAMPLED
○ EW 11A	GAS EXTRACTION WELL
(443.0)	SEPTEMBER 2011 GROUNDWATER ELEVATION
▲	FORMER WATER SUPPLY WELL (NOT IN USE)
←	INTERPRETED FLOW DIRECTION
～	SHALLOW BEDROCK GROUNDWATER POTENTIOMETRIC CONTOUR (DASHED WHERE INTERPRETED)

NOTE

MONITORING WELLS USED TO DEVELOP THE DEEPER BEDROCK GROUNDWATER POTENTIOMETRIC CONTOURS INCLUDE WELLS K-40, H-28, J-38, MW-4, MW-7, MW-10, C-18, E-24 & G-26

SCALE: 1" = 200'

```
0    100   200        400        600
```

LEGEND

▬▬▬▬▬	LANDFILL SOLID WASTE BOUNDARY
----380----	EXISTING CONTOUR
✛ MW-6	MONITORING WELL
⬦ MW-6	MONITORING WELL CURRENTLY SAMPLED
○ EW 11A	GAS EXTRACTION WELL
(443.0)	SEPTEMBER 2011 GROUNDWATER ELEVATION
▲	FORMER WATER SUPPLY WELL (NOT IN USE)
⬅	INTERPRETED FLOW DIRECTION
⎯	SHALLOW BEDROCK GROUNDWATER POTENTIOMETRIC CONTOUR (DASHED WHERE INTERPRETED)

CONNECTICUT RIVER

Tel.: (207) 795-6009
www.summitenv.com

Summit
Environmental Consultants, Inc

640 MAIN ST.
LEWISTON, ME 04240

SCALE:	1" = 200'
CADD:	12001 FIG8 (838)

DRAWN BY:	KRF
CHECKED BY:	SBM

DATE:	FEBRUARY 2012
JOB NUMBER:	16819

DEEPER BEDROCK
GROUNDWATER POTENTIOMETRIC CONTOURS
SEPTEMBER 2011
DISPOSAL SPECIALIST, INC.
LANDFILL

FIGURE 8

TABLES 1-4

Table 1
Major Cations and Anions in Bedrock Groundwater
Averages from Fall/Spring 2009 and 2010 Monitoring Events
Disposal Specialists Inc. (DSI) Landfill - Rockingham, Vermont

Well ID	Screened Zone	Sodium (mg/L)	Calcium (mg/L)	Magnesium (mg/L)	Potassium (mg/L)	Bicarbonate (as mg CaCO3/L)	Chloride (mg/L)	Flouride (mg/L)	Sulfate (mg/L)
MW-B3	SBR	17.9	8.2	0.39**	21.7	77	1.4	<0.1	7.8
MW-4	DBR	34.9	71.2	38.4	3.7***	159	180.0	0.16	7.9
MW-6	SBR	188.3	71.3	39.3	50.1	513	277.0	<0.1	<5
MW-7	DBR	13.5	66.4	24.4	1.3***	198	84.1	0.19	9.8
MW-9	SBR	112.8	21.3	3.71**	1.0***	81	162.5	<0.1	15.0
MW-10	DBR	63.6	27.4	5.9	1.1***	61	113.3	<0.1	15.3
MW-G25	SBR	1.98*	14.2	4.3	0.8***	84	2.1	<0.1	13.2
MW-G26	DBR	11.7	10.4	0.68**	0.9***	36	1.3	0.16	13.3
MW-H27	SBR	3.09*	6.4	2.72**	0.7***	20	4.2	<0.1	10.8
MW-H28	DBR	4.75*	9.4	2.51**	0.8***	30	1.1	<0.1	11.7
MW-J37	SBR	15.7	37.6	16.4	7.3	65	85.4	<0.1	28.0
MW-J38	DBR	31.2	74.4	8.5	12.2	183	64.6	<0.1	<5
MW-K39	SBR	8.7	62.2	8.8	1.5***	150	39.7	0.105^	10.7
MW-K40	DBR	6.4	27.1	4.44**	0.8***	100	5.8	0.14	16.9

NOTES:

DBR = deeper bedrock well generally screened greater than 50 feet below the bedrock surface
SBR = shallow bedrock well generally screened within the upper 10 feet of bedrock
Deeper and shallow bedrock well couplets include: MW-6/7, MW-9/10, MW-G25/G26, MW-H27/H28, MW-J37/J38 and MW-K39/K40.

*	Sodium was detected at the concentration indicated above in Spring 2009 when the laboratory detection limit was 1 mg/L. Sodium was not reported present the laboratory detection limit (5 mg/L) in Fall 2009 and Spring/Fall 2010.
**	Magnesium was detected at the concentration indicated above in Spring 2009 when the laboratory detection limit was 0.2 mg/L. Magnesium was not reported present above the laboratory detection limit (5 mg/L) in Fall 2009 and Spring/Fall 2010.
***	Potassium was detected at the concentration indicated above in Spring 2009 when the laboratory detection limit was 0.5 mg/L. Potassium was not reported present above the laboratory detection limit (5 mg/L) in Fall 2009 and Spring/Fall 2010.
^	Flouride was detected at 0.105 mg/L during Spring 2010; however, flouride was not reported present above the detection limit (0.1 mg/L) during Spring/Fall 2009 and Fall 2010.

Table 2
Redox Sensitive Parameters in Bedrock Groundwater
Averages from Fall/Spring 2009 and 2010 Monitoring Events
Disposal Specialists Inc. (DSI) Landfill - Rockingham, Vermont

Well ID	Screened Zone	pH (SU)	DO (mg/L)	ORP (mV)"	Manganese (mg/L)	Iron (mg/L)	Arsenic (mg/L)	Sulfate (mg/L)	Nitrate-N (mg/L-N)	Methane (mg/L)	Total Organic Carbon (mg/L)	VOCs Reported Present Since 2004
MW-B3	SBR	10.2	3.3	87	<0.015	0.18	<0.01	7.8	0.11	<0.001	<1.0	
MW-4	DBR	6.2	0.9	8	5.26	63.33	0.03	7.9	0.11	2.16	3.25	x
MW-6	SBR	6.3	0.6	-47	1.81	29.08	0.25	<5	0.14	7.70	22.13	x
MW-7	DBR	7.1	0.4	-79	1.52	3.57	<0.01	9.8	<0.05	4.00	1.20	x
MW-9	SBR	6.5	0.9	90	0.16	1.38	<0.01	15.0	2.6*	0.17	1.38	x
MW-10	DBR	6.5	0.5	36	0.00	0.08	<0.01	15.3	0.08	0.016	<1.0	x
MW-G25	SBR	5.8	0.8	9	3.15	42.38	0.07	13.2	0.05	7.13	5.55**	x
MW-G26	DBR	8.7	2.3	-41	0.18	0.57	0.01^	13.3	0.15	0.006	<1.0	
MW-H27	SBR	5.5	2.9	225	0.01	0.20	<0.01	10.8	0.21	<0.001	<1.0	
MW-H28	DBR	5.9	2.3	194	0.01	<0.1	<0.01	11.7	0.20	<0.001	<1.0	
MW-J37	SBR	6.6	0.2	-96	3.01	7.19	<0.01	28.0	<0.05	0.09	10.70	
MW-J38	DBR	6.8	0.2	-41	0.49	2.42	<0.01	<5	0.19	0.05	2.1**	x
MW-K39	SBR	7.7	0.7	-75	0.88	0.18	<0.01	10.7	<0.05	0.35	<1.0	
MW-K40	DBR	7.5	0.7	21	0.17	<0.1	<0.01	16.9	<0.05	0.004	<1.0	

NOTES:

DO = dissolved oxygen
ORP = Oxidation Reduction Potential
DBR = deeper bedrock well generally screened greater than 50 feet below the bedrock surface
SBR = shallow bedrock well generally screened within the upper 10 feet of bedrock
VOCs = volatile organic compounds

* At MW-9 reported nitrate concentrations were <0.05 mg/L during Spring sampling events and 0.389 mg/L and 4.88 mg/L during Fall events
** Total organic carbon concentrations vary significantly at MW-G25 (<1.0 to 15.6 mg/L) and MW-J38 (<1.0 to 38.3 mg/L).
^ At MW-G26 arsenic was reported below the detection limit (<0.1 mg/L) for three of the four sampling rounds
" Oxidation Reduction Potentials vary signficantly from event to event in all bedrock wells.

Deeper and shallow bedrock well couplets include: MW-6/7, MW-9/10, MW-G25/G26, MW-H27/H28, MW-J37/J38 and MW-K39/K40.

Table 3
DSI Landfill - Rockingham, Vermont
Groundwater Redox Assignments

Sample ID	Redox Variables	Dissolved O_2 (millig/L)	NO_3^- (as Nitrogen) (millig/L)	Mn^{2+} (microg/L)	Fe^{2+} (microg/L)	SO_4^{2-} (millig/L)	Sulfide (sum of H_2S, HS^-, S^{2-}) (millig/L)	Num of Params	General Redox Category	Redox Process	Notes	Monitored Zone
	Units / Threshold values	0.5	0.5	50	100	0.5	none					
MW-4	Jun-09	1.16	0.07	5190	22400	9.6		5	Mixed(oxic-anoxic)	O2-Fe(III)/SO4		DBR
	Oct-09	0.85	0.05	6110	30900	8.2		5	Mixed(oxic-anoxic)	O2-Fe(III)/SO4		
	May-10	0.92	0.05	5080	28000	8		5	Mixed(oxic-anoxic)	O2-Fe(III)/SO4		
	Sep-10	0.85	0.148	4650	172000	5.9		5	Mixed(oxic-anoxic)	O2-Fe(III)/SO4		
MW-6	Jun-09	0.55	0.14	1790	28000	0.51		5	Mixed(oxic-anoxic)	O2-Fe(III)/SO4	(1)	SBR
	Oct-09	0.37	0.05	1820	30700	0.51		5	Anoxic	Fe(III)/SO4	(1)	
	May-10	0.72	0.05	1770	28000	0.51		5	Mixed(oxic-anoxic)	O2-Fe(III)/SO4	(1)	
	Sep-10	0.58	0.05	1850	29600	0.51		5	Mixed(oxic-anoxic)	O2-Fe(III)/SO4	(1)	
MW-7	Jun-09	0.49	0.05	1640	4180	10.6		5	Anoxic	Fe(III)/SO4		DBR
	Oct-09	0.24	0.05	1600	4040	12.1		5	Anoxic	Fe(III)/SO4		
	May-10	0.75	0.05	1400	3030	9		5	Mixed(oxic-anoxic)	O2-Fe(III)/SO4		
	Sep-10	0.27	0.05	1440	3040	7.4		5	Anoxic	Fe(III)/SO4		
MW-9	Jun-09	0.99	0.05	305	3730	13.8		5	Mixed(oxic-anoxic)	O2-Fe(III)/SO4		SBR
	Oct-09	1.06	0.389	90	611	16.6		5	Mixed(oxic-anoxic)	O2-Fe(III)/SO4		
	May-10	0.9	0.05	128	963	12.8		5	Mixed(oxic-anoxic)	O2-Fe(III)/SO4		
	Sep-10	0.61	4.88	122	203	16.8		5	Mixed(oxic-anoxic)	O2-Fe(III)/SO4	(5)	
MW-10	Jun-09	0.45	0.05	3.8	82	15.4		5	Suboxic	Suboxic		DBR
	Oct-09	0.62	0.069	15	99.9	15.7		5	Oxic	O2	(2)	
	May-10	0.27	0.05	15	99.9	15.1		5	Suboxic	Suboxic	(2)	
	Sep-10	0.77	0.108	15	99.9	14.9		5	Oxic	O2	(2)	
MW-B3	Jun-09	4.88	0.11	3	50	7.8		5	Oxic	O2		SBR
	Oct-09	3.47	0.123	15	99.9	0.51		5	Oxic	O2	(1), (2)	
	May-10	2.75	0.078	15	104	0.51		5	Mixed(oxic-anoxic)	O2-Fe(III)/SO4	(1)	
	Sep-10	2.06	0.143	15	248	0.51		5	Mixed(oxic-anoxic)	O2-Fe(III)/SO4	(1)	
MW-G25	Jun-09	1.06	0.05	2620	29900	8.5		5	Mixed(oxic-anoxic)	O2-Fe(III)/SO4		SBR
	Oct-09	0.57	0.05	3630	57500	0.51		5	Mixed(oxic-anoxic)	O2-Fe(III)/SO4	(1)	
	May-10	0.84	0.05	1660	25300	0.51		5	Mixed(oxic-anoxic)	O2-Fe(III)/SO4	(1)	
	Sep-10	0.84	0.05	4670	56800	17.9		5	Mixed(oxic-anoxic)	O2-Fe(III)/SO4		
MW-G26	Jun-09	3.16	0.11	461	569	13.5		5	Mixed(oxic-anoxic)	O2-Fe(III)/SO4		DBR
	Oct-09	2.25	0.138	28.8	99.9	12.4		5	Oxic	O2		
	May-10	1.81	0.138	15	99.9	15.9		5	Oxic	O2	(4)	
	Sep-10	2.01	0.206	38.7	99.9	11.4		5	Oxic	O2		

Table 3
DSI Landfill - Rockingham, Vermont
Groundwater Redox Assignments

Well	Date								General Category	Redox Process	Notes	
MW-H27	Jun-09	3.93	0.19	7.8	181	11.7		5	Mixed(oxic-anoxic)	O2-Fe(III)/SO4		SBR
	Oct-09	2.56	0.25	15	99.9	8.8		5	Oxic	O2	(2), (4)	
	May-10	2.55	0.185	15	168	12.6		5	Mixed(oxic-anoxic)	O2-Fe(III)/SO4	(4)	
	Sep-10	2.36	0.233	15	249	10.1		5	Mixed(oxic-anoxic)	O2-Fe(III)/SO4	(4)	
MW-H28	Jun-09	3.57	0.17	6.5	50	11.7		5	Oxic	O2	(3)	DBR
	Oct-09	2.47	0.246	15	99.9	9		5	Oxic	O2	(2), (4)	
	May-10	1.8	0.177	15	99.9	12.2		5	Oxic	O2	(2), (4)	
	Sep-10	1.52	0.19	15	99.9	14		5	Oxic	O2	(2), (4)	
MW-J37	Jun-09	0.13	0.05	3820	7250	24.9		5	Anoxic	Fe(III)/SO4		SBR
	Oct-09	0.47	0.05	1290	5530	0.51		5	Anoxic	Fe(III)/SO4	(1)	
	May-10	0.08	0.05	3490	8640	28		5	Anoxic	Fe(III)/SO4		
	Sep-10	0.07	0.05	3420	7340	31.2		5	Anoxic	Fe(III)/SO4		
MW-J38	Jun-09	0.31	0.05	512	2450	0.51		5	Anoxic	Fe(III)/SO4	(1)	DBR
	Oct-09	0.21	0.05	719	3070	0.51		5	Anoxic	Fe(III)/SO4	(1)	
	May-10	0.22	0.242	295	2230	0.51		5	Anoxic	Fe(III)/SO4	(1)	
	Sep-10	0.13	0.132	447	1930	0.51		5	Anoxic	Fe(III)/SO4	(1)	
MW-K39	Jun-09	0.95	0.05	988	196	11.5		5	Mixed(oxic-anoxic)	O2-Fe(III)/SO4		SBR
	Oct-09	0.85	0.05	797	99.9	12.5		5	Mixed(oxic-anoxic)	O2-Mn(IV)	(2)	
	May-10	0.43	0.05	921	170	0.51		5	Anoxic	Fe(III)/SO4	(1)	
	Sep-10	0.52	0.05	817	99.9	8.2		5	Mixed(oxic-anoxic)	O2-Mn(IV)	(2)	
MW-K40	Jun-09	0.57	0.05	55.9	50	17.1		5	Mixed(oxic-anoxic)	O2-Mn(IV)	(3)	DBR
	Oct-09	0.66	0.05	368	99.9	18.3		5	Mixed(oxic-anoxic)	O2-Mn(IV)	(2)	
	May-10	0.82	0.05	84.1	99.9	16.2		5	Mixed(oxic-anoxic)	O2-Mn(IV)	(2)	
	Sep-10	0.73	0.05	182	99.9	16		5	Mixed(oxic-anoxic)	O2-Mn(IV)	(2)	

NOTES (Well Specific):

(1) Sulfate was reported at reported at <5.0 ug/L. Since sulfate is likely >0.5 mg/L, a value of 0.51 mg/L was assigned. If this was not done the general redox category
   would be "O2 < 0.5 mg/L" or "O2 > 0.5 mg/L" and redox process would be "Unknown"

(2) Iron was reported at <100 ug/L. A value of 99.9 ug/L was assigned because the threshold value is 100 ug/L.

(3) Iron was reported at <50 ug/L. A value of 50 ug/L was assigned because it is below the threshold value of 100 ug/L.

(4) Manganese was reported at <15 ug/L. A value of 15 ug/L was assigned because it is below the threshold of 50 ug/L.

(5) Reported nitrate concencentration (4.88 mg/L) is anonamously high.

NOTES (General):

-- Source: "An Excel Workbook for Identifying Redox Processes in Ground Water" by Bryant C. Jurgens, Peter B. McMahon, Francis H. Chapelle, and Sandra M. Eberts
   U.S. Geological Survey Open-File Report 2009-1004.

-- Non-detect concentration of Nitrate-N (<0.05 mg/L) were entered as 0.05 mg/L, which is below the threshold and does not affect the redox assignment detemination

Table 4
DSI Landfill - Rockingham, Vermont
VOCs in Bedrock Groundwater

Well ID	Monitored Zone	VOC Analyte	Lowest Concentration	Highest Concentration	Visual Trend
MW-3	SBR	1,1-dichloroethane	6.3	11	NST
		1,2-dichlorobenzene	<0.5	3.5	NST
		1,4-dichlorobenzene	<3.6	7	NST
		acetone	<17	64	NST
		benzene	<3.5	13	NST
		1,2,4-trimethylbenzene	<0.5	17	NST
		1,3,5-trimethylbenzene	<0.5	3.7	NST
		1-methylethylbenzene	<0.5	5.4	NST
		carbon disulfide	<0.5	3.1	NST
		chlorobenzene	<3.2	11	NST
		chloroethane	5.7	14	NST
		chloromethane	<1.9	6.7	NST
		ethylbenzene	<3.4	650	NST, S
		methyl ethyl ketone	<2.5	17	NST
		methyl isobutylketone	<5.0	22	NST
		methylene chloride	<1.0	21	NST
		napthalene	2.5	17	NST
		toluene	<0.96	420	NST
		xylene (total)	<10	2500	NST, S
MW-4*	DBR	chloroethane	1.2	1.4	NA
		cis-1,2-dichloroethane	<0.5	0.5	NA
		dichlorodiflouromethane	<0.5	0.74	NA
		vinyl chloride	0.84	1.1	NA
MW-6	SBR	1,1-dichloroethane	<0.5	6	D
		1,2-dichlorobenzene	3.1	5.9	NST
		1,4-dichlorobenzene	5	9.6	NST
		acetone	2.5	20	NST
		benzene	3.8	9.4	D
		1,2,4-trimethylbenzene	<0.5	6.5	D
		1,3,5-trimethylbenzene	<0.5	0.64	NST
		1-methylethylbenzene	1.5	4.1	NST
		chlorobenzene	11	18	NST
		chloroethane	3.3	6.6	D
		chloromethane	<0.5	1.8	NST
		dichlorodiflouromethane	<0.5	0.67	NST
		ethylbenzene	<0.5	29	D
		napthalene	5.1	18	D
		n-butylbenzene	<0.5	1.6	NST
		n-propylbenzene	0.66	1.6	NST
		sec-butylbenzene	<0.5	2.6	NST
		tert-butylbenzene	<0.5	0.89	NST
		toluene	<0.5	0.63	NST
		xylene (total)	1.6	15	D

Table 4
DSI Landfill - Rockingham, Vermont
VOCs in Bedrock Groundwater

Well ID	Monitored Zone	VOC Analyte	Lowest Concentration	Highest Concentration	Visual Trend
MW-7*	DBR	1,1-dichloroethane	0.69	0.76	NA
		chloroethane	<0.5	0.54	NA
		vinyl chloride	0.8	1	NA
MW-9	SBR	1,1-dichloroethane	<0.5	0.5	NST
		acetone	<2.5	16	NST
		chloroform	<0.5	1	NST
		cis-1,2-dichloroethene	<0.5	1.9	NST
		dichlorodiflouromethane	<0.5	1.6	NST
		napthalene	<0.5	1.1	NST
		tetrachloroethene	3.7	10	D
		trichloroethene	<0.5	0.84	D
MW-10	DBR	cis-1,2-dichloroethene	<0.5	0.56	NST
		dichlorodiflouromethane	<0.5	0.96	NST
		tetrachloroethene	0.68	3.9	D
		trichloroethene	<0.5	0.5	NA
MW-B3*	SBR	All Analytes Reported below the detection limit			
MW-C17*	SBR	toluene	<0.5	1	NA
MW-C18*	DBR	All Analytes Reported below the detection limit			
MW-E23*	SBR	toluene	<0.5	2.1	NA
MW-E24*	DBR	toluene	<0.5	4.1	NA
MW-G25*	SBR	acetone	<2.5	6.2	NA
		benzene	<0.5	0.99	NA
		1-methylethylbenzene	<0.5	0.78	NA
MW-G26*	DBR	All Analytes Reported below the detection limit			
MW-H27*	SBR	All Analytes Reported below the detection limit			
MW-H28*	DBR	All Analytes Reported below the detection limit			
MW-J37*	SBR	All Analytes Reported below the detection limit			
MW-J38**	DBR	acetone	<2.5	4.3	NA
		carbon disulfide	<0.5	0.7	NA
MW-K39*	SBR	All Analytes Reported below the detection limit			
MW-K40*	DBR	All Analytes Reported below the detection limit			

Notes:

1. Table is based on samples collected from April 2003 to Fall 2011, estimates were ignored if no detections are present

NST   no substantial trend is apparent

S   a seasonal variation is apparent with highest concentration reported in spring

NA   data not suitable for visual trend analysis

D   a visually decreasing trend is apparent

SBR   well screened in shallow bedrock

DBR   well screened in deeper bedrock

*   Well sampled on a semi-annual basis for selected metals only because VOC cleanup criteria have been met. Data included in table is from May and September 2004 "5-year" sampling round.

**   Well sampled on a semi-annual basis for selected metals only because VOC cleanup criteria have been met. Data included in table is from May and September 2004 "5-year" sampling round and April 2005.
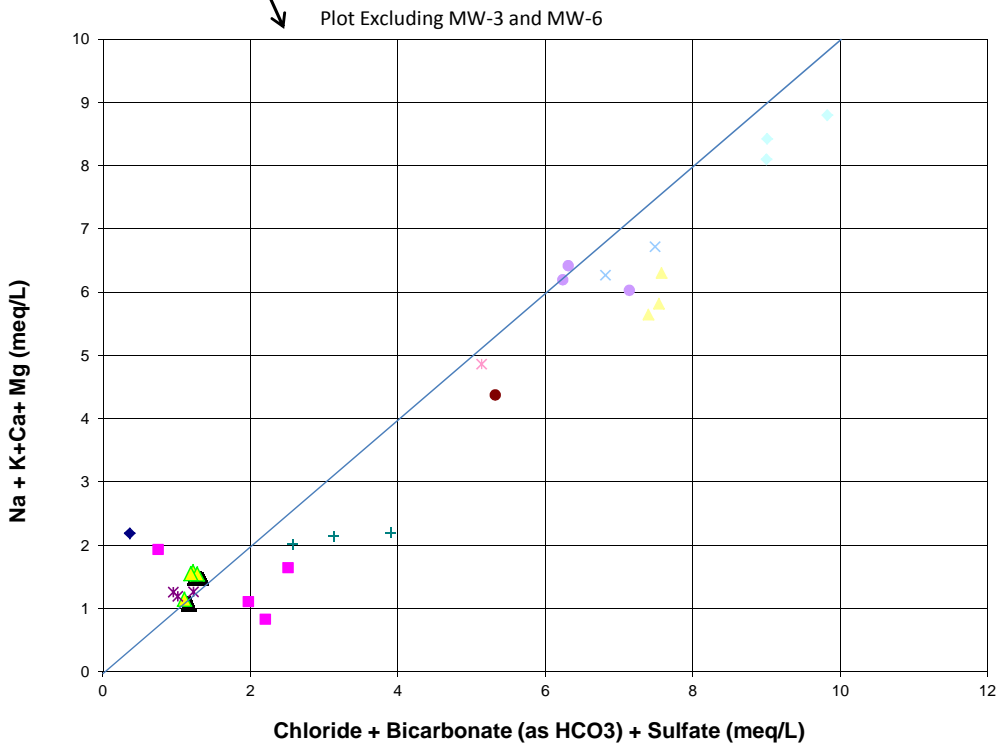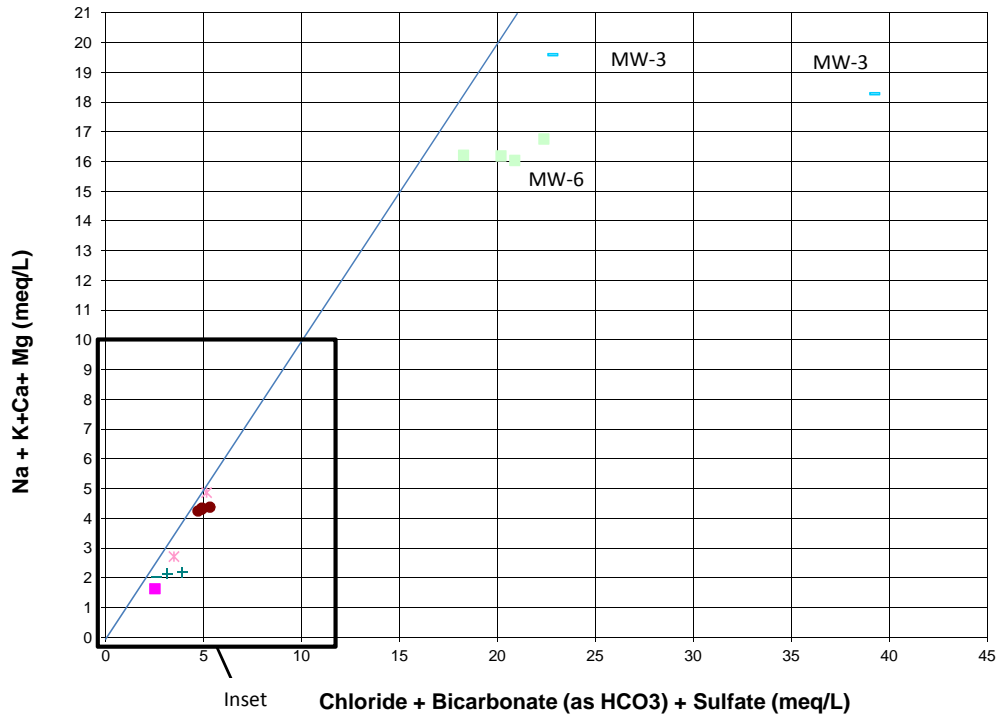
APPENDIX A

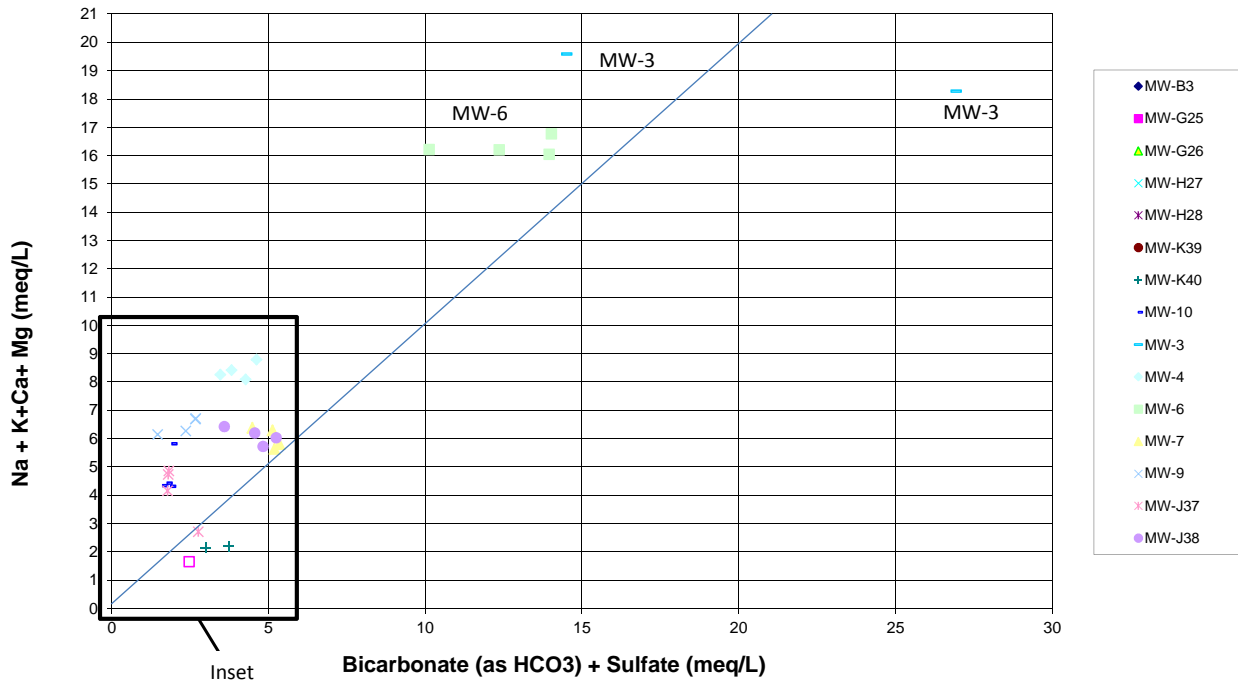Major Cations and Anions in Bedrock
Groundwater Scatter Plots

Disposal Specialists, Inc. Rockingham, Vermont
Bedrock Groundwater Quality
Calcium + Magnesium -vs- Sodium + Potassium
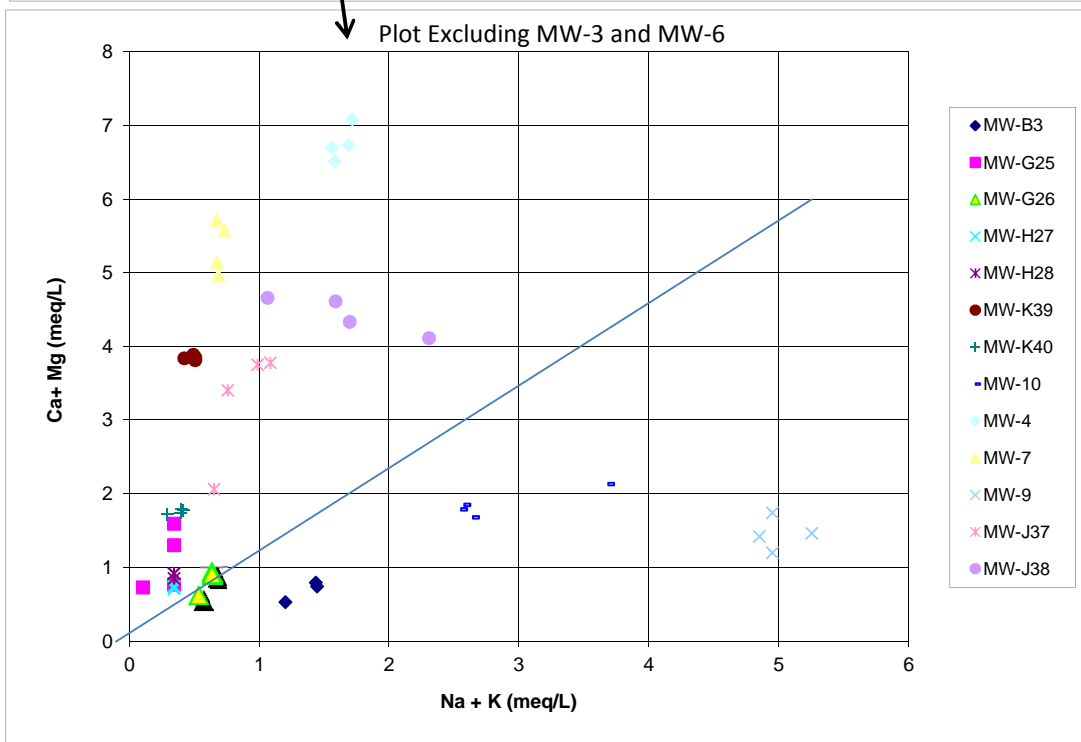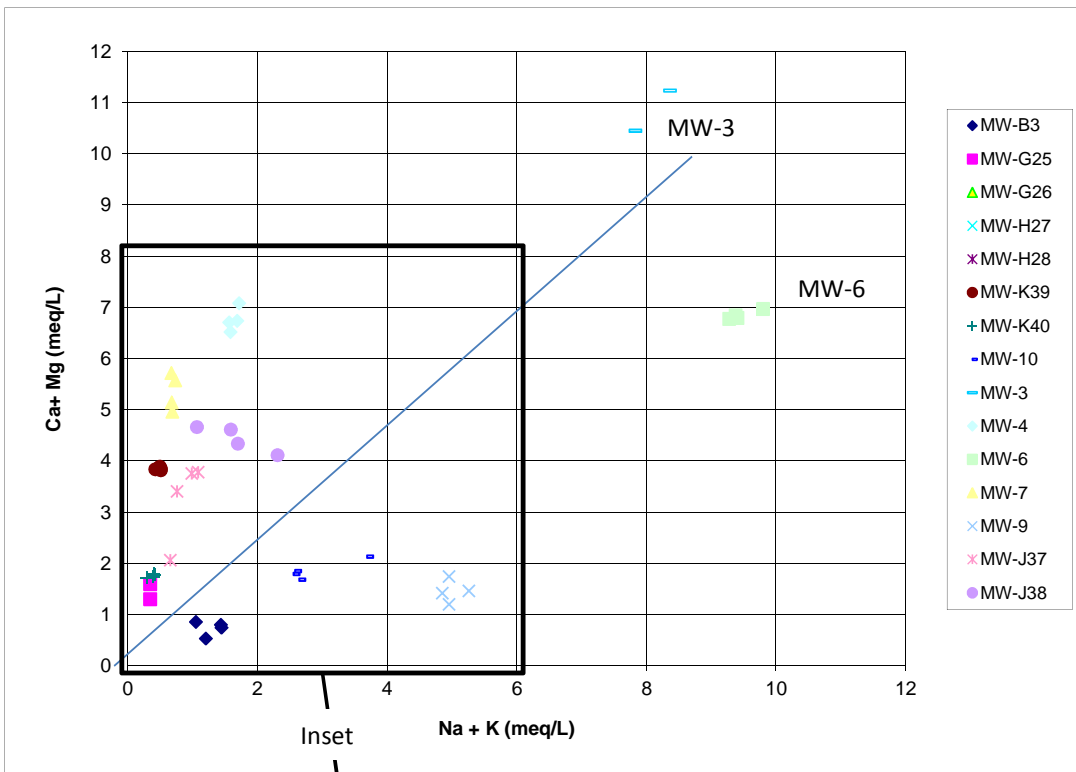
Plot Excluding MW-3 and MW-6

Disposal Specialists, Inc. Rockingham, Vermont
Bedrock Groundwater Quality
Sum of Major Cations -vs- Sum of Major Anions

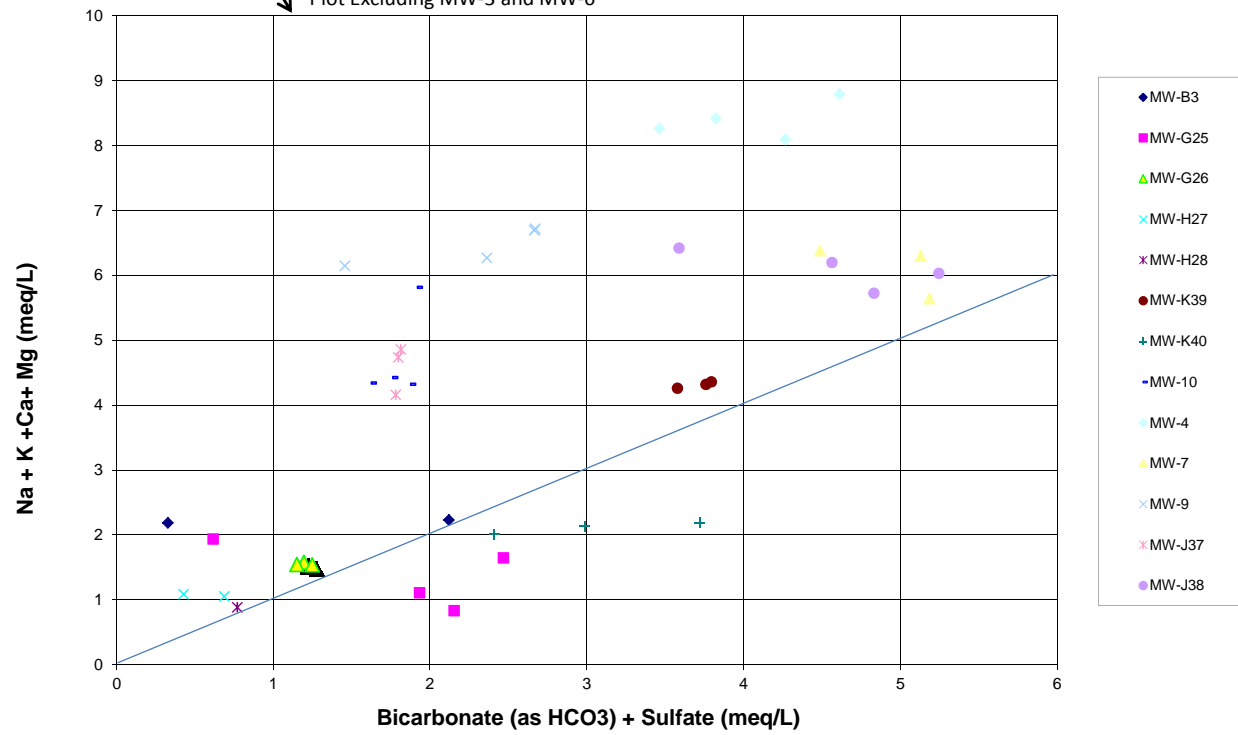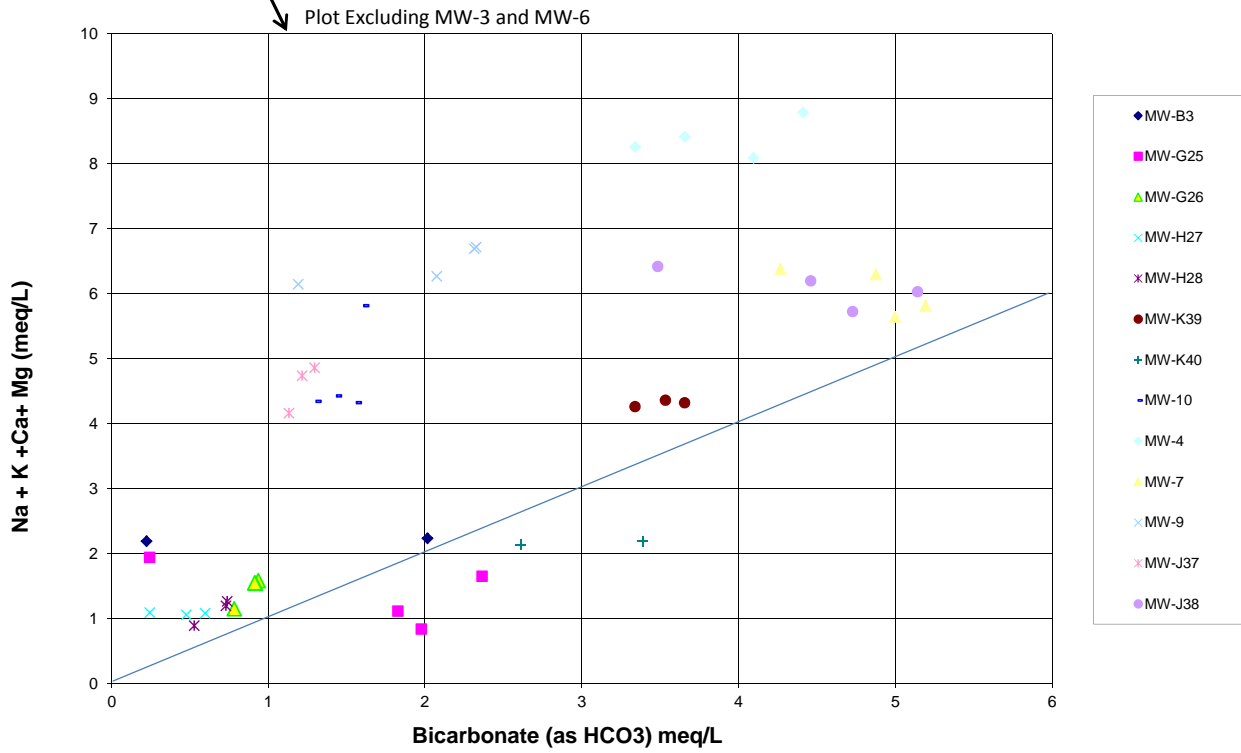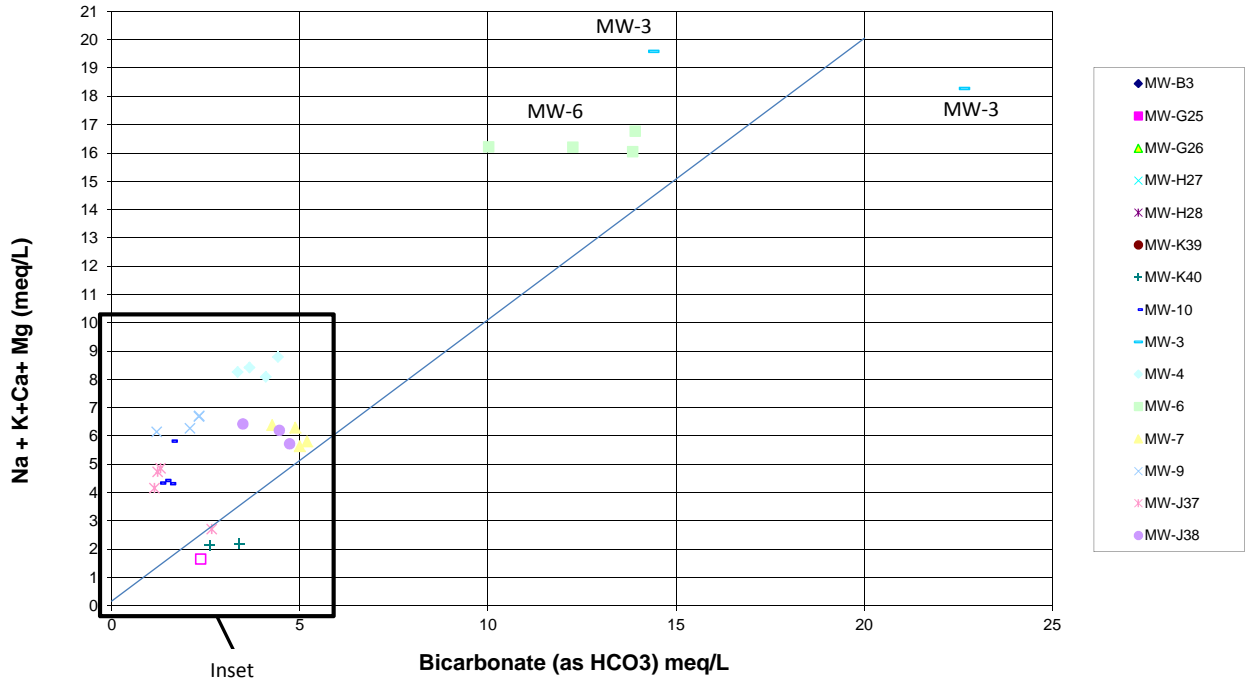**Disposal Specialists, Inc. Rockingham, Vermont**
Bedrock Groundwater Quality
Sum of Major Cations -vs- Bicarbonate + Sulfate

Disposal Specialists, Inc. Rockingham, Vermont
Bedrock Groundwater Quality
Sum of Major Cations -vs- Bicarbonate

APPENDIX B

Iron and Manganese Trends in Bedrock Groundwater

Montoring Well MW-3 (Shallow Bedrock Zone)

Total Iron (ug/L)

Date	Concentration	Flag
5/18/1994	98500	
10/7/1994	73300	
5/24/2001	393000	
5/22/2002	82000	
5/22/2002	27600	
5/20/2003	101000	
5/12/2004	25000	
9/22/2004	109000	
6/2/2009	34100	
5/26/2010	65000	
9/28/2011	42600	
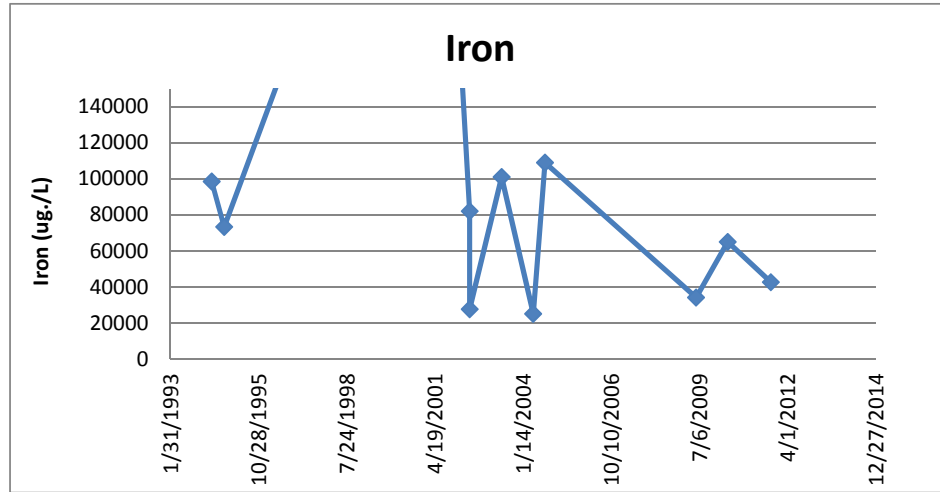
Total Manganese (ug/L)

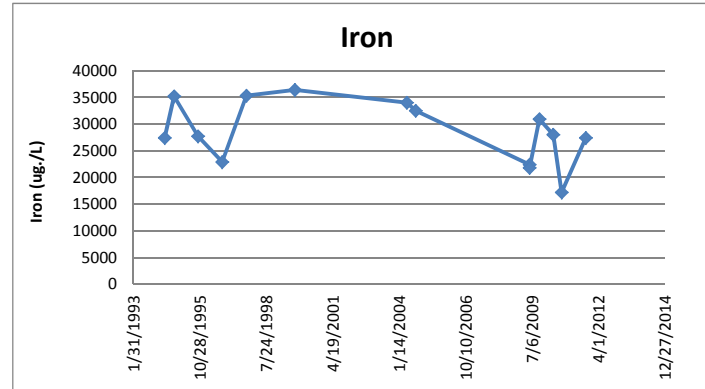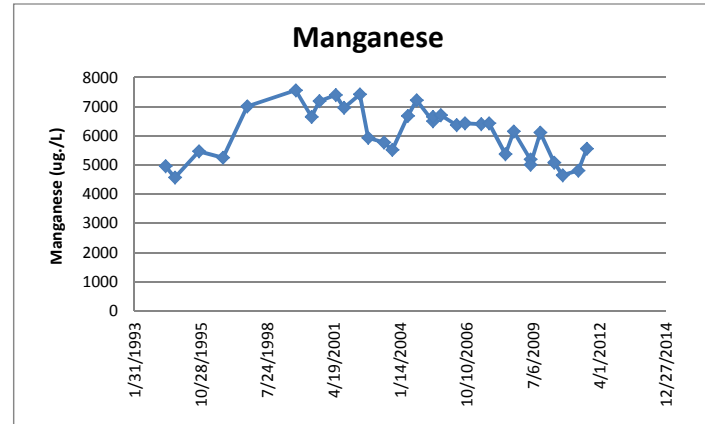| Date	Concentration	Flag
5/18/1994	755	
10/7/1994	779	
5/24/2001	6250	
5/22/2002	861	
5/22/2002	425	
5/20/2003	413	
5/12/2004	304	
9/22/2004	732	
5/25/2005	394	
5/17/2006	207	
9/20/2006	256	
5/22/2007	335	
5/20/2008	552	
6/2/2009	312	
5/26/2010	380	
9/28/2011	301	
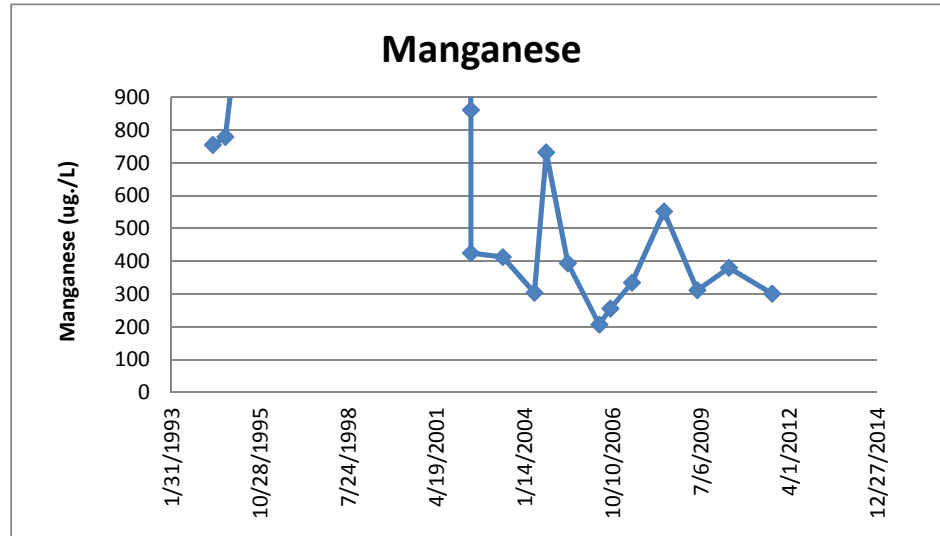
Flag Abbreviations:

E = laboratory estimated concentration between

U = Not detected above reporting limit;

B = estimated concentration between instrument detection limit and reporting limit

Montoring Well MW-4 (Deeper Bedrock Zone)

Total Iron (ug/L)		
Date	**Concentration**	**Flag**
5/18/1994	27400	
10/7/1994	35200	
10/3/1995	27700	
9/30/1996	22900	
9/30/1997	35300	
9/29/1999	36400	E
5/12/2004	34000	
9/22/2004	32500	
6/2/2009	22400	
6/2/2009	21800	
10/28/2009	30900	
5/25/2010	28000	
9/28/2010	17200	
9/27/2011	27400	

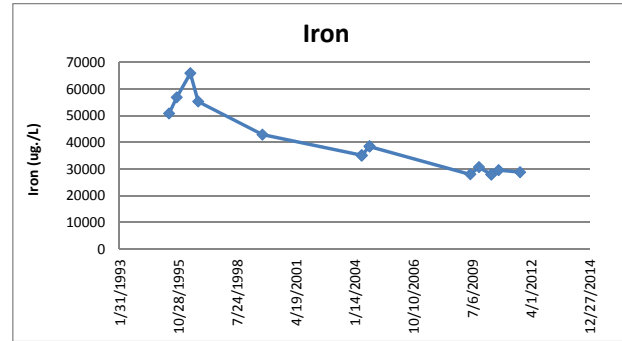| Total Manganese (ug/L)		
Date	**Concentration**	**Flag**
5/18/1994	4960	
10/7/1994	4570	
10/3/1995	5470	
9/30/1996	5250	
9/30/1997	7010	
9/29/1999	7560	E
5/24/2000	6650	
9/20/2000	7190	E
5/23/2001	7400	
9/26/2001	6960	
5/21/2002	7420	
9/24/2002	5930	
5/20/2003	5770	
9/23/2003	5520	
5/12/2004	6680	
9/22/2004	7220	
5/25/2005	6500	
5/25/2005	6650	
9/20/2005	6710	
5/16/2006	6370	
9/19/2006	6430	
5/22/2007	6400	
9/18/2007	6430	
5/20/2008	5370	
9/23/2008	6150	
6/2/2009	5190	E
6/2/2009	5010	E
10/28/2009	6110	
5/25/2010	5080	
9/28/2010	4650	
5/24/2011	4810	
9/27/2011	5560	

Flag Abbreviations:
E = laboratory estimated concentration between
U = Not detected above reporting limit;
B = estimated concentration between instrument detection
    limit and reporting limit

Montoring Well MW-6 (Shallow Bedrock Zone)

Total Iron (ug/L)		
Date	Concentration	Flag
5/25/1995	50800	
10/2/1995	56900	
5/20/1996	65900	
9/30/1996	55300	
9/29/1999	42900	E
5/12/2004	35200	
5/12/2004	35000	
9/22/2004	38600	
9/22/2004	38400	
6/2/2009	28000	
10/27/2009	30700	
5/25/2010	28000	
5/25/2010	27900	
9/28/2010	29600	
9/27/2011	28800	

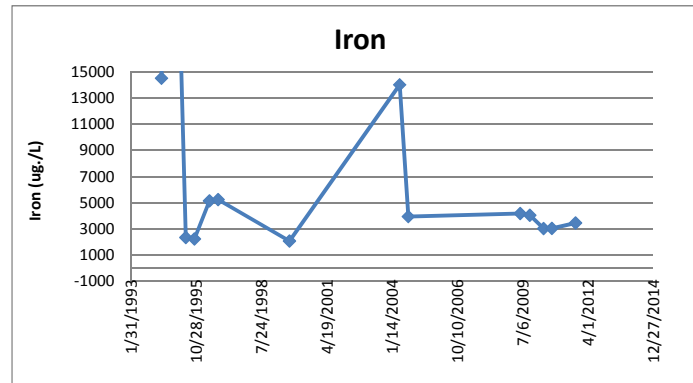| Total Manganese (ug/L)		
Date	Concentration	Flag
5/25/1995	1980	
10/2/1995	2260	
5/20/1996	2360	
9/30/1996	2090	
10/1/1997	1940	
5/19/1998	1980	
9/29/1999	1890	E
5/23/2000	1600	
5/23/2000	1610	
9/19/2000	1850	
5/22/2001	1810	
9/25/2001	1700	
5/22/2002	1720	
9/24/2002	1820	
5/20/2003	1680	
5/20/2003	1700	
9/23/2003	1700	
5/12/2004	1880	
5/12/2004	1860	
9/22/2004	2050	
9/22/2004	2030	
5/24/2005	1980	
9/20/2005	1870	
5/16/2006	1730	
9/19/2006	1790	
5/22/2007	1730	
9/18/2007	1760	
5/20/2008	1640	
5/20/2008	1610	
9/23/2008	1930	
6/2/2009	1790	E
10/27/2009	1820	
5/25/2010	1770	
5/25/2010	1770	
9/28/2010	1850	
5/24/2011	1710	
5/24/2011	1710	
9/27/2011	1780	
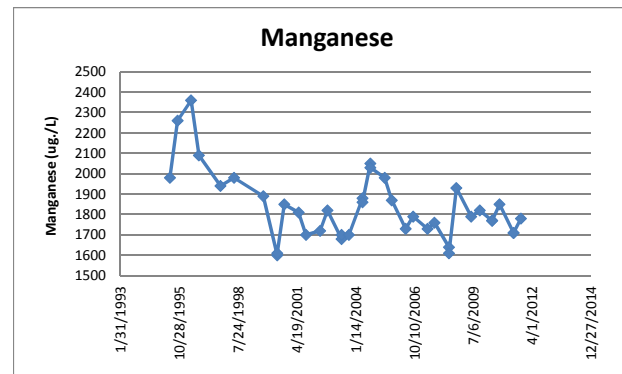
Flag Abbreviations:
E = laboratory estimated concentration between
U = Not detected above reporting limit;
B = estimated concentration between instrument detection
    limit and reporting limit

Montoring Well MW-7 (Deeper Bedrock Zone)

Total Iron (ug/L)		
Date	**Concentration**	**Flag**
5/18/1994	14500	
10/10/1994	44600	
5/25/1995	2340	
10/4/1995	2240	
5/22/1996	5140	
10/1/1996	5240	
9/29/1999	2070	E
5/12/2004	14000	
9/22/2004	3940	
6/2/2009	4180	
10/27/2009	4040	
5/25/2010	3030	
9/28/2010	3040	
9/27/2011	3460	

Iron

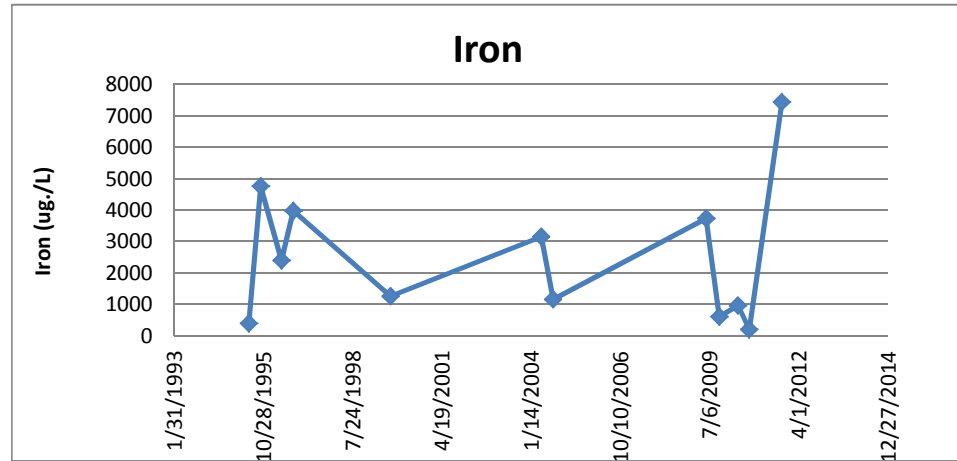| Total Manganese (ug/L)		
Date	**Concentration**	**Flag**
5/18/1994	1290	
10/10/1994	5290	
5/25/1995	906	
10/4/1995	983	
5/22/1996	1020	
10/1/1996	1010	
10/1/1997	783	
5/19/1998	1020	
9/29/1999	1050	E
5/23/2000	1060	
9/19/2000	1180	
5/22/2001	1280	
9/25/2001	1220	
5/22/2002	1330	
9/24/2002	1390	
5/20/2003	1330	
9/23/2003	1360	
5/12/2004	1920	
9/22/2004	1600	
5/24/2005	1550	
9/20/2005	1560	
5/16/2006	1530	
9/19/2006	1690	
5/22/2007	1680	
9/18/2007	1650	
5/20/2008	1620	
9/23/2008	1540	
6/2/2009	1640	E
10/27/2009	1600	
5/25/2010	1400	
9/28/2010	1440	
5/24/2011	1460	
9/27/2011	1510	
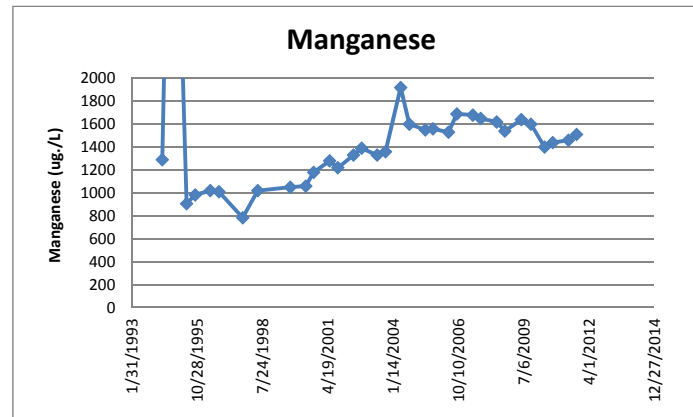
Manganese

**Flag Abbreviations:**
E = laboratory estimated concentration between
U = Not detected above reporting limit;
B = estimated concentration between instrument detection
limit and reporting limit

Montoring Well MW-9 (Shallow Bedrock Zone)

Total Iron (ug/L)		
Date	Concentration	Flag
5/22/1995	402	
10/2/1995	4750	
5/21/1996	2400	
10/1/1996	3970	
9/28/1999	1260	
5/11/2004	3150	
9/21/2004	1160	
6/2/2009	3730	
10/27/2009	611	
5/25/2010	963	
9/28/2010	203	
9/27/2011	7430	

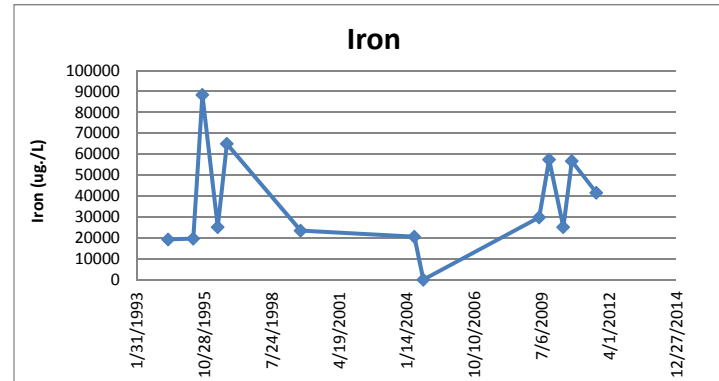| Total Manganese (ug/L)		
Date	Concentration	Flag
5/22/1995	69	
10/2/1995	173	
5/21/1996	425	
10/1/1996	492	
10/1/1997	169	
9/28/1999	62.5	
5/23/2000	573	
9/20/2000	125	E
5/22/2001	157	
9/25/2001	57.5	
5/22/2002	21.9	
5/11/2004	256	
9/21/2004	94	
6/2/2009	305	
10/27/2009	90	
5/25/2010	128	
9/28/2010	122	
9/27/2011	854	
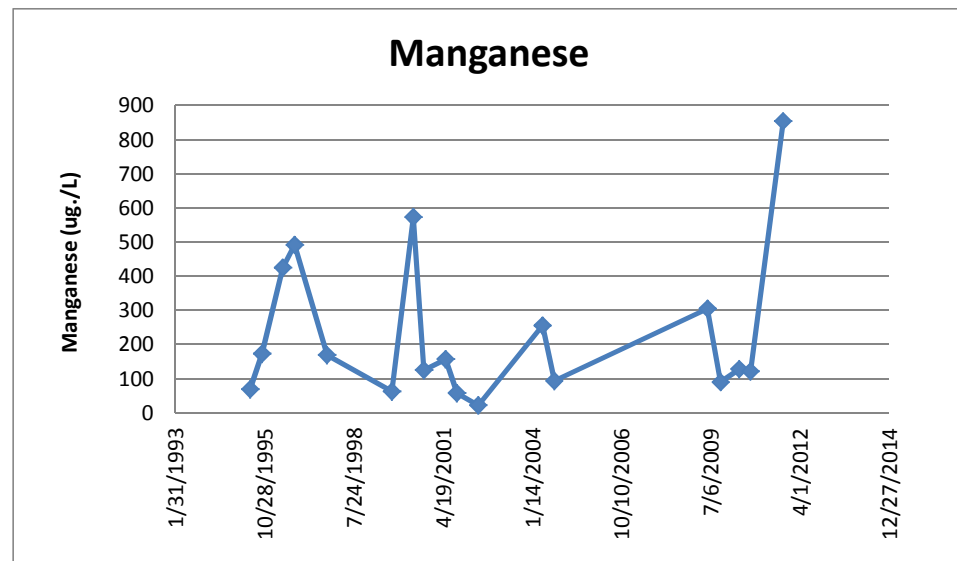
Flag Abbreviations:

E = laboratory estimated concentration between

U = Not detected above reporting limit;

B = estimated concentration between instrument detection
limit and reporting limit

Montoring Well MW-10 (Deeper Bedrock Zone)

Total Iron (ug/L)		
Date	Concentration	Flag
5/18/1994	10500	
10/7/1994	1820	
5/23/1995	291	
10/2/1995	897	
5/20/1996	1050	
9/30/1996	2220	
9/27/1999	32	U
5/11/2004	56	
9/21/2004	100	U
6/2/2009	82.8	
10/27/2009	100	U
5/25/2010	100	U
9/28/2010	100	U
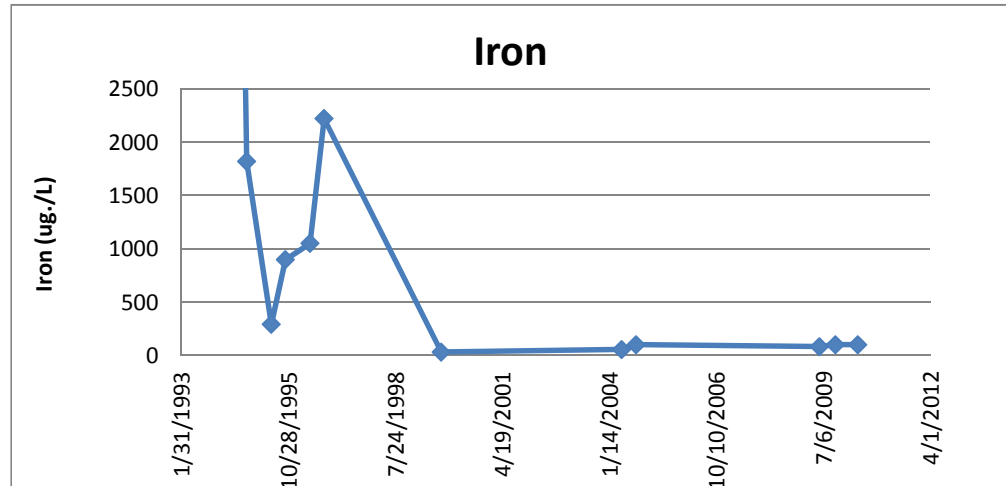
Total Manganese (ug/L)		
Date	Concentration	Flag
5/18/1994	665	
10/7/1994	88.9	
5/23/1995	26.2	
10/2/1995	40.4	
5/20/1996	28.2	
9/30/1996	74.3	
9/27/1999	8.4	
5/11/2004	5.5	
9/21/2004	15	U
6/2/2009	3.8	
10/27/2009	15	U
5/25/2010	15	U
9/28/2010	15	U
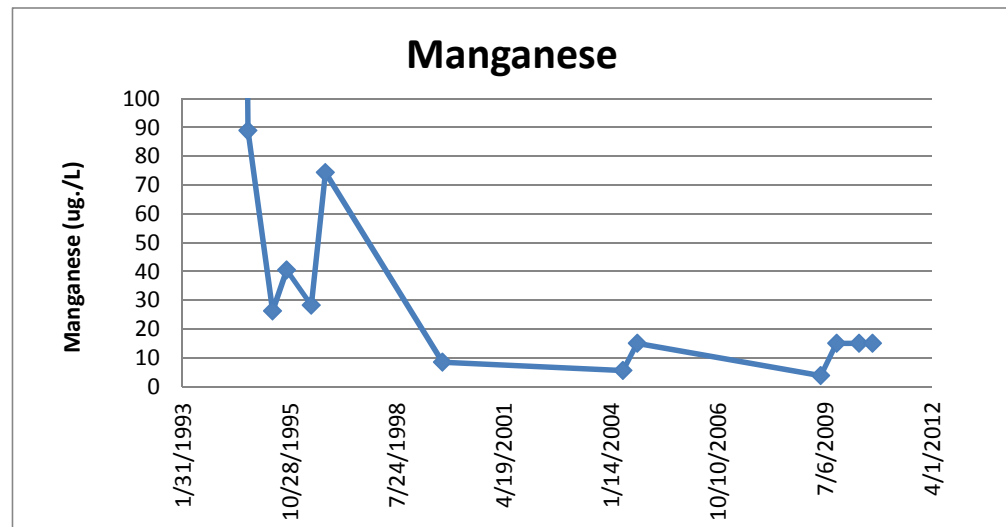
Flag Abbreviations:
E = laboratory estimated concentration between
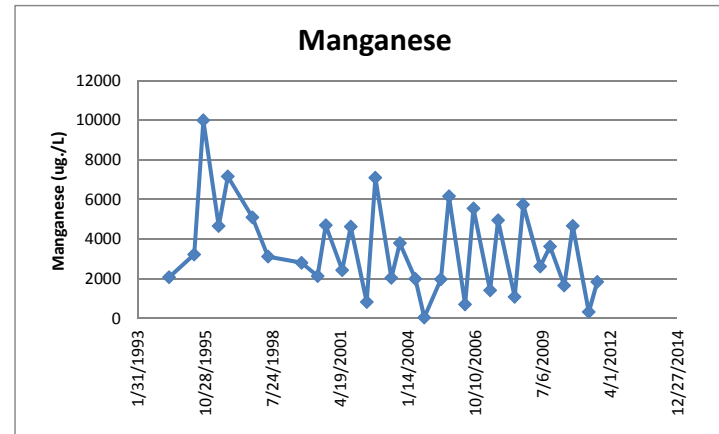U = Not detected above reporting limit;
B = estimated concentration between instrument detection limit and reporting limit

Montoring Well MW-G25 (Shallow Bedrock Zone)

Total Iron (ug/L)		
Date	**Concentration**	**Flag**
5/15/1994	19400	
5/22/1995	19800	
10/3/1995	88400	
5/19/1996	25300	
9/30/1996	65000	
9/28/1999	23600	
5/10/2004	20700	E
9/20/2004	153	
6/3/2009	29900	
10/28/2009	57500	
5/26/2010	25300	
9/29/2010	56800	
9/27/2011	41700	

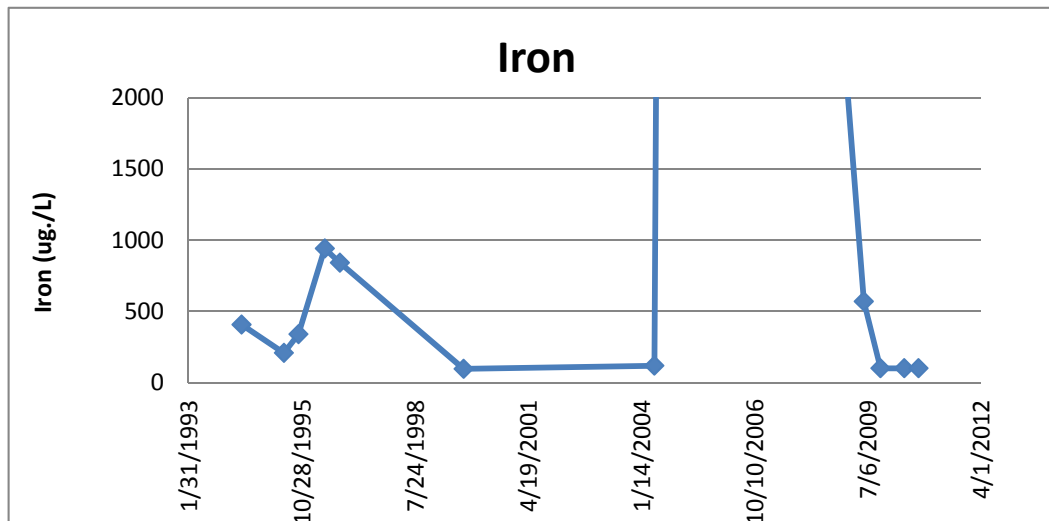| Total Manganese (ug/L)		
Date	**Concentration**	**Flag**
5/15/1994	2080	
5/22/1995	3230	
10/3/1995	9990	
5/19/1996	4660	
9/30/1996	7160	
9/30/1997	5100	
5/20/1998	3120	
9/28/1999	2810	
5/24/2000	2140	
9/21/2000	4700	E
5/23/2001	2440	
9/26/2001	4630	
5/21/2002	829	
9/25/2002	7100	
5/20/2003	2050	
9/24/2003	3800	
5/10/2004	2000	
9/20/2004	51	
5/24/2005	1980	
9/21/2005	6160	
5/17/2006	710	
9/19/2006	5550	
5/23/2007	1420	
9/19/2007	4950	
5/21/2008	1090	
9/24/2008	5740	
6/3/2009	2620	E
10/28/2009	3630	
5/26/2010	1660	
9/29/2010	4670	
5/25/2011	329	
9/27/2011	1850	

Flag Abbreviations:

E = laboratory estimated concentration between

U = Not detected above reporting limit;

B = estimated concentration between instrument detection
limit and reporting limit

Montoring Well MW-G26 (Deeper Bedrock Zone)

Total Iron (ug/L)

Date	Concentration	Flag
5/16/1994	407	
5/25/1995	208	
10/1/1995	339	
5/20/1996	941	
10/1/1996	841	
9/28/1999	95.9	
5/10/2004	118	
9/20/2004	18100	
6/3/2009	569	
10/28/2009	100	U
5/26/2010	100	U
9/29/2010	100	U

Total Manganese (ug/L)

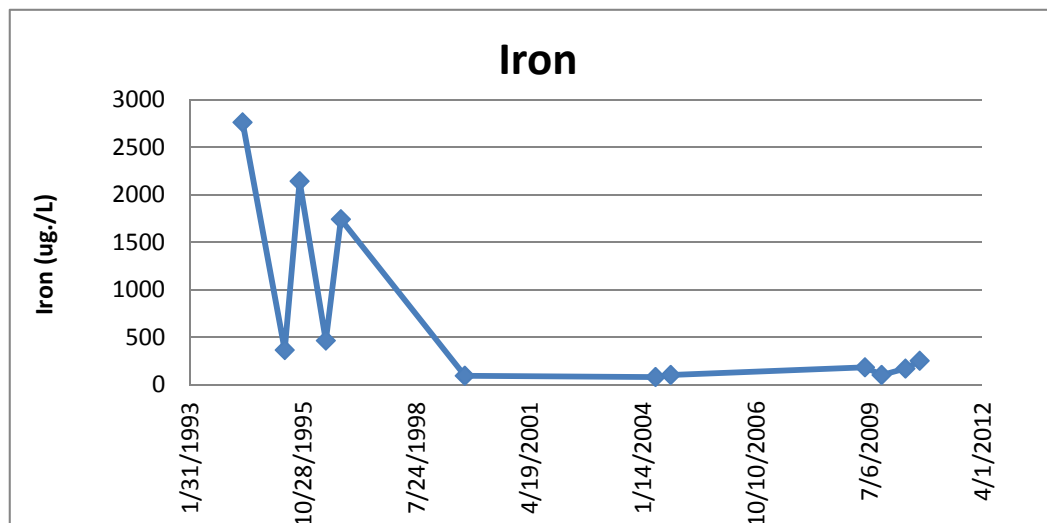| Date	Concentration	Flag
5/16/1994	297	
5/25/1995	207	
10/1/1995	479	
5/20/1996	472	
10/1/1996	625	
9/28/1999	282	
5/10/2004	136	
9/20/2004	879	
6/3/2009	461	
10/28/2009	28.8	
5/26/2010	15	U
9/29/2010	38.7	
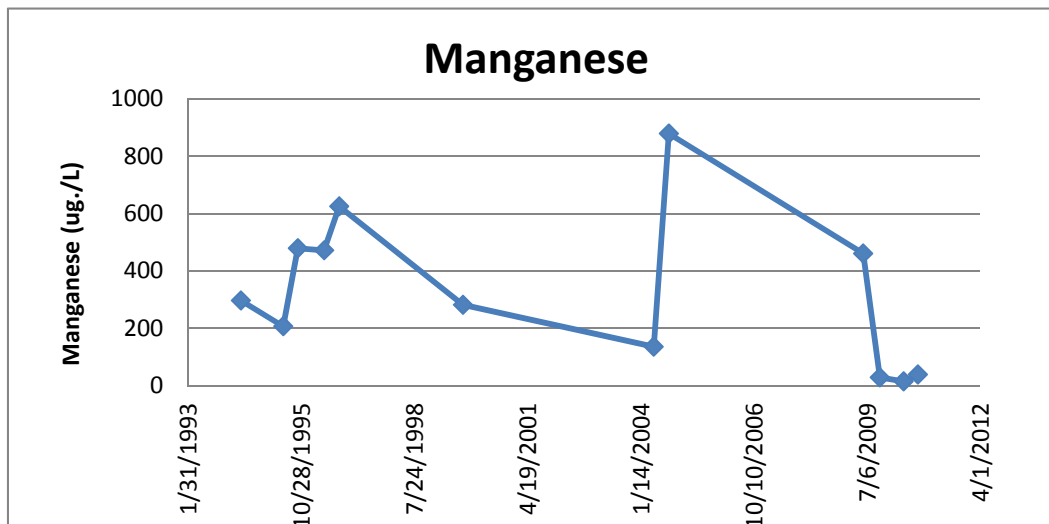
Flag Abbreviations:

E = laboratory estimated concentration between
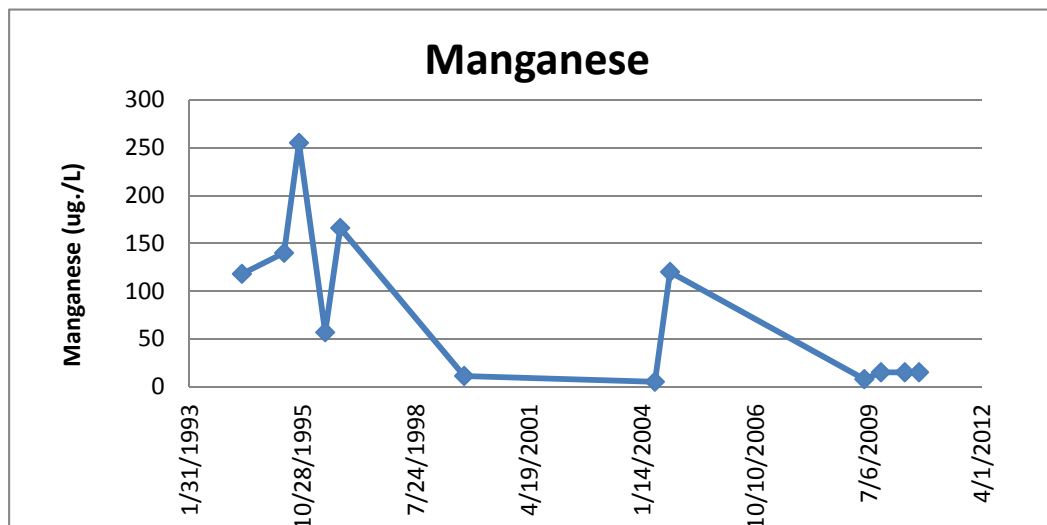
U = Not detected above reporting limit;

B = estimated concentration between instrument detection limit and reporting limit

Montoring Well MW-H27 (Shallow Bedrock Zone)

Total Iron (ug/L)

Date	Concentration	Flag
5/15/1994	2760	
5/22/1995	363	
10/1/1995	2140	
5/19/1996	462	
9/29/1996	1740	
9/29/1999	91.9	EB
5/10/2004	78.4	
9/20/2004	100	U
6/3/2009	181	
10/28/2009	100	U
5/26/2010	168	
9/29/2010	249	

Total Manganese (ug/L)

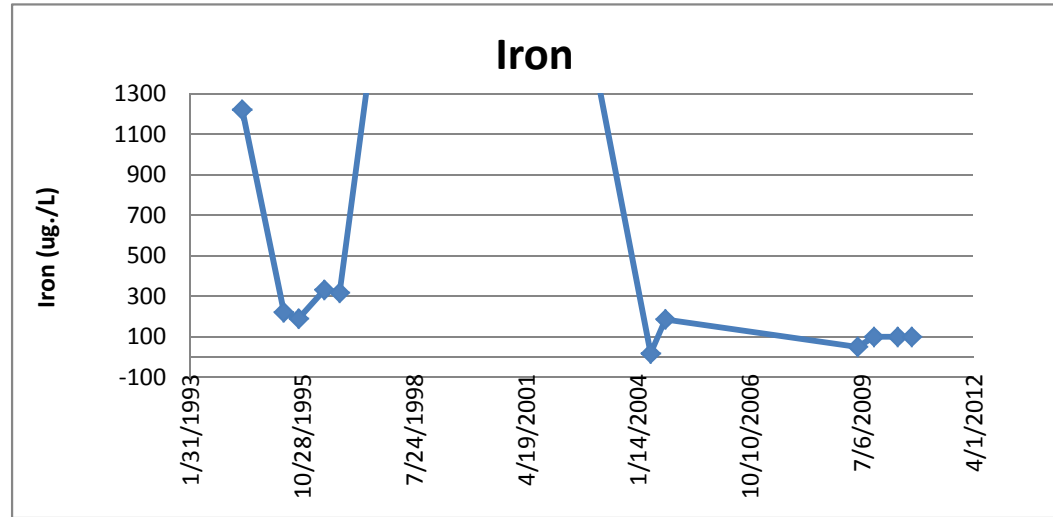| Date	Concentration	Flag
5/15/1994	118	
5/22/1995	140	
10/1/1995	255	
5/19/1996	56.8	
9/29/1996	166	
9/29/1999	11.2	EB
5/10/2004	5.1	
9/20/2004	120	
6/3/2009	7.8	
10/28/2009	15	U
5/26/2010	15	U
9/29/2010	15	U

Iron

Manganese

Flag Abbreviations:

  E = laboratory estimated concentration between
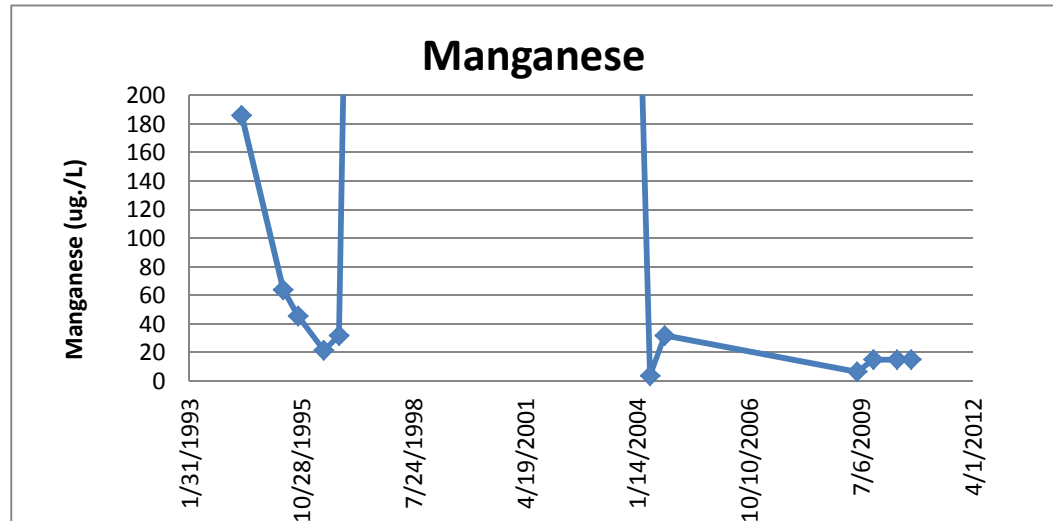
  U = Not detected above reporting limit;

  B = estimated concentration between instrument detection limit and reporting limit

Montoring Well MW-H28 (Deeper Bedrock Zone)

Total Iron (ug/L)		
Date	Concentration	Flag
5/15/1994	1220	
5/22/1995	221	
10/1/1995	190	
5/19/1996	332	
10/2/1996	317	
9/29/1999	4850	E
5/10/2004	18	
9/20/2004	186	
6/3/2009	50	U
10/28/2009	100	U
5/26/2010	100	U
9/29/2010	100	U

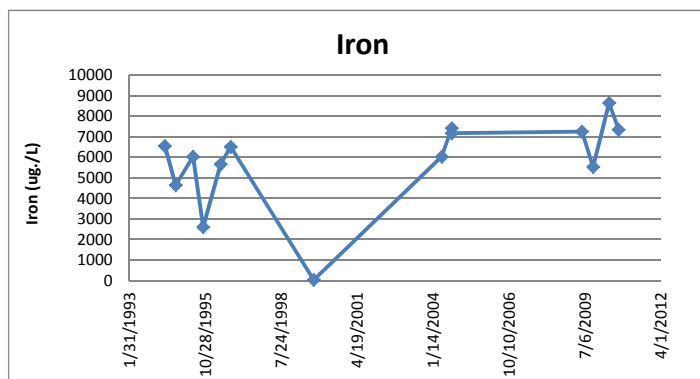| Total Manganese (ug/L)		
Date	Concentration	Flag
5/15/1994	186	
5/22/1995	64	
10/1/1995	45.6	
5/19/1996	21.5	
10/2/1996	31.8	
9/29/1999	4920	E
5/10/2004	3.7	
9/20/2004	31.9	
6/3/2009	6.5	
10/28/2009	15	U
5/26/2010	15	U
9/29/2010	15	U

Flag Abbreviations:

E = laboratory estimated concentration between

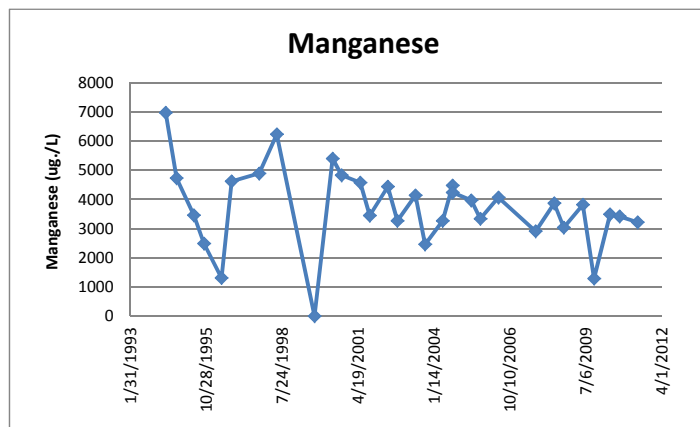U = Not detected above reporting limit;

B = estimated concentration between instrument detection limit and reporting limit

Montoring Well MW-J37 (Shallow Bedrock Zone)

Total Iron (ug/L)

Date	Concentration	Flag
5/17/1994	6550	
10/7/1994	4640	
5/23/1995	6030	
10/3/1995	2600	
5/21/1996	5660	
10/1/1996	6510	
9/29/1999	32	U
5/12/2004	6030	
9/20/2004	7410	
9/20/2004	7170	
6/2/2009	7250	
10/27/2009	5530	
5/25/2010	8640	
9/28/2010	7340	

Iron

Total Manganese (ug/L)

Date	Concentration	Flag
5/17/1994	6970	
10/7/1994	4730	
5/23/1995	3460	
10/3/1995	2490	
5/21/1996	1310	
10/1/1996	4620	
9/30/1997	4890	
5/19/1998	6230	
9/29/1999	4.7	EB
5/23/2000	5400	
9/19/2000	4830	
5/23/2001	4580	
9/25/2001	3450	
5/21/2002	4440	
9/24/2002	3270	
5/20/2003	4140	
9/24/2003	2460	
5/12/2004	3270	
9/20/2004	4480	
9/20/2004	4240	
5/24/2005	3970	
9/20/2005	3340	
5/16/2006	4070	
9/18/2007	2910	
5/20/2008	3870	
9/23/2008	3040	
6/2/2009	3820	E
10/27/2009	1290	
5/25/2010	3490	
9/28/2010	3420	
5/24/2011	3220	

Manganese

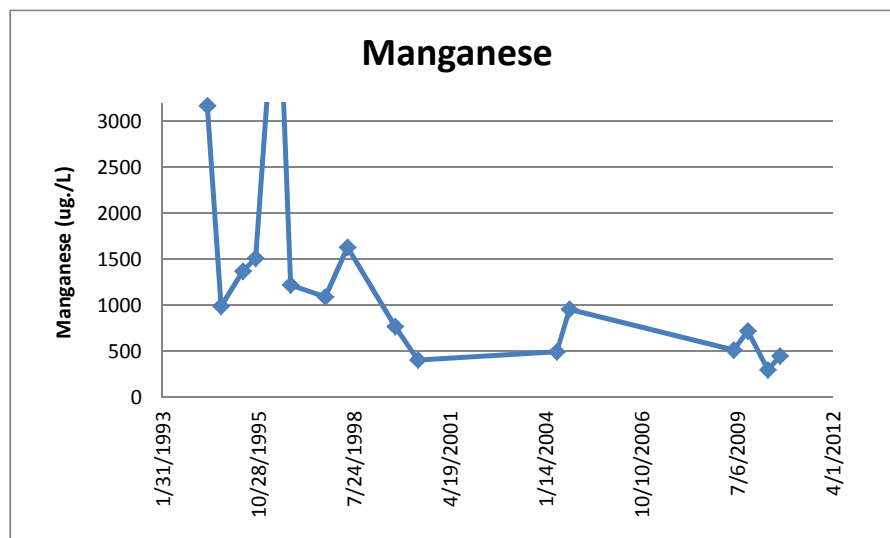**Flag Abbreviations:**

E = laboratory estimated concentration between

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B = estimated concentration between instrument detection
limit and reporting limit

Montoring Well MW-J38 (Deeper Bedrock Zone)

Total Iron (ug/L)

Date	Concentration	Flag
5/17/1994	30800	
10/7/1994	1240	
5/23/1995	1420	
10/3/1995	874	
5/21/1996	9330	
10/2/1996	488	
9/29/1999	1790	E
5/12/2004	3740	
9/22/2004	3890	
6/2/2009	2450	
10/27/2009	3070	
5/25/2010	2230	
9/28/2010	1930	
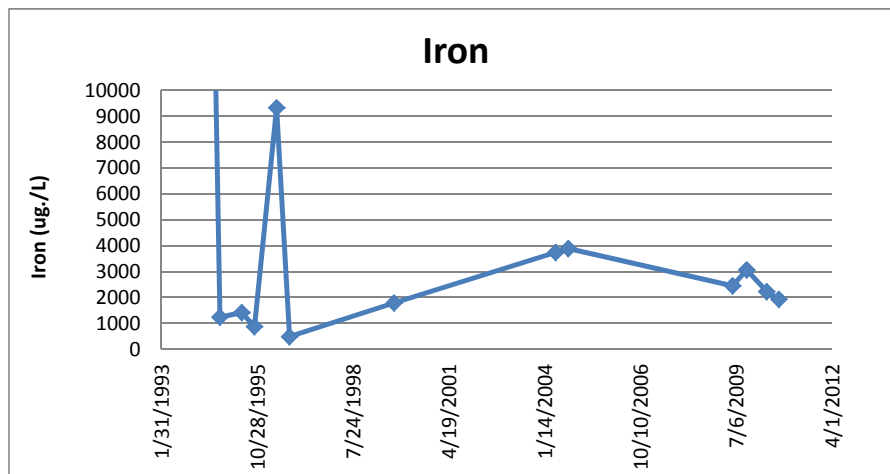
Total Manganese (ug/L)

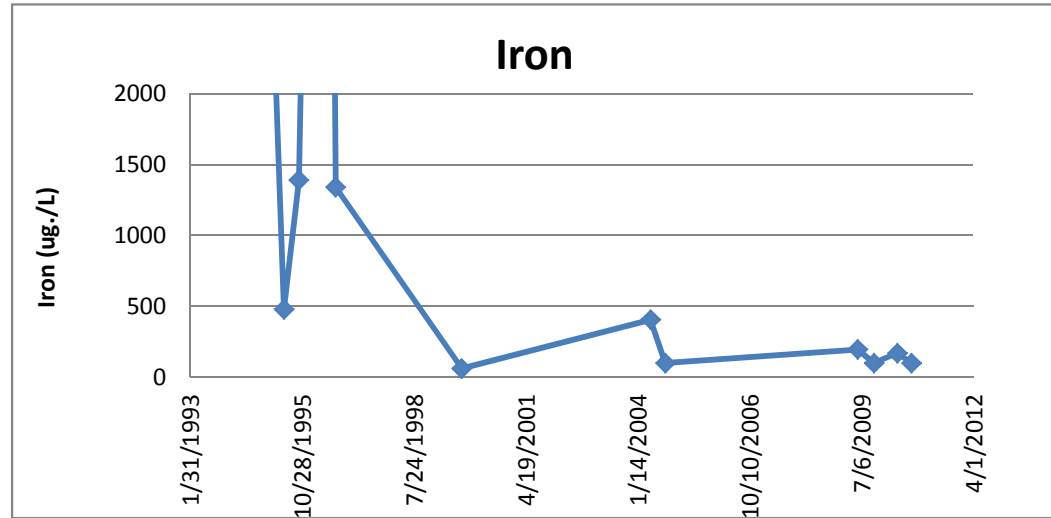| Date	Concentration	Flag
5/17/1994	3170	
10/7/1994	988	
5/23/1995	1370	
10/3/1995	1510	
5/21/1996	4870	
10/2/1996	1220	
9/30/1997	1090	
5/19/1998	1630	
9/29/1999	767	E
5/23/2000	403	
5/12/2004	493	
9/22/2004	955	
6/2/2009	512	
10/27/2009	719	
5/25/2010	295	
9/28/2010	447	

Flag Abbreviations:
 E = laboratory estimated concentration between
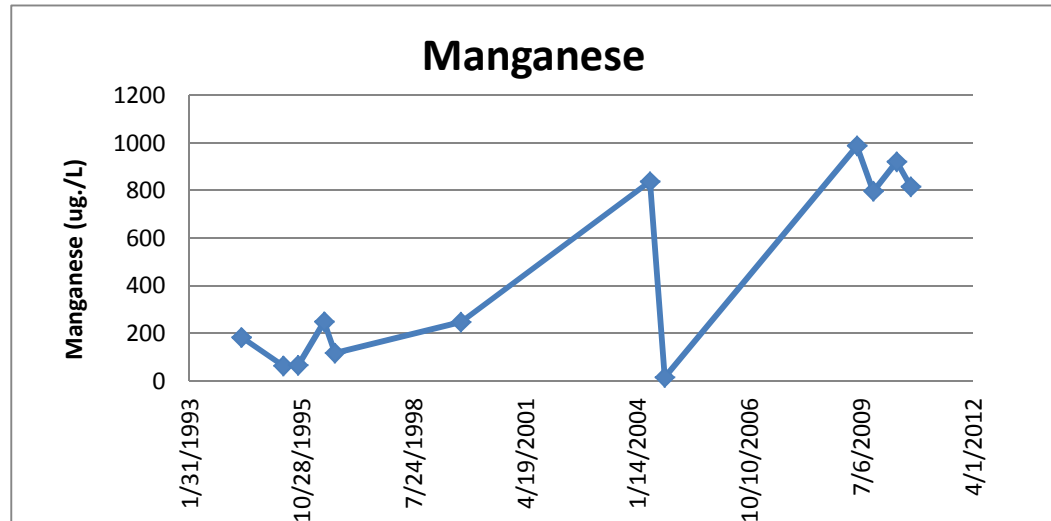 U = Not detected above reporting limit;
 B = estimated concentration between instrument detection limit and reporting limit

Montoring Well MW-K39 (Shallow Bedrock Zone)

Total Iron (ug/L)

Date	Concentration	Flag
5/15/1994	8690	
5/24/1995	479	
10/3/1995	1390	
5/22/1996	10900	
8/27/1996	1340	
9/27/1999	61.4	
5/11/2004	406	
9/20/2004	100	U
6/3/2009	196	
10/27/2009	100	U
5/25/2010	170	
9/28/2010	100	U

Total Manganese (ug/L)

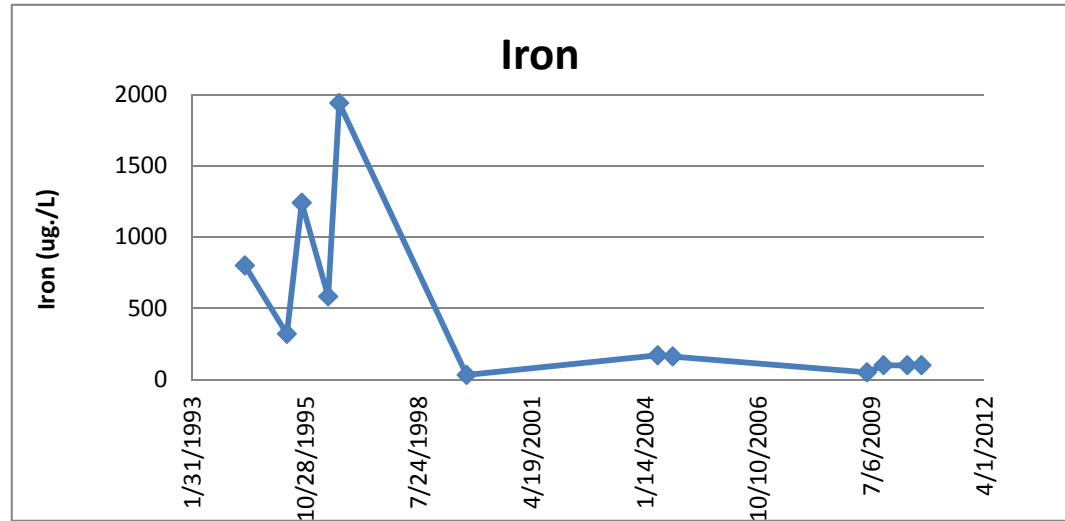| Date	Concentration	Flag
5/15/1994	183	
5/24/1995	63.5	
10/3/1995	66.6	
5/22/1996	249	
8/27/1996	118	
9/27/1999	248	
5/11/2004	838	
9/20/2004	15	U
6/3/2009	988	
10/27/2009	797	
5/25/2010	921	
9/28/2010	817	

Flag Abbreviations:

E = laboratory estimated concentration between
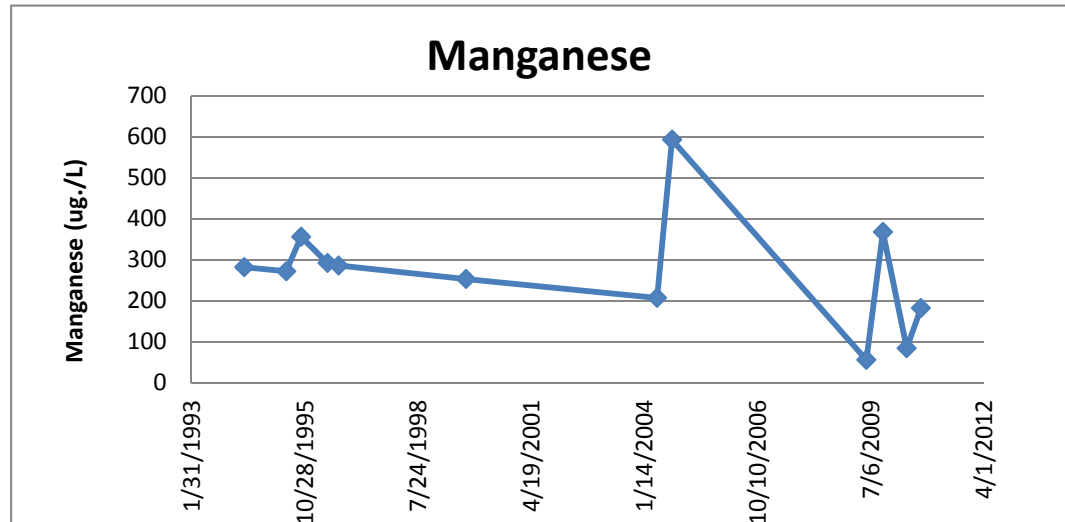
U = Not detected above reporting limit;

B = estimated concentration between instrument detection limit and reporting limit

Montoring Well MW-K40 (Deeper Bedrock Zone)

Total Iron (ug/L)

Date	Concentration	Flag
5/17/1994	801	
5/24/1995	320	
10/2/1995	1240	
5/22/1996	583	
8/27/1996	1940	
9/27/1999	32	U
5/11/2004	170	
9/20/2004	162	
6/3/2009	50	U
10/27/2009	100	U
5/25/2010	100	U
9/28/2010	100	U

Total Manganese (ug/L)

Date	Concentration	Flag
5/17/1994	282	
5/24/1995	272	
10/2/1995	356	
5/22/1996	292	
8/27/1996	286	
9/27/1999	253	
5/11/2004	207	
9/20/2004	593	
6/3/2009	55.9	
10/27/2009	368	
5/25/2010	84.1	
9/28/2010	182	

Flag Abbreviations:

E = laboratory estimated concentration between

U = Not detected above reporting limit;

B = estimated concentration between instrument detection limit and reporting limit