Prepared for:

MORETOWN LANDFILL, INC.
19 Kaiser Drive
Waterbury, Vermont 05676

GROUNDWATER CORRECTIVE ACTION PLAN ADDENDUM 4

Moretown Landfill
Moretown, VT

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March 2016

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1 INTRODUCTION

The Moretown Landfill (the "Site"), which is owned and operated by Moretown Landfill, Inc. ("MLI"), entered into a Consent Order and Judgment Order (the "Consent Order") with the Vermont Agency of Natural Resources ("ANR") effective on September 16, 2013, and amended on December 3, 2015, to perform groundwater corrective action for three groundwater contaminants of concern ("COCs"), those being arsenic, iron, and manganese.

A requirement of the Consent Order included the preparation of a groundwater Corrective Action Plan ("CAP"). A first draft of the CAP was submitted to the ANR on May 12, 2014 (EPS, 2014a). In its review, the ANR requested final design and technical specifications be sufficiently detailed for the groundwater treatment system prior to final approval (ANR, 2014). In response, MLI submitted Addendum 1 to the CAP on July 31, 2014, in which an interim groundwater treatment system, referred to as Phase I of the CAP, was proposed to assess the remediation technology and gather the necessary data to develop final design specifications for a full-scale system (EPS, 2014b). The Phase I system was installed as detailed in Addendum 1 of the CAP and operated from September 10, 2014 to November 12, 2014. A report summarizing the performance of the Phase I system was submitted to the ANR on March 16, 2015 (EPS, 2015a). A second addendum (Addendum 2) was submitted to the ANR on April 2, 2015 responding to the ANR's request for design detail of the proposed corrective action system (EPS, 2015c). Just prior to submission of Addendum 2, MLI chose to withdraw its request for an expansion of the landfill and seek closure of the Site. In response to pending Site closure, the CAP was modified with submission of Addendum 3 on August 13, 2015 (EPS, 2015e). Addendum 3 amended the CAP implementation and schedule to coordinate with Site closure activities. On August 31, 2015, the ANR submitted a comment letter and requested that MLI revise the CAP (ANR, 2015). This submission, referred to as Addendum 4 to the groundwater CAP, serves to address the comments received from the ANR, including a requested to update the Conceptual Site Model ("CSM").

The remainder of this report updates the CSM, outlines the remedial strategy and monitoring programs for the Site. The report is organized as follows:

Section 2 - update to the CSM;

Section 3 - statistical approach for background concentrations;

Section 4 - update to Site groundwater conditions and defining corrective action areas;

Section 5 - corrective action responses for defined areas;

Section 6 - a description of the monitored natural attenuation plan and assessment;

Section 7 - a description of the active remediation approach;

Section 8 - a revised schedule; and

Section 9 - cited references.

2 UPDATE TO THE CSM

2.1 Overview

The original CSM was detailed in the Feasibility Study ("FS") (EPS, 2013) and corroborated by activities completed for the Site Studies Report (EPS, 2015b). The CSM is being updated in response to a request from the ANR with respect to groundwater metals source, mobilization, and fate.

In this update the original elements of the CSM are conserved, including the source of the metals, and two additional potential mobilization pathways of metals are discussed. The first pathway involves the mobilization of metals due to organic carbon loading from the former sludge pond located adjacent to Cell 1 (Figure 1). The sludge pond was excavated in 2012. However, in 2015 MLI determined that some of this material remains in place at the north rim of the pond up-gradient of the groundwater Phase I pilot area[1] (Figure 1). The second pathway involves the potential mobilization of metals due to past bedrock blasting operations and short-term weathering of exposed fragmented bedrock ("Shot Rock"). Shot Rock currently covers portions of the Site, largely up-gradient of the existing landfill cells. This material will be reworked as part of the MLI Closure Plan in order to reduce exposure and infiltration (Cornerstone, 2015). These potential mobilization pathways are amended to the CSM below and assessed with respect to existing Site data and the corrective action response activities in this addendum.

2.2 Moretown Conceptual Site Model

2.2.1 CSM Components

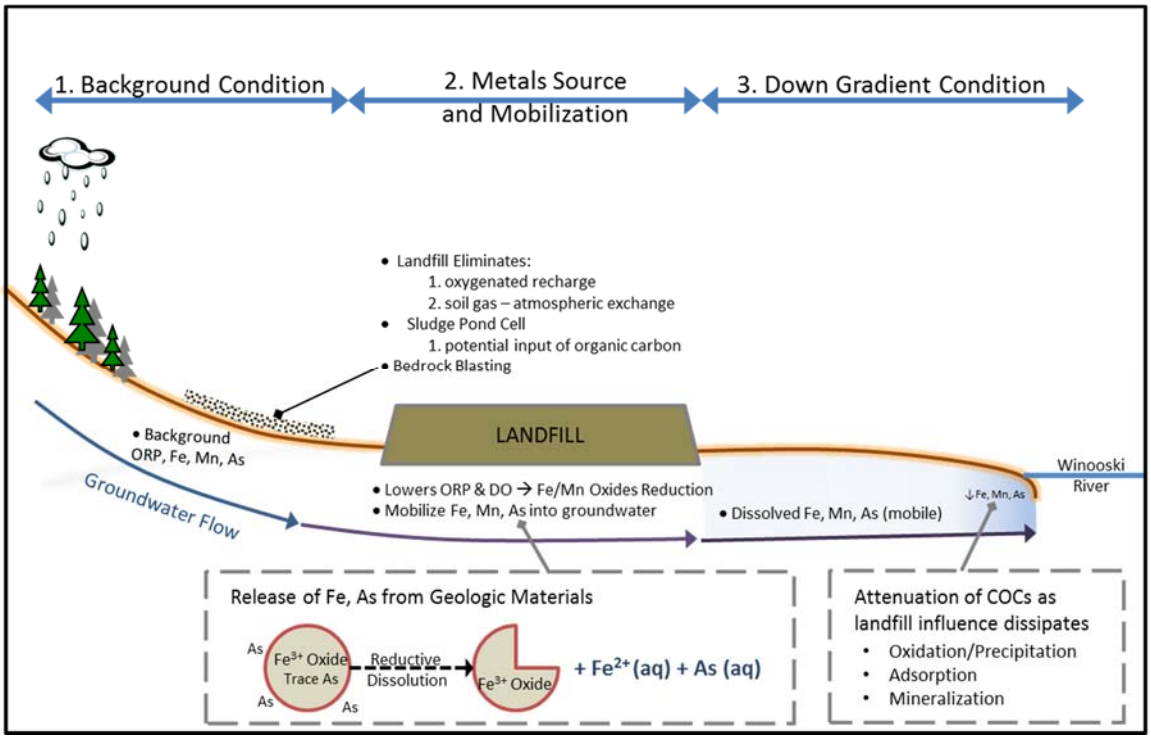
The original CSM, as offered in the FS, was presented to support understanding of processes controlling the origin, transport, and fate of Site COCs. The three components of the CSM were summarized in the FS with the following illustration below and include:

1. Background condition – condition of Site groundwater prior to any potential anthropogenic influence (*i.e.* from the landfill);
2. Metals source and mobilization – landfill and geochemical model of metals source and mobilization from geologic materials as a result of landfill influence (direct or indirect release) and activities; and
3. Down-gradient condition – size, stability and potential attenuation mechanisms governing metals plume and fate.

[1] The potential existence of residual sludge material beneath the Site access road was discovered in 2014, with confirmation of its existence in November 2015 through exploratory excavations (Appendix A).

The CSM depiction of component 2, metals source and mobilization, has been amended to include potential mobilization pathways influenced by the sludge pond and past bedrock blasting operations.

Updated MLI Conceptual Site Model



2.2.2 Background Condition

The source of the background metals condition as provided in the preliminary CSM was metals geochemically released from native geologic materials, a defensible model based on prior studies of local and regional geologic influence on groundwater quality, including a study completed in the immediate region of the MLI Site as described in the FS. The mineralogical studies performed for the Site Studies reaffirmed that native geologic materials are the probable source of metal COCs, with both the spectroscopic analysis (*i.e.* x-ray diffraction ("XRD")) and tested metals content of Site geologic samples, providing a consistent line of evidence as to the metals' origin. The mineralogical studies performed also reaffirmed that native geologic materials are the probable source of metal COCs based on the sequential extraction data, with extraction results providing reasonable pathways (*e.g.*, weathering and reductive dissolution of bedrock) by which local geochemistry is anticipated to influence the release of Site COCs.

2.2.3 Metals Source and Mobilization

The mineralogical characterizations and tests performed for the Site Studies report supports a model with native geologic materials as the most reasonable source of metals to the Site groundwater, including identified natural sources of arsenic, iron and manganese (EPS, 2015b). In this update to the CSM, the mobilization of COC from native geologic material is expanded

from the original mobilization pathway centered on geochemical alteration of the Site due to the landfill liner system, which is conserved as the probable pathway for the larger footprint of the Site, to include two additional potential pathways for metals mobilization from native geologic material. As introduced in Section 2.1, the first pathway is metals mobilized due to organic carbon loading from the former sludge pond. The second pathway is potential mobilization of metals due to blasting and weathering of Shot Rock. These supplementary pathways of potential metals mobilization are discussed below following review of the original CSM pathway.

2.2.3.1 Landfill Liner/Cap Pathway

The original CSM proposed that the elevated COC concentrations exhibited in the down-gradient monitoring wells may be a result, at least in part, of mobilization from the geologic material, in which the landfill liner/cap systems alter the subsurface geochemical conditions promoting reductive dissolution of native geologic materials. The FS provided several studies in which landfill liner systems have been directly tied to enhancement of reductive dissolution of underlying geologic materials and subsequent release of metals to groundwater including the Site-specific COCs (EPS, 2013). The shift in subsurface geochemical conditions beneath the landfill can be triggered or initiated by one or more changes as a result of the landfill's presence. The presence of landfill liner/cap itself creates a barrier cutting off natural pathways for soil-atmospheric gas exchange and direct recharge by oxygenated precipitation. As a result, the ambient influx of oxygen to the subsurface is removed and the native microbial ecosystem adapts to use alternate terminal electron acceptors, typically in the sequential order of nitrate>> manganese oxides >> iron oxides >> sulfate based on their susceptibility to redox transformation, eventually resulting in an iron and manganese reducing condition (*i.e.* reductive dissolution of geologic materials). A shift in subsurface geochemical conditions can also be initiated through the presence of direct releases of landfill constituents (*i.e.* carbon sources) to groundwater; however, Site groundwater data indicates this pathway is not the impelling cause of the groundwater condition across the Site (EPS, 2013).

As presented in the Site Studies Report, metals availability and potential mechanisms of metals mobilization from Site geologic material was evaluated through sequential extraction analysis, including exposure of samples to reducing conditions (*i.e.* negative oxidation-reduction potential ("ORP")) as anticipated to occur beneath the landfill cells. The analysis found that the fraction of iron released to solution under reducing conditions was significant, accounting for a majority of the iron considered extractable under normal geochemical conditions (the largest fraction of iron was in the residual fraction, however this fraction is not available under most environmental conditions). For manganese, its susceptibility to geochemical mobilization into groundwater under reducing conditions was found to be far more significant than iron, with the reducible fraction accounting for a majority of extractable manganese with up to 61% of manganese in bedrock samples and up to 55% in overburden samples. The extraction data also illustrates the dependence of other trace metals on the reductive dissolution of iron and manganese oxides. In general, higher extractable iron and manganese correspond to higher extractable trace metals, providing a reasonable pathway for the occurrence of other metals detected in groundwater (*e.g.* arsenic, nickel, cobalt, etc.).

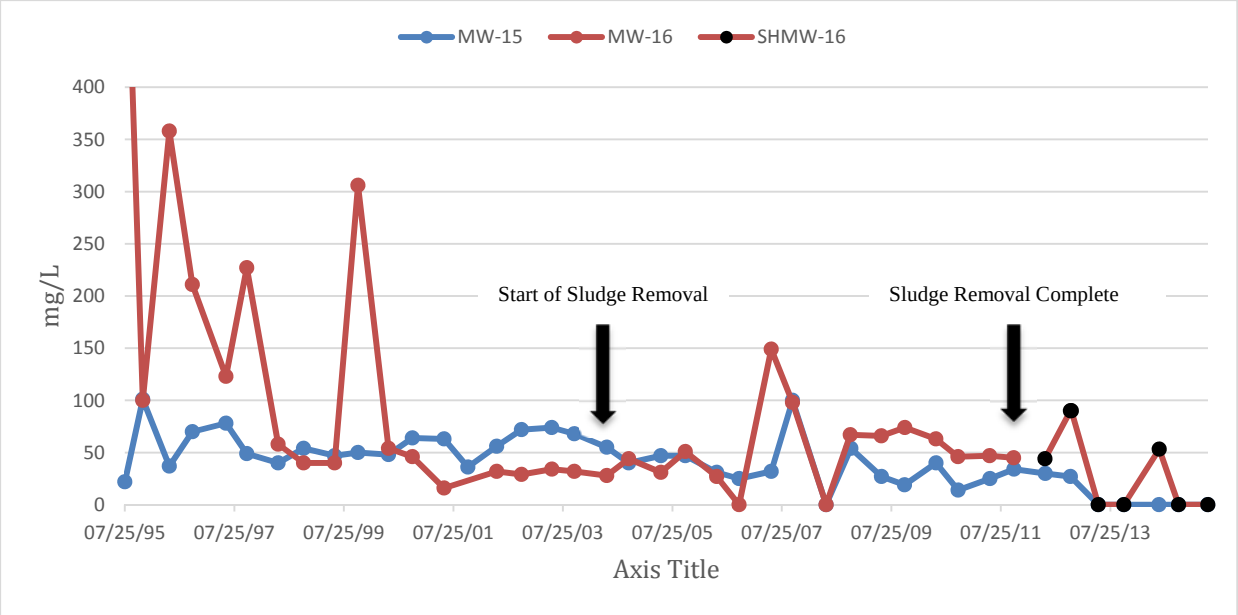
2.2.3.2 Former Sludge Pond Pathway

Early in the history of the landfill (1990s), there existed a sludge pond adjacent to Cell 1 that accepted paper mill process sludge. Excavation and removal of the sludge material and pond subsoil began on 2004, with sludge removal activities reported complete in 2009 and subsoil removal activities reported complete in 2011. In 2015, MLI determined that sludge material along the northeast perimeter of the former sludge pond had not been completely removed, as excavation in this area would have undermined the existing Site access road (Appendix A).

The existence of an organic sludge is expected to alter the adjacent and down-gradient aquifer through input of organic carbon to groundwater. The introduction of organic carbon to the aquifer stimulates microbial activity, with rapid consumption of available dissolved oxygen ("DO") by aerobic microorganisms as the organic carbon source is oxidized. Once available DO is depleted, anaerobic microorganisms will continue to oxidize the organic carbon, but will tie the oxidation of the organic carbon to alternate electron acceptors following the same utilization pathway as previously presented for the landfill liner/cap pathway (sequential order of nitrate>> manganese oxides >> iron oxides >> sulfate). The result is a lowering of the groundwater ORP and probable reductive dissolution of metals-bearing oxides with release of dissolved-state metals to the groundwater.

A review of historical data for groundwater monitoring wells north of the former sludge pond with respect to chemical oxygen demand ("COD") was performed to assess potential contribution of organic material to groundwater from the former sludge pond (COD is used as a proxy for oxidizable organic carbon, but is influence by all available oxidizable constituents present including reduced metals). Reported COD values for MW-15 and MW-16/SHMW-16 finds groundwater exhibits peak COD in the 1990's (> 200 milligrams per liter ("mg/L") in MW-16/SHMW-16) when the sludge pond was active, with COD concentrations remaining on average between 40 to 50 mg/L from 2000 to 2013, and recent testing reporting a rapid decline to non-detect COD for both wells. The COD time profiles with respect to the former sludge pond actions indicate the sludge pond may have contributed to the groundwater metals condition, and may still influence the groundwater condition due to the continued presence of sludge material.

Groundwater COD Down-gradient of Former Sludge Pond



Note: SHMW-16 replaced MW-16 in 2012

2.2.3.3 Bedrock Blasting Pathway

Blasting operations have occurred during the history of the Site to supply daily cover material, with blasting operations expanded in 2010 to 2012 in a borrow area. Blasting of native bedrock may temporarily mobilize metals as the native bedrock is fragmented and shattered, thus exposing fresh bedrock surface area to groundwater and weathering. The primary mineral phases anticipated to be affected by blasting operations are the reduced sulfides, which are present in the native bedrock based on regional geologic reports and work completed for the Site Studies Report (EPS, 2015b). Bedrock that is day lighted from blasting operations, i.e. Shot Rock, is not anticipated to be a persistent source of iron and manganese as the same oxidative conditions that promote their release from reduced sulfides, concurrently precipitate both metals as insoluble oxides with exposure to oxygen rich ambient air and precipitation.

2.2.3.4 Shot Rock Storage Pathway

Shot rock generated from on-site blasting operations was used for daily cover and as an aggregate supply for adjacent municipalities with excess material staged on-Site, including storage in the former borrow area at the western extent of the property. Storage of Shot Rock at the western borrow area began on or around August 2012. The surface storage of Shot Rock is not anticipated to be a probable source of Site COC as surface conditions (*i.e.* oxidative conditions) and exposure do not support either the mobilization or transport of soluble forms of iron and manganese.

2.2.4 Assessment of Unlined Cell Influence on Groundwater

As presented in the original CSM, the Unlined Cell was discussed as a potential contributing factor to the geochemical alteration of native bedrock and subsequent release of metals. The Unlined Cell, in contrast to the lined cells, offers the potential for direct input of organic carbon, either

dissolved organic carbon and/or methane gas. If released, an organic carbon source can stimulate native microbial populations to consume available oxygen, which also causes an eventual shift to other terminal electron acceptors resulting in manganese and iron-reducing conditions as described previously, with subsequent release of dissolved metals. Examples of this occurrence at landfills were provided in the FS CSM discussion (EPS, 2013).

In review of the down-gradient groundwater condition with respect to the Unlined Cell, no exacerbated metals condition or distinct geochemical profile exists. This provides another line of evidence supporting the CSM in this regard.

2.2.5 Natural Attenuation in the Down-Gradient Region of the Site

Natural attenuation processes are reasonably expected to occur down-gradient of the landfill since the landfill influence represents a transitory event, and background geochemical conditions will reestablish with distance from the landfill or with time as potential landfill inputs (*e.g.*,organic carbon or methane) diminish with landfill age. Natural attenuation of groundwater metals concentrations may also improve as mineral phases susceptible to reductive dissolution are geochemically weathered, thus reducing the rate of future metals release.

Natural attenuation mechanisms applicable to metals include immobilization by precipitation, co-precipitation, and adsorption. Immobilization by precipitation and co-precipitation occurs at the leading edge of the groundwater plume as low ORP, low DO groundwater is diluted by interaction with background groundwater and natural oxidants (*e.g.* dissolved oxygen). Immobilization by adsorption may occur more broadly on geologic media, but is facilitated at the plume fringe due to interaction with oxidized iron and manganese oxides.

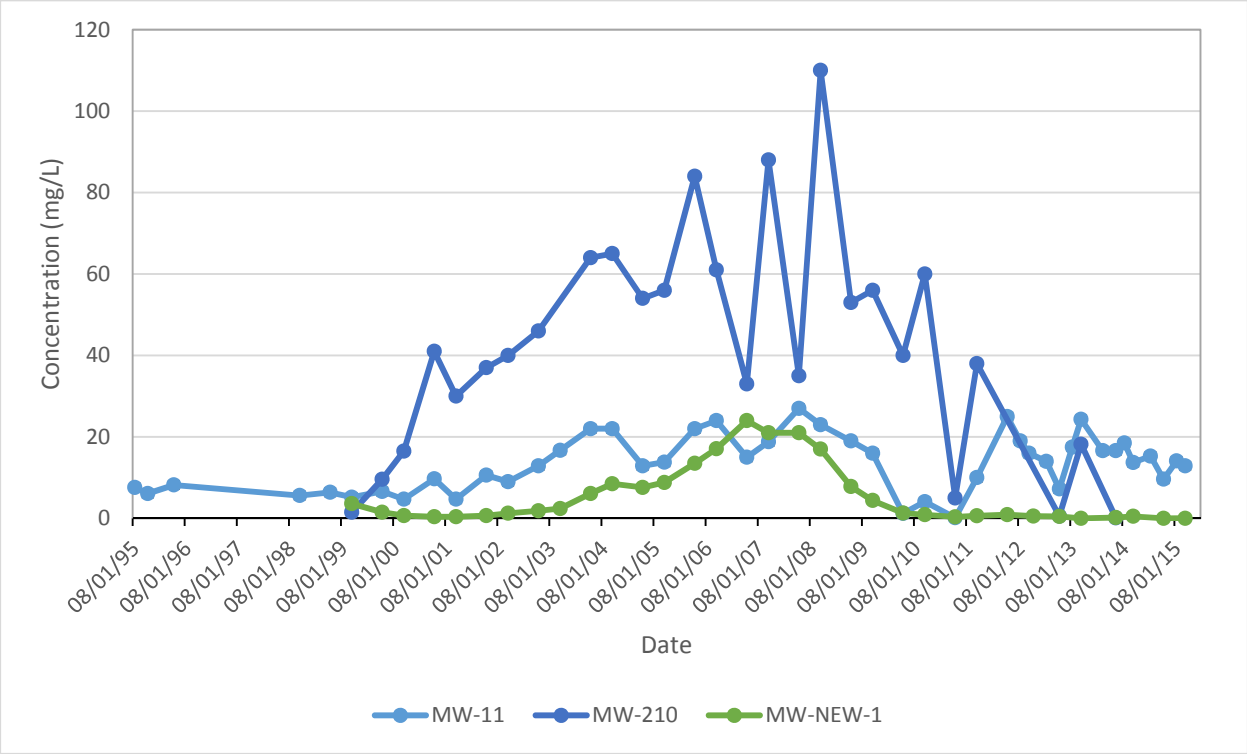
The mineralogical studies performed indicate that dissolved iron oxides have attenuated down-gradient of the landfill based on the presence of hematite. It is probable that other iron oxides, precursors to hematite, are also present down-gradient of the landfill but due to their less ordered structure are not accounted for by XRD spectroscopy (*i.e.* XRD only reports well crystalline solids). As discussed, hematite is primarily formed as a secondary mineral precipitate from dissolved iron as it precipitates from solution in more oxidizing environments, thus supporting a model of iron liberation from native bedrock (background or landfill effect) with subsequent transport and/or precipitation.

2.3 Applied CSM and Natural Attenuation

The CSM proposes the enhanced COC concentrations exhibited in the down-gradient monitoring wells are primarily a result of mobilization from the geologic material, in which the landfill liner/cap systems alter the subsurface geochemical conditions promoting reductive dissolution of native geologic materials. Cell 2 was constructed in 1999-2000. An assessment of groundwater data trends on the eastern portion of the Site, including before and after the construction of Cell 2, support this hypothesis.

Three monitoring wells down-gradient of Cell 2 are available for the evaluation and include MW-11, MW-210 and MW-NEW-1. Consistent with the CSM, data trends for the three down-gradient monitoring wells exhibit distinct and parallel patterns of increasing groundwater manganese following construction of Cell 2 (post-2000). An equivalent increase for iron and arsenic are not reported, indicating the geochemical condition imparted by the Cell 2 liner system is sufficient for reduction of manganese oxides, but reduction of iron is currently limited either due to the abundance of manganese or conditions do not favor reduction of the existing iron oxide phases (and associated arsenic) that tend to require lower ORP conditions. Groundwater manganese concentrations in the down-gradient wells continued to increase until approximately 2007 to 2008, after which manganese concentrations decrease in MW-NEW-1 and MW-210, but less so in MW-11. MW-11 is further down-gradient from Cell 2 and based on its location, is influenced by groundwater from the broader landfill area.

Groundwater Manganese Down-Gradient of Cell 2



The deflection point in groundwater manganese concentrations from a trend of increasing concentration from baseline to a trend of decreasing concentration towards baseline occurred approximately 10 years following the construction of Cell 2. This indicates the finite nature of the duration of metals mobilization from native geologic material due to the altered geochemical environment caused by the cell liner. Natural attenuation processes, either from depletion of the metal's source or down-gradient geochemical processes, mitigate the release of metals. Data from wells located down-gradient of Cell 2 indicates natural attenuation process can reduced metals concentrations. For example, manganese concentrations in MW-NEW-1 for 2013 to 2015 range from 0.009 mg/L to 0.495 mg/L, below the background of 0.5 mg/L (Section 3). In comparison,

manganese was reported at 24 mg/L in MW-NEW-1 in 2007. Data trends in MW-210 are also reported intermittently below background after exhibiting significantly higher concentrations in comparison to MW-NEW-1.

3 BACKGROUND COC CONCENTRATIONS

3.1 Corrective Action Goals

The objective of the groundwater corrective action is to mitigate the concentrations of groundwater COCs to background or regulatory levels in Pont of Compliance ("POC") wells at the Site. Preliminary background levels for COCs, as presented by the ANR in the Reclassification Order,[2] are used for the current assessment and will be used until approval of any proposed background concentrations developed from the reassessment of background groundwater, which is expected to be completed in 2017. The reassessment is necessary as the preliminary background values were based entirely on groundwater conditions as reported in Site bedrock wells. The preliminary background values are as follows:

- Arsenic: 10 µg/L
- Iron: 2,000 µg/L
- Manganese: 500 µg/L

Use of bedrock well data for determination of Site background concentrations was performed as suitable testing locations were unavailable for the glacial overburden overlying bedrock, at the time of the Reclassification Order. This comparison, however, is not entirely suitable. Suitable background concentrations require assessment of conditions in the same medium of concern (*i.e.* the overburden aquifer) (USEPA, 1995). Here, bedrock and overburden represent different media and a Site-specific background value should account for both environments, including potential crossover of groundwater from bedrock to overburden near the Winooski River, an expected groundwater discharge boundary.

As provided in the Site Studies Report, MLI has initiated a background study to assess COCs in the regional overburden aquifer in geologic media consistent with the Site (EPS, 2015b). The assessment added three overburden background monitoring wells (BG-1, BG-2, and BG-3) to supplement on-Site wells. Since submission of the Site Studies Report (EPS, 2015b), additional data from the BG wells are available and future sample events will be performed allowing for an update to the COC background condition. Data from the background monitoring wells has been submitted in site semi-annual reports and will continue to be included for interim review. The reassessment of background COC concentrations will be performed with the US EPA software package ProUCL 5.0 ("ProUCL"). The ProUCL software will be used to assess the dataset for statistical outliers and to compute a background threshold value ("BTV") consistent with EPA guidance. The details of the proposed statistical analysis are provided below.

[2] Groundwater at the Moretown Landfill was reclassified from Class III to Class IV in conjunction with a "Findings of Fact & Reclassification Order" issued by the Vermont Department of Environmental Conservation Drinking Water and Groundwater Protection Division of the Vermont Agency of Natural Resources, and the Vermont Groundwater Coordinating Committee, dated November 28, 2012.

3.2 Statistical Assessment of Background COCs.

3.2.1 Background Locations

Background assessment locations comprised of on-Site and off-Site wells (*i.e.* BG wells). The criteria for selection of on-Site background wells included locations up-gradient or side gradient of the landfill and which were outside the footprint of prior bedrock blasting zones. In total, data from 13 monitoring wells, including historical data, will be assessed for background and included the following locations: BG-2, BG-3, BG-4, SH-2R, SH-4SR, SH-5R, SH-7R, SH-110R, SH-111R, SH-112R, MW-201B, MW-212 and MW-213 (Figure 2).

3.2.2 Background Outlier Assessment

Prior to calculation of a BTV in ProUCL, the data from the background monitoring wells will be assessed for two criteria to identify potential outliers that may skew the analysis. The first assessment will remove data outliers reasonably attributed to low sample quality, that being elevated sample turbidity defined as greater than 25 Nephelometric Turbidity Units ("NTU"). Data censored for elevated turbidity will then be assessed for statistical outliers graphically with box plots following ProUCL guidance. The outliner analysis will include a summary table of data records excluded from the background analysis. In addition, box plots prior to and after outlier analysis will be provided to illustrate statistical outlier analysis.

3.2.3 Background Threshold Value

Background data conserved through the outlier analysis will be used to calculate a 95% Upper Prediction Limit ("UPL") BTV for each COC in the ProUCL software. An UPL predicts the upper limit of possible future values based on a background dataset and will be used as a benchmark to compare to observations from POC wells (*i.e.* the 95% Upper Confidence Limit ("95UCL") of data from POC wells).

3.2.4 Background Schedule

Background locations will be sampled semi-annually during routine semi-annual groundwater compliance monitoring. A total of four background sampling events will occur following the revised CAP schedule (Section 8). At the completion of the background monitoring period (4Q 2017), a BTV will be determined following the procedure provided above.

4 EVALUATION AND DEFINING OF CORRECTIVE ACTION AREAS

4.1 Overview

Defining Site areas for potential corrective action involved a holistic evaluation of groundwater data that included a baseline evaluation of current conditions (*i.e*. metals concentrations), an assessment of historical data trends and for this update inclusion of potential alternate metals mobilization pathways presented in the update to the CSM. A baseline assessment of current COC profiles, updated for this CAP, focused on a direct comparison of groundwater metals data to groundwater criteria. The baseline COC profiles are used to confirm the distribution of COC from prior CAP submittals and assess the stability of COC concentrations.

The process of defining corrective action areas built upon the baseline assessment, and evaluated groundwater metals concentrations in the context of concentration trends and the CSM. As detailed in the Site Studies Report (EPS, 2015b) and herein, metals concentration trends are used to identify areas of groundwater in which natural attenuation processes can reasonably be inferred to be mitigating elevated metals conditions. Lastly, the inclusion of alternate metals mobilization pathways amended to the CSM (*i.e.* organics from residual sludge or bedrock blasting), considerers how these pathways and actions to address the pathways (*i.e.* removal of former sludge pond material) may mitigate potential mobilization of metals to groundwater.

4.2 Current COC Groundwater Profiles

4.2.1 Arsenic

The spatial distribution of arsenic in overburden monitoring wells is presented in Figure 3. Arsenic concentrations above 10 micrograms per liter ("µg/L") (background) spans a transect from MW-15 (west) to MW-4S (east) with an isolated occurrence in MW-215 at 13 µg/l, just above background. The highest arsenic concentrations along this transect in 2015 occur in wells MW-4S (ranging from 142 µg/l to 186 µg/l) and MW-15 (ranging from 61 µg/l to 96 µg/l), with MW-15 exhibiting the lowest arsenic concentration to date for the location. Four other down-gradient overburden wells exceeded the background value of 10 µg/l in at least one of the 2015 sampling events, MW-3S, SHMW-3, SHMW-6, and SHMW-16. The remaining down-gradient wells exhibit arsenic levels below background. This spatial pattern is consistent with groundwater iron concentrations and in general with ORP, which is spatially lowest (*i.e*. most reducing) at the northwest down-gradient edge of the landfill.

There are three on-Site bedrock monitoring wells down-gradient of the landfill, wells MW-3BR, MW-4BR and MW-16BR (Figure 3). Bedrock groundwater here is at or below the background concentration with the exception of MW-3BR, which is an artifact of the well grout contamination

(arsenic was non-detect in MW-3BR until the pH was artificially elevated from grout contact). On-Site and adjacent to the landfill cells, bedrock groundwater is characterized by MW-107DR, MW-5R and SH-1R, and reports arsenic ranging from 13 µg/l to 172 µg/L. Up-gradient bedrock is typically 5 µg/l to 10 µg/L or less. Testing of off-Site bedrock water supply wells to the west of the Site found all wells non-detect for arsenic in 2015.

4.2.2 Iron

The spatial distribution of iron in overburden monitoring wells is presented in Figure 4, and matches that of the arsenic distribution reinforcing the CSM of co-release of metals from native geologic material. Iron concentrations above background in the overburden wells down-gradient of the landfill ranged from approximately 3 mg/L to 41 mg/L in 2015. Up-gradient of the landfill, iron is typically below 2 mg/L, with a single exception for MW-201B in 2015.

In the three down-gradient bedrock wells, iron concentrations ranged from 0.57 mg/L in well MW-3BR to 16.8 mg/L in well MW-4BR (Figure 4). On-Site and adjacent to the landfill cells, bedrock wells MW-107DR and SH-1R reported iron ranging from 2.2 mg/L to 121 mg/L. Bedrock wells to the immediate west of the landfill cells and off-Site all report iron concentrations below background.

4.2.3 Manganese

The spatial distribution of manganese in overburden monitoring wells is presented in Figure 5. The concentration profile for manganese is largely consistent with the profiles for arsenic and iron distribution; however, the highest reported groundwater manganese condition is exhibited more easterly in MW-11 where the manganese concentration ranges from 9.6 mg/L to 15.3 mg/L in 2015. Manganese concentrations in the overburden wells in the northwestern down-gradient area ranges from approximately 0.002 mg/L (MW-17) to 11.7 mg/L (SHMW-3).

In the three down-gradient on-Site bedrock wells, manganese concentrations were considerably lower with MW-4BR ranging from 0.16 mg/L to 0.4 mg/L and well MW-3BR ranging from 0.002 mg/L to 0.004 mg/L (Figure 5), consistent with up-gradient manganese concentrations. MW-16BR reported higher manganese at 1.69 mg/L and 1.97 mg/L in 2015. Adjacent to the landfill cells MW-107DR exhibited the highest bedrock manganese concentrations ranging from 5.97 mg/L to 8.71 mg/L. Bedrock wells to the immediate west of the MLI landfill cells are reported below background with the exception of SH-112R. Off-site bedrock wells report manganese below background with the exception of the former Sandretto well.

4.2.4 Summary

The groundwater profiles for COCs, which was updated through the 2015 monitoring period, remain largely consistent with conditions reported in the original groundwater CAP. Site conditions west of the landfill cells continue to exhibit groundwater statically below background (e.g. SH-8R, MW-17 and MW-18BR) with the exception of SH-112R (Figures 3, 4 and 5). SH-112R historically exhibits sample quality issues due to limited groundwater in the well casing resulting in elevated suspended solids (high turbidity), a condition that biases metals

concentrations high. The central and eastern portions of the Site, as present in Addendum #3 and herein, exhibit improved groundwater quality in particular the east portion of the Site down-gradient Cell 2. The area immediately north of the landfill exhibits interspersed conditions with respect to background, with POC wells above and below background in recent sampling events.

4.3 Defined Corrective Action Areas

4.3.1 Phase I/II Groundwater Area

The Phase I/II Groundwater Area encompasses the down-gradient region of the landfill approximately bounded by MW-15 and SHMW-6 and includes the region of the Site where the Phase I remediation pilot study was performed and assessed for expansion (*i.e.* Phase II) (Figure 6). The area continues to exhibit concentrations of COC and geochemical parameters above or altered from background. The potential causation of the groundwater condition in this area, as provided in the updated CSM, may be attributed to all three proposed metal mobilization pathways. The hydrogeologic model for the Site (north-northwesterly flow) places this area within the anticipated zone of influence for both the landfill liner pathway and former Bedrock Blasting operations area. The third pathway, limited to this area of the Site, is modification of the area geochemistry and mobilization of metals due to organic carbon loading from the residual material recently determined to be located along the north rim of the former sludge pond.

4.3.2 Cell 2 Area (Eastern Area)

The Cell 2 Area encompasses the far eastern extent of the of the landfill property and includes a series of down-gradient monitoring wells influenced primarily or solely by groundwater emanating from the Cell 2 portion of the landfill (Figure 6). The monitoring wells down-gradient of Cell 2 (MW-210, MW-NEW-1 and MW-11) exhibit distinct and parallel patterns of increasing groundwater manganese concentration following construction of Cell 2 (1999-2000), followed by an analogous decline in concentration within approximately a 10-year period. manganese is the primary elevated metal of concern on the eastern portion of the Site as presented in the June 2015 Semi Annual Report (*i.e.* manganese is reported to statistically exceed background in MW-210, MW-NEW-1 and MW-11 based on calculated Confidence Intervals) (EPS, 2015d). However, when assessed in context of recent sampling events, manganese concentrations have declined to below background since 2013 in MW-NEW-1, which is nearest Cell 2. Manganese in MW-210, last sampled in 2014 due to low water level, reported manganese below background. Lastly, MW-11, which is located furthest down-gradient of Cell 2 only recently began exhibiting a measured decline in manganese, with a steady decrease since October 2013, but is still above background.

With respect to other metals in this area, arsenic is not reported to statistically exceed background in this region; iron is only reported to statistically exceed background in MW-210 (but not in down-gradient MW-11); and nickel is reported to statistically exceed background in MW-210, but is reported below the Vermont Primary Groundwater Quality Standard ("PGQS") in eight of the last ten sample events and not reported in down-gradient MW-11.

4.3.3 Northern Cell Area (Unlined Cell)

The Northern Cell Area covers a wide expanse centered across the northern limit of the landfill property adjacent to Route 2 (Figure 6). Monitoring wells down-gradient of the Unlined Cell (MW-2/SHMW-2, MW-3/SHMW-3, MW-10R, MW-3S and MW-4S) generally exhibit decreasing metals concentrations over the course of the landfill monitoring history, with MW-3S and MW-10R no longer reported to statistically exceed background based on calculated Confidence Intervals (EPS, 2015c). Monitoring well MW-2/SHMW-2 exhibits a substantial decline in COC concentrations since 2007, with arsenic below background for twelve consecutive sampling events, iron below background for nine out of the last eleven sampling events, and manganese exhibiting a strong decline, but still slightly above background for the past two sample events in 2015. Only manganese continues to statistically exceed groundwater quality criteria in SHMW-2. Monitoring well SHMW-3 exhibits a decline in iron and arsenic concentrations since 2004, with recent 2015 results reporting the lowest concentrations to date for arsenic. Manganese in SHMW-3 increased from 1995 to 2011, but has since stabilized. Continued sampling for SHMW-3 is required to determine if manganese will decline consistent with manganese trends reported in nearby monitoring wells. MW-4S exhibits all three COCs above background with no apparent trend for arsenic and iron, and a stable manganese concentration, thus representing an outlier in this area.

4.3.4 Western Area (and Sandretto Well area)

The Western Area encompasses the Site property west of the Site access road including the area bound by SH-8R, SH-112R, MW-17 and MW-18BR. In these four wells two of the three COC, iron and arsenic, are below background for all 2015 sample events. The most western monitoring well (farthest from the landfill cells), SH-112R, exhibits highly variable and fluctuating concentrations of manganese and iron that have exceeded background. The conditions reported above background in SH-112R are reasonably attributed to the sampling limits imposed by the bedrock monitoring well, those limits being insufficient water to sample (an average only 2 feet of water column in the well casing), sampling by bailer methodology, and subsequent elevated suspended solids.

Although groundwater conditions in the Western Area are statically below background, with the exception of SH-112R, the ANR previously identified this region as requiring further study due to relatively recent exceedances (post-2010) of the PGQS for manganese in the off-Site Sandretto Well (now owned by MLI). The ANR requested further monitoring be performed specifically directed towards improved understanding of groundwater flow directions near Cell 1 and the western limit of the MLI property boundary. In response, MLI enacted a multiple lines of evidence study that included: (1) a seismic refraction bedrock mapping study to evaluate preferential groundwater flow, (2) an update to the hydrogeologic model with installation of additional monitoring wells, and lastly, (3) an evaluation of the groundwater chemical profile at the off-Site Sandretto well.

The results of these studies were provided in the Site Studies Report (EPS, 2015b). In summary, the bedrock mapping study did not identify a preferential pathway for groundwater off-Site from

the landfill cells and groundwater flow was verified to flow north-northwest, inconsistent with flow form the landfill to the Sandretto well (*i.e.* due west). The chemical evaluation of groundwater from the Sandretto well recognized a unique signature of elevated sodium and manganese, a condition inconsistent with groundwater influenced by the metal mobilization pathways presented in the CSM and with on-Site groundwater, which reports elevated arsenic, iron and manganese. In addition, a linkage of the Sandretto well condition to that of SH-112R is not supported by the chemical composition of the two groundwaters, as chloride, a conservative groundwater ion used for tracing studies, is on average 5x less in upgradient SH-112R in comparison to the Sandretto well.

MLI has assessed other potential sources or causation for the manganese condition in the Sandretto well. The first is the compost processing and storage operation located immediately up-gradient of the Sandretto well. As provided in Appendix B, the recent chemical alteration of groundwater in the Sandretto well (*e.g.*, co-elevated sodium and manganese) is consistent with the chemical profile expected for groundwater impacted by compost operations. Compost operations release abundant organic carbon to the underlying subsurface, which perturbs the local geochemistry to one favorable for metals mobilization, with manganese specifically recognized as the metal most closely associated with compost impacted groundwater. The second, albeit less likely cause, is the current surface storage of Shot Rock near the western property line of the landfill. However, no lines of evidence support release of manganese from surface storage of fragmented bedrock.

5 CORRECTIVE ACTION RESPONSE

5.1 Overview

Monitored natural attenuation (”MNA”) is selected as the baseline technology for each of the four areas. This approach is based on current groundwater COC concentrations (and overall trends in COC concentrations) and the cause of the area groundwater condition as understood from the current interpretation of the CSM (Section 2), with the CSM for each area subject to further verification and updating. Outlined below are the actions to be performed for MNA assessment and verification of the CSM. In the event data gathered do not support the CSM for a specific area (*i.e.* after the 5-year MNA period), MLI will implement a contingency action, including further assessment and/or active remediation. Active remedial action, if necessary, will comprise of enhanced MNA as outlined in Section 7. Enhanced MNA will be accomplished through the injection of oxygenated water to modify the aquifer chemistry to an oxidative state to reinforce natural process for removal of dissolved metals (*e.g.*, precipitation, adsorption and mineralization) (EPS, 2015a).

5.2 Corrective Action

5.2.1 Phase I/II Groundwater Area

As described in Section 4.3.1, the geographic location of the Phase I/II Groundwater Area is unique as all three CSM pathways for elevated metals may affect groundwater in this area of the Site. The Phase I/II Groundwater Area is the only area potentially influenced by the recently discovered sludge residuals, which may explain the elevated and sustained COC concentrations in this area in comparison to other portions of the Site. Accordingly, the corrective action response for this area will comprise of an initial corrective action to address the sludge pond area (*i.e.* removal) and final closure of the landfill, followed by MNA to assess the effectiveness of sludge removal. In the event MNA is found to be ineffective following the MNA monitoring period, a contingency action of enhanced MNA will be implemented. Details of the PhaseI/II area corrective action response are provided below.

Action #1: Removal of Residual Sludge Material

Exploratory investigation found the residual sludge material is easily identified based on appearance and color that is distinguishable from the native bedrock and overburden material. In conjunction with the other closure activities at the Site, the residual sludge material (and Shot Rock in the former pond) will be excavated and removed from the subsurface to prevent contact with groundwater.

Action #2: Cell 2/3 Closure

As detailed in the *Closure Plan of Cell 3/2* (Cornerstone, 2015), implementation of closure of the Site will be performed in 2016 with final capping of Cell 2 and Cell 3 and general Site improvements including improved stormwater management and site grading to include the borrow area.

Action #3: Implement MNA

Post-removal of the residual sludge material, MLI will implement the MNA program to assess for improvement in down-gradient groundwater quality according to Section 6. Mitigation of COC by means of MNA will be demonstrated for the Phase I/II area by COC concentrations exhibiting one or both of the following conditions:

1. POC wells exhibit COC concentrations (95UCL) at or below the BTV; or
2. POC wells exhibit decreasing COC trends.

The MNA plan outlines a five-year evaluation period.

Action #4: Enhanced MNA (Contingency Response)

Enhanced MNA (Section 7) will be the contingency corrective action response in the event mitigation of COC by means of MNA is not demonstrated post-removal of the former sludge pond area. The scale of the enhanced MNA system will be determined at the time of implementation based on the spatial distribution of COC above background.

5.2.2 Cell 2 Area (Eastern Area)

This area is impacted by geochemical alteration of the native geological material by the landfill liner system. Groundwater data for this area exhibits an overall decline in metal COC concentrations supportive of ongoing natural attenuation (EPS, 2015d), with several monitoring wells exhibiting COC concentrations below background. Therefore, the corrective action response for the Cell 2 area will comprise of continued monitoring to assess MNA.

Action #1: Implement MNA

An MNA program will be implemented to monitor for continued improvement in down-gradient groundwater quality according to Section 6. MNA will be demonstrated for the Cell 2 area by COC concentrations exhibiting one or both of the following conditions:

1. POC wells exhibit COC concentrations (95UCL) at or below the BTV; or
2. POC wells exhibit decreasing COC trends.

The MNA plan outlines a five-year evaluation period.

Action #2: Enhanced MNA (Contingency Response)

Enhanced MNA (Section 7) will be the contingency corrective action response in the event mitigation of COC by means of MNA is not demonstrated for the Cell 2 area. The scale of the enhanced MNA system will be determined at the time of implementation based on the spatial distribution of COC above background.

5.2.3 Northern Cell Area (Unlined Cell)

The CSM recognizes two mobilization pathways for metals across the Northern Cell Area: 1) geochemical alteration of the native geological material by the landfill liner system; and 2) potential influence by up-gradient blasting operations (*i.e.* Bedrock Blasting pathway). Summarized in Section 4.3.2, historical groundwater data finds four of the six monitoring wells exhibiting decreasing trends for COC concentrations, with two monitoring wells no longer exceeding background for COC. Because of the general improvement in groundwater quality for portions of the Northern Cell area and the planned Site improvements to be implemented during Site closure (*i.e.* reworking and closure of Shot Rock storage area), MNA is appropriate for this area of the Site.

MLI is proposing a five-year MNA monitoring period for this area of the Site to confirm MNA is reducing metals concentrations near the Winooski River, which currently exhibits no reported impairment in water quality based on semi-annual surface water monitoring. To further verify metals concentrations in groundwater north of the unlined cell are not impacting the Winooski River, MLI will replace former monitoring wells WP-1 and WP-2 as proposed in the FS (EPS, 2013) and in the MNA monitoring plan described herein (Section 7). If conditions in WP-1 and WP-2 are found to be above background with an increasing time trend, additional corrective action will be assessed for this region of the Site.

Action #1: Implement MNA

An MNA program will be implemented to monitor for continued improvement in down-gradient groundwater quality according to Section 6. MNA will be demonstrated for the North Cell area by COC concentrations exhibiting one or both of the following conditions:

1. POC wells exhibit COC concentrations (95UCL) at or below the BTV; or
2. POC wells exhibit decreasing COC trends.

The MNA plan outlines a five-year evaluation period.

Action #2: Enhanced MNA (Contingency Response)

Enhanced MNA (Section 7) will be the contingency corrective action response in the event mitigation of COC by means of MNA is not demonstrated for the Cell 2 area. The scale of the enhanced MNA system will be determined at the time of implementation based on the spatial distribution of COC above background.

5.2.4 Western Region

The updated CSM and assessment of groundwater data in the Western Region corrective action area finds groundwater does not statically exceed background (EPS, 2015d) with the exception of the SH-112R, which is afflicted with insufficient groundwater for sampling by standard practices. Further off-Site, the causation of the Sandretto well manganese condition remains to be finalized, but data linking the distinctive manganese and sodium chemical profile to MLI operations has not been established, nor has transport of any groundwater form the MLI property to the Sandretto well. MLI does recognize ANR's concern regarding storage of Shot Rock near the western

property line and will address the material during closure activities. However, data supporting a connecting between surface storage of Shot Rock to elevated manganese and sodium is not recognized. Based on the CSM and current condition MLI will enact the following actions in the Western Region.

Action #1 Install Western Boundary Monitoring Well

MLI will install a monitoring well on ADS property as shown in Figure 7 (MW-113) between existing wells SH-112R and SH-8R. The monitoring well will be installed adjacent to and east of the drainage feature, down gradient of the shot rock pile, with the intent to monitor groundwater on MLI property only. Placement of the monitoring well further west at the property line risks potential groundwater and surface water contributions from adjacent property that is topographically higher (surface and bedrock topography). The monitoring well will be installed following standard practices to an approximate depth of 30 to 40 feet (bedrock depth is estimated at 40 feet below ground surface based on the seismic refraction study performed in this area).

Action #2 Monitoring

The new western boundary monitoring well will be included in the Site MNA monitoring program as outlined in Section 6. The monitoring well will be assessed for changes in water quality during closure activities, during which the shot rock storage pile will be removed (Action #3), and post closure for a period of 5 years. If groundwater COCs are reported to statistically exceed background in MW-113, MLI will evaluate the need for addition monitoring and study to establish causation of background COC exceedances.

Action #3 Removal of the Shot Rock

MLI will remove the Shot Rock storage pile at the western property boundary during landfill closure activates to eliminate any uncertainty with regard to potential metals contributions to groundwater.

6 MNA MONITORING AND ASSESSMENT

6.1 MNA Overview

This section provides the detail of the MNA program to be implemented for the Site including updates to the POC well network and the assessment program to evaluate the efficacy of MNA. The MNA program will comprise of an improved network of POC wells that allows for characterization of groundwater COC and flow away from the landfill property to the Winooski River. The POC network will provide the ability to monitor COC concentrations, plume stability, and verify groundwater chemistry is consistent with conditions supportive of natural attenuation processes for metals (*e.g.*, adsorption and precipitation).

6.2 POC Well Network

The existing POC network will be expanded to assess natural attenuation of metals and to verify the groundwater plume remains static or diminishes. Expansion of the network will focus on the area west of MW-10R and down-gradient of the Phase I/II Groundwater area. For the eastern half of the Site (east of MW-10R), MW-11 will remain as a POC well based on its proximity to the Winooski River. No additional POC wells are proposed on the eastern half of the Site, as the groundwater nearer the landfill cells is generally improved or exhibits declining COC concentrations in the existing POC wells.

The proposed POC network, as illustrated on Figure 6, expands the current POC well northward with placement of six new POC wells at the MLI property boundary (and consistent with the Class VI Groundwater Reclassification Boundary) adjacent to the Winooski River. Two of the six wells replace WP-1 and WP-2, which were damaged by an ice flow in 2012. Three additional monitoring wells are proposed down-gradient of the Phase I/II area, placed at the approximate midpoint between the landfill and the Winooski River. These three monitoring wells will establish the interceding groundwater condition and assist in establishing potential attenuation gradients.

Installation and construction of new POC wells will follow standard practices, but may require use of hand-driven wells at access-limited locations adjacent to the Winooski River. Monitoring wells WP-1 and WP-2 were installed as hand-driven wells in 2012 and successfully sampled four times prior to being damaged by heavy ice flow. It is anticipated a third location, proposed well WP-3, may also require use of a hand-driven well, subject to assessing access limitations for a drill rig. Wells installed in areas subject to ice flow from the river will be installed as flush mount.

Locations with adequate access will be constructed with conventional drilling equipment for placement of a standard two-inch Schedule 40 PCV monitoring wells. Screen depth interval for each convention well will be determined at time of installation based on water table and bedrock depth. Screen depth interval of hand-driven wells will be subject to drive-rod refusal.

6.3 POC Sampling Frequency

The frequency of sampling for existing POC wells will continue to be semi-annual. The frequency of sampling for new POC wells will be quarterly for two years, after which the frequency will be reduced to semi-annual consistent with existing POC wells. The collection of quarterly data for new POC well will provide sufficient observations in two years (8 data points per well) to initiate statistical calculation of 95UCL. EPA guidance recommends a minimum of at least 8-10 observations to perform statistical inference.

POC Wells and Schedule for Corrective Action Areas

West	Phase I/II	Northern	East
Quarterly Sampling for Two-Years, Semi-Annual after Two-Years			
No additional wells	WP-4	WP-1	No additional wells
	WP-5	WP-2	
	WP-6	WP-3	
	WP-7		
	WP-8		
	WP-9		
Semi-Annual Sampling			
SH-8R	MW-15	MW-3S	MW-11
MW-17	MW-109	MW-4S	MW-210
	SHMW-6	MW-10R	MW-215
	SHMW-16	SHMW-2	MW-NEW-1
		SHMW-3	

6.4 Testing Parameters

The analytical program for the updated POC network will include the full suite of parameters required for the current semi-annual testing program.

The analytical program for new MNA wells will be limited to the following during quarterly and semi-annual sampling events:

- COC (arsenic, iron and manganese); and
- Field Parameters (ORP, pH, conductance, turbidity, temperature).

6.5 MNA Performance Criteria

Two criteria will be used to assess the effectiveness of MNA for groundwater COC. The criteria will be data driven and focused on groundwater in POC wells attaining a condition statistically equivalent to the background condition (*i.e.* BTV) or exhibiting a time trend capable of achieving a condition statistically equivalent to the background condition (*i.e.* time trend analysis). A third supporting assessment will also be performed to evaluate the feasibility of the CSM pathways for metals attenuation, that being immobilization and sequestration through adsorption, precipitation and mineralization due changes on groundwater chemistry.

6.5.1 Background and COC Trend Analysis

6.5.1.1 Background Comparison

Individual POC wells will be assessed for the 95UCL for each COC for the most recent five-year period, consistent with a five-year MNA review period. The 95UCL will be compared to the BTV (Section 3), with wells exhibiting a 95UCL below the BTV considered compliant with the applicable background standard and MNA an effective remedy for the area. Wells exhibiting a 95UCL above the BTV will be evaluated for COC trend analysis to determine if MNA may still be an appropriate corrective action.

6.5.1.2 Trend Analysis

In POC wells that exhibit a 95UCL for one or more COC above the BTV, the time series data will be evaluated for its Mann-Kendal Statistic ("*S*"). The Mann-Kendal statistic is used to draw the following conclusion for a time series data set (as outlined in ProUCL software):

- A positive value of *S* indicates an upward and increasing trend over time.
- A negative value for *S* indicates a downward and decreasing trend over time.
- A value of S close to zero indicates that the data do not exhibit any evidence of an increasing or decreasing trend.

MNA will be considered an effective approach for COC that do not significantly exceed background or exhibit a decreasing trend, with the decreasing trend verified through semi-annual reporting. MNA will not be considered an effective remedy for POC wells that exhibit static or increasing COC trends above background, and alternate remedies including enhanced MNA will be assessed based on the POC well condition and location.

6.5.2 CSM Attenuation Criteria

A component of MNA evaluation for inorganic constituents is a demonstration that conditions are amenable to the geochemical processes responsible for the proposed attenuation mechanisms. As provided in the CSM, natural attenuation mechanisms applicable to Site COCs include immobilization by precipitation, co-precipitation, and adsorption, with precipitation and co-precipitation considered the primary processes by which sustained immobilization can occur. Immobilization by precipitation and co-precipitation requires the aquifer condition to exhibit an available oxidant and ORP condition favorable for the metals oxidation. These conditions are anticipated to occur at a distance from the landfill as the landfill's influence is minimized with influxes or recharge from other groundwater flow paths (i.e. adjacent aquifer zones or Winooski River influence).

Verification that aquifer conditions are supportive of the proposed attenuation mechanism will be performed through collection of groundwater geochemical parameters during quarterly and semi-annual sampling events. Specifically, the aquifer ORP and DO concentration will be evaluated with respect to the area between the landfill and the Winooski River. Increasing DO and ORP along the flow path towards the Winooski River will be considered supportive of natural attenuation mechanisms.

6.6 MNA Review Schedule

Assessment of MNA effectiveness and an MNA decision point will occur after a five-year monitoring period. At year four of the five-year MNA monitoring period, a preliminary assessment of MNA effectiveness will be performed. The preliminary review will include a direct comparison of COC concentrations (*i.e.* 95 UCL) to updated background values (Section 3.2.3).

7 CONTINGENCY REMEDY

7.1 Overview

In the event MNA is not demonstrated for groundwater metals, active remediation will be implemented as a contingency response. The selected active remediation technology is enhanced MNA and is based on a modification of the Vyredox process, an in-situ metals attenuation technology utilized to source potable water and recently assessed for in-situ attenuation of arsenic (Hallberg, 1976; USGS, 2010).

In-situ attenuation of groundwater metals is achieved through modification of aquifer geochemistry from a reducing system (*i.e.* negative ORP, non-detect DO) to that of an oxidizing system (*i.e.* positive ORP, measureable DO), through cycled injections or "slugs" of oxygenated water. The preliminary groundwater treatment system (*i.e.* Phase I) utilized this technology by oxygenating potable water with ambient air to a DO concentration of approximately 10 mg/L and periodic distribution of the oxygenation water to two injection wells (EPS, 2015a). The Phase I treatment system proved effective for infusing oxygenated water into the aquifer and exhibited the capacity to reduce metals concentrations. Geochemical data indicated infused DO was rapidly consumed subject to the groundwater chemistry, in particular for groundwater exhibiting a low ORP. Accordingly, if implemented, the design of the full-scale system will account for this variable and will be improved to allow for delivery of greater DO mass to the aquifer through higher DO concentration and adjustable volumetric flow to each injection well.

7.2 Design Specifications Determined from Phase I System

7.2.1 Design Details of Phase I System

The overall objective of the Phase I treatment system was two-fold. The first objective was to demonstrate that modification of aquifer geochemistry from a reducing system (negative ORP, non-detect DO) to that of an oxidizing system (*i.e.*, positive ORP, measureable DO), through cycled injections or "slugs" of oxygenated water, is possible. The second objective was to demonstrate that once the aquifer geochemistry was modified to an oxidizing system, the aquifer geochemistry would be conducive to in-situ attenuation of the dissolved-state metal COCs. A report of the evaluation of the Phase I treatment system demonstrates these overall objectives were achieved. The Phase I treatment system provides direct evidence supporting the corrective action design basis, and allows scale up of the treatment system. Specifically, data from the Phase I treatment system provides a design basis for the quantity of oxygenated water required to attain modification of the aquifer geochemistry and an estimate for the expected design radius of influence ("ROI") for the injection well array.

7.2.2 Volumetric Requirements

The Phase I treatment system established that the volumetric input of oxygenated water will likely be variable across a selected corrective action area subject to aquifer thickness (*i.e.* volume) and geochemical baseline condition. The most challenging overburden condition for enhanced MNA recognized to date is reported in the Phase I area at Transect 1, which coincides with the deepest bedrock condition down-gradient of the landfill. Transect 1 exhibits a depth to bedrock of approximately 80 ft and a highly reducing baseline ORP of -350 mV. The remainder of the Site's potential corrective action areas are more comparable to conditions at Transect 2 of the Phase I area, which exhibits a depth to bedrock of approximately 50 ft and an ORP of -150 mV. The seismic refracting survey indicates that a majority of potential enhanced MNA injection wells for the Site would be set at a depth of approximately 40 ft, indicating these areas should exhibit a comparable if not better response to the geochemical modification observed in Transect 2 (shallower 50 ft depth) given an equivalent injection volume.

The Phase I treatment system results indicate the aquifer zone at Transect 1 of the Phase I layout will require a volumetric input comparable to the original Phase I design plan (*i.e*. 1,500+ gallon per an injection event). The remaining injection wells are likely to exhibit properties comparable to Transect 2 of the Phase I layout and will require approximately 750 to 1000 gallons per an injection event. The final CAP system incorporates this variable design detail to allow for flexibility in the volumetric supply of oxygenated water to each individual injection well.

7.2.3 Radius of Influence

The Phase I area layout involved three (3) injection wells offset laterally by 100 ft with the expectation that given sufficient time each injection well would have a down-gradient ROI of approximately 50 ft. This ROI was demonstrated in the Phase I area at Transect 2, but was less obvious at Transect 1, where the saturated thickness of the glacial overburden is exceptional, thus demanding a greater mass of applied DO (*i.e.* greater volume or concentration of oxygenated water) to achieve the desired geochemical alteration. The seismic survey along the northern flank of the Site encompassing the majority of the potential corrective action areas exhibit an overburden saturated thickness consistent with Transect 2, thus any initial injection well array will be established initially with on 100 ft centers. ROI is reasonably expected to exhibit variability across the Site. For that reason, the final CAP system incorporates the flexibility to augment aquifer zones with additional injection wells if determined to be necessary based on system monitoring.

7.3 Central Water Oxygenation System

7.3.1 System Description

The central oxygenated water system will comprise of a permanent climate-controlled structure that can function year-round to supply oxygenated water to the injection well array. The central structure will house the water receiving system, oxygenation equipment, distribution system, and process related controls including remote telemetry. The design basis of the oxygenation

equipment is modified for the Phase II system, from a system that utilizes diffusion of ambient air through a high-volume water storage tank to an on-demand oxygenation system that processes water by infusion of 95% pure gaseous oxygen. The revised system will produce a 95% pure oxygen gas source using pressure wing adsorption ("PSA") technology and a small volume contact tank. Utilizing PSA technology, the system is expected to achieve water DO saturation levels of 40 to 45 mg/L, which is significantly higher than the approximately 10 mg/L maximum that can be achieved through diffusion of ambient air through water. The oxygenation equipment modification provides the following benefits:

- four-fold increase in DO supplied to injection wells (increased oxidation capacity);
- quicker establishment and persistence of oxidative geochemical zones; and
- reduced water use (increased period between injections).

The central system is specified to process and distribute oxygenated water at a rate of up to 10 gallon per minute ("gpm"), approximately 3 times that of the Phase I treatment system. Processed oxygenated water will be distributed through a programmable solenoid manifold system mounted in the central structure. The manifold system will have individually controlled stations for each injection well, with each station programmable for duration of oxygenated water flow and monitored for total volumetric flow. The central oxygenated water system will initially be configured to have eight (8) programmable stations (*i.e.* 8 injection wells), but is scalable.

7.3.2 Water Supply

Water to supply the central water oxygenation system will entail one or more sources to sustain the initial volumetric requirement of the full-scale system, estimated between 5 to 10 gpm or 7,200 to 14,400 gallons per day (gpd). The first option involves installation of a one or more on-Site water wells to supplement the existing MLI water supply well. The existing MLI well yields approximately 5 gpm (7,200 gpd), but also serves the facility and other end-users. The second option is to withdraw water from the Winooski River, which is capable of supplying a quantity of water above the system requirement. A river withdraw of less than 5% of the 7Q10 stream flow, equivalent to 3,740 gpm (5% of 167 cubic feet per second) is considered a *de minimis* impact on the stream flow and is generally permitted. Withdrawal from the Winooski provides for a reliable water source, but may require added infrastructure (*e.g.*, filtration) adding to the complexity of the system. The technical and economic feasibility of these two options will be evaluated further should the contingent remedy be necessary.

7.3.3 System Control and Monitoring

The central oxygenated water system will be designed to have remote telemetry control and monitoring via a web-based interface. Remote telemetry capability will include the following functions:

- ability to program and adjust volumetric flow of oxygenated water to each injection well;
- ability to shutdown/restart oxygenated water flow to individual injection wells;
- monitoring of total volumetric flow to each injection well; and

- system notifications regarding errors or faults (*i.e*. inadvertent shut-downs).

Remote telemetry control will allow for modifications to system operation in real-time in response data gathered from dedicated down-well geochemical probes.

7.4 Injection Well Array

7.4.1 Injection Well Spacing

Injection wells will initially be placed at approximately 100 ft offsets perpendicular to groundwater flow as needed to address areas in which MNA is determined to be insufficient for mitigating groundwater metals concentrations. The sufficiency of injection well spacing will be evaluated based on groundwater metals concentration observed in down-gradient monitoring wells (Section 6.5), with the option to augment well arrays with additional intervening injection wells.

7.4.2 Injection Well Design

Injection wells will be completed as illustrated in Figure 8. Each well will be constructed of 2" Schedule 40 PVC well casing and screen, with the screen interval spanning the saturated zone of the overburden aquifer (*i.e.* from the water table to top of bedrock). A dedicated oxygenated water line will be connected to the solid casing of each injection well at a depth of 48" below ground surface or greater for freeze protection. Each injection well will have a surface completion comprised of a 24" by 24" flush-mount steel vault with a water resistant cover. The well casing, inside the well vault, will be completed with a 2" ball value to prevent release of oxygenated water during cycled injection events and a mechanical air release value to prevent airlock during the initiation of each injection cycle.

7.4.3 Oxygenated Water Distribution System

The oxygenated water distribution system will be comprised of a series of buried water lines (*e.g*., PEX tubing), one dedicated line per an injection well. Each water line will originate from the programmable solenoid manifold housed within the central water oxygenation system structure. From the manifold, each water line will be trenched into place at a minimum depth of 48" below ground surface below the applicable frost line for the region, and completed following standard construction practices. The final location of distribution paths between the central oxygenated water system and each individual injection well will be determined subject to equipment accessibility and restrictions based on existing utilities. At its termination, each water line will be connected to the well casing at a depth of no less than 48" below ground surface for freeze protection.

7.5 System Operation and Monitoring

7.5.1 Performance Monitoring Approach

The enhanced MNA remediation design relies upon an active monitoring program to regulate injection cycles of oxygenated water for the purpose of sustaining geochemical conditions conducive to metals attenuation across installed injection well arrays. The active monitoring program will comprise of a series of system monitoring wells set immediately down-gradient of injection wells (see Section 7.5.2), with dedicated down-well probes set in select system monitoring wells to monitor in real-time changes to groundwater chemistry. Each probe will monitor pH, ORP, DO and conductivity as well as groundwater elevation. A remote telemetry system will be established to allow for real-time review of geochemical data and data trends.

7.5.2 System Monitoring Wells

System monitoring wells will comprise of paired wells, one shallow and one deep, offset approximately 15 feet down-gradient of select injection wells. The purpose of the paired well is to verify distribution of oxygenated water vertically across the aquifer. Approximately one system monitoring well pair will be installed for every three to four active injection wells. The screened interval of each well pair will be determined at the time of installation, with the shallow well screen placed midpoint between the water table elevation and midpoint of the overburden aquifer thickness, and the deep well screen placed midpoint between the bedrock elevation and midpoint of the aquifer overburden thickness. The system monitoring well will be standard 2” schedule 40 PVC well installed following standard practices.

7.5.3 Injection Cycle Criteria

Oxygenated water injection events will be initiated based on data obtained from the dedicated down-well probes. Geochemical parameters to be used to trigger subsequent injection events include groundwater DO and ORP. Threshold values for DO and ORP, based on the performance of the Phase I treatment system (EPS, 2015a), that will trigger a subsequent injection event are provided below.

Initial Criteria to Trigger Injection Event

Parameter	Criterion
ORP	< 50 mV
DO	< 0.5 ppm

Criteria may be modified as additional data linking concentrations of COCs to the geochemical profile is gathered and evaluated.

7.5.4 Volumetric Flow Parameter

Based on the performance of the Phase I groundwater treatment system, the initial volumetric flow of oxygenated water to each injection well will be set between at 700 to 1,500 gallons per event.

If the desired geochemical modification of the aquifer (*i.e.* positive ORP and detectable DO) is not attained within a reasonable acclimation period, anticipated to require up to two months, the volumetric flow rate will be increased in steps of 100 to 200 gallons per an injection event. For injection wells not located near a dedicated down-well probe, volumetric adjustments will be made based on a comparative geochemical analysis to wells monitored with a dedicated geochemical probe. For example, aquifer zones exhibiting a comparable ORP in the baseline analysis will be adjusted in an equivalent manner to zones actively monitored.

7.6 Enhanced MNA Performance Evaluation

The performance of the enhance MNA remediation system will be evaluated by assessing groundwater geochemical parameters and metals concentrations in the system monitoring wells and the POC well network. The utilization of both well networks will allow for the observation of near system groundwater modification, which will occur within months of commencing injections based on the Phase I study, and distant changes anticipated to occur on the scale of several months or more subject to groundwater advective flow rates towards to the POC wells and the Winooski River.

As the objective of the MNA and enhance MNA programs are the same, the enhanced MNA system will continue the monitoring program established for the MNA program, including POC well locations and parameters. Parameters include:

- COC (arsenic, iron and manganese); and
- field parameters (ORP, pH, conductance, turbidity, temperature).

MLI will evaluate the effectiveness of the enhanced MNA approach at six (6) month intervals. The performance evaluation will include an assessment of the ability of the enhanced system to modify the aquifer geochemistry (*i.e.*, supportive of natural attenuation processes for the metal COCs) and effectiveness of the treatment zone or "geochemical barrier" to reduce the flux of COCs to the down-gradient aquifer. System performance wells and POC well will continue to be assessed for MNA performance criteria (Section 6.5), including COC trend analysis and verification that aquifer condition conducive to metals attenuation. Performance evaluations will continue on a semi-annual basis over the course of the operation of installed enhanced MNA systems.

8 REVISED SCHEDULE

	2016				2017				2018				2019				2020				2021			
Task	**1 Q**	**2 Q**	**3 Q**	**4 Q**	**1 Q**	**2 Q**	**3 Q**	**4 Q**	**1 Q**	**2 Q**	**3 Q**	**4 Q**	**1 Q**	**2 Q**	**3 Q**	**4 Q**	**1 Q**	**2 Q**	**3 Q**	**4 Q**	**1 Q**	**2 Q**	**3 Q**	**4 Q**
Groundwater CAP Approval																								
Landfill Closure -Final Cell 3/2 capping -Surface and stormwater controls -Reworking of Shot Rock																								
Field assess proposed POC well locations and Shot Rock Assessment wells; procure contractor for installation																								
Complete installation of expanded POC wells and western boundary well																								
Excavate sludge pond residuals (to be completed during cell closure activities)																								
MNA Program																								
MNA Sampling																								
MNA 5-Year Review/ Decision on Active Remediation																								
Background Program																								
Background Sampling																								
Background Statistical Assessment																								

9 REFERENCES

ANR. (2014). Groundwater Feasibility Study Response & Cell 4 Certification Application Technically Incomplete Letter Moretown Landfill, Solid Waste ID #WA470 (dated January 21, 2014).

ANR. (2015). ANR review of Groundwater Corrective Action Plan, Addendum 3. Moretown Landfill, (dated August 31, 2015).

Cornerstone (2015). Closure Plan of Cell 3/2, Moretown Landfill, Inc. June 2015, Revised October 2015.

EPS, Inc. (2013). Groundwater Feasibility, Moretown Landfill, Moretown, Vermont. December 2013.

EPS, Inc. (2014a). Groundwater Corrective Action Plan, Moretown Landfill, Moretown, Vermont. May 2014.

EPS, Inc. (2014b). Groundwater Corrective Action Plan, Addendum 1, Moretown Landfill, Moretown, Vermont. July 2014.

EPS, Inc. (2015a). Phase I Groundwater Corrective Action: Performance Assessment, Moretown Landfill, Moretown, Vermont. March 2015.

EPS, Inc. (2015b). Summary of Site Studies Performed to Support Conceptual Site Model Development and Groundwater Corrective Action Design. Moretown Landfill, Moretown, Vermont. March 2015.

EPS, Inc. (2015c). Groundwater Corrective Action Plan, Addendum 2, Moretown Landfill, Moretown, Vermont. April 2015.

EPS, Inc. (2015d). June 2015 Semi-Annual Water Quality Monitoring Report, Moretown Landfill, Moretown, Vermont. July 2015.

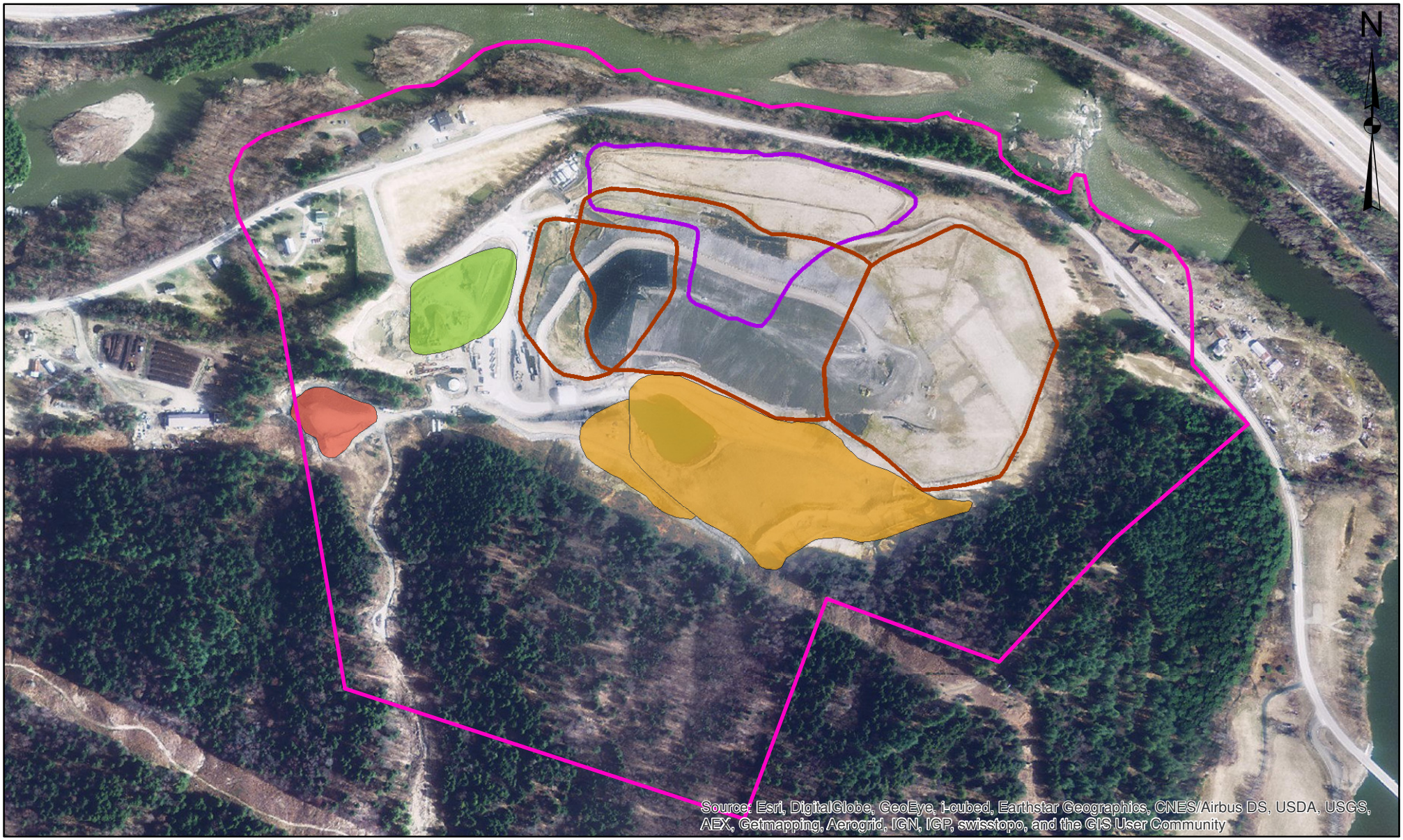
EPS, Inc. (2015e). Groundwater Corrective Action Plan, Addendum 3, Moretown Landfill, Moretown, Vermont. August 2015.

Hallberg, R.O.. and Matinell, R.. (1976). Vyredox – In Situ Purification of Groundwater.Groundwater, Vol. 16, No. 2.

USEPA. (1995). Establishing Background Levels. Office of Emergency and Remedial Response. EPA/540/F-94/030.

USGS. (2010). In-site Arsenic Remediation in Carson Valley, Douglas County, West-CentralNevada. Report 2010-5161.

FIGURES



0 125 250 500
Feet

Landfill Cells
- Lined Cell
- Unlined Cell

Site Areas
- Shot Rock Storage Area
- Approximate Bedrock Blasting Limits
- Former Paper Mill Sludge Cell

Groundwater Classification
- Class IV Groundwater Reclassification Boundary

Moretown Landfill Inc.
Site Layout and Features

Figure No.1

0 175 350 700
Feet

Landfill Cells

Lined Cell

Unlined Cell

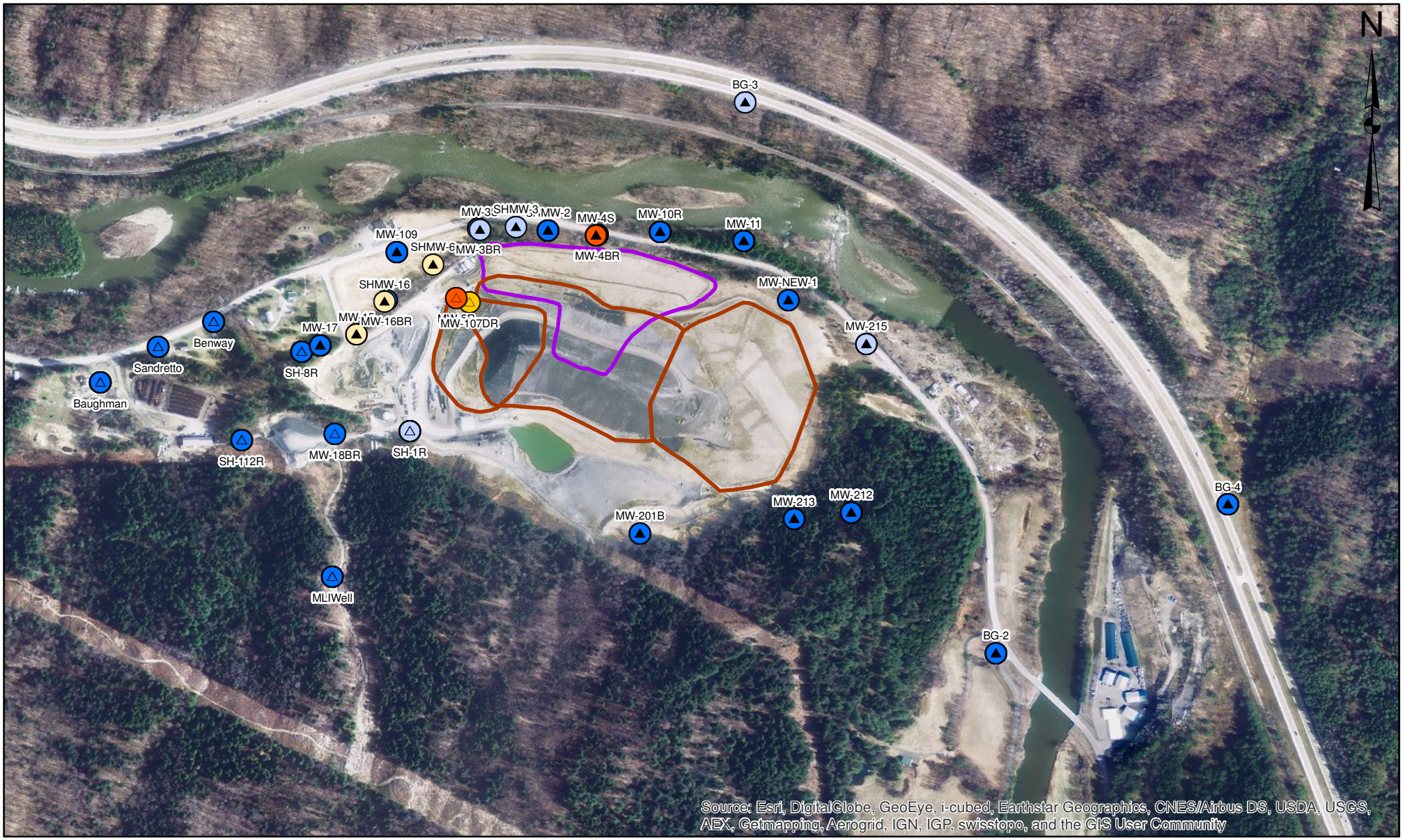
Monitoing Well Status

Background Assessment Location

Moretown Landfill Inc.

Background Assessment Locations

Figure No.2



0 175 350 700
Feet

Landfill Cells
- Lined Cell
- Unlined Cell

Monitoing Well Type
- Overburden
- Bedrock

Arsenic (µg/L)
- < 10 (background)
- 10 - 50
- 50 - 100
- 100 - 150
- 150 - 200

Moretown Landfill Inc.
2015 Groundwater Arsenic

Figure No.3

0 175 350 700
Feet

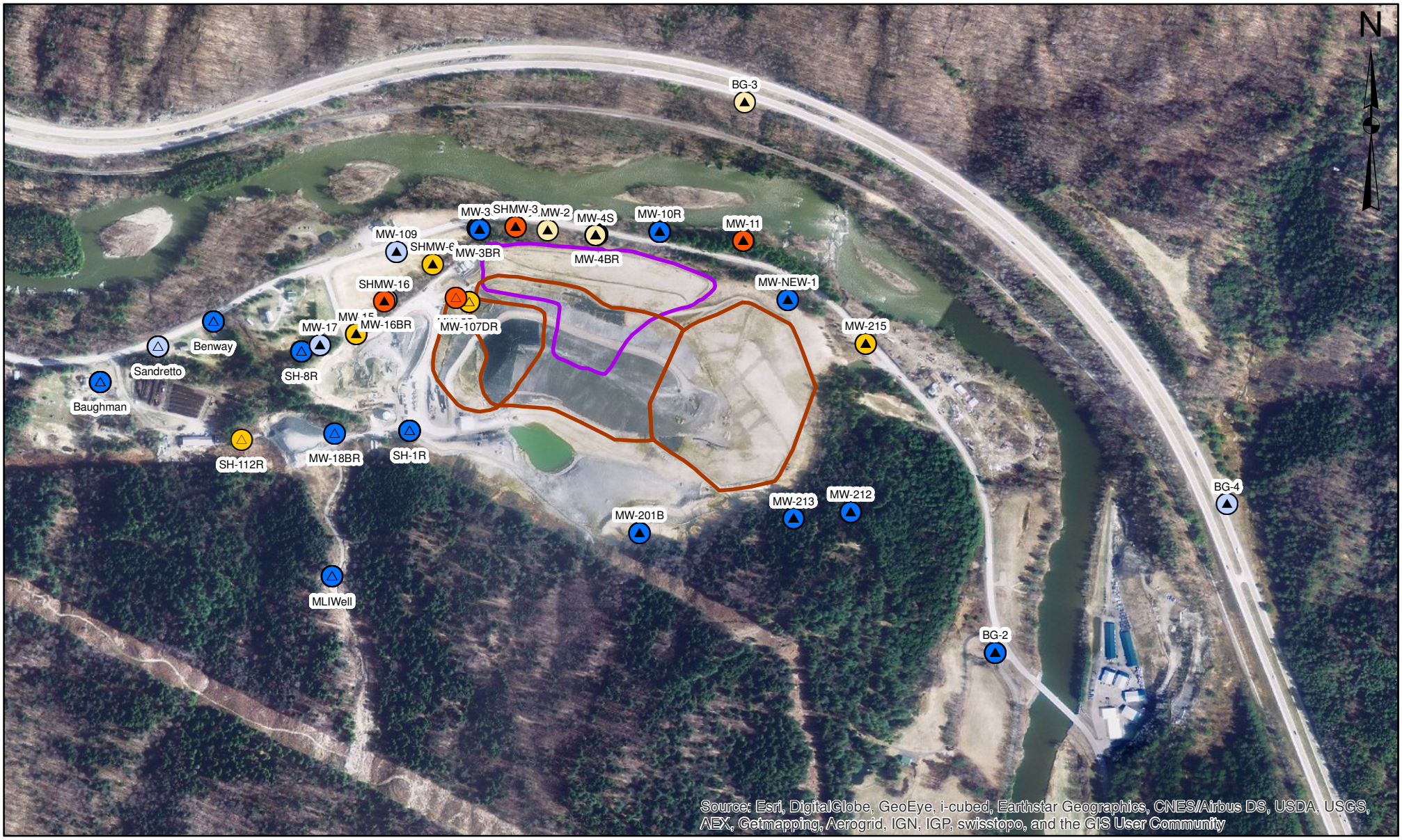
Landfill Cells
- Lined Cell
- Unlined Cell

Monitoing Well Type
- Overburden
- Bedrock

Iron (mg/L)
- < 2 (background)
- 2 - 10
- 10 - 25
- 25 - 50
- > 50

Moretown Landfill Inc.
2015 Groundwater Iron

Figure No.4



0 175 350 700
Feet

Landfill Cells
- Lined Cell
- Unlined Cell

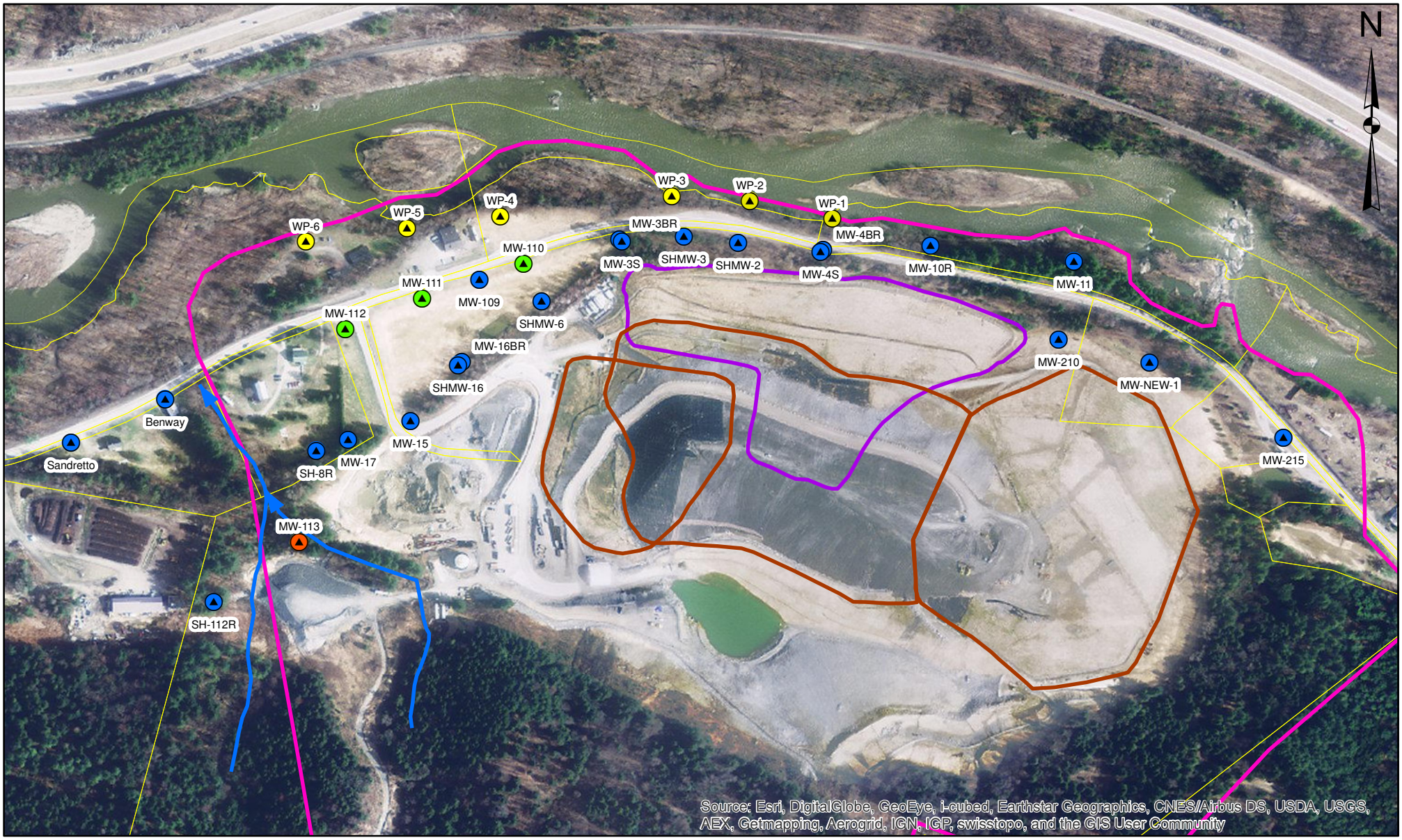
Monitoing Well Type
- Overburden
- Bedrock

Manganese (mg/L)
- < 0.5 (background)
- 0.5 - 2
- 2 - 5
- 5 - 10
- > 10

Moretown Landfill Inc.
2015 Groundwater Manganese

Environmental Planning Specialists, Inc.

Figure No.5



0 100 200 400
Feet

Landfill Cells
- Lined Cell
- Unlined Cell

Monitoing Well
- Proposed POC Well
- Existing POC Well
- MNA Assessment Well
- Western Boundary Well

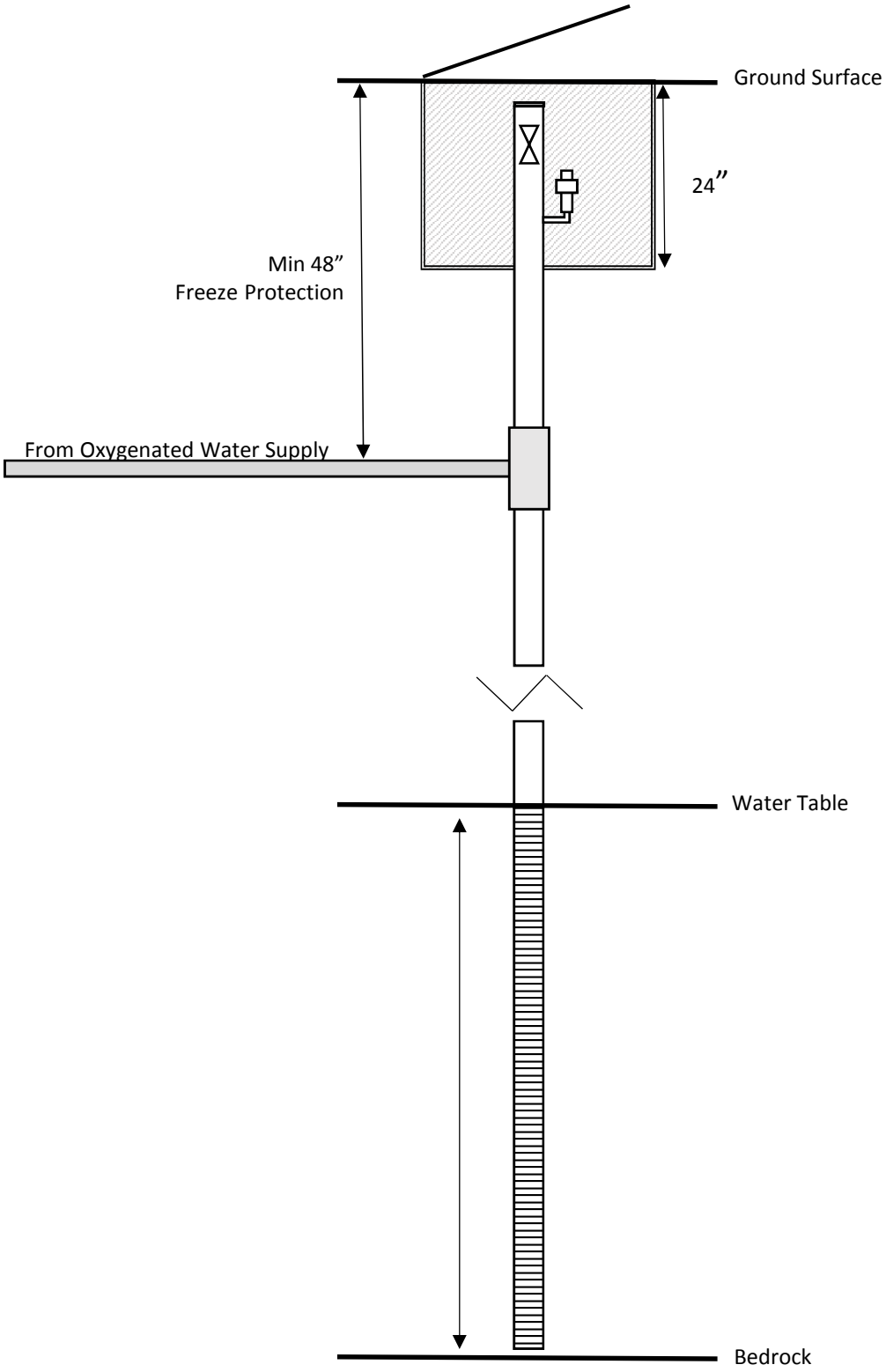
- Surfacewater Drainage
- Class IV Groundwater Boundary
- Parcel Boundary

Moretown Landfill Inc.
Point of Compliance Wells &
Proposed Western Well (MW-113)

Environmental Planning Specialists, Inc.

Figure No.6

Figure No.7
Injection Well Details



APPENDIX A
Sludge Investigation, Moretown Landfill, Inc.

cornerstone
environmental

320 Cowpath Road, Independence, PA 15001
T 802-236-3832 W www.john.schwalbe@cornerstoneeg.com

January 25, 2016

Adam G. Sowatzka
King and Spaulding, LLP
Peachtree Street, NE
Atlanta Georgia, 30309

Re: Moretown Landfill
Project Number 140553
Test Pit Program

Dear Mr. Sowatzka:

As requested, below is a summary of exploratory test pits completed by Cornerstone Environmental Group, LLC (Cornerstone) at the Moretown Landfill on November 30, 2015.

In an effort to determine if any non-native or organic material remains around the former monofill near the access road at the Moretown Landfill, three test-pits were dug immediately adjacent to the road to the scale area. (See attached plan) Conventional equipment was used with oversite by Cornerstone personnel. During excavation appropriate safety and environmental protocol were followed. The area was secured for E&S controls and test pits were photo logged and immediately backfilled and graded to protect from erosion. As evidenced by each photo (see attached) varying levels of a grayish material with a sludge consistency were evidenced in the three test pits. Based on the test pits, research of prior records, and elevation data we believe this material is limited to the area immediately adjacent to and under the access road as shown on the attached plan.

If you have any questions please call me at 802-236- 3832.

Sincerely,

Cornerstone Environmental Group, LLC

Daryl M. O'Dell for
John Schwalbe

Enclosure: Photographic Record
2015 Test Pit Plan

PHOTOGRAPHIC RECORD

November 2015

Client: King and Spaulding, LLP
Project Number: 140553
Site Name: Moretown Landfill
Site Location: Moretown Landfill

Photograph No.: 001 **Comments:**	
Photograph No.: 002 **Comments:**	

PHOTOGRAPHIC RECORD

November 2015

Client: King and Spaulding, LLP
Project Number: 140553
Site Name: Moretown Landfill
Site Location: Moretown Landfill

Photograph No.: 003 **Comments:**	

LEGEND

- PROPERTY BOUNDARY
- PERMITTED SOLID WASTE BOUNDARY
- INCLUDES DEEMED PERMITTED CELL 4
- PHASE BOUNDARY

NOTE

1. AERIAL PHOTOGRAPH TAKEN BY SOUTHERN RESOURCES MAPPING CORPORATION ON MAY 07, 2014.

N

0 100 200

SCALE IN FEET

REV	DATE	DESCRIPTION	DWN BY	DES BY	CHK BY	APP BY

DATE OF ISSUE

DRAWN BY
DESIGNED BY
CHECKED BY
APPROVED BY

cornerstone environmental

PREPARED BY:
CORNERSTONE ENVIRONMENTAL GROUP, LLC

This drawing represents intellectual property of Cornerstone Environmental Group LLC. Any modification to the original by other than Cornerstone Environmental Group LLC personnel violates its original purpose and as such is rendered void. Cornerstone Environmental Group LLC will not be held liable for any changes made to this document without express written consent of the originator.

ADVANCED DISPOSAL SERVICES
MORETOWN LANDFILL
WATERBURY, VERMONT

2015 Test Pit Program

SHEET NO.
0

PROJECT NO.
140553

File: X:\PROJECTS\MORETOWN\140553 - 2014 VOLUME COMPUTATIONS_Project Drawings\MTW553-S-00-AERIAL PHOTO.dwg Layout: Layout1 User: Bryce.Gibbons Jul 31, 2014 - 2:31pm

1" 1/2" 0" 1"

APPENDIX B
Assessment of Off-Site Groundwater Manganese Condition

APPENDIX B

ASSESSMENT OF OFF-SITE GROUNDWATER MANGANESE CONDITION
Moretown Landfill

Prepared for:

MORETOWN LANDFILL, INC.
19 Kaiser Drive
Waterbury, Vermont 05676

Prepared by:

EPS
1050 Crown Pointe Parkway, Suite 550
Atlanta, Georgia 30338
Tel: 404-315-9113

April 2015

ASSESSMENT OF OFF-SITE GROUNDWATER MANGANESE CONDITION
Moretown Landfill

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1 OFF-SITE GROUNDWATER MANGANESE

1.1 Overview

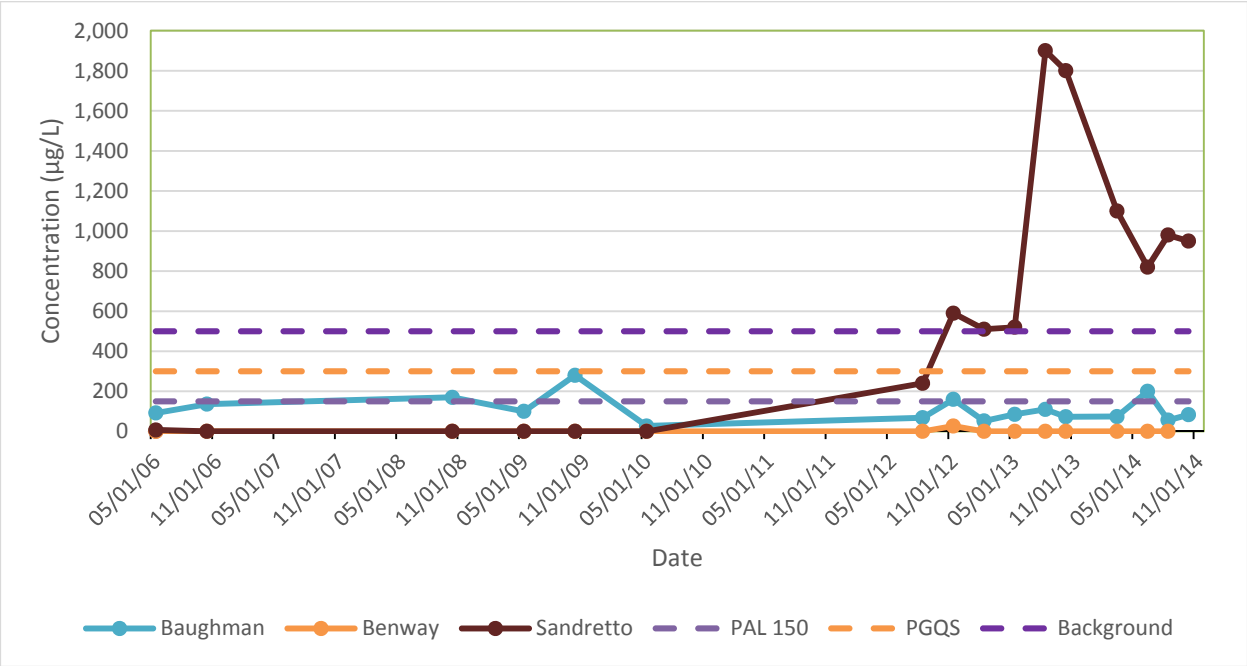
1.1.1 Background

In the ANR review of Site groundwater compliance data, the Sandretto potable water well was identified as a potential concern due to recent exceedances of the Vermont Primary Groundwater Quality Standard (PGQS) for manganese. As a result, ANR requested further effort be directed to understand the occurrence of manganese in the Sandretto water well, specifically directed towards improved understanding of groundwater flow directions near the western limit of the MLI property boundary. As provided in Appendix A, further effort to study groundwater flow near the western property boundary has been performed, with both the groundwater flow assessment and seismic refraction survey indicating groundwater from the MLI Site is highly unlikely to be the cause of the Sandretto well manganese condition. In response to these findings, further assessment of the Sandretto and nearby potable water wells was performed to survey potential causation for the Sandretto well manganese condition. Additional assessment included review of residential well data trends and evaluation of nearby land use.

1.1.2 Residential Well Data Review

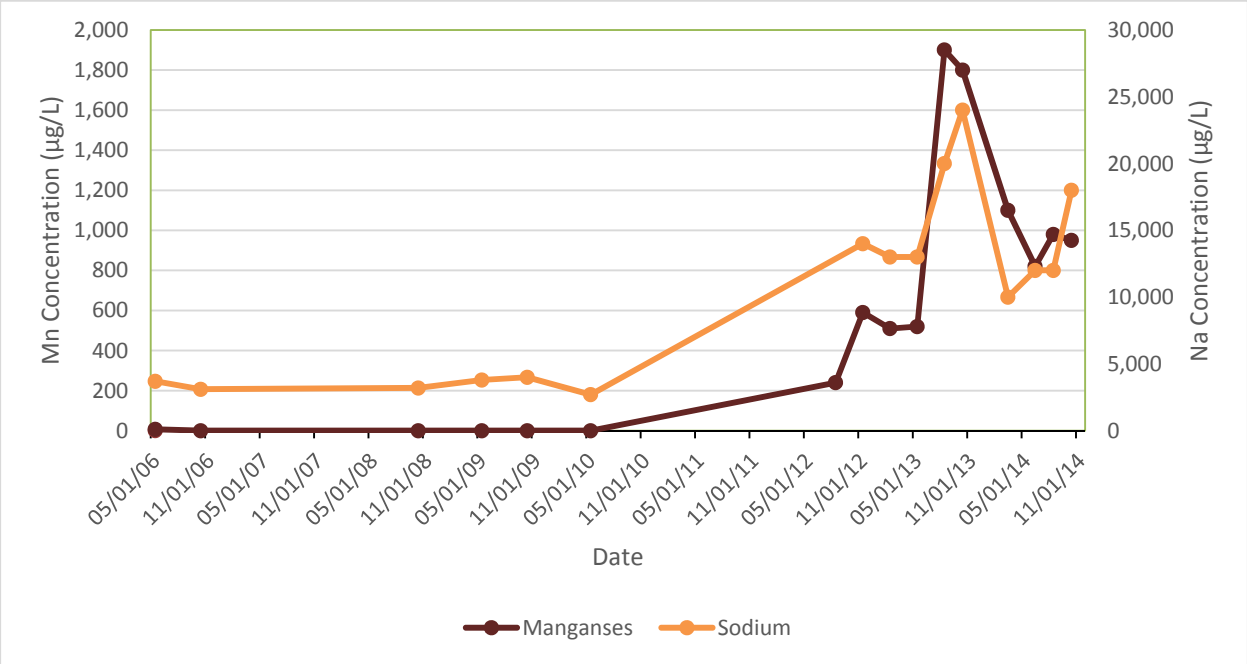
It is evident, based on the historical data set, that increased manganese concentrations in the Sandretto well is a recent phenomenon and was non-detect prior to 2010 (see "Residential Water Manganese Time Trends" below). In the period after 2010, manganese exhibits a marked increase in concentration in the Sandretto well, while the adjacent residential wells, the Benway and Baughman wells, remain at concentrations consistent with historical values. Figure 1-1 illustrates the locations of the off-Site residential wells. The Benway well (located between the landfill and Sandretto well) is with the exception of one year, non-detect for manganese. The Baughman well exhibits a relatively consistent manganese profile from 2006 to 2014 with an average concentration of 110 µg/L. Also evident in the groundwater data analysis for the Sandretto well is a concurrent increased in groundwater sodium with manganese (see "Sandretto Well Manganese and Sodium Time Trend"). Prior to 2010, sodium concentrations were stable near 3,000 to 4,000 µg/L. Then, as with manganese, sodium concentrations increased post-2010.

Residential Water Manganese Time Trends



PAL: Preventative Action Level
PGQS: Primary Groundwater Quality Standard

Sandretto Well Manganese and Sodium Time Trend



1.1.3 Land Use Review

An assessment of area land use was performed by reviewing aerial photographs for the period of 1996 to 2012 (Google Earth). The photographic review illustrates the western extent of the MLI landfill has remained consistent during this period. Visual assessment of land use west of the landfill indicates the area was largely residential with wooded or open grassland cover for the period of 1996 to 2009. Between 2009 and 2012, aerial photographs indicate a land use change due south of the Sandretto well. A row compost facility was constructed immediately upgradient of the Sandretto well with approximately 1.5 acres (May 2012 aerial) of compost processing and storage area (Figure 1-1). As discussed above, this land use change temporally coincides with the reported increase in groundwater manganese and sodium in the Sandretto well, with the first detection of manganese in the Sandretto well occurring in August 2012 (testing data not available for 2011).

1.2 Evaluation of Sandretto Manganese Condition

1.2.1 Effect of Compost Operations on Groundwater

Based on the proximity of the compost facility to the Sandretto well and corresponding change in groundwater quality, a literature review on the potential effects of compost operations on groundwater quality was performed. The literature search discovered that commercial composting facilities have recently been identified by the New York State Department of Environmental Conservation as a direct cause of elevated metals in groundwater, specifically for manganese and sodium (NYDEC, 2013). This finding was further supported in follow-up studies performed by the NYDEC that evaluated data from historic and recent groundwater monitoring at several other compost facilities that suggest compost facilities cause elevated concentrations of manganese in groundwater, often one or two orders of magnitude above drinking water standards (NYDEC, 2013). A summary of the NYDEC study, known as the “Horseblock Road Investigation” is provided below.

1.2.2 Summary of Horseblock Road Study

The Horseblock Road Investigation, which was overseen by several New York State government agencies (Suffolk County Department Health Service (SCDHS), the New York State Department of Environmental Conservation (NYDEC), and the New York State Department of Health (NYDH)) was initiated in response to groundwater testing data from a residential drinking water well located hydraulically down gradient of the Long Island Compost/Great Gardens composting facility, which reported manganese at levels exceeding drinking water standards (NYDEC, NYDH, SCDHS, 2013). Down gradient of Great Gardens, manganese was detected at concentrations as high as 31,600 µg/L and 15,300 µg/L. Samples collected up gradient of Great Gardens, in general, met drinking water quality standards. Additionally, the deterioration in groundwater quality in the residential drinking water well closely coincided with the commencement of site operations at Great Gardens. Great Gardens began operating in 1999 and

a review of sampling history revealed a deterioration in water quality in the residential well since 2000.

The impacts of compost/vegetative organic waste site operations on manganese concentrations in groundwater are not limited to Great Gardens facility. The Horseblock Road Investigation report cited data from three other investigations that yielded similar results: Long Island Compost's former facility in East Moriches, the Town of Brookhaven's compost facility in Manorville, and Main Street Yaphank vegetative organic waste facilities. Manganese was detected at concentrations up to 43,000 µg/L in three groundwater monitoring wells installed in the vicinity of the East Moriches facility. Samples collected from seven groundwater monitoring wells installed at the Manorville facility revealed concentrations of manganese up to 7,800 µg/L. Groundwater samples collected from three temporary wells down gradient of the vegetative organic waste facilities located in Yaphank revealed manganese concentrations up to 49,300 µg/L. The groundwater manganese concentrations reported down gradient of the facilities are in general higher than concentrations reported in the Sandretto well, however, these compost operations are considerably larger, with the Great Garden facility coving approximately 60 acres, and groundwater was better characterized with a net of monitoring wells better suited to identifying the range of groundwater manganese concentrations.

The mechanism by which compost causes elevated manganese and sodium in groundwater is not discussed in the Horseblock Road Study, but is reasonably inferred to be caused by direct reduction of native manganese oxides or by the geochemical modification of soil and groundwater by organic matter released by these facilities. Natural organic matter is a major reducing agent for the reductive dissolution of manganese (hydr)oxides in soil and aquatic systems. Natural organic matter can directly reduce and dissolve manganese (hydr)oxide particles (Godtfredsen and Stone, 1994; Stone and Morgan, 1984; Stone 1987(b)) or act as a carbon source for microbial mediated reductive dissolution (Guonot, 1994; Lovely, 1991; Myers and Nealson, 1988; Nealson and Myers, 1992; Stone, 1987(a)).

1.2.3 Summary

Based on the findings of the NYDEC investigations and the following site-specific conditions, it appears that the compost facility is the likely cause of elevated manganese and sodium in the Sandretto well. This conclusion is based the following multiple lines of evidence:

- Past and current groundwater flow studies do not support transport of Site COCs due west to the residential wells (EPS, 2015).
- The assessment of bedrock topography does not support transport of Site COCs due west to the residential wells (EPS, 2015).
- The Sandretto well is located <200 feet immediately down gradient of the compost processing and storage area (Figure 1-1).
- Residential wells side-gradient of the compost processing and storage area, Baughman to the west and Benway to the east, have not exhibited increases in manganese or sodium concentrations.

- Manganese and sodium concentrations in the Sandretto well were non-detect (manganese) or stable (sodium) prior to construction of the compost facility in 2009-2010.
- A direct relationship between compost facilities and elevated manganese and sodium in groundwater has been demonstrated at multiple facilities.

2 REFERENCES

EPS, Inc.. (2015). Summary of Site Studies Performed to Support Conceptual Site Model Development and Groundwater Corrective Action Design., Moretown Landfill, Moretown, Vermont. March 2015.

Godtfredsen, Kathy L., and Alan T. Stone. (1994). Solubilization of Manganese Dioxide-Bound Copper by Naturally Occurring Organic Compounds. *Environmental Science & Technology*. Vol 28.8; p. 1450-458.

Gounot, A. (1994). Microbial Oxidation and Reduction of Manganese: Consequences in Groundwater and Applications. *FEMS Microbiology Reviews*. Vol 14.4; p.339-49.

Lovely, Derek R. (1991). Dissimilatory Fe(III) and Mn(IV) Reduction. *Microbiological Reviews*. Vol 55.2: p. 259-87.

Myers, Charles R., and Kenneth H. Nealson. (1988). Microbial Reduction of Manganese Oxides: Interactions with Iron and Sulfur. *Geochimica Et Cosmochimica Acta*. Vol52.11; p. 2727-732.

Nealson, Kenneth H., and Charles R. Myers. (1992). Microbial Reduction of Manganese and Iron: New Approaches to Carbon Cycling. *Applied and Environmental Microbiology*. Vol 58.2; p. 439-43.

NYDEC, SCDHS, and NYDH. (2013). Horseblock Road Investigation: Yaphank, NY

Stone, Alan T(a). (1987). Microbial Metabolites and the Reductive Dissolution of Manganese Oxides: Oxalate and Pyruvate. *Geochimica Et Cosmochimica Acta*. Vol 51.4; p. 919-25.

Stone, Alan T(b). (1987). Reductive Dissolution of Manganese(III/IV) Oxides by Substituted Phenols. *Environmental Science & Technology*. Vol 21.10; p. 979-88.

Stone, Alan T., and James J. Morgan. (1984). Reduction and Dissolution of Manganese(III) and Manganese(IV) Oxides by Organics: 2. Survey of the Reactivity of Organics. *Environmental Science & Technology*. Vol 18.8; p. 617-24.

Moretown Landfill, Inc.
Off-Site Residential Wells and Compost Processing and Storage Area

0 125 250 500
Feet

Well Type
- Off-Site Potable Water Well

Poteniometric Model
- Groundwater Flow Line
- Potentiometric Surface Line

Site Feature
- Landfill Cell
- Compost Storage

Figure No. 1-1