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Unicorn Management
Consultants, LLC

September 28, 2016
Refer to: OP-3572

Mr. Michael Infurna
EPA Remedial Project Manager
U.S. Environmental Protection Agency
Region 2
Emergency and Remedial Response Division
290 Broadway, 22nd Floor
New York, New York 10007-1866

Subject: Draft Addendum 1 to the Final Remedial Investigation Report–Operable Unit 2 Groundwater
Lehigh Valley Railroad Derailment Superfund Site, LeRoy, NY

Dear Mr. Infurna:

In accordance with the Settlement Agreement and Order on Consent for Pre-Remedial Design Investigations, Remedial Design, and Remedial Investigation/Feasibility Study by and between Lehigh Valley Railroad Company (LVRR) and EPA, Index No. CERCLA-02-2006-2006 (Settlement Agreement), Unicorn Management Consultants, LLC (UMC), on behalf of the respondent, LVRR, hereby submits the Draft Addendum 1 to the Final Remedial Investigation Report–Operable Unit 2 Groundwater (Addendum 1)for the subject site.

LVRR's Remedial Investigation Report was submitted on December 3, 2014, and approved by EPA in correspondence letter correspondence dated December 16, 2014.

This Addendum 1 to LVRR's 2014 Remedial Investigation Report (LVRR 2014 RI) summarizes the findings of LVRR remedial investigation activities proposed in work plans both prior to, and following the issuance of the LVRR 2014 RIR. This Addendum 1 summarizes RI activities conducted consistent with three work plans including: (1) Addendum 7 to the EPA 2002 Remedial Investigation/Feasibility Work Plan submitted to the USEPA on October 30, 2014; (2) the November 4, 2014 Work Plan related to a fire at Commodities Resources Corp. in Caledonia; and (3), the September 8, 2015 Final MNA Work Plan. For reference, the three work plans included the following activities:

- October 30, 2014 Addendum 7 Work Plan
    - MNA sampling of all available conventional and FLUTe monitoring wells for MNA parameters
    - The installation of two new monitoring wells (LVRR 43 and LVRR-44) at the north end of Neid Road to delineate the northern limits of the TCE plume;
    - Sampling of the two new monitoring wells and other wells located on Neid Road for MNA and landfill parameters; Installation of transducers in monitoring wells and evaluation of their data for groundwater elevation trends;
    - Perform a Discrete Fracture Network (DFN) model for evaluating TCE mass transfer from rock matrix to groundwater; and,

- November 4, 2014 Work Plan related to a fire at Commodities Resources Corp. in Caledonia
    - Sampling of monitoring wells and springs along Spring Creek after a fire at the Commodities Resources Corp. in Caledonia;
- September 8, 2015 Final MNA Work Plan
    - Conduct a MNA sampling round with low-level dissolved gas and CSIA in support of the DFN model (September/October 2015).

For ease of your review, please find enclosed the Executive Summary from the Addendum 1 report.

If you should have any questions regarding this submittal, please call me at 203-205-9000, ext. 11.

Sincerely,
UNICORN MANAGEMENT CONSULTANTS, LLC

Francisco Trejo
Project Coordinator
Lehigh Valley Railroad Derailment Superfund Site

Enclosure

cc:	C. Magee, NYSDEC	enclosure (cd)
	D. Cutt, EPA	enclosure (via M. Infurno)
	M. Hill, Esq.	enclosure (cd)

ENCLOSURE

EXECUTIVE SUMMARY

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After the submission of the LVRR 2014 Remediation Investigation Report, the EPA posed several questions on the delineation and state of the plume in follow up memos and phone calls. These questions are presented here:

1) *How is the plume margin in the north defined?*
2) *What is the impact on the plume from recharge, originating from sinkholes and swallets?*
3) *Is any kind of natural degradation (abiotic and/or biological) taking place in the plume?*
4) *What is the impact of the Leroy Landfill on the plume?*
5) *What impact did the water used to suppress the CRC fire have on the plume?*
6) *Will removal of TCE product at the source improve concentrations in the plume?*

In response to these requests, LVRR conducted additional remedial investigation activities to delineate the TCE plume north of the Spill Area; provide additional data to assess the potential degradation of TCE; evaluate the seasonal influences of meteoric water on groundwater fluctuations and TCE concentrations; potential landfill impacts to groundwater within the Study Area; and, assess the CRC facility fire potential impacts to the aquifer within the Study Area. DFN numerical model simulations were also conducted to assess matrix diffusion effects on plume attenuation and impacts of source removal on plume concentrations.

How are the margins of the plume delineated?

In the north boundary additional wells suggest that the plume boundary is south of wells LVRR-43 and LVRR-44. The western and southern boundaries are controlled by surface runoff and groundwater flowing from watersheds to the south. The eastern boundary is controlled by the discharge zone associated with the Spring Creek fault.

To delineate the plume north of the Spill Area two new monitoring wells, LVRR-43 and -44 were installed at the north end of Neid Road. Samples collected from these wells during 2015 did not contain detectable concentrations of TCE, DCE or VC above laboratory detection limits. The absence of these compounds in the groundwater demonstrates that the northern limit of the dissolved-phase TCE plume has been delineated.

A SWAT model was performed to demonstrate that allogenic surface and ground water from near the Spill Area and from south of the Study Area contribute large volumes of fresh water that mixes with the TCE plume. The SWAT model demonstrated that throughout much of the calendar year Mud Creek infiltrates into the bedrock near the Spill Area. This water, other seasonal surface water streams, groundwater, and precipitation falling directly within the Study Area provide large volumes of fresh water that mixes with the TCE plume and is directed eastward through the Site aquifer system, eventually discharging at Spring Creek. The influx of fresh water along the southern boundary of the plume acts to dilute the TCE concentrations and acts to control the lateral extent of the plume to the south. Areas in the center and northern portions of the plume do not receive as much infiltrating water, but Oatka Creek , which borders the site on the north, receives any groundwater that may move in that direction. As noted in the LVRR 2014 RIR, Spring Creek is formed along a fault zone that extends from approximately Spring Street on the west to Route 36 on the east and acts as the discharge zone for Study Area groundwater. Much of the eastward-flowing Study Area groundwater is discharged to the surface through the fault zone forming Spring Creek. These controls are evident by the generally stable TCE plume condition observed during historical groundwater sampling events conducted between 1993 and the present. Therefore, the plume extent is constrained by natural processes and delineated horizontally and vertically.

Have meteoric water inputs from recharge impacted the plume?

Yes. Hydrological modeling supported by direct observations that the water table responds to individual meteorologic events suggest that large fluxes of meteoric water mix with the plume. Such fluxes will be greatest in the spring, winter, and fall outside of the growing season.

In an effort understand the relationship of groundwater fluctuations and TCE concentrations over time, transducers were installed in a number of monitoring wells throughout the plume. Water levels recorded by the transducers confirmed that large fluctuations occur during the spring, late fall, early winter, and during winter precipitation events augmented by snowmelt. Large precipitation events during the summer have little effect on the recharge rates, likely due to evapo-transpiration and storage capacity in the vadose zone. Reviewing the transducer curves for the various monitoring wells shows that the water level changes are often rapid, in a matter of hours or days, to a large precipitation or snow melt event during certain seasons. Comparing the water levels for different depths and geologic formations revealed that the water level responses within each formation are similar with very little or no lag time, indicating that the geologic formations act as a single aquifer and are hydraulically connected through a complex fracture network. The SWAT model identified significant amounts of recharge per month the average monthly flux within dilution zones varies between 3 mg/mo to 406 mg/mo. Historically, in October the plume receives the least amount of recharge and the highest TCE concentrations are detected.

Is abiotic and/or biological degradation taking place in the plume ?

Overall, the plume position is stable and TCE concentrations within the plume have decreased over time. The overall plume attenuation is due to combined influence of several processes / conditions including matrix diffusion, sorption and dilution enhanced by the large meteoric water inputs, combined with declining source inputs due to dissolution and disappearance of DNAPL that originally penetrated below the water table, combined with declining inputs from contaminant mass persisting in the vadose zone in the source area. DFN numerical simulations show that even slow rates of degradation can enhance plume attenuation when combined with diffusion and other processes, so abiotic degradation due to reactive Fe-S minerals in the rock matrix, and possibly biological degradation in zones where redox conditions are conducive, is likely enhancing plume attenuation.

The 2010 – 2015 VOC data indicates that the overall areal and vertical extent of Study Area TCE-impacted groundwater has been delineated. Further, although historical groundwater quality data indicate that the overall TCE impacts to groundwater have declined over time, a comparison of the 2014-2015 concentrations to historically generated TCE iso-concentration maps from 1993 – 1995 indicates that the overall shape and areal extent of the TCE plume has remained relatively stable for the past two decades.

Samples collected from monitoring wells between 2010 and 2015 were analyzed for VOCs and select MNA parameters. The MNA results showed that the aquifer was generally aerobic with little ability to degrade TCE. However, in some locations, such as near mid-plume, conditions may be suitable for limited anaerobic biological degradation. The 2015 CSIA data suggested that abiotic degradation of TCE may be occurring, with the TCE $\delta^{13}C$ enrichment factor increasing with distance from the source, but with the enrichment factor magnitude not typical of abiotic degradation only, likely due to combined effects of degradation and diffusion processes

The magnetic susceptibility of the bedrock cores collected during LVRR's 2014 RI were measured to assess whether ferromagnetic minerals are present in the bedrock matrix, that may potentially contribute to the abiotic degradation of TCE. Many negative results were obtained, indicating a diamagnetic condition and a predominance of non-magnetic minerals. However, the overall positive results, generally exceeding values reported in carbonate rocks, indicate a paramagnetic condition and the presence of ferromagnetic minerals. Based on these results, LVRR concludes that ferromagnetic minerals may be present in the Site bedrock matrix in amounts sufficient to contribute to abiotic TCE degradation processes.

Comparing the MNA trends with the SWAT model shows that the MNA parameters are affected by the infiltration of surface water near the Spill Area, along the southern boundary of the plume, and at the discharge zone. In these areas, the infiltrating surface water changes the groundwater chemistry such that it does not support anaerobic biota capable of degrading TCE. However, with less infiltration in the mid-plume area, the groundwater chemistry/redox conditions are more amenable for anaerobic degradation.

The DFN Report shows simulated plumes for a scenario with slow rates of degradation, assuming first-order decay of mass in both fractures and in the matrix with a slow half-life of 20 years. Comparison with the base case plumes without degradation, with slow rates of degradation the plume still reaches the downgradient boundary within 20 years, but with much stronger attenuation of internal plume concentrations. Effects of degradation are two-fold in fractured rock: a) direct removal of contaminant mass (either transformation to lesser chlorinated products, or complete dechlorination through to non-chlorinated end products), and b) indirect effects on diffusion since contaminant mass removal due to degradation can result in increased rates of mass transfer to the matrix while the plume is in forward diffusion stages, as well as, dampening of mass release back to fractures from the matrix during back diffusion stages. Therefore, while the Site conditions may only allow for limited degradation in portions of the plume, it may still be an important factor in overall plume attenuation in combination with other processes.

The MNA study provided evidence for some degradation occurrence within the plume. The attenuation processes identified are both destructive and non-destructive in nature and include, but are not limited to, matrix diffusion, sorption, dispersion, dilution, volatilization, and chemical or biological degradation. Overall these processes combine to cause strong attenuation of the plume between the source area and along the plume flow path prior to discharging at Spring Creek.

Does the Leroy Landfill impact the TCE plume?

No; but it may have provided additional contaminants such as TCA and other VOC's to the northern part of the spill area.

In an effort to assess if disposal activities at the former Town of LeRoy landfill have impacted Study Area groundwater quality, two monitoring well clusters were installed at the north end of Neid Road and east of the former landfill in December 2014, each consisting of four wells screened at specific stratigraphic intervals (LVRR-43 and LVRR-44). During January 2015, groundwater samples were collected from the well clusters and from clusters further south on Neid Road with the samples analyzed for VOCs, MNA parameters and landfill parameters, such as TKN, TDS, chloride, bromide, and metals. TCE was not detected in groundwater samples collected from the LVRR-43 or LVRR-44 well clusters, effectively delineating the northern limit of the TCE plume. However, 1,1-DCA and chloroethane were detected in groundwater samples collected from the LVRR-44 cluster. These VOCs have not been historically detected in groundwater samples collected at the Site. 1,1-DCA and chloroethane are degradation products of TCA but not TCE. Therefore groundwater in the vicinity of LVRR-44 may be impacted as the result of former Town of LeRoy landfill disposal activities. The MNA parameters were within the same ranges identified in other monitoring wells in the area. Several of the landfill parameters, such as sodium and chloride, as well as BOD, COD and ethane were relatively high in LVRR-44 but not in wells further south along Neid Road, indicating impacts from the landfill have affected groundwater quality locally, but not the groundwater quality in the TCE plume.

Did the Million gallons of water used to combat the CRC Fire impact the plume?

No. Changes in chemistry, water table elevation, or flow were not observed in the plume or Spring Creek.

To assess if the CRC fire and fire suppression water had an impact on Study Area groundwater quality, groundwater samples were collected from monitoring well clusters in the area (DC-14, GCM, LVRR-25, and LVRR-31) and a surface water sample was collected from McKay spring. The samples were analyzed for VOCs and select general chemistry parameters (ammonia, chloride, nitrate, nitrite, and phosphorus). Additionally, groundwater elevation data was collected from transducers installed in vicinity monitoring well clusters and in Spring Creek to assess the potential influence of fire mitigation water on Study Area the water levels. TCE was detected in the monitoring wells at concentrations within historical ranges and was not detected in the McKay spring sample. The general chemistry analyses were also within historical ranges. No significant changes in the water level at Spring Creek or in nearby monitoring well clusters were noted. Based on these observations, the CRC fire and subsequent release of fire mitigation water did not significantly impact Site groundwater quality.

<u>Will removing material from the source area impact the plume?</u>

Probably not. Modeling suggests the current plume is sustained mostly by the back diffusion of TCE from the rock matrix, with minor ongoing inputs from contaminant mass persisting in the vadose zone, and that even complete removal of TCE inputs at the source will not fundamentally impact the plume within any reasonably timeframes.

The conceptual site model, substantiated by field data including high resolution profiles of contaminant mass distribution from subsampling of continuous rock cores collected from within and immediately downgradient of the source zone and mid-plume, showed that TCE DNAPL entered the aquifer shortly after its release, and subsequent dissolution of this DNAPL formed a plume that began to move eastward in the groundwater flow system. All DNAPL that penetrated below the water table likely disappeared within a few to several years; however remnant DNAPL appears to persist in the vadose zone, likely imbibed into the rock matrix, which continues to slowly feed contaminant mass to the plume albeit at declining rates. The plume is strongly attenuated by matrix diffusion and other processes, such that at the current time nearly all of the contaminant mass in the groundwater zone occurs as dissolved and sorbed phase in the rock matrix.

DFN numerical simulations that incorporate matrix diffusion and other key processes, although necessarily simplified but informed by site parameters to the extent feasible, confirm the strong attenuation observed in the field due to matrix diffusion and other processes. Several scenarios were run to predict the migration of TCE over time, showing that the TCE concentrations extend to the discharge zone and will for a long period of time; however with decreasing source inputs the higher concentrations in the Spill Area and throughout the plume will continue to decline during this time. As a predictive tool, the model was used to examine hypothetical scenarios where the vadose zone inputs and/or high concentration zone of TCE below the water table in the Spill Area were removed to evaluate the effect on the TCE concentrations in the plume. Model runs show that such aggressive source mass removal has little to no impact on TCE concentrations downgradient in the plume and nearer the plume front over any reasonable timeframes versus scenarios where the TCE vadose zone source and/or high remnant concentrations below the water table are left in place. Thus the model runs thus suggest limited benefit to aggressive source mass removal if the goal is to minimize future impacts in the downgradient portion of the plume. However, simulations suggest that internal plume concentrations will continue to decline, particularly if vadose zone inputs continue to decline naturally, but that back diffusion will cause the plume to persist for extended periods of many decades or longer.

DRAFT ADDENDUM 1
TO THE UMC 2014 REMEDIAL INVESTIGATION REPORT
USEPA OPERABLE UNIT 2
GROUNDWATER PLUME

Lehigh Valley Railroad Derailment Superfund Site
LeRoy, New York
Index Number CERCLA-02-2006-2006

Prepared For:
Lehigh Valley Railroad Company
CINCINNATI, OHIO 45202

Prepared By:
Unicorn Management Consultants, LLC
52 Federal Road, Suite 2C
Danbury, CT 06810

September 2016

DOCUMENT AUTHORIZATION FORM
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AUTHORIZATIONS:

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Independent NYS Professional Engineer

Authorized By:

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Francisco Trejo Date
Project Coordinator
Lehigh Valley Railroad Derailment Superfund Site

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1 INTRODUCTION

Unicorn Management Consultants, LLC (UMC), on behalf of the Lehigh Valley Railroad Company (LVRR), prepared this Draft Addendum 1 to UMC's December 2014 LVRR Remedial Investigation Report (LVRR 2014 RIR) to summarize remedial investigation (RI) activities conducted subsequent to the completion of the LVRR 2014 RIR. LVRR is the respondent of the Settlement Agreement and Order on Consent for Pre-Remedial Design Investigations, Remedial Design, and Remedial Investigation/Feasibility Study, Index Number CERCLA-02-2006-2006 by signatory of the United States Environmental Protection Agency (USEPA) on September 22, 2006 (hereinafter, "SA") for the Lehigh Valley Railroad Derailment Superfund Site (Site) located in Genesee, Monroe, and Livingston Counties, near the Town of LeRoy, New York. Appendix A of the 2014 RIR contains a copy of the SA. Figure 1a is an Index Map depicting the approximate Site location. Figure 1b is a Regional Map using a United States Geological Survey (USGS) topographical map as a base and depicting the overall Study Area and Spill Area. Figure 2 is a Study Area Map using an aerial photograph as a base depicting features pertinent to RI activities discussed in this Addendum 1 report.

The scope of the LVRR 2014 RIR was incorporated in the SA, including a Record of Decision (ROD) prepared by the New York State Department of Environmental Conservation (NYSDEC) on March 28, 1997 and two USEPA memoranda to supplement the ROD (SA USEPA Memoranda) (Appendix A of the SA); a Statement of Work (SOW) (Appendix B of the SA); and the work plan titled "Final Work Plan for Remedial Investigation / Feasibility Study, Lehigh Valley Superfund Site, Town of Leroy, Genesee County, NY" prepared by Foster Wheeler Environmental Corporation (Foster Wheeler) on behalf of the USEPA dated February 2002 (USEPA 2002 RI/FS Work Plan) (Appendix C of the SA); and, Addendum dated September 11, 2006 (Appendix C of the SA).

Subsequent to preparation of the USEPA 2002 RI/FS Work Plan and Addendum, UMC prepared Addendums 2, 3, 4, 5, 6, and 7 a November 4, 2014 Work Plan; and a Final Monitored Natural Attenuation (MNA) Work Plan dated September 8, 2015. The LVRR 2014 RIR summarizes the findings of the LVRR RI activities proposed in the USEPA 2002 RI/FS Work Plan, September 11, 2006 Addendum, and UMC Addendums 2, 3, 4, 5, and 6. The LVRR 2014 RIR was approved by the USEPA via letter correspondence dated December 16, 2014.

This Addendum 1 to the 2014 RIR Report (Addendum 1) summarizes the findings of RI activities proposed in work plans both prior to, and following the issuance of the 2014 RIR. This Addendum 1 summarizes RI activities conducted consistent with three work plans including: (1) the Addendum 7 Work Plan submitted to the USEPA on October 30, 2014; (2) the November 4, 2014 Work Plan; and (3), the September 8, 2015 Final MNA Work Plan. Appendix A of this Addendum 1 contains copies of the respective work plans. A description of the purpose, objectives, tasks, procedures, and results of Addendum 1 RI activities follows.

1.1 PURPOSE OF THE ADDENDUM 1 REPORT

The purpose of this Addendum 1 is to address data gaps identified during the 2014 RIR and to provide the USEPA with additional data pursuant to the SA USEPA Memoranda within Appendix A of the SA.

1.2 REPORT ORGANIZATION

This Addendum 1 is organized into the following sections:

Section 1:	Provides the introduction, purpose, and organization of this report;
Section 2:	Describes the tasks and objectives of the three work plans discussed within Addendum 1;
Section 3:	Discusses the various procedures used to accomplish the various work plan tasks;
Section 4:	Presents the results of the various tasks accomplished as part of Addendum 1;
Section 5:	Reveals the conclusions of the activities associated with Addendum 1;
Section 6:	Includes references used throughout Addendum 1; and,
Section 7:	Lists the abbreviations and acronyms used throughout Addendum1.

2 TASKS AND OBJECTIVES

The overall objective of this Addendum 1 is to complete the investigation and delineation of the Site in support of the SA and provide the USEPA with additional data to supplement the NYSDEC's historical remedial investigations. The tasks and objectives of the three work plans discussed within this Addendum 1 report are summarized in the following sections.

2.1 ADDENDUM 7 WORK PLAN – OCTOBER 30, 2014

Addendum 7 to the USEPA 2002 RI/FS Work Plan included the following tasks and objectives:

2.1.1 Task 1 – Additional Monitored Natural Attenuation Groundwater Sampling and Analysis (Amends USEPA 2002 RI/FS Work Plan Section 3.3.5.1 Monitored Natural Attenuation Characterization Sampling [Subtask 3.05.01])

On August 26, 2014, the USEPA via email correspondence granted UMC approval to conduct a groundwater sampling event with the objective of obtaining additional MNA data to evaluate the potential natural degradation of dissolved-phase trichloroethene (TCE) in Site groundwater. UMC conducted the MNA sampling event in September and October 2014; groundwater sampling event procedures and results are discussed below in Sections 3.2.1 and 4.1.1.1, respectively.

2.1.2 Task 2 – Additional Transducer Installations and Data Assessment (Amends USEPA 2002 RI/FS Work Plan, Sections 3.3.4.2 and 3.3.4.3 Groundwater Elevation Measurements [Subtask 3.04.02])

In an email correspondence from UMC to the USEPA dated August 1, 2014, UMC proposed the installation of additional groundwater transducers in select Site monitoring wells and Spring Creek to continually record changes in groundwater and surface water elevations. Data collected from new and previously installed transducers allows for a comprehensive assessment of precipitation and snow melt events on the Study area groundwater, as well as, surface water fluctuations, vertical hydraulic gradients, and contamination migration. UMC received USEPA approval to install the additional transducers on August 26, 2014. Figure 3 depicts the locations of historically and newly installed transducers. The transducer installation procedures and assessment of the data collected is discussed below in Sections 3.4 and 4.3, respectively.

2.1.3 Task 3 – Discrete Fracture Network Numerical Modeling of Mass Transfer and Matrix Back Diffusion (Amends USEPA 2002 RI/FS Work Plan, Sections 3.6.2 and 3.6.3)

UMC received USEPA approval to conduct Discrete Fracture Network (DFN) modeling via letter correspondence dated February 10, 2015. The DFN modeling was conducted with the objective of providing estimates of the magnitude of TCE plume attenuation due to matrix diffusion and other key processes, as well as to assess TCE back diffusion effects on overall Site groundwater quality (Operable Unit 2) and the timeframes necessary to achieve Maximum Contaminant Levels (MCLs) under Site-specific attenuation conditions. In addition, the DFN numerical modeling was conducted to assess if the conditions at the Site are such that they would limit or prevent the effectiveness of groundwater remedial technologies including, but not limited to, the bedrock vapor extraction (BVE) remedy which is selected in the SA, NYSDEC ROD pursuant to Section III, Part A of the SOW for EPA Operable Unit 1.

A general discussion of the DFN modeling procedures and specific objectives is presented below in Section 3.5. More details on the DFN modeling procedures and results for specific scenarios including sensitivity analyses are provided in a report in Appendix E. The remedial scenarios are presented and evaluated in the Assessment of Groundwater Restoration Potential Report which will be submitted under separate cover.

2.1.4 Task 4 – Additional Monitoring Well Installations, Sampling, and Analysis (Amends USEPA 2002 RI/FS Work Plan, Section 3.3.3 Hydrogeological Assessment [Subtask 3.03])

Groundwater sampling was conducted in select monitoring well clusters in November 2014 (Figure 2). Following this sampling event, monitoring well clusters LVRR-43 and LVRR-44 were installed north-northeast of the Spill Area in December 2014 (Figure 2). Additional groundwater sampling was conducted in select monitoring well clusters and the newly installed LVRR-43 and LVRR-44 clusters in January 2015. The monitoring well installations and the November 2014 and January 2015 groundwater sampling events were conducted with the objective of delineating the horizontal and vertical extent of the TCE plume north-northeast of the Spill Area and to assess the potential influence on Site groundwater quality of an off-Site inactive landfill, where TCE waste disposal supposedly occurred. Also in November 2014, groundwater samples were collected from wells in the vicinity of the Commodities Resource Corporation (CRC) facility located at 2773 Caledonia-Leroy Road, Caledonia, New York. This sampling was conducted consistent with UMC's November 4, 2014 Work Plan (discussed below in Section 2.3) to investigate the potential impacts to groundwater as the result of a November 1, 2014 fire that occurred at the CRC facility. Locations of both the inactive landfill and CRC facility are shown in Figure 2. The LVRR-43 and LVRR-44 cluster installation procedures and observations are discussed below in Section 3.1. The November 2014 and January 2015 groundwater sampling event procedures and results related to MNA sampling are discussed below in Sections 3.2.2 and 4.1.1.2, respectively. Fire-related groundwater sampling procedures and results are discussed in Sections 3.2.4 and 4.1.3, respectively.

2.2 FINAL MNA WORKPLAN – SEPTEMBER 8, 2015

Upon completion of Task 1 of the Addendum 7 Work Plan activities (groundwater sampling and additional MNA) conducted in September/October 2014 and November 2014/January2015, UMC submitted a June 3, 2015 work plan to the USEPA to conduct supplemental MNA sampling of existing monitoring wells and magnetic susceptibility testing of bedrock cores collected during UMC 2014 RIR activities in 2010. The USEPA and NYSDEC commented on the work plan in letter correspondences dated July 14, 2015 and August 26, 2015. UMC incorporated the USEPA and NYSDEC comments within a September 8, 2015 Final MNA Work Plan that was subsequently approved by the USEPA on September 9, 2015 via letter correspondence to UMC.

2.2.1 MNA Groundwater Sampling Objectives

Consistent with the Final MNA Work Plan, supplemental MNA groundwater sampling and analysis was conducted in September/October 2015. Laboratory analysis of the samples were conducted consistent with analytical methods selected specifically with the objective of understanding whether TCE degradation (abiotic and/or biological) is occurring in site groundwater, providing supplemental MNA data for the DFN numerical modeling, allowing the development of a Site-specific attenuation factor and simulation of various TCE degradation scenarios, and refining of the Conceptual Site Model (CSM) as appropriate. Figure 4A is a cross-sectional view of the Study Area oriented generally along the center line of the TCE plume illustrating the elements of the CSM. Figure 4B conceptually illustrates the evolution of the TCE plume and TCE diffusion and back-diffusion mechanisms occurring in Study Area bedrock. Figure 4C is an aerial view that conceptually illustrates the generalized flow of groundwater throughout the overall Study Area. Section 5 discusses Addendum 1 activity conclusions including refinement of the CSM as appropriate. The procedures and findings of the September/October 2015 groundwater sampling event are discussed below in Sections 3.2.3 and 4.1.1.3, respectively.

2.2.2 Magnetic Susceptibility Testing Objectives

In addition to supplemental MNA groundwater sampling, the Final MNA Work Plan proposed magnetic susceptibility testing of bedrock core samples collected by UMC during 2010 RI activities. The objective of the magnetic susceptibility testing is to assess the presence of reactive minerals (e.g. Fe-S minerals such as magnetite) in the bedrock matrix as an indication of whether abiotic degradation of TCE may potentially be occurring (for example, see Reference 50). The magnetic susceptibility testing data was in turn considered for inclusion in the DFN modeling efforts in a conceptual manner in sensitivity analyses (since the model only incorporates degradation in a simplified way assuming first-order degradation not tied to specific processes) to assess the potential effects of abiotic and/or biological degradation on the TCE plume attenuation timeframes. The procedures and findings of the magnetic susceptibility testing are discussed in Sections 3.3 and 4.2, respectively.

2.3 NOVEMBER 4, 2014 WORK PLAN – FIRE AT 2773 CALEDONIA-LEROY ROAD

On November 4, 2014, UMC prepared and submitted to the USEPA via letter correspondence a work plan to perform additional Site groundwater and surface water sampling due to the fire that occurred at the CRC facility. The work plan was approved by the USEPA on November 12, 2014, and the additional sampling was conducted in November 2014. The objective of the November 2014 groundwater and surface water sampling event was to assess the potential influence of fire mitigation water on Site groundwater quality, as well as, groundwater and surface water elevation fluctuations. The procedures and findings of the November 2014 groundwater and surface water sampling event are discussed below in Sections 3.2.4 and 4.1.3, respectively.

The following sections discuss the procedures used to accomplish the various work plan tasks and objectives, as presented above, that are incorporated into this Addendum 1 Report.

3 PROCEDURES

This section describes the Addendum 1 work plan procedures including test boring and monitoring well installations, groundwater sampling, magnetic susceptibility testing, transducer installations, and DFN Modeling.

3.1 TEST BORING AND MONITORING WELL INSTALLATION PROCEDURES

In accordance with Task 4 of the Addendum 7 Work Plan, between December 8 and 14, 2014, Nothnagle Drilling, Inc. (NDI) installed bedrock monitoring well clusters LVRR-43 and LVRR-44 with UMC oversight. Figure 2 depicts the locations of well clusters installed during historical RIs conducted by the NYSDEC and UMC as well as the newly installed LVRR-43 and LVRR-44 clusters. As depicted on Figure 2, monitoring well cluster LVRR-43 is located on the east side of the Neid Road right-of-way, and north of clusters LVRR-20 and LVRR-37 where the NYSDEC Standards, Criteria and Guidelines (SCG) of 5 micrograms per liter (µg/L) for TCE in groundwater have historically been exceeded. Monitoring well cluster LVRR-44 is located west of Neid Road on the Town of LeRoy-owned former General Crushed Stone Quarry. Both LVRR-43 and LVRR-44 are located north-northeast of the Spill Area and hydraulically downgradient (generally east) of a supposed former Town of LeRoy landfill (approximate location depicted in Figure 2) where the disposal of wastes likely included TCE. Monitoring well clusters LVRR-43 and LVRR-44 were installed to delineate the horizontal and vertical extent of the Study Area TCE plume north-northeast of the Spill Area and to assess the potential impact to Study Area groundwater from the former Town of LeRoy landfill.

NDI advanced the LVRR 43 and 44 borings using an Ingersoll Rand T4W air rotary drill rig. First, an approximately 8 foot by 12 foot containment area consisting of wood framing and plastic sheeting around the drill stem was constructed to collect water and drill cuttings as the borings were advanced. Then each boring was advanced approximately two feet into competent bedrock, corresponding to depths in LVRR-43 and LVRR-44 borings of approximately 8 feet and 13 feet below the ground surface (bgs), respectively, and then surficial casings were set comprised of eight inch diameter steel casing in each boring allowing approximately three feet of casing to extend as stand pipes above the ground surface, which were then grouted the casing in place using a bentonite/cement slurry, and allowed the grout to cure for approximately 24 hours before advancing six inch diameter borings below the casing to their final depths.

Following boring advancement to their final depths, NDI installed two conventional-style polyvinyl chloride (PVC) monitoring wells in each boring (two borings at each location) resulting in clusters with four monitoring intervals at each location. The wells were constructed by installing two 10 foot long sections of 2-inch diameter 0.20-inch slotted PVC well screen at the target depths in each boring, with solid PVC riser pipe placed from the top of each screen to the top of the steel casing. Filter sand was then placed in the boring annulus to a level approximately two feet above the top of the lower-most screen. A bentonite seal was then installed above the sand pack to the bottom of the upper-most well screen, followed by filter sand approximately two feet above the top of the upper-most screen, and a bentonite seal to the ground surface.

The monitoring wells were screened at various depth intervals with the objective of intercepting approximately the same stratigraphic intervals as those encountered in up gradient clusters LVRR-20 and LVRR-37. Accordingly, the screened intervals were selected based on an estimated elevation at each location, the distance of each location from up gradient monitoring wells, and an assumed bedrock dip of approximately one degree to the south based on available geologic literature and bedrock boring data. Based on these assumptions, the total depths, screened intervals, and corresponding screened bedrock units in each monitoring well are as follows:

Monitoring Well ID		Screened Interval (feet bgs)	Bedrock Unit
Boring LVRR 43A/B	LVRR-43A	15-25	Onondaga
(total depth 55 ft bgs)	LVRR-43B	45-55	upper Bertie
Boring LVRR-43C/D	LVRR-43C	55-65	lower Bertie
(total depth 83 ft bgs)	LVRR-43D	73-83	Camillus
Boring LVRR-44A/B	LVRR-44A	20-30	Onondaga
(total depth 60 ft bgs)	LVRR-44B	50-60	upper Bertie
Boring LVRR-44C/D	LVRR-44C	60-70	lower Bertie
(total depth 85 ft bgs)	LVRR-44D	75-85	Camillus

3.1.1 LVRR-43 and LVRR-44 Test Boring Observations

UMC periodically screened the bedrock cuttings as they were recovered from the borings for volatile organic compound (VOC) vapors using a photoionization detector (PID). PID readings of approximately 5 parts per million (ppm) and a slight sulphur-like odor were observed in boring LVRR-43C/D at depths between approximately 25 and 75 feet bgs. Screening of the remaining bedrock cuttings did not detect VOC vapors in concentrations exceeding background levels of approximately 2 ppm.

Minimal water was encountered as the borings were advanced. However, the static water level observed in the monitoring wells approximately 12 hours after completion was between approximately 30 and 60 feet bgs with the exception of LVRR-44A (screened from 20-30 ft bgs)which was dry.

Appendix B contains LVRR-43 and LVRR-44 boring logs depicting test boring observations and monitoring well construction details.

3.1.2 Monitoring Well Development

Following the LVRR-43 and LVRR-44 monitoring well cluster installations, NDI developed the wells by purging each well of groundwater and fine materials produced during drilling. The well development process consisted of first using a surge block to agitate the well to mobilize fine materials then evacuating the water and fine particles with Watera tubing attached to a submersible pump. Each well was developed until the extracted water was observed as clear or until no further change in groundwater turbidity was visually observed.

Approximately 150 gallons of waste groundwater was generated during the development of monitoring well clusters LVRR-43 and LVRR-44. NDI collected the water in 55 gallon drums and then transferred the water to a holding tank located in the on-Site secure support zone for later characterization and off-Site disposal. Generated waste disposal is discussed below in Section 3.6.

3.1.3 Monitoring Well Location and Elevation Survey

On January 15, 2015, Clough Harbor Associates (CHA) surveyed the aerial location and elevation of monitoring well clusters LVRR-43 and LVRR-44 with UMC oversight. Appendix B contains a copy of the LVRR-43 and LVRR-44 survey data provided to UMC by CHA including the northing and easting location of each well, the ground surface elevation, top of steel casing elevation, and top of PVC elevation of each well. Table 1 of this Addendum 1 Report updates Table 1 of the 2014 RIR to include clusters LVRR-43 and LVRR-44. The table also summarizes all NYSDEC and LVRR monitoring well cluster construction and elevation details, total boring depths, and screened stratigraphic intervals.

3.2 GROUNDWATER SAMPLING PROCEDURES AND ANALYSES

3.2.1 September/October 2014 Groundwater Sampling Event

Consistent with Addendum 7 to the Remedial Investigation Work Plan, between September 9 and October 14, 2014, UMC collected groundwater samples from all Site monitoring well clusters, with the exception of the LVRR-43 and LVRR-44 well clusters which had not yet been installed, and submitted the samples to ALS Environmental (ALS), Rochester, New York for selected analyses. Prior to sampling, UMC collected depth to groundwater data from the wells using an electronic water level meter. The wells were then purged and groundwater samples were collected from the conventional monitoring wells via low-flow sampling procedures consistent with UMC's standard operating procedure (SOP) 1-36. Site Flexible Liner Underground Technology (FLUTe) multilevel systems (MLS) wells were purged and sampled consistent with the procedures outlined by FLUTe. These procedures are discussed in detail in the 2014 RIR which contains copies of the Site Quality Assurance Project Plan (QAPP) and UMC's SOPs.

Following purging, UMC measured the dissolved oxygen (DO), turbidity, oxidation reduction potential (ORP), temperature, pH, and specific conductance of the stabilized well water using a multi-parameter meter. In addition, the concentrations of carbon dioxide (CO_2) and ferrous iron in the groundwater were measured using field test kits.

Following the collection of field parameter data and stabilization of wells, UMC collected groundwater samples from the wells in laboratory supplied containers and submitted the samples to ALS for selected analyses. The samples were collected and analyzed consistent with protocols established by the USEPA in Seminars on Monitored Natural Attenuation for Groundwater (Reference 27 of the 2014 RIR) and in the USEPA's Technical Protocol for Evaluating Natural Attenuation of Chlorinated Solvents in Groundwater (Reference 26 of the 2014 RIR). The analyses included VOC analysis by USEPA Method 8260 and select MNA parameters as follows:

- General chemistry analyses including: alkalinity by Standard Method 2320B; ammonia by USEPA Method 350.1; biological oxygen demand (BOD) by Standard Method 5210B; total organic carbon

(TOC) by Standard Method 5310C; chemical oxygen demand (COD) by USEPA Method 410.4; chloride, nitrate, nitrite, and sulfate by USEPA Method 300.0; total hardness by Standard Method 2340C; oil and grease by USEPA Method 1664A; total phosphorous by USEPA Method 365.1; and, total sulfide by Standard Method 4500-S2-F.

- Dissolved gas analyses including methane, ethane, and ethene by ALS laboratory SOP VOC-RSK-175Mod.
- Metals analyses including calcium, manganese, total iron and potassium by USEPA Method 6010.
- Microtoxicity analysis by ASTM D5660.
- Standard plate count analysis by Standards Method 9215B.

Following receipt of the September/October 2014 groundwater sampling event analytical results from ALS, UMC forwarded the data to Trillium, Inc. (Trillium), located in Downington, Pennsylvania for third party data validation. Appendix C of this Addendum 1 Report contains copies of validated laboratory reports for the September/October 2014 MNA sampling event provided to UMC by Trillium. Table 2 of this Addendum 1 Report summarizes the September/October 2014 groundwater sample analytical results which are discussed below in Section 4.1.1.1.

3.2.2 November 2014 and January 2015 Groundwater Sampling Events

Prior to the installation of the LVRR-43 and LVRR-44 clusters, between November 12 and 14, 2014, UMC collected groundwater samples from the DC-06, LVRR-20, and LVRR-37 clusters (Figure 2) and submitted the samples to ALS for landfill parameter analyses consistent with New York Codes, Rules and Regulations (NYCRR) Part 360-2. Specifically, the landfill parameter analyses included: total Kjeldahl nitrogen (TKN) by USEPA Method 351.2; total dissolved solids (TDS) by Standard Method 2540; total iron, lead, potassium, and sodium by USEPA Method 6010C, and total chloride, bromide, and sulfate by USEPA Method 300.0. In addition, because copper sulfate had historically been detected in domestic well water samples collected in the area, total copper analysis by USEPA Method 6010C was added to the landfill parameter list.

In addition, between January 13 and 15, 2015, UMC collected groundwater samples from the newly installed monitoring well clusters LVRR-43 and LVRR-44 and from well clusters DC-06 and LVRR-37 and submitted the samples to ALS for the same MNA and landfill parameter analyses as listed above.

Monitoring well clusters DC-06, LVRR-37, LVRR-43, and LVRR-44 all consist of conventional-style monitoring wells. Therefore, UMC collected the November 2014 and January 2015 groundwater samples using low-flow sampling methods consistent with UMC's SOP 1-36.

Following receipt of the November 2014 and January 2015 groundwater sample analytical results from ALS, UMC forwarded the data to Trillium for third party data validation. Appendix C of this Addendum 1 Report contains copies of validated laboratory reports for the November 2014 and January 2015 groundwater sampling events provided to UMC by Trillium. Table 3 of this Addendum 1 Report summarizes the November 2014 and January 2015 groundwater sample results pertinent to landfill and MNA parameter analyses. The January 2015 MNA-related analytical results are discussed below in Section 4.1.1.2, while the November 2014 and January 2015 landfill-related analytical results are discussed below in Section 4.1.2.

3.2.3 September/October 2015 Groundwater Sampling Event

Consistent with the Final MNA Work Plan, during the September/October 2015 groundwater sampling event groundwater samples were collected from monitoring well clusters located in the following general areas: Spill Area; downgradient of the Spill Area generally along the TCE plume axis; along the northern and southern edges of the TCE plume; in the vicinity of the TCE plume discharge area; and, up gradient of the Spill Area. Figure 2 and other applicable figures depict the TCE plume discharge area, generally defined as the Spring Creek Fault Zone at the hydraulically down-gradient eastern-most end of the TCE plume. The following table lists the clusters sampled in each area with the number of wells associated with each cluster in parentheses.

Up Gradient of Spill Area	**Spill Area**	**TCE Plume Axis**	**North Edge of TCE Plume**	**South Edge of TCE Plume**	**Discharge Area**
LVRR-18 (5)	DC-01 (4)	LVRR-30 (5)	LVRR-23 (1)	LVRR-27 (5)	LVRR-24 (3)
	LVRR-35 (5)	LVRR-33 (5)	LVRR-37 (4)	LVRR-31 (5)	LVRR-25 (3)
		GCM (3)			

The September/October 2015 groundwater samples were submitted for the following analyses:

- VOC analysis by EPA Method 8260;
- Low-level dissolved gas analyses including methane, ethane, ethene consistent with low level RSK-175;
- Low level acetylene, CO_2, nitrogen (N) and oxygen analyses consistent with AM-20Gax;
- Compound Specific Isotope Analysis (CSIA) via gas chromatograph isotope ratio mass spectrometer (GC-IRMS) with the GC-IRMS operated to measure carbon isotope ratios in the target VOCs (TCE, cDCE, VC);
- Anion analyses including nitrate, nitrite, and sulfate by EPA Method 9056 and cation analyses including ferric iron, ferrous iron, and manganese by laboratory SOP-WC 20, Revision 12.0;
- TOC analysis by EPA Method 9060A; and,
- Dissolved organic carbon (DOC) analysis by Standard Method 5310C-2011

The VOC target analyte list is presented in the Uniform Federal Policy for Quality Assurance Project Plans (UFP QAPP) submitted to the USEPA on October 13, 2014 and approved by the USEPA in a letter dated December 16, 2014. The target analyte lists for the CSIA, AM-20Gax, cations and anions, and RSK-175 analyses are presented on Worksheet 15 (Appendix A of the Final MNA Work Plan).

The groundwater samples were analyzed for the dissolved gases methane, ethane, and ethene according to the low-level RSK-175 method. The laboratory SOP for the method is presented in Appendix B of the Final MNA Work Plan. This analysis is able to produce lower reporting limits than the standard RSK-175 analysis.

The groundwater samples were analyzed for acetylene, CO_2, N and oxygen according to the AM-20Gax method. This method allows for lower reporting limits needed for these constituents. The laboratory SOP for the AM-20Gax method is presented in Appendix B of the Final MNA Work Plan.

The CSIA measures the ratio of carbon 13 to carbon 12 in each groundwater sample. The results were compared to the VOC analytical results to assess potential for degradation occurrence and rates for TCE, cis 1,2-dichloroethene (cDCE) and vinyl chloride (VC). There is currently no analytical method for CSIA that has been approved by USEPA; however, the selected method follows USEPA's guidance (A Guide for Assessing Biodegradation and Source Identification of Organic Groundwater Contaminants using Compound Specific Isotope Analysis, EPA 600/R-08/148) presented in Appendix B of the Final MNA Work Plan.

The groundwater samples were analyzed for cations and anions including nitrate, nitrite, sulfate, sulfide, ferric iron, ferrous iron, and manganese to characterize the chemical and biological degradative processes. The laboratory SOPs for these analyses are presented in Appendix B of the Final MNA Work Plan.

The groundwater samples were analyzed for TOC and DOC to assess available carbon and potential use in the DFN modeling sensitivity analyses. The laboratory SOP for TOC is presented in Appendix B of the Final MNA Work Plan. Consistent with the SOP, DOC samples were filtered in the field prior to collection by attaching a 0.45 micron filter on the sample tubing and then pouring the sample directly into the laboratory-supplied container.

Consistent with the Final MNA Work Plan, the sampling method employed during the September/October 2015 groundwater sampling event was dependent on the well type and the analysis to be conducted. Groundwater samples collected from FLUTe MLS (LVRR-18, -27, -30, -31, and -35) were collected following recommended FLUTe sampling procedures (http://www.flut.com/WaterProcedures/water_procedure.html) while groundwater samples collected from the conventional monitoring wells were collected using Snap Samplers and low-flow sampling methods consistent with UMC's SOP 1-36. Snap Samplers were used to collect the dissolved-gas samples, which allows the vials to be closed downhole and avoid volatile losses, while low-flow sampling methods were used to collect samples for all other analyses and to obtain in-field stabilized aquifer parameters using a multiparameter meter and flow cell including DO, conductivity, temperature, ORP, pH, and turbidity.

The Snap Sampler method allows samples to be collected in-situ with no exposure to the atmosphere. The method consists of attaching the sample containers to the Snap Sampler device, lowering the device into the well, and closing of the sample containers while down well following a suitable equilibration time. The Snap Sampler SOP is included in Appendix D of the Final MNA Work Plan and is also available at http://www.snapsampler.com/About-The-Snap-Sampler. Consistent with the USEPA-approved Final MNA Work Plan, the Snap Samplers were installed for an approximately three day residence time prior to closing and retrieving the vials to allow for formation equilibrium in each well after completion of low-flow purging and sampling for other parameters.

Groundwater samples collected during the September/October 2015 sampling event were collected in laboratory-supplied containers, packed in coolers with ice, and transported under chain-of-custody to ALS for the selected analyses. ALS in turn subcontracted Pace Analytical Energy Services, LLC (Pace) located in Pittsburgh, Pennsylvania for the low level dissolved gas, CSIA, cation, anion, DOC, TOC, and AM-20Gax analyses.

Following receipt of the September/October 2015 groundwater sampling event analytical results from ALS and Pace, UMC forwarded the data to Trillium for third party data validation. Appendix C contains copies of the validated laboratory reports for the September/October 2015 groundwater sampling event provided to UMC by Trillium. Table 4 summarizes the September/October 2015 groundwater sampling event results which are discussed below in Section 4.1.1.3.

3.2.4 November 2014 Groundwater and Surface Water Sampling Event

As discussed above, on the night of Saturday November 1, 2014 a fire occurred at the CRC facility. According to the CRC website, the facility, which was leased to and operated by Land-O-Lakes, was the region's largest dairy feed manufacturing facility and dry fertilizer distribution center. News reports of the fire stated that fire fighters used over 1,000,000 gallons of water to extinguish the fire.

Consistent with the November 4, 2015 Work Plan, between November 11 and 13, 2014, UMC collected groundwater samples from the DC-14, GCM, LVRR-25, and LVRR-31 monitoring well clusters. In addition, UMC collected a surface water sample from a spring located at MacKay Park at the south end of Spring Street. Figure 2 depicts the location of the CRC facility and the nearby groundwater and surface water sampling points. LVRR-31 is located hydraulically up gradient of the CRC facility while DC-14, GCM, LVRR-25, and the MacKay Park spring are located generally downgradient or side gradient of the facility.

Groundwater samples from FLUTe MLS LVRR-31 were collected consistent with FLUTe sampling procedures, while groundwater samples collected from conventional monitoring well clusters DC-14, GCM, and LVRR-25 were collected using low-flow sampling methods consistent with UMC’s SOP 1-36. The surface water sample collected from the MacKay Park spring was collected as a grab sample by filling laboratory-supplied containers directly from the spring.

In conjunction with the November 2014 groundwater and surface water sampling, UMC collected groundwater elevation data from transducers installed in Site monitoring well clusters, including the DC-14, GCM, and LVRR-25 clusters, and from a transducer installed in Spring Creek. UMC analyzed the transducer data to assess if infiltration of the fire mitigation water resulted in noticeable changes in groundwater elevation in the vicinity of the CRC facility.

The November 2014 groundwater and surface water samples were collected in laboratory-supplied containers, packed in coolers with ice, and transported under chain-of-custody to ALS for VOC analysis by EPA Method 8260, and select general chemistry analyses including phosphorus by EPA Method 365.1, ammonia by EPA Method 35.1, and nitrate, nitrite, and chloride by EPA Method 300.0.

Following receipt of the November 2014 groundwater sample analytical results from ALS, UMC forwarded the data to Trillium for third party data validation. Appendix C of this Addendum 1 Report contains copies of the validated laboratory reports for the November 2014 groundwater sampling event provided to UMC by Trillium. Table 5 of this Addendum 1 Report summarizes the November 2014 fire-related groundwater and surface water sample analytical results which are discussed below in Section 4.1.3.

3.3 MAGNETIC SUSCEPTIBILITY TESTING PROCEDURES

On November 18 and 19, 2015, UMC conducted magnetic susceptibility screening of the bedrock core samples collected during UMC's RI activities in 2010. The bedrock cores evaluated for magnetic susceptibility have been stored in the onsite secured staging area since 2010. The core samples were collected from borings LVRR-33, LVRR-35, and LVRR-36, conducted to total depths of 160 feet, 180 feet, and 65 feet bgs, respectively.

The magnetic susceptibility testing was conducted using a handheld KT-20 Magnetic Susceptibility and Conductivity Meter made by Terraplus of Richmond Hill, Ontario, Canada. A SOP for use of the KT-20 meter has not been prepared by the manufacturer; however, the user's guide provides instructions on the operation of the instrument which were followed by UMC, and is provided in Appendix C of the Final MNA Work Plan.

The KT-10 utilizes a 10 kilohertz (kHz) LC oscillator with an inductive coil to measure the magnetic susceptibility. The susceptibility is calculated from the oscillator frequency difference between that of the sample and free air measurements. Thus the meter is operated using a three step method: 1) the oscillator frequency is measured in free air, holding the meter away from the sample to be tested, 2) the oscillator frequency is then measured when the meter is placed on or passed over a sample, 3) finally, the oscillator frequency is measured again in free air and the results are displayed. The results are displayed as the magnetic susceptibility of the sample relative to its volume, expressed as a dimensionless proportionality constant indicating the degree of magnetization of the sample in response to the magnetic field applied by the meter. Positive readings indicate a paramagnetic condition where the magnetic field in the sample is strengthened by the magnetic field applied by the meter. Alternatively, negative readings indicate a diamagnetic condition where the magnetic field in the sample is weakened by the magnetic field applied by the meter. Generally, non-magnetic minerals such as calcite, the major mineral in the limestones typical of Site bedrock, are said to be para- or diamagnetic because they do not possess permanent magnetization without the influence of an external magnetic field. Ferromagnetic minerals such as magnetite have a positive susceptibility and possess permanent magnetization, even without the influence of an external magnetic field.

UMC operated the meter in scan mode allowing for continuous measurements to be collected along each core run. UMC laid each five foot section of bedrock core on a wooden plank held above a table with concrete blocks. UMC held the meter at a height of approximately one inch above the core and scanned each section of core with the meter at a rate of approximately eight seconds per foot. Following completion of the scanning, UMC downloaded the raw data from the meter and generated graphs depicting the magnetic susceptibility of the bedrock core collected from each boring. UMC then superimposed the stratigraphic changes on the graphs based on historical RI boring observations and geophysical testing results presented in the 2014 RIR. Appendix D of this Addendum 1 Report contains the bedrock core magnetic susceptibility graphs prepared by UMC. A discussion of the magnetic susceptibility testing results is presented below in Section 4.2.

3.4 TRANSDUCER INSTALLATION PROCEDURES

In an email correspondence from UMC to the USEPA dated August 1, 2014, UMC proposed the installation of additional groundwater transducers in select Site monitoring wells and Spring Creek to continually record changes in groundwater and surface water elevations. Data collected from new and previously installed transducers would allow for a comprehensive assessment of the impact of precipitation and snow melt events on the Study area groundwater and surface water elevation fluctuations, vertical hydraulic gradients, and contaminant migration. UMC received USEPA approval to install the additional transducers on August 26, 2014.

3.4.1 New Transducer Installation

During the September/October 2014 MNA sampling event, UMC installed new transducers in groundwater monitoring well clusters DC-05, LVRR-25, LVRR-33, LVRR-38, LVRR-39, LVRR-40 and GCM. Additionally, one transducer was installed in Spring Creek on the NYSDEC's Fish Hatchery Property downstream (north) of groundwater monitoring well cluster LVRR-24.

For data consistency and as described in Section 4.9.1.2.3.1.1 of the 2014 RIR, UMC installed/re-installed all Solinst Levelogger transducers at predetermined depths in conventional groundwater monitoring wells using direct read transducer cables. The direct read cables allow UMC to collect groundwater elevation data from the transducers without removing the transducer from the well. The cables minimize the chance of unintended changes in transducer depth or of losing a transducer down-well caused by the tangling or breaking of the nylon strings which were previously used.

In addition, barometric transducers are used for barometric compensation of the groundwater elevation data obtained from the Solinst Levelogger transducers. UMC installed an in-situ BaroTroll barometric transducer in 2011 and a Solinst Barologger barometric transducer adjacent to the Site trailer in October 2014 for the collection of barometric pressure data, which was subsequently used for compensation of all downhole transducer datasets.

The transducer installations, and subsequent data collection and interpretation were conducted in accordance with Task 2 of the Addendum 7 work plan.

Figure 3 indicates the monitoring well clusters where transducers have historically been installed. The transducers are set to record raw groundwater elevation readings every 15 minutes. To date, transducers have been installed in the following groundwater monitoring wells / clusters / multilevel wells:

- DC-01A/B/C/D (DC-01A is lost down-well)
- DC-05A/B/C/D
- DC-13A/B
- DC-14A/B
- LVRR-24A/B/C
- LVRR-25A/B/C
- LVRR-30-1/2/3/4/5 (FLUTe multilevel well)
- LVRR-32-1/2/3/4/5 (FLUTe multilevel well)
- LVRR-33A/B/C/D/E
- LVRR-38A/B/C
- LVRR-39A/B/C
- LVRR-40A/B/C
- GCM-1/2/3

3.4.2 Transducer Data Collection

Since the installation of the new transducers in October 2014, UMC has downloaded data from the Site transducers periodically. Data was collected from the transducers following the instructions given by each transducer's manufacturer. A discussion of the transducer data processing, results, and interpretation is included below in Section 4.3.

3.5 DISCRETE FRACTURE NETWORK (DFN) NUMERICAL MODELING

The DFN model addresses key questions relative to the degree of plume attenuation due to matrix diffusion and other processes, as well as the magnitude and longevity of back diffusion effects from the rock matrix and timeframes to meet the MCLs. In general, the modeling consists of screening-level or 'stylistic' DFN flow and transport model incorporating Site parameters and data to the extent possible, using a 2-dimensional steady state flow and transient contaminant transport DFN numerical model (FRACTRAN), based on Sudicky and McLaren (1992) (Reference 52), that incorporates matrix diffusion and other relevant processes, but requires simplifications of the fracture network and flow system. The model simulations are process-based in that the matrix diffusion and other key processes are included; however, it is recognized that this screening level modeling with steady state flow cannot incorporate the full complexity of the Site flow system, the simulations were informed by site measured parameters and incorporate the key processes that control contaminant transport in a dual porosity system. This includes rapid groundwater flow in a system of interconnected fractures, with diffusion between fractures and the rock matrix, which has much higher porosity than the bulk fracture porosity and provides a significant reservoir for contaminant mass storage as dissolved and sorbed phase.

Therefore, simulations required several assumptions and simplifications given the complexity of the actual flow system conditions. Some of the uncertainties in the model simulations and potential ranges of behavior are addressed through sensitivity analyses. The DFN model scenarios include, but are not limited to, the following:

- Current conditions, no further remedial action;
- Complete removal of mass from the unsaturated source zone; and
- Complete source removal from both the vadose and saturated zones.

It is important to note that the latter two modeling scenarios represent hypothetical scenarios, in that such actions / conditions may not be a realistic possibility (i.e. complete source removal) given the Site conditions and practical limitations to remedial technologies in fractured bedrock systems. The modeling report is attached as Appendix E to this Addendum 1 Report.

3.6 INVESTIGATION DERVIED WASTE

UMC investigation activities completed as part of this Addendum 1 report generated solid and liquid wastes. This section discusses the generation, handling, and disposal of Addendum 1 investigation derived wastes (IDW).

As discussed in above sections, approximately 150 gallons of groundwater IDW were generated during the development of monitoring well clusters LVRR-43 and LVRR-44; and 250 gallons was generated during the September/October 2014 groundwater sampling event due to the purging of wells. During both events, the groundwater IDW was transferred to a holding tank located in the on-Site secure support zone for waste characterization analysis and ultimate disposal.

On December 13, 2014, UMC collected a sample of the holding tank IDW and submitted the sample to ALS for VOC analysis by EPA Method 8260. Laboratory analysis of the IDW sample did not detect VOCs in concentrations exceeding NYSDEC SCGs. Following receipt of the IDW sample analytical report from ALS, UMC discharged the contents of the holding tank onto the ground surface adjacent to the staging area. Appendix C of this Addendum 1 Report contains a copy of the waste water sample laboratory report provided to UMC by ALS. One 55 gallon drum of waste water was also generated from the cleaning of the holding tank used to house liquid IDW (discussed below). Currently, the holding tank within the on-Site secure support zone is approximately half full and contains groundwater IDW generated during the November 2014, January 2015, September/October 2015, and the November 2015 groundwater sampling events.

In addition to the groundwater IDW, soil IDW was generated during the advancement of the LVRR-43 and LVRR-44 borings/wells. NDI transferred the rock cuttings generated during boring advancement to 55 gallon drums which were in turn transported to the on-Site secure support zone for temporary storage. A total of 13 drums of cuttings were generated during the monitoring well cluster LVRR-43 and LVRR-44 installations. On December 18, 2014, UMC collected one grab sample of rock cuttings from each of the 13 drums, composited the 13 grab samples into one composite sample, and submitted the sample to ALS for analyses as required by Wayne Disposal, Inc. (WDI), Site #2 Landfill, located in Belleville, Michigan. These analyses included total VOC and toxic characteristic leaching procedure (TCLP) vinyl chloride analysis and semi-VOC (SVOC) analysis by EPA Methods 8260 and 8270, respectively, total and amenable cyanide analysis by EPA Method 9012, reactive cyanide and sulfide analysis by EPA Methods 9014 and 9034, respectively, TCLP arsenic, barium, cadmium, chromium, lead, selenium, and silver analysis by EPA Method 9010, and TCLP mercury analysis by EPA Method 7470. Laboratory analysis of the composite rock cutting sample detected analytes in concentration ranges acceptable for soil IDW disposal at the WDI facility. Appendix C contains a copy of the rock cutting sample laboratory report provided to UMC by ALS. On April 7, 2015, EQ Industrial Services located in Ypsilanti, Michigan transported the 13 drums of rock cuttings, as well as, one 55 gallon drum of waste water that had been generated during cleaning of the holding tank, to the WDI facility, arriving at the facility on April 16, 2015. The IDW was transported under waste manifest, tracking number 014480015 JJK, naming LVRR as the waste generator. Appendix C contains a copy of the waste manifest.

4 RESULTS

4.1 GROUNDWATER SAMPLING EVENT RESULTS AND DISCUSSION

UMC conducted the following groundwater sampling events as part of this Addendum 1 Report:

September/October 2014 for MNA;

- November 2014 for fire-related parameters;
- November 2014 for landfill parameters prior to the installation of LVRR-43 and LVRR-44;
- January 2015 for MNA and landfill parameter analyses including LVRR-43 and LVRR-44; and,
- September/October 2015 for supplemental MNA sampling.

For discussion purposes, the results from each groundwater sampling event is presented and discussed in accordance with its intended purpose; i.e., MNA-Related Parameter Groundwater Results (Section 4.1.1), Landfill-Related Parameter Groundwater Results (Section 4.1.2), and Fire-Related Parameter Groundwater and Surface Water Results (Section 4.1.3).

4.1.1 MNA-Related Parameter Groundwater Results

The LVRR 2014 RIR concluded that reductive dechlorination processes may be occurring on a very limited scale in isolated areas of the Study Area, but that these processes are not a significant factor in mitigating TCE groundwater impacts below MCLs within a reasonable timeframe. However, as modeling simulations in the DFN modeling report (Appendix E) suggest, even slow rates of degradation can play an important role in long-term plume attenuation when combined with matrix diffusion processes.

In an effort to obtain additional information regarding the various MNA processes, UMC conducted additional MNA investigations in 2014 and 2015. In accordance with Task 1 of the Addendum 7 Work Plan, UMC conducted additional MNA sampling in September/October 2014, including sampling of conventional monitoring wells / clusters, and FLUTe multilevel wells, in order to provide a more comprehensive assessment of Site groundwater geochemical conditions as they relate to potential for reductive dechlorination and other attenuation processes. In accordance with Task 4 of the Addendum 7 Work Plan, UMC conducted additional MNA sampling in January 2015, including sampling of newly installed monitoring well clusters LVRR-43 and LVRR-44, located hydraulically downgradient (i.e. east) of the former Town of LeRoy landfill in order to assess hydro-geochemical conditions and delineate the TCE plume north-northeast of the Spill Area.

In addition, upon completion of the Addendum 7 Work Plan activities (groundwater sampling and additional MNA) conducted in September/October 2014, UMC performed supplemental MNA sampling of select monitoring wells in accordance with the Final MNA Workplan during September/October 2015. The supplemental MNA activities were intended to provide additional information on field evidence of the potential for abiotic and/or biological degradation. Effects of slow degradation were also examined conceptually in the DFN numerical modeling.

The MNA sampling consisted of field stabilization parameters recorded during sample collection and laboratory sample analysis for dissolved gases, anions and cations, general chemistry, microbiology, and CSIA. The results of the MNA sampling provide a picture of the aquifer and its ability to degrade TCE.

The following subsections present a summary of MNA related groundwater sampling data from 2010 – 2015, as well as, the presentation of Addendum 1 MNA groundwater sampling analytical results collected from the September/October 2014, January 2015 and September/October 2015 sampling events. MNA Groundwater Sampling Summary 2010 – 2015.

4.1.1.1 MNA Summary 2010 – 2015

The following subsections present a summary of MNA related groundwater sampling data from 2010 – 2015, as well as, the presentation of Addendum 1 MNA groundwater sampling analytical results collected from the September/October 2014, January 2015 and September/October 2015 sampling events.

4.1.1.1.1 Summary of Volatile Organic Compounds

The 2010 – 2015 VOC data indicates that the overall aerial and vertical extent of Study Area TCE-impacted groundwater has been delineated. Further, although historical groundwater quality data indicates that the overall TCE impacts to groundwater have declined over time, a comparison of the 2014-2015 concentrations to historically generated TCE iso-concentration maps indicates that the overall shape and aerial extent of the TCE plume has remained relatively stable between these sampling events and earlier sampling events conducted by NYSDEC in the 1993-1995 timeframe. Figure 5 depicts the highest TCE concentration detected in groundwater samples collected from each of the Study Area monitoring well clusters during the September/October 2014, January 2015, or September/October 2015 sampling events, regardless of the bedrock unit. Figures 5A through 5D depict the highest TCE concentration detected during those events in groundwater samples collected from Study Area monitoring wells screened in the Onondaga, Bertie, Camillus, and Syracuse Formations, respectively. The figures also depict TCE iso-concentration contours depicting the overall aerial extent of groundwater contamination in the Study Area containing dissolved phase TCE in concentrations exceeding the SCG of 5 µg/L. UMC concludes that the overall stability of the TCE plume is the result of conditions that act to control the lateral dispersion of the plume and eventual discharge of TCE-impacted groundwater to Spring Creek.

4.1.1.1.2 Summary of Field Stabilization Parameters

The field stabilization parameters, as measured with the multi-meter used during low-flow sampling, were plotted along the plume axis (plume longsect) by distance from the Spill Area. The plume axis was selected as this is the area where degradation of TCE would be of the most value. Evaluating the field stabilization parameters showed that dissolved oxygen (DO) and oxygen/reduction potential (ORP) provided the most useful data to illustrate the changes in chemistry along the plume axis. Graphs of these data are presented in Appendix F.

Graph 10 shows the DO trends for the different sampling events. The DO trend for the December 2010 – January 2011 sampling event was different than the trends for the August/November 2013, September/October 2014 and September/October 2015 sampling events. The DO during the December 2010 – January 2011 sampling event showed more variability than during the other events. A possible reason is the time of the year the sampling was performed. Review of the transducer data shows that there are fewer large fluctuations of the water table during the late summer and early fall, whereas there are more fluctuations of the water table during the late fall and winter. Higher infiltration of oxygenated water entered the system resulting in differences in the DO recorded during the December 2010 – January 2011 sampling event. However, it should be noted that the time of the year with the highest TCE concentrations is generally during the fall.

The DO trends show that the DO concentrations are higher in the Spill Area and down gradient portions of the plume than in the mid-plume at Lime Rock Road (LVRR-33). A possible explanation is the presence of sink holes near the Spill Area and along the southern boundary of the plume, through which fresh oxygen rich water enters the system whereas there are no sink holes present near LVRR-33. Review of the SWAT model results, discussed in detail in Section 4.3 below, reveals that large amounts of fresh water enter the aquifer in the vicinity of the Spill Area and along the southern boundary of the plume and then move eastward but little fresh water enters the aquifer in the mid-plume area.

The ORP parameters were also plotted along the plume longsect (Graph 11) for the same sampling events as the DO. The ORP, unlike the DO, show similar trends along the plume axis for all sampling events. The ORP levels are positive in the Spill Area to Church Road and again in the down gradient portion of the plume. However, along Lime Rock Road (LVRR-33) the ORP is negative. This is a similar pattern to the DO concentration trends and the explanation for it is fresh water entering the aquifer near the Spill Area and in the down gradient portion of the plume but not near LVRR-33.

4.1.1.1.3 Summary of Dissolved Gases

Dissolved gas results were evaluated to identify the gas whose results were most useful to draw conclusions on the potential degradation of TCE; the gases selected were carbon dioxide and methane. As with the field stabilization parameters discussed above, the results were from sampling events performed during December 2010 - January 2011, August/November 2013, September/October 2014, and September/October 2015. The results were plotted on graphs which are presented in Appendix F.

Methane concentrations were plotted on Graph 12. Methane showed variation in only the September/October 2014 sampling event in the up gradient well (DC-04) and the mid-plume well on Lime Rock Road (LVRR-33). The methane in the LVRR-33 well exceeded 250 mg/L. This methane trend appears to be opposite the DO and ORP trends, indicating that the influx of fresh water in the Spill Area and down gradient portions of the plume also affect the methane. The less fresh water in the mid-plume area may allow for methane production during certain times of the year.

The carbon dioxide results, plotted on Graph 13, showed variation but the trends were not consistent between events. With the exception of the December 2010/January 2011 event, the carbon dioxide levels were elevated at the Spill Area. Only in the August/November 2013 did the carbon dioxide increase in the mid-plume area. It decreased during the September/October 2015 event.

4.1.1.1.4 Summary of Anions and Cations

Anions and cations were evaluated for the presence of electron acceptors. The constituents that showed the most useful trends were manganese, ferrous iron, nitrate, and sulfate. As with the field stabilization parameters discussed above, the results were from sampling events performed during December 2010 - January 2011, August/November 2013, September/October 2014, and September/October 2015. The results were plotted on graphs which are presented in Appendix F.

The manganese concentration trends are plotted on Graph 14. The manganese trends for the December 2010 - January 2011 sampling event is low at the Spill Area and down gradient portion of the plume but elevated in the mid-plume area. The September/October 2014 is similar but higher in the up gradient (DC-04) and down gradient (LVRR-24) sections. The August/November 2013 and September/October 2015 exhibited no trends.

The ferrous iron trends are plotted on Graph 15. Ferrous iron trends showed some similarities to the manganese trends, high levels in the mid-plume well (LVRR-33) and lower levels in the Spill Area and down gradient areas. The trend for the December 2010 - January 2011 and September/October 2014 sampling events follow the manganese trends the other sampling events do not. The August/November 2013 sampling event has no trend and the September/October 2015 event has elevated iron at the mid-plume area, unlike the manganese.

The nitrate trends are plotted on Graph 16. Nitrate trends are similar for the December 2010 - January 2011, August/November 2013, September/October 2014 sampling events, low levels in the up gradient, Spill Area and mid-plume with slightly higher in the down gradient wells. However, the September/October 2015 event exhibited different results. During this event, nitrate was high in the Spill Area and down gradient wells and low in mid-plume. Although the concentrations were different, from mid-plume to the discharge area the pattern for each sampling event was consistent.

The sulfate trends are plotted on Graph 17. Sulfate trends were plotted on a graph for the four sampling events to evaluate the potential effects of sulfate on the degradation of TCE. During the first sampling event, December 2010 - January 2011, sulfate was high in the Spill Area but decreased down gradient, suggesting potential sulfate reduction down gradient of the Spill Area. During August/November 2013, sulfate was low in the Spill Area and down gradient portion but higher in the mid-plume. This pattern is similar to that observed for other parameters and may be a result of fresh water entering the aquifer up gradient and along the southern plume boundary. The last two sampling events, September/October of 2014 and 2015, exhibited the same pattern with low sulfate concentrations.

4.1.1.1.5 Summary of Organic Carbon

Organic carbon was analyzed for during each sampling round. The results were plotted on Graph 18 to identify any potential trends. The total organic carbon concentrations decreased down gradient of the mid-plume area. In the up gradient, Spill Area and the mid-plume area no repeatable trends were identified.

4.1.1.1.6 Summary of CSIA

CSIA was only analyzed during the last sampling event; therefore no temporal trends can be assessed.

In support of the above summary, the following sections and subsections present the results of the Addendum 1 MNA groundwater sampling events.

4.1.1.2 **September/October 2014 MNA Parameter Groundwater Analytical Results and Discussion**

UMC completed the September/October 2014 MNA sampling between September 29 and October 16, 2014. UMC collected groundwater MNA samples utilizing low-flow and or FLUTe sampling protocols from monitoring wells DC-01 through 07R; DC-09 through 17; LVRR-18; LVRR 20 through 42; and, GCM-1, 2, and 3. Due to dry well conditions samples were not collected from several shallow wells in the well clusters and shallow FLUTe multilevel ports, including DC-04-A; DC-07R-A; DC-10-A; LVRR 20-1,2, and 3; LVRR-21-4; LVRR-26-3; LVRR-27-1 and 4; LVR-29-4 and 5; LVRR-30-1 and 3; LVRR-31-2 and3; LVRR-32-1 and 5; LVRR-34-3; LVRR-37-A. During the September/October 2014 MNA sampling event groundwater samples were analyzed for in field low-flow well stabilization parameters (pH, conductivity, temperature, ORP, and turbidity). In addition, groundwater samples were submitted to ALS Laboratory for the analysis of VOCs, dissolved gasses, anions, cations, metals, and general chemistry parameters. The September/October 2014 MNA groundwater sample locations are illustrated on Figure 5 and Figures 5A through 5D and analytical results are summarized on Table 2.

4.1.1.2.1 Field Stabilization Parameters

Prior to the collection of groundwater samples for off-Site laboratory analysis, the wells were purged and stabilized. The well stabilization parameters were analyzed in the field using a multiparameter meter for pH, temperature, conductivity, turbidity, and ORP. The groundwater pH ranged from 2.27 pH Units in LVRR-32-4 (only location below 5 pH units) to 13.06 pH Units in LVRR-28-2 with an average pH of 7.26 for the 123 groundwater samples analyzed. Temperature ranged from 7.98 degrees Celsius (°C) in LVRR-34-2 to 22.11 °C in DC-06-C with an average of 11.41 °C for the 123 groundwater samples analyzed. Conductivity ranged from 0.030 millisiemens per centimeter (mS/cm) in DC-10-C to 26.10 mS/cm in LVRR-28-4 with an average of 1.43 mS/cm for the 123 groundwater samples analyzed. Turbidity was measured at 0.0 nephelometric turbidity units (NTU) in 63 of 123 groundwater samples analyzed. Turbidity measurements above 0.0 NTU ranged from 0.2 NTU in DC-03-D to 996 NTU in LVRR-30-4 with an average of 44.22 NTU for the 123 groundwater samples analyzed. ORP (uncorrected field values) ranged from -319 millivolts (mV) in LVR-33-A to +243 mV in DC-16 with an average of +75.1 mV for the 123 groundwater samples analyzed.

4.1.1.2.2 Volatile Organic Compounds

As indicated on Table 2, TCE and TCE degradation products including cis 1,2-DCE and VC were occasionally detected at concentration levels (or estimated concentration levels) exceeding the SCG for TCE and cis 1,2-DCE of 5 µg/L and the SCG for VC of 2 µg/L. The TCE degradation product analytical results are consistent with historical results. In addition to the primary Site contaminants of concern (TCE and degradation products), other VOCs not related to the Site contaminants of concern were detected and are also presented within Table 2.

Table 6 summarizes the historical concentrations of TCE detected in Site groundwater since the November 1993 sampling event, and updates Table 17 of UMC's 2014 RIR. As noted on Table 6, for the purpose of assessing mean concentrations, a concentration equaling the laboratory reporting limit was conservatively assumed for non-detect results. TCE concentrations reported in the September/October 2014 groundwater samples are generally within the same order of magnitude as those reported in previous sampling events. TCE concentrations remain highest in monitoring wells located in the Spill Area and screened in the Onondaga and Bertie Formations. A notable exception is the TCE concentration of 66 µg/L observed in monitoring well DC-15B, screened in the Syracuse Formation. TCE concentrations detected in groundwater samples collected from DC-15B previous to the September/October 2014 event had not exceeded the SCG of 5 µg/L since the December 2010 sampling event. TCE concentrations decrease steadily down gradient of the Spill Area and near the discharge zone at Spring Creek. TCE concentrations remain at levels below laboratory detection limits in well clusters located east of Spring Creek, suggesting Spring Creek is the final plume discharge / termination area.

4.1.1.2.3 Dissolved Gasses

During the September/October 2014 sampling event, the groundwater samples were analyzed for the dissolved gasses ethane, ethene, methane, DO, CO_2, propane, and propene.

Ethane was detected in 17 groundwater samples ranging from the estimated concentration (J) of 0.20 µg/L in LVRR-26-2 to 4.3 µg/L in LVRR-18-4. Ethene was detected in two groundwater samples both at estimated concentrations of 0.26 µg/L in LVRR-32-3 and 0.39 µg/L in LVRR-25-C, respectfully. Ethene is a potential end product of TCE dechlorination reactions. Methane was detected in 75 groundwater samples ranging from the estimated concentration of 0.22 µg/L in DC-01-A to 270 µg/L in LVRR-33-A. Dissolved Oxygen (DO) was detected in 91 groundwater samples ranging in concentration from 0.02 milligrams per liter (mg/L) in DC-02-A to 8.00 mg/L in DC-06-A. Carbon Dioxide was detected in 112 groundwater samples at concentrations ranging from 5 mg/L in four locations (LVRR-20-2, LVRR-26-2, LVRR-26-4, and LVRR-28-4) to 150 mg/L in DC-05-A.

4.1.1.2.4 Anions and Cations

The groundwater samples collected during the September/October 2014 event were analyzed for various anions and cations to evaluate attenuation.

4.1.1.2.4.1 Anions

The following anions were analyzed during the September/October 2014 event: Sulfate, Sulfide, Nitrate, Nitrite, Nitrate plus Nitrite, Ammonia as N, Chloride, and Phosphorous. Sulfate was detected in 118 groundwater samples ranging in concentration from 17.9 mg/L in LVRR-21-1 to 1630 mg/L in DC-09-C. Sulfide was detected in 28 groundwater samples ranging from the estimated concentration of 0.18J mg/L in DC-17-A and LVRR-39-B to 2.8 mg/L in LVRR-18-4. Nitrate was detected in 65 groundwater samples ranging from the estimated concentration of 0.2J mg/L in LVRR-35-1 to 11.3 mg/L in DC-12-A. Nitrite was not detected in any groundwater samples above laboratory detection limits. Nitrate plus nitrite was detected in 65 groundwater samples ranging in concentration from 0.0021 mg/L in DC-01-D to 6.74 mg/L in DC-12-A. Ammonia as Nitrogen was detected in 65 groundwater samples ranging from an estimated concentration of 0.006 mg/L in GCM-2 to 1.39 mg/L in LVRR-27-5. Chloride was detected in 128 groundwater samples ranging in concentration from 4.3 mg/L in DC-02-A to 188 mg/L in LVRR-29-1. Phosphorous was detected in 53 groundwater samples ranging in concentration from 0.0032 in LVRR-31-4 to 0.206 mg/L in LVRR-42-A.

4.1.1.2.4.2 Cations

The following cations were analyzed during the September/October 2014 event: ferrous iron, manganese, calcium, potassium, and hardness. Ferrous iron was measured as 0.0 mg/L in 72 of 116 groundwater samples analyzed. Ferrous iron concentrations above 0.0 mg/L ranged from 0.1 mg/L in 14 groundwater samples to 10 mg/L in LVRR-23. Manganese was detected in 57 groundwater samples ranging from an estimated concentration of 2.2J µg/L in DC-01-C to 859 µg/L in LVRR-18-4. Calcium was detected in 116 groundwater samples ranging in concentration from 39,300 µg/L in LVRR-20-4 to 600,000 µg/L in LVR-39-C. Potassium was detected in 98 groundwater samples ranging from the estimated concentration of 1,080 µg/L in DC-03-A to 1,830,000 µg/L in LVRR-28-2. Hardness ranged from 211 µg/L in LVRR-32-3 to 1,750 µg/L in DC-07R-D.

4.1.1.2.5 Microbiological

UMC collected groundwater samples for microtoxicity and standard plate count microbiological analysis during the September/October 2014 event. Microtoxicity was measured as >100 the 20% inhibitory concentration (IC_{20}) for all 117 groundwater samples analyzed. Standard Plate Count analysis was conducted on 95 groundwater samples three groundwater samples (LVRR-31-5, LVRR-20-2, and LVRR-18-1) detected <1 CFU/ml., the remainder ranged in concentration from 3 colony forming units per milliliter (CFU/ml) in LVRR-18-2 to >5700 CFU/ml in 38 locations.

4.1.1.2.6 General Chemistry

The groundwater samples collected during the September/October 2014 event were analyzed for various general chemistry parameters including, alkalinity, BOD, TOC, COD, and oil and grease. Alkalinity was analyzed in 117 groundwater samples ranging from 158 mg/L in LVRR-32-3 to 411 mg/L in DC-02-A. BOD was measurable in 12 groundwater samples ranging from 2.1 mg/L in GCM-3 to 17.4 in LVRR-35-4. TOC was detected in 76 groundwater samples ranging from an estimated concentration of 0.7 mg/L in LVRR-42-B to 103 mg/L in LVRR-37-C. COD was measured in 8 groundwater samples ranging from 6.2 mg/L in LVRR-21-1 to 19.9 mg/L in LVRR-33-A. Oil and Grease was not detected in any groundwater samples above laboratory reporting limits.

4.1.1.2.7 MNA Parameter Scoring – September/October 2014

UMC analyzed the September/October 2014 groundwater sample analytical results for each monitoring well sampled using the USEPA Technical Protocol MNA screening process which assigns a score to each MNA parameter result for a given sample. The individual parameter scores are then summed resulting in a total score for each sample, which provides an indication as to whether or not there is adequate evidence that anaerobic biodegradation is occurring. A total score of 0 to 5 represents inadequate evidence, 6 to 15 represents limited evidence, 16 to 20 represents adequate evidence, and over 20 represents strong evidence that anaerobic biodegradation is occurring.

Table 7A summarizes MNA parameter scoring for the September/October 2014 groundwater sampling event. Note that monitoring well clusters LVRR-43 and 44 had not been installed at this time. The MNA parameter scoring for these clusters is presented on Table 7B which reflects the results of MNA sampling conducted during the January 2015 sampling event (discussed below in Section 4.1.1.2).

The September/October 2014 MNA parameter scoring results indicate there is generally inadequate or limited evidence that anaerobic biodegradation processes are occurring in Spill Area monitoring well clusters and in clusters down gradient of the Spill Area to Spring Creek. Table 7D compares the September/October 2014 MNA parameter scoring results to the scoring results obtained during historical MNA parameter sampling events including those conducted in 2010 and 2013 and summarized in the 2014 RIR as well as the more recent events conducted in January 2015 and September/October 2015. As indicated on Table 7D, the September/October 2015 MNA parameter scoring results are generally consistent with those obtained during historical MNA parameter sampling events, indicating that there is inadequate or limited evidence that anaerobic biodegradation processes are occurring at the Site.

In summary, the detection of TCE degradation products including cis 1,2-DCE and VC in groundwater samples collected during the September/October 2014 sampling event, and the MNA parameter scoring for the event, suggest that degradation of TCE is occurring to a limited degree in portions of the Site from the Spill Area to the distal portion of the TCE plume at Spring Creek. However, the overall RI findings indicate that the primary mechanisms for the TCE concentration reductions historically observed both in the Spill Area and down gradient of the Spill Area are matrix diffusion, dilution and dispersion, augmented by the rapid infiltration of surface water (through sinkholes) and the movement of groundwater primarily through the fractures and solution cavities that characterize the karstic bedrock conditions prevalent at the Site.

4.1.1.3 **January 2015 MNA Parameter Groundwater Analytical Results and Discussion**

Table 3 summarizes the MNA and landfill parameter analytical results for groundwater samples collected from monitoring well clusters DC-06, LVRR-20, LVRR-37, LVRR-43, and LVRR-44 during the November 2014 and January 2015 sampling event. A total of 14 groundwater samples were collected during the January 2015 event including a duplicate sample collected form well LVRR-37C for QA/QC purposes. UMC notes that all the cluster LVRR-20 wells as well as wells LVRR-37A, LVRR-43A, and LVRR-44A were dry during the January 2015 event and no groundwater samples were collected from the wells. The November 2014 and January 2015 event landfill parameter analytical results are discussed below in Section 4.1.2. A discussion of the January 2015 event MNA parameter analytical results follows.

4.1.1.3.1 Field Stabilization Parameters

Prior to the collection of groundwater samples for off-Site laboratory analysis, the wells were purged and stabilized. The well stabilization parameters were analyzed in the field for pH, temperature, conductivity, turbidity, and ORP. The groundwater pH ranged from 6.90 pH Units in LVRR-44B to 9.01 pH Units in LVRR-44D with an average pH of 7.51 for the 13 groundwater samples analyzed. Temperature ranged from 2.45 °C in DC-06A to 12.89 °C in LVRR-37C with an average of 7.86 °C for the 13 groundwater samples analyzed. Conductivity ranged from 0.454 mS/cm in DC-06A to 2.170 mS/cm in DC-06D with an average of 1.058 for the 13 groundwater samples analyzed. Turbidity was measured at 0.0 NTU in 10 of 13 groundwater samples analyzed. Turbidity measurements above 0.0 NTU ranged from 0.3 NTU in DC-06C to 194 NTU in LVRR-43C with an average of 16.02 NTU for the 13 groundwater samples analyzed. ORP ranged from -79 mV in LVR-37D to +162 mV in DC-6A with an average of +65.3 mV for the 13 groundwater samples analyzed.

4.1.1.3.2 Volatile Organic Compounds

As indicated on Table 3, analysis of the groundwater samples collected from monitoring wells DC-06A, DC-06B, LVRR-37B, and LVRR-37C detected TCE at concentrations of 130 µg/L, 740 µg/L, 23 µg/L, and 45 µg/L, respectively, exceeding the SCG for TCE of 5 µg/L. TCE was detected in analysis of the groundwater sample collected from DC-06C at a concentration of 3 µg/L, which does not exceed the SCG for TCE of 5 µg/L. Laboratory analysis of groundwater samples collected from the newly installed LVRR-43 and LVRR-44 well clusters did not detect TCE at concentrations exceeding the laboratory reporting limits for that analyte of 0.22 µg/L.

The TCE degradation product cis 1,2-DCE was detected in analysis of groundwater sample DC-06B at a concentration of 240 µg/L, exceeding the SCG for that analyte of 5 µg/L. Cis 1,2-DCE was also detected in groundwater samples collected from DC-06A and LVRR-37C at estimated concentrations of 0.48 µg/L and 0.42 µg/L, respectively, that do not exceed the SCG for that analyte. The TCE degradation product trans 1,2-DCE was detected in analysis of groundwater sample DC-06B at an estimated concentration of 3.7 µg/L which does not exceed the SCG for that analyte of 5 µg/L. Laboratory analysis of groundwater samples collected from the newly installed LVRR-43 and LVRR-44 well clusters did not detect TCE degradation products at concentrations exceeding their respective laboratory reporting limits.

The chlorinated solvent-related VOC 1,1-DCA was detected at a concentration of 2.2 µg/L in groundwater sample LVRR-44C and at an estimated concentration of 0.32 µg/L in ground water sample LVRR-44B. Chloroethane was detected at an estimated concentration of 0.37 µg/L in sample LVRR-44C. 1,1-DCA and chloroethane have not been detected in other groundwater samples historically collected at the Site. Further, 1,1-DCA and chloroethane occur as degradation products of trichloroethane (TCA) but not TCE.

As indicated on Table 6, TCE concentrations reported in the January 2015 groundwater samples collected from monitoring well clusters DC-06 and LVRR-37 are generally within the same order of magnitude as those reported in previous sampling events. The monitoring well cluster LVRR-43 and LVRR-44 TCE concentrations listed on Table 6 (not sampled prior to the January 2015 event) reflect the laboratory reporting limit of 0.22 µg/L.

4.1.1.3.3 Dissolved Gasses

During the January 2015 sampling event, the 14 groundwater samples collected were analyzed for the dissolved gasses ethane, ethylene, methane, DO, CO_2, propane, and propene. Ethane was detected in analysis of groundwater samples LVRR-43C and LVRR-44B at concentrations of 1.1 µg/L and 5.7 µg/L, respectively. Ethylene was detected in analysis of groundwater sample LVRR-44B at an estimated concentration of 0.30 µg/L. Methane was detected in analysis of nine of the 14 groundwater samples at concentrations or estimated concentrations ranging from 0.28 µg/L in LVRR-44C to 8.7 µg/L in LVRR-44B. Dissolved oxygen was detected in analysis of three of the 13 groundwater samples at concentrations ranging from 1.42 µg/L in LVRR-44B to 3.30 µg/L in LVRR-37B. The groundwater and duplicate samples collected from LVRR-37C were not analyzed for CO_2. CO_2 was detected in analysis of the remaining samples at concentrations ranging from 10 µg/L in DC-06A to 75 µg/L in DC-06D. Propane was detected in analysis groundwater sample LVRR-44B at a concentration of 5.5 µg/L and at an estimated concentration of 0.54 µg/L in sample LVRR-43C. Propene was not detected in analysis of the January 2015 event groundwater samples in concentrations exceeding laboratory reporting limits.

4.1.1.3.4 Anions and Cations

The groundwater samples collected during the January 2015 event were analyzed for various anions and cations to evaluate attenuation.

4.1.1.3.4.1 Anions

The following anions and chemical parameters were analyzed during the January 2015 event: sulfate, sulfide, nitrate, nitrite, TKN, ammonia as N, chloride, phosphorous, COD, and hardness.

Sulfate was detected in all of the 14 groundwater samples at concentrations ranging from 13.2 mg/L in DC-06A to 1,280 mg/L in DC-06D. Sulfide was not detected in any of the 14 groundwater samples in concentrations exceeding the laboratory reporting limits ranging from 0.98 mg/L to 1.0 mg/L. Nitrate was detected in eight of the 14 groundwater samples ranging from an estimated concentration of 0.30 mg/L in LVRR-37C to a concentration of 3 mg/L in DC-06A. Nitrite was not detected in any of the 14 groundwater samples at concentrations exceeding the laboratory reporting limit of 1.0 mg/L. TKN was detected in eight of the 14 groundwater samples at concentrations or estimated concentrations ranging from 0.18 mg/L in LVRR-44C to 0.31 mg/L in DC-06A. Ammonia as N was detected in four of the 14 groundwater samples ranging from an estimated concentration of 0.103 mg/L in LVRR-37D to a concentration of 0.181 mg/L in DC-06C. Chloride was detected in all of the 14 groundwater samples at concentrations ranging from 6.6 mg/L in LVRR-44C to 338 mg/L in LVRR-43B. Phosphorous was detected only in groundwater samples DC-06A and LVRR-44C at concentrations of 0.0287 mg/L and 0.0127 mg/L, respectively. COD was detected in five of the 14 groundwater samples ranging from an estimated concentration of 5.9 mg/L in DC-06A to a concentration of 23.6 mg/L in LVRR-44B. Hardness ranged from 204 mg/L in DC-06A to 1,550 mg/L in DC-06D.

4.1.1.3.4.2 Cations

The following cations were analyzed during the January 2015 sampling event: calcium, copper, iron, potassium, manganese, sodium, and lead. Copper and lead were not detected in any of the 14 groundwater samples at concentrations exceeding laboratory reporting limits. Calcium was detected in all of the 14 groundwater samples at concentrations ranging from 350,000 µg/L in LVRR-37D to 67,700 µg/L in DC-06A. Iron was detected in nine of the 14 groundwater samples at concentrations or estimated concentrations ranging from 27.2 µg/L in LVRR-37C to 927 µg/L in LVRR-37D. Potassium was detected in all of the 14 groundwater samples at concentrations or estimated concentrations ranging from 1,080 µg/L in LVRR-44C to 3,040 µg/L in DC-06C. Manganese was detected in seven of the 14 groundwater samples at concentrations or estimated concentrations ranging from 10.2 µg/L in LVRR-43B to 88.3 µg/L in LVRR-

44C. Sodium was detected in all of the 14 groundwater samples at concentrations ranging from 7,060 µg/L in LVRR-44C to 175,000 µg/L in LVRR-43B.

4.1.1.3.5 General Chemistry

The 14 groundwater samples collected during the January 2015 event were analyzed for various general chemistry parameters including, alkalinity, BOD, bromide, TDS, TOC, and oil and grease. Alkalinity was detected in all of the 14 groundwater samples ranging at concentrations ranging from 183 mg/L in DC-06D to 311 mg/L in LVRR-43D. BOD was detected only in sample LVRR-44B at a concentration of 4.2 mg/L. Bromide was not detected in any of the 14 groundwater samples at concentrations exceeding laboratory reporting limits. The groundwater samples collected from monitoring well cluster LVRR-44 were not analyzed for TDS. TDS was detected in all of the remaining groundwater samples at concentrations ranging from 259 mg/L in DC-06A to 2,180 in DC-06D. TOC was detected in all of the 14 groundwater samples ranging from an estimated concentration of 0.90 mg/L in LVRR-44D to a concentration of 9.55 mg/L in DC-06A. Oil and grease was not detected in any of the 14 groundwater samples in concentrations exceeding the laboratory reporting limits of 4.7 mg/L or 4.8 mg/L.

4.1.1.3.6 Microbiological

UMC submitted the January 2015 event groundwater samples for microtoxicity and standard plate count microbiological analysis and the results are presented in Appendix C. Microtoxicity was measured at concentrations exceeding 100 IC_{20} for all of the 14 groundwater samples analyzed. Standard plate count concentrations were reported in all of the 14 groundwater samples ranging from a concentration of 4 CFU/ml in DC-06A to estimated concentrations exceeding 5,700 CFU/ml in samples DC-06B, DC-05D, LVRR-37C, LVRR-37D, LVRR-43C, and LVRR-44B, C, and D.

4.1.1.3.7 MNA Parameter Scoring – January 2015 Sampling Event

UMC assessed the January 2015 groundwater sample analytical results for the monitoring wells sampled using the USEPA Technical Protocol MNA screening process as described above in Section 4.1.1.1.7. Table 7B summarizes MNA parameter scoring for the January 2015 groundwater sampling event. Table 7D compares the January 2015 MNA parameter scoring results with those observed during historical MNA sampling events. A summary of the January 2015 groundwater sample MNA parameter scoring results and a comparison of the results with historical scoring results follows.

As indicated on Table 7B, the January 2015 MNA parameter scoring results indicate there is inadequate evidence that anaerobic biodegradation processes are occurring in the vicinity of well clusters DC-06, and LVRR-37. As indicated on Table 7D, these results are generally consistent with scoring results for these clusters observed during historical MNA sampling events, ranging from inadequate to limited evidence.

As indicated on Tables 7B and 7D, MNA parameter scoring results for groundwater samples collected from the LVRR-43 and LVRR-44 well clusters (not sampled prior to or since the January 2015 event) generally indicate there is inadequate evidence that anaerobic biodegradation processes are occurring in the vicinity of these well clusters. The exception is the limited evidence scoring result observed at LVRR-44C.

In summary, the concentrations or estimated concentrations of the TCE degradation products cis 1,2-DCE and trans 1,2-DCE reported in one or more groundwater samples collected from DC-06 and LVRR-37 monitoring wells during the January 2015 sampling event, and the MNA parameter scoring results for those samples, suggest that degradation of TCE is occurring to a limited degree in the vicinity of the wells.

Conversely, the non-detect TCE and TCE degradation product analytical results reported in LVRR-43 and LVRR-44 groundwater samples indicates that the horizontal and vertical limits of the TCE plume north-northeast of the Spill Area has been effectively delineated.

However, the concentrations or estimated concentrations of the chlorinated solvent-related VOCs 1,1-DCA and chloroethane reported in one or more groundwater samples collected from the LVRR-43 and LVRR-44 monitoring well clusters indicates that the groundwater in the vicinity of the wells may be impacted by historical disposal activities at the former Town of LeRoy landfill. The November 2014 and January 2015 groundwater sampling event results relating to potential impacts from the landfill are discussed further below in Section 4.1.2.

4.1.1.4 **September/October 2015 MNA Parameter Groundwater Analytical Results and Discussion**

The September/October 2015 MNA parameter groundwater sampling event included the collection of groundwater samples from monitoring well clusters DC-01, GCM, LVRR-18, LVRR-23, LVRR-24, LVRR-25, LVRR-27, LVRR-30, LVRR-31, LVRR-33, LVRR-35, and LVRR-37. Table 4 summarizes the results of the September/October 2015 MNA parameter groundwater sampling event. As indicated on Table 4, wells LVRR-18-5, LVRR-27-3, LVRR-27-4, LVRR-27-5, LVRR-30-3, LVRR-31-2, LVRR-35-5, and LVRR-37A were dry at the time of sampling and no groundwater samples were collected from the wells. A summary of the MNA parameter results reported in the remaining wells follows.

4.1.1.4.1 Field Stabilization Parameters

Prior to the collection of groundwater samples for off-site laboratory analysis, the wells were purged and stabilized. The well stabilization parameters were analyzed in the field for DO, pH, temperature, conductivity, turbidity, and ORP. The groundwater DO ranged from 0.00 in 10 of the 40 groundwater samples analyzed to 8.52 mg/L in LVRR-35-1 with an average DO of 2.69 mg/L. The groundwater pH ranged from 5.83 pH Units in LVRR-33E to 7.82 pH Units in LVRR-33A with an average pH of 6.81 for the 40 groundwater samples analyzed. Temperature ranged from 6.97 °C in LVRR-35-4 to 15.04 °C in LVRR-31-1 with an average of 10.42 °C for the 40 groundwater samples analyzed. Conductivity ranged from 0.468 mS/cm in GCM-3 to 2.64 mS/cm in DC-01D with an average of 1.120 for the 40 groundwater samples analyzed. Turbidity was measured at 0.0 NTU in 15 of the 40 groundwater samples analyzed. Turbidity measurements above 0.0 NTU ranged from 0.4 NTU in LVRR-33E to 1,000 NTU in LVRR-37C with an average of 95.82 NTU for the 40 groundwater samples analyzed. ORP ranged from -158 mV in LVR-23 to 276 mV in DC-01B with an average of 64.76 mV for the 40 groundwater samples analyzed.

4.1.1.4.2 Volatile Organic Compounds

Table 6 compares TCE concentrations reported during historical groundwater sampling events with those reported during the September/October 2015 sampling event. TCE concentrations were highest in the Spill Area with a maximum TCE concentration of 12,000 µg/L reported in sample DC-01A. TCE concentrations generally decreased down gradient of the Spill Area, reaching double or single digit concentrations or non-detect levels in the vicinity of Spring Creek. Groundwater samples were not collected from well clusters located east of Spring Creek during the September/October 2015 sampling event. The TCE concentrations detected in the September/October 2015 groundwater samples are consistent with those reported in historical sampling events.

As indicated on Table 4, chlorinated solvent-related VOCs including 1,1 dichloroethylene (1,1-DCE), cis 1,2-DCE, trans 1,2-DCE, and VC were detected in the September/October 2015 event groundwater samples at concentrations or estimated concentrations exceeding their respective SCGs.

4.1.1.4.3 Dissolved Gasses

Dissolved gases were analyzed in samples collected from the monitoring wells to identify trends that may be suggestive of degradation of TCE. The gases measured by AM-20Gax include dissolved oxygen (DO), carbon dioxide (CO_2), nitrogen (N), and acetylene while gases measured by low-level RSK-175 include methane, ethane, ethene, propane, propene, iso-butane, and n-butane.

4.1.1.4.3.1 Low Level AM-20Gax Dissolved Gases

As indicated on Table 4, acetylene was not detected in concentrations exceeding laboratory reporting limits during the September/October 2015 sampling event. Carbon dioxide was detected in 36 of the 39 groundwater samples tested in concentrations ranging from 6.10 mg/L in LVRR-30-4 to 83 mg/L in LVRR-35-1. Oxygen was detected in 38 of the 39 groundwater samples tested in concentrations or estimated concentrations ranging from 0.82 mg/L in LVRR-30-1 to 7.80 mg/L in LVRR-30-2. Nitrogen was detected in 37 of the 39 groundwater samples tested in concentrations or estimated concentrations ranging from 19 mg/L in LVRR-35-1, LVRR-37B, and DC-01A to 37 mg/L in LVRR-18-3.

The dissolved gas concentrations for both the low-level RSK-175 and Am-20Gax were plotted along the plume axis and in transects along Church Road and at mid-plume. Graph 1 illustrates the concentrations along the plume axis. This graph shows that CO2 was low up gradient of the Spill Area and increased sharply at the Spill Area followed by a decrease down gradient. On the other hand, methane increased at Lime Rock Road but was low both up gradient and down gradient of Lime Rock Road. The other detected gases showed no appreciable changes along the plume axis.

The dissolved gas concentrations were plotted vertically for each sample location to identify any trends with depth throughout the aquifer. The up gradient well, LVRR-18, has decreasing concentrations of CO_2 and increasing levels of nitrogen with depth. In the Spill Area, DC-01 and LVRR-35, CO_2 decreases with depth and the concentrations of the other gases are consistent with depth. The nitrogen levels in the up gradient well are considerably higher than those in the Spill Area. At the Church Road transect, the dissolved gas concentrations are consistent with depth at LVRR-30. However, the deepest level shows an increase in nitrogen and methane. At the north end of the Church Road transect in LVRR-37, CO_2 decreases with depth while nitrogen and methane increase. In the central area of the plume (LVRR-33), methane and CO_2 increase slightly with depth while nitrogen increases significantly. At depth, the nitrogen levels have returned to those reported in the up gradient well (LVRR-18). In the mid-plume transect, the nitrogen levels in both LVRR-31 and GCM are at the same levels as those reported for LVRR-18. For LVRR-31, at the south end of the plume transect, methane and CO_2 decrease with depth while nitrogen increases with depth. At GCM, the concentrations are consistent with depth. The furthest down gradient well, LVRR-24, methane increases in concentration with depth while the other gases are consistent in concentration. In LVRR-18, nitrogen increases with depth. Generally, the CO_2 levels are higher in the Spill Area than in wells outside of that area.

4.1.1.4.3.2 Low Level RSK-175 Dissolved Gases

As indicated on Table 4, propene, iso-butane, and n-butane were not detected in concentrations exceeding laboratory reporting limits during the September/October 2015 sampling event. Ethane and propane were detected in groundwater sample LVRR-27-2 at estimated concentrations of 0.43 µg/L and 0.21 µg/L, respectively. Ethylene was detected in groundwater sample LVRR-33D at a concentration of 0.32 µg/L. Methane was detected in 22 of the 39 groundwater samples tested in concentrations or estimated concentrations ranging from 0.59 µg/L in LVRR-35-3 to 120 µg/L in LVRR-23.

Along the Church Road transect, ethene and propane exhibited little variation. Methane decreased from 6.6 µg/L at the south end of the transect to 3.5 µg/L at the north end of the transect. Oxygen increased from 2.8 mg/L at the southern end of the transect to about 4.8 mg/L at the north end. Nitrogen was high at both the south and north ends of the transect (32 mg/L at both ends) while it was 25 mg/L in the center of the transect. CO_2 was low at the south end (8.3 mg/L) and increased to 20 mg/L at the center and north end of the transect. At the mid-plume transect, ethene and propane were not detected. Methane was high at the south end (52 µg/l) and north end (120 µg/L) but low in the center (not detected). Oxygen was low at both the south and north ends of the transect, below 5 mg/L. Nitrogen decreased from south to north and CO_2 increased from south to north.

4.1.1.4.4 Cations and Anions

As indicated on Table 4, nitrite and manganese were not detected in concentrations exceeding laboratory reporting limits during the September/October 2015 sampling event. UMC did not submit the September/October 2015 event groundwater samples for sulfide analysis. However, as indicated on Table 2, analysis of groundwater samples collected during the September/October 2014 event detected sulfide in 28 of the 120 samples tested, at concentrations or estimated concentrations ranging from 0.18 µg/L in LVRR-38C and DC-17A to 5.89 µg/L, in LVRR-33A with an overall average concentration of 0.67 µg/L. Nitrite was detected in 22 of the 39 groundwater samples tested in concentrations or estimated concentrations ranging from 0.72 µg/L in LVRR-30-4 to 15 µg/L in DC-01A. Sulfate was detected in 39 of the 39 groundwater samples tested in concentrations or estimated concentrations ranging from 48 µg/L in DC-01A to 1,400 µg/L in LVRR-25C, LVRR-30-5, and DC-01D. Ferric iron was detected in 3 of the 39 groundwater samples tested in concentrations or estimated concentrations ranging from 0.58 µg/L in LVRR-31-4 to 1.6 µg/L in LVRR-23. Ferrous iron was detected in 3 of the 39 groundwater samples tested in concentrations or estimated concentrations ranging from 0.61 µg/L in LVRR-33A to 6.3 µg/L in LVRR-23.

Electron acceptors, such as ferrous iron, manganese, ferric iron, nitrate, sulfate, and oxygen, were analyzed to determine if attenuation of TCE is occurring within the plume. As there were only two detections of ferric iron, it was determined to not be a contributing factor to degradation of TCE at the Site. Graph 2 illustrates the electron acceptors with distance along the centerline of the plume. This plot shows that sulfate and nitrate have the largest changes over distance. Both have high concentrations near the Spill Zone, decrease down gradient of the Spill Zone and then increase again near Spring Creek. At the Church Road transect, only nitrate and sulfate were detected. The nitrate concentration was low near the center of the plume and high at the edges (north and south edges) whereas the sulfate showed the opposite pattern. At the mid-plume transect, the sulfate was high at the plume edges and low in the plume center. This pattern was also exhibited by ferric and ferrous iron. On the other hand, nitrate was high at the south edge and center of the plume and low at the north edge of the plume.

The electron acceptors were plotted by depth for each sampling location on Graphs 3a-3k. The up gradient sampling location, LVRR-18, exhibits generally consistent concentrations with depth for all indicators. In the Spill Area (DC-02 and LVRR-35), nitrate has a high concentration in the shallow sampling ports declining with depth, whereas sulfate exhibits the opposite pattern. The remaining indicators show a consistent concentration with depth. At the Church Road transect, samples were collected from only the top two sampling ports as the deeper ones were dry; therefore, trends cannot be ascertained. At LVRR-30, in the center of the transect and along the centerline of the plume axis, the nitrate is high in the top two sample ports and the bottom port with a lower level in the fourth port. No sample was collected from the third port. Sulfate had a low concentration in the top two ports with higher levels in the bottom two ports. The remaining analytes exhibited a consistent concentration with depth. At the north end of the Church Road transect (LVRR-37) only sulfate shows a change in concentration with depth. The top sampling level was dry, the middle two contained similar sulfate concentrations while the bottom one increased significantly. The other electron acceptors had consistent concentrations with depth. At the mid-plume transect, in both LVRR-31 and GCM nitrate decreased in concentration with depth while sulfate increased. However, both nitrate and sulfate were detected at higher concentrations in GCM than in LVRR-31. The other receptors were consistent with depth at both sampling locations. The down gradient LVRR-24 showed the same pattern as GCM but at much higher sulfate concentrations.

4.1.1.4.5 General Chemistry

TOC was detected in 14 of the 39 groundwater samples tested in concentrations or estimated concentrations ranging from 1.10 mg/L in LVRR-18-1 to 4.5 mg/L in LVRR-27-1. DOC was detected in 39 of the 39 groundwater samples tested in concentrations or estimated concentrations ranging from 1.10 mg/L in DC-01D to 23 mg/L in LVRR-27-1.

Graphs in Appendix F plot DOC levels along transects generally coincident with the plume axis, along Church Road, and across the mid-plume. The DOC levels along the plume axis show a marked increase at LVRR-33 of 17 mg/L, the other detections are all below 5 mg/L. The TOC levels are all less than 2 mg/L. Along the Church Road transect both the DOC and TOC levels are higher at the south end (LVRR-27), decrease in the center (LVRR-30), and increase slightly at the north end (LVRR-37). At the mid-plume transect, the DOC steadily increases from south to north but does not exceed 5 mg/L. The TOC is high at both the north and south ends and low in the center (GCM), but never exceeds 2 mg/L. With the exception of LVRR-33, there were no discernable vertical trends in either the DOC or TOC levels. At LVRR-33, the DOC levels increased with depth while TOC was only detected in the shallow well.

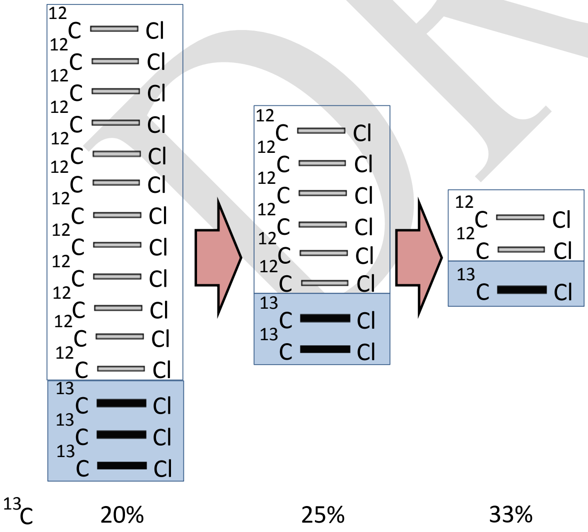
4.1.1.4.6 Compound Specific Isotope Analysis

As discussed above, UMC submitted groundwater samples for the analysis of CSIA to PACE analytical laboratory. The following descriptions of CSIA results and interpretations of Site specific data are summarized from the PACE analytical reports provided for reference in Appendix G.

In this study, the CSIA focused on measurement of the ratio of carbon 13 (^{13}C) to carbon 12 (^{12}C) in each groundwater sample, expressed relative to an internationally agreed upon standard for carbon (known as VPDB) in parts-per-thousand or ‰ notation. With this nomenclature, δ^{13}C is the delta or change of carbon, which is linearly related to the ^{13}C/^{12}C ratio. The September/October 2015 groundwater sampling event included a CSIA of TCE, cDCE, and VC detected in the samples. A given element contains a set number of protons and electrons. In the case of carbon there are six protons and six electrons. However, that element may have a variable number of neutrons, and because of the difference in the number of neutrons there is a difference in the mass of the element. In the case of carbon there are three different naturally occurring masses or isotopes, the stable ^{12}C, ^{13}C, and the radioactive ^{14}C. In CSIA only the stable isotopes are measured.

In a given compound, the isotopic composition is initially established when the compound is manufactured. It is a function of the isotopic composition of the raw materials; the chemical reactions employed in the manufacturing; any separation steps and the temperatures involved. This results in a particular isotopic composition unique to the particular chemical lot. Over time a stable process that has a constant source of raw materials and uses a very rigid manufacturing procedure may produce many lots with minimal variance in the isotopic procedure. However, that isotopic composition may change significantly if there is any small change in the manufacturing chain such as a raw material supplier now getting their raw materials from a different location. This makes CSIA an excellent tool for forensics (e.g. Lima et al., 2012) (Reference 53), but it must be remembered that a single source of VOC's can have varying isotopic composition over time. Since the release at LVRR was a one-time, sudden release of a product being shipped by rail, this is not likely to be relevant at the Site.

After manufacturing, the isotopic composition can be changed as the VOC's are used and as they are destroyed. It takes a little less energy to break a bond between a light isotope (^{12}C) and another atom than it takes to break a bond between a heavy isotope (^{13}C) and that same atom. This leads to slightly slower reaction rates for heavy isotopes compared to light isotopes, and this in turn leads to a pooling, or increased percentage of heavy isotopes in the reactants of a reaction that breaks a bond and a pooling of light isotopes in the products of that reaction. This is called isotopic fractionation. It should be kept in mind that while this effect is significant, reproducible, and measureable it is very small and the absolute number of light isotopes reacting is still much larger than the number of heavy isotopes reacting. In fact, the isotopic fractionation effect is so small that it would require a very large figure to illustrate that effect at scale. Accordingly, a somewhat exaggerated example of isotopic fractionation is shown for a carbon-chlorine (C-Cl) bond in Figure below.



In CSIA the ratio of $^{13}C/^{12}C$ (or "isotopic ratio") is measured in each of the individual compounds TCE, cDCE, and VC. This makes it possible to detect differences such as that exemplified in Figure A. Those differences can be from degradation or from different sources (as discussed briefly above).

Isotopic fractionation is most pronounced when chemical bonds are broken. Dilution, diffusion, and volatilization don't significantly change the original isotopic ratio of TCE, cDCE or VC in groundwater. For an isotopic ratio to significantly change, a bond must be broken. That means degradation of a compound is the only significant cause of increasing isotopic composition (delta's) for that compound.

4.1.1.4.6.1 CSIA Reporting

CSIA is a very sensitive technique. Much is learned through the observation of small changes in the isotopic ratio of an element. Because the differences in isotope ratios are so small, it is more convenient to express the ratios relative to some standard and in "per mil" (parts-per-thousand or ‰) notation. This is accomplished by using the "delta" formula. The standard is the isotopic ratio of an internationally agreed upon standard, $R_{std} = 0.01118$. The delta formula, in "per mil" is:

$$\delta_x = 1000\left(\frac{R_x - R_{std}}{R_{std}}\right)$$

where the R_x is the isotopic ratio of sample "x" and δ_x (called "delta" of sample "x") is linearly related to the isotopic ratio. Thus, if the $\delta^{13}C$ for a TCE sample is "-27 per mil", (a typical value for undegraded TCE) this means that the $^{13}C/^{12}C$ in the sample is 27 per mil, or 2.7 percent, lower than in the standard. It turns out that the internationally agreed upon standard for carbon (known as VPDB) has a very high isotopic ratio, so $\delta^{13}C$ is negative for nearly all carbon. A $\delta^{13}C$ = -27‰ is very different from a $\delta^{13}C$ = +27‰, but the important point is that they differ by 54 ‰, not that one is positive and one is negative. Hunkeler et al. (2008) (Reference 54) provides more information on use of CSIA data for assessing biodegradation and source identification.

As indicated on Table 4, the CSIA indicated average $\delta^{13}C$ for TCE, cDCE, and VC of -18.46 ‰, -22.73 ‰, and -31.14 ‰, respectively. The $\delta^{13}C$ for TCE ranged from -21.21 ‰ in DC-01A located in the Spill Area to -17.47 ‰ in LVRR-24A located in the down gradient end of the TCE plume at Spring Creek.

4.1.1.4.6.2 Isotopic Evidence

Isotopic evidence is evaluated using two methods: 1) plot the $^{\delta}13C$ (per mil) vs distance from the source along the plume axis, and 2) plot the TCE concentration on the x-axis and the $^{\delta}13C$ (per mil) plotted on the y-axis. As abiotic and/or biological degradation enriches ^{13}C relative to ^{12}C, the $^{13}C/^{12}C$ ratio can be plotted against the distance or TCE concentration.

Graph 5 presents the plot of $^{\delta}13C$ against distance, which shows $^{\delta}13C$ is lightest near the source area (DC-01) and progressively becomes heavier with distance down gradient with the heaviest at LVRR-24, the furthest down gradient well. This demonstrates that degradation of TCE is occurring along the plume flow path and is preferentially consuming the ^{12}C in the TCE. Removing the scatter of wells not located along the plume axis and plotting the results from the Spill Area to the discharge area (DC-01, LVRR-35, LVRR-30, LVRR-33, GCM, and LVRR-24), the trend is more pronounced. A linear trend line applied to this data has a fit of 62% and a logarithmic trend line has a 96% fit. As DNAPL may be present in the bedrock matrix of the Spill Area affecting the groundwater chemistry, DC-01 was removed from the plot and a linear trend line applied with a resulting fit of 86%. These graphs show that ^{12}C is greater in areas of the groundwater plume where the TCE concentration is highest and, as in the Spill Area, NAPL may still be present in the bedrock matrix above the water table.

Plotting the $^{\delta}13C$ against TCE concentration (Graph 6) shows that the ratio $^{\delta}13C$ extends from approximately -18 to -21 ‰, with the lower ratios at the higher TCE concentrations. The isotopic enrichment of $^{\delta}$13C ceases at about 50 µg/L of TCE. The rate of cleavage for ^{12}C is greater than ^{13}C resulting in enrichment of the heavier isotope in the remaining compound. The bulk enrichment factor (magnitude of isotope fractionation) has been reported to be in the range of -17.2 to -5.7 ‰ for microbial reduction. Abiotic degradation by FeS resulted in more negative bulk enrichment values than those produced by microbial degradation alone. Graph 6 shows that the bulk enrichment factor is more negative than what is expected from anaerobic degradation, suggesting that abiotic TCE degradation is likely occurring at the LVRR Site.

4.1.1.4.6.3 Rayleigh Equation

The Rayleigh Equation examines the isotopic fractionation over time. The Rayleigh equation is a plot of the $^{\delta}$13C (‰) to the natural logarithm of TCE. A straight line fit shows that a single biodegradation or abiotic transformation process likely controls the concentrations at field scale. Other processes, such as sorption, volatilization, dilution, dispersion and mixing with other contaminant sources would cause the data to fall off a straight line.

Graph 7 shows the Rayleigh Equation for the data collected at the Site. The line is a good fit for TCE concentrations above 50 µg/L. An enrichment factor was also calculated to show the amount of fractionation of the sample; the more negative the enrichment factor the more fractionation has occurred. The graph shows that fractionation of $^{\delta}$13C (‰) is occurring. However, the enrichment factor is less negative than what is expected from abiotic degradation.

CSIA detections were plotted for the sampled wells by depth and as transects along the centerline of the plume and transects across the plume to identify zones where degradation may be reducing the TCE. Where TCE, cDCE or VC were not detected there no $^{\delta}$13C value for that compound.

The CSIA data was plotted on longsects along the plume centerline, and along transects orthogonal to groundwater flow at Church Road and at mid-plume (Graphs 8a to 8c). No detections were reported for the up gradient well, LVRR-18 consequently there are no $^{\delta}$13C for LVRR-18. The $^{\delta}$13C values were markedly negative at the Spill Zone (LVRR-35 and DC-01) for TCE and cDCE, VC was not detected. Downgradient of the Spill Zone, the $^{\delta}$13C values for $^{\delta}$13C TCE value became less negative but remained above -17 ‰. cDCE downgradient of the Spill Zone became less negative by Church Road, east of that area cDCE was not detected. VC was not detected outside the Spill Zone. The Church Road transect VC was not detected in any of the wells and cDCE was not detected northern and southern wells. Along this transect the $^{\delta}$13C TCE value between -18‰ and -19‰ for the middle and northern wells but was not detected in the southern well. The $^{\delta}$13C cDCE value for the middle well was between -21‰ and -23‰. TCE was the only compound detected in samples collected from the mid-plume transect. The south and mid-transect sampling points (LVRR-31 and GCM, respectively) contained low $^{\delta}$13C TCE (-17‰ to -19‰) values whereas the northern point, LVRR-23, had no TCE reported.

The $^{\delta}$13C for TCE, cDCE, and VC were also plotted by depth for each well sampled, the Graphs (9a-9c) are presented in Appendix F. No detections of target VOCs were reported for the up gradient well, LVRR-18, therefore no graph was prepared for this well. The Spill Area well DC-01 did not contain VC. The $^{\delta}$13C TCE and cDCE plots show a generally consistent response with depth. LVRR-35, located just down gradient of the Spill Area, also shows the $^{\delta}$13C TCE is generally consistent with depth. However, the $^{\delta}$13C cDCE exhibits a more negative value in the shallow depth with less negative values to zero at the deepest sampling point, this is based on the cDCE concentrations declining with depth. This pattern indicates that degradation is greatest in the shallow parts of the aquifer and declines with depth.

Along the Church Road transect, only TCE was detected in the northern and southern sampling points LVRR-37 and LVRR-27, respectively, whereas TCE and cDCE were detected in LVRR-30 in the center of the transect. All three sampling locations have $^{\delta}$13C TCE being generally consistent in the upper sampling points with values between -15 and -20 ‰. However, samples from the deepest sampling point had $^{\delta}$13C values at zero because TCE was not detected in the deepest samples. The $^{\delta}$13C cDCE values in LVRR-30 mimicked the $^{\delta}$13C TCE values. In wells further down gradient, only TCE was detected. Along Lime Rock Road, $^{\delta}$13C TCE values were measured in the two middle sampling points but TCE concentrations in the shallow point and in the two deepest points were too low to allow CSIA determination. At GCM and LVRR-24, $^{\delta}$13C TCE values were measured in the two shallow points but not in the deep point where TCE concentrations were too also too low.

4.1.1.4.7 MNA Parameter Scoring – September/October 2015 Sampling Event

UMC assessed the September/October 2015 groundwater sample analytical results for the monitoring wells sampled using the USEPA Technical Protocol MNA screening process as described above in Section 4.1.1.1.7. Table 7C summarizes MNA parameter scoring for the September/October 2015 groundwater sampling event. Table 7D compares the September/October 2015 MNA parameter scoring results with those observed during historical MNA sampling events. A summary of the September/October 2015 groundwater sample MNA parameter scoring results and a comparison of the results with historical scoring results follows.

As indicated on Table 7C, the September/October 2015 MNA parameter scoring results indicate there is generally inadequate or limited evidence that anaerobic biodegradation processes are occurring in the vicinity of well clusters DC-01, GCM, LVRR-18, LVRR-23, LVR-24, LVRR-31, LVRR-33, LVRR-35, LVRR-37, LVRR-27, and LVRR-30. As indicated on Table 7D, these results are generally consistent with scoring results for these clusters observed during historical MNA sampling events.

In summary, the concentrations or estimated concentrations of TCE degradation products reported in the September/October 2015 groundwater samples, and the MNA parameter scoring results for those samples, suggest that degradation of TCE is occurring to a limited degree in portions of the Site from the Spill Area to the distal portion of the TCE plume at Spring Creek. However, as discussed above, the overall RI findings indicate that the primary mechanisms for the TCE concentration reductions historically observed both in the Spill Area and down gradient of the Spill Area are dilution and dispersion, augmented by the infiltration of surface water and the movement of groundwater primarily through the fractures and solution cavities that characterize the karstic bedrock conditions prevalent at the Site.

4.1.1.5 **MNA Groundwater Sampling Conclusions**

The MNA sampling revealed trends for a number of parameters. The trends for TOC, DO, ORP, Nitrate, Sulfate and CO2 in the Spill Area and just down gradient reveal no relation between subsequent sampling events for each constituent. In the mid-plume and discharge areas, the constituent trends are less variable than in the Spill Area. Additionally, in the mid-plume area (LVRR-33) the constituent concentrations are generally different than those from the Spill Area or the discharge area.

The LVRR 2014 RIR showed that a large influx of fresh water into the aquifer occurs near the Spill Area along Mud Creek which provides a continuing source of surface water with potentially different chemistry than the aquifer water into which it is infiltrating. This infiltrating surface water has a potential significant effect on the chemistry of the aquifer water, preventing the aquifer water chemistry from becoming anoxic with constantly changing cation and anion and dissolved gas levels. This prevents or limits the aquifer from establishing the reducing conditions necessary to allow a microbial population to thrive allowing for anaerobic degradation of CE.

The LVRR 2014 RIR also showed that large influxes of surface water are present along the southern boundary of the plume from Church Road eastward to Caledonia. The infiltrating surface water then flows through the aquifer eastward to discharge at Spring Creek. As with the Spill Area, this influx of fresh water prevents the chemistry of the aquifer from establishing a microbial population to allow for anaerobic degradation of the TCE.

However, surface water infiltration in the mid-plume area is significantly less than in the Spill Area or along the plume's southern boundary. Consequently, the aquifer chemistry is more amenable to anaerobic degradation in this area as can be seen in the differences in the chemistry in LVRR-33 which is not as affected by fresh water inputs.

In summary, the infiltration of large volumes of surface water have affected the aquifer in several locations to the degree that prevents or limits formation of the anaerobic conditions required for anaerobic degradation of TCE. . The trends of the constituents monitored during UMC's various sampling events identified the areas where surface water was infiltrating and altering the chemistry. Infiltration of surface water prevents degradation of TCE along common degradation pathways resulting in 'Inadequate' to 'Limited Attenuation' MNA scores. Figure 6 illustrates average MNA scoring from the 2010 through 2015 sampling events.

The following section discusses the evaluation of landfill related groundwater parameters sampled during the November 2014 and January 2015 events.

4.1.2 November 2014 and January 2015 Landfill-Related Parameter Groundwater Analytical Results and Discussion

Table 3 summarizes the November 2014 and January 2015 groundwater sample analytical results collected for assessment of landfill parameters. In November 2014, prior to the installation of the LVRR-43 and LVRR-44 well clusters, nine groundwater samples were collected from clusters DC-06, LVRR-20, and LVRR-37, including a duplicate sample collected from well LVRR-37C for QA/QC purposes. The groundwater samples collected in both November 2014 and January 2015 were submitted for analysis of the landfill-related parameters bromide, chloride, TKN, TDS, sulfate, copper, iron, potassium, sodium, and lead. Only the groundwater samples collected in January 2015, following installation of monitoring well clusters LVRR-43 and LVRR-44, were submitted for VOC analysis (summarized above in Section 4.1.1.2.2).

A discussion of the November 2014 groundwater sample analytical results with comparison to the overall January 2015 results relevant to the landfill parameter analyses (summarized above in Section 4.1.1.2) follows. Stabilized low flow field parameters observed in the November 2014 groundwater samples are comparable to those observed in January 2015. A notable exception is the ORP value of 118 mV observed in the groundwater sample collected from LVRR-37D in November 2014 as compared to the value of -79 mV observed in that sample in January 2015. Laboratory analysis of groundwater samples collected during both the November 2014 and January 2015 sampling events did not detect bromide in concentrations exceeding laboratory detection limits. Copper was not detected in the January 2015 groundwater samples at concentrations exceeding laboratory reporting limits but was detected in the November 2014 groundwater sample collected from LVRR-37C at a concentration of 28.7 µg/L. Lead was not detected in the January

2015 groundwater samples at concentrations exceeding laboratory reporting limits but was detected in the November 2014 groundwater sample collected from LVRR-37C at a concentration of 4.4 µg/L and in sample DC-06D at an estimated concentration of 1.3 µg/L. Chloride was detected in the January 2015 at concentrations ranging from 6.6 mg/L in LVRR-44C to 338 mg/L in LVRR-43B. Chloride was detected in all of the groundwater samples collected in November 2014 at concentrations ranging from 19.3 mg/L in LVRR-44C to 61.6 mg/L in DC-06D. TKN was detected in the January 2015 groundwater samples at concentrations or estimated concentrations ranging from 0.18 mg/L in LVRR-44C to 0.31 mg/L in DC-06A. TKN was detected in eight of the 9 November 2014 groundwater samples at concentrations ranging from 0.11 mg/L in LVRR-37C to 0.65 mg/L in LVRR-20-2. TDS was detected in the January 2015 groundwater samples at concentrations ranging from 259 mg/L in DC-06A to 2,180 in DC-06D. TDS was detected in all of the November 2014 groundwater samples at concentrations ranging from 508 mg/L in DC-06B to 2,180 in DC-06D. Sulfate was detected in the January 2015 groundwater samples at concentrations ranging from 13.2 mg/L in DC-06A to 1,280 mg/L in DC-06D. Sulfate was detected in all of the November 2014 groundwater samples at concentrations ranging from 87.6 mg/L in LVRR-20-2 to 1,290 mg/L in LVRR-20-4. Iron was detected in the January 2015 groundwater samples at concentrations or estimated concentrations ranging from 27.2 µg/L in LVRR-37C to 927 µg/L in LVRR-37D. Iron was detected in five of the 9 November 2014 groundwater samples at concentrations or estimated concentrations ranging from 75.6 µg/L in LVRR-20-4 to 2,140 µg/L in LVRR-37C. Potassium was detected in the January 2015 14 groundwater samples at concentrations or estimated concentrations ranging from 1,080 µg/L in LVRR-44C to 3,040 µg/L in DC-06C. Potassium was detected all of the November 2014 groundwater samples at concentrations ranging from 1,310 µg/L in LVRR-37B to 156,000 µg/L in LVRR-20-2. Sodium was detected in the January 2015 groundwater samples at concentrations ranging from 7,060 µg/L in LVRR-44C to 175,000 µg/L in LVRR-43B. Sodium was detected in the November 2014 groundwater samples at concentrations ranging from 8,170 µg/L in LVRR-37D to 116,000 µg/L in LVRR-20-2.

4.1.2.1 **Assessment of November 2014 and January 2016 Groundwater Quality Data**

Table 3 allows a comparison of the November 2014 and January 2015 landfill parameters collected from DC-06, LVRR-20 and LVRR-37 with groundwater samples collected from LVRR-43 and LVRR-44 during the January 2015 event. This comparison indicates the following:

- Sodium and chloride concentrations detected in groundwater samples collected from LVRR-43 wells are generally an order of magnitude higher than concentrations detected in other samples. The LVRR-43 cluster is located within the Neid Road right-of-way where the winter application of sodium chloride salt may be impacting groundwater.

- Relatively high sulfate concentrations are detected in ground water samples collected from DC-06 and LVRR-37 wells. The sulfate may be associated with the dissolution of sulfate from gypsum which also occurs in the underlying Syracuse Formation.

- In January 2015, ethane was detected in cluster LVRR-43 and LVRR-44 groundwater samples but not in DC-06 or LVRR-37 samples. Propane was detected only in sample LVRR-44B and at an estimated concentration in sample LVRR-43C. These gases have been historically detected only in groundwater samples collected from cluster LVRR-33 and LVRR-23 wells, located significantly down gradient. The BOD and COD are relatively high and the TOC is relatively low in sample LVRR-44B, the sample with the highest ethane and propane concentrations. The ethane and propane detected in LVRR-43 and LVRR-44 groundwater samples could potentially be the result of decomposition of organic material in the nearby former Town of LeRoy landfill or could be the result of decomposition of naturally occurring organic material.

UMC reviewed a document titled "Ambient and Landfill-Impacted Groundwater Quality in the Hudson Valley of Southeastern New York State" (Reference 49). The document detailed a study conducted in the vicinity of 46 inactive landfills located in the lower Hudson Valley, New York. In the study, ambient (i.e. up gradient) groundwater concentrations of parameters considered to be most useful in detecting landfill-derived groundwater impacts were compared to concentrations of those parameters in landfill leachate-impacted groundwater. The study concluded that elevated levels of ammonia, manganese and alkalinity were the most reliable indicators of landfill-derived groundwater impacts, followed by TDS, hardness, chloride, arsenic, COD, iron, and phenols as less reliable indicators. Further, the study indicated that higher groundwater manganese concentrations are not expected in a carbonate-rich environment characteristic of the Site since the solubility of manganese is lowest in the alkaline pH conditions typical of that environment.

As indicated on Table 3, the average manganese concentrations detected in the January 2015 LVRR-43 and LVRR-44 groundwater samples are approximately four times higher than those detected in the DC-06 and LVRR-37 samples. In addition, the chloride concentrations reported in LVRR-43 groundwater samples are an order of magnitude higher than those reported in other samples. Based on these data, the elevated manganese and chloride concentrations reported in LVRR-43 and LVRR-44 groundwater samples could potentially be the result of landfill leachate impacts to groundwater.

As discussed above in Section 4.1.1.2.2, the chlorinated solvent-related VOC 1,1-DCA was detected in concentrations or estimated concentrations in groundwater samples collected from wells LVRR-44B, and LVRR-44C and the chlorinated solvent-related VOC chloroethane was detected at an estimated concentration in sample LVRR-44C. 1,2-DCA and chloroethane have not been detected in other groundwater samples historically collected at the Site. Further, 1,2-DCA and chloroethane occur as degradation products of trichloroethane (TCA) but not TCE. Therefore, the relatively low concentrations of 1,2-DCA and chloroethane reported in LVRR-43 and LVRR-44 groundwater samples may also be the result of landfill leachate impacting LVRR-43 and LVRR-44 groundwater.

Based on the data summarized above, UMC concludes that groundwater in the vicinity of the LVRR-43 and LVRR-44 well clusters may potentially be impacted from leachate derived from the former Town of LeRoy landfill. However, as evidenced by the non-detect concentrations of TCE detected in groundwater samples collected from clusters LVRR-43 and LVRR-44, the horizontal and vertical extent of the TCE plume north-northeast of the Spill Area has effectively been delineated.

4.1.3 November 2014 Fire-Related Parameter Groundwater and Surface Water Analytical Results and Discussion

As discussed above, UMC collected groundwater samples from select monitoring well clusters and a surface water sample from MacKay Spring in response to a November 1, 2014 fire at CRC, a dairy feed manufacturing and dry fertilizer distribution facility located near the southeast boundary of the TCE-impacted groundwater plume (Figure 2). The sampling was conducted to assess the potential influence of fire mitigation water on Site groundwater quality, and groundwater and surface water elevation fluctuations. Figure 2 indicates the approximate location of the CRC facility and MacKay Spring. Table 5 summarizes

TCE and general chemistry analyte concentrations reported in groundwater and surface water samples collected during the November 2014 sampling event.

TCE was not detected in the surface water sample collected from MacKay Spring (designated as MacKay SW on Table 5) at a concentration exceeding laboratory detection limits. As indicated on Table 5, TCE was detected in analysis of groundwater samples collected from DC-14A, DC-14B, GCM-1, GCM-2, and LVRR-31-1 at concentrations of 2.6 µg/L, 4.5 µg/L, 37 µg/L, 17 µg/L, 6.8 µg/L, respectively. As indicated on Table 6, these concentrations are generally within historical ranges.

The general chemistry analytes ammonia, nitrite, and phosphorus were not detected in surface water sample McKay SW at concentrations exceeding laboratory reporting limits. Chloride and nitrate were detected in surface water sample McKay SW at concentrations of 63.2 mg/L and 1.7 mg/L, respectively.

The general chemistry analytes were detected in the November 2014 groundwater samples in concentration ranges as follows:

Ammonia :	<0.01 to 0.27 mg/L
Chloride:	21.1 to 66.9 mg/L (estimated)
Nitrate:	<1 to 2.9 mg/L
Nitrite:	<1 mg/L
Phosphorus:	<0.0034 to <0.0115 mg/L

The general chemistry analyte concentrations detected in monitoring well clusters DC-14, GCM, LVRR-25, and LVR-31 are generally within historical ranges. A review of raw transducer data and hydrographs did not indicate a significant rise in groundwater levels or in Spring Creek on November 1, 2014 or during the following days. Based on these results, the November 1, 2014 fire at the CRC facility and the associated release of fire suppressing water resulted in no discernable effects on Site groundwater and surface water quality and no significant rise of Site groundwater or surface water elevations.

4.2 MAGNETIC SUSCEPTIBILITY TESTING RESULTS AND DISCUSSION

UMC reviewed two documents related to magnetic susceptibility: 1) "Notes on Rock Magnetization Characteristics in Applied Geophysical Studies" (Clark and Emerson, 1991; Reference 55) the EPA document "Identification and Characterization Methods for Reactive Minerals Responsible for Natural Attenuation of Chlorinated Organic Compounds in Ground Water" (He et el., 2009; Reference 51). These documents indicate that the magnetic susceptibility of rocks is mainly dependent on the percentage by volume of the ferromagnetic mineral magnetite in the rock. The documents indicate that a variety of iron-bearing minerals including magnetite have been shown to support complete or nearly complete transformation of PCE. The reactions occur at the surfaces of minerals, and the rates of reaction are generally proportional to the surface areas of the minerals presented to water. Further, the documents indicates that sedimentary rocks such as carbonates and shales typically contain less than approximately 0.1% magnetite or other ferromagnetic minerals by volume, resulting in magnetic susceptibilities of approximately 10^{-4} International System of Units (SI) or less.

The data and graphs in Appendix D indicate the magnetic susceptibility of the core samples collected form LVRR-33 ranges from an overall average of approximately $-0.026\text{x}10^{-3}$ SI in the Nedrow Formation to $0.074\text{x}10^{-3}$ SI in Falkirk Formation with an overall average magnetic susceptibility over the entire core interval of $0.0278\text{x}10^{-3}$ SI. The magnetic susceptibility of the core samples collected from LVRR-35 ranges from an overall average of approximately $-0.007\text{x}10^{-3}$ SI in the Nedrow Formation to $0.072\text{x}10^{-3}$ SI in

Camillus Formation with an overall average magnetic susceptibility over the entire core interval of 0.040×10^{-3} SI. The magnetic susceptibility of the core samples collected from LVRR-36 ranges from an overall average of approximately -0.024×10^{-3} SI in the Nedrow Formation to 0.038×10^{-3} SI in Falkirk Formation with an overall average magnetic susceptibility over the entire core interval of -0.007×10^{-3} SI.

As discussed above in Section 3.3, the observed positive magnetic susceptibility readings indicate a paramagnetic condition and the presence of ferromagnetic minerals while the negative readings indicate a diamagnetic condition, generally indicating the predominance of non-magnetic minerals such as calcite. In addition, the positive values observed exceed the magnetic susceptibility range of 10^{-4} SI or less for carbonates and shales cited in the document referenced above. These conditions suggest the presence of ferromagnetic minerals in portions of the bedrock core samples. Based on these data, UMC concludes that, although limited, ferromagnetic minerals including magnetite may be present in the Site bedrock matrix in amounts exceeding values typically reported for carbonate rocks and may contribute to abiotic TCE degradation processes.

4.3 TRANSDUCER DATA ANALYSIS, DISCUSSION, AND SWAT MODELING (ADDENDUM 7, TASK 2)

4.3.1 Transducer Data Processing

In order to calculate the groundwater elevations in Site FLUTe multilevel wells, raw data collected from In-Situ BaroTroll transducers installed in the wells and the In-Situ BaroTroll barometric pressure transducer data was input into a spreadsheet provided by FLUTe, Inc.

Groundwater elevations for conventional groundwater monitoring wells were calculated by UMC using the raw Solinst transducer data, the Solinst barometric pressure data, and the known elevations of each transducer. The raw data was corrected using barometric pressure data collected from the Solinst barometric pressure transducer. On August 24, 2015, the Solinst barometric pressure transducer ran out of memory and stopped recording. The stored data was downloaded and the transducer was restarted on October 18, 2015. Data from the In-Situ BaroTroll barometric transducer recorded between August 24, 2015 and October 18, 2015 was used to correct Solinst transducer data over the period when the Solinst barometric transducer was not recording.

Tables 8a to 8s present the corrected groundwater elevation transducer data including those data collected from the newly installed transducers. Due to the size of the overall data set, the tables are copied on the attached CD. Appendix H includes hydrographs plotting the corrected groundwater elevation transducer data, as well as the groundwater elevation data collected manually during quarterly groundwater sampling events, and the TCE concentrations detected during those events. UMC notes that the transducer data from DC-5 could not be analyzed because of the position of the transducer. Further, UMC notes that due to extreme fluctuations, the elevation of the Site groundwater table periodically fell below the transducer elevations. Therefore, some of the corrected groundwater elevation data is not representative of the actual elevations and was not considered when constructing the hydrographs in Appendix H.

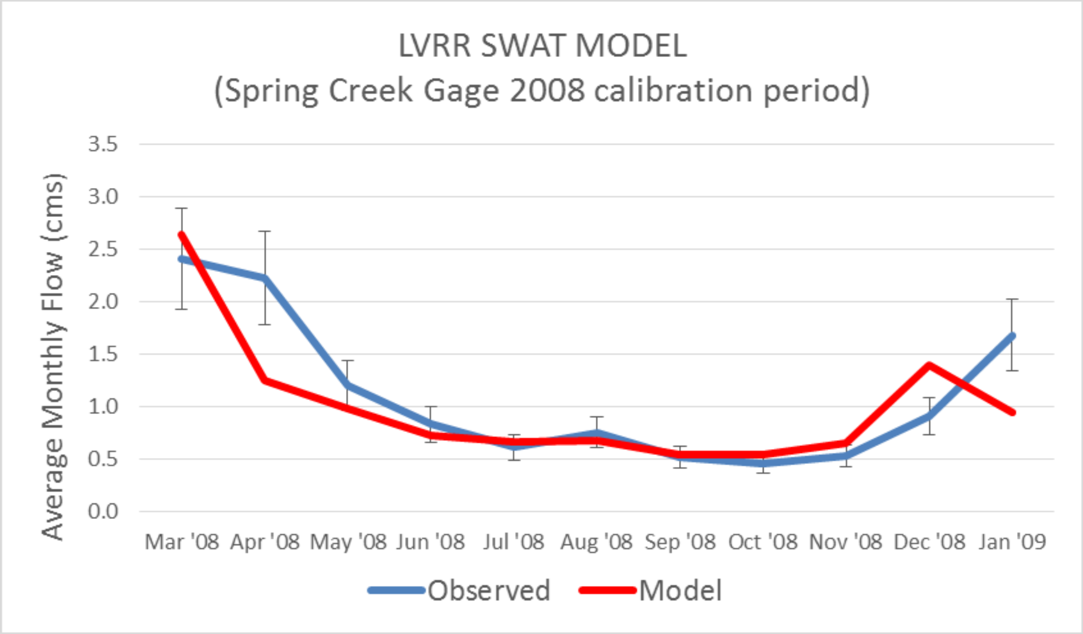
UMC provided the groundwater and Spring Creek elevation and TCE concentration data to Prof. Paul L. Richards, State University of New York Brockport. Appendix H contains a graph prepared by Prof. Richards depicting Spring Creek flow volume in cubic feet per second (cfs) between approximately September 2014 and August 2016 based on Spring Creek transducer data provided to him by UMC. Prof. Richards in turn assessed the relationship between the magnitude and timing of water table fluctuations relative to documented seasonal meteorological events and seasonal fluctuations in Site groundwater TCE concentrations. In addition, Prof. Richards conducted Soil Water Assessment Tool (SWAT) modeling to quantify the flow of allogenic surface water and groundwater originating from highlands south of the Study Area that mixes with and dilutes the TCE plume, ultimately discharging to Spring Creek. Appendix I contains a copy of the SWAT modeling report provided to UMC by Prof. Richards, and a summary of the modeling procedures and conclusions is provided below.

4.3.2 SWAT Modeling Procedures

The SWAT model (Reference 50) is a physically-based model used to predict surface water runoff and subsequent recharge to groundwater aquifers. The model contains routines for routing channelized and non-channelized (i.e. surface water and groundwater) flow between sub-basins. The model also contains parameterizations for the accumulation and melting of snow-packs. Model inputs assume key watershed properties including soil thickness and infiltration properties, land use distribution, vegetative cover, and the influences of snowmelt and evapotranspiration based on precipitation records obtained from nearby climate stations and observed groundwater and surface water elevation fluctuations.

The SWAT model contains a groundwater component whereby water accumulated below the soil zone is leaked to the outlet of model sub-basins using a base-flow recessional coefficient. Parameters in the model are adjusted to reproduce the observed total volume and distribution of monthly flows at Spring Creek, the point at which the TCE plume discharges to surface streams. The objective of the SWAT modeling is to assess the influence of the diluting effects of allogenic water entering the Site groundwater system from upland areas south of the Study Area on TCE concentrations throughout the plume and the impact of the water on the overall shape and aerial extent of the plume.

The SWAT model as constructed by Prof. Richards assumes that the sum volume of groundwater and surface water minus evapotranspiration from 33 upland area sub-basins infiltrates through sinkholes and other karst features, and a thin veneer of soil cover into 17 recharge zones in the Study Area, ultimately mixing with the TCE plume and discharging to a single outlet at Spring Creek. Accordingly, Spring Creek flow data was used to calibrate the model for water balance and monthly flow distribution. The following graph, provided by Prof. Richards, compares the recorded average Spring Creek monthly flow in cubic meters per second (cms) with the flow predicted by the final SWAT modeling calibration data for the time period between March 2008 and January 2009. The modeling calibration conducted by Dr. Richards predicts an average monthly flow in Spring Creek within approximately 9% of the observed flow.



The SWAT modeling conducted by Prof. Richards includes an analysis of temperature and precipitation climate data collected for a 44-year period between 1957 and 2016 and obtained primarily from the Leroy Wunderground climate station located approximately 4 miles from the Spill Area. The data was analyzed by seasons defined as: Winter - December of the previous year plus January and February; Spring - March, April, and May; Summer - June, July, and August; and, Fall - September, October, and November. Based on an analysis of monthly precipitation totals, the year 1969 was the most "typical" with 34.8 inches of precipitation as compared to a 44-year average of 34.6 inches.

Table 2 in the SWAT report summarizes the date and magnitude of precipitation and snowmelt events occurring between 2012 and 2016 that resulted in a water table response, the highest recorded temperature during each event, and the corresponding transducer data for Spill Area monitoring well DC-01B including the water table response and time of concentration (TOC) defined as defined as the time period between when the water table first started to respond and the peak response. The TOCs listed on Table 2 vary between approximately one and five days indicating that the water table response time to a given precipitation or snowmelt event in the Spill Area is relatively short, on the order of days and significantly shorter than the scale of a month.

Tables 3 through 5 of the SWAT report list the type of precipitation event (i.e. precipitation driven, snowmelt driven, or both), the season, the event magnitude, and the corresponding water table response for each event in: "Source Area Wells" DC-01B and DC-01C (Table 3); "Neck Well" LVRR-30-3, "Mid-plume Well" LVRR-32-1, "Distal Plume Well" GCM-2 (Table 4); and "Plume End Wells" DC-13A, LVRR-24C, and DC-14A (Table 5). Based on these data, a discussion of the Study Area water table response to documented precipitation events follows.

4.3.3 Water Table Responses by Season

Scatter diagram Figure 4a in the SWAT report plots the water table response in well DC-01B for each storm event listed on Table 2. Although highly variable, the figure indicates that the water table response in the

Spill Area for a storm event of given magnitude is generally lower during the summer season and higher during the winter season. Scatter diagram Figure 4b in the report compares the water table response in well DC-01B for precipitation events vs. snowmelt augmented precipitation events. The figure indicates that above freezing precipitation events augmented by snowmelt generally result in higher magnitude water table responses. Even relatively small precipitation events of less than 0.5 inches/24 hours result in significant water table responses when they are augmented by snowmelt, thus increasing the diluting effect of allogenic recharge on the TCE plume during those events.

Bar graph Figure 5 in the SWAT report plots the average water table response in “Source Area”, “Neck”, “Mid-plume”, and “Distal End” wells for a September 4, 2012 storm event with a magnitude of 5.74 inches/24 hours and an October 29, 2012 event with a magnitude of 0.85 inches/24 hours. The figure indicates that the September 2012 (late growing season) precipitation event, although significantly higher in magnitude than the October 2012 (late fall) event, resulted in lower water table responses. As indicated on scatter diagram Figure 4a and Tables 2 through 5, there are exceptionally unresponsive periods during summer months when storms fail to result in a marked water table response, even with storms sized between 0.5 and 1.0 inches/24 hours. Smaller magnitude precipitation events of less than 0.5 inches/24 hours that occur during growing season months generally result in little or no water table response. In general, the water table response to a given precipitation event decreases as late summer is approached when the uptake of water by native and crop vegetation and evapotranspiration from vegetation is highest.

As indicated on Table 2 of the SWAT report, the water table response to precipitation/snowmelt events in Spill Area monitoring well DC-01B is as large as 19.2 feet, occurring as the result of an April 23, 2012 precipitation event with a magnitude of 0.7 inches/24 hours. The dynamic water table response to meteorological events indicated by the transducer data is evidence of the diluting effect of allogenic recharge on the TCE plume. Further, the large water table responses are indicative of a well interconnected fractured bedrock system with low bulk fracture porosity. As discussed above, the transducer data generally indicates that the highest magnitude water table responses generally occur as the result of meteorological events in the winter, spring, and late fall, outside of the growing season. This indicates that the diluting effect of allogenic recharge on the TCE plume is highest during these seasons. Conversely, the lowest magnitude water table responses generally occur as the result of meteorological events in the summer and early fall growing seasons, indicating that the TCE plume experiences less dilution due to allogenic recharge during these months.

4.3.4 Spatial Variability in Water Table Response

Bar graphs in Figures 4a and 4b in the SWAT report plot water table responses to specific seasonal precipitation and snowmelt augmented events in various parts of the TCE plume from the “Source Area” to the “Distal End” of the plume at Spring Creek. The plots indicate that the water table response to precipitation events is variable along the longitudinal axis of the TCE plume with “Source Area”, ”Neck”, and ”Mid-plume” wells being generally more responsive than wells at the distal end of the plume and plume end near Spring Creek. The lowest magnitude water table responses are generally observed during all seasons at the distal end of the plume at Spring Creek that acts as the discharge zone for Study Area groundwater and is partially controlled by the head of Spring Creek. The highest magnitude water table responses are generally observed in “Neck” and Mid-plume” wells during the Spring. Note that winter snowmelt augmented events of relatively low magnitude (0.21 inches/24 hrs to 0.39 inches/24 hrs) result in similar summer season water table responses for storms of significantly greater magnitude (1.59 inches/24 hrs to 2.62 inches/24 hrs).

Figures 1a through 1e and Figures 2a through 2e in the SWAT report plot the seasonal potentiometric surface water table responses to precipitation events in the Akron, Bertie and Camillus Formations in DC-1 and LVRR-30 wells over several seasons. Little or no delay in hydraulic head response between the Akron, Bertie and Camillus is evident in these clusters. There are differences, however, in the peak height of the response, and the shape of the recession. The differences in hydraulic head response between bedrock units are likely caused by differences in the storativity and hydraulic conductivity of the bedrock units. From the perspective of timing, however, the responses appear to be triggered generally at the same time. Based on observed similar water table responses within well clusters, fractures between bedrock units are generally hydraulically connected.

4.3.5 TCE Concentrations by Season

Graphs 13 a through 13e in the SWAT report plot the seasonal variation in log normal TCE concentrations observed in groundwater samples collected during sampling events conducted between 1993 and 2015 from well clusters DC-01, DC-02, and DC-03. The plots for wells DC-01B, DC-01C, DC-03A indicate that the highest TCE concentrations generally occur during the fall season, potentially the result of overall rising groundwater levels in the wells after the summer and early fall growing season and the mixing of residual TCE-impacted water entrapped on bedding plane surfaces and in dead-end fractures and in the rock matrix in the vadose zone during drier seasons. However, as depicted on the plots, the overall relationship between TCE concentrations and seasons appears to be highly variable, likely influenced by variations in storage capacity due to differences in the fracture network density and connectivity, and the resulting flow paths in the vicinity of the wells. Further, although some tendencies are evident, there is generally a high degree of uncertainty in predicting the magnitude and timing of hydraulic head responses for a given precipitation event during any given season. Based on these observations, the value of conducting post-storm event groundwater sampling with the objective of assessing storm influence on TCE concentrations is questionable.

4.3.6 Quantifying Allogenic Flux to the TCE Plume

Table 12 of the SWAT report lists the average monthly recharge of water (both surface and groundwater) in millions of gallons per month (mg/mo) to each dilution zone in a “typical” year, which as described above is based on an analysis of climate data collected over the 44-year period between 1957 and 2016. The SWAT modeling allows an estimate of the recharge in each dilution zone by summing the water yield of all basins hydraulically connected to the zone. By this method, the average monthly flux within dilution zones varies between 3 mg/mo to 406 mg/mo. The highest fluxes are associated with watersheds that drain north into dilution zones along the southern portion of the plume. Smaller fluxes are evident in dilution zones along the northern boundary of the plume that are recharged primarily by precipitation and receive lower water yields from the southerly watersheds. Monthly fluxes are generally highest in spring months April and May and lowest in fall months September and October. These results generally correspond to the observed seasonally highest and lowest groundwater levels.

The large influx of allogenic water to the TCE plume is expected to be well oxygenated due to turbulent flow along stream channels prior to infiltration and mixing with the TCE plume. This water in turn can be expected to influence groundwater chemistry in recharge areas along the southern boundary of the plume, changing from anaerobic to aerobic conditions during recharge periods. However, due to the variability involved, the timing and magnitude of these changes and their potential effect on attenuation rates is difficult to predict.

4.4 DFN MODELING RESULTS

The DFN modeling results are presented in a report titled "Discrete Fracture Network Numerical Modeling of Matrix Mass Transfer and Back Diffusion Effects, Lehigh Valley Railroad Derailment Superfund Site, LeRoy, NY" prepared by Steven Chapman, M.Sc. and Dr. Beth Parker (DFN Report) (Appendix E).

The DFN report concludes that the simulations presented required many assumptions and simplifications owing to the complexity of the field conditions at the LVRR site, including a complex 3D flow system in the fractured dolostone aquifer with karst conditions including sinkholes and dissolution channels, very transient conditions including rapidly varying water table / hydraulic head and inputs of water to the plume, complex source inputs that were exacerbated by water floods shortly after releases occurred, etc. Therefore simulation results should be considered 'stylistic' in nature, but incorporate key processes controlling contaminant transport in dual porosity systems and tailored to site conditions to the extent feasible. The flow system was constrained by hydraulic information on bulk K and plume scale hydraulic gradients and matrix parameters by lab measurements on core samples (see Appendix E and Appendix F for graphs). Overall the simulations show that matrix diffusion is expected to have strongly attenuated plume transport at the LVRR site, consistent with field monitoring data showing strong declines in contaminant concentrations with distance from the source area along the plume longsect. Simulation results indicate the majority of contaminant mass is now present in the rock matrix, which is consistent with results from detailed rock matrix sampling at key locations along the plume flow path (LVRR-36, LVRR-35 and LVRR-33). Under these conditions, it is expected that mass discharge within the downgradient portions of the plume in fractures, which carry nearly all groundwater flow, should be relatively low. With declining contaminant inputs to the plume, due to depletion of DNAPL mass that penetrated below the water table likely occurring within a few years after releases occurred, and inputs from the larger mass persisting in the vadose zone also declining, model results suggest conditions within the plume should slowly improve over time with declining mass discharge to downgradient receptors. As discussed elsewhere in this report, such trends are consistent with site groundwater monitoring data collected between 1993-1995 by NYSDEC, and in the more recent investigations by UMC between 2010-2015, showing concentrations generally stable or declining throughout the plume.

Simulations suggest that aggressive remedial efforts to further reduce mass inputs to the plume, including complete removal of ongoing vadose zone source inputs, remediation of hotspot mass present in the groundwater zone near and below the source area, and/or cut off plume mass discharge downgradient of the source area would have only minor influence on improving water quality downgradient within the plume and only after extended periods of time, and negligible impact on conditions nearer the plume front within any reasonable timeframe. Inclusion of slow degradation in simulations, based on field evidence suggesting degradation may be playing a minor role at the site, would lead to greater impacts on the downgradient plume following source depletion or cutoff; however the extent to which degradation is occurring and influencing the plume is unclear and appears to only be a minor process, so such evaluations are likely not justified based on site data collected to date.

5 CONCLUSIONS

After submittal of the LVRR 2014 RIR, UMC conducted additional remedial investigation activities to delineate the TCE plume north of the Spill Area; provide additional data for evaluating the potential degradation of TCE; evaluate the seasonal influences of meteoric water on groundwater fluctuations and TCE concentrations; assess the historic Town of Leroy Landfill potential impacts to groundwater within the

Study Area; and, assess the CRC facility fire potential impacts to the aquifer within the Study Area. Key findings from each of these efforts are summarized below.

Plume Delineation

To delineate the plume north of the Spill Area two new monitoring wells, LVRR-43 and -44 were installed. Samples collected from these wells during 2014 did not contain detectable concentrations of TCE, DCE or VC above laboratory detection limits. The absence of these compounds in the groundwater demonstrates that the northern limit of the dissolved-phase TCE plume has been delineated. The SWAT model demonstrated that allogenic surface and ground water from near the Spill Area and from south of the Study Area contribute large volumes of fresh water that mixes with the TCE plume. The SWAT model demonstrated that throughout much of the calendar year Mud Creek infiltrates into the bedrock near the Spill Area. This water, other seasonal surface water streams, groundwater, and precipitation falling directly within the Study Area provide large volumes of fresh water that mixes with the TCE plume and is directed eastward through the Site aquifer system, eventually discharging at Spring Creek. The influx of fresh water along the southern boundary of the plume acts to dilute the TCE concentrations and acts to control the lateral extent of the plume to the south. Areas in the center and northern portions of the plume do not receive as much infiltrating water, but Oatka Creek acts to control lateral extent of the plume to the north. As noted in the LVRR 2014 RIR, Spring Creek is formed along a fault zone that extends from approximately Spring Street on the west to Route 36 on the east and acts as the discharge zone for Study Area groundwater. Much of the eastward-flowing Study Area groundwater is discharged to the surface through the fault zone forming Spring Creek. These controls are evident by the generally stable TCE plume condition observed during historical groundwater sampling events conducted between 1993 and the present. Therefore, the plume extent is constrained by natural processes and delineated horizontally and vertically.

Influences of Meteoric Water on Groundwater Fluctuations and TCE Concentrations Over Time

In an effort understand the relationship of groundwater fluctuations and TCE concentrations over time, transducers were installed in a number of monitoring wells throughout the plume. Water levels recorded by the transducers confirmed that large fluctuations occur during the spring, late fall, early winter, and during winter precipitation events augmented by snowmelt. Large precipitation events during the summer have little effect on the recharge rates, likely due to evapotranspiration and storage capacity in the vadose zone. Reviewing the transducer datasets for the various monitoring wells shows that the water level changes are often rapid, in a matter of hours or days, to a large precipitation or snow melt event during certain seasons. Comparing the water levels for different depths and geologic formations revealed that the water level responses within each formation are similar with very little or no lag time, indicating that the geologic formations act as a single aquifer which is hydraulically interconnected through a complex fracture network. The SWAT model identified significant amounts of recharge per month the average monthly flux within dilution zones varies between 3 mg/mo to 406 mg/mo. Historically, in October the plume receives the least amount of recharge and the highest TCE concentrations are detected.

Evaluation of MNA

The 2010 – 2015 VOC data indicates that the overall aerial and vertical extent of Study Area TCE-impacted groundwater has been delineated. Further, although historical groundwater quality data indicates that the overall TCE impacts to groundwater have declined over time, a comparison of the 2014-2015 concentrations to historically generated TCE iso-concentration maps from 1993-1995 indicates that the overall shape and aerial extent of the TCE plume has remained relatively stable during the past two decades.

Samples collected from monitoring wells between 2010 and 2015 were analyzed for VOCs and select MNA parameters. The MNA results showed that the aquifer was generally aerobic with little ability to degrade TCE. However, in some locations, such as near mid-plume, conditions may be suitable for limited anaerobic degradation. The 2015 CSIA data suggested that abiotic degradation of TCE may be occurring, with the TCE $\delta^{13}C$ enrichment factor increasing with distance from the source, but with the enrichment factor magnitude not typical of abiotic degradation only, likely due to combined effects of degradation and diffusion processes.

The magnetic susceptibility of the bedrock cores collected during UMC's 2014 RI were measured to assess whether ferromagnetic minerals are present in the bedrock matrix that may potentially contribute to the abiotic degradation of TCE. Many negative results were obtained, indicating a diamagnetic condition and a predominance of non-magnetic minerals. However, the overall positive results, generally exceeding values reported in carbonate rocks, indicate a paramagnetic condition and the presence of ferromagnetic minerals. Based on these results, UMC concludes that ferromagnetic minerals may be present in the Site bedrock matrix in amounts sufficient to contribute to abiotic TCE degradation processes.

Comparing the MNA trends with the SWAT model shows that the MNA parameters are affected by the infiltration of surface water near the Spill Area, along the southern boundary of the plume, and at the discharge zone. In these areas, the infiltrating surface water changes the groundwater chemistry such that it does not support anaerobic biota capable of degrading TCE. However, with less infiltration in the mid-plume area the groundwater chemistry is more amenable for anaerobic degradation. Additionally, in this area the CO_2 production is less than in the up gradient areas and the reduction of sulfate is less. This indicates that, with less surface water infiltration, the groundwater chemistry may allow for the anaerobic degradation of TCE.

The DFN Report, Figure 13, shows simulated plumes for a scenario with slow rates of degradation, assuming first-order decay of mass in both fractures and in the matrix with a small half-life of 20 years. Comparison with the base case plumes without degradation, with slow rates of degradation the plume still reaches the downgradient boundary within 20 years, but with much stronger attenuation of internal plume concentrations. Effects of degradation are two-fold in fractured rock: a) direct removal of contaminant mass (either transformation to lesser chlorinated products, or complete dechlorination through to non-chlorinated end products), and b) indirect effects on diffusion since contaminant mass removal due to degradation can result in increased rates of mass transfer to the matrix while the plume is in forward diffusion stages, as well as, dampening of mass release back to fractures from the matrix during back diffusion stages. Therefore, while the Site conditions may only allow for limited degradation in portions of the plume, it may still be an important factor in overall plume attenuation in combination with other processes.

The MNA study provided evidence for some degradation occurrence within the plume. The attenuation processes identified are both destructive and non-destructive in nature and include, but are not limited to, matrix diffusion, dispersion, dilution, sorption, biodegradation, volatilization, and chemical or biological stabilization, transformation, or destruction of contaminants. Overall these processes combine to cause strong attenuation of the plume between the source area and along the plume flow path prior to discharging at Spring Creek.

Landfill Sampling

In an effort to assess if disposal activities at the former Town of LeRoy landfill have impacted Study Area groundwater quality, two monitoring well clusters were installed at the north end of Neid Road and east of the former landfill in December 2014, each consisting of four wells screened at specific stratigraphic intervals (LVRR-43 and LVRR-44). During January 2015, groundwater samples were collected from the well clusters and from clusters further south on Neid Road with the samples analyzed for VOCs, MNA parameters and landfill parameters, such as TKN, TDS, chloride, bromide, and metals. TCE was not detected in groundwater samples collected from the LVRR-43 or LVRR-44 well clusters, effectively delineating the northern limit of the TCE plume. However, 1,1-DCA and chloroethane were detected in groundwater samples collected from the LVRR-44 cluster. These VOCs have not been historically detected in groundwater samples collected at the Site. 1,1-DCA and chloroethane are degradation products of TCA but not TCE. Therefore groundwater in the vicinity of LVRR-44 may be impacted as the result of former Town of LeRoy landfill disposal activities. The MNA parameters were within the same ranges identified in other monitoring wells in the area. Several of the landfill parameters, such as sodium and chloride, as well as BOD, COD and ethane were relatively high in LVRR-44 but not in wells further south along Neid Road, indicating impacts from the landfill have affected groundwater quality but not the groundwater quality in the TCE plume.

Fire-Related Sampling

To assess if the CRC fire and fire suppression water had an impact on Study Area groundwater quality, groundwater samples were collected from monitoring well clusters in the area (DC-14, GCM, LVRR-25, and LVRR-31) and a surface water sample was collected from McKay spring. The samples were analyzed for VOCs and select general chemistry parameters (ammonia, chloride, nitrate, nitrite, and phosphorus). Additionally, groundwater elevation data was collected from transducers installed in vicinity monitoring well clusters and in Spring Creek to assess the potential influence of fire mitigation water on Study Area the water levels. TCE was detected in the monitoring wells at concentrations within historical ranges and was not detected in the McKay spring sample. The general chemistry analyses were also within historical ranges. No significant changes in the water level at Spring Creek or in nearby monitoring well clusters were noted. Based on these observations, the CRC fire and subsequent release of fire mitigation water did not significantly impact Site groundwater quality.

DFN Modeling Conclusions

The results of the DFN model are consistent with Site data that show that TCE entered the aquifer shortly after the release occurred and began to move eastward in the groundwater flow system, where it is strongly attenuated by a number of processes in the fractured bedrock system including matrix diffusion, dispersion, dilution, sorption and some degradation. The simulations are ‘stylistic’ in that site conditions are too complex to be fully represented in DFN numerical models; however the simulations were informed and constrained by Site data to the extent possible.

Several scenarios were run to predict the migration of TCE over time. The scenarios show that the TCE concentrations extend to the discharge zone and the plume will continue to discharge for a long period of time. However, the higher input concentrations in the Spill Area will continue to decline during this time, and the long-term plume persistence will mostly be a result of back diffusion of mass out of the rock matrix. As a predictive tool, the high concentrations of TCE in the Spill Area were removed in hypothetical simulations to evaluate the effect on the TCE concentrations in the plume and over time. These model runs show little to no impact of complete source mass removal on the TCE concentrations downgradient in the plume and nearer the plume front over any reasonable timeframes, suggesting limited benefit to aggressive source mass removal if the goal is to minimize or prevent future impacts in the downgradient portion of the plume.

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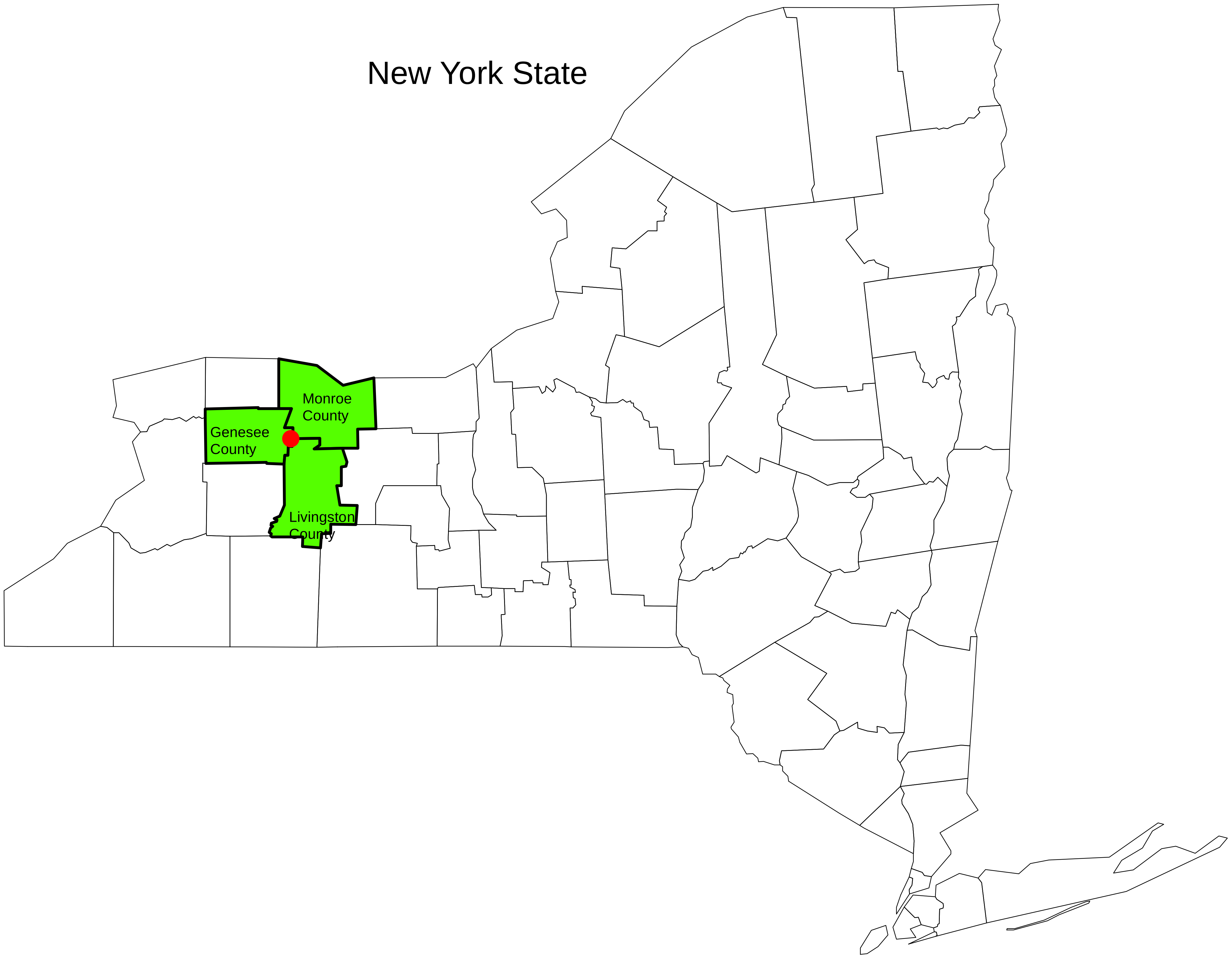
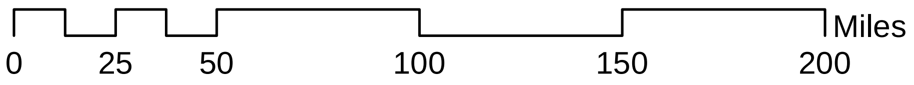
7 ABBREVIATIONS AND ACRONYMS

°C	Degrees Celsius
µg/L	Micrograms Per Liter
δx	Delta of "x"
‰	Per mil or parts per thousand
1,1-DCA	1,1-Dichloroethane (CAS# 75-34-3)
1,1-DCE	1,1-Dichloroethene (CAS# 75-35-4)
^{12}C	Carbon 12
^{13}C	Carbon 13
ALS	ALS Environmental
ATSDR	Agency for Toxic Substances and Disease Registry
bgs	Below Ground Surface
BOD	Biological Oxygen Demand
BVE	Bedrock Vapor Extraction
Ca	Calcium
CAS	Chemical Abstract Service
cDCE	cis-1,2-Dichloroethene (CAS#156-59-2)
CERCLA	Comprehensive Environmental Response, Compensation, and Liability Act
cfs	Cubic Feet Per Second
CFU/ml	Colony Forming Units per milliliter
CHA	Clough Harbor and Associates of Rochester, NY
CO2	Carbon Dioxide
COD	Chemical Oxygen Demand
CRC	Commodities Resource Corporation
CSIA	Compound Specific Isotope Analysis
CSM	Conceptual Site Model
DC	New York State Department of Environmental Conservation Monitoring Well
DCE	1,2-Dichloroethene (CAS#540-59-0)
DFN	Discrete Fracture Network
DO	Dissolved Oxygen
DOC	Dissolved Organic Carbon
Dunn	Dunn Geoscience Engineering Company P.C.
FLUTe	Flexible Liner Underground Technologies
FS	Feasibility Study
ft	Feet
GC	Gas Chromatograph
GC-IMRS	Gas Chromatograph Isotope Ratio Mass Spectrometer
IC20	20% Inhibitory Concentration
IDW	Investigation Derived Waste

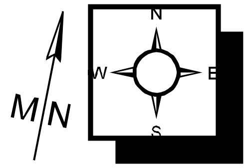
K	Potassium
kg	Kilogram
KHz	kilohertz
LVRR	Lehigh Valley Railroad
m3/sec	Cubic meters per second
MCL	Maximum Contaminant Level
mg/L	Milligram Per Liter
mL	Milliliter
MNA	Monitored Natural Attenuation
mS/cm	Micro Siemens Per Centimeter
mV	Millivolts
N+N	Nitrate and Nitrite
NA	Not Applicable
NAPL	Non-Aqueous Phase Liquid
NDI	NDI Drilling Inc., Scottsville, NY
NTU	Nephelometric Turbidity Units
NYCRR	New York Code of Rules and Regulations
NYS	New York State
NYSDEC	New York State Department of Environmental Conservation
NYSDOH	New York State Department of Health
ORP	Oxidation-Reduction Potential
OU	Operable Unit
PACE	Pace Analytical Energy Services
PCE	Tetrachloroethene (CAS# 127-18-4)
PID	Photoionization Detector
ppm	Parts Per Million
PVC	Polyvinyl Chloride
QA	Quality Assurance
QA/QC	Quality Assurance/Quality Control
QAPP	Quality Assurance Project Plan
QC	Quality Control
RI	Remedial Investigation
RI/FS	Remedial Investigation and Feasibility Study
RIR	Remedial Investigation Report
ROD	Record of Decision
SA	Settlement Agreement
SCGs	New York State Standards, Criteria, and Guidelines
SOP	Standard Operating Procedure
SOW	Statement of Work

SVOC	Semi-Volatile Organic Compound
SWAT	Soil Water Assessment Tool
TCA	Trichloroethane
TCE	Trichloroethene (CAS# 79-01-6)
tDCE	trans-1,2-Dichloroethene (CAS# 156-60-5)
TDS	Total Dissolved Solids
TKN	total Kjeldahl Nitrogen
TOC	Total Organic Carbon or Time of Concentration
Trillium	Trillium Inc., Dowington, PA
UFP	Uniform Federal Policy
UMC	Unicorn Management Consultants, LLC, Danbury, CT
USEPA	United States Environmental Protection Agency
USGS	United States Geological Survey
VC	Vinyl Chloride
VOC	Volatile Organic Compound
VPDB	Vienna Pee Dee Belemnite
WDI	Wayne Disposal, Inc.
WP	Work Plan





Index Map



Unicorn Management Consultants, LLC

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06810

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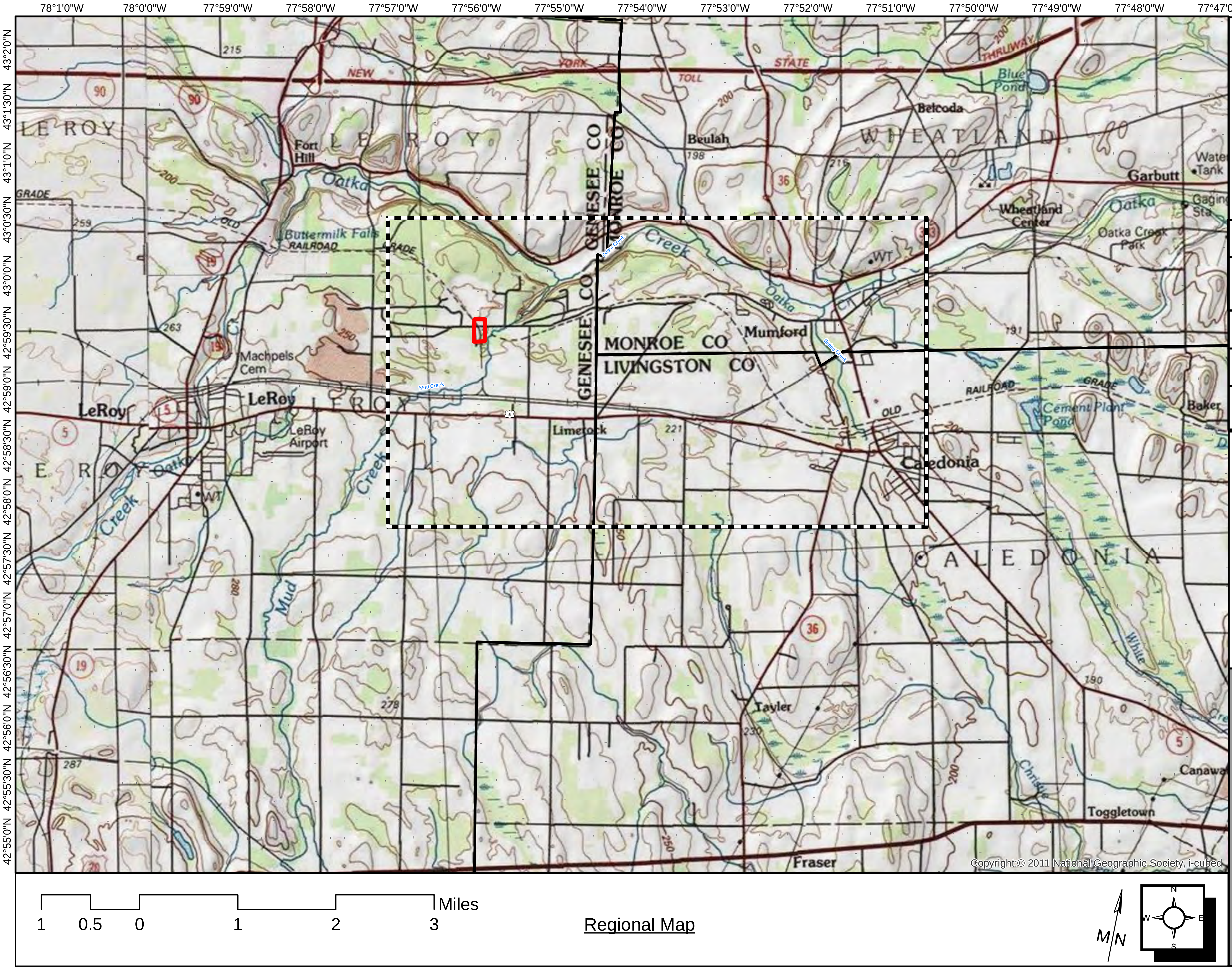
Project Name: Lehigh Valley Railroad Derailment Superfund Site

Figure 1a
Addendum 1 to RIR

Author: RTM
Checked By:
Project #: 2032
Created: 10/27/09
Revised: 11/13/13
Scale: 1 inch = 250,000 feet
File: Fig1a_Index

Legend

● Approximate Study Area



Regional Map

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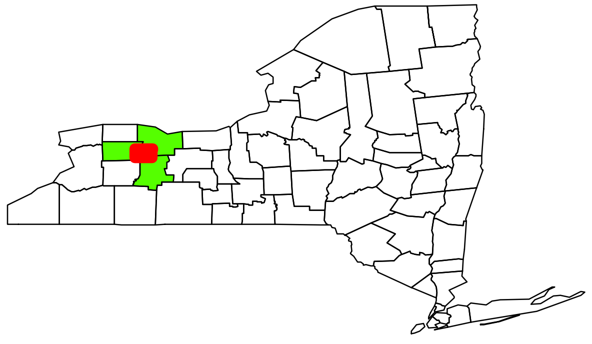
Project Name:	Lehigh Valley Railroad Derailment Superfund Site

Figure 1b
Addendum 1 to RIR

Author:	RTM	**Checked By:**	
Project #:	2032	**Created:**	10/27/09
		Revised:	8/22/16
Scale:	1 in:5,000 ft	**File:**	Fig1b_Regional

New York State



● = Approximate Study Area

Legend

🟥 Approximate Spill Area

▨ Approximately Study Area

☐ County Boundary