Site Investigation and Interim Actions Report
February 2012 – January 2013

Madison-Kipp Corporation
201 Waubesa Street
Madison, Wisconsin

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Madison-Kipp Corporation
Madison, Wisconsin

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Acronyms and Abbreviations

amsl	Above mean sea level
AST	Aboveground Storage Tank
bls	Below land surface
BTRTS	Bureau of Remediation and Redevelopment Tracking System
^{o}C	Celsius
CORE^{DFN}	Characterization of Rock Environments using a Discrete Fracture Network
CSM	Conceptual site model
CVOC	Chlorinated volatile organic compounds
DNAPL	Dense non-aqueous phase liquid
DRO	Diesel Range Organics
EDR	Environmental Data Resources
ES	Enforcement Standards
ESA	Environmental Site Assessment
EQ	Environmental Quality Company
^{o}F	Fahrenheit
ft/day	Feet per day
ft/ft	Foot/foot
FID	Flame Ionization Detector
GIS	Geographic Information System
gpm	Gallons per minute
GRO	Gasoline Range Organics
IDW	Investigation-Derived Waste
ISCO	In-Situ Chemical Oxidation
NAD	North American Datum
NAVD	North American Vertical Datum
µg/kg	Micrograms per kilogram
µg/L	Micrograms per liter
µS/cm	MicroSiemens per centimeter
mg/kg	Milligrams per kilogram
MKC	Madison-Kipp Corporation
MS	Middle of the screen

MTBE	Methyl tertiary-butylether
PAHs	Polycyclic Aromatic Hydrocarbons
PAL	Preventive action limit
PCBs	Polychlorinated Biphenyls
PCE	Tetrachloroethene
PID	Photoionization Detector
ppmv	Parts per million by volume
PVOC	Petroleum volatile organic compounds
R&R	Remediation and Redevelopment
RCL	Residual contaminant level
RCRA	Resource Conservation and Recovery Act
RJN	RJN Environmental Services, LLC
Site	Madison-Kipp Corporation
SOP	Standard Operating Procedures
SOW	Scope of Work
SSDS	Sub-slab depressurization systems
SSRCL	Site specific residual contaminant level
SVE	Soil vapor extraction
TSCA	Toxic Substance Control Act
TCE	Trichloroethene
UST	Underground Storage Tank
U.S. EPA	United States Environmental Protection Agency
USGS	United States Geological Survey
VOCs	Volatile Organic Compounds
WDHS	Wisconsin Department of Health Services
WDNR	Wisconsin Department of Natural Resources

Executive Summary

ARCADIS was retained by Madison-Kipp Corporation (MKC) to complete investigation activities at its facility located at 201 Waubesa Street in Madison, Wisconsin (Site). Environmental investigation and remediation activities have been ongoing since 1994. From 1994 to 2012, activities focused on the investigation and remediation of tetrachloroethene (PCE). In 2012, activities were expanded to evaluate polychlorinated biphenyls (PCBs), polycyclic aromatic hydrocarbons (PAHs), and Resource Conservation and Recovery Act (RCRA) metals.

This report was prepared to provide the results of investigation, interim actions, and remediation pilot test activities completed between February 2012 and January 2013. To help place this work into context with previous activities and to develop a conceptual site model (CSM), this report provides a summary of available Site history and previous investigations. The report also presents recommendations for additional work in 2013. This Executive Summary was prepared to provide an overview of the information presented in the report.

The Site is approximately 7.5 acres in size. A 130,000-square foot building occupies much of the Site. Asphalt parking lots are located in the northeastern, southwestern and southeastern portions of the Site. The building has a 25,000 square-foot second floor and a 25,000 square-foot basement.

The Site is located in the eastern portion of Madison, in a mixed use area of commercial, industrial and residential land use. The Site is also located at the northeast end of the Madison Isthmus, which is a narrow strip of land separating Lake Mendota and Lake Monona. This is important from a hydrogeological perspective because the lakes function as hydrologic boundaries for the Site. The Site and surrounding area is serviced by municipal water supply and sewer systems.

MKC initially purchased and developed the northern portion of the property in 1898, and the southern portion in 1917. Development initially consisted of a building at the north end of the Site and a building along Atwood Avenue to the south. Building additions were constructed in several phases, and the current configuration of the building was established by 1968. The Site has been used for manufacturing activities since its initial development. The Site is currently operated as a metal die casting facility.

Site investigation activities were initiated at the Site in 1994 in response to a request from the Wisconsin Department of Natural Resources (WDNR) due to the results of an investigation on an adjacent property to the west of the Site (Madison Brass Works) that identified PCE in shallow groundwater.

Initially, investigation activities were conducted in the northern portion of the Site to evaluate soil and groundwater conditions in the area of the off-site groundwater detections. One of the earliest groundwater samples, collected from a direct push soil boring advanced immediately northeast of the building, contained PCE and TCE. It was determined that a PCE-containing aboveground storage tank (AST) was formerly located outside the northern portion of the building. Also, a drainage ditch was located along the east side of the building and extended from the former AST area northward to the property boundary. The former AST was taken out of service at an unknown date, and the ditch was filled and the area paved in 1995. As the investigation progressed, two historic locations of a vapor degreaser were identified as potential PCE sources. One vapor degreaser location was in the northwestern portion of the building along the east exterior wall, and a second vapor degreaser location was identified in the eastern portion of the building.

Several phases of investigation were completed between 1994 and 2011 to evaluate soil, groundwater, and soil vapor for PCE and related VOCs. The investigations included:

- Installation and sampling of 64 direct-push soil borings, five hand auger soil borings, and five hollow-stem auger borings for collection of soil samples.

- Installation of 11 temporary monitoring wells for groundwater sampling.

- Installation of 5 permanent groundwater monitoring wells and 13 piezometers.

- Installation and sampling of 13 soil vapor probes on the Site, and soil vapor sampling at 3 adjacent residential properties.

Soil and groundwater remediation activities were completed to treat impacts identified during the investigations. In-situ soil treatment in the northern portion of the Site was completed in 1998 and 1999 to address impacted soil in the area of the former AST, ditch, and the vapor degreaser location in the northern portion of the building. A second phase of in-situ soil treatment was completed in the central portion of the Site in 2005 to address soil impacts identified near the second vapor degreaser location.

An ozone sparge system was installed in the central portion of the Site in 2008 to remediate shallow groundwater in this area. The system operated from 2008 to early 2012.

ARCADIS was retained in early 2012 to conduct additional investigation, implement interim measures, and evaluate remedial options for the Site. The following investigation activities were completed between February 9, 2012 and January 25, 2013:

- Advanced and sampled 189 soil borings on the Site to evaluate the extent and degree of soil impacts. A total of 327 soil samples were collected.
- Advanced and sampled 121 hand auger borings off Site at 32 residential properties to evaluate the extent and degree of soil impacts in the upper 4 feet at these locations. A total of 183 soil samples were collected.
- Installed 10 single-screened groundwater monitoring wells and four Westbay multiport groundwater monitoring wells to further evaluate the lateral and vertical extent of groundwater impacts.
- Installed four vapor probes along the northern property boundary and collected soil gas vapor samples from these and the 12 previously installed vapor probes located around the perimeter of the Site.
- Installed 22 sub-slab vapor points at 11 residential properties adjacent to the Site. Collected 32 sub-slab and 34 indoor air vapor samples from residences located in the neighborhood adjacent to the Site. A portion of these vapor samples were collected as split-samples with the WDNR. WDNR collected additional sub-slab and indoor air vapor samples throughout the neighborhood adjacent to the Site.
- Collected groundwater elevations and groundwater samples from the current network of 55 wells.

The investigation data were used to develop a CSM to evaluate the extent of impacts in soil, groundwater, and soil vapor, and to evaluate potential exposure pathways. The following is an overview of the elements comprising the CSM:

- The Site geology consists of fill material and glacially-derived unconsolidated deposits underlain by a sequence of sandstone bedrock units, underlain by crystalline bedrock. The native unconsolidated soils consist of stiff clay over a very fine to coarse-grained sand and silt unit. Gravel lenses were also observed at varying depths and thicknesses in the sand silt unit. The underlying sandstone units include the Lone Rock Formation, the Wonewoc Formation, and the Eau Claire Formation.

- The sandstone formations beneath the Site are intensely to highly fractured with primarily horizontally-oriented fractures associated with bedding plane partings and limited high-angle joints. Several fractures which may be capable of transmitting water were identified by geophysical tools.

- The city of Madison's hydrostratigraphy can be divided into four units including, from the upper to lower aquifers: (1) Unconsolidated Aquifer; (2) Upper Paleozoic Aquifer; (3) Eau Claire Aquitard; and, (4) Mount Simon Aquifer. Monitoring wells installed on Site and off Site are located within the Unconsolidated Aquifer and the Upper Paleozoic Aquifer.

- The hydraulic gradient direction in wells completed in the unconsolidated zone is variable and in the on-Site area generally ranges from south to southeast. In the Lower Lone Rock Formation the hydraulic gradient direction is generally to the south and southeast in the southern half of the Site, and possibly to the north in the northern half of the Site. In the Lower Wonewoc Formation the hydraulic gradient direction is to the southeast. Hydraulic gradient directions have varied with time.

- The magnitude of the horizontal hydraulic gradient was calculated at 0.01 ft/ft in the northern half of the Site and 0.001 ft/ft in the southern half of the Site in the Unconsolidated Aquifer and Lower Lone Rock Formations. The magnitude of the horizontal hydraulic gradient was calculated at 0.001 ft/ft in the Upper Wonewoc Formation.

- The direction of the vertical hydraulic gradient was generally downward across the Site. The magnitude of the vertical hydraulic gradient between the Unconsolidated Aquifer and Lone Rock Formation was calculated at approximately 0.011 to 0.084 ft/ft. The magnitude of the vertical hydraulic gradient from the Lone Rock Formation to the Lower Wonewoc Formation was calculated at approximately 0.012 to 0.033 ft/ft. While the direction of the Site-wide vertical gradient is generally downward, localized upward vertical hydraulic gradients were observed at several well locations including Monitoring Wells MW-5D2 and MW-5D3 at 0.002 ft/ft and MW-22S to MW-22D at 0.009 ft/ft. A predominant downward vertical hydraulic gradient exists across the Site as a result of the city of Madison municipal wells pumping groundwater from the Upper Paleozoic and Mount Simon Aquifers. Furthermore, the vertical gradient is limited by the low permeability sediments (Eau Claire shale).

- Soil samples were analyzed on Site and off Site for VOCs, PCBs, PAHs, RCRA metals and cyanide. Soil concentrations are delineated by on-Site and/or off-Site soil borings.
  - Soil VOC concentrations above soil criteria were generally observed on Site near the former oil shed in the upper 2 feet of soil. Soil VOC concentrations were reported below soil criteria off Site. Soil VOC concentrations decrease with depth and were delineated by on-Site and off-Site soil results.
  - Soil PAH concentrations decrease with depth and are delineated by on-Site and off-Site soil results, where soil PAH concentrations were determined to be background and not attributed to MKC activities. Soil PAH concentrations above soil criteria were generally observed across the Site.
  - Soil PCB concentrations above soil criteria were generally observed on-Site along the western property line, under the building and under the north parking lot in the upper 4 feet of soil, and below the building in soils collected from greater than 4 feet. Soil PCB concentrations decrease with depth and are delineated by on-Site and off-Site soil samples results.
  - Soil RCRA metal concentrations above soil criteria were generally observed on Site in random locations for lead, mercury, barium, and selenium. Soil RCRA metal concentrations decrease with depth and are delineated by off-Site soil sample results.
  - Soil cyanide concentrations were reported below soil criteria at all on-Site and off-Site borings.

- Off-Site vapor was evaluated by collecting sub-slab and indoor air vapor samples at residences adjacent to the Site.
  - None of the VOC detections in the indoor air or sub-slab soil vapor samples collected by ARCADIS in 2012 exceeded the Wisconsin residential vapor action levels or calculated residential screening levels.
  - Two indoor air samples collected by the WDNR's consultant indicated a concentration of TCE above the residential vapor action level. However, split samples and subsequent samples did not confirm the TCE concentrations. WDNR's consultant installed SSDSs at these residences in 2012.

- Groundwater VOC concentrations were reported above ESs in Site monitoring wells. The main constituent of concern is PCE and limited degradation products (i.e., TCE, cis-1,2-Dichloroethene).
  - Based on the elevated PCE concentrations in groundwater, the source area is in the north parking lot area of the Site. PCE impacts in groundwater are delineated in the Unconsolidated Aquifer. PCE is delineated to the north, east and west in groundwater in the Lower Lone Rock Formation. PCE is delineated in the Upper Wonewoc Formation to the east and west. The plume is also delineated vertically on Site.
  - Based on the bedrock groundwater PCE analytical results, the bulk of the dissolved phase contaminant mass resides in three zones: A shallow zone from approximately 60 to 90 feet bls, an intermediate zone from 110 to 140 feet bls, and a deeper zone at 160 feet bls. Similar PCE concentrations at Monitoring Well MW-3D3 were reported from the fracture surfaces and matrix samples from approximately 60 to 90 feet bls. This implies that the PCE in this area has penetrated into the bedrock matrix in this interval. Conversely, the PCE concentrations from the fracture surfaces were higher than the matrix samples collected from 110 to 140 feet, and in samples collected from Monitoring Well MW-5D3, indicating that PCE has not diffused into the bedrock matrix to an appreciable extent in these locations.
  - Groundwater PAH ES exceedances were only reported at MW-3D3.
  - Groundwater PCB exceedances were limited to Monitoring Wells MW-22S, MW-22D and MW-23D, which are all within the building footprint.
  - Groundwater dissolved RCRA metal concentrations above the ES were only reported at Monitoring Well MW-3S with exceedances of chromium and mercury. PAL exceedances of RCRA metals were limited to the north parking lot and under the building with exceedances of chromium, lead, mercury and arsenic. The metal exceedances are limited to the on-Site well locations.

- As stated earlier, groundwater impacts are present in the Upper Paleozoic Aquifer (in the Lone Rock and Wonewoc Formations). Constituent transport in fractured sandstone bedrock is best conceptualized using the “dual-porosity” model. In the dual-porosity conceptual model, the primary porosity is associated with the bedrock matrix porosity which is often considered to be of lower relative permeability (or hydraulic conductivity). The primary bedrock matrix represents the less mobile pore space. Constituents can be transported into or out of the bedrock matrix through slow groundwater movement and chemical diffusion. The secondary porosity in the dual-porosity conceptual model is associated with fractures within the bedrock. Secondary porosity of sandstone is commonly referred to as “mobile porosity.” Constituents can be transported through the secondary porosity, also known as the fracture network, due to processes such as advection and dispersion.

- Based on multiple lines of evidence, dense non-aqueous phase liquid (DNAPL) is not present at the Site.

- Potential routes of migration for PCE and associated degradation products within the immediate vicinity of the Site are principally through groundwater and vapor migration.

The CSM was used to design and implement interim actions between February 2012 and January 2013 The interim actions focused on addressing soil containing PCBs and the migration routes for PCE as identified by the CSM:

- A SVE pilot test was conducted. Using the pilot test results, a full-scale SVE system was designed and installed. The system consists of nine SVE wells, located along the east property boundary. The system started continuous operation on March 9, 2012 and routine monitoring has confirmed the SVE system’s effectiveness.

- Existing SSDS systems at five adjacent residences were inspected.

- One 1,000-gallon petroleum UST in the southeast parking lot was removed.

- A PCB soil excavation was conducted. Approximately 670 tons of soil was excavated from the Site between December 17, 2012 and January 11, 2013.

The investigation data and CSM were also used to evaluate potential remedial options for groundwater. In-situ chemical oxidation (ISCO) was selected as the remedial option for groundwater. An ISCO pilot test was initiated in 2012 for further evaluate this technology and to obtain design parameters for a full-scale system. Successful distribution of injection reagents was achieved up to a radial distribution of 10 to 20 feet through gravity-feed injection. In addition, localized vertical connection has been observed between the shallow and deep bedrock intervals. The preliminary results indicate that the ISCO injection has achieved a measured benefit within the injection area. An evaluation of the extent of mass diffusion from the bedrock matrix to the fractures is ongoing and will be monitored through additional post-injection monitoring in 2013. Information from the additional monitoring activities will be utilized to finalize recommendations for a full-scale remedial design.

The results of the investigation, interim actions and groundwater remediation pilot testing were used to develop the following recommendations for additional work.

- On-Site soil exceedances will be managed through maintenance of the Site building and paved areas as an engineered barrier (cap). A Cap Maintenance Plan and Materials Handling Plan will be prepared. A deed restriction for the residual soil impacts located along the bike path and land leased by MKC from the city of Madison will be prepared. Residual on-Site soil exceedances will also be placed on the WDNR's Soil GIS Registry.

- Off-Site soil PCB concentrations above the non-industrial direct contact RCL will be excavated and disposed of at an approved landfill, pending approval by U.S. EPA and WDNR.

- Groundwater monitoring will continue in 2013 to evaluate trends in constituent concentrations and collect additional data from the ISCO pilot test area.

- In 2013, semi-annual sampling of the on-Site network of 16 soil vapor probes (summer and winter) will be performed. Additionally, the four soil vapor probes located within the bike path north of the Site will be sampled on a quarterly basis in 2013.

- No additional off-site residential vapor sampling is recommended.

- Operation and maintenance of the SVE system will continue in 2013. A permanent SVE system will be installed to replace the current Phase I SVE system in spring 2013. Influent and effluent SVE system samples will be analyzed for VOCs. Vacuum monitoring will continue at the nine SVE Extraction Wells and the existing six on-Site Soil Vapor Probes located within the radius of influence of the SVE system.

- One additional well will be installed to serve as a southern delineation well for the plume.

- Based on the ISCO pilot test results collected to date, continued groundwater monitoring will be completed in 2013 to fully evaluate the pilot test effectiveness and treatment performance to guide the remedial design. Upon completion of post-injection monitoring, recommendations regarding potential full-scale application of the ISCO technology for treatment of chlorinated ethenes at the Site, or whether alternative remedial technologies and approaches (e.g., monitored natural attenuation) are more appropriate for the Site, will be developed and provided to WDNR.

1. Introduction

ARCADIS was retained by Madison-Kipp Corporation (MKC) to complete investigation activities at its facility located at 201 Waubesa Street in Madison, Wisconsin (Site). Environmental investigation and remediation activities have been ongoing since 1994. Investigation activities focused on tetrachloroethene (PCE) prior to 2012 and in 2012 were expanded to evaluate polychlorinated biphenyls (PCBs), polycyclic aromatic hydrocarbons (PAHs) and Resource Conservation and Recovery Act (RCRA) metals.

This report presents a detailed summary of available Site history, previous investigations, a description of investigation and remedial pilot test activities completed between February 2012 and January 2013, summary of the observations and analytical results, and recommendations.

ARCADIS implemented an investigation designed to characterize Site conditions in soil, bedrock, groundwater, and vapor. ARCADIS performed a pilot test to evaluate an in-situ groundwater remedial alternative, and installed a soil vapor extraction (SVE) system along the northeast property line of the Site.

1.1 Report Organization

This report is organized as follows:

- Section 1: Introduction - Discusses the purpose of the report and the general report organization.
- Section 2: Site Background - Summarizes the Site background, location, description, Site history and facility operations, previous investigations, off-site sources of contamination, and potential receptors.
- Section 3: Site Investigation - Describes the objectives and corresponding scope of work including a summary of the activities, sample locations, and analytical methods.
- Section 4: Site Characterization - Discusses regional and local geology and hydrogeology and potential receptors.
- Section 5: Site Investigation Results - Discusses applicable regulatory criteria, analytical results, and nature and extent of impacts by media.

- Section 6: Interim Actions - Describes the scope of work including a summary of the activities, sample locations, and analytical methods.

- Section 7: Conceptual Site Model - Provides the Site conceptual model based on the Site investigation activities.

- Section 8: Summary of Findings and Conclusions - Provides a summary of the Site investigation results.

- Section 9: Recommendations - Provides the recommended activities for soil, groundwater, and vapor programs and remediation evaluation.

- Section 10: References - Lists the references used for the development of the report.

2. Site Background

The following sections present a summary of the Site location, contacts, description, summary of previous Site investigations, and off-Site contaminated sites.

2.1 Site Location, Contacts, and Description

The Site is located at 201 Waubesa Street in Madison, Wisconsin. The Site is located in the southwest quarter of Section 5, Township 7 North, Range 10 East in Dane County. The location of the Site is illustrated on a topographic quadrangle presented as Figure 2-1.

The following contact information is provided for the facility and environmental consultant:

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The Site is approximately 7.5 acres in size. A 130,000-square foot building occupies much of the Site. Asphalt parking lots are located in the northeastern, southwestern and southeastern portions of the Site. The building has a 25,000 square-foot second floor and a 25,000 square-foot basement. Figure 2-2 depicts the layout of the Site. The Site is zoned M-1 (industrial/manufacturing). The Site is currently operated as a metal die casting facility.

The Site is located in the eastern portion of Madison, in a mixed use area of commercial, industrial and residential land use. The Site is bounded by the Capital City Bike Trail to the north, Atwood Avenue to the south, and Waubesa Street to the west. Residences are located adjacent to the east and west sides of the Site, and further west (across Waubesa Street) and east (across Marquette Street). Commercial properties are located to the south (across Atwood Street) and further east. The Goodman Community Center is located to the north across the Capital City Bike Trail.

The Site is also located at the northeast end of the Madison Isthmus, which is a narrow strip of land separating Lake Mendota and Lake Monona. The Site is approximately 1,500 feet north of Lake Monona and approximately 6,800 feet east of Lake Mendota. This is important from a hydrogeological perspective because the lakes function as hydrologic boundaries for the Site. The topography of the Site is relatively flat, with an elevation ranging from approximately 870 to 880 feet above mean sea level (amsl). The Site and surrounding area is serviced by municipal water supply and sewer systems.

2.2 Site History

Phase I Environmental Site Assessments (ESAs) were completed for the Site in 2002, 2006 and 2010, and provided information regarding the Site history. A Phase I ESA was drafted but not finalized by URS in April 2002. An update to the 2002 Phase I ESA was completed by RSV Engineering in 2006, and another Phase I ESA was drafted but not finalized by RJN Environmental Services, LLC (RJN) in 2010.

The Phase I ESA reports indicated that MKC purchased the northern portion of the property in 1898, and the southern portion in 1917. Development initially consisted of a building at the north end of the Site and a building along Atwood Avenue to the south. Building additions were constructed in several phases, and by 1955 the initial two buildings were connected by these additions. The current configuration of the building was established by 1968.

Initially, MKC produced an automatic lubrication system for steam cylinders found in machinery such as farm tractors and power units. In 1928, MKC began designing and manufacturing die-casts and die-casting machines. In 1938 MKC began die-casting aluminum ammunition parts for the United States Military.

After World War II ended, MKC began retooling for post-war production, and by 1953 was manufacturing a wide array of parts for items such as tape recorders, washing machines, and space heaters. MKC also still supplied the military with parts including tailfins for mortars used in the Korean War.

During the May 2010 Site visit for the most recent Phase I ESA, the Site was being utilized as a metals casting facility. Natural gas-fired furnaces were used for melting metals, which are then poured into molds to cast parts. The facility conducts limited post-casting processing of parts. Chemical usage at the facility included chlorine, hydraulic oils, caustic solutions and stoddard solvent. No floor drains were observed in the building. Waste streams consisted primarily of solid wastes such as aluminum byproduct, used steel shot, wastewater sludge, and general refuse.

2.3 Aerial Photograph and Sanborn Map Review

Aerial photographs of the Site and surrounding properties from 1937 to 2010 were obtained and reviewed to evaluate historical Site conditions and operations, and changes in the surrounding land uses over time. Sanborn fire insurance maps from 1908, 1942, 1950, and 1986 were also reviewed to supplement the information available on the aerial photographs. The aerial photographs and Sanborn Maps are included in Appendix A. Key observations, organized chronologically, and are summarized below.

2.3.1 1908 Sanborn Map

Madison-Kipp Site*:* The earliest historical map available for the Site and surrounding vicinity is a 1908 Sanborn fire insurance map. The map shows only a small portion of the Site, with coverage limited to the northwest, southwest, and southeast corners. The northwest corner of the Site is occupied by one building labeled “Machine Shop” and an associated storage building south of the Machine Shop. The Machine Shop appears to be part of the current structure in the northwest portion of the Site, and expanded over the years. The Site is labeled “Madison-Kipp Lubricator Co.” The lots south of the Machine Shop (land that is currently part of the Site) are vacant. The portion of the Site that extends west was vacant in 1908.

There is a stable and residential structure in the southwest corner of the Site. There is no map coverage of the remaining central and eastern portions of the Site.

Surrounding Properties*:* There is a rail line present along the northern Site boundary. A brass foundry labeled “Madison Brass Works” is shown west of the Site, on the west side of Waubesa Street and south of the rail line. There is one residential structure west of the Site on the east side of Waubesa Street. The remaining lots are vacant. There are two residential structures east of the Site on the west side of Marquette Street; the remaining lots along the west side of Marquette Street are either vacant or map coverage is absent. A public street (Atwood Ave) is adjacent to the southern Site boundary, and Waubesa and Marquette Streets are to the west and east, respectively.

2.3.2 1937 Aerial Photograph and 1942 Sanborn Map

Madison-Kipp Site*:* The Site is further developed on the 1937 aerial photograph, and the features shown on the 1942 Sanborn Map are generally consistent with the aerial photograph. Approximately two-thirds of the Site is occupied by buildings, and there has been significant building construction/expansion since 1908. There is a rectangular building located on the south portion of the Site and a second, smaller building, is located northwest of the larger building. This second, smaller building was expanded southward from the original structure present in 1908. The two primary buildings are separate structures.

The Sanborn Map also shows a boiler house and a separate, small building for die casting located north of the larger building. One small structure is visible approximately 60 feet north of the die casting structure (150 feet north of the main building). A second small structure is present 60 feet northwest of the boiler house.

Two railroad spurs extend across the northeastern quarter of the Site from the main rail line located along the northern property boundary. The western spur extends to the north side of the main building, and the eastern spur terminates approximately 150 feet north of the building.

One residential structure is visible on the aerial photograph and Sanborn Map on the southwest corner of the Site.

A small building that appears to be a residential structure is visible on the southwest corner of the Site (currently occupied by a parking lot). The stable shown on the 1908 Sanborn Map is absent. A structure is present in the southeast corner of the Site (currently occupied by a parking lot) in the 1937 aerial photograph, and the 1942 Sanborn Map indicates the structure is a service station.

Surrounding Properties*:* The land use around the Site appeared to be primarily residential in 1937 with a few industrial or commercial structures present. There was significant residential construction since 1908. A rail line is visible along the northern Site boundary. The parcel north of the rail line (across from the Site and currently occupied by the Goodman Community Center) is occupied by a large, elongated building. The parcel is identified as the "Theo Kupfer Iron Works Machine Shop" on the Sanborn Map.

A structure is visible on a triangular-shaped parcel that is located immediately south of the rail line and west of the Site (identified as the Madison Brass Works Foundry on the Sanborn Map). The size of the structure has increased since 1908 to occupy nearly the entire parcel.

Residential structures are visible adjacent to the eastern and western Site boundaries. Atwood Avenue is visible adjacent to the southern Site boundary, and additional residential and commercial structures are visible south of the street.

2.3.3 1949 Aerial Photograph and 1950 Sanborn Map

Madison-Kipp Site*:* Some minor changes to the Site since 1937 are evident on the 1949 aerial photograph and 1950 Sanborn Map. The larger buildings on the Site have not been altered from 1937, but there are two structures visible to the north of the main building. The other structure is not shown on the Sanborn Map but is visible on the 1949 aerial photograph.

The residential structure that was located on the southwest corner of the Site was removed by 1949.

Surrounding Properties*:* Minimal changes were depicted on the adjacent properties. The rail line that was along the northern Site boundary may not have been functional based on the excess vegetation that obscures the tracks. One additional structure is present in the central portion of the parcel north of the rail line (the Goodman Community Center parcel). This parcel is still referenced as the Theo Kupfer Iron Works on the 1950 Sanborn Map. The area immediately surrounding the Site remains residential, but there is some expansion of commercial and industrial development evident northeast of the residential area east of the Site.

2.3.4 1955 Aerial Photograph

Madison-Kipp Site: The structure (possible residence) that had been located on the southwest corner of the Site (in the area currently occupied by a parking lot) appears to have been demolished.

Surrounding Properties*:* No significant changes on surrounding properties are evident on the 1955 photograph.

2.3.5 1962 Aerial Photograph

Madison-Kipp Site*:* There are minimal changes depicted on the Site in 1962. Two unidentified structures are visible in the southwest corner of the Site (currently occupied by a parking lot). One of the structures appears to be vertical in nature, but the purpose of the vertical feature and the other structure is not apparent. The area north of the main building (in the northeastern quarter of the Site) is used more heavily for vehicle parking. In addition, the southwest portion of the Site appears to have been graded with a gravel surface to facilitate additional parking.

Surrounding Properties*:* No significant changes on surrounding properties are evident on the 1962 photograph, with the exception of a new structure that is visible northwest of the Site and west of the parcel currently occupied by the Goodman Community Center.

2.3.6 1968 Aerial Photograph

No significant changes to the Site are evident on the 1968 photograph. The structures that were visible in the southwest corner of the Site on the 1962 aerial photograph are not present in 1968. The area appears to be used for vehicle parking. The railroad spurs located in the northeast corner of the Site are not clearly visible and may have been removed or taken out of service by 1968.

No significant changes to the surrounding properties are evident on the 1968 photograph.

2.3.7 1976 Aerial Photograph

Madison-Kipp Site*:* A modification to the building footprint is visible. Prior to the 1976 photograph, the larger, main building located on the south half of the Site was not connected to the building located in the northwest quarter of the Site. Building modifications were made between 1968 and 1976 to construct an addition that connected the two buildings.

The area north of the building and the portion of the Site that extends west appear to have been freshly graded with gravel, and vehicles are absent from both areas. The gravel appears to have been graded across the areas in anticipation of surface paving for future parking. In addition, the southwest corner of the Site (currently used as a parking lot) appears to have been paved with asphalt.

Surrounding Properties*:* One new structure is visible in the north portion of the parcel that is currently occupied by the Goodman Community Center. No other significant changes to the surrounding properties are evident on the 1976 photograph.

2.3.8 1980 Aerial Photograph

Madison-Kipp Site*:* The quality and resolution of the 1980 photograph is poor. A building addition is visible along the west side of the original building.

The only other change to the Site that is readily apparent is that the area north of the building and the portion of the Site that extends west appears to have been paved as asphalt parking lots.

Surrounding Properties: No significant changes to the surrounding properties are evident on the 1980 photograph.

2.3.9 1986 and 1987 Aerial Photographs and 1986 Sanborn Map

The quality and resolution of the 1986 and 1987 aerial photographs are poor. There are no significant or discernible changes to the Site and the surrounding properties evident on either aerial photograph.

Madison-Kipp Site: The only significant change to the Site evident on the 1986 Sanborn Map is that a small structure labeled “pump house” is shown north of the main building, near the northeast corner of two horizontal oil storage tanks. Based on the aerial photographs, the pump house (and oil storage tanks) have been present in this area of the Site since approximately 1949, and one of the oil storage tanks was present as early as 1942.

Surrounding Properties: The Madison Brass Works facility is depicted with a small building addition on the south side of the building. This property is referenced as “Madison Brass Works Inc & Ace Builders & Surf Inc” on the Sanborn Map.

2.3.10 1992 and 1993 Aerial Photographs

Madison-Kipp Site*:* By 1992, the structure that was located on the southeast corner of the Site (identified as a former service station from other historical sources) has been demolished and removed. It is unclear in the photographs if the ground surface in this area is paved or unpaved. No other changes to the Site are evident on either photograph.

Surrounding Properties*:* No significant changes to the surrounding properties are evident on the 1992 and 1993 photographs.

2.3.11 2000 Aerial Photograph

Madison-Kipp Site*:* The southeast corner of the Site (where a service station was formerly located) is now a paved parking lot. No other significant changes to the Site are evident.

Surrounding Properties*:* The land formerly occupied by the rail line (adjacent to the northern Property boundary) was re-developed as a bike/walking path. The bike path appears to be paved.

2.3.12 2005 and 2006 Aerial Photographs

No significant changes to the Site or the surrounding properties are evident on the 2005 and 2006 photographs. Some additional landscaping is present in the area north of the Property, along the bike path.

2.3.13 2008 and 2010 Aerial Photographs

No significant changes to the Site are evident on the 2008 and 2010 photographs. The oil storage tanks that were located north of the building (as shown on the 1949 aerial photograph and 1986 Sanborn map) are no longer present on the 2008 photograph.

The only significant change to surrounding properties that is evident is that the parcel north of the Site (currently occupied by Goodman Community Center) was re-developed between 2006 and 2008 into the current community center. The original structure that has occupied the parcel since prior to 1937 remains intact in 2008, and the building footprint appears relatively unchanged from the 1937 aerial photograph. However, three smaller structures that were east of the main structure have been demolished and removed. One newly constructed building is present on the north side of the parcel, and the remaining parcel is re-developed with an asphalt parking lot and green space.

2.3.14 Summary of Aerial Photograph and Sanborn Map Observations

The following is a summary of key observations made from review of the historical aerial photographs and Sanborn Maps.

Madison-Kipp Site

- The original Madison-Kipp Corporation was operating as Madison-Kipp Lubricator Co. in one building on the northwest corner of the Site in 1908. By 1937, the original structure was expanded significantly to the south, and the main building located on the south half of the Site was constructed. The two main structures were connected by an addition between 1968 and 1976. Another addition to the west side of the south building was constructed between 1976 and 1980.

- Die casting was conducted in a small structure located on the north side of the main south building since 1937. The structure where these operations were conducted currently remains on the Site.

- A small storage structure was located on the Site northwest of the boiler house. This structure was constructed prior to 1942 and was labeled as an Oil Warehouse between 1942 and 1986. This structure was likely used for oil storage based on the Sanborn Map descriptions, and currently remains on the Site.

- Up to two horizontal oil storage tanks and a pump house were located in the northeast portion of the property, north of the main south building. One of the oil storage tanks was present between approximately 1937 and 2005. The other oil storage tank was present between approximately 1949 and 2005. The tanks appear to have been removed between 2005 and 2008.

- A service station operated on the southeast corner of the Site between approximately 1937 and 1992. The service station was removed by 1992, and this area was utilized for parking sometime after 1992. The parking area was paved prior to 2000.

- A residential structure and associated stable occupied the southwest corner of the Site between approximately 1908 and 1955. The stable was demolished prior to 1937 and the residence was demolished prior to 1955. This area has been utilized for parking since approximately 1968.

- One residential structure was present on the southwest portion of the Site. The residential structure was present between 1937 and 1942, and had been removed by 1949. This portion of the Site remained vacant and has been utilized for parking since approximately 1976.

- Two railroad spurs extended across the northeastern quarter of the Site from a main rail line located parallel to the northern property boundary. The railroad spurs curved south from the northeast corner of the Site toward the building. The spurs were present prior to 1937. The spurs appeared to be out of service and possibly removed from the Site by 1968.

Surrounding Properties

- A rail line was located north of the Site in 1908, and appeared to be out of use by approximately 1949. The railroad bed was converted to a bike path sometime prior to 2000.

- The Madison Brass Works foundry located west of the Site and south of the rail line was present in 1908. The original manufacturing building tripled in size prior to 1937. An addition was constructed on the south side of the building by 1986. The company operated as a brass foundry between 1908 and approximately 1986. By 1986 the parcel occupied by the foundry included Ace Builders Inc. and Surf Inc. The structures remain on the property through the present time.

- The parcel north of the rail line was developed prior to 1937 and occupied by the "Theo Kupfer Iron Works Machine Shop" until at least 1986. The footprint of this original structure currently remains intact. The iron works company constructed one additional structure prior to 1949, and a third structure between 1968 and 1976. This property was re-developed into the Goodman Community Center between 2006 and 2008.

- The majority of the residential developments east and west of the Site were constructed prior to 1937. A few residences west of the Site were constructed between 1937 and 1950.

2.4 Summary of Previous Investigations

Site investigation activities were initiated at the Site in 1994, and are ongoing. The Site Investigation Work Plan (ARCADIS, 2012) provided a detailed discussion of investigation activities completed prior to 2012. The following sections present a brief summary of the previous investigations.

2.4.1 Site Investigations, 1994 to 2011

Site investigation activities were initiated in 1994 in response to a request from the Wisconsin Department of Natural Resources (WDNR) due to the results of an investigation on an adjacent property. An investigation at the Madison Brass Works facility located west of the Site identified PCE in shallow groundwater at a concentration of 11 micrograms per liter (µg/L) and trichloroethene (TCE) at 1.3 µg/L. Groundwater flow at the Madison Brass Works was also reported west-southwest. Based on these off-site results, WDNR requested MKC conduct a Site investigation.

Initially, investigation activities were conducted in the northern portion of the Site to evaluate soil and groundwater conditions in the area of the off-Site groundwater detections identified by WDNR. One of the earliest groundwater samples, collected from a direct push soil boring (MK-2) advanced immediately northeast of the building, contained several chlorinated volatile organic compounds (CVOCs) including PCE and TCE. It was determined that a PCE-containing aboveground storage tank (AST) was formerly located outside the northern portion of the building. Also, a drainage ditch was located along the east side of the building and extended from the former AST area northward to the property boundary. This PCE-containing AST was taken out of service at an unknown date, and the ditch was filled and the area paved in 1995. The location of the former PCE-containing AST area and drainage ditch are depicted on Figure 2-3.

Subsequent investigation activities were completed to define the extent of soil and groundwater impacts in the northern portion of the Site. Groundwater monitoring wells were installed to evaluate groundwater quality over time. In addition, piezometers were installed to evaluate the vertical extent of groundwater impacts. Deeper piezometers were installed at several depth intervals in an attempt to delineate groundwater impacts.

As the investigation progressed, additional potential sources were identified as follows (Figure 2-3):

- A former vapor degreaser, which utilized PCE. The vent for the vapor degreaser was located in the northwestern portion of the building, along the east exterior wall. Soil borings were advanced in this area. that indicated that the former vapor degreaser in the northwestern portion of the building was a potential source of soil and groundwater impacts.

- A former fuel oil AST located in the northern portion of the building. A soil boring (GP-101) was advanced near the vent pipe for the former AST. The soil sample collected from the boring did not contain detectable concentrations of volatile organic compounds (VOCs), polycyclic aromatic hydrocarbons (PAHs) or diesel range organics (DRO). Based on these results, the AST was not considered a source and was eliminated from further investigation.

- A second vapor degreaser and vent location had been identified in the eastern portion of the building, near Monitoring Wells MW-5S/MW-5D.

Until 2001, investigation activities focused on soil and groundwater conditions on the Site. After a second former vapor degreasing unit location was identified, near Monitoring Wells MW-5S/MW-5D, investigation activities were implemented at adjacent residential properties in 2002 due to the proximity of the former vapor degreasing unit location to the property boundary. Soil samples were collected from residential properties bordering the Site to the east. Off-Site groundwater monitoring wells were also installed and sampled. Soil vapor probes were installed on Site and sampled in 2004 to evaluate the potential for vapor migration. Additional off-Site investigation continued, including installation and sampling of soil vapor probes at 150, 154, and 162 South Marquette. In 2011 soil vapor samples were also collected from on-Site vapor probes located adjacent to the following residential properties: 237, 249, and 261 Waubesa Street and 102, 114, 126, 202, 210, and 222 South Marquette Street.

In summary, investigation activities were completed during several phases between 1994 and 2011, with results being reported to the WDNR. The investigations included:

- Installation and sampling of 82 direct-push soil borings, five hand auger soil borings, and five hollow-stem auger borings for collection of soil samples.

- Installation of 11 temporary monitoring wells for groundwater sampling.

- Installation of five permanent groundwater monitoring wells and thirteen piezometers.

- Installation and sampling of 13 soil vapor probes on the Site, and soil vapor sampling at three adjacent residential properties.

Please refer to the *Site Investigation Work Plan* prepared by ARCADIS dated May 2012 for sampling locations from the previous investigations (ARCADIS, 2012). The soil, groundwater, and vapor sampling activities completed between 1994 and 2011 identified the following:

- Soil consisted of a surficial unit of silt clay extending to a depth of 6 to 8 feet. The silty clay unit graded to a sandy clay, which extended to a depth of approximately 12 feet, where there was a sharp transition to a fine-grained silty sand. The unit was stratified and had appreciable amounts of gravel. Fill material, consisting of sand and gravel mixed with cinders and slag were identified at several locations in the northern portion of the Site.

- Bedrock was encountered at a depth of approximately 35 feet. The upper part of the bedrock consists of sandstones of the Lone Rock and Wonewoc Formations, which is approximately 210-feet thick.

- The water table in the northern portion of the Site is located within the unconsolidated soil, but is located in the bedrock in the southern portion of the Site. As a result, no monitoring wells are screened within the unconsolidated soil in the southern portion of the Site.

- The water table at the Site generally ranged between 15 and 35 feet below land surface (bls). Shallow groundwater flow trended to the east and south; flow in the bedrock appeared to trend south but has shown more variability than in the upper zones. Based on the groundwater levels measured from nested monitoring wells, the vertical hydraulic gradient is downwards at the Site.

- Several areas of impacted soil were identified during the investigation. These include:
  - An area encompassing the former drainage ditch and former AST area in the northern portion of the Site. The maximum PCE concentration detected this area was 6,440 milligrams per kilogram (mg/kg) (GP-9), which is also the highest concentrations of PCE detected at the Site.
  - An area north of the loading dock area. The concentration of PCE in this area ranged up to 74 mg/kg (Soil Boring BE-23).
  - A soil sample (HA-25) collected from an east adjacent residential property contained PCE at 2.68 mg/kg.

- Vapor sampling completed on Site and off Site identified VOCs in soil gas:
  - The four vapor probes (VP-1S, VP-2S, VP-1N and VP-2N) installed along the east property boundary contained detectable concentrations of VOCs. PCE concentrations were reported up to 51.8 parts per million by volume (ppmv).
  - The soil vapor samples collected from on-Site vapor probes located adjacent to select residential properties (237, 249, and 261 Waubesa Street and 102, 114, 126, 202, 210, and 222 South Marquette Street) contained PCE concentrations up to 4.6 ppmv.
  - The soil vapor probes installed off Site in the backyards of three residential properties adjacent to the Site (150, 154, and 162 South Marquette Street) contained PCE concentrations up to 1.9 ppmv.

- Periodic groundwater monitoring has been ongoing since 1995. There were 18 monitoring wells and piezometers installed through 2011. The following is an overview of groundwater conditions:
  - Historically, the primary constituents of interest in groundwater have been chlorinated VOCs, primarily PCE. Petroleum hydrocarbons have been detected in Monitoring Wells MW-6S and MW-6D, located at the southeastern

portion of the Site. The petroleum hydrocarbons are likely associated with the former gasoline service station, and another service station with a known release is located further west, across Atwood Avenue.

- Concentrations of chlorinated VOCs in groundwater during the initial phases of investigation were highest in Well Nest MW-3S/MW-3D/MW-3D2, located in the northern portion of the Site. When MW-3S was first sampled in 1995, the concentration of PCE in groundwater was 2,600 µg/L. When MW-3D was installed and sampled in 1999, the concentration of PCE was 1,400 µg/L. When MW-3D2 was installed and sampled in 2001, PCE was detected at 450 µg/L.
- Elevated concentrations of chlorinated VOCs were also detected at Well Nest MW-5S/MW-5D/MW-5D2, installed southeast of Well Nest MW-3S/MW-3D/MW-3D2 and northeast of the building. During a July 2001 sampling event, the concentration of PCE at MW-5S was 520 µg/L, and was 8,800 µg/L in MW-5D. When MW-5D2 was installed and sampled in 2003, PCE was detected at 35 µg/L.
- Piezometer MW-6D contained benzene at 3,900 µg/L in April 2010, which is indicative of a separate release. Other petroleum VOCs indicative of a gasoline release were also present.

Additional investigation activities were completed in 2012 to further evaluate soil, groundwater, and vapor conditions. The investigation activities are discussed in detail in later sections of this report.

2.5 Summary of Previous Remedial Measures

Several phases of remediation have been conducted at the Site. The *Site Investigation Work Plan* (ARCADIS, 2012) provided a detailed discussion of remediation activities completed prior to 2012. The following sections present an overview of the previous and ongoing remedial measures. Figure 2-3 depicts the locations of the remediation areas.

2.5.1 Soil Remediation

Several soil remedial action options were evaluated during the early phases of the Site investigation. Following the completion of additional investigation activities and further evaluation of alternatives, soil excavation was deemed to be infeasible due to the close proximity of soil to the building and the presence of utilities, which created a significant risk of damaging these structures during excavation. Bioremediation was therefore subsequently recommended and implemented in two phases.

The first phase of soil bioremediation at the Site was completed in 1998 and 1999. A reagent with the trade name of BiOx was initially applied to impacted soils at the Site in June and July 1998. Injections were completed in two areas: the northern portion of the former drainage ditch; and the area near the north former vapor degreaser vent. Two additional applications were completed in the former drainage ditch area in December 1998 and May 1999. Verification soil sampling was conducted during the remediation activities. The data showed that concentrations of PCE were reduced to below the Site-specific residual contaminant level (RCL) of 1 mg/kg established for the remedy.

A second phase of soil bioremediation was completed in 2005 when the area of impacted soil north of the loading dock was treated with Cool-Ox. Based on the results of the 1998 and 1999 soil remediation, a comparable remedy was conducted in 2005 to address impacts from the second location of a former vapor degreaser unit. Cool-Ox was selected as the reagent for this phase of remediation. In summary, 119 borings were advanced in the treatment area located along the loading dock to apply the reagent, which stimulated the biodegradation of the chlorinated VOCs. Comparison of pre- and post-treatment soil samples indicate that PCE concentrations decreased from the 487 to 782 mg/kg range to less than 3.2 mg/kg.

2.5.2 Groundwater Remediation

Several groundwater remedial action options were evaluated during the early phases of the Site investigation. A pilot test for ozone sparging was completed in 2007. The pilot test was conducted near Monitoring Wells MW-3S/MW-3D/MW-3D2. Based on these results, a sparge point was installed, and ozone sparging was conducted for 2 weeks. Reductions in PCE concentrations were observed at Monitoring Wells MW-3S and MW-3D. An ozone sparge system, consisting of three ozone sparge wells, was installed in the eastern portion of the Site, north of the Monitoring Wells MW-5S/MW-5D/MW-5D2 well nest. The system operated from 2008 to 2012.

2.6 Off-Site Contaminated Sites

A WDNR file review was completed for several other sites that are near Madison-Kipp. The sites include the Goodman Community Center, Madison Brass Works, Clark Oil, Classic Cleaners and the Olbrich Park Landfill (Figure 2-1). A summary of the environmental findings from the file review for each site is provided below.

2.6.1 Goodman Community Center

The Goodman Community Center is located at 149 Waubesa Street in Madison, Wisconsin and is located to the north of the Site. The Goodman Community Center was entered into the Remediation and Redevelopment (R&R) Program Bureau of Remediation and Redevelopment Tracking System (BRRTS # 02-13-262205) in June 1987 and (BRRTS # 02-13-552584) in October 2008. In 1987, four petroleum underground storage tanks (USTs) were removed and 7,500 cubic yards of soil impacted with petroleum and paint was excavated. Groundwater sampling identified petroleum impacts at two monitoring wells near two of the former USTs and chlorinated solvents near the south end of the former garage building. A no further action letter was issued by the WDNR in June 1987.

A Phase I and Phase II ESA was completed in 2000 that identified metals in soil samples at concentrations above the RCLs and a low concentration of PCE in a soil sample near the southwest corner of the property. The WDNR indicated that no further investigation or remediation was required as long as the property stays in commercial or industrial use. An additional investigation completed by a potential buyer indicated TCE and PCE in groundwater, which flows to the southeast. The WDNR granted the request for an off-site liability exemption which states the PCE migrated onto the site from MKC. However, the potential buyer's consultant indicated that the PCE detected in a shallow soil sample on the Goodman Community Center property was not likely due to migration onto the Goodman Community Center property from an off-site location, and the direction of groundwater flow is from the Goodman Community Center toward the Site. In 2005, an additional investigation was completed by a potential buyer identifying metals and PAHs at concentration above the RCLs. A soil sample from the northern portion of the property contained 1,1,1-trichloroethane. This investigation also identified ACM and PCBs in building materials, which were subsequently encapsulated. Although soil contamination still exists, the site received closure on October 24, 2008. As a condition of closure, pavement, an engineered cover, or a soil barrier is required over contaminated soil.

2.6.2 Madison Brass Works

Madison Brass Works is located at 214 Waubesa Street in Madison, Wisconsin and is located to the west of the Site. Madison Brass was entered into the R&R Program

(BRRTS # 03-13-001683) in November 1992. A 1,000-gallon fuel oil tank was removed on November 9, 1992 and a soil sample collected during the tank closure assessment indicated the presence of DRO in high concentrations and petroleum volatile organic compounds (PVOCs) in low concentrations. A release was subsequently reported on November 11, 1992. Four soil borings were advanced in and around the former UST and three monitoring wells were installed near the property boundaries. Soil samples from the borings contained DRO and PVOCs. A groundwater sample from the monitoring well located southeast of the former UST contained PCE at 11 µg/L. The well was side gradient from the former UST since groundwater flow was to the west-southwest. Approximately 108 tons of impacted soil was excavated from the former UST area in January 1994. Confirmation soil samples indicated DRO at concentrations less than 10 mg/kg and no detections of PVOCs. An additional round of groundwater sampling was conducted to investigate the presence of PCE, which was detected at 6.5 µg/L. Since there was no indication that Madison Brass Works was a source of chlorinated solvents and it appeared the PCE was emanating from an up-gradient source, site closure was granted on July 8, 1994.

2.6.3 Classic Cleaners

Classic Cleaners is part of the Madison East Shopping Center (Center) located at 2701 – 2829 E Washington Avenue and is located northwest of the Site. It was entered into the R&R Program (BRRTS # 02-13-522764) in February 2004 after the discovery of CVOCs during a petroleum investigation being conducted at the Center after the removal of multiple heating oil tanks. The CVOCs were likely the result of the operation at Classic Cleaners. This release was eligible for reimbursement under the dry cleaner environmental response program. A site investigation was conducted in 2005 and included six Geoprobe soil borings, installation of two off-site monitoring wells, replacement of an on-Site monitoring well, and installation of an on-site piezometer. Monitoring wells were installed to a depth of 16 feet bls and the piezometer was installed to a depth of 45 feet bls. Installation of four monitoring wells and other soil sampling activities had been conducted previously as part of the petroleum investigation at the Center. Soil sampling indicated the presence of CVOCs at two soil boring locations; however, only vinyl chloride was detected above the site specific residual contaminant level (SSRCL). Groundwater appears to flow to the southeast. Groundwater analysis indicated the presence of CVOCs in groundwater, with Enforcement Standards (ES) exceedances of vinyl chloride (12 to 71 mg/L) at two monitoring wells. No remedial actions were performed. A Site Investigation Report and Closure Request were submitted to the WDNR in May 2010. Although soil and groundwater contamination still existed above the SSRCL and ES, respectively, the site was included in the WDNR's Soil Geographic Information System (GIS) Registry and closed on June 7, 2010, due to the limited extent of the contamination and the decreasing concentrations in soil and groundwater due to natural attenuation.

2.6.4 Clark Oil

Clark Oil is located at 2801 Atwood Avenue in Madison, Wisconsin and is located south of the Site. It was entered into the R&R Program (BRRTS # 03-13-113339) in December 1996. Soil samples taken during the removal of two USTs revealed concentrations of PVOCs and gasoline range organics (GRO) exceeding the RCLs. A site investigation work plan was developed and nine borings were advanced and five monitoring wells and a piezometer were installed to evaluate the extent of contamination. Bedrock was encountered between 23 and 36 feet bls and water was encountered between 35 and 40 feet bls. Soil sampling indicated concentrations of PVOCs and GRO above the RCLs. Groundwater flow was generally to the south/southeast and analysis indicated concentrations of PVOCs, naphthalene, methylene chloride and lead above the ES. Free product was encountered in MW-1 and MW-4 which was managed through bailing and use of adsorbent socks. The soil and groundwater exceedances were located near the tank bed and pump islands. A Site Investigation Report was submitted to the WDNR on December 18, 2001. The WDNR requested a work plan on July 12, 2002 to further delineate the contaminant plume. Two additional monitoring wells and four additional piezometers were installed and sampled in February 2003, with additional rounds of groundwater sampling conducted in January 2010, October 2010 and April 2011. Free product still exists in the tank bed and MW-4.

2.6.5 Olbrich Park Landfill

The Olbrich Park Landfill is located at Atwood Avenue and Walter Street in Madison, Wisconsin, and is located southeast of the Site. It was entered into the R&R Program (BRRTS # 02-13-526338) in January 2004 and transferred to the Solid Waste Program in June 2005. The landfill was a non-licensed, non-engineered landfill with no liner. The landfill operated between 1933 and 1950 and accepted mostly residential and demolition waste including foundry sand, possible hazardous materials, and burned waste. The landfill was capped with 12 to 24 inches of granular fill and 4 to 8 inches of topsoil. In 1995, waste cells along the ditch that was originally constructed in 1948 became exposed due to erosion. Approximately 200 feet of the 1,000-foot ditch was dug through the landfill. The exposed waste was removed and the area was capped. Three gas probes were installed in 1990 and one monitoring well was installed in 1995.

Approximately 21 borings were advanced on March 17, 1995, to delineate the limits of waste. Additional geotechnical investigations were conducted to evaluate the potential for constructing a boat ramp and a restroom facility and were submitted to the WDNR on April 4, 1995, as part of a request for an exemption to build on an abandoned landfill. The exemption was granted on April 21, 2005, and the construction documentation was submitted December 11, 1995. A second exemption request was submitted in March 2001, to construct a pedestrian bridge, flower garden, walkways and a pavilion on the landfill. The exemption request was granted on April 24, 2001. Two additional monitoring wells were installed in 2003 to help determine if leachate control was required. The groundwater analytical results indicated low levels of VOCs and elevated levels of iron and manganese. Samples collected from two locations along the creek did not indicate the landfill was affecting the water quality in the creek. Groundwater flow is generally to the southeast. Gas monitoring has indicated that there are no methane or gas problems related to the landfill waste. Analysis of the water from Municipal Unit Well #8 has not revealed any impacts due to the landfill. There is no indication that the landfill waste is significantly affecting the environment, therefore, a No Further Action letter was issued on March 7, 2005, that includes a biennial cap inspection and maintenance requirement.

3. Site Investigation

The goal for the Site is to develop and implement a long-term remedial strategy that prevents or eliminates the potential for vapor intrusion into structures; prevents or eliminates the potential for direct contact with soil and groundwater contamination; and facilitates groundwater restoration or containment. The scope of the investigation activities was developed by reviewing the historical record to obtain information to complete the evaluation of relevant items enumerated under NR 716.07 (1) through (11) and develop a conceptual site model (CSM).

The following sections present an overview of Site investigation objectives, scope of work, and means and methods to complete the investigation. The results of the investigation will be used in conjunction with the previous investigation data to evaluate the extent of impacts and to develop a CSM and long-term remediation strategy.

3.1 Site Investigation Objectives

A CSM synthesizes all relevant data including the facility and release history, geologic and hydrogeologic conditions, nature and extent of contamination, potential receptors and transport mechanisms. Based on a review of historical information and data, the following investigation objectives were identified:

- Determine the constituents of concern and lateral and vertical extent of impacts in the unconsolidated soils, bedrock, groundwater, and vapor.

- Understand the vertical distribution of VOCs, including whether significant VOC mass may be stored in the bedrock's primary porosity (also referred to as matrix porosity). The degree to which VOCs have diffused into the primary porosity of the bedrock is a key factor that directly influences the feasibility and clean-up time-frames of remedial strategies.

- Understand the bedrock fracture frequency, degree of fracture interconnectivity, and how this portion of the CSM influences VOC mass transport both laterally and vertically, and how it influences treatment of VOCs in the bedrock and groundwater.

- Evaluate hydrogeologic variability in the strata beneath the Site and how it may influence VOC mass transport and recoverability under potential remedial approaches.

- Understand spatial and temporal variability in hydraulic head to better understand patterns of groundwater flow.

3.2 Regulatory Correspondence

All investigation and remediation activities were completed with approval from the WDNR. A complete list of work plans, summary reports, correspondence, and permits, and a copy of corresponding WDNR correspondence are included in Appendix B.

3.3 Site Investigation Activities

In addition to the Site investigation activities completed between 1994 and 2012, ARCADIS and RJN conducted investigation activities between February 9, 2012 and January 25, 2013. The location of the on-Site and off-Site sample locations is presented on Figure 3-1. Investigation activities included the following:

- Advanced and sampled 189 soil borings on the Site to evaluate the extent and degree of soil impacts. A total of 327 soil samples were collected and analyzed for concentrations of VOCs, PCBs, PAHs, PCB Homolog, RCRA metals, and total cyanide.

- Advanced and sampled 121 hand auger borings off Site at 32 residential properties to evaluate the extent and degree of soil impacts in the upper 4 feet at these locations. A total of 183 soil samples were collected and analyzed for concentrations of VOCs, PCBs, PAHs, RCRA metals, and total cyanide.

- Installed 10 single-screened groundwater monitoring wells (MW-3D3, MW-5D3, MW-10S, MW-11S, MW12S, MW-17, MW-22S, MW-22D, MW-23S, and MW-23D) and four Westbay multiport groundwater monitoring wells (MP-13 through MP-16).

- Installed three injection wells (IW-1S, IW-2D, IW-2D2) and seven injection monitoring wells (MW-18S, MW-19D, MW-19D2, MW-20D, MW-20D2, MW-21D, MW-21D2) for use during an in-situ chemical oxidation pilot test study.

- Installed four vapor probes along the northern property boundary and collected soil gas vapor samples from these and the 12 previously installed vapor probes located around the perimeter of the Site.

- Installed 22 sub-slab vapor points at 11 residential properties adjacent to the Site. Collected 32 sub-slab and 34 indoor air vapor samples from residences located in the neighborhood adjacent to the Site. A portion of these vapor samples were collected as split-samples with the WDNR. WDNR collected additional sub-slab and indoor air vapor samples throughout the neighborhood adjacent to the Site.

- Collected groundwater elevations and sampled 55 wells for concentrations of VOCs, PCBs, PAHs, and dissolved RCRA metals.

- Surveyed the locations of newly completed soil borings and wells.

- Collected and disposed of nonhazardous and hazardous investigative-derived waste (IDW).

3.4 Site Preparation

Prior to any intrusive work Site utilities were cleared in accordance with the ARCADIS Utility Locate Policy, where a minimum of three lines of evidence are required. ARCADIS contacted the Wisconsin One-Call, “Digger’s Hotline,” and a private locator. ARCADIS also contracted for a ground penetrating radar survey and consulted with Madison-Kipp employees to confirm the locations of known utilities.

3.5 On-Site Soil Investigation

Areas of impacted soil were identified at the Site including PCBs and VOCs in soil beneath the north parking lot area. To evaluate the extent of the PCB and VOC impacts in soil and develop a remediation strategy for the Site, a Site-wide investigation program was developed. A component of the Site-wide investigation program included soil investigation activities designed to collect a sufficient set of data to identify background and source areas. Below is a summary of the soil investigation program including selected drilling methodology, soil sample collection methodology, and laboratory analyses.

3.5.1 Soil Boring Advancement

The on-Site soil investigation included advancing soil borings outside and inside the footprint of the building. A total of 189 soil borings were advanced on Site between June 1, 2012 and January 4, 2013. The soil boring locations are presented on Figure 3-1. The soil borings were advanced using multiple drilling technologies including direct push, sonic, and hand augers. The soil borings were advanced by Giles Engineering Associates Inc. of Waukesha, Wisconsin; Probe Technologies of Palmyra, Wisconsin; and Boart Longyear, of Schofield, Wisconsin. Below is a summary of the exterior and interior building soil investigation activities.

- Exterior Soil Borings
  A total of 146 soil borings (B-1 through B-133, W-4 through W-15, and W-17) were advanced outside the limits of the building footprint. The borehole depths ranged from 4 to 35 feet. The borehole depths were selected to evaluate the background and potential source areas in direct contact soils (0 to 4 feet), soils above the groundwater table, and above the soil-bedrock interface. These soil borings were initially advanced in a grid pattern across each of the three parking lot areas and the western portion of the Site in a 50 foot by 50 foot grid. A denser spacing was used along the north, east, and west property boundaries. Following the initial phase of drilling, additional soil borings were advanced to refine the limits of the soil impacts.

- Interior Soil Borings
  A total of 43 soil borings (B-134 through B-174, MW22S, and MW23S) were advanced inside the limits of the building footprint. The borehole depths ranged from 3.5 to 50 feet. The soil boring locations were selected based on a Site visit attended by personnel from MKC, ARCADIS, and the WDNR. During the Site visit, historic facility operation areas with potential chemical usage were noted (Figure 2-3).

Soil cores were continuously collected from ground surface to the total boring depth at each location. Companion soil sampling procedures were conducted for each 1 to 2-foot interval including the collection of an aliquot of soil placed in a plastic bag for field screening, and a second plastic bag filled with soil and kept on ice in a cooler pending collection for laboratory analysis. The plastic bag for field screening was warmed prior to screening with a pre-calibrated flame ionization detector (FID) or photoionization detector (PID) to provide a qualitative assessment of the presence of organic vapors. This was conducted as an aid to determine intervals for laboratory analysis. The soil characteristics were described and recorded on soil boring logs. The boreholes were abandoned with bentonite or soil cuttings and the surface repaired to match its surroundings. Soil Boring Logs (WDNR Form 4400-122) and Borehole Abandonment Forms (WDNR Form 3300-005) are included in Appendix C.

3.5.2 Soil Sample Collection and Analysis

Up to two soil samples per boring were collected and submitted for laboratory analysis. In general, one soil sample was submitted from 0 to 4 feet bls and one from greater than 4 feet bls. Soil samples selected for laboratory analysis were determined based on field observations including presence or absence of staining, presence or absence of odors, and the FID or PID readings. Each soil sample selected for laboratory analysis was collected in laboratory-supplied containers and placed in a cooler on ice. The soil samples were submitted under standard chain-of-custody procedures to TestAmerica Laboratories, Inc. (TestAmerica) of University Park, Illinois for the following analyses:

- VOCs – SW-846 Method 8260B
- PCBs – SW-846 Methods 8082 and 680
- PAHs – SW-846 Method 8270C
- RCRA Metals – SW-846 Method 6010B/7471A
- Total Cyanide – SW-846 Method 9014

PCB analysis using Method 8082 provides results based on Aroclor concentrations. Additionally, a subset of soil samples was also submitted for laboratory analysis of PCB homolog by Method 680. Soil laboratory analytical reports are presented in Appendix D.

3.6 Off-Site Soil Investigation

The Site-wide investigation was expanded to include soil investigation activities on the residential properties located immediately adjacent to the Site along Marquette Street and Waubesa Street. Below is a summary of the soil investigation program including selected drilling methodology, soil sample collection methodology, and laboratory analyses.

3.6.1 Hand Auger Advancement

The off-Site soil investigation included advancing soil borings in the backyards of residences adjacent to the Site by RJN and ARCADIS. A total of 121 soil borings were advanced at 32 adjacent residences from April 27 through August 22, 2012. An additional 17 soil borings were advanced at adjacent residences in November 2012. The hand auger boring locations are presented on Figure 3-1. The soil borings were completed at the residential properties using a hand auger to a depth of approximately 4 feet bls and abandoned with the soil cuttings.

3.6.2 Soil Sample Collection and Analysis

Sample intervals were predetermined by the WDNR and RJN and included the collection of one soil sample from 0 to 1 foot bls and one soil sample from 3 to 4 feet bls. Select sample intervals were adjusted due to the presence of obstructions such as rocks and tree roots (206 and 210 South Marquette Street and 261 Waubesa Street), or removed from the sampling plan if a building or pavement were present (only one soil boring was advanced at the 130 and 154 South Marquette Street properties).

Soil was transferred directly from the hand auger to plastic bags from each sample interval, homogenized, and placed in clean, laboratory-supplied containers in a cooler on ice. The soil samples were shipped under standard chain-of-custody procedures to TestAmerica for laboratory analysis of VOCs, PCBs, PAHs, RCRA metals, and total cyanide using the same methods as the on-Site soil samples.

3.7 On-Site and Off-Site Bedrock Investigation

PCE has migrated downward through the subsurface, where it has reached the fractured sandstone bedrock beneath the Site. The Site investigation included characterization of the bedrock and groundwater. The following sections are a summary of the bedrock investigation activities.

3.7.1 Bedrock Boring Advancement

Mud rotary drilling technology was selected to install wells on Site and off Site. Mud rotary drilling is accomplished by a hydraulically powered top head drive with a bit attached to the bottom of the pipe that rotates a drill pipe. Rock is broken up by the rotating bit as it is lowered into the formation. Mud and drilling fluid is pumped through the rotating drill pipe through holes in the drill bit. The drilling fluid then swirls at the bottom of the hole, picking up all the rock chips that have been broken by the drill bit and transports them to the ground surface through the space between the drill pipe and borehole. The rock chips are deposited at the surface and the drilling fluids are re-circulated back down to the bottom of the borehole through the drill bit.

Four bedrock wells were installed on Site (MW-3D3, MW-5D3, MP-13, and MW-17) and three bedrock wells were installed off Site (MP-14, MP-15 and MP-16). Precautions to limit drag-down of contaminants were necessary when advancing boreholes through a known contaminated zone on Site. MW-3D3 and MW-5D3 were advanced through approximately 180 feet of temporary casing before advancing to their target depths of approximately 237 feet. The purpose of the temporary casing was to isolate impacted zones shallower than 180 feet. The depth of approximately 180 feet was selected based on the current Site well screen depths and the presence of known impacts to this depth. Bedrock Wells MP-13 through MP-16 and MW-17 were drilled approximately 5 feet into competent bedrock and permanent casing was installed before advancing to target depths of approximately 200 feet.

3.7.2 Bedrock Core Evaluation

Characterization of rock environments utilizing a discrete fracture network approach ($CORE^{DFN}$) was completed at the MW-3D3 and MW-5D3 boring locations. $CORE^{DFN}$ is an approach to investigate contamination in fractured bedrock. Contaminant distributions in chlorinated solvent plumes in fractured sedimentary rock can have strong spatial variability due to heterogeneity in source zone contaminant mass distributions, heterogeneity of the fracture network, heterogeneous rock matrix characteristics, and temporal variability in groundwater flow.

Constituent transport in fractured rock environments such as the sandstone bedrock sequence found at the Site is best conceptualized using the “dual-porosity” model. In the dual-porosity conceptual model, the primary porosity is associated with the bedrock matrix porosity which is the inter-granular porosity between rock grains. The primary porosity of sandstone can vary between approximately 5% and 25% and is often considered to be of lower relative permeability (or hydraulic conductivity). The primary bedrock matrix represents the less mobile pore space. Constituents can be transported into or out of the primary porosity (i.e., matrix or immobile porosity) through slow groundwater movement and chemical diffusion.

The secondary porosity in the dual-porosity conceptual model is associated with fractures which may form naturally due to tectonic activity, loading and unloading of glaciers, and other natural processes. Because bedrock fractures are capable of transmitting groundwater at velocities up to approximately 5 to 10 feet per day, secondary porosity of sandstone is considered to be the “mobile porosity” in the dual-porosity conceptual model. Secondary porosity of sandstone is often less than 0.1%. Constituents can be transported through the secondary porosity, also known as the fracture network, due to processes such as advection and dispersion. Typical monitoring wells installed during environmental investigations often intersect open, flowing fractures; therefore, monitoring well samples are useful for characterizing groundwater quality in the secondary porosity.

Because of the relatively large difference between primary and secondary porosity in fractured bedrock environments, such as is found in the sandstone bedrock beneath the Site, the majority of the contaminant mass resides in the low permeability high-porosity rock matrix, with down-gradient transport only occurring in the high permeability low-porosity fracture network.

To characterize the dual-porosity nature of the fractured bedrock system beneath the Site, ARCADIS selected $CORE^{DFN}$ technology to evaluate concentrations in each porosity regime.

$CORE^{DFN}$ technology involves specialized techniques for sampling, extracting and analyzing contaminants in the bedrock matrix at discrete locations. Approximately one rock sample was collected per linear foot of cored rock and submitted for laboratory analysis of select VOCs using a Gas Chromatograph-Electron Capture Detector method developed at the University of Waterloo. The following analytes were reported in the VOC scan: carbon tetrachloride, chloroform, 1,1-dichloroethene, cis-1,2-dichloroethene, trans-1,2-dichloroethene, methylene chloride, 1,1,1-trichloroethane, PCE, and TCE. Nitrile gloves were worn by the sampling personnel and discarded between each sampling interval and following any activity that may produce cross-contamination. This sampling frequency was based on rock quality description, location and spatial distribution of fractures, and rock characterization. The rock VOC concentrations were utilized to select the location of the piezometer well screen for the vertical delineation of groundwater. The Rock Core Sampling and Analysis Data Report is presented under Appendix E.

3.7.2.1 *Rock Sample Collection*

HQ-3 wireline rock coring techniques were used to collect rock cores from each boring to provide a continuous profile of the bedrock. A HQ-3 rock core drill string consists of a sample core barrel advanced inside a larger outer drive casing through the bedrock. This method was selected to increase the probability of quality core collection, as this method allows for the retrieval of the inner drill pipe and sample core barrel while the outer casing remains in place to maintain the outer borehole. The rock was sampled and characteristics logged at depths up to approximately 234 feet at MW-3D3 and 237 feet at MW-5D3. The bedrock at Bedrock Boreholes MW-13 through MW-17 was blind drilled. Vertical mixing of groundwater in the borehole was reduced by the temporary installation of flexible liners manufactured by FLUTe™ Ltd. Co. at these locations after reaching the target end depth, the borehole had been adequately flushed, and geophysical logging were completed.

3.7.2.2 *Down-Hole Geophysical Logging*

Down-hole geophysical logging was conducted at MW-3D3 and MW-5D3 to depths up to approximately 237 feet and at MP-13 through MP-16 and MW-17 to depths of approximately 200 feet. Multiple geophysical logging tools were utilized including gamma, fluid temperature, fluid resistivity, caliper, heat-pulse flow meter, and high resolution acoustic and optical borehole televiewers. The primary purpose of geophysical logging was to determine the depths and orientations of open, flowing fractures that intersected the boreholes, and to identify transmissive groundwater – bearing zones. The geophysical reports are presented under Appendix F.

3.8 Groundwater Investigation

Site investigation activities included the installation and sampling of temporary wells, vertical aquifer profiling in bedrock boreholes, and installation and sampling of permanent wells. The purpose of the groundwater investigation was to identify and characterize the nature and extent of potential dissolved phase impacts both vertically and horizontally, and to provide data that can be used in feasibility screening of groundwater remedial strategies. Temporary and permanent monitoring well locations are presented on Figure 3-1. Below is a summary of well installation and development procedures, groundwater sampling methodologies and laboratory analyses.

3.8.1 Temporary Well Installation

A total of 23 soil borings (B-3, B-6, B-10, B-14, B-18, B-24, B-28, B-30, B-33, B-35, B-37, B-41, B-43, B-45, B-47, B-51, B-53, B-55, B-56, B-59, B-63, B-73, and B-78) were converted to temporary groundwater wells to evaluate groundwater quality in the unconsolidated soils. The temporary well locations are presented on Figure 3-1. The soil borings were advanced to the top of bedrock or probe refusal, whichever came sooner. The temporary wells were constructed of 1-inch diameter Schedule 40, 0.010-slot polyvinyl chloride screen and riser set to depths ranging from 22 to 35 feet bls. Several other soil borings were converted to temporary wells; however, the potentiometric surface did not intersect the screens. These wells were primarily in the southern portion of the Site, where the potentiometric surface is located below the top of bedrock.

The temporary wells were developed by purging groundwater using dedicated polyethylene tubing and a peristaltic pump to remove a minimum of one casing volume. After purging and allowing the well to recharge, groundwater samples were collected in clean, laboratory-supplied containers and placed in a cooler with ice. The groundwater samples were shipped under standard chain-of-custody procedures to TestAmerica for laboratory analysis of VOCs by Method 8260B. The groundwater laboratory analytical report is presented in Appendix G.

Upon completion of groundwater sampling, the temporary well screens and casing were removed and the boreholes were abandoned using granular bentonite and the surface repaired to match the surrounding material. Abandonment forms for the temporary well boreholes are presented in Appendix C.

3.8.2 Vertical Aquifer Profiling

Groundwater samples were collected from the MW-13 through MW-17 boreholes in bedrock using a double packer. Results were used to determine the vertical extent of groundwater impacts and aid in selecting the target intervals for single-screen monitoring wells and multiport wells. Vertical aquifer profiling was completed at each borehole location using a “top-down” sampling approach. Groundwater samples were collected from every other 10-foot interval from the base of the permanent casing (estimated 40 feet bls) to 180 feet, and then every 10 to 200 feet bls. After the drill casing was advanced to the desired sampling depth, the lead drill casing was retracted and the packer system was installed. The packer system limits the flow of groundwater from above and below the desired sampling interval, so a discrete interval of the borehole can be sampled. Prior to sampling, the interval was purged using a decontaminated Grundfos submersible pump. Approximately 200 to 300 gallons were removed from each interval before sampling. Groundwater samples were collected in clean, laboratory-supplied containers and placed in a cooler with ice. The samples were submitted to TestAmerica for laboratory analysis of VOCs by Method 8260B. The groundwater laboratory analytical report is presented in Appendix G.

3.8.3 Well Installation and Development

Thirteen monitoring wells, four multiport wells with four to seven sample intervals, and three injection wells were installed as part of the investigation and remediation pilot test. Well construction details are summarized in Table 3-1. Below is a summary of the wells including installation dates and purpose of each well.

- Monitoring Well MW-10S was installed west of the Site, and MW-11S and MW-12S were installed in the unconsolidated soils east of the Site during April 4 to 10, 2012. These wells were installed in an effort to delineate groundwater impacts above the bedrock surface.

- Monitoring Wells MW-3D3 and MW-5D3 were installed on July 12 and 13, 2012. These wells were installed in an effort to delineate groundwater impacts vertically at the MW-3 and MW-5 well nests.

- Multiport Well MP-13 was installed on Site in the north parking lot on December 1, 2012. This multiport well was installed to evaluate groundwater quality in the bedrock at discrete intervals and in an effort to delineate the vertical extent of impacts at this location.

- Multiport Wells MP-14 through MP-16 were installed west, north, and east of the Site, respectively. These wells were installed between January 9 and 14, 2013. These multiport wells were installed to evaluate groundwater quality in the bedrock at discrete intervals and to attempt to delineate the vertical extent of impacts at these locations.

- Monitoring Well MW-17 was installed nested with MW-6S and MW-6D on January 8, 2013. This well was installed in an effort to delineate the vertical extent of groundwater impacts at this location.

- Injection Well IW-1S was installed in the unconsolidated soils, and IW-2D and IW-2D2 were installed in the bedrock on November 2, 2012. These wells were installed to conduct a pilot test of in-situ chemical oxidation technology using potassium permanganate to treat groundwater impacts.

- Monitoring Wells MW-18S, MW-19D, MW-19D2, MW-20D, MW-20D2, MW-21D, and MW-21D2 were installed between November 17 and 19, 2012. These wells were installed to monitor the radius of influence and effectiveness of the in-situ chemical oxidation pilot test.

Well construction details are summarized in Table 3-1. Monitoring well construction forms (WDNR Form 4400-113A) and Westbay multiport diagrams are included in Appendix H.

The goal of well development is to produce groundwater samples that are representative of the water quality in the target interval, and to produce samples that are free of sediment, drill cuttings and drilling fluids. Monitoring wells screened in unconsolidated soils were developed by surging and pumping with a submersible pump or dedicated bailer. Wells screened in bedrock were developed before the wells were constructed by brushing the borehole and purging a minimum of 5,000 gallons. After the bedrock wells were installed the screen intervals were developed using air lifting techniques to remove sediment-laden water. Well development forms (WDNR Form 4400-113B) are included in Appendix H.

3.8.4 Monitoring Well Groundwater Elevation Measurements

Static groundwater and well-depth-to-bottom measurements were collected at the Site monitoring network in April, July, and November 2012, and in January 2013. The monitoring wells were opened and allowed to equilibrate prior to measuring depth to groundwater. Measurements were collected from the north side of the casing using an electronic water level capable of measuring to an accuracy of plus or minus 0.01 feet. Groundwater elevations are summarized in Table 4-1. The water level meter was decontaminated between well locations using non-phosphate laboratory grade detergent water and rinsed with distilled water.

3.8.5 Monitoring Well Sample Collection and Analysis

Groundwater samples were collected in April, May, July, November, and December 2012 and January 2013. Groundwater samples were collected and submitted from select wells for analysis of VOCs, PCBs, PAHs, and/or dissolved RCRA metals. Groundwater samples were collected from monitoring wells using low-flow sampling techniques, with the exception of MW-22S and MW-23S which were bailed. Field parameters were recorded using a multi-parameter meter for pH, conductivity, dissolved oxygen, redox potential, and temperature. Groundwater samples were collected from the multiport wells using the Westbay-supplied sampling equipment. All non-dedicated field equipment was decontaminated between each well location using non-phosphate laboratory grade detergent water and rinsed with distilled water. Purge water was containerized in steel 55-gallon drums.

3.8.6 Hydraulic Conductivity Testing

Hydraulic conductivity testing was completed at a subset of the Site monitoring well network to characterize the hydraulic conductivity of soil and bedrock materials in the immediate vicinity of the tested wells. Hydraulic conductivity testing was conducted at 20 monitoring wells as follows: MW-1, MW-2S, MW-2D, MW-3S, MW-3D, MW-3D2, MW-3D3, MW-4S, MW-4D, MW-4D2, MW-5S, MW-5D, MW-5D2, MW-5D3, MW-6S, MW-6D, MW-9D, MW-9D2, MW-11S, and MW-17. The tests were completed between July 14, 2012 and February 2, 2013. These wells were selected for hydraulic conductivity testing based on lithology, water levels, well screen lengths, well depths, and recharge rates.

Two methods of hydraulic conductivity testing were utilized including bail-down slug tests and pneumatic slug tests. The following methodologies were implemented to collect groundwater level monitoring data during hydraulic conductivity testing:

- Bail-down slug tests were conducted at Monitoring Wells MW-1, MW-2S, MW-3S, MW-4S, MW-6S, and MW-11S. These wells are screened in unconsolidated soils. The tests were conducted by removing a column of approximately 2 to 3 feet of groundwater from the well using a whale pump with a check valve, and measuring groundwater level data with a pressure transducer.

- Pneumatic slug tests were conducted at Monitoring Wells MW-2D, MW-3D, MW-3D2, MW-3D3, MW-4D, MW-4D2, MW-5S, MW-5D, MW-5D2, MW-5D3, MW-6D, MW-9D, MW-9D2, and MW-17. These wells are screened in the bedrock. Pneumatic slug tests are conducted by using a specialized well apparatus that pressurizes the air column in the well. Pressurizing the well results in a depression of the groundwater level as the increased air pressure forces groundwater out of the well. Once the groundwater level has stabilized, the well is rapidly depressurized, and the change in groundwater head over time is recorded. A pressure transducer was used to monitor the water column during the test.

3.9 Sample Location Elevation Survey

The newly completed soil borings and well locations were surveyed by North Shore Engineering of Mequon, Wisconsin, a Wisconsin licensed surveyor. The survey included the northing, easting, ground elevations, and top of casing elevations for the monitoring wells. Vertical elevation accuracy was established at plus or minus 0.01-foot and horizontal location accuracy was set at plus or minus 0.1 foot. Horizontal coordinates are referenced to the North American Datum of 1983 (NAD 83 [1991]) and elevations are referenced to the North American Vertical Datum of 1988 (NAVD 88).

To minimize disruptions to the property owners, the locations of select off-Site hand auger soil borings were measured in the field in relation to the property boundary/fence-line and estimated using an aerial photograph image by an ARCADIS Geographic Information System Specialist.

3.10 IDW

IDW was generated during the Site investigation activities including soil and rock cuttings, development water, purge water, and decontamination water. Nonhazardous soil and rock cuttings were collected in rolloffs and transported off Site for disposal at Veolia Glacier Ridge Landfill LLC in Horicon, Wisconsin. Potentially hazardous soil and rock cuttings were collected in steel 55-gallon drums or loaded into end dump trucks and disposed of off Site at Wayne Disposal, Inc., in Belleville, Michigan. Development, purge, and decontamination water that was nonhazardous was collected in aboveground polyethylene storage tanks or tankers and disposed of off Site at CWT Wisconsin in West Allis, Wisconsin or steel 55-gallon drums and disposed of by MKC with facility wastewaters. Disposal documentation is presented in Appendix I.

3.11 Vapor Investigation

3.11.1 On-Site Vapor Investigation

As presented in ARCADIS' *Site Investigation Work Plan* dated May 31, 2012, vapor monitoring was initiated on Site in 2004. Four vapor probes (VP-1S, VP-2S, VP-1N and VP-2N) were installed along the east property boundary. The vapor sample from each vapor probe contained detectable concentrations of VOCs. PCE concentrations were reported up to 48 ppmv. These probes were periodically sampled using a variety of collection methods to evaluate changes in vapor concentrations.

Additional on-Site vapor probes are located in close proximity to the residential properties located adjacent to the Site (237, 249, and 261 Waubesa Street and 102, 114, 126, 202, 210, and 222 South Marquette Street). Soil vapor sampling was conducted at these locations in 2011. The locations of the vapor probes are shown on Figure 3-1.

A SVE system was installed along the northeastern property boundary in February and March 2012 to prevent the potential off-Site migration of vapors. The system is discussed in more detail in subsequent sections.

In April 2012, four soil borings (VP-3 through VP-6) were advanced to approximately 8 feet below ground surface along the bike path located north of the Site (Figure 3-1). Soil vapor probes were installed in each soil boring with 6-inch steel screens approximately 7.5 feet below ground surface. Soil vapor samples were collected from the probes over an approximate 30-minute time period using 6-liter summa canisters. The vapor samples were submitted for analysis of five VOCs by Method TO-15: PCE, TCE, cis-1,2-dichloroethene, trans-1,2-dichloroethene, and vinyl chloride to Air Toxics Inc. in Folsom, California. The results of the vapor samples indicated that none of the samples contained vapor concentrations above the non-residential deep soil gas screening levels.

As proposed in the *Site Investigation Work Plan*, a full round of vapor probe samples was collected from the existing network of soil vapor probes on the Site in October 2012. Vapor samples were collected from 16 vapor probes: VP-1N, VP-1S, VP-2N, VP-2S, VP-3, VP-4, VP-5, VP-6, VP-102, VP-114, VP-126, VP-202, VP-210, VP-222, VP-237, and VP-249. As a note, the soil vapor probe located on Site adjacent to 261 Waubesa Street (VP-261) was not sampled as it had been abandoned. Soil vapor samples were collected from these vapor probes over an approximate 30-minute time period using 6-liter summa canisters. The vapor samples were submitted for analysis of five VOCs by United States Environmental Protection Agency (U.S. EPA) Method TO-15: PCE, TCE, cis-1,2-dichloroethene, trans-1,2-dichloroethene, and vinyl chloride to Air Toxics Inc. in Folsom, California. The analytical results of this vapor probe sampling round are presented below in Section 5.8.

3.11.2 Off-Site Vapor Investigation

Off-site vapor sampling activities have been performed since 2006. In 2006, soil vapor probes were installed in the backyards of three residential properties adjacent to the Site: 150, 154, and 162 South Marquette Street. These soil vapor probes were monitored on a routine basis for VOCs. In 2011, sub-slab and indoor air (basement) vapor samples were collected from the 150, 154, and 162 South Marquette Street residences for laboratory analysis of VOCs. Subsequently, sub-slab depressurization systems (SSDSs) were installed at 146, 150, 154, 162, and 166 South Marquette Street in 2011.

During 2012, initial off-Site vapor sampling activities were performed per discussions with the WDNR and the tasks listed in the *Draft #9 - Environmental Response Activity Scope of Work (Draft SOW)* dated March 27, 2012. The *Draft SOW* task included the collection of sub-slab vapor and indoor air samples at 11 residences adjacent to the Site, subject to access approval. The 11 residences included 102, 106, 110, 114, 118, 126, 128, 130, 134, 138, and 142 South Marquette Street.

Prior to the implementation of vapor sampling activities, ARCADIS provided Standard Operating Procedures (SOPs) for indoor air/ambient air sampling, soil gas sampling using sub-slab ports, and tracer gas leak testing to the WDNR on February 20, 2012. The WDNR approved these SOPs via electronic correspondence on February 21, 2012. Following access approval from the residences, a building survey and chemical inventory was performed at each residence and two sub-slab vapor probes were installed in the basement of each residence in accordance with the SOP.

In accordance with the SOP, following installation, the sub-slab vapor probes were allowed to equilibrate for a minimum of 24 hours prior to sampling. A total of two indoor air samples (a sample collected from the basement of the residence and a sample collected from the first floor of the residence) were collected from each residence. The indoor air samples were collected over a 24-hour period using 6-liter summa canisters. Following the collection of the indoor air samples, a sub-slab vapor sample was collected from each of the two sub-slab vapor probes at each residence. Leak detection testing was performed at the sub-slab vapor probe sample locations in accordance with the SOP. The sub-slab vapor samples were collected over an approximate 30-minute time period using 6-liter summa canisters. The indoor air and sub-slab vapor samples were submitted to Air Toxics, Inc. Laboratory for analysis of five VOCs by U.S. EPA Method TO-15: PCE, TCE, cis-1,2-dichloroethene, trans-1,2-dichloroethene, and vinyl chloride, as outlined in the *Draft SOW*. For quality control purposes, ambient outdoor air samples were collected at the same time (over a 24-hour period) each day indoor air samples were collected. Duplicate samples, from approximately 10% of the samples, were also collected for quality assurance purposes.

Upon receipt of the laboratory analytical results, a letter was sent to each resident that included a summary of the sampling activities, building survey and chemical inventory, sample logs, and laboratory reports. The results of the initial vapor sampling activities in 2012 were also documented in the *Summary of Vapor Sampling Activities* letter report dated May 7, 2012 and submitted to WDNR and the Wisconsin Department of Health Services (WDHS). This letter report included the results of 9 of the 11 residences, as at that time access had not been provided by the home owners of 106 and 138 South Marquette Street. These home owners have since granted access and the results of the sub-slab and indoor air vapor sampling activities at 106 and 138 South Marquette Street were provided to each resident, the WDNR, and the WDHS.

The WDNR led an additional vapor sampling investigation in the neighborhood adjacent to the Site in 2012. The WDNR's consultant, SCS/BT2, performed sub-slab and/or indoor air vapor sampling at 43 residences. Some residences were sampled more than once. ARCADIS, on behalf of MKC, collected split samples along with WDNR's consultant at selected residences. At each residence accessed by ARCADIS, one sub-slab vapor split sample and one indoor air basement split sample was collected. The sub-slab vapor split samples were collected by ARCADIS at the same time that SCS/BT2 collected its samples, over an approximate 30-minute time period using 6-liter summa canisters. Following the collection of the sub-slab vapor split sample, an indoor air vapor split sample was collected over a 24-hour period using a 6-liter summa canister. The SCS/BT2 indoor air and sub-slab vapor samples were submitted to the Wisconsin State Laboratory of Hygiene for analysis of VOCs by U.S. EPA Method TO-15. Split-samples collected by ARCADIS were submitted to Air Toxics, Inc. for analysis of VOCs by Method TO-15.

A summary of the WDNR's vapor investigation was presented in WDNR's *Review of Vapor Sampling Results for the Neighborhood Surrounding the Madison Kipp Corporation* published in December 2012 (WDNR, PUB-RR-931). Any additional off-Site vapor sampling performed by ARCADIS after May 7, 2012 was documented in letters to the individual residents (with copies to WDNR and WDHS) and summarized in the Bi-Monthly Reports submitted routinely to the WDNR. The off-Site vapor analytical results are discussed in Section 5.8.

4. Site Characterization

The regional geology and hydrogeologic conditions were obtained from publically available technical reports, articles, and maps. The Site geology and hydrogeologic conditions were evaluated by interpreting drilling and sampling soil borings and monitoring wells within the context of the regional hydrogeology.

4.1 Climate

The city of Madison has a continental climate with an average annual temperature of approximately 47 degrees Fahrenheit (ºF) (NOAA, 2013). The summer, fall, winter and spring temperature averages in 2012 were 70 ºF, 49 ºF, 22 ºF, and 46 ºF, respectively. The average annual precipitation is approximately 34.5 inches, and the average monthly precipitation is approximately 2.9 inches. The average annual snowfall is 50.4 inches, with an average of 7.2 inches per month during winter. Snowfall peaks in January and December. The city of Madison experiences snowfall roughly seven months a year.

4.2 Topography

A historical topographic map report of the Site and surrounding area was prepared by Environmental Data Resources Inc., (EDR) of Milford, Connecticut for the years 1892, 1906, 1959, 1969, 1974 and 1983 (EDR, 2012). A copy of the EDR report is included in Appendix A. Topographic maps were reviewed for temporal topographic and land use variations as well as drainage patterns. Below is a summary of the key observations made.

The Site's topography gradually slopes upward from the north toward the south. Continuing south, the topography continues to gradually slope upward to approximately 880 feet amsl before beginning a sharp decline to 844 feet amsl towards Lake Monona. To the west, the topography gradually slopes upward from the east to the west. The elevation reaches 880 feet amsl approximately one quarter-mile west where it then begins gradually sloping down to 847 feet amsl at Lake Mendota. Total Site relief is approximately 40 feet from the north to the south.

4.3 Potential Receptors

In accordance with the standard risk assessment process of evaluating sources, pathways, and receptors, ARCADIS completed a desktop survey of potential receptors for the identified impacted media (soil, groundwater, and vapor).

4.3.1 Exposure Pathways

For soil, the potential exposure pathways include ingestion (residential, commercial/industrial worker and construction worker), dermal contact (residential, commercial/industrial worker and construction worker), inhalation (residential, commercial/industrial worker and construction worker), and migration to groundwater. For groundwater, the potential exposure is via ingestion (commercial/industrial worker). For vapor, the potential exposure is inhalation (residential and commercial/industrial worker).

4.3.2 Water Well Survey

ARCADIS performed a water well survey near the Site that identified three public water supply wells utilized by the city of Madison (Figure 2-1). Municipal Unit Well 8 is located approximately 1,400 feet southeast of the Site; Municipal Unit Well 11 is located approximately 1.2 miles east of the Site; and Municipal Unit Well 7 is located approximately 1.8 miles northwest of the Site. Municipal Unit Well 8 is a bedrock well open across the Mount Simon formation that was tested at a pumping rate of approximately 1,965 gallons per minute with 65 feet of drawdown, yielding a specific capacity of approximately 30 gallons per minute per foot of drawdown (gpm/foot). Municipal Unit Well 7 is a bedrock well open across the lower part of the Eau Claire and Mount Simon formations and was-tested at a pumping rate of approximately 1,750 gallons per minute with 94 feet of drawdown, yielding a specific capacity of approximately 19 gpm/foot. Municipal Unit Well 11 is a bedrock well open across the Lone Rock, Wonewoc, Eau Claire (shale was not logged for this well), and Mount Simon formations that was tested at a pumping rate of approximately 2,152 gallons per minute (gpm) with 111 feet of drawdown, yielding a specific capacity of approximately 19 gpm/foot. Copies of the boring logs and well construction details for these wells are presented under Appendix J.

4.3.3 Surface Water

The Site is located at the northeast end of the city of Madison on an isthmus between Lake Mendota and Lake Monona (Figure 2-1). Lake Mendota is located approximately 6,800 feet west of the Site and Lake Monona is located approximately 1,500 feet north of Site.

4.3.4 Sensitive Habitats

ARCADIS conducted Site visits and reviewed documents such as topographic maps, Phase I ESA reports, and WDNR water resources maps to evaluate whether there may be the following sensitive receptors on the Site or on nearby properties:

- Species, habitat or ecosystems sensitive to the contamination.
- Wetlands.
- Outstanding water resources and exceptional water resources.
- Sites or facilities of historical or archeological significance.

The Site is located in a mixed-use area of commercial, industrial and residential developments. The Site is almost completely paved and has limited areas of landscaping. All of the adjoining properties consist of residences that have limited areas of landscaping. Vegetation in the area is limited to landscaping species and urban trees. No sensitive species, habitat, ecosystem, wetlands, or outstanding resource waters were identified in the vicinity of the Site.

There is a feature identified as a “rain garden” located adjacent to the northeast property line (Figure 2-3). The rain garden is a demonstration project completed by the city of Madison to illustrate how runoff of precipitation in an urban setting can be reduced through the use of vegetated areas. The rain garden captures precipitation runoff from an adjoining bike path. While not a habitat for sensitive species, this area was identified as part of the investigation scoping because rain gardens are designed to retain storm water and facilitate infiltration to groundwater. Care was taken during the investigation to reduce the potential for runoff contacting investigative activities.

4.4 Regional Geology and Hydrogeology

Dane County's regional geology is characterized by a series of geologic units consisting of unconsolidated deposits underlain by a sequence of bedrock units: sandstone overlying crystalline bedrock. A summary of the various geologic units from youngest to oldest is presented below.

4.4.1 Unconsolidated Glacial Geology

Dane County unconsolidated deposits are divided by two geologic areas: the unglaciated area to the west, referred to as the Driftless Area; and the glaciated area to the east (WGNHS, 1997). The Site is located in the glaciated area. The glaciated area was formed during the Quaternary Period, which started approximately 1.6 million years ago. As the Laurentide Ice Sheet advanced from central and eastern Canada into Wisconsin, several distinct lobes were formed. The Green Bay Lobe transected Dane County from the northwest corner to the south central part of the county. As the lobe retreated, melt water flowed south under and above the ice sheet and deposited massive amounts of sand and gravel, along with clay and silt, in a glacio-fluvial depositional environment. From this information it can be expected that unconsolidated deposits in the area consist of heterogeneous mixtures of gravel, sand, silt, and clay in an approximately horizontal layered system, with individual soil units in the shape of lenses and layers.

Madison's unconsolidated surficial deposits are also glacially-derived and consist primarily of the Horicon Member of the Holy Hill Formation. The origins of the Madison soils are subglacial till formed from end moraines. The till near the Site generally consists of a brown silty sand matrix with interspersed dolomitic gravel. The sand content ranges from approximately 50 to 80% with approximately 80 to 95% silt, and approximately 5 to 20% clay.

During the last Wisconsin Glaciation approximately 20,000 years ago, the bedrock surface was heavily eroded forming the Yahara River valley in central Dane County (WGHNS, 2007). The Yahara River valley is present beneath Lakes Mendota, Monona, Wingra, Waubesa, and Kegonsa. As the glacier receded, meltwater was trapped between the end moraine and a western drainage divide forming glacial lakes. The glacial meltwater carried significantly volumes of gravel, sand, and silt, which filled the lakes with deposits more than 300-feet thick.

4.4.2 Bedrock

Bedrock units in Dane County (WGNHS, 1999), from youngest to oldest, include the Cambrian-aged Lone Rock, Wonewoc, Eau Claire, Mount Simon Formations, and Precambrian-aged crystalline rock. Below is a brief description of these formations.

4.4.2.1 *Lone Rock Formation*

The Lone Rock Formation is a pale yellow, glauconitic, thin to medium horizontal laminated to cross-bedded, poorly to moderately cemented, very fine to fine-grained sandstone (Baumann, 2010). This sandstone is interbedded with light brown to green, very glauconitic, bioturbated, friable to soft, dolomitic sandstone. The Lone Rock Formation varies in thickness along the isthmus since it is the upper bedrock formation and was heavily eroded during previous glaciation (Ruekert Mielke, 2011). Along the isthmus, the formation pinches out to the southwest, but is approximately 55- to 95-feet thick to the east based on boring logs and city of Madison municipal well logs. The Lone Rock Formation is absent under Lake Mendota and Lake Monona. The contact between the Lone Rock and Wonewoc formations is gradual.

4.4.2.2 *Wonewoc Formation*

The Wonewoc Formation is subdivided in three members including the Ironton (transition zone), Ironton, and Galesville (Baumann, 2010). The Wonewoc Formation is pale yellow to white, friable, poorly to moderately sorted, fine to coarse-grained sandstone displaying medium to large scale cross stratification. The Wonewoc Formation is absent under Lake Mendota and Lake Monona.

4.4.2.3 *Eau Claire Formation*

The Eau Claire Formation is white to light gray to light pink, moderately well sorted, predominantly fine to medium-grained dolomitic sandstone with interbedded siltstone and shale (WGNHS, 1999). The interbedded siltstone and shale is primarily in the upper part of the formation. The shale in the vicinity of the Site is estimated to range from 10- to 20-feet thick based on literature and city of Madison municipal well logs. The lower part of the formation grades into the Mount Simon Formation making the contact between the two formations difficult to discern. However, the formation thickness varies from over 60-feet thick in northwestern Dane County to erratic or partially absent in the central Yahara River basin. The shale is absent under Lake

Mendota and Lake Monona, and pinches out between the city of Madison Municipal Unit Wells 8 and 11, but is present on the isthmus.

4.4.2.4 *Mount Simon Formation*

The Mount Simon Formation is a white to light gray, well-cemented, fine to medium-grained sandstone (WGNHS, 1999). The thickness of the formation is dependent on the heavily eroded surface of the underlying Precambrian crystalline rocks. In Dane County, the Mount Simon Formation ranges from 200- to 450-feet thick.

4.4.2.5 *Crystalline Bedrock*

Underlying the Cambrian Period sandstone is Precambrian age crystalline bedrock that was formed during the Precambrian Period that ended approximately 540 million years ago (WGNHS, 1999). Crystalline bedrock underlies the Cambrian Age sandstone and slopes to the south. The surface of the crystalline bedrock in the vicinity of the Site is approximately 100 feet amsl. The thickness of the crystalline bedrock is unknown.

4.4.3 Hydrology

The Site is located at the northeast end of the city of Madison isthmus between Lake Mendota and Lake Monona (Figure 2-2). Lake Mendota is located approximately 6,800 feet west of the Site and Lake Monona is located approximately 1,500 feet south of Site. Lake Mendota discharges into the Yahara River as surface water flows south and discharges into Lake Monona. Lake Mendota has a surface water elevation of approximately 849 feet amsl while Lake Monona has a surface elevation of approximately 845 feet amsl. There is a lock and dam located at the head of the Yahara River to control the flow of surface water to Lake Monona. Starkweather Creek is located approximately 1,200 feet northeast of the Site and discharges into the north side of Lake Monona.

4.4.4 Hydrogeology

The city of Madison's hydrostratigraphy can be divided into four units including, from the upper to lower aquifers: (1) Unconsolidated Aquifer; (2) Upper Paleozoic Aquifer; (3) Eau Claire Aquifer; and, (4) Mount Simon Aquifer (WGNHS, 1999). The city of Madison municipal wells located nearest to the Site include Municipal Unit Wells 3 (abandoned), 7, 8, 11, and 24. Below is a brief description of the aquifers based on a review of technical reports, maps, and city of Madison municipal well logs.

4.4.4.1 *Unconsolidated Aquifer*

The Unconsolidated Aquifer consists of saturated glacial sediments overlying bedrock. The Unconsolidated Aquifer in the vicinity of the Site ranges from approximately 18 to 50 feet, with the exception of 110 feet logged at Municipal Unit Well 8 located near the shoreline of Lake Monona.

Shallow groundwater is not consistently observed in the Unconsolidated Aquifer (e.g., the water table is at or below the bedrock surface). The Unconsolidated Aquifer is not used for water supply in Madison since groundwater is not consistently observed in the unconsolidated soils. In Madison, the potentiometric surface in the unconsolidated aquifer flows towards the nearest surface water body. The geometric mean hydraulic conductivity for the Site, where sandy diamicton soils are present, is 0.6 feet per day.

4.4.4.2 *Upper Paleozoic Aquifer*

The Upper Paleozoic Aquifer includes the Lone Rock, Wonewoc, and the upper part of the Eau Claire Formation, starting above the shale (WGHNS, 1999). The aquifer in the vicinity of the Site ranges from approximately 145 to 185 feet thick. The Upper Paleozoic Aquifer is the not extensively used for water supply by the city of Madison.

The Upper Paleozoic Aquifer acts like a confined unit in Madison, where an unconsolidated clay layer is present. However, the Upper Paleozoic Aquifer has been eroded under the Yahara Lakes (Lake Mendota, Lake Monona, Lake Waubesa, and Lake Kegonsa) including portions of Lake Mendota and Lake Monona (United States Geological Survey [USGS], 2001; WGNHS, 1972). The groundwater model that was part of the Dane County Regional Hydrogeologic Study shows there is connection between the Upper Paleozoic and Mount Simon Aquifers.

The total porosity of the Lone Rock and Wonewoc Formations in the Upper Paleozoic Aquifer at the Site ranges from 17 to 29% (Stone Environmental, 2012).

In Madison, the potentiometric surface in the Upper Paleozoic Aquifer is towards the isthmus from Lake Mendota and Lake Monona. A downward gradient is induced by the pumping of municipal wells in the Mount Simon Aquifer (WGNHS, 1999). The unit is not used extensively for water supply, but is moderately permeable, with a hydraulic conductivity estimated at approximately 5 feet/day (Ruekert/Mielke, 2011).

4.4.4.3 *Eau Claire Aquitard*

The Eau Claire Aquitard is considered to be a leaky confining unit located between the Upper Paleozoic and Mount Simon Aquifers (WGNHS, 1999). The shale unit located within the Eau Claire Formation serves as the upper and lower boundary for the Aquifers. Although the shale in the vicinity of the Site is estimated to range from 10- to 20-feet thick, it has been eroded in portions of the central Yahara Lakes. Where present, the shale impedes groundwater flow from the Upper Paleozoic Aquifer and protects the Mount Simon Aquifer by limiting downward flow.

Presence of the Eau Claire Aquitard is based primarily on the significant hydraulic head change observed in wells located above and below the unit. Gamma logs for the shale have recorded approximately 100 to 250 counts per second for the aquitard. The total porosity of the Eau Claire shale ranges from 8 to 15% (WGHNS, 2013). A vertical hydraulic conductivity of 0.0006 feet per day was used for the Eau Claire Aquitard in the Dane County regional groundwater model.

4.4.4.4 *Mount Simon Aquifer*

The Mount Simon Aquifer includes the Mount Simon and the lower part of the Eau Claire Formations, starting below the shale (WGNHS, 1999). The Aquifer in the vicinity of the Site is approximately 500-feet thick. The Mount Simon Aquifer is the chief water supply aquifer used by the city of Madison. The Mount Simon aquifer is confined in most of Dane County, except where the Eau Claire Formation is absent under portions of the Yahara Lakes (USGS, 2001).

The Dane County Regional Hydrogeologic Study included a groundwater model that looked at pre-development and post-development groundwater levels and flow direction. The model shows the southern half of Lake Mendota and all of Lake Monona discharge to groundwater due to the aggressive pumping from the city of Madison municipal wells. There is likely a direct connection between the surface water of Lake Monona and the Mount Simon Formation.

The total porosity of the Mount Simon Formation ranges from 11 to 20% (WGHNS, 2013). The geometric mean hydraulic conductivities of city of Madison municipal wells calculated from pump test data is 10 feet per day (WGNHS, 1999).

In Madison, the potentiometric surface in the Mount Simon Aquifer flows to the southeast and is located below the level at the Yahara Lakes (WGNHS, 1999). A cone of depression is present in Madison, with groundwater moving downward in the isthmus and near Lake Mendota and Lake Monona. The geometric mean of the hydraulic conductivity of the Aquifer is estimated at approximately 10 feet per day.

4.5 Site Geologic and Hydrogeologic Conditions

Below is a summary of the Site geologic and hydrogeologic conditions based on soil and bedrock boreholes advanced and monitoring wells installed at the Site. Geologic cross sections were prepared to illustrate subsurface conditions using the Site wells. The locations of geologic cross sections are depicted on Figure 4-1. Geologic Cross Sections A-A’, B-B’, and C-C’ are presented on Figures 4-2 through 4-4, respectively.

4.5.1 Site Geology

The Site’s near-surface geology consists of two unconsolidated units consisting of fill material and glacially-derived deposits, which overlie weakly cemented sandstone bedrock. A brief description of each unit is presented below.

4.5.1.1 *Unconsolidated Soils*

Below is a summary of the fill material, consisting of debris and non-native sand, observed on Site.

- **Debris**
  The fill material classified as debris included a dense and vesicular slag, glass fragments, crushed brick, aluminum and steel pieces, wire, and rubber. The debris ranged in color from a dark brown (7.5YR 3/4) to black (10YR 2/1). Slag was observed as shallow as 0.2 feet bls at Soil Boring B-48 and as deep as 4.9 feet bls at Soil Boring B-94. Slag was observed across the Site with an average thickness of approximately 0.5 feet.

- **Non-Native Sand**
  The fill material classified as non-native sand was described as yellow (10YR 7/8), well to poorly sorted, very fine to medium grained sand with trace subangular to subround gravel. This fill material was reported as shallow as 0.4 feet bls at Soil Boring B-95 and as deep as 4.7 feet bls at Soil Boring B-94. This fill material averaged from 2- to 4-feet thick and was observed in the southeast corner of the north parking lot and generally where underground utilities were present or an excavation had been completed.

Underlying the fill material are several glacially-derived deposits including an upper clay unit, several gravel lenses, and a lower sand unit. The three unconsolidated glacial soil horizons are Pleistocene in age and are part of the Horicon Member of the Holy Hill Formation. Photographs of fill and unconsolidated soils are included in Appendix K. Below is a description of each unit.

- **Clay Unit**
  The uppermost native soil at the Site is referred to as the clay unit. The clay unit consists of dark yellowish brown (10YR 4/4) clay with some to little silt and trace to some very fine to fine sand. Streaks and mottling were observed in the stiff to medium stiff clay. The clay unit was encountered from the land surface to an average depth of 6.0 feet bls. The origin of the clay unit is likely glacial lake sediments that were sourced from melt water streams.

- **Gravel Lenses**
  Several continuous gravel lenses were identified within the upper clay and lower sand units. The dolomitic gravel lenses contained sand and varied in depth and thickness. However, three distinct gravel lenses were identified and appear to be laterally continuous across the Site. The shallowest and middle gravel lenses occur at average depths of approximately 6.8 and 15.4 feet bls. Both lenses average approximately 0.3-feet thick. The deepest gravel lense occurs at an average depth of approximately 23.8 feet bls and averages 1-foot thick. The origin of the gravel lenses is likely dendritic glacial meltwater streams migrating across the landscape resulting in inclusions of gravel interbedded into the sand and clay units.

- **Sand Silt Unit**
  The sand unit located beneath the clay unit consists of yellowish brown (10YR 5/6), poorly sorted, very fine to coarse grained sand (mostly very fine to fine) with little to some silt and trace subround gravel. Planar to cross bedding structures were observed with depth. The sand unit was encountered from an average of 6.0 feet bls to bedrock which was encountered at an average of 30 to 34 feet bls. The origin of the sand is likely glacial meltwater streams created during the retreating ice sheets.

4.5.1.2 *Bedrock*

Bedrock at the Site was investigated through the collection of rock cores for geologic logging, down-hole geophysical logging, and collection of rock cores for laboratory analysis of VOCs. Photographs of various bedrock formations are included in Appendix K. A brief description of each formation is presented below.

- **Lone Rock Formation**
  The Lone Rock Formation is part of the Tunnel City Group, which was described as a light yellowish brown (10YR 6/4) to a pale brown (10YR 6/3), friable to moderately hard, glauconitic, very fine to fine grained quartz sandstone containing laminated beds of yellow dolomitic sand. The Lone Rock Formation is intensely to highly jointed with predominantly horizontal, with limited high angle, fractures. The fractures occur primarily along bedding planes.

  The estimated bedrock topography is illustrated on Figure 4-5. There is a topographic high in the bedrock located near the center of the Site. However, the top of the Lone Rock Formation is heavily eroded, and regionally slopes to the south (WGNHS, 1999).

  The base of the Lone Rock Formation was encountered at approximately 95 feet bls and averaged approximately 65-feet thick on Site. The transition from the Lone Rock to the Wonewoc Formation was observed at approximately 92 feet bls at MW-3D3 and at approximately 98 feet bls at MW-5D3. The Lone Rock Formation is a near-shore marine shelf deposit whose origin was likely a transgression of the Cambrian sea across the continent.

- **Wonewoc Formation**
  The Wonewoc Formation is part of the Elk Mound Group which is further subdivided into two Members including the Ironton and the Galesville Members. Below is a summary of the Members.

  - Ironton Member:
    The Ironton Member was described as a very pale brown (10YR 7/3) to a brownish yellow (10YR 6/6), friable to moderately hard, fine to coarse grained sandstone. The Ironton Member contained glauconitic laminated, cross laminated, and cross bedded structures. Bioturbation and very hard red and orange sandstone containing iron-rich cementation are key characteristics of this Member. The Ironton Member is intensely to highly jointed with predominantly horizontal, with limited high angle, fractures.

    The base of the Ironton Member was encountered at approximately 125 feet at MW-3D3 and at approximately 130 feet at MW-5D3. The average thickness of the Member was approximately 32 feet. The Ironton Member is a beach and shallow marine deposit.

- <u>Galesville Member:</u>
  The Galesville Member was described as a very pale brown (10YR 8/3) to a yellowish brown (10YR 5/8) sandstone. The Member consists of alternating beds of hard very fine to fine sandstone and friable, rounded, medium to coarse grained sandstone. The beds are horizontally laminated to thin planes and shallow angle cross beds. There are pale green shale laminated partings interbedded with very hard red and orange sandstone displaying a very iron rich cementation. The Galesville is intensely to highly jointed with predominantly horizontal, with limited high angle, fractures.

  The base of the Galesville Member was encountered at approximately 222 feet at MW-3D3 and at approximately 231 feet at MW-5D3. The average thickness of the Member was approximately 99 feet. The Galesville Member is an aeolian beach and shallow marine deposit.

- **Eau Claire Formation**

  The Eau Claire Formation was described as a white (2.5YR 8/1), well sorted, hard to moderately hard, very fine to fine grained sandstone interbedded with laminated, pale green siltstone and shale. The beds are horizontally laminated to shallow angle (10 degrees or less) hummocky cross beds.

  The Eau Claire Formation is intensely to highly jointed with laminated horizontal beds and limited low angle fractures (up to 10 degrees). The Eau Claire Formation is likely a low energy near-shore beach and aeolian deposit.

4.5.1.3 *Geophysical Data*

Down-hole geophysical data were collected at boreholes MW-3D3, MW-5D3, MW-13, MW-14, MW-15, and MW-16 for the purpose of characterizing the geology and hydrogeology and nature and extent of constituents in the fractured bedrock groundwater zone beneath the Site. Multiple geophysical logging tools were utilized including gamma, fluid temperature, fluid resistivity, caliper, heat-pulse flow meter, high-resolution acoustic borehole televiewer, and optical borehole televiewer. Below is a summary of each tool’s purpose.

- Gamma - All rock and soils emit gamma radiation in varying amounts. Gamma logging records the amount of natural gamma radiation emitted from the rock and provides a useful means of identifying formations and correlating stratigraphy between drilling locations.

- Fluid Temperature – The fluid temperature tool records water temperature. Since water flowing into or out of the well at a water-bearing zone, like a fracture, can create perturbations in the temperature profile in a well, a fluid temperature log can provide an indication of open flowing fractures and other transmissive zones.

- Fluid Resistivity - Fluid resistivity records electric conductivity of groundwater, and can identify and discriminate between different water-bearing zones if the total dissolved solids or ionic content of the water in the two zones are different.

- Caliper - The caliper tool measures the borehole diameter. Perturbations in the caliper logs can indicate fractures, fracture zones, or areas of friable rock where drilling has enlarged the borehole beyond the nominal bit diameter.

- Heat Pulse Flowmeter - The heat pulse flow meter was conducted under static (i.e., non-pumping) and dynamic (i.e., pumping) conditions. The heat pulse flow meter measures vertical flow rate of water in the borehole under non-pumping or pumping conditions. Variations in the flow rate can help identify open flowing fractures.

- Acoustic Televiewer - The acoustic televiewer provides an oriented, accurately-scaled, 360-degree image of the borehole walls, allowing for identification and measurement of fractures, solution openings, and an estimation of fracture orientation and thickness using sonar pluses.

- Optical Televiewer - The optical televiewer provides a continuous, detailed and oriented 360 degree image of the borehole walls, allowing for identification of fractures and measurement of fracture strike, dip, and frequency.

These datasets are illustrated on Figures 4-6 through 4-11, respectively, which included stratigraphic descriptions and plots of the data with depth so that apparent correlations, if present, may be determined. Below is a summary of the findings by well.

- **Well MW-3D3**

  The above geophysical tools were implemented between 25 and 232 feet bls at Well MW-3D3. Geophysical data for Borehole MW-3D3 are illustrated on Figure 4-6.

  - Fractures were subjectively ranked by Colog Inc. on a scale from 0 to 5 to represent flow potential (the higher the ranking, the more potential for flow through the fractures). The highest ranking fractures at MW-3D3 were identified as Ranking 2 (clean, distinct continuous fracture) primarily between 205 and 211 feet and Ranking 3 (distinct fracture with apparent aperture) at 222 and 232 feet. Additionally, average fracture spacing was calculated to understand the overall intensity of fractures and determine where potentially the greatest flow and contaminant mass may be present. The highest fracture intensity was identified between 205 to 211 feet and 218 to 232 feet bls. A fracture was also identified at approximately 155 feet by the caliper tool.
  - Natural gamma readings varied between approximately 25 and 75 counts per second, with prominent peaks indicated at depths of approximately 36, 40, 50, 68, 84, 158, and 232 feet bls. Changes in natural gamma readings are due to changes in lithology. These data demonstrate the heterogeneous and horizontally-layered structure of the bedrock units. The natural gamma readings can be used to estimate formation breaks at this Site since the Lone Rock Formation is highly glauconitic and the upper part of the Eau Claire Formation is interbedded sandstone and siltstone.
  - The base of the Lone Rock Formation is interpreted at approximately 92 feet bls, and the top of the Eau Claire Formation is interpreted to begin at approximately 222 feet bls. These depths were verified in the rock core.
  - Conductivity values varied between approximately 500 microSiemens per centimeter (µS/cm) and 2,500 µS/cm. Changes in conductivity along a borehole may indicate intervals where groundwater is entering the borehole from discrete fractures. There was a prominent conductivity change from approximately 176 to 180 feet bls, suggesting this interval may contain an open flowing fracture that transmits groundwater.
  - Fluid temperature varied between approximately 10 and 13 degrees Celsius (^{o}C), with a prominent decrease in temperature occurring between approximately 160 and 180 feet bls that is correlated with the conductivity profile and supports the conclusion that this interval contains an open flowing fracture that transmits groundwater.
  - The heat pulse flow meter measured vertical flow rates in the borehole that varied between approximately 0.03 and 0.68 gpm. Heat pulse flow meter data identified a change from downward vertical groundwater flow in the borehole to

upward vertical flow under pumping conditions beginning at approximately 180 feet bls. This supports the conclusion that a discrete groundwater flow pathway exists at this depth.

- **Well MW-5D3**

  The above geophysical tools were implemented between 25 and 236 feet below ground at Well MW-5D3. Geophysical data for Borehole MW-5D3 are illustrated on Figure 4-7.

  - The highest ranking fractures at MW-5D3 were identified as Ranking 2 (clean, distinct continuous fracture) primarily between 185 and 210 feet and Ranking 3 (distinct fracture with apparent aperture) at 198, 215 and 236 feet. Additionally, average fracture spacing was calculated to understand the overall intensity of fractures and determine where potentially the greatest flow and contaminant mass may be present. The highest fracture intensity was identified between 195 to 200 and 232 to 236 feet bls. Fractures were also identified at approximately 39 feet and 108 feet by the caliper tool.
  - Natural gamma readings varied between approximately 25 and 75 counts per second, with prominent peaks indicated at depths of approximately 45, 60, 90, and 165 feet bls. These data demonstrate the heterogeneous and horizontally-layered structure of bedrock.
  - The base of the Lone Rock Formation is interpreted at approximately 98 feet bls, and the top of the Eau Claire Formation is interpreted to begin at approximately 232 feet bls. These depths were verified in the rock core.
  - Fluid temperature varied between approximately 10 and 13 ^{o}C and showed a gradual decrease with depth along the length of the borehole. There was a subtle conductivity shift at approximately 162 feet bls, suggesting the possibility of a discrete groundwater flow pathway (i.e., open, flowing fracture) at this interval.
  - The heat pulse flow meter measured vertical flow rates along the borehole under pumping conditions that varied between approximately 0.03 and 1.0 gpm. The heat pulse flow meter data at approximately 192 feet bls also demarcated a change from downward vertical groundwater flow in the borehole to upward vertical flow during pumping conditions, suggesting that a discrete groundwater flow pathway (i.e., open, flowing fracture) may exist at this depth.

- **Bedrock Borehole MP-13**

  The above geophysical tools were implemented between approximately 38 feet and 201 feet below ground at Well MW-13. Geophysical data for Borehole MW-13 (converted to MP-13) is illustrated on Figure 4-8.

  - The highest ranking fractures at MP-13 were identified as Ranking 3 (distinct fracture with apparent aperture) at 53, 83, and 100 feet and Ranking 4 (very distinct fracture with apparent aperture) at 154 feet. Additionally, average fracture spacing was calculated to understand the overall the intensity of fractures and determine where potentially the greatest flow and contaminant mass may be present. The highest fracture intensity was identified between 48 to 53, 88 to 93, 134 to 138 and 153 to 158 feet bls. The fracture at 154 feet was also identified by the caliper tool.
  - Natural gamma readings varied between approximately 25 and 100 counts per second, with prominent peaks indicated at depths of approximately 40, 45, 50, 55, 85, 100, 112, 160, and 190 feet bls. These data demonstrate the heterogeneous and horizontally-layered structure of bedrock.
  - The base of the Lone Rock Formation is interpreted at approximately 87 feet bls. The borehole at MP-13 was not deep enough to reach the Eau Claire Formation.
  - Conductivity values were relatively consistent at approximately 750 µS/cm and did not vary much along the depth of the borehole.
  - Fluid temperature varied between approximately 8 and 12 ^{o}C, with a gradual decrease in temperature occurring with depth along the borehole.
  - The heat pulse flow meter measured vertical flow rates along the borehole under pumping conditions that varied between approximately 0.1 and 0.5 gpm. Heat pulse flow meter data at approximately 60 to 70 feet bls appears to demarcate a change from upward vertical groundwater flow in the borehole to downward vertical flow during pumping conditions, which indicates that different hydraulic stresses influence groundwater in the upper part of the bedrock as compared with the deeper interval at this location.

- **Bedrock Borehole MP-14**

  The above geophysical tools were implemented between approximately 48 and 181 feet. Geophysical data for Borehole MW-14 (converted to MP-14) are illustrated on Figure 4-9.

  - The highest ranking fractures at MP-14 were identified as Ranking 3 (distinct fracture with apparent aperture) at 50, 51, 72 and 103 feet and Ranking 4 (very distinct fracture with apparent aperture) at 49 and 51 feet. Additionally, average fracture spacing was calculated to understand the overall intensity of fractures and determine where potentially the greatest flow and contaminant mass may be present. The highest fracture intensity was identified between 49 to 54 and 99 to 104 feet bls. The fractures at 49 to 51 feet, 72 and 103 feet were also identified by the caliper tool.

- Natural gamma readings at this location varied between approximately 25 and 100 counts per second, with prominent peaks indicated at depths of approximately 54, 70, 86, 102, and 175 feet bls. These data demonstrate the heterogeneous and horizontally-layered structure of bedrock.
- The base of the Lone Rock Formation is interpreted at approximately 89 feet bls. The borehole at MP-14 was not deep enough to reach the Eau Claire Formation.
- Conductivity values were relatively consistent at approximately 800 µS/cm and did not vary much along the depth of the borehole.
- Fluid temperature varied between approximately 9 and 10 ^{o}C, with a gradual decrease in temperature occurring with depth along the borehole.
- The heat pulse flow meter measured low flow rates ranging from 0.01 to 0.77 gpm. Heat pulse flow meter data from approximately 54 to 56 feet bls appears to demarcate a change from upward vertical groundwater flow in the borehole to downward vertical flow during pumping conditions, which indicates that different hydraulic stresses influence groundwater in the upper part of the bedrock as compared with the deeper interval at this location.

- **Bedrock Borehole MP-15**

  The above geophysical tools were implemented between approximately 41 and 192 feet bls. Geophysical data for Borehole MW-15 (converted to MP-15) are illustrated on Figure 4-10.

  - The highest ranking fractures at MP-15 were identified as Ranking 2 (clean, distinct continuous fracture) at 56 feet, 72 feet and 75 feet and Ranking 3 (distinct fracture with apparent aperture) at 90 feet. Additionally, average fracture spacing was calculated to understand the overall intensity of fractures and determine where potentially the greatest flow and contaminant mass may be present. The highest fracture intensity was identified between 87 to 92 feet bls. The fractures at 56, 75 and 90 feet were also identified by the caliper tool.
  - Natural gamma readings varied between approximately 25 and 100 counts per second, with prominent peaks indicated at depths of approximately 56, 60, 75, 80, 95, 100, 124, 134, 145, 155, 170, and 190 feet bls. These data demonstrate the heterogeneous and horizontally-layered structure of bedrock units beneath the Site.

- The base of the Lone Rock Formation is interpreted at approximately 75 feet bls. The borehole at MP-15 was not deep enough to reach the Eau Claire Formation.
- Fluid conductivity values were relatively consistent and varied between approximately 400 µS/cm and 600 µS/cm, but exhibited noticeable changes at depths of approximately 65, 88, 114, 140, and 155 feet bls. These changes in fluid conductivity indicate that groundwater was entering or leaving the borehole through discrete flow pathways.
- Fluid temperature varied between approximately 8 and 11 ^{o}C, with a gradual decrease in temperature occurring with depth along the borehole. Several noticeable spikes in fluid temperature were observed at depths of approximately 125 feet and in the interval between 130 and 140 feet bls. This also indicates that groundwater was entering or leaving the borehole through discrete fractures within these intervals.
- The heat pulse flow meter measured low rates ranging from 0.05 to 0.86 gpm. Heat pulse flow meter data indicate the groundwater flow direction was vertically upward during pumping conditions.

- **Bedrock Borehole MP-16**

The above geophysical tools were implemented between approximately 47 and 201 feet bls. Geophysical data for Borehole MW-16 (converted to MP-16) are illustrated on Figure 4-11.

- The highest ranking fractures at MP-16 were identified as Ranking 3 (distinct fracture with apparent aperture) at 108 feet. Additionally, average fracture spacing was calculated to understand the overall intensity of fractures and determine where potentially the greatest flow and contaminant mass may be present. The highest fracture intensity was identified between 107 and 112 feet bls. The fracture at 108 was also identified by the caliper tool.
- Natural gamma readings varied between approximately 25 and 100 counts per second, with prominent peaks indicated at depths of approximately 60, 92, 120, and 200 feet bls. These data demonstrate the heterogeneous and horizontally-layered structure of bedrock units beneath the Site.
- The base of the Lone Rock Formation is interpreted at approximately 98 feet bls. The borehole at MP-16 was not deep enough to reach the Eau Claire Formation.
- Fluid conductivity values were relatively consistent and varied between approximately 500 µS/cm and 600 µS/cm, but exhibited noticeable changes at depths of approximately 65, 95, 104, 130, 145, and 190 feet bls. These

changes in fluid conductivity indicate that groundwater was entering or leaving the borehole through discrete flow pathways.

- Fluid temperature varied between approximately 8 and 10 ^{o}C, with a gradual decrease in temperature occurring with depth along the borehole. Several noticeable spikes in fluid temperature were observed at depths of approximately 150, 160, and 198 feet, indicating that groundwater was entering or leaving the borehole through discrete fractures within these intervals.
- The heat pulse flow meter measured low flow rates ranging from 0.07 to 1.04 gpm. Heat pulse flow meter data indicate the groundwater flow direction was vertically upward during pumping conditions.

In summary, the geophysical data and other down-hole data indicate that bedrock beneath the Site is heterogeneous and horizontally layered, which is consistent with the depositional environments in which the sandstone layers were deposited. The data show that groundwater flow beneath the Site occurs in discrete fractures that intersect boreholes at different depths, and are most likely associated with horizontal bedding plane partings parallel to the horizontally layered sandstone units.

4.5.2 Hydrogeologic Conditions

The 2012 investigation included the installation of 35 wells (15 single-cased wells and four multiport wells with 20 total sample intervals) to the current well network. Below is a summary of the Site's potentiometric surfaces, hydraulic gradient directions, and horizontal and vertical gradients using data from the current well network.

4.5.2.1 *Potentiometric Surface, Hydraulic Gradient Direction, and Gradient*

Site-wide groundwater elevations were collected in April and July 2012, and January 2013. Groundwater elevations are summarized in Table 4-1. The data from January 2013 was selected to illustrate the hydraulic gradient direction and calculated horizontal gradients since this was first event following the completion of the current groundwater well network. Below is a summary of the findings.

- **Unconsolidated Aquifer Potentiometric Surface**

  The potentiometric surface in the Unconsolidated Aquifer using January 2013 data is presented on Figure 4-12. The hydraulic gradient direction in the Unconsolidated Aquifer is to the southeast. This is influenced by the lock and dam where the Yahara River drains from Lake Mendota south into Lake Monona. The horizontal gradient in the saturated unconsolidated soils was calculated as 0.01 foot per foot (ft/ft) in the northern half of the Site and 0.001 ft/ft in the southern half of the Site.

- **Lower Lone Rock Formation Potentiometric Surface**

  The potentiometric surface in the Lower Lone Rock Formation using January 2013 data is presented on Figure 4-13. Wells screened in the Lower Lone Rock Formation are located approximately 75 to 95 feet bls. The hydraulic gradient direction in the Lower Lone Rock Formation is generally to the south and southeast in the southern half of the Site, and to the north in the northern half of the Site. The northerly gradient direction is based by the groundwater elevation high measured at Multiport Well MP-13 and will be confirmed with subsequent monitoring events.

  The horizontal gradient in the Lower Lone Rock Formation was calculated as 0.01 ft/ft north of Multiport Well MP-13 and 0.001 ft/ft south of Multiport Well MP-13.

- **Lower Wonewoc Formation Potentiometric Surface**

  The potentiometric surface in the Lower Wonewoc Formation using January 2013 data is presented on Figure 4-14. Wells screened in the Lower Wonewoc Formation are located between approximately 160 to 180 feet bls. The hydraulic gradient direction in the Lower Wonewoc Formation is uniformly to the southeast consistent with the regional hydraulic gradient. Hydraulic gradients in the Lower Wonewoc Formation do not appear to be influenced by pumping at the nearest water supply wells. The horizontal gradient in the Lower Wonewoc Formation was calculated as 0.001 ft/ft across the Site.

4.5.2.2 *Vertical Gradients*

Vertical gradients were calculated for well pairs using the 2004 through January 2013 groundwater elevation data. Wells are screened or have sample intervals in four geologic units including the Unconsolidated Aquifer, Lone Rock Formation, Wonewoc Formation, and Eau Claire Formation. Vertical gradient data are summarized in Table 4-2. Below is a summary of vertical gradients by monitoring wells and multiport wells.

- **Monitoring Wells**

  The current well network includes eight wells nests including MW-2 through MW-6, MW-9, MW-22, and MW-23. The direction of the vertical gradients for the Site was nearly consistently downward. The magnitude of the average vertical gradients between the Unconsolidated Aquifer and Lone Rock Formation were calculated at 0.011 to 0.084 ft/ft. The magnitude of the average vertical gradients between the Lone Rock Formation to the Lower Wonewoc Formation was calculated at 0.012 to 0.033 ft/ft. A lower vertical gradient of 0.006 was calculated between MW-9D to M-9D2. There were upward gradients calculated between MW-5D2 and MW-5D3 at 0.002 ft/ft and between MW-22S to MW-22D at 0.009 ft/ft.

- **Multiport Wells**

  There are currently four multiport wells (MP-13 through MP-16) with four to seven sample intervals at each well. The vertical gradients for the multiport wells were nearly consistently downward. The average vertical gradients between the Lone Rock and Wonewoc Formations were calculated at 0.013 to 0.019 ft/ft, with the exception of Multiport Well MP-15. Multiport Well MP-15 is nested with the MW-9 well nest. The average vertical gradient at MP-15 was 0.002 ft/ft. This vertical gradient is similar to the vertical gradients calculated for MW-9D to MW-9D2.

The finding that there is a predominantly downward hydraulic gradient at the Site is consistent with a mathematical groundwater flow model commissioned by Dane County (WGNHS, 1999). The pumping rates of the municipal wells vary and subsequently their zones of influence will vary with time (WGNHS, 1996). Differing municipal well pumping trends induce overlapping cones of depression both in the Upper Paleozoic and Mount Simon Aquifers. As pumping trends change from month to month, so do the zones of influence. When the overlapping cones of depression shift the result is a downward vertical gradient.

4.5.2.3 *Hydraulic Conductivity Testing*

The hydraulic conductivity data for the Unconsolidated Aquifer is from monitoring wells MW-1, MW-2S, MW-3S, MW-6S, and MW-11S. The Bouwer Rice (1976) confined solution was used for wells screened in the Lone Rock, Wonewoc, and Eau Claire Formations. ARCADIS utilized AQTESOLV for Windows (Duffield, 2007) to graph the results of the solutions and to obtain the best-fit line for the data. Best-fit plots of the data are included under Appendix L. A summary of the hydraulic conductivities is presented in Table 4-3 and summarized below.

Geologic Unit	Hydraulic Conductivity Range (feet/day)	Hydraulic Conductivity Average (feet/day)
Unconsolidated Aquifer	0.09 - 1.6	0.5
Lower Lone Rock Formation	3.7 – 7.6	5.5
Upper Lone Rock Formation	0.08 – 13.2	5.9
Upper Wonewoc Formation	2.7 – 3.1	2.8
Lower Wonewoc Formation	12.7 – 13.1	12.9
Wonewoc/Eau Claire Formations	7.9 – 9.1	8.4

5. Site Investigation Results

Below is a summary of the soil and groundwater analytical results from the investigation completed between February 2012 and January 2013.

5.1 Soil Criteria

Regulations for evaluating soil conditions were established in NR 720, Wis. Admin. Code. The first step in the evaluation process is to determine RCLs for each detected constituent in soil, which are then used as cleanup criteria. NR 720 includes RCLs for five VOCs (benzene, 1,2-dichloroethane, ethylbenzene, toluene, and xylene) and four metals (arsenic, lead, cadmium, and trivalent chromium). The WDNR R&R Program has prepared a spreadsheet with direct contact RCLs for non-industrial and industrial land use and soil to groundwater pathway RCLs for chemicals listed and not listed in NR 720. The spreadsheet presents RCLs calculated using the U.S. EPA Regional Screening Table web calculator, with input parameters based on the requirements of NR 720 and other risk assumptions that are consistent with WDNR regulations. The soil results from the investigation activities are compared to the RCLs. The RCLs for VOCs, PCBs, PAHs, RCRA metals, and total cyanide are summarized in Tables 5-1 and 5-2.

In addition to the WDNR RCLs, Title 40 CFR §761.61 provides cleanup and disposal options for PCB remediation waste. Soil PCB analytical results were compared to the bulk remediation waste cleanup level for high occupancy of less than or equal to 1 mg/kg and total detected PCB concentrations (the sum of the individual PCB Aroclors) were compared to the Toxic Substance Control Act (TSCA) disposal limit of 50 mg/kg to determine soil disposal options. These criteria are summarized in Tables 5-1 and 5-2.

5.2 Groundwater Criteria

Groundwater cleanup criteria are set forth in NR 140, Wis. Admin. Code. For each regulated constituent, two standards are established in NR 140: an enforcement standard (ES) and a preventive action limit (PAL). The ES and PAL for each constituent for which a standard has been adopted are summarized in Tables 5-3 through 5-5.

The PAL is lower than the ES, and was developed as a ‘trigger’ standard for situations where a long-term monitoring program is in place, such as downgradient of a landfill.

Exceedance of a PAL in such a situation is a warning that constituent migration may be occurring and could adversely affect groundwater quality. If a constituent concentration is below the ES but exceeds the PAL, NR 140 establishes a list of potential response actions, which generally are associated with continued evaluation or monitoring. NR 140 also established an exemption process, which allows sites to obtain a 'no further action' designation where constituent concentrations are above the PAL, but below the ES. If an ES is exceeded, NR 140 establishes a list of potential responses, which are more aggressive than those for PAL exceedances, and range from further investigation to implementation of remediation.

5.3 Vapor Criteria

The indoor air analytical results were compared to the Wisconsin residential vapor action levels for indoor air, and the sub-slab vapor and vapor probe analytical results were compared to calculated screening levels for sub-slab vapor/deep soil gas to indoor air in accordance with the guidelines presented in the WDNR's *Addressing Vapor Intrusion at Remediation and Redevelopment Sites in Wisconsin Update* dated December 2010 and updated July 2012 (WDNR, PUB-RR-800). The action levels and calculated screening levels are based on the U.S. EPA Residential Air Screening Levels that represent health-protective concentrations that an individual can be exposed to for 30 years for 24 hours a day. The U.S. EPA provided updated regional screening level tables in November 2012. The November 2012 screening levels have been utilized for this evaluation.

5.4 On-Site Soil Analytical Results

A total of 195 soil borings were advanced on Site between June 1, 2012 and January 4, 2013. This included 43 building interior soil borings and 152 exterior soil borings. A total of 327 soil samples were collected and submitted for laboratory analysis including VOCs, PAHs, PCBs, PCB homolog, RCRA metals, and total cyanide. Soil analytical results for soil samples collected between 0 and 4 feet bls were compared to the industrial direct contact RCL and soil samples collected from greater than 4 feet bls were compared to the industrial direct contact RCL and soil to groundwater RCL. A summary of the soil analytical results are presented in Table 5-1. The locations of soil borings with soil samples collected from 0 to 2 feet; 2 to 4 feet; and greater than 4 feet are presented on Figures 5-1 through 5-12. The soil laboratory analytical reports are included in Appendix D.

5.4.1 VOCs

A total of 224 soil samples were collected and submitted for laboratory analysis of VOCs. The locations of on-Site soil VOC samples collected from 0 to 2 feet; 2 to 4 feet; and greater than 4 feet are presented on Figures 5-1 through 5-3, respectively. Soil VOC concentrations were reported above the industrial direct contact RCL in four soil borings (B-16 through B-18, and B-35) from 0 to 2 feet and in one soil boring (B-24) from 10 to 12 feet bls. Soil VOC analytical results were reported below the industrial direct contact RCL from 2 to 4 feet. Soil VOC concentrations were reported above the soil to groundwater pathway RCL in 41 soil borings (greater than 4 feet bls).

Soil VOC concentrations were reported above criteria generally near the former oil shed in the upper 2 feet of soil. Soil VOC concentrations reported above the soil to groundwater pathway RCL were primarily located under the building and in the north parking lot. Temporary wells were installed in the north parking lot and permanent wells (MW22S/D, MW23S/D) were installed inside the building to evaluate groundwater quality. Soil VOC concentrations decrease with depth and are delineated by the off-Site soil VOC samples collected from the adjacent residential properties (Figures 5-13 and 5-14). Please refer to Section 5.5.1 for off-Site soil VOC analytical results. On-Site soil VOC exceedances will be managed by maintaining the existing paved areas as a cap and through the WDNR's Soil Geographic Information System Registry.

5.4.2 PCBs

A total of 327 soil samples were collected and submitted for laboratory analysis of PCBs. The locations of on-Site soil PCB samples collected from 0 to 2 feet; 2 to 4 feet; and greater than 4 feet are presented on Figures 5-4 through 5-6, respectively. An additional 12 soil samples were submitted for laboratory analysis of PCB homolog. Soil PCB analytical results were compared to the industrial direct contact RCL, U.S. EPA high occupancy cleanup level of 1 mg/kg, and TSCA disposal limit of 50 mg/kg. Below is a summary of the results.

- Soil PCB concentrations analyzed from 0 to 2 feet bls were reported above the industrial direct contact RCL at 43 locations; above the high occupancy cleanup level at 37 locations; and above the TSCA disposal limit at 9 locations.

- Soil PCB concentrations analyzed from 2 to 4 feet bls were reported above the industrial direct contact RCL at 18 locations; above the high occupancy cleanup level at 16 locations; and above the TSCA disposal limit at 2 locations.

- Soil PCB concentrations analyzed from depths greater than 4 feet bls were reported above the industrial direct contact RCL at seven locations; above the high occupancy cleanup level at 5 locations; and above the TSCA disposal limit at 3 locations

The PCB results of the homolog analysis were compared to the PCB laboratory analytical results obtained with Method 8082 for the same 12 soil samples. In all cases, the PCB homolog analytical results were lower than the PCB results reported by Method 8082.

Soil PCB concentrations were generally observed along the western property line, under the building, and in the north parking lot in the upper 4 feet of soil. The concentrations observed from greater than 4 feet bls were from soil samples collected below the building.

Soil PCB concentrations decrease with depth and are delineated by on-Site soil samples or off-Site soil samples collected from the adjacent residential properties (Figures 5-15 and 5-16). Please refer to Section 5.5.2 for off-Site soil PCB analytical results. On-Site soil PCB exceedances above the TSCA disposal limit of 50 mg/kg in the north parking lot were excavated in December 2012/January 2013 (excluding soils beneath the building). Please refer to the Section 6.4 of this report for more information. Site wells were sampled between November 2012 and January 2013 for PCBs to evaluate the groundwater quality. Remaining on-Site soil PCBs will be managed by maintaining the existing paved areas and building slab as a cap and through the WDNR's Soil Geographic Information System Registry.

5.4.3 PAHs

A total of 220 soil samples were collected and submitted for laboratory analysis of PAHs. The locations of on-Site soil PAH samples collected from 0 to 2 feet; 2 to 4 feet; and greater than 4 feet are presented on Figures 5-7 through 5-9, respectively. Soil PAH concentrations were reported above the industrial direct contact RCL in 40 soil borings from 0 to 2 feet; in four soil borings from 2 to 4 feet; and two soil borings advanced to depths greater than 4 feet. Soil PAH concentrations were reported above the soil to groundwater pathway RCL in three soil borings collected greater than 4 feet. Soil PAH concentrations decrease with depth and are delineated by on-Site or off-Site soil PAH samples collected from the adjacent residential properties, where the soil PAH concentrations were determined to be background and not attributed to MKC activities (Figures 5-17 and 5-18). Please refer to the *Polynuclear Aromatic*

Hydrocarbon Evaluation report prepared by ARCADIS, dated January 2013 for more information on off-Site soil PAH analytical results. Site wells were sampled between November 2012 and January 2013 for PAHs to evaluate the groundwater quality and are presented in Section 5.7.3. On-Site soil PAH exceedances will be managed by maintaining the existing paved areas as a cap and through the WDNR's Soil GIS Registry.

5.4.4 RCRA Metals

A total of 220 soil samples were collected and submitted for laboratory analysis of RCRA metals. The locations of soil RCRA metal samples collected from 0 to 2 feet; 2 to 4 feet; and greater than 4 feet are presented on Figures 5-10 through 5-12, respectively.

Arsenic was detected in all 220 soil samples analyzed with concentrations ranging from 0.37 to 100 mg/kg. The average and geometric mean for the arsenic concentrations were 6.3 mg/kg and 4.5 mg/kg, respectively. Based on the widespread distribution of arsenic in the soil within such a narrow range of concentrations, the presence of arsenic appears to represent naturally occurring background conditions. Based on this evaluation, arsenic was not further evaluated and not represented on the above-referenced figures.

Soil RCRA metal concentrations, excluding arsenic, were reported above the industrial direct contact RCL in Soil Boring B-54 for lead (5,600 mg/kg) and mercury (19 mg/kg) and Soil Boring B-134 for mercury (9 mg/kg) from 0 to 2 feet bls and in Soil Boring B-50 for lead (1,300 mg/kg) from 2 to 4 feet bls. These metals were delineated vertically by soil samples analyzed from the same borings or an adjacent boring and horizontally by adjacent borings and/or off-Site soil samples collected from the adjacent residential properties (Figures 5-19 and 5-20). Soil metal concentrations were reported above the soil to groundwater pathway RCL in 10 soil borings for barium, mercury, lead, or selenium from depths greater than 4 feet bls. Site wells were sampled between November 2012 and January 2013 for dissolved RCRA metals to evaluate groundwater quality. On-Site soil metals detected above the soil criteria will be managed by maintaining the existing paved areas as a cap and through the WDNR's Soil GIS Registry.

5.4.5 Total Cyanide

A total of 220 soil samples were collected and submitted for laboratory analysis of total cyanide. All soil total cyanide concentrations were reported below the industrial direct contact and soil to groundwater pathway RCLs.

5.5 Off-Site Soil Analytical Results

A total of 62 hand auger borings were advanced at 32 residential properties. A total of 148 soil samples were collected and submitted for laboratory analyses including VOCs, PAHs, PCBs, RCRA metals, and total cyanide. Off-Site soil analytical results were collected between 0 and 4 feet bls and compared to the non-industrial direct contact RCLs. A summary of the soil analytical results are presented in Table 5-2. The locations of soil borings with soil samples were generally collected from 0 to 1 foot and 3 to 4 feet are presented on Figures 5-13 through 5-20. The soil laboratory analytical reports are included in Appendix D.

5.5.1 VOCs

A total of 125 soil samples were collected and submitted for laboratory analysis of VOCs. The locations of off-Site soil VOC samples were generally collected from 0 to 1 foot and 3 to 4 feet are presented on Figures 5-13 and 5-14, respectively. Off-Site soil VOC concentrations were reported below the non-industrial direct contact RCL for all soil samples collected from 0 to 4 feet bls. TCE was reported above the non-industrial direct contact RCL at 106 Marquette Street from 3 to 4 feet; however, four additional samples were collected from 106 Marquette Street on November 14, 2012, and the results of the subsequent samples were all below the non-residential direct contact RCL for TCE.

5.5.2 PCBs

A total of 148 soil samples were collected and submitted for laboratory analysis of PCBs. The locations of off-Site soil PCB samples were generally collected from 0 to 1 foot and 3 to 4 feet are presented on Figures 5-15 and 5-16, respectively. Off-Site soil PCB concentrations were reported above the non-industrial direct contact RCL of 0.22 mg/kg at four residences (241, 245, 253, and 257 Waubesa Street) from 0 to 2 feet and at 245 Waubesa Street from 2 to 4 feet. Additionally, soil PCB concentrations were reported above the high occupancy self-cleanup level of 1 mg/kg at 245 Waubesa from 0 to 4 feet. As presented in the *Addendum to the Final Revised Work Plan for*

Polychlorinated Biphenyl Recommended Activities dated December 14, 2012, it is recommended that off-Site soils containing PCBs at concentrations above the WDNR's non-industrial direct contact residual contaminant level of 0.22 mg/kg be excavated and disposed of at an approved landfill.

5.5.3 PAHs

A total of 121 soil samples were collected and submitted for laboratory analysis of PAHs. The locations of off-Site soil PAH samples collected from 0 to 2 feet and 2 to 4 are presented on Figures 5-17 and 5-18, respectively. Off-Site soil PAH concentrations were reported above the non-industrial direct contact RCLs for one or more analytes from all soil samples collected from 0 to 2 feet, and from nine soil samples collected from 2 to 4 feet.

As presented in the *Polynuclear Aromatic Hydrocarbon Evaluation* report prepared by ARCADIS, dated January 2013, it is our opinion to a reasonable degree of scientific certainty that the PAHs found at the residential properties surrounding the MKC facility are part of the normal background concentrations of PAHs found in Madison, Wisconsin and other urban areas in the United States. It is also our opinion to a reasonable degree of scientific certainty that the sources of PAHs found at the residential properties surrounding the Site are not from MKC. These opinions were developed based upon a thorough review of the regulations, published papers and peer reviewed scientific literature, and the execution of a statistical evaluation of the data from the Site. Please refer to the above-referenced report for additional information. No further PAH investigation or remediation activities are necessary or planned for off-Site properties.

5.5.4 RCRA Metals

A total of 121 soil samples were collected and submitted for laboratory analysis of RCRA metals. The locations of soil RCRA metal samples collected from 0 to 2 feet and 2 to 4 feet are presented on Figures 5-19 through 5-20, respectively.

Arsenic was detected in all 121 soil samples analyzed with concentrations ranging from 2.2 mg/kg to 13 mg/kg. The average and geometric mean for the arsenic concentrations were 7.5 mg/kg and 7.2 mg/kg, respectively. Based on the widespread distribution of arsenic in the soil within such a narrow range of concentrations, the presence of arsenic appears to represent naturally occurring background conditions.

Based on this evaluation, arsenic was not further evaluated and not represented on the above referenced figures.

Soil RCRA metal concentrations, excluding arsenic, were reported above the industrial direct contact RCL for lead (400 mg/kg) at 106 Marquette Street (900 mg/kg), 142 Marquette Street (470 mg/kg), and 261 Waubesa Street (660 mg/kg) from 0 to 1 foot. All metal concentrations were reported below the non-industrial direct contact RCLs from soil samples collected from 2 to 4 feet. Concentrations of lead were not reported in soil samples collected on Site near these residential properties. Therefore, the lead concentrations reported from these residential properties is not attributed to the Site and no further action is recommended to address these concentrations.

5.5.5 Total Cyanide

A total of 121 soil samples were collected and submitted for laboratory analysis of total cyanide. All soil total cyanide concentrations were reported below the non-industrial direct contact RCL.

5.6 On-Site Rock Analytical Results

Concentrations of VOCs were analyzed in selected rock samples obtained from rock cores at sampling locations MW-3D3 and MW-5D3 by Stone Environmental Inc. from June 14 to June 28, 2012. These were collected and analyzed to determine where contamination resided in the rock. Rock core samples were collected using HQ-3 wireline coring techniques from the top of bedrock at approximately 40 feet bls to a depth of 234 and 237 feet bls at sampling locations MW-3D3 and MW-5D3, respectively. Rock samples were collected from three different zones including: 1) fracture surfaces, 2) an area between two closely spaced fractures, or 3) rock matrix where no fractures were identified within 2 to 18 inches of the sample. The rock samples were collected as 0.1-foot disks from the core and were crushed and immediately preserved in methanol on-Site. The rock samples were shipped on ice under chain of custody to Stone Environmental Inc. for laboratory analysis of select VOCs. The porewater concentrations were calculated from the rock VOC concentrations and physical properties data. A combination of the rock concentrations was used to determine where the bulk of the contamination resides. The rock analytical and physical properties data is presented on Figures 5-21 through 5-24 and included in Appendix E. Below is a summary of the rock VOCs and the porewater concentrations by well.

5.6.1 MW-3D3 Rock VOCs and Porewater Concentrations

Rock samples were analyzed from MW-3D3 from approximately every 1 to 2 feet from approximately 34 to 234 feet bls. Estimated porewater concentrations of PCE based on equilibrium-assumed partitioning calculations ranged from 0.17 to 180 µg/L. The highest PCE concentrations were reported from 60 to 90 feet bls, 110 to 135 feet bls, and at 160 feet bls. There was also a spike in the calculated PCE concentration at approximately 160 feet bls of 79 µg/L. The calculated PCE concentration spike estimated at 160 feet bls correlates to the depth of a fracture identified by the caliper tool (Figure 4-6). The PCE rock concentrations are graphically presented on Figure 5-21. Calculated PCE porewater concentrations closely mirrored the rock PCE concentrations, but at an order of magnitude higher than the rock PCE concentrations ranged from 1.1 to 1000 µg/L. Porewater PCE concentrations are graphically presented on Figure 5-22. PCE concentrations from the fractures and matrix samples were similar from approximately 60 to 90 feet bls. This implies that the PCE has likely penetrated the bedrock matrix. However, in the 110 to 135 feet bls sampling interval, the PCE concentrations from the fracture surfaces were higher than the matrix samples collected from 110 to 140 feet bls indicating that PCE has not diffused into the bedrock matrix to an appreciable extent in this interval. Concentrations decrease to low levels after the fracture zone identified at 160 feet bls. The rock data was subsequently used to determine a single-screen interval for the vertical delineation Well MW-3D3.

5.6.2 MW-5D3 Rock Core VOCs and Porewater Concentrations

Rock samples were analyzed from MW-5D3 from approximately every 1 to 2 feet from approximately 38 to 237 feet bls. Rock PCE concentrations ranged from 0.24 to 260 µg/L. The highest PCE concentrations were reported from 55 to 70 feet bls, 85 to 110 feet bls, and 120 to 153 feet bls. The highest concentration was identified at approximately 152.5 feet bls. After 152.5 feet, the PCE concentrations decreased to 10 µg/L or less. The PCE rock concentrations are graphically presented on Figure 5-23. Calculated porewater concentrations closely mirrored the rock PCE concentrations, but are an order of magnitude higher than concentrations reported at MW-3D3 with concentrations ranging from 1.1 to 2,000 µg/L. The porewater concentrations are graphically presented on Figure 5-24. PCE concentrations from the fracture surfaces were higher than the bedrock matrix samples collected at Monitoring Well MW-5D3 indicating that PCE has not diffused into the bedrock matrix to an appreciable extent at this location. The rock data was subsequently used to determine a single-screen interval for the vertical delineation Well MW-5D3.

5.6.3 Summary of Rock Core Findings

The rock core and calculated porewater concentrations indicate where the majority of the PCE mass is located. These data were used to develop the injection area for the In-Situ Chemical Oxidation (ISCO) sodium permanganate pilot test study. Both the 60 to 90 feet bls and 110 to160 feet bls intervals were targeted for pilot testing at the MW-3 sampling location. The data confirmed that the vertical extent of the PCE plume is no deeper than approximately 160 feet bls at the MW-3 and MW-5 well nests. The rock concentrations also indicate that there is variability between the wells nests with respect to where the PCE mass is located. PCE concentrations were similar between fracture surfaces and the bedrock matrix at key intervals, as well as higher at fracture surfaces and lower in the matrix at other key intervals. The calculated porewater concentrations were higher at Monitoring Well MW-5D3 than Monitoring Well MW-3D3.

5.7 Groundwater Analytical Results

Groundwater samples were collected from temporary wells, bedrock boreholes for vertical aquifer profiling, monitoring wells, and multiport wells. Groundwater analytical laboratory reports are included under Appendix G. The following subsections describe the samples collected, and the nature and distribution of groundwater impacts.

5.7.1 Temporary Well VOC Analytical Results

The groundwater quality was evaluated in the Unconsolidated Aquifer through the installation and sampling of temporary wells in the three on-Site parking lots, landscaped areas, and loading docks. The primary constituent of concern was PCE. A total of 23 groundwater samples were collected from temporary wells and submitted for laboratory analysis of VOCs between June 1 and 21, 2012. Groundwater temporary well VOC analytical results are summarized in Table 5-3. Temporary well locations and PCE concentrations are presented on Figure-25.

VOC concentrations are likely biased high due to the turbidity of the groundwater samples collected. Groundwater PCE concentrations ranged from approximately 0.77 to 2,600 µg/L. The lowest PCE concentrations measured in groundwater were reported for sampling locations in the southeast and southwest parking lots. The highest PCE concentrations measured in groundwater were reported for sampling locations in the north parking lot.

5.7.2 Vertical Aquifer Profiling VOC Analytical Results

A total of 45 groundwater samples were collected from bedrock boreholes MW-13 through MW-17 and submitted for laboratory analysis of VOCs between September 26 and December 11, 2012. A summary of the groundwater VOC analytical results is summarized in Table 5-4. Groundwater laboratory analytical reports are presented in Appendix G.

The purpose of these groundwater samples was to complete vertical aquifer profiling in bedrock to identify and characterize the nature and extent of potential dissolved phase impacts both vertically and horizontally and to aid in deciding where to set permanent monitoring wells. Bedrock Boreholes MW-13 through MW-16 were renamed MP-13 through MP-16 following the installation of multiport wells at these locations. Double packers were used to collect groundwater samples using a "top-down" approach with samples collected from every other 10-foot interval from approximately 40 to 180 feet bls and within every 10-foot interval from 180 to 200 feet bls. The groundwater VOC concentrations and down-hole geophysical data were used to select sample intervals for MP-13 through MP-16 and MW-17.

5.7.3 Permanent Well Groundwater Analytical Results

The current permanent groundwater well network at the Site includes 35 single-cased wells and four multiport wells with a total of 20 sample intervals. The sample intervals are designed to collect samples from four geologic units including from shallowest to deepest: the Unconsolidated Aquifer; Lone Rock Formation; Wonewoc Formation; and the Eau Claire Formation. Groundwater samples were collected for select analyses in April, May, July, November, and December 2012 and January 2013. Groundwater samples were collected and submitted for laboratory analysis of VOCs, PCBs, PAHs, and dissolved RCRA metals from on-Site wells and VOCs from off-Site wells in January 2013. Groundwater analytical results are presented in Table 5-5.

A groundwater remediation pilot test study utilizing potassium permanganate was implemented in December 2012 at the MW-3 well nest. Pre-treatment groundwater PCE isoconcentration maps for the upper three geologic units (Unconsolidated Aquifer, Upper Lone Rock Formation, and Upper Wonewoc Formation) are presented as Figures 5-26 through 5-28, respectively. Select temporary well data were incorporated in the Unconsolidated Aquifer PCE isoconcentration map. The isoconcentration maps were prepared using pre-treatment groundwater PCE concentrations from the November/December 2012 sampling event for Wells MW-3S, MW-3D, MW-3D2, MW-

3D3, MW-18S, MW-19D, MW-19D2, MW-20D, MW-20D2, MW-21D, MW-21D2, and the January 2013 groundwater PCE concentrations from wells located outside the treatment area. Below is a summary of the groundwater analytical results and extent of impacts by geologic unit.

5.7.3.1 *Groundwater Analytical Results for the Unconsolidated Aquifer*

Monitoring wells located in the Unconsolidated Aquifer include MW-1, MW-2S, MW-3S, MW-7, MW-8, MW-10S, MW-11S, MW-12S, MW-18S, MW-22S and MW-23S. Groundwater analytical results for the Unconsolidated Aquifer are presented in Table 5-5. Below is a summary of the pre-treatment groundwater concentrations reported above ESs between 2012 and 2013.

- VOC concentrations were reported above ESs for PCE, TCE, cis-1,2-dichloroethene, and benzene in one or more well. PCE was the primary VOC reported above the ES in the groundwater samples collected at MW-1 (22 to 23 µg/L), MW-3S (1,600 to 2,400 µg/L), MW-18S (3,300 µg/L), MW-22S (180 µg/L), and MW-23S (290 µg/L). Benzene was reported above the ES in the groundwater sample collected at MW-6S at 9.3 µg/L. PCE was reported below the ES in the groundwater samples collected at MW-2S, MW-4S, MW-6S, MW-7, MW-8, MW-10S, MW-11S, and MW-12S. The presence of PCE degradation products (i.e., TCE, cis-1,2-Dichloroethene) in groundwater is limited and localized in extent.

- PAH concentrations were reported below the ESs for all groundwater samples.

- PCB concentrations were detected in groundwater samples collected at Monitoring Well MW-22S (12 µg/L) and MW-23S (0.24 µg/L) above the ES of 0.03 µg/L. Detectable concentrations of PCBs in groundwater samples collected at the Site appear to be limited to beneath the building.

- Dissolved RCRA metal concentrations were detected above the ESs in groundwater samples collected at MW-3S for chromium (510 µg/L) and mercury (4.1 µg/L). The ES for chromium is 100 µg/L and mercury is 2 µg/L.

The estimated extent of PCE in groundwater in the Unconsolidated Aquifer is presented on Figure 5-26. As shown, the zone containing PCE is centered near the MW-3 well nest and the MP-13 sampling location in the north parking lot. PCE impacts in groundwater are delineated in the Unconsolidated Aquifer to north by Monitoring

Well MW-12S, to the east by Monitoring Wells MW7, MW-8, and MW-11S, to the south by MW-6S, and to the west by Monitoring Well W10S.

A groundwater monitoring program is proposed in Section 9. Additional groundwater samples will be collected and analyzed for concentrations of VOCs, PCBs, and dissolved chromium and mercury from select wells located within the Unconsolidated Aquifer. In addition to the ongoing monitoring program, the WDNR has requested re-sampling of Monitoring Wells MW-22S and MW-23S for both filtered and unfiltered PCBs to confirm the 2013 groundwater results.

5.7.3.2 *Groundwater Analytical Results for the Lone Rock Formation*

Monitoring wells screened in the Lone Rock Formation include Monitoring Wells MW-2D, MW-3D, MW-3D2, MW-4S, MW-4D, MW-4D2, MW-5S, MW-5D, MW-6S, MW-6D, MW-9D, MW-9D2, MP-13 (67 to 71 feet bls; 81 to 85 feet bls), MP-14 (70 to 75 feet bls), MP-16 (80 to 84 feet bls), MW-19D, MW-20D, and MW-21D. Groundwater analytical results for the Lone Rock Formation are presented in Table 5-5. Below is a summary of the pre-treatment groundwater concentrations reported above ESs between 2012 and 2013.

- VOC concentrations were reported above the ESs for PCE, TCE, cis-1,2-dichloroethene, and benzene in one or more well. PCE was the most prevalent VOC reported above the ES in groundwater samples collected at Monitoring Wells MW-2D (610 to 720 µg/L), MW-3D (1,100 to 1,800 µg/L), MW-3D2 (2,600 to 2,800 µg/L), MW-5S (240 to 360 µg/L), MW-5D (400 to 2,000 µg/L), MW-6D (20 to 25 µg/L), MW-9D2 (10 to 29 µg/L), MP-13 (44 to 48 feet, 640 to 760 µg/L), MP-13 (67 to 81 feet, 3,800 to 4,300 µg/L), MP-13 (81 to 85 feet, 5,600 to 6,800 µg/L), MP-14 (70 to 75 feet, 4,300 µg/L), MW-19D (2,400 µg/L), MW-20D (1,600 µg/L), MW-21D (1,200 µg/L), MW-22D (520 µg/L), and MW-23D (100 µg/L). Benzene was reported above the ES in the groundwater sample collected at Monitoring Well MW-6D at a concentration of 1,300 µg/L. PCE was reported below the ES in the groundwater samples collected at MW-4D, MW-4D2. MW-9D, MP-14 (70 to 75 feet), and MP-16 (80 to 84 feet).

- PAH concentrations were reported below the ESs for all groundwater samples from the Lone Rock Formation.

- PCB concentrations were detected in the groundwater sample collected at Monitoring Well MW-23D (0.24 µg/L) above the ES of 0.03 µg/L. Detectable concentrations of PCBs in Site groundwater appear to be limited to samples collected from beneath the building.

- Dissolved RCRA metal concentrations were reported below the ESs for all groundwater samples collected from the Lone Rock Formation.

The estimated extent of PCE in groundwater in the Lower Lone Rock Formation is presented on Figure 5-27. The zone containing PCE is centered near Multiport Well MP-13 in the north parking lot and extends south under the building. PCE is delineated in groundwater in the Lower Lone Rock Formation to the north by Monitoring Well MW-9D2, to the east by Multiport Well MP-16, and to the west by Multiport Well MP-14.

A groundwater monitoring program is proposed in Section 9. Additional groundwater samples will be collected for VOCs and PCBs from select wells located within the Lone Rock Formation. In addition to the ongoing monitoring program, the WDNR has requested re-sampling of Monitoring Well MW-23D for both filtered and unfiltered PCBs to confirm the 2013 groundwater results.

5.7.3.3 *Groundwater Analytical Results for the Wonewoc Formation*

Monitoring wells screened in the Wonewoc Formation include Monitoring Wells MW-3D3, MW-5D2, MW-5D3, MP-13 (102 to 106; 121 to 125; 135 to 139; 163 to 167 feet bls), MP-14 (100 to 105; 135 to 140; 170 to 179 feet bls), MP-15 (88 to 92; 100 to 105; 120 to 125; 142 to 146; 177 to 187 feet bls), MP-16 (106 to 116; 140 to 144; 175 to 179 feet bls), MW-17, MW-19D2, MW-20D2, and MW-21D2. Groundwater analytical results for the Wonewoc Formation are presented in Table 5-5. Below is a summary of the pre-treatment groundwater concentrations reported above ESs between 2012 and 2013.

- PCE was the primary VOC reported above the ES at Multiport Wells MP-13 [(102 to 106 feet, 1,100 to 1,800 µg/L), (121 to 125 feet, 1,500 to 2,600 µg/L), (135 to 139 feet, 1,900 to 2,300 µg/L), and (163 to 167 feet, 930 to 1,400 µg/L)], MP-15 [(88 to 92 feet, 130 µg/L), (100 to 105 feet, 230 µg/L), (120 to 125 feet, 1,100 µg/L), (142 to 146 feet, 170 µg/L), (183 to 187 feet, 240 µg/L)], MP-16 [(106 to 116 feet, 23 µg/L), (140 to 144 feet, 14 µg/L), and (175 to 179 feet, 13 µg/L)], and Monitoring Wells MW-17 (1,300 µg/L), MW-19D2 (680 µg/L), MW-20D2 (1,300 µg/L) and MW-21D2 (2,600 µg/L). PCE concentrations were below the ES at Multiport Well MP-14 [(135 to 140 and 178 to 187 feet)].

- PAH, PCB, and dissolved RCRA metal concentrations were reported below the ESs for all groundwater samples from the Wonewoc Formation.

- PCB concentrations were reported below the ESs for all groundwater samples from the Wonewoc Formation.

- Dissolved RCRA metal concentrations were reported below the ESs for all groundwater samples from the Wonewoc Formation.

The estimated extent of PCE in groundwater in the Upper Wonewoc Formation is presented on Figure 5-28. The PCE plume is centered on Multiport Well MP-13 in the north parking lot and extends south and north. PCE is delineated in the Upper Wonewoc Formation to the east by Multiport Well MP-16 and to the west by Multiport Well MP-14.

A groundwater monitoring program is proposed in Section 9. Additional groundwater samples will be collected for VOCs from wells located within the Wonewoc Formation.

5.7.3.4 *Groundwater Analytical Results for the Eau Claire Formation*

Monitoring wells screened in the Eau Claire Formation include Monitoring Wells MW-3D3 and MW-5D3. Groundwater analytical results for the Eau Claire Formation are presented in Table 5-5.

As shown, the analytical results demonstrate that VOC, PAH, PCB, and dissolved RCRA metal concentrations in all groundwater samples collected from the Eau Claire Formation were below ESs.

- Monitoring wells MW-3D3 and MW-5D3 serve as vertical delineation wells on Site.

- PAH concentrations were reported above ESs at Monitoring Well MW-3D3 for benzo(a)pyrene, benzo(b)fluoranthene, and chrysene.

- PCB concentrations were reported below the ESs.

- Dissolved RCRA metal concentrations were reported below ESs.

5.8 Vapor Analytical Results

Below is summary of on-Site and off-Site vapor analytical results.

5.8.1 On-Site Vapor Analytical Results

As discussed above, a full round of soil vapor samples was collected from the existing network of soil vapor probes on the Site in October 2012. Vapor samples were collected from 16 on-Site vapor probes. The soil vapor probe located on Site adjacent to 261 Waubesa Street (VP-261) could not be sampled as it had been abandoned. Soil vapor samples were collected from these vapor probes over an approximate 30-minute time period using 6-liter summa canisters. The vapor samples were submitted for analysis of five VOCs by U.S. EPA Method TO-15: PCE, TCE, cis-1,2-dichloroethene, trans-1,2-dichloroethene, and vinyl chloride.

A summary of the vapor probe analytical data is presented in Table 5-6. The analytical data were compared to the calculated screening levels for deep soil gas to indoor air. The data show a decrease in VOC concentrations in soil vapor within the influence of the Site SVE system. The data from soil vapor probes beyond the influence of the SVE system vary within an order of magnitude of the previous sample results as shown on Table 5-6. The soil vapor sample collected at Soil Vapor Probe SVP-102 was the only sample that contained PCE at a concentration above its screening level when compared to residential criteria. This soil vapor probe location is within the influence of the SVE system and the most recent PCE concentration was lower than the PCE concentration measured during the previous sampling event. None of the soil vapor samples contained VOC concentrations above non-residential screening levels in October 2012.

5.8.2 Off-Site Vapor Analytical Results

A summary of the 2012 to 2013 indoor air and sub-slab soil vapor analytical results from samples collected by ARCADIS and/or the WDNR's consultant is presented in Table 5-7. Table 5-7 presents the vapor data for five VOCs: PCE, TCE, cis-1,2-dichloroethene, trans-1,2-dichloroethene, and vinyl chloride. A summary of the indoor air and sub-slab vapor results for PCE is also shown on Figures 5-29 and 5-30. The indoor air analytical results were compared to the Wisconsin residential vapor action levels for indoor air, and the sub-slab soil vapor analytical results were compared to calculated screening levels for sub-slab soil vapor to indoor air in accordance with the guidelines presented in the WDNR's *Addressing Vapor Intrusion at Remediation and Redevelopment Sites in Wisconsin* dated December 2010 and *Addressing Vapor Intrusion at Remediation and Redevelopment Sites in Wisconsin Update* dated July 2012 (WDNR, PUB-RR-800). The action levels and calculated residential screening levels are based on the U.S. EPA Residential Air Screening Levels that represent health-protective concentrations that an individual can be exposed to for 30 years for 24 hours a day. The U.S. EPA provided updated regional screening level tables in November 2012. The November 2012 screening levels are included in Table 5-7.

As presented in Table 5-7, none of the VOC detections in the indoor air or sub-slab soil vapor samples collected by ARCADIS in 2012 exceeded the Wisconsin residential vapor action levels or calculated residential screening levels. Two indoor air samples collected by the WDNR's consultant contained a concentration of TCE above the residential vapor action level of 0.39 ppbv. These samples were collected from 113 South Marquette in July 2012 (0.491 ppbv) and from 249 Waubesa Street in June 2012 (0.722 ppbv). At 113 South Marquette Street, both the ARCADIS and WDNR consultant samples collected in April 2012 did not contain concentrations of TCE above laboratory detection limits. At 249 Waubesa Street, the data appears to be anomalous since the indoor air sample collected by the WDNR consultant in April 2012, the indoor air split-sample collected by ARCADIS in June 2012, and the indoor air sample collected by ARCADIS in January 2013 did not contain a concentration of TCE above laboratory detection limits.

WDNR's consultant installed SSDSs at 113 South Marquette Street and 249 Waubesa Street in 2012. A summary of the WDNR's vapor investigation was presented in WDNR's *Review of Vapor Sampling Results for the Neighborhood Surrounding the Madison Kipp Corporation* published in December 2012 (WDNR, PUB-RR-931). Copies of the laboratory analytical reports for the vapor samples collected by ARCADIS are included as Appendix M.

6. Interim Actions

Concurrent with the Site investigation, ARCADIS conducted interim actions to address the identified impacts. ARCADIS completed the following activities between February 2012 and January 2013:

- A SVE pilot test was conducted.
- A full-scale SVE system was designed and installed.
- Existing SSDS systems at five adjacent residences were inspected.
- One 1,000-gallon UST in the southeast parking lot was removed with oversight from RJN.
- A PCB soil excavation was conducted.
- An ISCO injection pilot study using sodium permanganate was conducted.

The following subsections provide details regarding these remediation activities.

6.1 SVE System

To address VOCs present in soil vapors on the northeastern portion of the Site and mitigate potential risks associated with vapor intrusion, ARCADIS performed a SVE pilot test on February 9 and 10, 2012 to obtain Site-specific data required to design a full-scale SVE system. The results of the SVE pilot test performed at the Site and the basis of design for the Phase I SVE system were provided in the *Soil Vapor Extraction Pilot Test Summary and Phase I System Basis of Design Report* dated February 27, 2012 and approved by WDNR.

The Phase I SVE system was installed at the Site between February 23 and March 9, 2012. Eight SVE wells (SVE-2 through SVE-9) were installed on February 24 and 25, 2012, and are used in conjunction with existing SVE Well SVE-1. The nine SVE wells are located along the eastern property boundary and are used to extract soil vapor from the subsurface to prevent potential vapor migration from the Site.

The SVE system is operated at a total vacuum of approximately 10 inches of mercury and at a total extraction rate of approximately 275 standard cubic feet per minute with the make-up air closed. Total VOC concentrations in the influent air samples vary between approximately 180 and 2,250 ppbv, with a general decreasing trend since system start-up.

The SVE system started continuous operation on March 9, 2012. Samples of the extracted soil vapor are collected from the effluent of the carbon treatment system in accordance with NR 419 of the Wis. Adm. Code. Performance monitoring, outlined in *Monitoring and Sampling Plan for the Phase I SVE System* and submitted to the WDNR on March 8, 2012, is currently conducted on a monthly basis and consists of monitoring the nine SVE extraction wells, the existing on-Site soil vapor probes within the radius of influence of the SVE system, and SVE system operations.

Vacuum measurements are collected on a monthly basis at Soil Vapor Probes VP-1N, VP-2N, VP-1S, VP-2S, VP-102, VP-114, and VP-126, which are located on the Site and are within the radius of influence of the Phase I SVE system. The purpose of the monitoring is to evaluate the effectiveness of the Phase I SVE system in preventing the potential off-Site migration of soil vapors within the vadose zone. Vacuum monitoring completed to date indicates the SVE system is effectively controlling sub-surface vapors within the vadose zone in the radius of influence.

The SVE effluent data are used to calculate the total mass of each VOC constituent discharged from the system per hour and per year. The calculated values are compared to the discharge limits listed in Table A of Wis. Admin. Code NR 445 (based on stack height between 25 and 40 feet) to confirm that the discharge is in compliance with the State of Wisconsin discharge requirements. Tables 6-1 through 6-5 present the SVE effluent discharge calculations.

Summaries of the SVE system operational data along with tables of routine monitoring data, influent and effluent vapor sample analytical data, and discharge compliance calculations are provided in the routine Bi-Monthly Reports submitted to WDNR. The SVE system is effectively providing capture and treatment of soil vapors on Site. A permanent SVE system will be installed to replace the current Phase I SVE system in spring 2013. The permanent SVE system will be located in the same area as the Phase I SVE and will utilize SVE Wells SVE-1 through SVE-9 to provide capture and treatment of soil vapors.

6.2 Vapor Mitigation

As discussed above, SSDSs were installed at 146, 150, 154, 162, and 166 South Marquette Street in 2011. In May 2012, ARCADIS personnel, on behalf of Madison-Kipp, completed inspections of the SSDSs at each of these five residences. The inspections were documented in the *Results of Sub-Slab Depressurization System Inspection* letters dated May 15, 2012 and submitted to each resident, WDNR and WDHS.

Recommendations for improvements to the SSDSs were presented, specific to each residence, in the *Results of Sub-Slab Depressurization System Inspection* letters. Access was provided to ARCADIS and Radon, Inc., to complete SSDS improvements at each of the residences in May 2012. Following completion of the activities at each residence, *Summary of Sub-Slab Depressurization System Activities* letters were provided to each resident, WDNR, and WDHS. This work was completed in cooperation with the WDNR.

The WDNR and their consultant (SCS/BT2) offered SSDSs throughout the neighborhood adjacent to the Site. As of December 2012, a total of 21 additional SSDSs have been installed by WDNR's consultant in homes throughout the neighborhood. The locations of the SSDSs are shown on Figures 5-29 and 5-30.

6.3 UST Removal

On November 8, 2012, RJN, of Oregon, Wisconsin, supervised the removal of one 1,000-gallon waste oil UST located near the center of the southeast parking at the Site. The UST was registered with the Wisconsin Department of Safety and Professional Services as a fuel oil UST. Approximately 215 gallons of liquid were collected from inside the UST prior to removal from the ground. Holes were observed in the bottom of the UST. A soil sample was collected and submitted for laboratory analysis from the base of the excavation for DRO and PVOCs. The soil analytical results exceeded the NR 720 Wis. Admin. Code RCLs for DRO at 6,700 mg/kg and total xylenes at 7.7 mg/kg. Based on visual evidence, a release was reported to the WDNR on November 9, 2012. On November 16, 2012, the WDNR issued a responsible party letter to Madison-Kipp and a BRRTS Number 03-13-559600 was assigned. On January 14, 2013, an *Underground Storage Tank Site Investigation Work Plan* was submitted to the WDNR. The work plan was subsequently approved by the WDNR on January 15, 2013, and this work will be initiated in first quarter 2013.

6.4 PCB Excavation Areas

6.4.1 On-Site Excavation Areas

On-Site soils containing PCBs at concentrations above 50 mg/kg located in the north parking lot were excavated and disposed of at a TSCA-approved landfill (Environmental Quality Company [EQ] located in Belleville, Michigan). The two excavation areas, referred to as the west excavation and east excavation, are shown on Figure 6-1. These excavation areas encompassed soil samples with total detected PCBs above 50 mg/kg at depths of approximately 0 to 2 feet bls. These excavation activities were performed per the U.S. EPA- and WDNR-approved *Final Revised Work Plan for Polychlorinated Biphenyl Recommended Activities* (Final Work Plan) dated December 4, 2012.

Excavation and backfill activities were performed on Site from December 17, 2012 through January 11, 2013. The west excavation area measured approximately 45-feet long by 45-feet wide by approximately 2- to 3-feet deep as shown on Figure 6-2. The east excavation area measured approximately 135-feet long by 18- to 36-feet wide by approximately 2- to 4-feet deep as shown on Figure 6-3.

Confirmation soil samples were collected from approximately every 5 feet along the side walls and every 8 feet along the base of the excavation areas in accordance with the Final Work Plan. Confirmation soil samples were submitted for laboratory analysis of PCBs by U.S. EPA SW-846 Method 8082. Additional excavation activities were required following receipt of the confirmation soil sample results as some confirmation samples contained concentrations of PCBs above 50 mg/kg. ARCADIS worked with WDNR to identify these areas, and additional excavation activities were performed to depths of approximately 3 to 4 feet bls in some areas. Additional confirmation soil samples were collected from the base and/or sidewalls of these areas, as necessary. Following receipt of these additional confirmation soil sample results and confirming that all PCB results were below 50 mg/kg, results were conveyed to WDNR and the excavation areas were backfilled with crushed stone and compacted in a maximum of 6-inch lifts using a vibrating plate compactor. The asphalt will be replaced by Madison-Kipp in spring.

A total of approximately 670 tons of soil was excavated and disposed of at EQ. A summary of the confirmation soil sample analytical results is presented in Table 6-6, and laboratory reports are attached as Appendix D.

6.4.2 Off-Site Excavation Areas

As presented in the *Addendum to the Final Revised Work Plan for Polychlorinated Biphenyl Recommended Activities* dated December 14, 2012, it was recommended that off-Site soils containing PCBs at concentrations above the WDNR's non-industrial direct contact residual contaminant level of 0.22 mg/kg be excavated and disposed of at an approved landfill. There are four recommended excavation areas, located at 241, 245, 253, and 257 Waubesa Street. A thin strip of landscaping (approximately 2 feet wide) where soils contained PCB concentrations above 1 mg/kg to a depth of 2 feet bls, will also be excavated on-Site immediately east of the fence-line adjacent to the residences. The *Addendum to the Final Revised Work Plan for Polychlorinated Biphenyl Recommended Activities* is currently being reviewed for approval by U.S. EPA and WDNR.

6.5 ISCO Pilot Test

6.5.1 Pilot Test Activities and Preliminary Results

ISCO pilot test activities were completed on Site per the approved *In-Situ Chemical Oxidation Groundwater Pilot Test Work Plan* (Pilot Test Work Plan) dated October 17, 2012. Pilot test activities were conducted to support evaluation of potential full-scale deployment of the ISCO technology to treat chlorinated VOCs in groundwater at the Site. The following paragraphs present a brief description of the activities conducted to date as part of the approved pilot test design presented in the Pilot Test Work Plan:

- The pilot test injection and monitoring well network was installed in the vicinity of the Monitoring Well MW-3 nest, as shown on Figure 6-4. The pilot test well network consists of the following: Two new injection wells (IW-1S and IW-2D/2D2), three new monitoring wells (MW-18S, MW-19D/19D2, and MW-21D/21D2), one new injection dose response well (MW-20D/20D2), and one existing monitoring well (MW-3S).

- The injection wells were used to deliver a solution of a known volume and concentration of sodium permanganate and non-reactive hydraulic tracers within the subsurface. A different tracer was used for each of the three injection intervals (one interval in the unconsolidated unit, one interval in the shallow bedrock, and one interval in the deep bedrock) to monitor subsurface tracer distribution within the monitoring network. A total of 18,350 gallons of 5% sodium permanganate solution was injected into the three injection intervals (approximately 2,350; 7,000 and 9,000 gallons into the unconsolidated unit, shallow bedrock and deep bedrock units, respectively) during the pilot test from December 11 through December 17, 2012. The mixed sodium permanganate and tracer solutions were delivered to injection wells through above-grade piping manifolds under gravity-feed conditions. The injection sequence started with the shallow bedrock injection interval (IW-2D), followed by the deep injection interval (IW-2D2), and concluded with the shallow unconsolidated unit injection interval (IW-1S).

- Prior to initiation of the injection event, baseline water level and groundwater analytical monitoring was conducted from a combination of new and existing monitoring wells in the injection area.

- During the injection event, dose response and monitoring wells were monitored to evaluate for potential breakthrough of sodium permanganate and tracers.

- Following completion of the injection event, a post-injection tracer and performance monitoring program was implemented and included weekly tracer sampling for 3 weeks, followed by bi-weekly sampling for two additional months following the injection event. The tracer and performance monitoring programs were used to characterize the distribution of sodium permanganate and tracer, characterize the rate of sodium permanganate consumption relative to the destruction of chlorinated ethenes, evaluate the rate of groundwater washout of the injection solution from the treatment area, and evaluate the extent of VOC rebound as mass diffuses from the bedrock matrix into the bedrock fractures. Analytical data collected through the first performance monitoring event, conducted January 14 through 18, 2013, are presented in Table 6-7.

The data presented in the *Implementation Summary and Recommendations - In-Situ Chemical Oxidation Groundwater Pilot Test* letter (ISCO Summary Letter), submitted to the WDNR on February 15, 2012, included results from the well installation, baseline sampling, pilot test injection, and preliminary post-injection monitoring events.

Preliminary results presented in the ISCO Summary Letter include field observations and analytical results available through February 1, 2013. Based on the continued presence of reactive sodium permanganate within the injection area, post-injection monitoring activities are still in progress. The preliminary results reported will be further refined following completion of the planned or supplemental post-injection monitoring events to evaluate the ISCO effectiveness for full-scale application and remedial design.

Summaries of conductivity and injection volume over time for the middle of the screen and the interval with highest conductivity are presented on Figures 6-5 through 6-12. Conductivity and color breakthrough were used as the primary indicators of injection solution breakthrough during the field event. A summary of color breakthrough and color longevity is presented in Table 6-8. Continuous conductivity measurements are provided in Appendix N.

The first full round of groundwater performance monitoring was conducted the week of January 14, 2013, 5 weeks post-injection. Analytical results are presented in Table 6-7. Groundwater samples were collected from two intervals during this event. Grab samples were collected from the screen interval determined to have the highest conductivity (i.e., strongest breakthrough response, "HC") during the vertical conductivity sampling. HC samples were collected to remain consistent with the injection and tracer monitoring methods. A second, low-flow sample was collected from the middle of the screen (MS). This sample was collected for consistency with the Site-wide sampling methodology.

Based on the added value of collecting and analyzing preliminary VOC treatment data prior to complete permanganate exhaustion, the U.S. EPA Ground Water Issue titled *Ground Water Sample Preservation at In-Situ Chemical Oxidation Sites-Recommended Guidelines* was used as a guidance document for sample collection and quenching of groundwater with residual sodium permanganate present during the performance monitoring event. During the groundwater performance monitoring event, evidence of sodium permanganate was observed in the following monitoring wells: MW-3S, MW-19D, MW-20D, MW-20D2, MW-21D, and MW-21D2 (Table 6-8). VOC samples collected from these wells (both MS and HC) were quenched per the U.S. EPA guidance after sample collection before laboratory analysis. The intention of the quenching is to stop the chemical reaction at the time the sample is collected to accurately represent the chemical concentrations within the aquifer at the time of sampling. Unquenched samples submitted to the lab have additional reaction time during transit and therefore, may not be representative of actual aquifer conditions at the time of sampling. A summary of baseline and preliminary post-injection PCE results is presented on Figure 6-13.

6.5.2 ISCO Pilot Test Recommendations

Based on the results reported in the ISCO Summary Letter, preliminary data collected following injection indicate that reductions in PCE concentration were observed in the shallow unconsolidated soil interval (83% reduction), shallow bedrock interval (29 to

88% reduction), and deep bedrock interval (54% to 85% reduction). The extent of PCE reduction was correlated with permanganate breakthrough strength at individual monitoring wells. The injection activities were also successful in determining the hydraulic parameters associated with potential full-scale implementation including: 1) the injection volume to radial distribution relationship, 2) achievable injection flow rates and wellhead pressures to achieve breakthrough, and 3) an improved understanding of fracture communication and its influence on subsurface fluid distribution. These results were all required to support a determination of the design well spacing and injection volumes for a full-scale ISCO remedial program.

As described in the ISCO Summary Letter and the sections above, continued groundwater monitoring is required to fully evaluate the longevity of treatment effectiveness and characterize the extent of which the ISCO approach can promote destruction of PCE within both bedrock fractures and the bedrock matrix. Monthly performance monitoring is proposed for up to an additional 6 months beginning in March 2013 at Monitoring Wells MW-18S, MW-19D/19D2, MW-20D/20D2, and MW-21D/21D2, Multiport Well MP-13, and the MW-3 and MW-5 series wells. During this period, monitoring frequency and analytes may be modified to support data assessment and evaluation.

Once the existing sodium permanganate solution has been depleted, rebound monitoring will begin. This monitoring is critical to evaluate the extent of VOC rebound, as the diffusion of PCE from the bedrock matrix into the fractures will guide remedial design considerations pertaining to the recommended sodium permanganate injection strength, quantity of injection events, and anticipated improvements in bedrock groundwater quality during full-scale implementation. This understanding will be used in conjunction with the bedrock lithologic data to further characterize the dual-porosity bedrock model and the extent of diffusion (of both PCE and permanganate) between the bedrock fractures and bedrock matrix. As the dual-porosity relationship will control the extent of which PCE can be successfully treated within the bedrock matrix, this information will also have a bearing on the final selection of an ISCO technology for source remediation or whether alternative remedial technologies and approaches (e.g., monitored natural attenuation) are more appropriate for the Site.

Final ISCO pilot test field observations and final monitoring results collected during the course of the pilot test and post-injection monitoring will be summarized in a final remedial summary letter. This letter will include an evaluation of injection operations and treatment performance observed during post-injection monitoring activities and will include recommendations regarding full-scale remedial design application of the ISCO technology for source treatment of chlorinated ethenes at the Site.

7. Conceptual Site Model

The ultimate goal for the Site is to develop and implement a long-term remedial strategy that prevents or eliminates the potential for vapor intrusion into structures; prevents or eliminates the potential for direct contact with soil and groundwater contamination; and facilitates groundwater restoration or containment. Development of a successful remedial strategy is dependent on the assembly and testing of the CSM. A CSM synthesizes all relevant data (e.g., the facility and release history, geologic and hydrogeologic conditions, nature and extent of contamination, potential receptors and transport mechanisms, etc.) to provide a technical basis for remedial decision-making. Below is summary of the CSM.

- The Site is located at 201 Waubesa Street, Madison, on the isthmus between Lake Mendota and Lake Monona. Lake Mendota discharges into the Yahara River as surface water flows south and discharges into Lake Monona. Lake Mendota has a surface water elevation located approximately 4 feet higher than Lake Monona due to a lock and dam system.

- The Site geology is characterized by a series of geologic units consisting of glacially-derived unconsolidated deposits underlain by a sequence of sandstone bedrock units underlain by crystalline bedrock. The Site's geology from youngest to oldest consists of:
  - Two unconsolidated units consisting of fill material and glacially-derived deposits. The native soils consist of stiff clay over a very fine to coarse-grained sand and silt unit. Gravel lenses were also observed at varying depths and thicknesses in the sand silt unit.
  - The Lone Rock Formation consists of a friable to moderately hard, very glauconitic, very fine to fine-grained sandstone. This formation is approximately 65-feet thick. There is a topographic high in the bedrock surface on Site; however, the formation regionally slopes to the south.
  - The Wonewoc Formation consists of friable to moderately hard, fine to coarse-grained sandstone grading to friable to hard, iron rich, rounded, medium to coarse-grained sandstone.
  - The Eau Claire Formation consists of moderately hard to hard, very fine to fine-grained sandstone interbedded with siltstone and shale laminations.

- The sandstone formations beneath the Site are intensely to highly fractured with primarily horizontally-oriented fractures associated with bedding plane partings and limited high-angle joints. Using the rock VOC analytical results from fracture surfaces and matrix and down-hole geophysical data from the borehole, fractures which may be capable of transmitting water were observed or interpreted at the following locations and depths:

- Monitoring Well MW-3D3: Based on the rock VOC analytical results, fractures which may be capable of transmitting water were interpreted to be present from 60 to 90 feet bls, 110 to 140 feet bls, and at 155 feet bls. Calculated porewater VOC concentrations reduce to generally less than 10 µg/L below 165 feet bls.
- Monitoring Well MW-5D3: Based on the rock VOC analytical results, fractures which may be capable of transmitting water were interpreted to be present between 40 and 45 feet bls, 55 and 65 feet bls, 90 to 110 feet bls, and 120 to 155 feet bls. Calculated porewater VOC concentrations reduce to generally less than 20 µg/L below 155 feet bls.
- Multiport Well MP-13: Fractures which may be capable of transmitting water were interpreted to be present at depths of 53, 83, 100, and 154 feet bls with the highest fracture intensity observed between approximately 48 and 53 feet bls, 88 and 93 feet bls, 134 and 138 feet bls and 153 and 158 feet bls. Heat pulse flow meter data collected from approximately 54 to 56 feet bls appear to demarcate a change from upward vertical groundwater flow in the borehole to downward vertical flow during pumping conditions. The heat pulse flow meter measured low flow rates ranging from 0.1 to 0.54 gpm under pumping conditions.
- Multiport Well MP-14: Fractures which may be capable of transmitting water were interpreted at depths of 49, 50, 51, 72, and 103 feet bls, with the highest fracture intensity observed between approximately 49 and 54 and 99 and 104 feet bls. The fractures identified at 49 to 51, 72 and 103 feet bls were also indicated by the caliper tool. The heat pulse flow meter data collected from approximately 54 to 56 feet bls appear to demarcate a change from upward vertical groundwater flow in the borehole to downward vertical flow during pumping conditions. The heat pulse flow meter measured low-flow rates ranging from 0.27 to 0.77 gpm under pumping conditions.
- Multiport Well MP-15: Fractures which may be capable of transmitting water were interpreted at depths of 56, 72, 75, and 90 feet bls, with the highest fracture intensity observed between approximately 87 to 92 feet bls. The heat pulse flow meter measured low upward flow rates in the borehole ranging from 0.05 to 0.86 gpm during pumping conditions.
- Multiport Well MP-16: Fractures which may be capable of transmitting water were interpreted at 108 feet, with the highest fracture intensity observed between approximately 107 and 112 feet bls. The heat pulse flow meter

measured low upward flow rates in the borehole ranging from 0.07 to 1.04 gpm during pumping conditions.

- Soil samples were analyzed on Site and off Site for VOCs, PCBs, PAHs, RCRA metals and cyanide. Soil concentrations are delineated by on-Site and/or off-Site soil borings.

- An SVE system was installed on the northeast portion of the Site in February 2012. On-Site soil vapor was evaluated by collecting soil vapor samples from the on-Site vapor probe network in October 2012. The data show a decrease in VOC concentrations in soil vapor within the influence of the Site SVE system. The data from soil vapor probes beyond the influence of the SVE system vary within an order of magnitude of the previous sample results as shown on Table 5-6. None of the soil vapor samples contained VOC concentrations above non-residential screening levels during the October 2012 event.

- Off-site vapor was evaluated by collecting sub-slab and indoor air vapor samples at residences adjacent to the Site. None of the VOC detections in the indoor air or sub-slab soil vapor samples collected by ARCADIS in 2012 exceeded the Wisconsin residential vapor action levels or calculated residential screening levels.

- The city of Madison’s hydrostratigraphy can be divided into four units including, from the upper to lower aquifers: (1) Unconsolidated Aquifer; (2) Upper Paleozoic Aquifer; (3) Eau Claire Aquitard; and, (4) Mount Simon Aquifer.
  - The Unconsolidated Aquifer is located in the unconsolidated soils. This aquifer is not a primary source of drinking water in Madison since it is not consistently observed. The geometric mean hydraulic conductivity for the diamicton (Unconsolidated Aquifer) is estimated at approximately 0.6 feet per day (ft/day).
  - The Upper Paleozoic Aquifer includes the Lone Rock, Wonewoc, and the upper part of the Eau Claire Formations, starting above the shale. The Upper Paleozoic Aquifer in the vicinity of the Site ranges from approximately 145- to 185-feet thick. The total porosity of the Lone Rock and Wonewoc Formations in the Upper Paleozoic Aquifer at the Site ranges from approximately 17 to 29% with an average hydraulic conductivity estimated at approximately 5 ft/day.
  - The Upper Paleozoic Aquifer has been eroded under the Yahara Lakes including portions of Lake Mendota and potentially under Lake Monona. The Upper Paleozoic Aquifer is used for water supply by the city of Madison at

Municipal Unit Well 11. The groundwater model that was part of the Dane County Regional Hydrogeologic Study assumes there is connection between the Upper Paleozoic and Mount Simon Aquifers (WGNHS, 1999). This connection is stronger where the shale unit is absent and weaker where the shale unit is present.

- The Eau Claire Aquitard is considered to be a leaky confining unit located between the Upper Paleozoic and Mount Simon Aquifer. The shale unit located within the Eau Claire Formation serves as the boundary between the Aquifers. Although the shale in the vicinity of the Site is estimated to range from 10- to 20-feet thick, it has been eroded in portions of the central Yahara Lakes. Where present, the shale limits groundwater flow from the Upper Paleozoic Aquifer and offers limited protection to the Mount Simon Aquifer. There is a groundwater connection between the Upper Paleozoic and Mount Simon Aquifers in the city of Madison due to several reasons, including the absence and thickness of the shale or fractures within the shale. The total porosity of the Eau Claire shale ranges from approximately 8 to 15%.
- The Mount Simon Aquifer includes the Mount Simon and the lower part of the Eau Claire Formations, starting below the Eau Claire shale. The Mount Simon Aquifer in the vicinity of the Site is approximately 500-feet thick. The total porosity of the Mount Simon Formation ranges from approximately 11 to 20% with a geometric mean hydraulic conductivity of approximately 10 ft/day.
- The Mount Simon Aquifer is the chief water supply aquifer used by the city of Madison. The Mount Simon Aquifer is confined in most of Dane County, except where the Eau Claire Formation is absent under portions of the Yahara Lakes. The Dane County Regional Hydrogeologic Study shows the southern half of Lake Mendota and all of Lake Monona discharge to groundwater due to the aggressive pumping from the city of Madison municipal wells. There is likely a direct connection between the surface water of Lake Monona and the Mount Simon Formation.

- Three city of Madison municipal wells were identified near the Site:
  - Municipal Unit Well 8 is located approximately 1,400 feet southeast of the Site. This bedrock well is open across the Mount Simon sandstone formation and was pump-tested at 1,965 gallons per minute with 65 feet of drawdown (specific capacity 30.2 gpm/foot). This well is typically operated in the summer months. In 2011, Municipal Unit Well 8 pumped approximately 56,800 total gallons between July and September 2011. In 2012, this well pumped approximately 8,800 total gallons between July and August 2012.

- Municipal Unit Well 11 is located approximately 1.2 miles east of the Site. This bedrock well is open across the Lone Rock, Wonewoc, Eau Claire (open across the shale unit, if present), and Mount Simon sandstone formations and was pump-tested at 2,152 gpm with 111 feet of drawdown (specific capacity 19.2 gpm/foot). This well is operated year-round.
- Municipal Unit Well 7 is located approximately 1.8 miles northwest of the Site. This bedrock well is open across the lower part of the Eau Claire and Mount Simon sandstone formations and was pump-tested at 1,750 gallons per minute with 94 feet of drawdown (specific capacity 18.6 gpm/foot). This well is operated year-round.

· The hydraulic gradient direction in wells completed in the unconsolidated zone is variable and in the on-Site area generally ranges from south to southeast. In the Lower Lone Rock Formation the hydraulic gradient direction is generally to the south and southeast in the southern half of the Site, and possibly to the north in the northern half of the Site. In the Lower Wonewoc Formation the hydraulic gradient direction is to the southeast. These hydraulic gradient directions are based on a single round of groundwater elevations as shown on Figures 4-12 through 4-14, but are consistent with prior groundwater elevations.

· The magnitude of the horizontal hydraulic gradient was calculated at 0.01 ft/ft in the northern half of the Site and 0.001 ft/ft in the southern half of the Site in the Unconsolidated Aquifer and Lower Lone Rock Formations. The magnitude of the horizontal hydraulic gradient was calculated at 0.001 ft/ft in the Upper Wonewoc Formation.

· The direction of the vertical hydraulic gradient was generally downward across the Site. The magnitude of the vertical hydraulic gradient between the Unconsolidated Aquifer and Lone Rock Formation was calculated at approximately 0.011 to 0.084 ft/ft. The magnitude of the vertical hydraulic gradient from the Lone Rock Formation to the Lower Wonewoc Formation was calculated at approximately 0.012 to 0.033 ft/ft. The downward vertical gradient at the Monitoring Well MW-9 well nest was an order of magnitude lower than at the other Site well nests, with averages ranging from approximately 0.002 to 0.006 ft/ft. While the direction of the Site-wide vertical gradient is generally downward, localized upward vertical hydraulic gradients were observed at several well locations including Monitoring Wells MW-5D2 and MW-5D3 at 0.002 ft/ft and MW-22S to MW-22D at 0.009 ft/ft. A predominant downward vertical hydraulic gradient exists across the Site as a result of the city of Madison municipal wells pumping groundwater from the Upper Paleozoic and Mount Simon Aquifers. Furthermore, the vertical gradient is limited by the low permeability sediments (Eau Claire shale).

- Contaminant Fate and Transport
  - Groundwater VOC concentrations were reported above ESs in Site monitoring wells. The main constituent of concern is PCE. Based on the elevated PCE concentrations in groundwater, the source area is in the north parking lot of the Site. There is primarily a south to southeast horizontal hydraulic gradient direction and a downward vertical hydraulic gradient at the Site. The PCE contour maps are presented as Figures 5-26 through 5-28.

    PCE impacts in groundwater are delineated in the Unconsolidated Aquifer to the north by Monitoring Well MW-12S, to the east by Monitoring Wells MW-7, MW-8, and MW-11S, to the south by MW-6S, and to the west by Monitoring Well W-10S. PCE is delineated in groundwater in the Lower Lone Rock Formation to the north by Monitoring Well MW-9D2, to the east by Multiport Well MP-16, and to the west by Multiport Well MP-14. PCE is delineated in the Upper Wonewoc Formation to the east by Multiport Well MP-16 and to the west by Multiport Well MP-14. The plume is also delineated vertically on Site by Monitoring Wells MW-3D3 and MW-5D3.

  - PCE and limited degradation products (i.e., TCE, cis-1,2-Dichloroethene) were reported in the groundwater beneath the Site. Potential routes of migration for PCE and associated degradation products within the immediate vicinity of the Site are principally through groundwater and vapor migration.

    There are several transport mechanisms that aid in reducing groundwater concentrations as the plume migrates downgradient including diffusion, advection, dispersion, retention, and dilution.

  - Constituent transport in fractured sandstone bedrock is best conceptualized using the “dual-porosity” model. In the dual-porosity conceptual model, the primary porosity is associated with the bedrock matrix porosity which is often considered to be of lower relative permeability (or hydraulic conductivity). The primary bedrock matrix represents the less mobile pore space. Constituents can be transported into or out of the bedrock matrix through slow groundwater movement and chemical diffusion.

- The secondary porosity in the dual-porosity conceptual model is associated with fractures within the bedrock. Secondary porosity of sandstone is commonly referred to as “mobile porosity”. Constituents can be transported through the secondary porosity, also known as the fracture network, due to processes such as advection and dispersion.

- Because of the relatively large difference between primary and secondary porosity in fractured bedrock environments, such as is found in the sandstone bedrock beneath the Site, the groundwater constituents can reside in both the low porosity rock matrix and high porosity fractures, with down-gradient transport occurring primarily in the high porosity fracture network. While plume migration occurs due diffusion, advection, and dispersion, dilution and retention transport mechanisms are also key to reducing concentrations as the groundwater migrates downgradient.

- Based on multiple lines of evidence, dense non-aqueous phase liquid (DNAPL) is not present at the Site. No DNAPL has been encountered in any investigation soil borings or monitoring wells at the Site. No DNAPL was observed during extensive, detailed soil and bedrock characterization studies at depths of up to 235 feet at the Site. The U.S. EPA recommends a weight of evidence approach to determine whether or not DNAPL is present in the subsurface. The following converging lines of evidence derived from detailed lithologic characterization; soil, bedrock and groundwater analytical sampling; and extended groundwater monitoring duration all demonstrate that DNAPL is not present within the subsurface:
  - Based on the historical elevated groundwater concentrations detected at the MW-3 and MW-5 well nests and the concentrations of PCE within the unconsolidated interval at these locations, these wells were considered indicative of on-Site source areas. The bedrock at MW-3D3 and MW-5D3 was cored and logged by a geologist to record lithology, fractures, and the potential presence of DNAPL. No staining, pools, ganglia, and/or globules of DNAPL were observed in or on the cores.
  - Evidence of separate-phase, pooling or residual DNAPL has not been encountered in any other borings or wells installed in the unconsolidated soil or bedrock at the Site around its periphery.
  - Water levels have been measured in the Site monitoring wells since 1995. DNAPL has not been observed in any of the Site monitoring wells.

- Decreasing concentrations of VOCs in groundwater have been observed in on-Site source area monitoring wells. If DNAPL were present, decreases in VOC concentrations would not be expected to occur.
- The presence or absence of separate phase DNAPL can be inferred based on qualitative rule of thumb screening estimates in the absence of extensive characterization data (U.S. EPA 1991; Cohen and Mercer 1993; Pankow and Cherry 1996; U.S. EPA 2009). Rule of thumb dissolved-phase concentrations that are between 1 – 10% of their aqueous solubility have generally been used to suggest that there is the potential for DNAPL to have historically existed within the subsurface. Based on a PCE pure-phase aqueous solubility of 200,000 µg/L (U.S. EPA 2009), the equivalent range of dissolved-phase PCE concentration is between 2,000 µg/L (1% solubility) and 20,000 µg/L (10% solubility). While the highest PCE concentration observed on Site is above the lower end of the qualitative range, the 1% rule of thumb is inappropriate for interpretation of source zone conditions in fractured porous media (Parker et al., 1997). As a result, the 10% end of the screening range is more appropriate for estimating purposes, and therefore, based on this conclusion, groundwater data would indicate that DNAPL is not present at the Site.

8. Summary of Findings and Conclusions

Below is a summary of findings and conclusions from the Site investigation and interim action activities.

8.1 On-Site and Off-Site Soil Investigation Activities

Below is a summary of on-Site and off-Site soil investigation activities for the reporting period.

- A total of 195 on-Site soil borings and 62 off-Site hand auger borings were advanced. A total of 224 on-Site and 148 off-Site soil samples were collected and submitted for laboratory analyses including VOCs, PCBs, PAHs, and RCRA metals. An additional 12 soil samples were submitted for laboratory analysis of PCB homolog.

- Soil VOC concentrations above soil criteria were generally observed on Site near the former oil shed in the upper 2 feet of soil. Soil VOC concentrations were reported below soil criteria off Site. Soil VOC concentrations decrease with depth and were delineated by on-Site and off-Site soil results.

- Soil PCB concentrations above soil criteria were generally observed on Site along the western property line, under the building and under the north parking lot in the upper 4 feet of soil, and below the building in soils collected from greater than 4 feet. Soil PCB concentrations decrease with depth and are delineated by on-Site and off-Site soil samples results. On-Site soil PCB exceedances above the TSCA disposal limit of 50 mg/kg in the north parking lot were excavated in December 2012/January 2013 (excluding soils beneath the building) as presented in Section 6.4.1. Additionally, it is recommended that off-Site soils containing PCBs at concentrations above the WDNR's non-industrial direct contact residual contaminant level of 0.22 mg/kg at four residences (241, 245, 253, and 257 Waubesa Street) be excavated and disposed of at an approved landfill as presented in Section 6.4.2. Soil PAH concentrations above soil criteria were generally observed across the Site. Soil PAH concentrations decrease with depth and are delineated by on-Site and off-Site soil results, where soil PAH concentrations were determined to be background and not attributed to MKC activities.

- Soil RCRA metal concentrations above soil criteria were generally observed on Site in random locations for lead, mercury, barium, and selenium. Soil RCRA metal concentrations decrease with depth and are delineated by off-Site soil sample results.

- Soil cyanide concentrations were reported below soil criteria at all on-Site and off-Site borings.

8.2 On-Site Bedrock Soil Investigation Activities

Below is a summary of on-Site and off-Site bedrock investigation activities for the reporting period.

- Based on the bedrock PCE analytical results from Monitoring Well MW-3D3, the bulk of the contaminant mass resides from 60 to 90 feet bls, 110 to 140 feet bls, and at 160 feet bls. Similar PCE concentrations were reported from the fracture surfaces and matrix samples from approximately 60 to 90 feet bls. This implies that the PCE has penetrated into the bedrock matrix in this interval. Conversely, the PCE concentrations from the fracture surfaces were higher than the matrix samples collected from 110 to 140 feet indicating that PCE has not diffused into the bedrock matrix to an appreciable extent in this interval.

- Based on the rock PCE analytical results from Monitoring Well MW-5D3, the bulk of the contaminant mass resides from 55 to 70 feet bls, 85 to 110 feet bls, and 120 to 153 feet bls. PCE concentrations from the fracture surfaces were higher than the matrix samples collected at Monitoring Well MW-5D3 indicating that PCE has not diffused into the bedrock matrix to an appreciable extent at this location.

Groundwater investigation activities:

- A total of 55 groundwater sample locations exist (not including the three injections wells) consisting of 35 monitoring wells and 4 multiport wells containing a total of 20 sampling locations. Samples were collected from all locations and submitted for laboratory analysis of VOCs, PCBs, PAHs and/or dissolved RCRA metals.

  Groundwater VOC concentrations were above the ES at most of the on-Site well locations. The main constituent of concern is PCE. Using the current PCE data for the Site, the source area is in the north parking lot area of the Site. There is primarily a south to southeast horizontal hydraulic gradient direction and a downward vertical hydraulic gradient at the Site. As a result, the PCE plume is elongated horizontally with depth (Figures 5-26 through 5-28). PCE impacts in groundwater are delineated in the Unconsolidated Aquifer to the north by Monitoring Well MW-12S; to the east by Monitoring Wells MW-7, MW-8, and MW-11S; to the south by MW-6S, and to the west by Monitoring Well W-10S. PCE is delineated in groundwater in the Lower Lone Rock Formation to the north by Monitoring Well MW-9D2, to the east by Multiport Well MP-16, and to the west by Multiport Well MP-14. PCE is delineated in the Upper Wonewoc Formation to the east by Multiport Well MP-16 and to the west by Multiport Well MP-14. The plume is also delineated vertically on Site by Monitoring Wells MW-3D3 and MW-5D3.

- Groundwater PAH ES exceedances were only reported at MW-3D3.

- Groundwater PCB exceedances were limited to Monitoring Wells MW-22S, MW-22D and MW-23D, which are all within the building footprint. ES exceedances of PCB 1016 are indicated at Monitoring Wells MW-22S and MW-22D and an ES exceedances of PCB 1242 is indicated at Monitoring Well MW-23D. However, U.S. EPA studies have demonstrated that PCBs are “insoluble in water,” strongly adsorb to soils, and generally will not leach significantly in aqueous soil systems (USEPA2012). As a result, PCBs are not expected to dissolve or migrate in groundwater. Additional groundwater monitoring will be completed to confirm the presence of PCBs in the groundwater.

- Groundwater dissolved RCRA metal concentrations above the ES were only reported at Monitoring Well MW-3S with exceedances of chromium and mercury. PAL exceedances of RCRA metals were limited to the north parking lot and under the building with exceedances of chromium, lead, mercury and arsenic. The metal exceedances are limited to the on-Site well locations.

- Groundwater elevations were measured during each sampling event and potentiometric contour maps were created for the Unconsolidated Soils, the Lower Lone Rock Formation and the Lower Wonewoc Formation. All of the potentiometric maps indicate that the direction of the horizontal hydraulic gradient is toward the south/southeast. The Lower Lone Rock Formation potentiometric contour map also indicates that there is a potentiometric high located near Multiport Well MP-13 with horizontal gradient directions oriented toward the north and south. The interpretation that a potentiometric high exists beneath the Site is based only on the January 2013 groundwater elevation dataset, and will be confirmed during subsequent monitoring events.

8.3 On-Site and Off-Site Vapor Investigation Activities:

Below is a summary of on-Site and off-Site vapor investigation activities for the reporting period.

- A full round of soil vapor samples was collected from the existing network of soil vapor probes on the Site in October 2012. Vapor has been evaluated with sampling locations both on Site and in off-Site residential homes. A SVE system was installed in February 2012 along the eastern property line of the north parking lot to mitigate the potential migration of soil vapors containing VOCs. Prior to the operation of the SVE system, five of the soil vapor probes produced vapor samples with VOC concentration exceedances above calculated residential screening levels for deep soil gas to indoor air. The vapor samples collected at these locations in October 2012 following operation of the SVE system indicate that only Soil Vapor Prove VP-102 contains a vapor VOC exceedance of the residential screening level. Soil Vapor Probe VP-102 is within the influence of the SVE system and the most recent PCE concentration was lower than measured during the previous sampling event.

- The off-Site residential vapor samples were collected from sub-slab vapor probes and indoor air. None of the VOC detections in the indoor air or sub-slab soil vapor samples collected by ARCADIS exceeded the Wisconsin vapor action levels or calculated residential screening levels. Two indoor air samples collected by the WDNR's consultant indicated a concentration of TCE above the residential vapor action level. However, split samples and subsequent samples did not confirm the TCE concentrations. WDNR's consultant installed SSDSs at these residences, 113 South Marquette Street and 249 Waubesa Street, in 2012.

8.4 ISCO Pilot Test Activities

Below is a summary of ISCO pilot test activities for the reporting period.

- As presented in the ISCO Summary Letter, successful distribution of injection reagents was achieved up to a radial distribution of 10 to 20 feet through gravity-feed injection. In addition, localized vertical connection has been observed between the shallow and deep bedrock intervals. The preliminary results indicate that the ISCO injection has achieved a measured benefit within the injection area. Based on the continued presence of sodium permanganate, it is anticipated that additional reduction in the concentrations of VOCs will occur in monitoring wells where sodium permanganate solution persists. An evaluation of the extent of mass diffusion from the bedrock matrix to the fractures is ongoing and will be monitored through additional post-injection monitoring. Continued post-injection monitoring will be used to evaluate sodium permanganate presence, sodium permanganate washout, conductivity change, and potential concentration rebound in the injection area. Information from the additional monitoring activities will be utilized to finalize recommendations for a full-scale remedial design.

9. Recommendations

Below is a summary of the recommendations based on the Site investigation activities.

9.1 Soil Recommendations

On-Site soil VOC, PCB, PAH, and RCRA metal exceedances will be managed through maintenance of the Site building and paved areas as an engineered barrier (cap). A Cap Maintenance Plan and Materials Handling Plan will be prepared. A deed restriction for the residual soil impacts located along the bike path and land leased by MKC from the city of Madison will be prepared. Residual on-Site soil exceedances will also be placed on the WDNR's Soil GIS Registry.

Off-Site soil PCB concentrations above the non-industrial direct contact RCL of 0.22 mg/kg will be excavated and disposed of at an approved landfill, pending approval of the work plan by U.S. EPA and WDNR.

9.2 Groundwater Monitoring Program

The 2013 groundwater monitoring program will consist of the following:

- Collection of quarterly groundwater elevations

- Collection of quarterly groundwater samples for VOCs from the entire network of 55 sampling locations.

- Collection of one round of groundwater samples in March to verify PCB, PAH, and RCRA metal concentrations.
  - Groundwater samples from Monitoring Wells MW-22S, MW-22D, and MW-23D will be analyzed for PCBs (filtered and unfiltered samples)
  - Groundwater samples from Monitoring Well MW-3D3 will be analyzed for PAHs
  - Groundwater samples from Monitoring Well MW3S will be analyzed for dissolved chromium and mercury.

- In addition, monitoring wells will be sampled for up to 6-months to further evaluate the results of the ISCO pilot test.

Sampling will be conducted using low-flow sampling techniques. After 1 year of quarterly sampling, the monitoring well network will be evaluated to determine the sampling program going forward.

9.3 Vapor Monitoring Program

In 2013, semi-annual sampling of the on-Site network of soil vapor probes (summer and winter) will be performed. The soil vapor samples will be collected from 16 Vapor Probes: VP-1N, VP-1S, VP-2N, VP-2S, VP-3, VP-4, VP-5, VP-6, VP-102, VP-114, VP-126, VP-202, VP-210, VP-222, VP-237, and VP-249. Additionally, the soil vapor probes located within the bike path north of the Site (VP-3 through VP-6) will be sampled on a quarterly basis in 2013. Soil vapor samples will be collected from these vapor probes over an approximate 30-minute time period using 6-liter summa canisters. The vapor samples will be submitted for analysis of five VOCs by U.S. EPA Method TO-15: PCE, TCE, cis-1,2-dichloroethene, trans-1,2-dichloroethene, and vinyl chloride.

No additional off-Site residential vapor sampling is recommended.

9.4 SVE Program

In 2013, SVE performance monitoring will be conducted on a monthly basis. The SVE performance monitoring will consist of:

- A permanent SVE system will be installed to replace the current Phase I SVE system in spring 2013.
- Vacuum monitoring at the nine SVE Extraction Wells SVE-1 through SVE-9;
- Vacuum monitoring at the existing on-Site Soil Vapor Probes VP-1N, VP-2N, VP-1S, VP-2S, VP-102, VP-114, and VP-126, located on the Site and within the radius of influence of the SVE system;
- SVE system operation documentation including: instantaneous flow rate for each vapor extraction well, vacuum/pressure at various locations throughout the system, air temperature, and the combined flow rate for the system; and
- Influent and effluent SVE system samples to be analyzed for VOCs using U.S. EPA Method TO-15.

These data will be used to optimize system operation, demonstrate capture of soil vapors via the extraction system, evaluate the potential for off-Site migration of soil vapors within the vadose zone, and calculate the total pounds of each constituent discharged from the system per hour and per year. The calculated values will be compared to the discharge limits listed in Table A of Wis. Adm. Code NR 445 to confirm that the discharge is in compliance with the State of Wisconsin discharge requirements and to determine whether continued treatment of the soil vapor stream is required. After 1 year of monthly monitoring and SVE operational sampling, the maintenance and sampling schedule will be evaluated to determine the operation, maintenance, and sampling program going forward.

9.5 Site Investigation

The groundwater plume is defined at the Site with the exception of the northern and southern flow direction in the Upper Wonewoc Formation. There is a southern flow component at the Site. One additional well will be installed to serve as a southern delineation well for the plume. The well will be installed as follows:

- Advance one boring off Site using a combination of hollow stem auger and mud rotary drilling methods. The 8-inch boring will be advanced to an elevation of approximately 664 feet amsl (approximately 200 feet bls). This depth was selected based on the contaminant mass in the bedrock on Site, which was reported to an approximate depth of approximately 160 feet, and to confirm the concentrations off Site below this depth. The boring will not be advanced to the Eau Claire shale. Vertical aquifer profiling will be collected every other 10 feet from the base of the temporary or permanent casing (estimated 60 feet bls) to 200 feet bls and submitted for laboratory analysis of VOCs.

- Complete down-hole geophysical logging to identify and characterize fractures and water-bearing zones from approximately 60 to 200 feet bls. The geophysical tools will include gamma, fluid temperature, fluid resistivity, caliper, heat-plus flowmeter, and high resolution acoustic and optical borehole televiewers.

- Up to two 2-inch diameter well screens will be selected using a combination of the vertical aquifer profiling analytical data and the geophysical data.

An additional well to the north is not included in this scope of work for the following reasons:

- The predominant regional groundwater flow direction is toward the south via the Wonewoc Formation and is controlled by Lake Mendota surface water elevations.

- While some limited groundwater flow may occur to the north within the Lone Rock Formation, this would be considered a localized effect due primarily to local recharge patterns, and is inconsistent with regional hydraulic gradients which are oriented toward the south. Groundwater that temporarily flows toward the north in the Lone Rock Formation eventually migrates deeper downward into the system and turns toward the south along the regional hydraulic gradient. This phenomenon is verified by hydraulic gradients observed during drilling and observations of permanganate transport during the ISCO pilot test.

- Other remediation sites are located north of the Site, particularly a dry cleaner where chlorinated solvents were previously detected. The impacts at the dry cleaner were not monitored at depth beneath the Unconsolidated, and represents a potential contribution to deeper bedrock groundwater north of the Site based on the regional flow direction.

- The presence of methyl tertiary-butyl ether (MTBE) in Monitoring Well MW-9D2 (screened 64 to 60 feet bls) indicates that there are other upgradient sources that have not been identified. MTBE is not detected in on-Site monitoring wells.

9.6 Groundwater Remediation

The injection activities were successful in determining the hydraulic parameters associated with potential full-scale implementation including: 1) the injection volume to radial distribution relationship, 2) achievable injection flow rates and wellhead pressures to achieve breakthrough, and 3) an improved understanding of fracture communication and its influence on subsurface fluid distribution.

Based on the results reported in the ISCO Summary Letter, continued groundwater monitoring will be required in 2013 to fully evaluate the pilot test effectiveness and treatment performance to guide the remedial design. Monthly performance monitoring is proposed for up to 6 months beginning in March 2013 at Monitoring Wells MW-18S, MW-19D/19D2, MW-20D/20D2, and MW-21D/21D2, Multiport Well MP-13, and the MW-3 and MW-5 series wells. Groundwater samples collected during these events may be analyzed for VOCs, total metals (arsenic, chromium, manganese, and iron), dissolved metals (RCRA metals, manganese, and iron), chloride, bromide, and deuterium. Monitoring frequency and analytes may be modified to support data assessment and evaluation.

Continued groundwater monitoring is critical to evaluate the extent of VOC rebound as mass may diffuse from the bedrock matrix to the fracture network and will further guide the remedial design. Upon completion of post-injection monitoring, recommendations regarding potential full-scale application of the ISCO technology for treatment of chlorinated ethenes at the Site, or whether alternative remedial technologies and approaches (e.g., monitored natural attenuation) are more appropriate for the Site, will be developed and provided to WDNR.

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