



Corrective Measures Study (CMS)
Columbia Manufacturing Company (CMC) Restoration Project
Westfield, Massachusetts
Support for Monitored Natural Attenuation (MNA) of Groundwater



The purpose of this document is to provide evidence in support of MNA as a reasonable and appropriate final corrective measure for both the North End Groundwater and South End Groundwater.

The following discussion focuses on three primary questions relevant to MNA as a final site remedy in these areas:

- **Source Control** – Is there a continuing source of constituents of concern to the groundwater?
- **Stability of the Plume** – Is the size of the plume increasing or decreasing?
- **Can the Aquifer Support MNA** – Does groundwater data indicate that aquifer properties are supportive of MNA?

North End Groundwater

Short-term, continued operation of the groundwater recovery system with MNA represents the final corrective measure for North End Groundwater. Operation of the groundwater recovery system as an interim corrective measure (ICM) will continue until constituents of concern (COCs) concentrations in the recovery wells fall below media protection standards (MPS). When the groundwater recovery system operations are discontinued, the remainder of groundwater restoration will be achieved through MNA. MNA represents a reasonable and appropriate final corrective measure for the North End Groundwater, because sources of the COCs (tetrachloroethene [PCE], trichloroethene [TCE], and daughter products) have been remediated via prior ICMs, the chlorinated volatile organic compound (VOC) plume has contracted, and the presence of daughter products (*e.g.*, vinyl chloride, *cis*-1,2-dichloroethene [*cis*-1,2-DCE]) and low levels of dissolved iron in the groundwater are taken as evidence that ongoing VOC degradation is occurring.

The details of these conclusions are provided in the discussion below.

Source Control

Historically, the primary COCs in the North End Groundwater have been PCE, TCE, and related degradation products. The source of the chlorinated VOCs, primarily TCE, in the North End Groundwater occurred as releases from the former vapor degreasing room. Elevated concentrations of PCE have been observed in monitoring well MW-13SRR, just side-gradient of the former vapor degreasing room. The source of the PCE was a release from piping associated with a formerly abandoned UST (AOC 50). This piping and the abandoned UST were removed during the final ICM conducted in November 2009. Additional sources were not identified. This area of the site has been capped. This cap will be maintained as a part of the final corrective measures for Site-wide Soil. The location of the former vapor degreasing room and the MW-13S area are shown on the [Groundwater ICM Locations Map](#).



Groundwater ICM Locations Map

ICMs have now been completed in five locations within the North End Groundwater area. With the exception of the groundwater migration control system, all the completed ICMs were focused in the area of the VOC plume where PCE and TCE concentrations were the highest and where measurable light nonaqueous-phase liquid (LNAPL) was identified. These areas included the former vapor degreasing room and immediately adjacent former Building 1 (downgradient of former vapor degreasing room), and the area around well MW-13S. These ICMs have effectively reduced the observed levels of PCE and TCE in the groundwater to concentrations below the MPS everywhere in the North End. While the dual-phase extraction (DPE) system recovered only 10 pounds of LNAPL during its



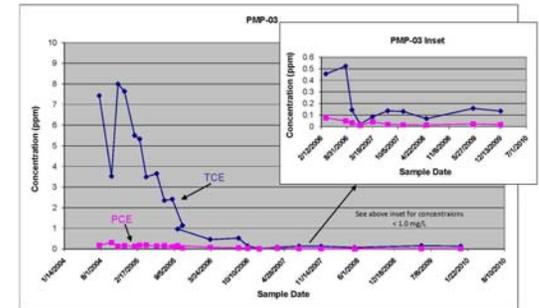
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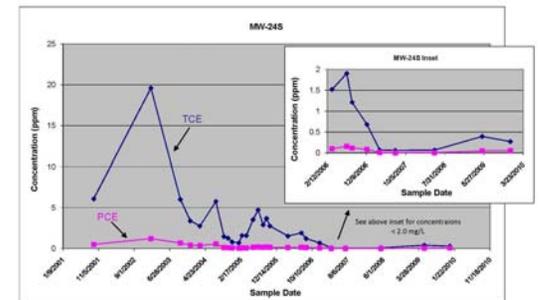
brief operational history, it was successful in reducing the amount of LNAPL that was present in the capillary fringe above residual concentrations. While TPH is still observed in some compliance groundwater monitoring wells, the concentrations are now below the MPS.

Monitoring well PMP-03 is located in the former vapor degreasing room. This well was installed in the latter part of 2004 to monitor the performance of the *in situ* ozone sparging ICM. The well was also utilized during the *in situ* sodium persulfate injections. The declining concentration of PCE and TCE in this well over time demonstrates the success of the ICMs in source reduction. Concentrations of PCE and TCE have declined in well PMP-03 from 0.312 mg/L and 7.99 mg/L, respectively (the highest concentration detected in this well in November 2004) to 0.022 mg/L and 0.13 mg/L, respectively (detected during December 2009). The decline of these constituents over time is shown on [Concentrations of PCE and TCE Over Time in PMP-03 \(Vapor Degreasing Source Area\)](#). Since completion of the North End Groundwater ICMs in October 2007, no VOC rebound has been observed in well PMP-03.



Concentrations of PCE and TCE Over Time in PMP-03 (Vapor Degreasing Source Area) (North End Groundwater)

TCE concentrations detected in wells downgradient of the former vapor degreasing room area have also continued to decline, further confirming the success of the ICMs in VOC source reduction. Monitoring well MW-24S, located downgradient of the former vapor degreasing area has shown a pronounced reduction in TCE concentrations from 19.6 mg/L (this well's highest concentration, detected in January 2003) to 0.272 mg/L in December 2009. The decline of PCE and TCE over time in well MW-24S is shown on [Concentrations of PCE and TCE in MW-24S Over Time \(Downgradient of Source Area\)](#).



Concentrations of PCE and TCE in MW-24S Over Time (Downgradient of Source Area) (North End Groundwater)

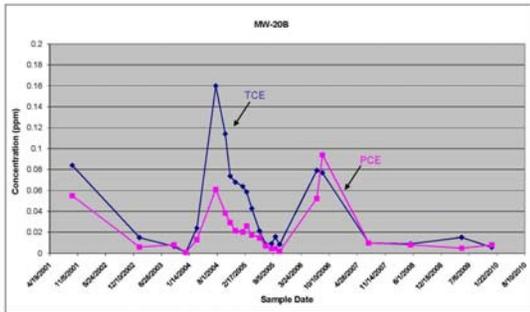
While concentrations of PCE detected in well MW-13SRR did exhibit VOC rebound following demolition of the buildings in early 2009, the focused ICM conducted in this area of the site in November 2009 was successful in reducing the PCE concentrations to below the MPS. Concentrations of PCE in well MW-13SRR were reduced in this well from 9.72 mg/L in May 2009 to 0.252 mg/L in December 2009. This data documents that the November 2009 ICM was successful in removing the residual source material responsible for the observed VOC rebound. Groundwater samples collected from MW-13SRR as well as from several other monitoring wells located downgradient of the former vapor degreasing area and other areas targeted during the ICMs (MW-20B, MW-20CR, PMP-01, and PMP-02) demonstrate the success of the PCE and TCE source control measures. Concentrations of PCE and TCE over time in these wells are shown on the following figures: [Concentrations of PCE in MW-13SRR Over Time \(PCE Source Area\)](#), [Concentrations of PCE and TCE in MW-20B Over Time \(Downgradient of Source Area\)](#), [Concentrations of PCE and TCE in MW-20CR Over Time \(Downgradient of Source Area\)](#), [Concentrations of PCE and TCE in PMP-01 Over Time \(Downgradient of Source Area\)](#), and [Concentrations of PCE and TCE in PMP-02 Over Time \(Downgradient of Source Area\)](#).



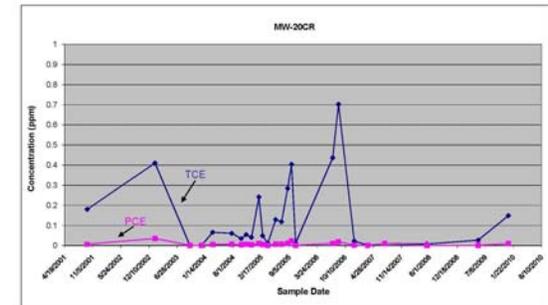
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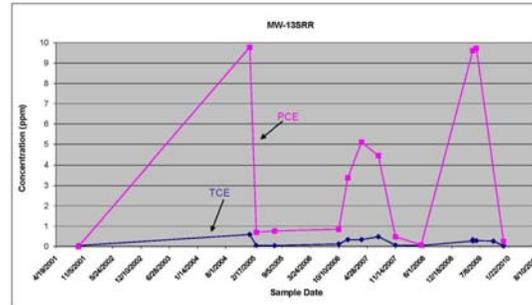
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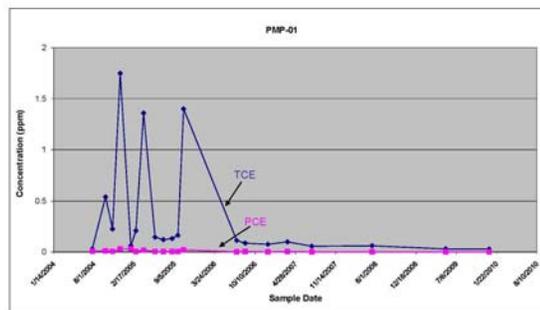
Concentrations of PCE and TCE in MW-20B Over Time
 (Downgradient of Source Area)
 (North End Groundwater)



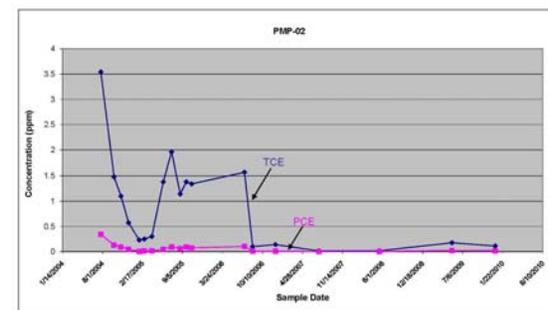
Concentrations of PCE and TCE in MW-20CR Over Time
 (Downgradient of Source Area)
 (North End Groundwater)



Concentrations of PCE and TCE in MW-13SRR Over Time
 (Downgradient of Source Area)
 (North End Groundwater)



Concentrations of PCE and TCE in PMP-01 Over Time
 (Downgradient of Source Area)
 (North End Groundwater)

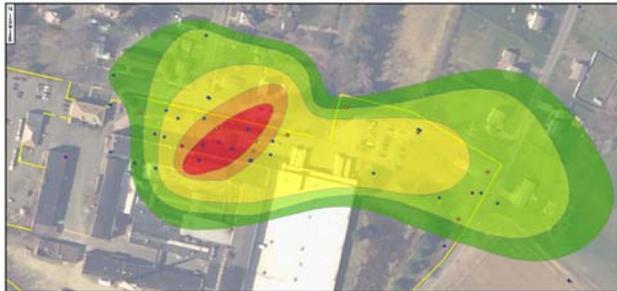


Concentrations of PCE and TCE in PMP-02 Over Time
 (Downgradient of Source Area)
 (North End Groundwater)

Support for Monitored Natural Attenuation (MNA) of Groundwater

Stability of the Plume

Since operation of the groundwater migration control system in March 2003 and the completion of the groundwater ICMs, the extent of the chlorinated VOCs in the North End Groundwater has been steadily shrinking. The spatial extent of total VOCs following each ICM is shown on the following figures: [Distribution of VOCs in North End Groundwater Before Migration Control System Operation](#), [Distribution of VOCs in North End Groundwater \(2004\) After Migration Control System Operation](#), [Distribution of VOCs in North End Groundwater After In situ Ozone Sparging](#), and [Distribution of VOCs in North End Groundwater After In situ Sodium Persulfate](#). The TCE and PCE concentrations reported in the recovery wells along the property line have declined to concentrations below the calculated MPS for the North End Groundwater. The decline in PCE and TCE concentrations in the recovery wells is shown on [Concentrations of TCE in Recovery Wells Over Time](#) and [Concentrations of PCE in Recovery Wells Over Time](#). The extent of *cis*-1,2-DCE and vinyl chloride in the North End Groundwater has either declined or remained consistent since the operation of the groundwater migration control system and completion of the ICMs. The consistent presence of these two constituents (breakdown products of the TCE) also indicates that natural attenuation is taking place.



Distribution of VOCs in North End Groundwater (2000)
 Before Migration Control System Operation



Distribution of VOCs in North End Groundwater (2004)
 After Migration Control System Operation



Distribution of VOCs in North End Groundwater (2006)
 After *In situ* Ozone Sparging



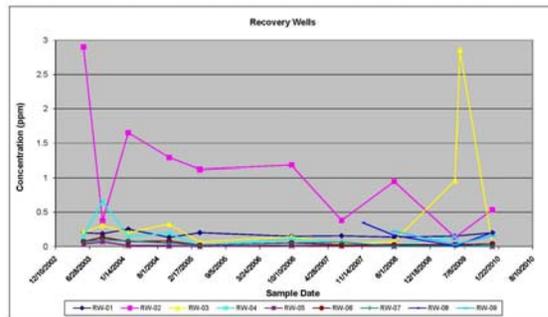
Distribution of VOCs in North End Groundwater (2007)
 After *In situ* Sodium Persulfate



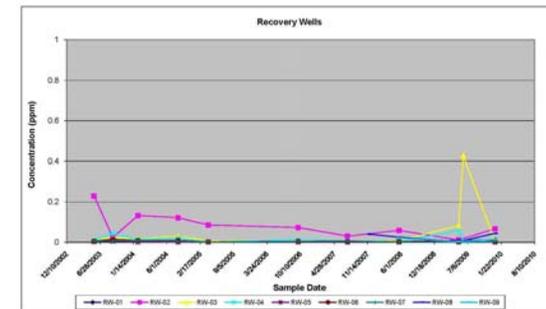
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Concentrations of TCE in Recovery Wells Over Time



Concentrations of PCE in Recovery Wells Over Time

As a part of the final corrective measure for North End Groundwater, the recovery system will remain in operation for the short-term. The groundwater recovery wells will be monitored as a part of the compliance and perimeter monitoring program and the recovery system will continue operating until the groundwater at the recovery wells falls below the MPS for the primary COCs of the North End Groundwater. When the MPS are achieved and the recovery system is discontinued, MNA will be relied upon to complete the groundwater restoration process.

MNA Parameters

During the May 2009 sampling event, groundwater samples were collected for analysis of a few specific MNA parameters. These MNA parameters included dissolved oxygen (DO), oxidation reduction potential (ORP), pH, specific conductivity, dissolved organic carbon, ethane, ethane, nitrate, sulfate, alkalinity, and total and dissolved manganese and iron. The MNA parameters recommended for North End Groundwater monitoring are summarized on [Table 1 \(Summary of May 2009 Groundwater Monitoring Results Indicator and MNA Parameters – North End\)](#). [Laboratory data sheets for May 2009, June 2009, and December 2009](#) are provided for information.

Several lines of evidence are supportive of MNA as the final corrective measure for the North End Groundwater:

- PCE and TCE concentrations have declined over time and *cis*,1-2, DCE and vinyl chloride (degradation products of the PCE and TCE) are present.
- DO was measured at concentrations below 1 mg/L in the area of the North End Groundwater where concentrations of TCE and PCE are the highest: MW-13SR, MW-20B, MW-24S, and PMP-02. Reductive dechlorination is suppressed in oxygen-rich environments, thus reduction is more likely to occur with lower DO concentrations. Concentrations of DO increase in the more dilute portions of the plume and are generally greater than 6.5 mg/L in the off-site wells where no constituents of concern are detected.
- Low ORP was also measured in the area of the North End Groundwater where concentrations of PCE and TCE are the highest. Reductive dechlorination is more likely to take place where the ORP is low (*i.e.*, in a reducing environment).
- The presence of nitrate potentially suppresses reductive dechlorination. Nitrate was not detected in the area of the North End Groundwater where concentrations of TCE and PCE are the highest (MW-13SR, MW-20B, MW-24S, PMP-03, and PMP-02).



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- Dissolved iron was detected in several wells in the North End Groundwater. The presence of dissolved iron indicates reducing conditions are likely present.

The MNA parameters measured and detected in the wells in the North End Groundwater support a conclusion that MNA is an appropriate and reasonable option as the final corrective measure.

South End Groundwater

MNA is also an appropriate and reasonable final corrective measure for the South End Groundwater because sources of the COCs (site-specific metals (cadmium, chromium, copper, nickel, and zinc) and chlorinated VOCs (PCE, TCE, and daughter products)) have been remediated, the area of groundwater affected by site-specific metals is stable or contracting, the area of groundwater affected by TCE and daughter products is stable, and daughter products (*e.g.*, vinyl chloride, *cis*-1,2-DCE, low dissolved iron) are present in the groundwater.

The details of these conclusions are provided in the discussion below.

Source Control

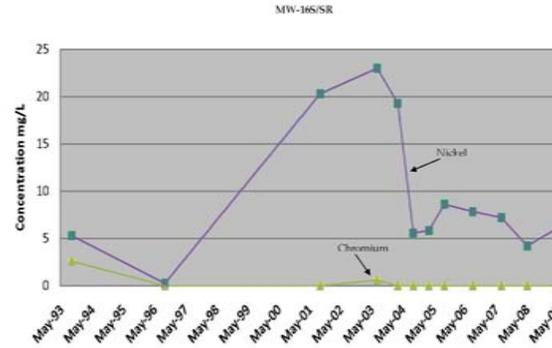
Historically, the primary constituents of concern in the South End Groundwater have been site-specific metals (cadmium chromium, copper, nickel, and zinc), chlorinated VOCs (PCE, TCE, and related degradation products), and TPH.

Site-specific Metals

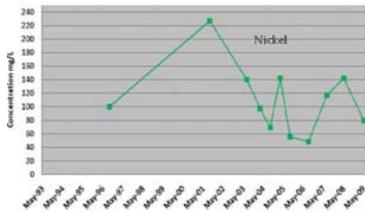
The source of the site-specific metals, primarily nickel and chromium, to the South End Groundwater was a release from the former chromium and zinc plating operations. The source of these metals was removed during soil ICMs conducted during December 2001. In March 2009, additional metals-affected soil was stabilized/solidified around the footers of the former plating building, as it was torn down during demolition activities. A summary of the completed soil ICMs is provided in the [Soil Site Restoration Activities \(ICMs and Current Conditions\)](#). The ICM activities completed in this area of the site were successful in removing the source materials that were adversely impacting the groundwater. The success of these source removal activities is supported by the decline in the site-specific metals concentrations detected in the monitoring well located downgradient (MW-27S) and the well within the immediate vicinity of the former chromium and zinc plating operations, MW-16SR. Nickel concentrations detected in the groundwater at MW-16SR have declined from 23 mg/L in 2003 (the year following excavation activities) to 5 mg/L (one year later). An order of magnitude decline in the nickel concentration was also observed in the groundwater quality of downgradient well MW-27S. Concentrations of chromium, copper, and zinc have also declined following the ICM conducted in the former chromium and zinc plating area. Declines of these metal constituents are shown on [Concentrations of Nickel and Chromium MW-16SR \(Source Area Well\)](#), [Concentrations of Site Metals MW-27S \(Downgradient of Source Area\)](#), and [Concentrations of Site Metals MW-52S \(Downgradient of Source Area\)](#). Though an increase in the metals concentrations was observed during the *in situ* oxidation ICM conducted in the South End Groundwater, concentrations have declined since completion of the oxidation activities and now continue to naturally attenuate over time.



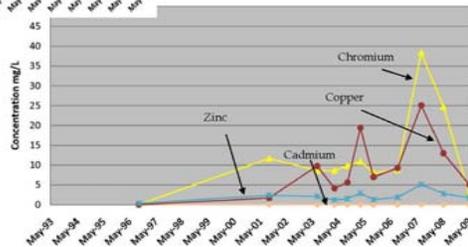
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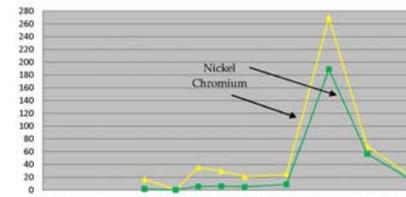
Concentrations of Nickel and Chromium MW-16SR
(Source Area Well)
(South End Groundwater)



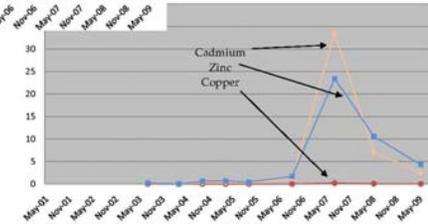
MW-27S
Site Metals



Concentrations of Site Metals MW-27S
(Downgradient of Source Area)
(South End Groundwater)



MW-52S
Site Metals



Concentrations of Site Metals MW-52S
(Downgradient of Source Area)
(South End Groundwater)



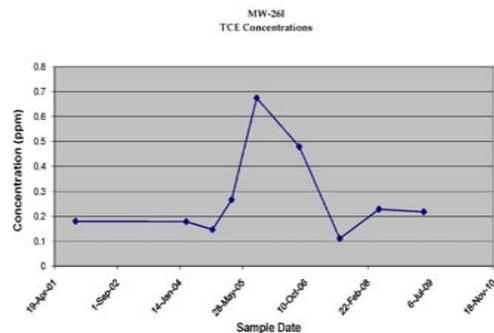
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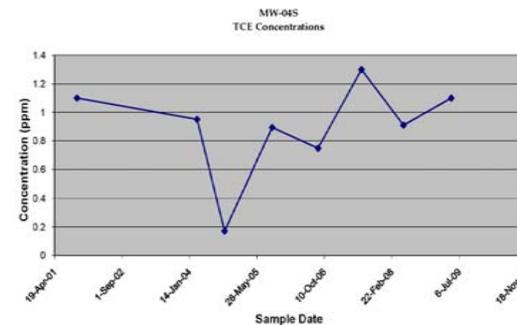
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Chlorinated VOCs

There are three known sources of chlorinated VOCs, primarily TCE, to the South End Groundwater: the former lagoons, reflecting pond, and wastewater treatment. The impacted soil of the former lagoons and reflecting pond were effectively removed during the ICM completed in April and June 2000. Groundwater monitoring wells in these areas show stable concentrations of TCE that demonstrate the effectiveness of the ICMs. Monitoring well MW-04S is located in the immediate vicinity of the former lagoons and monitoring well MW-26I is located immediately downgradient of the former reflecting pond. The concentration of TCE in these wells over time is shown on [Concentration of TCE MW-04S \(Downgradient of Former Lagoons\)](#) and [Concentration of TCE MW-26I \(Downgradient of Former Reflecting Pond\)](#).



**Concentrations of TCE MW-26I
(Downgradient of Former Reflecting Pond)**



**Concentration of TCE MW-04S
(Downgradient of Former Lagoons)**

Because the South End PCE source area is located beneath one of the few remaining buildings on the site where active manufacturing operations are still conducted and in an area of the site where concerns over the structural stability of the building itself makes aggressive treatment of the shallow soils impracticable, treatment in the South End PCE source area was limited solely to groundwater. This area of the site has been the focus of numerous investigations and subsequent ICMs. These ICMs have resulted in successfully reducing the size and concentration of the PCE plume by at least 50 percent. Additional sources of PCE have not been identified in this area of the site. PCE in this area of the site will be evaluated by monitoring groundwater concentration trends. Stable and declining trends support the conclusion that there is no continuing source of PCE to groundwater

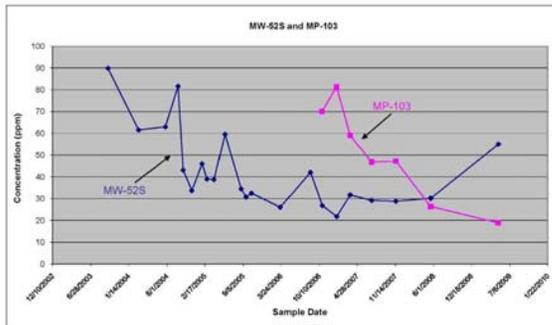


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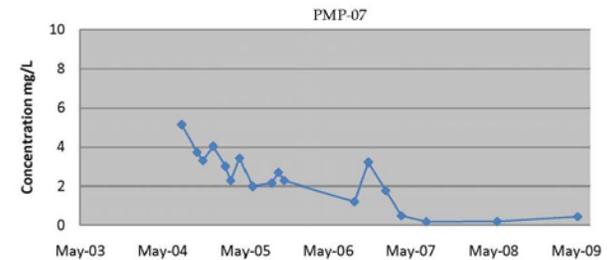
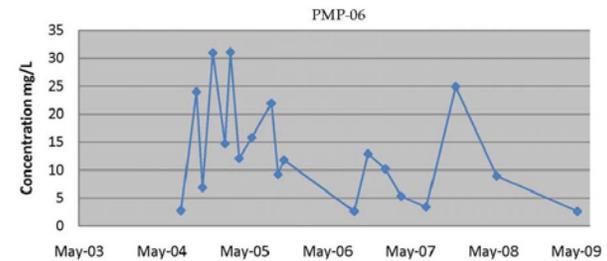


Support for Monitored Natural Attenuation (MNA) of Groundwater

While concentrations of PCE have fluctuated in well MW-52S since the completion of the *in situ* chemical oxidation (ISCO) groundwater ICM completed in this area of the site, concentrations show an overall decline since initiation of the ICM (89.9 mg/L detected in September 2003 to 55 mg/L detected in May 2009). Concentrations of PCE further downgradient of this source area well (MP-103) have also shown an overall decline from 70.1 mg/L in October 2006 to 18.9 mg/L in May 2009. PCE concentrations in the groundwater collected from well PMP-06 have declined from over 12.0 mg/L to 2.6 mg/L reported during May 2009. Concentrations of PCE have also declined in the groundwater collected from wells MP-103, MW-27I, and PMP-07. The details of the concentrations of PCE over time in these wells are shown on [Concentrations of PCE Over Time MW-52S and MP-103 \(Source Area\)](#) and [Concentrations of PCE Over Time PMP-06 and PMP-07 \(Source Area\)](#).



Concentrations of PCE Over Time MW-52S and MP-103
(Source Area)
(South End Groundwater)



Concentrations of PCE Over Time PMP-06 and PMP-07
(Source Area)
(South End Groundwater)



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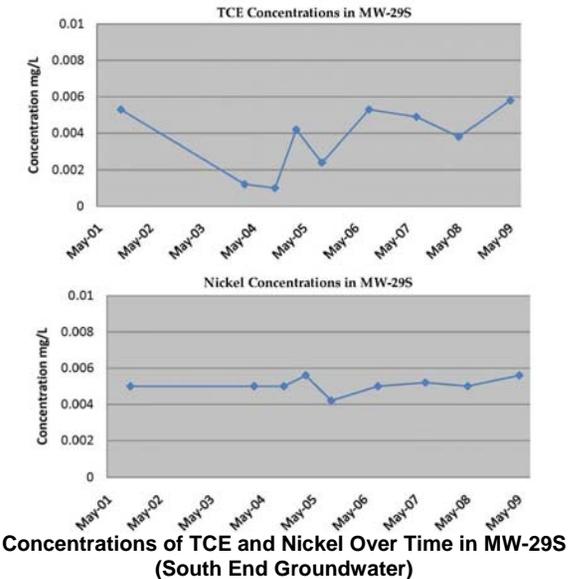


Stability of the Plume

Since the completion of the ICMs conducted for the South End Groundwater, the distributions of PCE, TCE, and site-specific metals in the groundwater have remained stable. Of the primary VOCs reported in the South End Groundwater, TCE is the constituent that is the most widely dispersed and the only site VOC that has migrated off the site. Of the site-specific metals, nickel is the constituent that is the most widely distributed and is the only site metal that has migrated off the site. Based on the direction of groundwater flow in the southern portion of the site, monitoring well MW-29S appears to be the leading downgradient edge of both the TCE and nickel plumes. Concentrations of TCE and nickel detected in this well over time have fluctuated but remained relatively stable. This is shown graphically on [Concentrations of TCE and Nickel Over Time in MW-29S](#).

MNA Parameters

In addition to groundwater samples for analysis of VOCs and TPH during the May 2009 sampling event, groundwater samples were collected for analysis of a few specific MNA parameters. These MNA parameters included DO, ORP, pH, specific conductivity, dissolved organic carbon, ethane, ethane, nitrate, sulfate, alkalinity, and total and dissolved manganese and iron. The MNA parameters for South End Groundwater are summarized on [Table 2 \(Summary of May 2009 Groundwater Sampling Results Indicator and MNA Parameters – South End\)](#). [Laboratory data sheets for May 2009](#) are provided for information.



Several lines of evidence support MNA as the final corrective measure for the South End Groundwater:

- PCE and TCE concentrations have declined over time and cis,1-2, DCE and vinyl chloride (degradation products of the PCE and TCE) are present.
- DO was measured at concentrations below 1 mg/L in the area of South End Groundwater where concentrations of TCE and PCE are the highest: MW-50I, MW-52S, and MW-27I. Reductive dechlorination is suppressed in oxygen-rich environments, thus reduction is more likely to occur with lower DO concentrations. Concentrations of DO increase in the more dilute portions of the plume and are generally greater than 6.5 mg/L in the off-site wells where no constituents of concern are detected.
- Low to negative ORP was also measured in the area of the South End Groundwater where concentrations of PCE and TCE are the highest. Reductive dechlorination is more likely to take place where the ORP is low.
- The presence of nitrate potentially suppresses reductive dechlorination. Nitrate was not detected in the area of the North End Groundwater where concentrations of TCE and PCE are the highest.
- Dissolved iron was detected in several wells in the South End Groundwater. The presence of dissolved iron indicates reducing conditions are likely present.

The MNA parameters measured and detected in the wells in the South End Groundwater support that MNA is an appropriate and viable option as the final corrective measure.