April 24, 2012

Mr. Larry Brill  
Branch Chief, OSRR Branch I 
United States Environmental Protection Agency – Region I  
5 Post Office Square - Suite 100  
Boston, MA 02109-3912

Subject: Monitored Natural Attenuation Assessment for PAC Source Area of the Peterson-Puritan Superfund Site  
Peterson/Puritan, Inc. Superfund Site, OU1  
Cumberland and Lincoln, Rhode Island

Dear Mr. Brill,

The United States Environmental Protection Agency (USEPA) has requested that Lonza update the evaluation submitted on March 29, 2011 concerning the Prediction of MNA Effectiveness at the PAC Source Area of the Peterson-Puritan Superfund Site to Support Potential Remedy of Monitored Natural Attenuation (MNA) to include the most recent sampling results from April 2011 and to address relevant elements from the 1999 and 2007 USEPA MNA Guidance.

The attached report responds to USEPA’s request. The body of the report considers the four tiers of evidence defined by USEPA’s 2007 MNA Guidance for inorganic compounds. Lonza’s 2011 data assessment is updated with the most recently available data to support Tier II of the guidance. The updated data analysis is provided as an appendix to the report and is generally consistent with Lonza’s findings in 2011.

The report concludes that implementation of MNA in the PAC Source Area is an appropriate remedy as it is consistent with the four-tiered framework defined in the 2007 MNA Guidance for inorganics (USEPA, 2007a; USEPA, 2007b) as follows:

- The PAC Source Area has been characterized and it has been demonstrated that arsenic concentrations are generally stable or decreasing (Tier I);
- The apparent rate and mechanism of attenuation have been demonstrated (Tier II);
- The capacity of the aquifer to continue and sustain attenuation has been shown (Tier III); and
- A monitoring plan, along with triggers for reevaluation, has been developed (Tier IV).
We look forward to discussing this assessment and working with USEPA to implement an MNA remedy for the PAC Source Area. Please call us if you have any questions or comments on the attached document.

Yours sincerely,

Mark Gerath  
Technical Director

Carolyn K. Scott  
Senior Project Manager

cc: Mike Jasinski, USEPA  
David Newton, USEPA  
Ruthann Sherman, USEPA  
John Hultgren, USEPA  
David Freeman, Paul Hastings LLP  
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Project File
Monitored Natural Attenuation Assessment for PAC Source Area of the Peterson-Puritan Superfund Site

Summary

This assessment updates the March 27, 2011 Assessment of Arsenic and Total Organic Carbon (TOC) "Decay" in the PAC Source Area at the Peterson/Puritan Superfund Site in Cumberland, RI (AECOM, 2011c). For the 2011 assessment, temporal trends in organic carbon and arsenic were evaluated in data collected over 15 years in several monitoring wells to evaluate the potential for natural processes to affect Monitored Natural Attenuation (MNA) of arsenic concentrations elevated above the Maximum Contaminant Level (MCL) in groundwater in the PAC Source Area. This update includes the most recent sampling results from April 2011 (Joint Groundwater Monitoring Program [JGWMP] Round 22). This report also evaluates the available site-related data and information in the context of the relevant elements of the 1999 and 2007 United Stated Environmental Protection Agency (USEPA) guidance to demonstrate consistency of the MNA remedy for the PAC Source Area at the Peterson/Puritan Superfund Site with that guidance (USEPA, 1999; USEPA, 2007a; USEPA, 2007b).

The 1999 USEPA guidance states that MNA may, under certain conditions, effectively reduce dissolved concentrations in groundwater.

"Natural attenuation processes are typically occurring at all sites, but to varying degrees of effectiveness depending on the types and concentrations of contaminants present and the physical, chemical, and biological characteristics of the soil and groundwater. Natural attenuation processes may reduce the potential risk posed by site contaminants in three ways:

1. Transformation of contaminant(s) to a less toxic form through destructive processes such as biodegradation or abiotic transformations;
2. Reduction of contaminant concentrations whereby potential exposure levels may be reduced; and
3. Reduction of contaminant mobility and bioavailability through sorption onto the soil or rock matrix.

Where conditions are favorable, natural attenuation processes may reduce contaminant mass or concentration at sufficiently rapid rates to be integrated into a site's soil or groundwater remedy" (USEPA, 1999).

As shown below under the criteria set out in the USEPA MNA guidance for inorganics (USEPA, 2007a), MNA is occurring at the PAC Source Area. The geochemical processes occurring in the PAC Source Area are reducing arsenic concentrations in the groundwater through mechanisms that are well understood and within reasonable timeframes, indicating the appropriateness of an MNA remedy for the PAC Source Area.

Background

On September 30, 1993, USEPA documented the arsenic cleanup remedy in a Record of Decision (ROD) (USEPA, 1993). The remedial actions selected for the PAC Source Area were excavation and removal of contaminated soils from leachfields in the PAC Source Area (ENSR, 1997); in-situ oxidation treatment in the form of an Oxidant Delivery System (ODS) to reduce the mobility of the arsenic in groundwater migrating from the leachfields in the PAC Source Area; institutional controls; and environmental monitoring. These remedies have been implemented, with the environmental monitoring ongoing. Based on data collected in the PAC Source Area, it has been determined that: (a) the operation of the ODS had only a localized and transient effect on arsenic levels in the aquifer; (b) biodegradation of organic carbon is occurring irrespective of ODS operation; (c) natural attenuation is occurring in the absence of ODS operation; (d) arsenic concentrations in the groundwater at the PAC Source Area did not and do not currently pose a threat to human health or the environment and are not likely to pose such a threat in the future; and (e) operation of the ODS was not a cost-effective method for arsenic remediation at the PAC Source Area (AECOM, 2011b).
As documented in the first Five-Year Review, "Further understanding of aquifer geochemistry, upgradient water quality, and residual carbon at the PAC Source Area has changed significantly since remedy selection and design" (USEPA, 2002). These changes have affected the expected efficacy of the remediation and remediation time estimates for arsenic in the PAC Source Area. The ROD states that groundwater arsenic contamination stems from discharge of arsenic-contaminated wastewater and dissolution of native aquifer minerals. Information collected since the ROD was issued indicates that arsenic groundwater contamination is solely attributable to dissolution of aquifer minerals, and the detection of arsenic in wastewater was an artifact of an inferior analytical method that yielded unreliable data and false positive analytical results (ENSR, 2001).

In addition, "Since preparation of the ROD in 1993, considerable knowledge has been gained on the occurrence and transport of arsenic in groundwater. For example, the book “Arsenic in Ground Water” (Welch and Stollenwerk 2003) provides useful information that was not available in 1993. Information in this book and related studies in New England (Stollenwerk and Colman 2004) indicate that arsenic can be widely distributed in groundwater systems and tends to persist for a very long time after it dissolves in groundwater” (USEPA, 2007c).

The geochemistry describing mobilization of arsenic from aquifer sediments is better understood than at the time of remedy selection. Biodegradation of organic carbon leads to consumption of oxygen, as well as other terminal electron acceptors, and reduced aquifer conditions. Dissolution of iron hydroxides in reduced aquifers liberates arsenic, which is naturally associated with iron hydroxide minerals. Furthermore, sources of organic carbon, which create reducing conditions in the aquifer, are now known (or suspected) to exist in numerous locations (e.g., release of hydrocarbons at the LukOil site to the east of the PAC Source Area [AECOM, 2011a; AECOM, 2011b]).

Based upon discussions with USEPA, including a technical call with USEPA's expert in arsenic dynamics, Dr. Robert Ford, on October 8, 2010 and calls between USEPA and Settling Defendants' attorneys on February 23, 2011 and March 3, 2011, the site conditions appear to support an application for MNA as the remedy for arsenic.

**Implementation of MNA**

USEPA guidance (USEPA, 2007a; USEPA, 2007b) provides a four-tiered framework by which to evaluate site data in a step-wise process to show that MNA is a viable remedy for the site. The four tiers include the following objectives:

- Demonstration, through site characterization, that the plume is static or shrinking (Tier I);
- Determination of the apparent rate and mechanism of attenuation (Tier II);
- Determination of the system capacity and stability of attenuation (Tier III); and
- Establishment of a monitoring plan (Tier IV).

Support for implementation of MNA in the PAC Source Area is presented below within the four-tiered framework. The re-assessed rates of arsenic attenuation (i.e., the update to AECOM, 2011c) are provided as part of the Tier II assessment.

**Tier I**

Under this tier of data assessment, USEPA (2007a) asks that the site characterization data be used to evaluate whether the plume is static or shrinking. The objective under Tier I is "to eliminate sites where site characterization indicates that the groundwater plume is continuing to expand in aerial or vertical extent" and "demonstrate active contaminant removal from ground water" (USEPA, 2007a).

Site characterization data for the PAC Source Area has been collected since the early 1990s. Numerous soil and groundwater samples have been analyzed as part of the Remedial Investigation, excavation of the PAC Source Area leachfields, 22 rounds of JGWMP groundwater monitoring, and groundwater
monitoring associated with the three years of ODS operation. Data from these investigations and monitoring are provided in a variety of reports, including the Remedial Investigation Report (ABB-ES, 1993), Remedial Action Report (ENSR, 1998a), MNA Report (ENSR, 2000a), JGWMP Report (ENSR, 2000c) and annual JGWMP submittals, and are summarized in the Settling Defendants’ Five Year Review Reports (ENSR, 2001; ENSR, 2007; AECOM, 2011b). The extensive and lengthy data record indicates that the arsenic plume is not expanding, that arsenic concentrations at most wells have declined, and that the concentrations in some wells have declined to below the MCL.

Groundwater flow as measured during the JGWMP shows consistent results between rounds and has been modeled by USEPA’s contractor. The general direction of groundwater flow is southwest across the PAC Source Area towards the Blackstone River followed by a more southerly trend in the PAC Downgradient Area. Figures depicting groundwater flow at the site may be found in the JGWMP reports described above.

Demonstration of stable or declining arsenic concentrations is provided through the data collected as part of the JGWMP, established in 1995 to meet the requirement for environmental monitoring specified in the ROD. To date, 22 rounds of groundwater sampling (between October 1995 and April 2011) have been conducted for the PAC Source Area for constituents as specified in the ROD and Remedial Design/Remedial Action Statement of Work. This ongoing effort has included parameters appropriate for evaluating the presence and fate of arsenic in groundwater. Initially, isopropyl alcohol and acetone, potential sources of organic carbon, were included as analytes in the JGWMP; however, these constituents are not currently monitored as they have not been detected in groundwater for many years.

Current JGWMP groundwater monitoring parameters will serve to assess arsenic attenuation patterns in the future. The annual groundwater monitoring parameters (as described under the Tier IV discussion, below) include TOC, arsenic, iron (Fe) (II), dissolved oxygen, pH, and oxygen reduction potential (ORP). Analytes for the five-year sampling round include the annual parameters plus methane, sulfate, nitrate, manganese, and carbon dioxide, which provide additional information on the redox state in the monitoring wells.

Data for the JGWMP wells, as provided in the reports mentioned above, show that arsenic concentrations in groundwater for most of the wells have either a declining or stable trend. (See Appendix 1 for a complete set of graphs showing arsenic concentrations in PAC Source Area-related wells as measured during the JGWMP.) As a demonstration that the plume is not expanding, the arsenic concentration in the well at the downgradient edge of the PAC Source Area (see Figure 1), shows a generally declining trend in arsenic concentrations over time.
For several of the JGWMP wells shown in Appendix 1, there is no clear trend or a slightly increasing trend in arsenic concentrations; in each of these wells, methanogenic conditions exist (methane levels over 1,000 ug/l), including the fact that iron hydroxides that control arsenic solubility have yet to re-form (as discussed under Tier II). Such behavior is consistent with the conceptual model of arsenic behavior at the site: the arsenic concentration is expected to be relatively stable until the aquifer becomes more oxidized (and the mass of reduced materials are exhausted) and the iron and manganese hydroxides reform, co-precipitating arsenic. Thus, the concentration of arsenic is expected to behave in a “binary” fashion: it will persist until the controlling solids reform, and then it should decline rapidly.

As discussed below, such behavior has been observed at the site, and the lower concentration of arsenic has been maintained (see the discussion of the Tier III line of evidence). This anticipated behavior is consistent with the literature and with USEPA’s review of arsenic at the PAC Source Area. As stated in USEPA Second Five Year Review (USEPA, 2007c) with regard to PAC Source Area arsenic concentrations:

“The apparent stable concentration of arsenic...is consistent with results from column studies on arsenic transport reported (Stollenwerk and Colman 2004), where numerous pore volume flushes with oxygenated water were required to reduce arsenic concentrations to 10 µg/L. Furthermore, a nearly stable plume configuration is predictable on the basis of transport models for phosphorous, which has similar transport properties to arsenic (Colman, 2004; John Colman, U.S. Geological Survey, verbal communication, July 2007).”

In summary, the stable or decreasing trends in arsenic concentrations and groundwater flow data support a static to shrinking area affected by arsenic, satisfying the requirements of Tier I. Based on the results of the site characterization data demonstrating that the arsenic concentrations are generally stable to declining (contaminant removal from groundwater), the PAC Source Area is appropriate for evaluation under Tier II for arsenic attenuation.

**Tier II**

Under Tier II of the MNA Guidance for inorganics, the mechanism(s) and apparent rate of attenuation should be determined (USEPA, 2007a). The objective under Tier II is “to eliminate sites where further analysis shows that attenuation rates are insufficient for attaining cleanup objectives estimated for the site within a timeframe that is reasonable compared to other remedial alternatives” (USEPA, 2007a).
In the following discussion, the geochemical mechanism of arsenic liberation and MNA is defined based on the literature. Site-specific characterization of the redox status of each monitoring well is then considered as it relates to the potential mobility of arsenic in the context of the geochemical mechanisms. This data evaluation provides evidence that the mechanisms are understood and provides a basis for estimating the overall rate of MNA for arsenic across the PAC Source Area. This section also provides a summary of the estimated rate of MNA for arsenic including estimation of "half-lives" for arsenic concentration. The rates presented here were originally presented in the March 27, 2011 Assessment of Arsenic and Total Organic Carbon (TOC) "Decay" in the PAC Source Area at the Peterson/Puritan Superfund Site in Cumberland, RI (AECOM, 2011) and have been updated with the 2011 data.

The mechanism for attenuation is based on the conceptual site model developed for the site. As presented in the Second USEPA Five-Year Review (USEPA, 2007c),

"The conceptual model that has been presented for arsenic in groundwater involves local geochemical processes that cause reducing conditions. The reducing conditions, in turn, dissolve arsenic that is present naturally in the rock and sediments. Although analyses for arsenic in overburden soils have not been performed recently at the PAC Source Area, analytical results for soils and bedrock at the LukOil gas station indicate that arsenic is present in both media. Elevated arsenic concentrations in water from wells near operable unit 2 (J.M. Mills landfill) (ARCADIS, 2007) further supports the concept of a natural source for arsenic in valley-fill sediments. Other Site features that could cause the mobilization of arsenic might include release of BTEX chemicals and alteration of ground-water recharge patterns such as by construction of impermeable surfaces."

This process of reductive dissolution of arsenic is described in the MNA guidance for arsenic (USEPA, 2007b), where "Houndslow (1980) and Kinniburge (2002) provide an assessment of geochemical triggers that may lead to arsenic mobilization in subsurface systems." These include the trigger occurring in the PAC Source Area: "desorption/dissolution due to a change to a reducing chemical environment" (USEPA, 2007b).

As discussed in the ODS Report (ENSR, 2000b), the addition of biodegradable carbon to the aquifer starts the process leading to the release of arsenic through reductive dissolution. The activity of microorganisms in aquifers is usually limited by a lack of carbon. Addition of biodegradable carbon stimulates microbial growth and utilization of oxygen. When oxygen is depleted, microorganisms utilize alternative electron acceptors such as iron and manganese in order to continue degrading available carbon (Table 1). As iron oxides dissolve upon reduction, adsorbed and co-precipitated arsenate is released into solution (Smith, 1998; Massacheley, 1991). In addition, the arsenic itself is reduced from arsenic (As)(V) to As(III), which has a lower tendency to bind with mineral surfaces than does As(V).
**MICROBIAL ELECTRON ACCEPTORS**

<table>
<thead>
<tr>
<th>Electron Acceptor</th>
<th>Oxidized Species (oxidation state)</th>
<th>Reduced Species (oxidation state)</th>
<th>Water Quality Indicator</th>
</tr>
</thead>
<tbody>
<tr>
<td>oxygen</td>
<td>$O_2$ (0)</td>
<td>$H_2O$ (-2)</td>
<td>Dissolved oxygen (DO) present</td>
</tr>
<tr>
<td>nitrogen</td>
<td>$NO_3^-$ (+5)</td>
<td>$NO_2^-$ (+3)</td>
<td>low nitrate $^a$</td>
</tr>
<tr>
<td>manganese</td>
<td>$Mn^{4+}$ (+4)</td>
<td>$Mn^{2+}$ (+2)</td>
<td>high soluble manganese (Mn)</td>
</tr>
<tr>
<td>iron</td>
<td>$Fe^{3+}$ (+3)</td>
<td>$Fe^{2+}$ (+2)</td>
<td>high soluble Fe</td>
</tr>
<tr>
<td>sulfur</td>
<td>$SO_4^{2-}$ (+6)</td>
<td>$H_2S$ (-2)</td>
<td>low sulfate, high sulfide$^b$</td>
</tr>
<tr>
<td>carbon</td>
<td>$CO_2$ (+4)</td>
<td>$CH_4$ (-4)</td>
<td>high methane</td>
</tr>
</tbody>
</table>

(a) Subsequent reactions may convert nitrite to nitrogen gas or other reduced nitrogen species.

(b) Sulfide may form insoluble precipitates with iron and arsenic lowering aqueous sulfide concentrations.

**Table 1: Indicators of Groundwater Redox Status (ENSR, 2000a)**

At the PAC Source Area, at least three septic systems, various sumps and dry wells, underground disposal of boiler blowdown discharge, and the accidental release of isopropanol to the subsurface all added biodegradable carbon to the aquifer; these releases initiated the series of bio-geochemical processes leading to arsenic concentrations in groundwater above the MCL (ENSR, 1995; ENSR, 1996; Bates, 1996, ENSR, 1998b). In addition, there is evidence of other releases of organic substances to the subsurface surrounding the PAC Property (ENSR, 2000a), including the LukOil gasoline spill east (upgradient) of the Peterson/Puritan site in the 1990s, effects of which were seen in PAC Source Area wells (peaks in benzene and arsenic concentrations in between 2001 and 2003) (ENSR, 2007; USEPA, 2007c).

These primary sources of reducing agents led to production of other reducing agents (e.g., reduced iron, sulfide) which must be oxidized before the iron and manganese hydroxides can re-form and reduce arsenic concentrations. As described above, under the conceptual site model of arsenic mobilization in the subsurface, organic carbon present in soils and groundwater results in the depletion of oxygen and the subsequent geochemical reduction of the aquifer. Under reducing conditions, iron and manganese oxides are reduced and dissolved to liberate co-precipitated arsenic. To reverse these conditions, organic carbon must be exhausted, followed by the reintroduction of oxygen, the reformation of iron and manganese hydroxides and the co-precipitation of arsenic.

The literature on similar settings (e.g., Delemos et al., 2006; Welch et al., 2000; Kelly et al., 2005; Smedley and Kinniburgh, 2002) and site-specific data are consistent in showing that arsenic is present at elevated concentrations in groundwater only when manganese and iron are reduced (i.e., iron and manganese hydroxides become unstable, leading to soluble manganese and iron in groundwater). This conceptual model has been used to construct a strategy for characterizing groundwater quality relative to its oxidation-reduction status as well as likely presence of arsenic at elevated concentrations (ENSR, 2000a). To determine the redox state of the aquifer at individual wells, the concentrations of relevant geochemical parameters were compared with their concentrations at wells which did not appear to be affected by groundwater contaminants; these wells are referred to as "unimpacted wells."

Table 2 provides a summary of the evaluation of groundwater quality used to define the redox status of each well and assess the potential for the elevation of arsenic concentration. Based on this evaluation, wells were categorized as shown in Table 3 for data collected up to 1999 (ENSR, 2000a). In some cases, the historical trends in a parameter's concentration is indicated by an arrow indicating an increasing or decreasing trend based on the Mann-Kendall test. The arsenic concentration observed in the various on-site wells correlated well with the presence of reducing conditions (i.e., 'manganese reducing or more reduced) and is shown in Figure 2.
### Table 1: MNA Rating Criteria

<table>
<thead>
<tr>
<th>Well Type - Estimated Redox State</th>
<th>MNA Rating Criteria</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>ORP depressed</td>
</tr>
<tr>
<td>aerobic</td>
<td>no (&gt;350)</td>
</tr>
<tr>
<td>aerobic, oxygen low compared to background</td>
<td>no (&gt;350)</td>
</tr>
<tr>
<td>nitrate-reducing</td>
<td>no (&gt;200)</td>
</tr>
<tr>
<td>Mn-reducing</td>
<td>yes (&lt;300)</td>
</tr>
<tr>
<td>iron-reducing</td>
<td>yes, &lt;300</td>
</tr>
<tr>
<td>iron or sulfate-reducing</td>
<td>no (320)</td>
</tr>
<tr>
<td>≥ Mn-reducing</td>
<td>no (290)</td>
</tr>
<tr>
<td>≤ sulfate-reducing</td>
<td>yes (&lt;300)</td>
</tr>
<tr>
<td>≤ iron-reducing</td>
<td>yes (180)</td>
</tr>
</tbody>
</table>

ns: parameter not measured or data rejected during validation

(a) Fraction of results less than 1 mg/L DO (meter).
(b) Redox state uncertain due to few results &/or because results unavailable for all geochemical parameters.
(c) Redox state uncertain because geochemical parameters are not consistent with a particular redox state. (In this example ORP is high for sulfate-reducing conditions and sulfate concentration is not as depressed as in other wells. Since arsenic is elevated and nitrate depressed, probably at least iron-reducing and may be sulfate-reducing. High ORP reading could be an error.)

### Table 2: Groundwater Quality Ranking Criteria (ENSR, 2000a)

<table>
<thead>
<tr>
<th>Well</th>
<th>ORP depressed</th>
<th>DO(meter) depressed (fraction &lt; 1 mg/L)</th>
<th>Nitrate depressed (magnitude of conc.)</th>
<th>Fe(II) elevated</th>
<th>Sulfate depressed (value)</th>
<th>Methane (conc. mg/L)</th>
<th>Arsenic elevated</th>
<th>Estimated Redox State</th>
</tr>
</thead>
<tbody>
<tr>
<td>AD-1</td>
<td>yes</td>
<td>yes, 14/15</td>
<td>yes</td>
<td>yes</td>
<td>20/23</td>
<td>no</td>
<td>ns</td>
<td>21/22</td>
</tr>
<tr>
<td>AD-2</td>
<td>yes</td>
<td>yes, 6/8</td>
<td>yes</td>
<td>yes, 5U</td>
<td>ns</td>
<td>ns</td>
<td>ns</td>
<td>2/8</td>
</tr>
<tr>
<td>AW-2</td>
<td>no</td>
<td>yes, 1/3</td>
<td>no</td>
<td>ns</td>
<td>ns</td>
<td>ns</td>
<td>ns</td>
<td>0/4</td>
</tr>
<tr>
<td>AW-3</td>
<td>yes</td>
<td>yes, 7/8</td>
<td>yes</td>
<td>yes, 5.7</td>
<td>ns</td>
<td>ns</td>
<td>ns</td>
<td>6/8</td>
</tr>
<tr>
<td>DW-1</td>
<td>yes</td>
<td>yes, 3/3</td>
<td>no</td>
<td>yes</td>
<td>ns</td>
<td>ns</td>
<td>ns</td>
<td>8/10</td>
</tr>
<tr>
<td>DW-2</td>
<td>yes</td>
<td>yes, 2/3</td>
<td>yes</td>
<td>yes</td>
<td>18.6</td>
<td>ns</td>
<td>ns</td>
<td>11/10</td>
</tr>
<tr>
<td>MW-101C</td>
<td>ns</td>
<td>ns</td>
<td>yes</td>
<td>yes</td>
<td>4/5</td>
<td>≤ Mn-reducing</td>
<td>no</td>
<td>ns</td>
</tr>
<tr>
<td>MW-302A</td>
<td>yes</td>
<td>yes, 6/7</td>
<td>yes</td>
<td>yes</td>
<td>5U</td>
<td>ns</td>
<td>ns</td>
<td>6/8</td>
</tr>
<tr>
<td>MW-302B</td>
<td>yes</td>
<td>yes, 7/7</td>
<td>yes</td>
<td>yes</td>
<td>5U</td>
<td>ns</td>
<td>ns</td>
<td>6/8</td>
</tr>
<tr>
<td>MW-303</td>
<td>yes</td>
<td>yes, 6/8</td>
<td>yes</td>
<td>yes</td>
<td>5U</td>
<td>ns</td>
<td>ns</td>
<td>6/8</td>
</tr>
<tr>
<td>MW-304</td>
<td>yes</td>
<td>yes, 6/8</td>
<td>no</td>
<td>yes</td>
<td>11/12</td>
<td>ns</td>
<td>ns</td>
<td>yes</td>
</tr>
<tr>
<td>MW-307</td>
<td>no</td>
<td>yes, 1/5</td>
<td>yes</td>
<td>ns</td>
<td>ns</td>
<td>no</td>
<td>ns</td>
<td>yes</td>
</tr>
<tr>
<td>MW-308</td>
<td>yes</td>
<td>yes, 8/9</td>
<td>yes</td>
<td>yes</td>
<td>10U</td>
<td>ns</td>
<td>ns</td>
<td>yes</td>
</tr>
<tr>
<td>MW-401</td>
<td>no</td>
<td>yes, 0/2</td>
<td>yes</td>
<td>ns</td>
<td>ns</td>
<td>ns</td>
<td>ns</td>
<td>1/4</td>
</tr>
</tbody>
</table>

ns: parameter not measured or data rejected during validation

(a) Fraction of results less than 1 mg/L DO (meter).
(b) Redox state uncertain due to few results &/or because results unavailable for all geochemical parameters.

### Table 3: Estimated Aquifer Redox State 1999 (ENSR, 2000a)
Figure 3 presents the geochemical and arsenic data (ENSR, 2000a) as a cross-section constructed near the lower edge of the PAC Source Area. In this figure, the groundwater redox state and arsenic...
concentration are both included as labels on the wells' screened intervals. Generally, elevated arsenic concentrations are associated with iron- and sulfate-reducing conditions.\(^1\)

Using the ENSR (2000a) assessment methods, wells were re-evaluated for their redox state based on data collected in 2008. See Table 4 and Figure 4.

<table>
<thead>
<tr>
<th>Well</th>
<th>ORP depressed (&lt;250)</th>
<th>DO(meter) depressed (&lt;6.2)</th>
<th>Nitrate depressed (&lt;6.2)</th>
<th>Mn elevated</th>
<th>Fe(II) elevated (&gt;2.5)</th>
<th>Sulfate depressed (&lt;27 &lt;11))</th>
<th>Methane (conc. ug/L)</th>
<th>Arsenic elevated (&gt;4)</th>
<th>2008 Estimated Redox State</th>
</tr>
</thead>
<tbody>
<tr>
<td>AD-1</td>
<td>80.4</td>
<td>1.32</td>
<td>2.2</td>
<td>NA</td>
<td>0</td>
<td>31</td>
<td>not analyzed</td>
<td>2.13</td>
<td>nitrate-reducing</td>
</tr>
<tr>
<td>AD-2</td>
<td>NA</td>
<td>NA</td>
<td>0.22 J</td>
<td>NA</td>
<td>5</td>
<td>5</td>
<td>5140</td>
<td>178</td>
<td>methanogenic</td>
</tr>
<tr>
<td>AW-1RR</td>
<td>-103.3</td>
<td>0.23</td>
<td>R</td>
<td>NA</td>
<td>15</td>
<td>22</td>
<td>Na</td>
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<td>iron-reducing</td>
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<td>DW-1</td>
<td>-38.1</td>
<td>1.18</td>
<td>0.97</td>
<td>NA</td>
<td>7.5</td>
<td>31</td>
<td>44.7</td>
<td>87.5</td>
<td>iron-reducing</td>
</tr>
<tr>
<td>DW-2</td>
<td>-74.4</td>
<td>-0.08</td>
<td>0.1 U</td>
<td>NA</td>
<td>20</td>
<td>26</td>
<td>183</td>
<td>201</td>
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</tr>
<tr>
<td>DW-3</td>
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<td>0.37</td>
<td>0.32</td>
<td>NA</td>
<td>1</td>
<td>27</td>
<td>10.4</td>
<td>1.67</td>
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</tr>
<tr>
<td>MP-2</td>
<td>-136.3</td>
<td>0.09</td>
<td>0.1 U</td>
<td>NA</td>
<td>45</td>
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<td>218</td>
<td>65.4</td>
<td>methanogenic</td>
</tr>
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<td>0.1 UJ</td>
<td>NA</td>
<td>NR</td>
<td>1 U</td>
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<td>MW-302B</td>
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<td>6.02</td>
<td>1.4</td>
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<td>NA</td>
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<td>1.2</td>
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<td>55.4</td>
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<tr>
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<td>0.1 U</td>
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<td>85.1</td>
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<td>5.65</td>
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<td>21</td>
<td>0.3 U</td>
<td>2.84</td>
<td>nitrate-reducing</td>
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</table>

Table 4: Estimated Aquifer Redox State 2008

Comparisons between 1999 (Figure 3) and 2008 (Figure 4) show that the redox state in several wells has become less reduced (e.g., AD-1, MW-304) and, as a result, arsenic concentrations have decreased.

\(^1\) Note that methane concentration data were not collected during this period. Several of the wells indicated as sulfate reducing in this assessment were subsequently found to exhibit methanogenic conditions.
Several wells also became more reduced (e.g., MW-302A, MW-302B, AD-2, and MP-2); however, this is attributed to the addition of organic carbon to the subsurface (LukOil gasoline spill upgradient of the site) impacting those wells (AECOM, 2011a).

Based on the conceptual site model, as we evaluate temporal trends in order to estimate a rate of attenuation of arsenic, we expect that declines in arsenic should lag the decline in TOC concentration and the change in aquifer redox status. Therefore, the concentration of arsenic may be relatively stable in concentration until the necessary geochemical changes have occurred. AECOM notes that this sequence of necessary conditions, as well as the spatial/temporal geochemical variability in the aquifer (i.e., both soil and groundwater) and the difficulty in predicting the rates of several critical processes (e.g., rate of oxygen recharge), make prediction of future trends in arsenic concentration uncertain (ENSR, 2000a; ENSR, 2000b).

The variations in arsenic and TOC are readily apparent in the data, and the uncertainty is manifested in the variability in the projected times to reach the MCL for arsenic. Having said that, the trend at most wells indicates a decline in the concentration of arsenic. This has been acknowledged by USEPA's expert in arsenic dynamics, Dr. Robert Ford, who suggested during a technical call on October 8, 2010 that using trend analysis such as the one described in this assessment may be helpful to support an application for MNA.

In order to evaluate temporal trends, the March 2011 assessment of arsenic and TOC "decay" was updated to include the April 2011 groundwater monitoring data. For the assessment, up to 22 separate results were evaluated at 15 groundwater monitoring wells. The updated assessment is provided in Appendix 2. For each well, the predicted year of decline below the MCL depends upon the rate constant itself (which is the same for all wells), the amount by which the concentration used as a starting point exceeds the MCL, and the year of the latest observation. As shown in Appendix 2, the predicted year of decline below the MCL varies from 2027 to 2041 (i.e., 15 to 29 years in the future) with an average of 2034 (i.e., 22 years in the future). These rates are slower (i.e., yield longer estimated times to cleanup) than those estimated in 2011 but are still consistent with an overall decline in arsenic concentration in the PAC Source Area.

As stipulated by USEPA Guidance (USEPA, 2007b), data collection and analysis performed for Tier II (as described above) indicate that "MNA processes are capable of achieving remediation objectives, based on current geochemical conditions at the site." These mechanisms are understood and are consistent with the literature as well as USEPA (2007b). The rates of change in groundwater quality have been estimated consistent with recommendations from USEPA staff and, while they are associated with some uncertainty, they indicate declining trends in concentration. Therefore, AECOM believes that Tier II of USEPA's 2007 MNA Guidance is satisfied.

Tier III

Under the MNA guidance (USEPA, 2007a), Tier III evaluates sites as to whether there is sufficient capacity in the aquifer to attenuate the arsenic in groundwater to meet the MCL, that the immobilization of arsenic is a stable condition, and that attenuation rates are sufficient for attaining cleanup objectives established for the site (the arsenic MCL) within a timeframe that is reasonable compared to other remedial alternatives.

The data collected in and around the PAC Source Area indicate that PAC Source Area conditions are consistent with meeting the Tier III criteria. The reducing conditions seen in parts of the PAC Source Area are primarily the result of anthropogenic carbon sources that changed the natural geochemistry of the groundwater and enabled the dissolution of the native arsenic. AECOM believes that the presence of arsenic-containing iron and manganese hydroxides in the subsurface prior to the release of anthropogenic carbon strongly suggests that such solids were present in a stable form under "natural" conditions. It is reasonable to infer that once the introduced organic compounds are exhausted and the aquifer redox status returns to oxidized, the arsenic-containing solids will be stable. This is illustrated in
upgradient wells (e.g., MW-301 and MW-401) which show oxidized conditions and low levels of arsenic. This effect was also seen at wells in the southwest corner of the PAC Source Area, where the influx of carbon from LukOil caused temporary increases in arsenic concentrations and then a subsequent decline.

The lowering of the arsenic levels in the groundwater in the PAC Source Area is occurring and will continue to occur as the process of reductive dissolution is reversed and the aquifer returns to its natural state where the arsenic will be resorbed by iron and manganese hydroxide minerals. As biodegradable carbon levels drop, microbial activity will decrease (the natural influx of oxygen from the atmosphere and from upgradient groundwater will be greater than the reduction of oxygen by biodegradation). As the aquifer’s redox state rises, iron and manganese oxidize and form solid hydroxides. Arsenic is expected to be scavenged from the groundwater through co-precipitation with and adsorption onto the newly formed iron and manganese minerals (Oscarson, 1980; Fuller, 1993). Soluble iron and manganese are present in the wells containing arsenic, suggesting that these elements will not be limiting to the formation of iron and manganese hydroxides. In the absence of a new source of reducing agents (e.g., another hydrocarbon release), the reformed iron and manganese hydroxides should be stable.

There are two examples of the stable reversal of redox conditions and decline in arsenic concentrations within and near the PAC Source Area. First, in three wells in the PAC Source Area located near a former leachfield, arsenic concentrations have decreased substantially since the removal of that leachfield and have maintained low to nondetect concentrations since the decrease. These reversals include changes in arsenic concentrations from 600 ug/L in 1987 to not detected beginning in 1996 (in AW-2) (Figure 5); from 550 ug/L in 1992 to below the MCL of 10 ug/L beginning in 2008 (in MW-304) (Figure 6), and from 35.1 ug/l in 2003 to below the MCL beginning in 2007 and not detected in 2011 (in AD-1) (Figure 7). These changes have been preceded by the expected changes in redox conditions and have been maintained in a stable fashion since they occurred. AECOM believes that these three wells represent a good, site-specific model for how future arsenic concentrations are likely to evolve under the MNA remedy.

Note that the behavior of the arsenic concentration prior to the decline associated with redox change is characteristic of that observed in wells exhibiting elevated arsenic and low redox: there is typically substantial variation in arsenic concentration with the mean concentration well above the MCL. As seen in the discussion of the Tier II criterion, this variation contributes to the uncertainty in estimating the time to clean up.

![AW-2 Arsenic Graph](image-url)
The second example of the decline in arsenic concentration occurs at the site of the LukOil gasoline spill, in wells upgradient of the Peterson/Puritan Site. In these wells, concentrations of arsenic in groundwater were as high as 850 ug/L in the 2003 timeframe. Elevated arsenic in groundwater was associated with elevated concentrations of gasoline-related hydrocarbons and methyl tertiary-butyl ether (MTBE) as well as dissolved oxygen concentrations that were consistently less than 1.0 mg/l. Both of these circumstances strongly suggest that the local aquifer was experiencing reduced redox conditions. In more recent data, the concentrations of gasoline-related compounds have declined by orders of magnitude, and the concentration of dissolved oxygen has generally rebounded to higher concentrations (as high as 8.84 mg/l). In the most recent report obtained (CEA, 2009), arsenic concentrations had been substantially reduced from their peak concentrations in the five wells sampled. In two wells located downgradient of the point of release, the concentration of arsenic has been below the detection limit for

Detection limits were either 5 ug/l or 10 ug/l.
eight of the last nine sampling rounds and five of the last seven sampling rounds, respectively. Again, the observed behavior at these wells suggests that declines in arsenic concentration, once they occur, will be stable.

Both of these examples show the capacity of the aquifer to attenuate the arsenic in groundwater to meet the MCL and, that once attenuated, the immobilization of arsenic generally appears to be a stable condition. This behavior is consistent with the site-specific conceptual site model as well as the literature on reductive dissolution as a source of arsenic in the subsurface (USEPA, 2007b).

As discussed in the evaluation of the Tier II criterion, the estimated attenuation rates for arsenic result in predicted times to meet the MCL that are reasonable and consistent based on previous estimates. The reasonableness of these timeframe is substantially bolstered by the finding that, with the institutional controls in place and groundwater not being a drinking water source, arsenic in groundwater does not currently pose a threat to human health or the environment and is not likely to pose such a threat in the future.

Based upon the PAC Source Area meeting the criteria in Tier III, development of a performance monitoring plan for the PAC Source Area under Tier IV is appropriate.

Tier IV

Tier IV requires the design of a performance monitoring plan. “The objective under Tier IV analysis to develop a monitoring program to assess long-term performance of the MNA remedy and identify alternative remedies that could be implemented for situations where changes in site conditions could lead to remedy failure” (USEPA, 2007a).

There is currently, and has been for 17 years, an ongoing monitoring program in place in the PAC Source Area, the JGWMP, which will serve as a performance monitoring program and which is expected to continue to support monitoring the effectiveness of the remedy. Consistent with USEPA guidance, this monitoring program contains locations that provide adequate aerial and vertical coverage to verify that arsenic concentrations in the PAC Source Area are stable or decreasing and provide the ability to monitor groundwater chemistry where the arsenic attenuation is occurring to show that MNA processes are continuing (USEPA, 2007b).

As part of this monitoring program, and as specified in the MNA guidance (USEPA, 2007a), a subset of wells that represent the site’s heterogeneity is selected for annual sampling and a more comprehensive set of wells is sampled every five years. Groundwater flow as measured during previous JGWMP rounds, and particle tracking examples using the 2008 USEPA groundwater flow model for the site, indicate that the existing sampling locations are appropriate for the monitoring of arsenic mobilized as a result of activities at the PAC Source Area (AECOM, 2009).

Monitoring parameters for the annual round include: TOC, arsenic, Fe(II), dissolved oxygen, pH, and ORP. Monitoring parameters for the five-year sampling round include the annual parameters plus methane, sulfate, nitrate, manganese, and carbon dioxide. These parameters serve to assess attenuation efficiency and the attenuation mechanism (USEPA, 2007a). As part of the monitoring, groundwater levels across the site are measured to demonstrate consistency in groundwater flow behavior (USEPA, 2007b).

According to USEPA guidance, the performance monitoring program must include conditions that might trigger a re-evaluation of the adequacy of the monitoring program (USEPA, 2007a). For the PAC Source Area, these conditions include sustained upward trends in arsenic and TOC concentrations in groundwater.
Conclusion

Implementation of MNA in the PAC Source Area is an appropriate remedy as demonstrated within the four-tiered framework (USEPA, 2007a and 2007b) as follows:

- The PAC Source Area has been fully characterized, and it has been demonstrated that arsenic concentrations are generally stable or decreasing (Tier I);
- The apparent rate and mechanism of attenuation has been demonstrated (Tier II);
- The capacity of aquifer to continue and sustain attention has been shown (Tier III); and
- A monitoring plan, along with triggers for reevaluation, has been developed (Tier IV).

References


AECOM, 2011b. Settling Defendants’ Five-Year Review Report, Peterson/Puritan Superfund Site, Operable Unit 1, Cumberland, Rhode Island. October.


Appendix 1 Arsenic Graphs
LEGEND

MONITORING WELL
GROUNDWATER ELEVATION CONTOUR (APRIL 18, 2011)
(DASHED WHERE INFERRED)

PETEISON/PURITAN SUPERFUND SITE
OPERABLE UNIT 1
CUMBERLAND, RHODE ISLAND
PAC SOURCE AREA - RELATED WELLS

DATE: 04/24/12  DRWN: J.E.B.

FIGURE 1
Appendix 1
PAC Source Area-Related Wells Arsenic Concentrations
Peterson/Puritan, Inc. Superfund Site
Operable Unit 1
Cumberland and Lincoln, Rhode Island

AD-1 ARSENIC (PAC Source Area)
- Observations
- Detected
- Action Level

AD-2 ARSENIC (PAC Source Area-southwest corner)
- Observations
- Detected
- Undetected
- Action Level

AW-1RR ARSENIC (PAC Source Area)
- Observations
- Detected
- Action Level
- Non Detected

AW-2 ARSENIC (PAC Source Area)
- Observations
- Detected
- Undetected
- Action Level

AW-3 ARSENIC (PAC Source Area)
- Observations
- Detected
- Action Level

DW-1 ARSENIC (Owens Corning Property)
- Observations
- Detected
- Action Level

Date
Concentration (ng/L)

Page 1 of 3
Appendix 1
PAC Source Area-Related Wells Arsenic Concentrations
Peterson/Puritan, Inc. Superfund Site
Operable Unit 1
Cumberland and Lincoln, Rhode Island

DW-2 ARSENIC ARSENIC (Owens Corning Property)
- Observations • Detected Action Level

MW-301 ARSENIC (PAC Source Area)
- Observations • Detected Action Level

Note: Peak in arsenic level coincident with peak in benzene levels PAC Source Area southwest corner wells (MP-2, MW-302A and MW-302B)

MW-302B ARSENIC (PAC Source Area-southwest corner)
- Observations • Detected Action Level

Note: Peak in arsenic level coincident with peak in benzene levels PAC Source Area southwest corner wells (MP-2, MW-302A and MW-302B)
Appendix 1
PAC Source Area-Related Wells Arsenic Concentrations
Peterson/Puritan, Inc. Superfund Site
Operable Unit 1
Cumberland and Lincoln, Rhode Island

MW-304 ARSENIC (PAC Source Area)
- Observations • Detected Action Level

MW-308 ARSENIC (PAC Source Area)
- Observations • Detected Action Level

MW-401 ARSENIC (Owens Corning Property)
- Observations • Detected Action Level

MW-408R ARSENIC (PAC Source Area)
- Observations • Detected Action Level

MP-2 ARSENIC (PAC Source Area-southwest corner)
- Observations • Detected Action Level
Appendix 2 – Revised March 2011 Assessment of Arsenic and TOC “Decay” in the PAC Source Area to include April 2011 Groundwater Monitoring Data
The following assessment updates the March 29, 2011 evaluation of arsenic and TOC "decay" in the PAC Source Area at the Peterson/Puritan Superfund Site in Cumberland, RI.

In order to evaluate temporal trends, up to 22 separate results were evaluated at each of 15 groundwater monitoring wells. Samples were collected as early as October 1995 and as late as April 2011. It is important to note that the frequency of data collection effort has not been uniform in time and that at some locations (e.g., MW-303) data were not collected during a period of ten years or more. The methods used to collect and analyze groundwater samples have been consistent for all of the data employed in this assessment. In addition, data pre-dating the Joint Ground Water Monitoring Program, when arsenic concentrations were significantly higher at many locations, were not used. At each location, time series (i.e., arsenic and TOC concentration vs. time) plots were created and the resulting data fit to a first order decay\(^3\) equation (i.e., \(C_t = C_0 e^{-kt}\)). For each location, the decay coefficient (\(k\) – units of yr\(^{-1}\)) and the correlation coefficient (\(r^2\)) were calculated. Generally, the entire data series was used in the analysis. However, where the impacts of other sources of TOC (e.g., LukOil) were apparent as later peaks in concentration (e.g., at MW-302A and MW-302B), the time series were truncated to start with the later peak and evaluate the trend after that peak.

A relatively favorable fit to the data for arsenic is presented as Figure 1. The results for all 15 wells are presented in Table 1.

![MW-308 Arsenic](image)

**Figure 1: Trends in Arsenic Concentration at MW-308.** Note that \(k\) is calculated by Excel on a daily basis on this figure but has been converted to an annual basis in Table 1.

\(^3\) Decay is used in a generic manner to capture declines in aqueous concentration. Declines in arsenic concentration in water are not due to destruction but are associated with sorption to solids and to groundwater transport.
<table>
<thead>
<tr>
<th>Well ID</th>
<th>Location</th>
<th>Times sampled (1995 to 2011)</th>
<th>Arsenic Decay Constant (per year)</th>
<th>Arsenic Half Life (years)</th>
<th>Arsenic $r^2$</th>
<th>Total Organic Carbon Decay Constant (per day)</th>
<th>Total Organic Carbon Half Life (years)</th>
<th>Total Organic Carbon $r^2$</th>
</tr>
</thead>
<tbody>
<tr>
<td>AD-2</td>
<td>PAC Source Area</td>
<td>19</td>
<td>0.1095</td>
<td>6.3301</td>
<td>0.2350</td>
<td>3.00E-04</td>
<td>6.3301</td>
<td>0.7138</td>
</tr>
<tr>
<td>MP-2</td>
<td>CCL Near Source Area</td>
<td>21</td>
<td>0.0292</td>
<td>23.7379</td>
<td>0.2827</td>
<td>-3.00E-04</td>
<td>-</td>
<td>0.4927</td>
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<td>MW-302A</td>
<td>PAC Source Area</td>
<td>22</td>
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<td>0.9102</td>
<td>-9.00E-05</td>
<td>-</td>
<td>0.7938</td>
</tr>
<tr>
<td>MW-302B</td>
<td>PAC Source Area</td>
<td>22</td>
<td>0.1460</td>
<td>4.7476</td>
<td>0.8330</td>
<td>-7.00E-05</td>
<td>-</td>
<td>0.0894</td>
</tr>
<tr>
<td>AD-1</td>
<td>PAC Source Area</td>
<td>17</td>
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<td>0.5997</td>
<td>2.00E-04</td>
<td>9.4952</td>
<td>0.5862</td>
</tr>
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<td>PAC Source Area</td>
<td>12</td>
<td>0.0365</td>
<td>18.9903</td>
<td>0.0120</td>
<td>6.00E-04</td>
<td>3.1651</td>
<td>0.8353</td>
</tr>
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<td>PAC Source Area</td>
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<tr>
<td>DW-1</td>
<td>Owens Corning Property</td>
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<td>6.3301</td>
<td>0.6370</td>
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<td>4.00E-04</td>
<td>4.7476</td>
<td>0.5134</td>
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<td>20</td>
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<td>-7.00E-05</td>
<td>-</td>
<td>0.1333</td>
</tr>
<tr>
<td>MW-308</td>
<td>PAC Downgradient Area</td>
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<td>0.0365</td>
<td>18.9903</td>
<td>0.7032</td>
<td>3.00E-04</td>
<td>6.3301</td>
<td>0.3608</td>
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<tr>
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<td></td>
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<td>12.8</td>
<td>3.76E-05</td>
<td>9.6</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Table 1: Summary of Estimated Trends in Arsenic and TOC

Inspection of Table 1 shows that the first-order decay fit shown in Figure 1 for MW-308 is stronger than those evident at most other wells. In fact, despite the general decline in arsenic concentration across the PAC Source Area, in some wells, the trend in arsenic concentration is weakly positive. This behavior is consistent with the conceptual site model (i.e., organic carbon decline precedes arsenic decline). An example that illustrates the site conceptual model is presented in Figure 4. In this figure, the earlier decline in TOC is demonstrated for MW-304 followed by a decline in arsenic that lags by three years or more.
While the temporal trends in arsenic concentration are relatively strong at some wells, the site conceptual model indicates that arsenic will remain elevated over the volume of the aquifer affected by elevated organic carbon until the oxidizing conditions are re-established. This suggests that the soundest approach to estimating a decay constant for the decline in arsenic concentration is to aggregate the data on arsenic trends with time across the relevant wells in order to estimate an aggregate rate constant. This approach accounts for the rates of decline of wells including those that are already below the MCL and those that have a slightly positive trend in arsenic concentration.
Development of an aggregated rate constant involved plotting the normalized concentration (i.e., the concentration in all samples divided by the initial (peak) concentration such that all data sets start at a value of 1.0) against the elapsed time so that all data, regardless of the concentration and specific time interval, could be used in the estimating of the rate constant (see Figure 3). While the fit to the data is weaker than at some monitoring wells, an overall trend is apparent and the decay coefficient yields an arsenic half-life of about 9.21 years. This is very similar to the average decay coefficient calculated from the trends in arsenic concentration at each of the individual wells presented in Table 1 (the curve labeled “Concentration Based on Average Decay Constant” presented in Figure 3).

![Figure 3: Trends in Arsenic Concentration for All Wells (k = 0.0752 yr⁻¹, t₁/₂ = 9.21 years)](image)

To project this trend into the future, the aggregate rate constant for arsenic concentration was then applied to the observed concentration of arsenic in monitoring wells located around the PAC Source Area. As shown in Table 2, for those monitoring wells in which arsenic has most recently been observed above the MCL, the latest observed concentration and the date of observation were used to estimate the year at which groundwater concentration would decline below the MCL.
<table>
<thead>
<tr>
<th>Well ID</th>
<th>Location</th>
<th>Value on Trend (date)</th>
<th>Value on Trend (concentration ug/L)</th>
<th>Estimated Year when Arsenic Concentration = 10 ug/L</th>
</tr>
</thead>
<tbody>
<tr>
<td>AD-2</td>
<td>PAC Source Area</td>
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<td>156.7</td>
<td>2038</td>
</tr>
<tr>
<td>MP-2</td>
<td>CCL Near Source Area</td>
<td>4/25/2011</td>
<td>63.4</td>
<td>2030</td>
</tr>
<tr>
<td>MW-302A</td>
<td>PAC Source Area</td>
<td>4/29/2011</td>
<td>47.2</td>
<td>2027</td>
</tr>
<tr>
<td>MW-302B</td>
<td>PAC Source Area</td>
<td>4/29/2011</td>
<td>53.65</td>
<td>2028</td>
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<tr>
<td>AD-1</td>
<td>PAC Source Area</td>
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<td>-</td>
<td>Already Below 10 ug/L</td>
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<td>AW-1RR</td>
<td>PAC Source Area</td>
<td>4/27/2011</td>
<td>134.05</td>
<td>2038</td>
</tr>
<tr>
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<td>PAC Source Area</td>
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<td>4/28/2011</td>
<td>68.8</td>
<td>2031</td>
</tr>
<tr>
<td>DW-2</td>
<td>Owens Corning Property</td>
<td>4/28/2011</td>
<td>179.8</td>
<td>2041</td>
</tr>
<tr>
<td>DW-3</td>
<td>Owens Corning Property</td>
<td>-</td>
<td>-</td>
<td>Already Below 10 ug/L</td>
</tr>
<tr>
<td>MW-101C</td>
<td>PAC Source Area</td>
<td>-</td>
<td>-</td>
<td>Already Below 10 ug/L</td>
</tr>
<tr>
<td>MW-303</td>
<td>PAC Source Area</td>
<td>4/28/2011</td>
<td>93.2</td>
<td>2034</td>
</tr>
<tr>
<td>MW-304</td>
<td>PAC Source Area</td>
<td>-</td>
<td>-</td>
<td>Already Below 10 ug/L</td>
</tr>
<tr>
<td>MW-307</td>
<td>PAC Downgradient Area</td>
<td>-</td>
<td>-</td>
<td>Already Below 10 ug/L</td>
</tr>
<tr>
<td>MW-308</td>
<td>PAC Downgradient Area</td>
<td>4/26/2011</td>
<td>120</td>
<td>2037</td>
</tr>
<tr>
<td>Mean</td>
<td></td>
<td></td>
<td>92.125</td>
<td>2034</td>
</tr>
</tbody>
</table>

**Table 2: Estimated MNA Timeframe Using Aggregate Arsenic Rate Constant (k = 0.0752 yr⁻¹, t₁/₂ = 9.21 years)**

For each well, the predicted year of decline below the MCL depends upon the rate constant itself (which is the same for all wells), the amount by which the concentration used as a starting point exceeds the MCL, and the year of the latest observation. As shown in Table 2, the predicted year of decline below the MCL varies from 2027 to 2041 (i.e., 15 to 29 years in the future) with an average of 2034 (i.e., 22 years in the future).

The general behavior of the TOC and arsenic data, including their variability, are consistent with the site conceptual model articulated for the site over the last nearly 20 years. As demonstrated previously, the concentrations of organic carbon and arsenic are generally declining within the PAC Source Area and in the downgradient monitoring wells. While the approach used to estimate the time frames is reasonable and their range is generally consistent with the estimate from 2001 (i.e.,
10 to 30 years), uncertainty remains. In particular, co-precipitation of arsenic from groundwater is a complex, multi-step process, the rate of which is difficult to predict and likely to vary in space.