Alaska Department of Environmental Conservation (DEC)

Contaminated Sites Program

River Terrace RV Park (RTRVP)

Third 5 Year Review of the Record of Decision

December 16, 2015

Executive Summary

The Alaska Department of Environmental Conservation (DEC) issued its Record of Decision (ROD) for the River Terrace RV Park (RTRVP) in August 2000 and in September 2000 entered a Consent Decree with the RTRVP property owners. Since September 2000, DEC has implemented the cleanup approach dictated by the ROD using Hydrogen Release Compound (HRC™) to enhance natural attenuation (primarily bioremediation) of tetrachloroethene (PCE) and its degradation products to treat groundwater prior to it migrating off RTRVP property. Monitoring data has shown that HRC™ have successfully enhanced the attenuation of PCE, and at much of the site, PCE has degraded to below established cleanup levels. PCE remains above cleanup levels primarily in one deeper area of the lower contaminant plume and several degradation products, primarily vinyl chloride (VC) remain above cleanup levels in both the upper and lower plumes.

During the cleanup process, DEC has continually evaluated monitoring data and modifies its plans to best treat/monitor the site to protect the adjacent Kenai River and its ecological receptors. Because past sampling demonstrates that the HRC™ method has indeed enhanced reductive dechlorination of PCE and its degradation products to treat groundwater, and the total mass of chlorinated ethenes has decreased, DEC at this time has no intent to depart from this treatment/monitoring strategy as described in the ROD.

This is the third "five-year review" of the selected remedy. In the first two five-year reviews, ADEC concluded that the selected remedy was both appropriate and sufficiently protective.

Purpose

In accordance with the August 2000 ROD issued by DEC for the RTRVP site, DEC is required to review its cleanup decision every five years until all cleanup levels are achieved. The five-year review requires an evaluation of all relevant data to determine whether the implemented cleanup alternative continues to be both appropriate and sufficiently protective. Required components of the five-year review are listed below.

1. An evaluation of all relevant data to determine whether the implemented cleanup alternative continues to be both appropriate and sufficiently protective.
2. Consideration of any new toxicological data pertinent to the contaminants of concern,
3. A discussion of any discernable trends in contamination concentrations,
4. Concerns of the public, and
5. Any other relevant information.

It should be noted that, while this analysis includes a detailed review and presentation of the five criteria above, DEC and its contractor, ERM/OASIS/ERM Environmental, Inc. (in consultation with the RTRVP site owners or their consultants), have since 2000 continually evaluated the effectiveness of the site remediation and groundwater monitoring and provided recommendations for additional studies when necessary to meet DEC's obligations in the ROD and the 2000 Consent Decree.

The six sections of this five-year review document are listed below, along with a brief description of their contents.

I. Summary of RTRVP Site Information

   a. Background (contamination history, hydrogeology, 2000 ROD and Consent Decree, and cleanup levels).

   b. Activities to meet objectives (lists the cleanup actions, studies, and monitoring activities from 2000 through 2015)

   c. Cleanup actions to-date

   d. Groundwater monitoring summary

   e. Surface water/pore water/sediment sampling summary

II. Consideration of new toxicological data pertinent to the contaminants of concern.

III. Discernable trends in contamination concentrations

   a. Graphical Trend Analysis

   b. Mann-Kendall Trend Analysis

IV. Concerns of the Public

V. Other relevant information

VI. Conclusions. The primary conclusion of the 15-year review is that the selected remedy continues to be both appropriate and sufficiently protective.

I. Summary of RTRVP Site Information.

A. Background

RTRVP is a former dry cleaners located on approximately 10 acres adjacent to the Kenai River in Soldotna, Alaska. The drycleaning solvent, PCE, and some of its degradation compounds [trichloroethene (TCE); trans-1,2-dichloroethene (trans-DCE); cis-1,2-dichloroethene (cis-DCE); 1,1-dichloroethene (1,1-DCE), and vinyl chloride] have been documented in RTRVP soil and groundwater. In 1997, approximately 2,700 yards of contaminated soil were excavated from the site and transported out-of-state for treatment and disposal. The excavation was extended to a maximum depth of 35 feet below ground surface (bgs); however, some contamination remained below the base of the excavation. Figure 1 shows the layout of the RTRVP site.

The RTRVP hydrogeology is complex. There is a water table aquifer overlying a silty till confining layer overlying a confined aquifer. Depth to water in the water table aquifer varies from less than 2 feet below ground surface (bgs) in monitoring wells near the Kenai River to approximately 18 feet bgs near the former dry cleaner building. The till unit, which is encountered at depths between about 10 and 25 feet bgs across RTRVP, rises above the water table across the middle of the site, thus acting as a groundwater divide. The till unit also contains thin layers of sand that are capable of producing small amounts of water; they are referred to as "semi-confined water-bearing zones." The confined (artesian) aquifer underlying the till unit (at approximately 85 to 95 feet bgs) is used as a drinking water source for residents in the Soldotna area, including for the two community water system wells (formerly referred to as Class A wells) on RTRVP property that service the RTRVP occupants. Contamination has not been detected in the confined aquifer as measured in the RTRVP community water well by the former dry cleaner building.

Two groundwater contaminant plumes have been identified in the water table aquifer:

- the "upper" contaminant plume located near the former dry cleaner building, which migrates west toward the Sterling Highway, and
- the "lower" contaminant plume located south of the former dry cleaners building, which migrates south toward the Kenai River.

The remaining source area underlies the "lower" contaminant plume in the till and is referred to as the "source area." The remaining source area is in the vicinity of the deepest portion of the excavation (between MW-44 and MW-48) and was somewhat defined by Hart Crowser in 1998 and OASIS/ERM in 2002. The source area was better defined by additional assessment activities performed by OASIS/ERM/ERM between 2005 and 2015.

The 2000 Consent Decree requires DEC to perform cleanup and monitoring work as specified in the August 2000 ROD, and allow the State and its contractor's access to perform needed work. The remedial method established in the ROD was bioremediation using Hydrogen Release Compound (HRC™) to enhance biological treatment of the groundwater prior to it migrating off site to the adjacent Kenai River and Sterling Highway. HRC™ enhances a biological process known as reductive dechlorination, in which PCE degrades sequentially to TCE, then to cis-DCE, then to vinyl chloride (VC), and finally to a nontoxic endpoint (ethene)[1]. The ROD establishes cleanup levels for soil and groundwater on and off RTRVP property; compliance points to meet cleanup levels including for surface water at sentry wells; action levels for active treatment; selects bioremediation as the remedial remedy; requires scheduled groundwater monitoring and other DEC selected monitoring as determined; and provides for a mechanism by which to change the remedial method, if necessary.

Although the ROD does not estimate the time to meet established cleanup levels, the cleanup timeframe (i.e., 15 years so far) has exceeded estimates provided in the 2000 Remedial Investigation/Feasibility Study (RI/FS). The RI/FS provided an estimated timeframe of 5 years after initial treatment in the lower plume area and 10 years after initial treatment in the upper plume area, assuming that no additional source areas remained and site conditions were readily conducive to bioremediation of the PCE. However, since the completion of the RI/FS in 2000, field work has determined that the 1997 excavation did not remove all of the highly-contaminated soil, as discussed above. Additionally, site biodegradation rates have been slower than literature rates, potentially due to cold groundwater temperatures, site groundwater geochemistry (i.e., initially oxidizing redox conditions in the upper plume), and lack of the appropriate microbes (i.e., dehalococcoides ethenogens [DHC]).

A limited risk analysis was performed at the site in 1997 to support the development of Alternative Cleanup Levels (ACLs), and an updated risk evaluation was included in the 1999-2000 RI/FS. The RI/FS concluded that the primary risks from site contamination included: (1) potential human health risk due to vapor inhalation in the former dry cleaner building[2] and (2) potentially deleterious ecological effects due to contamination of the Kenai River sediments and surface water adjacent to RTRVP. In addition, since the groundwater is hydrologically connected to the Kenai River, the RI/FS concluded that cleanup must be performed to ensure that there is no violation of surface water criteria. If there are surface water

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[1] The HRC™ injections assist in driving the aquifer conditions anaerobic, i.e., more highly-reducing. Under natural (not contaminated) conditions, the groundwater conditions would be oxidizing. To reduce the groundwater to anaerobic conditions, microbes use HRC™ as a food source and dissolved oxygen in the groundwater for respiration. After the oxygen has been used up, microbes can use nitrate, dissolved manganese, dissolved iron, sulfate, and methane for respiration. The least reducing of these geochemical conditions is nitrate-reducing, with groundwater becoming sequentially more reducing until the most highly-reducing (methanogenic) conditions are reached. In order to reach methanogenic conditions, most of the available nitrate, dissolved iron and manganese, and sulfate must be utilized. Therefore, it takes longer to drive a previously-aerobic aquifer to methanogenic conditions (which are conducive for cis-DCE reduction) than it does to reach iron- or manganese-reducing conditions (which are conducive for PCE and TCE reduction). Current RTRVP unconfined aquifer conditions include a combination of iron- and manganese-reducing and methanogenic microenvironments.

[2] Concern regarding the indoor vapor was conveyed to the Hinkles' and their consultant, Jim Gill, during preparation for Phase I HRC™ injection in 2000. Although the Hinkles' consultant purchased the air monitoring equipment, the indoor air monitoring was never performed.

violations to 18 AAC 70 without remedial action (whether natural attenuation or a more active remedial approach) showing an effort to reduce the contaminant levels to meet applicable water quality standards (WQSs), the possibility exists that a portion of the Kenai River (adjacent to RTRVP) could be placed on the "impaired" water body list.

B. Summary of Activities to Meet Objectives

The following tasks have been performed since 2010 to meet the obligations in the Consent Decree:

- Performed HRC/HRC PRIMER™ injections in September 2011 and October 2012. Details about the HRC/HRC PRIMER injections are provided in Section I-C, which follows this section.
- Performed groundwater monitoring annually in 2011, 2012, 2013, and 2014. Three surface water samples are collected concurrently with the groundwater monitoring events. Details about the groundwater and surface water monitoring are provided in Section I-D.
- Monitored sediment and pore water of the Kenai River sediment in the spring of 2013. Details about the sediment and pore water monitoring are provided in Section I-E.
- Evaluated the groundwater treatment system on an ongoing basis.
- Consistently informed the property owners and/or their consultants of the assessment/cleanup findings and involved them in planning cleanup work.
- Communicated with interested members of the community to inform them of the status of the cleanup and address their concerns.
- Reviewed toxicological data of PCE and its degradation products to determine whether any recent such changes may impact the imposed cleanup strategy.

C. Cleanup Actions To-Date

For the first five years of remediation under the ROD, DEC's management of the site was focused on meeting site cleanup objectives by treating groundwater prior to it migrating off RTRVP property. HRC™ was injected into selected locations in the upper and lower contaminant plumes to enhance biodegradation (HRC™ treatment phases I through III). Between 2005 and 2015, the treatment of groundwater prior to migration off-property has been augmented by hot-spot treatment of the remaining source area (HRC™ treatment phases IV through VI, and HRC PRIMER treatment in 2011 and 2012). The HRC/HRC PRIMER™ treatment to-date is summarized below.

- In October 2000, the first injection of HRC™ occurred (Phase I). Permanent (i.e., re-injectable) injection points were installed as biotreatment barrier walls across both the lower and upper contaminant plumes. HRC™ was injected into all of the Phase I permanent injection points, i.e., 41 permanent injection points across the lower contaminant plume (L1 through L41) and 15 injection points across the upper contaminant plume (U1 through U15).
- In June 2001 (Phase II), additional injection points were installed to expand the Phase I treatment areas. The Phase II injection points are summarized below:
    - 10 injection points (L42 through L51) were installed 15 feet upgradient of the Phase I wells across the lower plume to lengthen the treatment zone.
    - 7 injection points (L52 through L58) were installed between MW-4A and the Kenai riverbank in the lower plume to intercept potential plume migration towards the Alaska Department of Transportation (ADOT) right-of-way.
    - 8 injection points (L59 through L66) were clustered around MW-4A in the lower plume.

- 13 injection points (U22 through U34) were installed 25 feet downgradient of the Phase I wells across the upper plume to provide coverage downgradient of the primary source area.
- 5 injection points (U35 through U39) were installed parallel to the NE side of the former dry cleaning facility to treat groundwater in the vicinity of MW-42.
- 5 injection points (U40 through U45) were installed parallel to the NW side of the former dry cleaning building to treat groundwater in the vicinity of MW-36.
- 3 injection points were installed to replace Phase I points U2, U16, and U19, which were dry.

HRC™ was injected into all of the non-dry Phase I and Phase II injection points (total number of non-dry Phase I and II injection points in the upper plume is 38 and in the lower plume is 66).

- In October 2002, a pilot bioaugmentation project was initiated in the lower plume around MW-9 to test whether this technique would break down the cis-DCE at the site. In the pilot test, a consortium of microorganisms known to degrade cis-DCE (KB-1) was injected into 5 injection points upgradient of MW-9.

  Also in 2002, a monitoring well (MW-44) was installed into the till in the lower plume to a depth of 35 feet bgs and completed across semi-confined water-bearing zones (from 25 feet bgs to 35 feet bgs) to investigate a suspected deep source area on the periphery of the large 1997 excavation (near MW-39 and MW-9 and here-in-after referred to as the "source area"). High PCE levels (up to 31,300 µg/L) detected in MW-44 groundwater suggested the presence of a source area.

- In November 2003 (Phase III), HRC™ was injected into 43 of the 66 Phase I and Phase II Lower Plume injection points after data showed that HRC™ was or soon would be depleted. Two additional deep monitoring wells (MW-45 and MW-46) installed to the southeast and southwest of MW-44 showed no contamination.
- Also in 2003, DEC entered a cooperative agreement with USGS to evaluate how to best accelerate bioremediation at the site. The principal findings of the USGS/DEC study were that the addition of HRC™ (or a similar substrate) was necessary for reductive dechlorination to occur at RTRVP, and, interestingly, a different degradation mechanism (e.g., aerobic and/or anaerobic oxidation to nontoxic carbon dioxide, instead of reductive dechlorination to nontoxic ethene[3]) may be degrading cis-DCE and VC in portions of the aquifer sediments and in the Kenai River sediments.
- In August 2005 (Phase IV), HRC™ was injected into most of the Phase I and Phase II injection points after data showed that HRC™ was becoming depleted. HRC™ was injected into all 38 of

[3] The number of chlorine atoms in chloroethenes plays a significant role in their reduction-oxidation (redox) character. The more highly-chlorinated ethenes (i.e., PCE and TCE) are highly oxidized compounds that readily undergo anaerobic reduction reactions but are less susceptible to microbial oxidation, whereas the less-chlorinated ethenes (i.e., DCE and VC) are more reduced compounds that are less susceptible to anaerobic reduction but more amenable to oxidation. Studies have shown that VC readily oxidizes to carbon dioxide under aerobic conditions; the oxidation rates slow under increasingly anaerobic conditions, but oxidation still occurs. DCE requires a more powerful oxidant than VC and oxidizes less readily than VC. Depending on groundwater redox conditions, it is possible for PCE and TCE to reductively dechlorinate to cis-DCE, and the cis-DCE can either reduce further to VC (if groundwater conditions are sufficiently reducing) or oxidize directly to carbon dioxide (if groundwater conditions are sufficiently oxidizing). The VC can then oxidize to carbon dioxide under aerobic or anaerobic conditions. Paul Bradley's 2003 article in *Bioremediation Journal* entitled History and Ecology of Chloroethene Degradation: A Review provides a detailed discussion about reductive dechlorination and oxidation of chlorinated ethenes.

At RTRVP, aerobic oxidation of cis-DCE and VC may occur in oxygenated environments that are present in the upper contaminant plume area and possibly the Kenai River sediments. Anaerobic oxidation of cis-DCE and VC may occur in manganese- and iron-reducing environments that are primarily present in the lower contaminant plume area.

the upper plume injection points and the following lower plume injection points: L42 through L51 north of MW-39/44; L2, L4, and L6 south of MW-39/44, L24 through L28 south of MW-19, and L52 through L58 near MW-10. The injection points near MW-4A could not be injected during Phase IV, because of ADOT construction activities (upgrading the adjacent Kenai River Bridge and Sterling Highway) which resulted in a number of injection points and several monitoring wells in/near the right-of-way and river to be temporarily covered with several feet of building material/gravel.

Phase IV also marked the first phase of HRC™ treatment of the deep source area in the till. To guide the source area treatment, seven exploratory soil borings (L67 through L73) were driven into the till near MW-44 and assessed for chlorinated ethenes using a Membrane Interface Probe (MIP) using direct push technology. Based on the MIP responses, HRC™ was injected into six deep (direct push or temporary) Phase IV injection points near MW-44 (L67D-HRC, L68D-HRC, L70D-HRC, L71D-HRC, L72D-HRC-E, and L72-HRC-W).

- In October 2006 (Phase V), HRC™ was injected into fourteen existing Phase I and II lower plume injection points where monitoring data indicated that HRC™ was nearly depleted (L7 through L16, L30, L32, L33, and L35). Additional source area assessment activities were also performed to guide further source area treatment, including four exploratory soil borings (L74 through L77) into the till for MIP and soil sample analysis and one new deep monitoring well (MW-47). HRC™ was also injected into four new deep permanent injection points (L78 to L81) and ten deep temporary injection points (L82 to L91) to treat the deep source area soil contamination.

- In August 2009 (Phase VI), HRC™ was injected into five Phase II lower plume injection points (L42 to L46). Additional source area assessment activities were also performed to guide further source area treatment, including five exploratory soil borings (L92 through L96) into the till for MIP and soil sample analysis and three new deep monitoring wells (MW-48, MW-49, and MW-50). HRC was injected into five new permanent deep injection points (L97 to L101) and eight deep temporary injection points (L102 to L109) to treat the deep source area soil contamination.

- In October 2010, four soil borings (L112 to L115) and three new monitoring wells MW-6A as a replacement for MW-6, MW-51, and MW-52 were installed.

- In September 2011, 600 pounds of HRC PRIMER™ was injected into four of the deep lower plume injection points (L79, L99, L100, and L101). HRC PRIMER™ was used due to its ability to more easily migrate in tight soils.

- In October 2012, three additional HRC injection points (L80, L102, and L103) were installed in the vicinity of monitoring wells MW-50, MW-51, and MW-48 respectively. 300 pounds of HRC PRIMER™ was injected into 5 injection points in the upper plume area and 1,200 pounds of HRC PRIMER™ was injected into 7 injection points in the deeper lower plume area. HRC PRIMER™ was used due to its ability to more easily migrate in tight soils.

D. Groundwater Monitoring Summary

Every year between 2000 and 2015, the monitoring well sampling has been reviewed and modified, if appropriate, to meet the goals of this project. As the remediation has progressed and understanding of site conditions has increased, the number of unconfined aquifer monitoring wells to be sampled has been decreased and the sampling frequency reduced.

The current status of RTRVP monitoring wells is summarized in **Table 1** below. In addition to the monitoring wells shown in **Table 1**, samples are sometimes collected from one or more of the deep HRC injection points (i.e., L-78 through L-81 and L-97 through L-101). Groundwater samples are collected for compliance purposes (i.e., comparison with established cleanup levels) as well as to evaluate the performance of the bioremediation system. Performance monitoring samples are analyzed for contaminant concentrations (i.e., PCE and its degradation products), remediation parameters (i.e., field measurements for dissolved oxygen, oxidation-reduction potential (ORP), pH, temperature, and conductivity, and laboratory measurements for dissolved iron and manganese, total organic carbon, metabolic volatile fatty acids, methane, ethane, and ethene). Additionally, samples are periodically collected for polymerase chain reaction (PCR) analysis to evaluate the size of the microbial colony necessary to degrade PCE.

Table 1: River Terrace Monitoring Well Summary 2012 - 2015

	Number sampled in 2014	Number sampled in 2013	Number sampled in 2012
Upper Plume	6	6	8
Lower Plume	16	13	17
Lower Plume semi-confined zone in the till	7	8	10

Groundwater monitoring results are used in Section III of this review to establish contaminant trends for the upper plume, lower plume, and deep source area in the till.

E. Kenai River Surface Water Column/Sediment/Pore Water Monitoring Summary

Surface water column sampling is generally performed concurrently with groundwater monitoring. Except for the October 2009 monitoring event, PCE and/or its degradation products were not detected in any surface water column samples collected after 1999. The concentrations detected in October 2009 were below water quality criteria protective of human health and the environment.

Sediment/pore water sampling has been performed to assess the effects of site treatment activities on the Kenai River. The most recent event was in 2013. Each sediment/pore water monitoring event utilizes the same sampling locations, to the extent possible, as the previous investigations and followed the same sampling methodologies. These sampling locations are generally between MW-8 and MW-35, and are below the mean high water line at the groundwater interface and extend about 10 feet into the Kenai River and about one foot below the sediment/surface water interface. The sediment and pore water sampling events are typically performed early in the spring when the Kenai River is near its lowest stage so as to ensure the river is gaining and to allow for access to the sample locations.

Conclusions from the 2013 sediment and pore water sampling event are summarized below.

- A Mann-Kendall trend analysis of the sediment and pore water analytical results shows that overall contaminant concentrations are declining or stable with a few exceptions where no trend was observed at the 90 percent confidence level.

- Overall, the pore water field screening and natural attenuation parameter sample results indicate that the pore water samplers successfully measured RTRVP groundwater just prior to entering and mixing with the Kenai River water column. The pore water samplers encountered predominately reducing geochemical conditions; with all sample locations showing evidence of methanogenesis along with iron and manganese reduction.

II. New Toxicological Data Pertinent to the Contaminants of Concern.

During the ten years since the signing of the ROD, DEC has continued to review toxicological data for PCE and its degradation products to evaluate whether the cleanup plans should be adjusted to ensure the Kenai River and its ecological receptors are protected. Most recently, DEC revised its 18 AAC 75.341 Method Two soil cleanup levels and 18 AAC 75.345 Table C groundwater cleanup levels on October 9, 2008. There were no changes in Table C groundwater cleanup levels for the RTRVP contaminants of concern; however, some of the Method Two soil cleanup levels for the RTRVP contaminants of concern were revised downward. The 2005 and 2008 18 AAC 75.341 soil cleanup levels for the RTRVP contaminants of concern are shown below in Table 2, along with the site-specific soil cleanup levels established in the ROD.

DEC reviewed the decrease in these cleanup levels (e.g., PCE from 80 mg/Kg to 10 mg/Kg for the outdoor air inhalation pathway) and concluded that the site ROD's cleanup levels coupled with the findings of contaminant concentrations and locations at the site, (e.g., high PCE remaining at 20 ft. bgs around MW-47) remain protective of the receptors at the RTRVP site. In addition, institutional controls can be placed on the property to ensure that the receptors are protected, if remaining contamination that can't be cleaned up is above risk levels.

Table 2: Comparison of 2008 and 2005 Soil Cleanup Levels with ROD Cleanup Levels (in mg/Kg) (18 AAC 75.341 Table B1, Method 2, Under 40-inch precip. zone)

	Direct Contact (2008)	Ingestion (2005)	**Outdoor Air Inhalation (2008)**	Inhalation (2005)	**Mig. to GW (2008)**	Mig. to GW (2005)	*ROD Cleanup Levels (on-RTRVP/off-RTRVP)*
PCE	**15**	160	**10**	80	**0.024**	0.03	*11.5/0.3*
TCE	**21**	750	**0.57**	43	**0.02**	0.027	*300/0.27*
1,1-DCE	**14**	14	**0.85**	0.9	**0.03**	0.03	*7.1/0.3*
cis-1,2-DCE	**1000**	1000	**130**	--	**0.24**	0.2	*72.1/2*
trans-1,2-DCE	**2000**	2000	**160**	--	**0.37**	0.4	*87.3/4*
VC	**5.5**	6	**4.3**	4	**0.0085**	0.009	*2.1/0.09*

Note: Differences between 2005 and 2008 cleanup levels (more than rounding differences) are highlighted in grey.

Although there were no changes to the Table C groundwater cleanup levels for the RTRVP contaminants of concern, the "ten times rule" (which was used to establish off-RTRVP property groundwater cleanup levels in the ROD) has been removed from regulation (18 AAC 75.345). The 18 AAC 75.345 groundwater cleanup levels for the RTRVP contaminants of concern are shown below in Table 3, along with the site-specific groundwater cleanup levels established in the ROD.

Table 3: Comparison of ADEC Groundwater Cleanup Levels with ROD Cleanup Levels (in mg/L) (18 AAC 75.345 Table C)

	Table C Cleanup Level	RTRVP On-Property Cleanup Level	RTRVP Off-Property Cleanup Level
PCE	0.005	0.84	0.05
TCE	0.005	21.9	0.05

cis-DCE	0.07	11.6	0.7
trans-DCE	0.1	11.6	1.0
VC	0.002	0.002	0.02

III. Discernable Trends in Contamination Concentrations

Because the selected remedy results in sequential dechlorination of PCE to TCE, to DCE (cis-DCE primarily), to VC, and finally ethene, there are two primary components in the contamination trend analysis.

1. Assessing the degree to which the PCE has degraded (e.g., has it degraded to cis-DCE, to vinyl chloride, or completely to its non-chlorinated end product, ethene). As discussed further below, this analysis is complicated by the likely occurrence of direct oxidation of the cis-DCE and vinyl chloride to carbon dioxide; however, it is difficult to verify the process, because carbon dioxide cannot practicably be measured in the field.

2. Assessing the degree to which the total chlorinated ethene concentrations (total chlorinated ethenes = PCE + TCE + cis-DCE + vinyl chloride) have decreased. To determine the total chlorinated ethene concentrations, the contaminant concentrations measured during sampling events (which are measured in units of mass per volume [micrograms per liter or ug/L]) are converted into molar concentrations (umol/L) and then summed to determine the total concentration of chlorinated ethenes.

The first 5-year review (2005) focused on the first component, i.e., the degree to which PCE has degraded to its daughter products. At that time, there was little or no significant decrease in total chlorinated ethene concentrations.

However, this 15-year review focuses on the second component, i.e., the degree to which the total chlorinated ethene concentrations have decreased. During the period between 2005 and 2015, the total chlorinated ethene concentrations have decreased in both the upper and lower plumes.

A. Graphical Analysis

Charts were constructed to display the progress of remediation in selected monitoring wells representative of conditions in the upper plume, lower plume, and deep source area. The only method to determine whether the mass of chlorinated ethenes is decreasing is to convert analyte (e.g., PCE and VC) concentrations to molar equivalents. The charts in the April 2014 Groundwater Monitoring report display the molar percentage of total ethenes made up of PCE + TCE (representative of source contaminant concentrations), cis-DCE (intermediate degradation product), and VC + ethene (representative of end degradation products), along with the molar concentration of total contamination over time for selected monitoring wells listed below.

- Chart 1: MW-16 (upper plume)
- Chart 2: MW-9 (lower plume)
- Chart 3: MW-6 (lower plume sentry well)
- Chart 4: MW-44 (deep source area)
- Chart 5: MW-47 (deep source area)

A review of these charts shows that there are generally four remedial stages at each location: pre-treatment; cis-DCE stall (i.e., PCE and TCE degrade to cis-DCE but not further); cis-DCE decline (i.e., cis-DCE is being reduced to vinyl chloride; and ongoing treatment (i.e., the molar percentage of VC + Ethene tends to be the dominate form of chlorinated ethene fractions). Information from the charts is summarized below in Table 4.

Table 4: Remediation Status Summary

Treatment Stage	Dates	% PCE + TCE	% cis-DCE	% VC + ethene
Upper Plume: MW-16				
Pre-Treatment	Through 9/2000	95 – 100%	0 – 5%	0%
cis-DCE Stall	3/01 – 10/05	0 – 5%	95 – 100%	0%
cis-DCE Decline: 5/06 – 5/07				
Ongoing Treatment	9/07 – present (4/14)	0 – 25%	12 – 88%	8 – 78%
Lower Plume: MW-9				
Pre-Treatment	Through 9/2000	15 – 60%	40 – 85%	0%
cis-DCE Stall	11/00 – 3/03	0 – 15%	85 – 100%	0 – 5%
cis-DCE Decline: 6/03 – 10/04				
Ongoing Treatment	5/05 – present (4/14)	0 – 5%	7 – 60%	35 – 89%
Lower Plume (Sentry Well): MW-6				
Pre-Treatment	Through 9/2000	10 – 30%	70 – 90%	0%
cis-DCE Stall	11/00 – 9/03	0 %	95 – 100%	0 – 5%
cis-DCE Decline: 1/04 – 10/04				
Ongoing Treatment	5/05 – present (4/14)	0 – 5%	5 – 35%	52 – 95%
Deep Source Area: MW-44				
Pre-Treatment	Through 6/2005	85 – 100%	0 – 15%	0%
cis-DCE Stall	10/05 – 9/06	Gradual decline from 85% to 0%	Gradual increase from 15% to 100%	0 – 5 %
cis-DCE Decline	5/07 – 5/09	0 – 5%	Gradual decline from 65% to 5%	Gradual increase from 25% to 95%
Ongoing Treatment	5/09 – present (4/14)	0%	< 16%	> 84%
Deep Source Area: MW-47				
Pre-Treatment	9/2006	37%	62%	1%
cis-DCE Stall	5/07 – present (4/14)	0% - 25%	> 71%	< 8%
cis-DCE Decline: Not yet reached				
Ongoing Treatment: *Not yet reached*				

B. Mann-Kendall Statistical Trend Analysis

In addition to graphical evaluation, a statistical approach was used to evaluate contaminant trends at the site. Total chlorinated ethene concentrations were calculated by their molar equivalents for seven monitoring wells from September 2000 to April 2014. The Mann-Kendall nonparametric trend analysis was used to evaluate the monitoring data from two upper plume wells (MW-16 and MW-36), two lower plume wells (MW-6A and MW-9), and two source area wells (MW-44 and MW-47).

The Mann-Kendall analysis is a nonparametric test that is commonly used to evaluate trends in groundwater monitoring results. In the Mann-Kendall analysis, the results are tabulated in the order collected over time, and then each result is compared to all of the previous results. The sign of the differences (i.e., positive or negative) is recorded, and the signs for each monitoring event are summed to determine the Mann-Kendall statistic, S. The S-statistic is compared to a 90-percent confidence level chart provided in the Air Force Center for Environmental Excellence (AFCEE) document *Designing Monitoring Programs to Evaluate the Performance of Natural Attenuation* (AFCEE, 2000). If the S-Statistic is less than the confidence criteria (i.e., coefficient of variance[4]) then no upward or downward trend is indicated, thus denoting stable conditions. A negative S statistic reflects a negative (downward) trend at a 90-percent confidence level, and a positive S reflects a positive (upward) trend at a 90-percent confidence level.

The Mann-Kendall analysis sheets are contained in the April 2014 Groundwater Monitoring report. The Mann-Kendall analysis shows a mostly decreasing contaminant mass trend throughout the site.

IV. Concerns of the Public

As a prefatory note, prior to and since the Consent Decree was signed, DEC has been active in communicating with interested members of the community. DEC has maintained close communication with the interested public by copying stakeholders with reports, informing them of events, and updating the Kenai River Special Management Area (KRSMA) board during their public meetings. DEC provides published reports to the Kenai River Center in Soldotna, which acts as a repository for RTRVP documents that are available to the public. DEC has also worked closely with the RTRVP owners' environmental consultant in the planning phase of work proposed for the site and discussed the findings with the consultant. DEC has also worked closely with DOT representatives regarding contamination at the site that may have impacted planned upgrade work. DEC duly considers input from the public, the RTRVP owner(s) and their consultant(s), and DOT while developing plans to perform further assessment/monitoring/cleanup activities. DEC continues to consider such comments by stakeholders and the public at large during this five-year review. DEC posts copies of its consultants' reports on the DEC web page at http://dec.alaska.gov/spar/csp/sites/riverterrace.htm .

V. Other Relevant Information

In 2009, DEC sampled the treated soil landspread in 2003 to determine whether a risk via indoor vapor intrusion may be possible. Low levels of PCE were detected in one out of seven samples.

Between January and June 2010, DEC conducted a vapor intrusion assessment at the site focusing around the former dry cleaner building. The assessment included the following work scope:

- Installation and sampling of thirty two soil gas monitoring points.

- Performance of a building assessment at the former dry cleaner building and three nearby trailer homes.
- Collection of indoor air, outdoor air, and sub-slab samples at the former dry cleaner building.
- Collection of indoor air, outdoor air, and soil gas or crawl space air samples at each of the trailer home locations.

January and April results indicated that PCE, the main contaminant of concern, was present in soil gas and sub-slab air samples at concentrations exceeding ADEC target soil gas levels; and indoor air samples at one of these locations also exceeded ADEC indoor air residential target levels for PCE, TCE, and benzene.

Vapor intrusion monitoring performed in April 2010 and June 2010 showed indoor air samples above ADEC target concentrations only in the basement of the former dry cleaner building. The target concentrations are based on a continuous use of that area of the building. Due to the limited use of the basement area it does not appear to be a current risk.

VI. Conclusions.

Upon evaluation of all relevant data presented in this current five-year review, ADEC concludes that the selected remedy continues to be both appropriate and sufficiently protective. While data shows that bioaugmentation works at RTRVP (i.e., at one area where bioaugmentation was conducted in a 2002 pilot project), data also shows that the total mass of chlorinated ethenes has decreased across both the upper and lower contaminant plumes (i.e., within and outside of the bioaugmentation pilot test area).

Results of an evaluation of the main considerations of the five-year review, as stated on page 1 of this document, are summarized below.

1. An evaluation of all relevant data to determine whether the implemented cleanup alternative continues to be both appropriate and sufficiently protective. Because past sampling demonstrates that the HRC™ method has indeed enhanced reductive dechlorination of PCE and its degradation products, and the total mass of chlorinated ethenes has decreased, DEC at this time has no intent to depart from this treatment/monitoring strategy as described in the ROD.

2. Consideration of any new toxicological data pertinent to the contaminants of concern – There are some changes to cleanup levels pertinent to the contaminants of concern. DEC reviewed the decrease in these cleanup levels (e.g., PCE from 80 mg/Kg to 10 mg/Kg for the outdoor air inhalation pathway) and concluded that the site ROD's cleanup levels remain protective of the receptors at the RTRVP site. In addition, institutional controls can be placed on the property to ensure that the receptors are protected if remaining contamination can't be cleaned up to below risk levels.

3. Concerns of the public – DEC has kept the public informed of the RTRVP cleanup process, and the public has not expressed any major opinions suggesting that they are dissatisfied with the selected remedy.

4. Any other relevant information – Vapor intrusion monitoring performed in April 2010 and June 2010 showed indoor air samples above ADEC target concentrations only in the basement of the former dry cleaner building. The target concentrations are based on a continuous use of that area of the building. Due to the limited use of the basement area it does not appear to be a current risk.

5. A discussion of any discernable trends in contamination concentrations – Groundwater, sediment and porewater monitoring since 2000 has shown that the selected treatment has been successful by using HRC/HRC PRIMER™ to enhance reductive dechlorination of PCE and its degradation products to treat groundwater prior to it migrating off RTRVP property. Mann-Kendall trend analysis shows downward trends in total contaminant levels in the upper plume, lower plume, and part of the source area within the till (i.e., MW-44).

DEC expects within the next five years to focus on successfully treating the source of the remaining contamination that is in the deep till around MW-44 and MW-48 as discussed above.

Table 6 provides a more detailed summary of conclusions regarding the contaminant degradation in the upper plume, lower plume, and source area within the till. Conclusions from the 2005 five year review are presented along with current conclusions to illustrate the progress of remediation at the site over the past 5 years.

Table 5: Comparison of Conclusions from the 2005 Five-Year Review and the 2015 Fifteen-Year Review

Topic	2005 Conclusion	2015 Conclusion
	Lower Plume	
Degradation of PCE to cis-DCE	The HRC injections were successful at rapidly degrading PCE to TCE to cis-DCE in the lower plume within a few months.	HRC/HRC PRIMER injections remain successful at degrading PCE to cis-DCE.
Bioaugmentation Pilot Test	The bioaugmentation pilot test successfully mediated degradation of the cis-DCE to vinyl chloride and ethene. Within the bioaugmentation pilot test area, the three 2005 monitoring events suggested a decrease in total chlorinated ethene concentrations, as the vinyl chloride is degraded to ethene.	Monitoring data between 2005 and 2015 suggest significant vinyl chloride and ethene production throughout and downgradient of the bioaugmentation pilot test. Most recent monitoring data show a significant decrease in total chlorinated ethene concentrations in the bioaugmentation pilot test area.
Outside of the bioaugmentation pilot test area	Outside of the bioaugmentation pilot test area, no significant production of vinyl chloride or ethene had been observed, and contaminant concentrations were generally stable, although they had declined from levels detected prior to 2002.	Most recent monitoring data suggests a significant decrease in total chlorinated ethene concentrations outside of the bioaugmentation pilot test area in both the lower and upper plumes areas. Because of the significant decrease in the total chlorinated ethenes in both plume areas, it was elected that no further bioaugmentation occur during the period between 2005 and 2015.
Kenai River sediments and	Near the Kenai River, the aquifer sediments appear to have a significant capacity for oxidizing	Sediment and pore water sampling show general

pore water	cis-DCE and vinyl chloride directly to carbon dioxide, thereby contributing further to the cleanup of contaminants from RTRVP.	decreasing contaminant concentrations between 2004 and 2014.
Kenai River surface water	The RTRVP site remedy does not appear to have adversely impacted the Kenai River. Although contamination was detected in the Kenai River surface water column prior to implementation of the bioremediation remedy, no contamination was detected in the Kenai River surface water column samples collected since the remedy was implemented in 2000 and through 2005. Sediment sampling results from 2002 and 2004 indicated less widespread contamination than sediment sampling results prior to 2000.	PCE, TCE, and cis-DCE were not detected in surface water column samples in April 2014
	Source Area in the Till	
Source area in till	The contaminated soil source area in the till around MW-44 is providing a continuing source of dissolved PCE contamination to the unconfined aquifer. The HRC in the unconfined aquifer is effectively dechlorinating the PCE before offsite migration. It is too early to evaluate the effectiveness of the August 2005 HRC treatment of the till in the MW-44 source area.	Additional monitoring at MW-47, MW-48, MW-49, and MW-50, as well as soil samples and MIP logs, have further delineated the deep source area (currently interpreted as an area roughly 35 feet long [i.e., from L100 to MW-49) by 20 feet wide [i.e., from MW-49 to L101], with a narrow "tail" extending towards MW-44 approximately 15 feet long by 12 feet wide), and between about 20 and 40 feet below ground surface. Five phases of HRC/HRC PRIMER injections into the deep till have been performed (2005, 2006, 2009, 2011, and 2012). MW-44 results show complete reductive dechlorination of PCE to ethene and a significant decrease in total chlorinated ethane concentrations. The till in this area is very dense, and the water-bearing layers show little connectivity (based on different geochemistry and vertical gradients). These conditions inhibit the lateral spreading of the HRC material in the till and slow remediation efforts.
	Upper Plume	
Degradation of	Although somewhat slower than in the lower	HRC/HRC PRIMER injections

PCE to cis-DCE	plume, the HRC injections were successful at rapidly degrading PCE to TCE to cis-DCE within about 12 months.	remain successful at degrading PCE to cis-DCE.
Degradation of cis-DCE to vinyl chloride and ethene	Only low levels of vinyl chloride are occasionally detected in upper plume monitoring wells, suggesting that only minor reductive dechlorination of cis-DCE is occurring. Similar to the lower plume outside of the bioaugmentation pilot test area, contaminant concentrations are generally stable, although they have declined from levels detected prior to 2002.	Significant vinyl chloride production in the upper plume began in May 2006 (nearly a 5-year time lag after Phase I of HRC injection). Ethene production in the upper plume began in 2007. Most recent monitoring data indicates a significant decrease in total chlorinated ethene concentrations in the upper plume.