S DETAILED ANALYSIS OF REMEDIAL ACTION ALTERNATIVES

In this appendix, detailed evaluations are performed for the six remedial alternatives identified in Section 10 for the lower contaminant plume area and six remedial alternatives identified for the upper contaminant plume area.

The remedial alternatives discussed in this section are designed to meet the site specific ACLs presented in Section 9. The ACLs would allow for groundwater containing a maximum PCE concentration of 840 μg/L (exceeding the WQS of 5 μg/L) to migrate from the site into the Kenai River.

S.1 APPROACH USED FOR DETAILED ANALYSIS

The detailed analysis of alternatives consists of the following components:

- An assessment and a summary profile of each alternative against the evaluation criteria.
- A comparative analysis among the alternatives to assess the relative performance of each alternative using specific evaluation criteria.

A summary of these steps is provided in the following sections.

S.1.1 Alternative Development Process

Six multimedia alternatives, including the no action alternative, have been assembled for detailed analysis for the lower contaminant plume, and six remedial alternatives, including the no action alternative, have been assembled for detailed analysis for the upper contaminant plume. These multimedia alternatives consist of combinations of media-specific alternatives that were developed and screened in Section 10. The alternatives were assembled using criteria specified by the state of Alaska and the National Contingency Plan (NCP).

- For source control actions, a range of alternatives that include treatment for reducing the toxicity, mobility, or volume of the contaminants were developed. The range of alternatives include (1) an alternative that removes or destroys contaminants to the maximum extent feasible, eliminating or minimizing the need for long-term management; (2) other alternatives that address the principal threats posed by the site but vary in the degree of treatment employed; and (3) an alternative that involves little or no treatment but provides protection of human health and the environment by preventing or controlling exposure to contaminants.
- For groundwater response actions, a limited number of remedial alternatives that attain site-specific remediation levels within different restoration times using one or more different technologies were developed.
- One or more innovative treatment technologies were evaluated, if these methods offer the potential for comparable or superior performance or implementability, fewer or lesser adverse impacts than other available approaches, or lower costs for similar levels of performance compared to demonstrated treatment technologies.
- The no action alternative, which may be no further action if some removal or remedial action has already occurred at the site, was evaluated.

S.1.2 Evaluation Criteria

The state of Alaska has established five criteria for evaluation of remedial alternatives, and the NCP contains nine criteria for evaluation of remedial alternatives. The nine NCP criteria were chosen for use in this FS, because they are more rigorous than and inclusive of the five state criteria.

The nine NCP evaluation criteria used in the detailed analyses and brief definitions of each are presented in Table S-1. The five state criteria are listed below, with the equivalent or most similar NCP criteria given in parentheses:

- Practicable (*implementability NCP criterion*),
- Protectiveness (*protective of human health and the environment NCP criterion*),
- Short- and long-term effectiveness (*combines the short- and long-term effectiveness NCP criteria*),
- Regulations (*compliance with ARARs NCP criterion*), and
- Public input (*community acceptance NCP criterion*).

The evaluation criteria used in the detailed analysis are divided into three categories: threshold criteria, balancing criteria, and modifying criteria. Threshold criteria are those conditions that must be met for the alternative to be viable, and they must be related directly to statutory findings that will be made in the record of decision (ROD); these criteria must be met. Balancing criteria form the primary basis for comparing alternatives, these criteria relate the alternative to the site-specific conditions. Modifying criteria factor in agency and community concerns; an alternative could be effective and technically implementable, but not viable based on these considerations.

The detailed evaluations focus on the threshold and balancing criteria. Modifying criteria (agency and community acceptance) are not included in this analysis since they depend upon the results of agency and public review. Modifying criteria are considered in the proposed plan stage of the NCP process.

Table S-1. Remedial Alternative Evaluation Criteria

Criteria Type	Evaluation Criteria	Definition
Threshold Criteria	Protective of human health and the environment	Protection of both human health and the environment is achieved through the elimination, reduction, or control of exposures to contaminated media. All migration pathways must be addressed.
	Compliance with ARARs	Attainment of applicable or relevant and appropriate requirements under federal environmental laws and state environmental or facility siting laws, or provide grounds for invoking applicable waivers.
Balancing Criteria	Long-term effectiveness and permanence	Protects human health and the environment after the remedial objectives have been met.
	Reduction in toxicity, mobility, or volume through treatment	The degree to which recycling or treatment reduces the toxicity, mobility, or volume of the contaminated media.
	Short-term effectiveness	Protects human health and the environment during construction and implementation. Degree of threat and the time period to achieve remedial action objectives are also considered.

Criteria Type	Evaluation Criteria	Definition
	Implementability	The ease or difficulty of implementing the alternative. Considers technical and administrative feasibility as well as the availability of services and materials.
	Cost	Costs include design, construction, startup, and present-worth costs for long-term monitoring and maintenance. Accuracy to within -30% and +50% (USEPA, 1998c).
Modifying Criteria	State Acceptance	The state's position and key concerns related to the preferred alternatives.
(These assessments may not be completed until comments to the proposed plan are received.)	Community Acceptance	The community's apparent preferences for or concerns about alternatives.

S.1.3 Identification of Remedial Alternatives

Each of the remedial alternative identified were evaluated using the seven threshold and balancing NCP criteria listed in Table S-1. The individual criteria scores were summed to derive a total score for that alternative. The total scores were then compared among all of the alternatives in the Comparative Analysis.

As discussed in Section S.1.1, the multimedia alternatives were developed to present a range of remedial options, from low-cost and low-effectiveness options (e.g., no action) to high-cost, high-effectiveness options (e.g., active remediation). The remedial alternatives were then applied to both of the two contaminant plume areas – those being the Lower Contaminant Plume between the former dry cleaner building and the Kenai River, and the Upper Contaminant Plume adjacent to the former dry cleaner building (Figures 16 and 18).

Remedial Alternatives for Lower Contaminant Plume: The remedial alternatives selected for detailed analysis at the lower contaminant plume of the River Terrace site are listed below. The primary RAO of these technologies is to prevent contaminants from entering the Kenai River at concentrations above the site specific ACLs. One alternative (Alternative L-F) also includes treatment of the lower contaminant plume source area, with the goal of meeting the same RAO within a shorter restoration time.

Alternative L-A: No action

Alternative L-B: Intrinsic remediation

Alternative L-C: Permeable reactive barrier

Alternative L-D: *In situ* air sparging curtain

Alternative L-E: Groundwater extraction wells with *Ex situ* air stripping

Alternative L-F: Reductive anaerobic biological *In situ* treatment technology

Remedial Alternatives for Upper Contaminant Plume: The remedial alternatives selected for detailed analysis at the upper contaminant plume of the RTRVP site are listed below. The most recent groundwater monitoring results indicate that PCE contaminant levels at the RTRVP property boundary are at or below the site specific ACLs. However, past groundwater PCE contaminant concentration in MW-25, which is adjacent to the property boundary, have exceeded the site specific ACL of 840 µg/L for PCE. Therefore, the primary focus of the remedial alternatives considered for the upper contaminant plume are designed for restoration of contamination on the property itself. However, two of the alternative U-C and U-F are also designed to prevent any migration of contaminants above the ACL off the property.

Alternative U-A: No action

Alternative U-B: Intrinsic remediation

Alternative U-C: Permeable Reactive Barrier

Alternative U-D: *In situ* air sparging and soil vapor extraction

Alternative U-E: Reductive Anaerobic Biological *In Situ* Treatment Technology

Alternative U-F: Excavation with Groundwater Treatment

High levels of groundwater contamination (up to 5,500 µg/L) near the building and PCE soil gas concentrations along two sides of the building in the tens of thousands of micrograms per liter of air range indicate that the building may be over an area of significant PCE contamination. If a contamination source is present beneath the building it is likely that the contamination has penetrated the glacial till material underlying the contaminated groundwater. Till in the lower portion of the site is contaminated to at least 35 feet below ground surface and there is no reason to believe that a spill in the upper area could not also significantly penetrate the till material. The contaminated till could serve to act as a source of groundwater contamination for several years as PCE continues to slowly be released. Furthermore, risk screening using the Johnson-Ettinger model, indicates that PCE vapors might pose a risk to building inhabitants. Attempts to collect samples from beneath the building have been unsuccessful because of cobbles and dense soils resulted in drill rig refusal before target sampling depths were reached. Regardless, the data from the periphery of the building indicate that a contamination source beneath the building is likely. The indication that a contamination source exists and the potential for risk to building occupants are sound basis for requiring that some remedial action be performed in this area.

Dissolved PCE contamination from the upper contaminant plume area is interpreted to be migrating from the RTRVP property to the ADOT ROW and entering the storm sewer system. Because contamination entering the storm-drain piping is presently discharging directly to the Kenai River at a concentration above the Alaska WQS for PCE, an interim action is being taken to treat this discharge before it enters the river. A water treatment system (based on air stripping technology) is to be installed inside the storm drain piping just prior to discharging into the Kenai River. This system is expected to remain in place until one of the remedial alternatives is operational or until contaminant concentrations decline to below the Alaska WQSs.

ADOT is planning to upgrade the Sterling Highway where it passes along the western boundary of the RTRVP property. One of the changes to be made during this upgrade is to abandon in place the lower portion of the existing storm drain system between the Kenai River and Kobuk Street, and construct a new storm drain system that no longer discharges into the Kenai River. At that time, it would be possible to grout a portion of the existing storm drain piping and the backfill around the piping to prevent further migration of PCE contaminants along this pathway. However, it is unknown how these changes may affect the current hydrogeologic environment. One possibility is that the present groundwater flow paths may be altered such as to promote off property migration of the upper contaminant plume in a northwesterly direction, thus, allowing the contaminant plume to extend beyond the western side of the Sterling Highway toward and past monitoring well MW-34 (see Figure 16 for reference).

S.1.4 Approach for Comparative Analysis

A comparative analysis was performed to identify the advantages and disadvantages of each remedial alternative relative to the other alternatives. The relative performance of each alternative is evaluated with respect to each of the State/CERCLA evaluation criteria, using the numerical scoring system presented in Table S-2. The scores have no independent value; they are only meaningful when compared among the different alternatives.

Table S-2. Evaluation Criteria Rating System

Evaluation Criteria	*Condition*	*Value*
Protective of Human Health and the Environment	Is fully protective	Yes
	Is not protective	No
Compliance with ARARs	Complies with all ARARs	Yes
	Does not comply	No
Long-Term Effectiveness and Permanence	Effective and permanent	5
	Future release possible	3
	No removal or destruction	0
Reduction in Toxicity, Mobility, or Volume Through Treatment	Eliminates toxicity, mobility, volume	5
	Reduces toxicity, mobility, volume	3
	No reduction or treatment	0
Short-Term Effectiveness	Low risk and high protection	5
	Limited risk and limited protection	3
	High risk and low protection	0
Implementability	High technical, administrative, and logistic feasibility	5
	Limited technical, administrative, or logistic feasibility	3
	Technically unproven, permitting uncertain, or resources unavailable	0
Cost	Actual predicted present worth costs were normalized to a 0 to 5 scale, with the Highest Cost Alternative earning a 0, and the no action alternative earning a 5	0 to 5
State Acceptance[1]	To be determined	TBD
Community Acceptance[1]	To be determined	TBD

NOTE TBD = To Be Determined

[1] These criteria are typically evaluated following comment on the FS report and the Proposed Plan. They will be addressed in the ROD.

As shown, the rating for threshold criteria can be one of two possibilities: the criterion is either fully met or not met. Therefore, no numerical values are assigned to the threshold criteria.

For balancing criteria, the rating can range from zero to five: if the criterion factors are fully met a five is scored, and if the criterion factors are not met a zero is scored. The numerical comparative analysis focuses on the balancing criteria. Determination of scoring values for each alternative is based on comparisons between the alternatives.

S.1.4.1 Balancing Criteria Scoring

An explanation of the balancing criteria scoring procedure is provided in this section.

Long-Term Effectiveness and Permanence: This criterion is used to distinguish between long-term, lasting technologies and technologies that are potentially reversible or can result in lasting contamination. For example, technologies relying on contaminant containment (e.g., slurry walls that could potentially fail, or binding contaminants in concrete that could eventually leach) would score lower than technologies relying on contaminant removal. All of the technologies evaluated in this FS, except the no action alternative, involve contaminant treatment or removal. The no action alternative earned a rating score of 0 for this criterion, intrinsic remediation earned a rating score of 1 for this criterion, and the active remedial technologies earned a rating score of 3 to 5 for this criterion.

Reduction in Toxicity, Mobility, or Volume Through Treatment: This criterion is used to distinguish between technologies that reduce or treat contaminant volume and technologies that do not actively treat contamination. For example, technologies relying on contaminant containment or treatment to prevent further migration would score lower than technologies relying on source-area contaminant treatment or removal.

Short-Term Effectiveness: This criterion is used to balance risks inherent in implementation with short-term effectiveness. The highest score, five, is earned by technologies offering low exposure risks and high protection. All of the active remedial technologies evaluated in this FS involve some implementation risk (e.g., risk to workers during system installation), which is balanced by their increased short-term effectiveness. All passive remedial technologies (e.g., no action) involve less short-term effectiveness, which is balanced by no implementation risk.

Implementability: This criterion is used to differentiate technologies that are easier to implement from technologies that are more difficult to implement. The no action and intrinsic remediation alternatives require no or minimal effort to implement; these alternatives generally earn a score of five for this criterion. The active remedial technologies evaluated in this FS require significant capital costs and design considerations, and some contained significant implementability concerns; these alternatives earned a score of four or less for this criterion.

Cost: This criterion is used to rate, on a relative scale, the different costs associated with each technology. The total present worth costs of each remedial alternative were estimated, and then the costs were normalized on a zero to five scale. The most expensive remedial alternative earns a score of zero, and the no action alternative (least expensive) earns a score of five.

S.1.4.2 Comparative Analysis Discussion

To aid in comparing alternatives, the total score and effectiveness-to-cost quotients for each alternative were calculated. The total score is the sum of the five balancing criteria scores. The effectiveness-to-cost quotient is the sum of the three effectiveness criteria divided by the total cost in millions ($1,000,000). The higher the effectiveness-to-cost quotient, the more cost-effective the alternative is. To assist in identifying preferred alternatives, effectiveness-to-cost quotients provide a qualitative measure of the ability of the alternative to provide remediation versus the cost required achieving the remedial goals.

The validity of the comparative analysis is limited by several assumptions. First, the analysis assumes that all contaminant transport pathways are of equal importance. Similarly, it assigns equal importance to each CERCLA criterion, since each is weighted the same. The analysis also does not quantify synergistic effects between combinations of groundwater, wetland, and soil pathways. Finally, the comparative analysis relies upon the five subjective scores of the balancing factors for each alternative.

Estimating the time required to achieve remedial action objectives is difficult to predict. The controlling factor in this estimate will be the time required for the residual phase PCE to be dissolved/desorbed by the groundwater flowing through the contaminated aquifer material. Due to the complexity of the flow system and unknown residual-phase concentrations, it is impossible to accurately predict a remediation time frame. This is further compounded by the possible presence of free phase DNAPLs at the RTRVP property as discussed in Section 7.6.

For the purposes of this feasibility study, a remediation timeframe of 10 years is assumed for all passive treatment alternatives in the lower contaminant plume (i.e., permeable reactive barrier), and a remediation timeframe of 15 years is assumed for all passive treatment alternatives in the upper contaminant plume. The basis for the passive treatment remediation timeframe estimate is the Appendix M analysis of the potential spill volume, remaining site contamination, and contaminant max flux off the site. Appendix M, which is based on a mass balance approach, indicates that a remediation timeframe of 15 years is a reasonable estimate of the time needed for the site to attenuate. The primary attenuation mechanism is off-site migration of dissolved contaminants with groundwater. It is difficult to rigorously apply this analysis to determine the remediation timeframe required for groundwater concentrations to reach the ACLs (specifically the groundwater ACL of 840 μg/L for PCE). However, a remediation timeframe of 10 years is reasonable for the lower contaminant plume, where a source removal has already occurred and the contamination is fairly well characterized. A remediation timeframe of 15 years is assumed for the upper contaminant plume due to the presence of a building that inhibits remedial efforts, the presence of higher groundwater concentrations, and due to increased uncertainty with the amount and concentration of remaining soil contamination.

Remedial technologies that included treatment of the source contamination area at the lower contaminant plume were assumed to achieve remedial action objectives in a 5-year time frame, due to source strength reduction. Remedial technologies that included treatment of the source contamination area at the upper contaminant plume were assumed to achieve remedial action objectives in a 5-year time frame, due to source strength reduction.

Since a similar time frame was applied to the similar types of remedial alternatives (i.e., barrier wall vs. source treatment), the selected time frames will have minimal impact on the comparative analysis of the alternatives. Should restoration times take longer than estimated here, their impact on the total remedial costs is relatively minor, due to the present value of money used in the cost estimates, provided no major capital expenditures occur in the future.

When selecting an apparently best alternative, preference is generally given to the highest-scoring remedial alternative. Ultimately however, the regulatory agencies and the community must agree on which alternative, or combinations of alternatives, are the most desirable to achieve the RAOs based on effectiveness, implementability, and cost.

S.2 ANALYSIS OF ALTERNATIVES FOR LOWER CONTAMINANT PLUME

In this section, each of the six remedial alternatives for the lower contaminant plume is evaluated in detail, using the numerical scores presented in Table S-2. Conceptual designs and cost estimates for each of the remedial alternatives are provided at the end of Appendix S.

Groundwater and surface water monitoring will be required for successful implementation of any of the remedial alternatives, with the exception of no action, and will have similar costs. Therefore, the monitoring costs were calculated separately and added into all of the remedial alternatives. The proposed monitoring program includes quarterly monitoring for the first three years of operation, followed by semiannual monitoring for the next two years, and annual monitoring thereafter. The monitoring frequency may be modified by the ADEC in order to comply with desired remedial objectives.

Monitoring is an important decision tool in determining rate of progress and effectiveness of selected remedial alternatives. In some cases, modifications to the selected remedial alternative may be required in order for the alternative to comply with the remedial objectives within desired restoration time and monitoring will help to determine this.

Alternative L-A: No Action

Alternative L-A, the no action alternative, is used as a baseline reflecting current conditions without remediation. This alternative is used for comparison with each of the other alternatives. Although natural processes may result in reduction of contaminant concentrations to acceptable levels over time, this alternative does not include any long-term monitoring, modeling, or treatability studies to evaluate the effectiveness of these processes. This alternative is applicable to all contaminant types found in water, soil, and wetland environments.

CERCLA Criteria Scoring Results – Alternative L-A

Criteria	Score
Protection of Human Health and the Environment	No
Compliance With ARARs	No
Long-Term Effectiveness and Permanence	0
Reduction in Toxicity, Mobility, and Volume Through Treatment	0
Short-Term Effectiveness	1
Implementability	5
Costs	5
Total Score	11

Protection of Human Health and the Environment. Alternative L-A provides no control of exposure to the contaminated soil, groundwater, and surface water and no reduction in risk to human health and the environment posed by the site contamination. It also allows for continued migration of the contaminant plume and further degradation of the groundwater. (Rating = No)

Compliance With ARARs. Because no action is taken, Alternative L-A would not comply with ARARs such as the site-specific ACL for PCE and its daughter products in soil and water. (Rating = No)

Long-Term Effectiveness and Permanence. This alternative includes no controls for exposure and no long-term management measures. Under this alternative, all current and potential future risks would remain. (Rating = 0)

Reduction in Toxicity, Mobility, and Volume Through Treatment. This alternative provides no reduction in toxicity, mobility, or volume of the contaminated soil or groundwater through treatment. (Rating = 0)

Short-Term Effectiveness. There would be no additional risks posed to the community, the workers, or the environment because of this alternative being implemented. However, release of contaminants from the subsurface environment to the groundwater and Kenai River would continue for the foreseeable future. (Rating = 1)

Implementability. There are no implementability concerns posed by this remedy since no action would be taken. (Rating = 5)

Cost. The total present-worth cost of Alternative L-A is estimated to be $0 since there would be no action. (Rating = 5)

Alternative L-B: Intrinsic Remediation

Description. Intrinsic remediation would not involve active remedial technologies. Groundwater, soil, and surface water would be left in their current state, and natural processes would continue to reduce contaminant concentrations. Dilution, adsorption, volatilization, precipitation, complexation, and biological degradation of the contaminants occur in the groundwater and subsurface soils. Intrinsic remediation would allow these processes to continue to occur as they have in the past, without disturbances potentially caused by implementation of active remedial technologies.

Intrinsic remediation is not the same as "no action." Implementation of this alternative requires modeling and evaluation of contaminant attenuation. This alternative would also include a groundwater and surface-water monitoring program to confirm predicted results. The water samples would be collected periodically and analyzed for the contaminants of concern. The data generated would be used to monitor degradation and provide an early indication of possible impacts, allowing time for remedial response to mitigate the impact. Intrinsic remediation involves no excavation or handling of contaminated materials. Therefore, site workers are not at risk during implementation and there is no risk to the community from extraction and treatment of contaminated water.

The target contaminants for intrinsic remediation are usually nonhalogenated volatile and semivolatile organics and fuel hydrocarbons. Halogenated volatiles and semivolatiles can also be allowed to naturally attenuate, although the process may be less effective and may only be applicable to some compounds within these contaminant groups. The primary contaminants of concern at the River Terrace site are halogenated volatiles, which are more difficult to treat via intrinsic remediation.

Based on current and historical sampling results, groundwater is leaving the site at levels above the ACLs established for this site. Based on these sampling results, the intrinsic remediation alternative is not compliant with ACLs at the site in the short-term but is expected to comply with ACLs in the long-term. As discussed previously it is estimated that site contamination will remain above the site specific ACLs for approximately another 10 years or more. A detailed cost evaluation for this alternative is presented at the end of this Appendix S.

CERCLA Criteria Scoring Results – Alternative L-B

Criteria	Score
Protection of Human Health and the Environment	No
Compliance With ARARs	No
Long-Term Effectiveness and Permanence	1
Reduction in Toxicity, Mobility, and Volume Through Treatment	1
Short-Term Effectiveness	2
Implementability	5
Costs	2.9
Total Score	11.9

Protection of Human Health and the Environment. By intrinsic remediation and institutional controls (already implemented), Alternative L-B would provide some reduction in risk to human health and the environment posed by site contamination. Concentrations of PCE and vinyl chloride have been observed in the compliance wells (MW-6 and MW-20) above the site specific ACLs, thus, this alternative does not ensure that groundwater leaving the site is protective of the Kenai River surface water. (Rating = No)

Compliance with ARARs. Because active remediation is not included, Alternative L-B would not meet ARARs (such as the ACL for PCE in groundwater) in the near term. Over time, intrinsic remediation is expected to reduce contaminant concentrations; however, groundwater currently leaving the site is not compliant with the ACLs established for the site. (Rating = No)

Long-Term Effectiveness and Permanence. Intrinsic remediation is effective in the long-term; however, there is risk of continued partitioning of contamination from the source area into site groundwater and migration of contaminants, as a result of this alternative. (Rating = 1)

Reduction in Toxicity, Mobility, and Volume Through Treatment. By intrinsic remediation and institutional controls, Alternative L-B would provide some reduction in risk to human health and the environment posed by site contamination. The primary short-term risk to human health or the environment that is not addressed by this alternative is potential migration of dissolved-phase PCE and its degradation products to the Kenai River. (Rating = 1)

Short-Term Effectiveness. There would be no additional risks posed to the community or the environment because of this alternative being implemented. This alternative does not provide short-term effectiveness for ecological protection from contaminants in the Kenai River. (Rating = 2)

Implementability. This alternative has low implementability concerns; only a long-term monitoring plan must be implemented. (Rating = 5)

Cost. The total present-worth cost of Alternative L-B is estimated to range from $275,000 to $590,000. Costing details are provided at the end of Appendix S. On a normalized cost scale (0 to 5), the total present-worth cost of Alternative L-B earned a rating of 2.9. (Rating = 2.9)

Alternative L-C: Permeable Reactive Barrier

Description. A permeable reactive treatment wall is installed across the flow path of the lower contaminant plume, allowing the water portion of the plume to passively move through the wall (Figure S-1). This type of barrier allows the passage of water while removing dissolved contaminants by physical, chemical, and/or biological processes. The mechanically simple barriers may contain such agents as zero-valent iron, chelators (ligands selected for their specificity for a given metal), sorbents, microbes, and others. Successful application of this technology requires sufficient characterization of the groundwater hydrology and contamination.

An iron treatment wall consists of iron granules or other iron-bearing minerals for the treatment of chlorinated contaminants such as PCE, TCE, DCE, and VC. As the iron is oxidized, a chlorine atom is removed from the compound by one or more reductive dechlorination mechanisms, using electrons supplied by the oxidation of iron. The iron granules are dissolved by the process, but the metal disappears so slowly that the remediation barriers can be expected to remain effective for many years, possibly even decades. The effectiveness of the iron treatment varies depending on the contaminant properties. The reaction rates for TCE and PCE are more rapid than the reaction rates for DCE and VC (USEPA, 1998a). Typically, permeable reactive barriers are designed to provide adequate residence time for the degradation of the parent compound and all toxic intermediate products that are produced. It is estimated that an iron treatment wall will result in complete conversion of the site contaminants to non-toxic compounds, however, bench-scale studies will be required to predict system performance (verify degradation rates) and provide data for field design. Iron treatment wall vendors have also stated that downgradient impacts, such as iron staining, from the installation of an iron treatment wall are unlikely as this has not been observed at any of the sites where the technology has been applied (Personal Communication, EnviroMetal Technologies).

In situ treatment walls have several advantages over other treatment methods. *In situ* technologies do not require exposing contamination to the surface for remediation. Operation and maintenance costs are minimal; no energy input is required, because the treatment occurs under the natural groundwater gradient. The only operation and maintenance (O&M) costs associated with this technology would be periodic replacement or rejuvenation of the reaction medium, which may be necessary if the media becomes plugged or its reactive surface capacity is diminished. A permeable reactive barrier installed at the Borden Aquifer, Ontario, Canada, showed only minimal amounts of calcium carbonate precipitate in the wall after five years of operation and it was estimated that the wall should remain active for at least another five years (USEPA, 1999).

Vidic and Pohland (1996) present a summary on the status of treatment wall technology. Examples of pilot-, field-, and commercial-scale treatment walls for chlorinated organic compounds are provided in this summary. Most of the systems reviewed included slurry walls (or other impermeable barriers) on both sides of a permeable treatment wall. The treatment walls were charged with a range of sand/iron mixtures (from 100 percent granular iron to a minimum of 22 percent [by weight] iron filings mixed with 78 percent sand). Treatment wall widths varied from 0.6 meters to 3.2 meters and groundwater residence times within the wall varied between 2 days and 15 days. Influent TCE concentrations ranged from 0.05 mg/L to 250 mg/L; the walls consistently removed 90 percent or more of the influent TCE concentrations.

Full-Scale installations of permeable reactive barriers indicate removal efficiencies of 90 to 95 percent for PCE and TCE, respectively (USEPA, 1999). A former drycleaner site in Germany with initial maximum plume concentration of 20 mg/L for PCE had effluent concentrations for PCE of less than 100 μg/L after treatment with a granular iron permeable reactive barrier. A pilot-scale demonstration at the Borden Aquifer in Ontario, Canada, showed that a permeable reactive barrier reduced TCE concentrations by 90 percent and PCE concentration by 86 percent (USEPA, 1999). Initial site concentrations were 250,000 μg/L for TCE and 43,000 μg/L for PCE.

The River Terrace lower contaminant plume permeable reactive wall would extend across the lower portion of the plume parallel to the Kenai River as shown in Figure S-1. The wall would be approximately 100-feet long by 20-feet deep with an active treatment layer of approximately 6 feet. The length of the treatment wall is based on treating groundwater between approximately MW-8 and MW-6, which is the zone in which PCE and/or VC have been detected above groundwater ACLs. Additional details and assumption used for the permeable reactive wall are provided in the back of Appendix S along with the estimated costs. Because this system functions as only a treatment barrier, the expected restoration time is the same as for intrinsic remediation (10 years). The difference between the reactive wall and intrinsic remediation scenarios is that the reactive wall would prevent contaminants from migrating into the Kenai River during the treatment timeframe.

An additional benefit of the permeable reactive wall is that the wall will be left in-place, therefore continuing to remediate site groundwater after the ACLs have been reached. Since treatment wall operation requires no O&M costs (aside from monitoring), there is no reason to remove the system from the site. Although the iron will eventually deplete, the treatment wall will likely continue to have some beneficial effect long after the 10-year remediation timeframe has been reached.

CERCLA Criteria Scoring Results – Alternative L-C

Criteria	Score
Protection of Human Health and the Environment	No
Compliance With ARARs	Yes
Long-Term Effectiveness and Permanence	5
Reduction in Toxicity, Mobility, and Volume Through Treatment	3
Short-Term Effectiveness	3
Implementability	1
Costs	1.1
Total Score	13.1

Protection of Human Health and the Environment. Alternative L-C is not expected to provide protection of human health and the environment. Contaminant concentrations above those generally considered protective of human health and the environment will still be allowed to migrate off the property if only PCE contamination above the ACL is to be remediated. No detailed risk assessment has been performed to demonstrate that the ACLs are protective of human health and the environment. (Rating = No)

Compliance With ARARs. ARARs compliance for dissolved PCE and its daughter products is expected downgradient of the reactive treatment wall shortly after installation. Intrinsic remediation is expected to adequately address the remaining groundwater and residual phase contaminants within the 10-year timeframe. (Rating = Yes)

Long-Term Effectiveness and Permanence. This alternative removes dissolved PCE from the groundwater, as it passes through the reactive wall, and instrinsic remediation addresses the residual soil contamination. Iron treatment walls have the potential for fouling and clogging through the precipitation of minerals in the groundwater, however, removal or mixing of the fouled material can often be done to rejuvenate the wall. This could range from as frequently as every five years in highly mineralized or oxygenated groundwater to a frequency of every 10 to 15 years in less mineralized waters (USEPA, 1998a). The permeable reactive barrier will likely remain operational even after the cleanup activities are terminated. Reductions in groundwater and residual contaminant concentrations are considered permanent. (Rating = 5)

Reduction in Toxicity, Mobility, and Volume Through Treatment. This alternative provides a reduction in toxicity, mobility, and volume of contaminated groundwater passing through the treatment wall. Source area contaminants are addressed only by intrinsic remediation. (Rating = 3)

Short-Term Effectiveness. There should be only minimal additional risks posed to the community or the environment because of this alternative being implemented. However, worker exposure may occur during the reactive treatment wall installation. The reactive iron treatment wall is not an effective short-term technology for addressing on-site contamination; however, it treats groundwater leaving the site to ensure no downgradient migration of the dissolved contamination. (Rating = 3)

Implementability. This alternative has moderate implementability concerns, regarding planning and implementation of PCE treatment wall installation activities. Costs for installation of an iron permeable reactive barrier in the lower contaminant plume area, as with all subsurface construction in a contaminated area, may significantly fluctuate based on:

- The need for dewatering during excavation,
- The means and costs of contaminated groundwater and soil disposal,
- The structural stability of the soils and potential need for excavation support particularly below the water table,
- Underground utilities within the excavation area will need to be temporarily terminated and later reconnected or permanently relocated, and
- Health and safety concerns for construction personnel working in both a contaminated area and an excavation operation simultaneously.

Equipment, materials, and labor for this type of installation are generally available from larger construction firms. However, granular iron suitable for use will need to be purchased and shipped from the Midwest section of the United States. Excavation and placement of the granular iron may be problematic depending on sloughing of trench walls. Implementation of institutional controls and a long-term monitoring plan have a minor contribution to implementability concerns. (Rating = 1)

Cost. The total present-worth cost of Alternative L-C is estimated to range from $508,000 to $1,089,000. Costing details are provided in the back of Appendix S. It was assumed that no operation and maintenance costs would be associated with the reactive treatment wall other than monitoring. On a normalized cost scale (0 to 5), the total present-worth cost of Alternative L-C earned a rating of 1.1. (Rating = 1.1)

Alternative L-D: Air Sparging Curtain

Description. This alternative would involve injecting air into the contaminated groundwater at the lower portion of the lower contaminant plume, creating an underground stripper that removes contaminants through volatilization. This process is designed to operate at high airflow rates in order to effect volatilization (as opposed to the lower airflow rates used to stimulate biodegradation). Air sparging is usually operated in tandem with soil vapor extraction (SVE) systems that capture volatile contaminants stripped from the saturated zone. Air sparging is a full-scale technology. If necessary, activated carbon can be used to control emissions from an SVE system, although monitoring and dispersion modeling are often sufficient to assess risk to human health.

The target contaminant groups for air sparging are halogenated and nonhalogenated volatile organic compounds and fuels. Air sparging technology is generally applicable to volatile compounds such as PCE, TCE, DCE, and VC.

Monitoring of the groundwater and SVE discharge would be required to document the effectiveness of this alternative and determine if the compliance objectives are being met.

The River Terrace lower contaminant plume air sparging system would contain a sparging curtain across the downgradient edge of the groundwater plume (Figure S-2). This sparge curtain would consist of 20 air-sparging wells connected to blowers housed in a connex or small building. The length of the sparge curtain is based on treating groundwater between approximately MW-8 and MW-6, which is the zone in which PCE and/or VC has been detected above groundwater ACLs. Additional details and assumption used for the sparge curtain are provided at the end of Appendix S along with the estimated costs. Because this system functions as only a treatment barrier, the expected restoration time is the same as for intrinsic remediation (10 years). The difference between the sparge curtain and intrinsic remediation scenarios is that the sparge curtain would prevent contaminants from migrating into the Kenai River during the treatment timeframe.

CERCLA Criteria Scoring Results – Alternative L-D

Criteria	Score
Protection of Human Health and the Environment	No
Compliance With ARARs	Yes
Long-Term Effectiveness and Permanence	3
Reduction in Toxicity, Mobility, and Volume Through Treatment	2
Short-Term Effectiveness	3
Implementability	4
Costs	0.8
Total Score	12.8

Protection of Human Health and the Environment. Alternative L-D is not expected to provide protection of human health and the environment. Contaminant concentrations above those generally considered protective of human health and the environment will still be allowed to migrate off the property if only PCE contamination above the ACL is to be remediated. No detailed risk assessment has been performed to demonstrate that the ACLs are protective of human health and the environment. (Rating = No)

Compliance With ARARs. Compliance with ARARs downgradient of the sparge curtain is expected shortly after remedial system installation. Intrinsic remediation is expected to adequately address the remaining groundwater and residual phase contaminants within the 10-year timeframe. (Rating = Yes)

Long-Term Effectiveness and Permanence. This alternative removes dissolved PCE from the groundwater as it passes through the air sparge curtain, and instrinsic remediation addresses the residual-phase contamination. The hydraulic conductivity values at the site are near the lower limit considered acceptable for air sparging and may limit its effectiveness. Reductions in groundwater and residual-phase contaminant concentrations are considered permanent. (Rating = 3)

Reduction in Toxicity, Mobility, and Volume Through Treatment. This alternative provides a reduction in toxicity, mobility, and volume of contaminated groundwater passing through the air sparge curtain. Air sparging is often not completely effective in the removal of dissolved groundwater contaminants due to air channelization and heterogeneties within the subsurface. Source area contaminants are addressed only by intrinsic remediation. (Rating = 2)

Short-Term Effectiveness. There should be only minimal additional risks posed to the community or the environment because of this alternative being implemented. However, worker exposure may occur during air sparging well installation. Source area contaminants are addressed only by intrinsic remediation. (Rating = 3)

Implementability. This alternative has only minor implementability concerns, primarily regarding planning and implementation of the air sparging wells. Implementation of institutional controls and a long-term monitoring plan have a minor contribution to implementability concerns. (Rating = 4)

Cost. The total present-worth cost of Alternative L-D is estimated to range from $557,000 to $1,194,000. Costing details are provided in the back of Appendix S. On a normalized cost scale (0 to 5), the total present-worth cost of Alternative L-D earned a rating of 0.8. (Rating = 0.8)

Alternative L-E: Extraction Wells with Air Stripping

Description. This alternative uses groundwater extraction wells to capture and direct shallow groundwater flow in the lower contaminant plume to an above ground treatment system. The collected water will be pumped to the surface for treatment with air stripping equipment. Once treated, the water will be returned to a drainage gallery in the alluvial deposits along the Kenai River. For the purpose of this feasibility study, it was assumed that return of treated groundwater to the drainage gallery would be allowed under the hazardous waste regulations. If not allowed, this alternative would effectively be eliminated from consideration.

Air strippers work by introducing air into contaminated water to maximize the air-water interface and volatilize contaminants. Three general types of air strippers are: packed tower, low-profile tray, and diffused bubble air strippers.

In the packed tower air-stripping system, water is pumped to the top of a tower and allowed to trickle over the packing material inside the air stripper. As the water flows downward over the packing, it spreads more thinly, creating a greater surface area. These thin films of water are met by a counter-flow of air blown in from the bottom of the tower. Packed towers are typically tall units that must be stationary for operation. This is the oldest form of air stripping and is still widely used.

Low-profile tray air strippers represent a large percentage of the type of air strippers used at newer remediation sites. The most common type of low-profile air stripper is the tray-type unit in which a shallow layer of water is allowed to flow along one or more trays. Air is blown through hundreds of holes in the bottom of the trays to generate a froth of bubbles that significantly enhance contaminant volatilization. Manufacturers often claim 99 percent removal rates from tray air strippers. Additionally, low-profile systems are much smaller than the packed tower type and are more resistant to media failure due to clogging (iron fouling). They are often configured on a mobile platform with all necessary ancillary devices to provide a complete portable water treatment solution.

Diffused air strippers are typically a series of tanks, or a single tank with a series of baffles. Air is introduced from the bottom by fine bubble diffusers to enhance volatilization. They are often more economical, since diffused air bubble type strippers may be built for a site-specific application using locally procured components. Such systems are probably less efficient than the prefabricated, packed tower or low profile type systems.

Monitoring of the groundwater, air stripper and water discharges would be required to document the effectiveness of this alternative. Activated carbon can be used to control emissions from an air stripping system, although monitoring and dispersion modeling is often sufficient to assess risk to human health.

The River Terrace lower contaminant plume groundwater extraction system would contain a series of eight extraction wells located across the downgradient edge of the groundwater plume (Figure S-3). These extraction wells would pump groundwater to the air stripper building for treatment prior to being discharged back the Kenai River alluvial deposits. The length of the extraction system is based on treating groundwater between approximately MW-8 and MW-6, which is the zone in which PCE and/or VC has been detected above groundwater ACLs. Additional details and assumption used for the extraction system are provided in the back of Appendix S along with the estimated costs. Because this system functions as only a treatment barrier, the expected restoration time is the same as for intrinsic remediation (10 years). The difference between the extraction system and intrinsic remediation scenarios is that the extraction system would prevent contaminants from migrating into the Kenai River during the treatment timeframe.

CERCLA Criteria Scoring Results – Alternative L-E

Criteria	Score
Protection of Human Health and the Environment	No
Compliance With ARARs	Yes
Long-Term Effectiveness and Permanence	4
Reduction in Toxicity, Mobility, and Volume Through Treatment	2
Short-Term Effectiveness	2
Implementability	3
Costs	0.7
Total Score	11.7

Protection of Human Health and the Environment. Alternative L-E is not expected to provide protection of human health and the environment. Contaminant concentrations above those generally considered protective of human health and the environment will still be allowed to migrate off the property if only PCE contamination above the ACL is to be remediated. No detailed risk assessment has been performed to demonstrate that the ACLs are protective of human health and the environment. (Rating = No)

Compliance With ARARs. With the capture and remediation of dissolved PCE collected by the extraction wells, Alternative L-E would meet ARARs downgradient of the groundwater extraction system. Intrinsic remediation is expected to adequately address the remaining groundwater and residual phase contaminants within the 10-year timeframe. (Rating = Yes)

Long-Term Effectiveness and Permanence. This system is intended to intercept the flow of contaminants into the Kenai River. However, some escapement of groundwater is expected to occur between the extraction wells. Air strippers provide one of the most aggressive and controllable methods of treating contaminated water, and they are particularly effective at volatilizing the types of chemical contaminants found at this site. Reductions in groundwater contaminant concentrations are considered permanent. (Rating = 4)

Reduction in Toxicity, Mobility, and Volume Through Treatment. This alternative provides a reduction in toxicity, mobility, and volume of contaminated groundwater collected by the extraction wells. Source area contaminants are addressed only by intrinsic remediation. (Rating = 2)

Short-Term Effectiveness. There should be only minimal risks posed to the community or the environment because of this alternative being implemented. Volatilization and discharge of vapors to the atmosphere should not represent an unacceptable risk. However, worker exposure may occur during groundwater extraction well installation. The use of extraction wells will not be as effective as a permeable barrier in preventing the flow of contaminated groundwater towards the Kenai River. (Rating = 2)

Implementability. Groundwater extraction well installation is commonly performed and has only minor implementability concerns. The materials necessary for the air stripper system are available from a vendor in Oregon and can readily be shipped to Kenai. Additional materials and labor can be obtained locally for drilling, trenching, and system installation. However, this alternative, unlike the other alternatives, may contain significant regulatory issues and costs associated with the above ground treatment and discharge of treated wastewater -- re-injection to shallow groundwater or, especially, into a storm water or sanitary sewer system. If above ground treatment of the groundwater

Reduction in Toxicity, Mobility, and Volume Through Treatment. This alternative provides a reduction in toxicity, mobility, and volume of contaminated groundwater passing through the HRC injection curtain. An HRC injection grid is used to address source area contaminants. (Rating = 4)

Short-Term Effectiveness. There should be no additional risks posed to the community or the environment because of this alternative being implemented. However, worker exposure may occur during HRC injection well installation. This is an active remedial technology resulting in an aggressive removal of dissolved PCE. (Rating = 4)

Implementability. This alternative has a couple of implementability concerns. Numerous HRC injection points are required to ensure complete coverage of the contaminated area, and the HRC must be replaced on a frequent basis. Biological treatment alternatives also require specific environmental site conditions and microorganisms for them to be effective. Re-oxygenation of the treated groundwater is required to prevent potential impacts to the Kenai River. Implementation of a long-term monitoring plan has a minor contribution to implementability concerns. (Rating = 2)

Cost. The total present-worth cost of Alternative L-F is estimated to range from $657,000 to $1,409,000. Costing details are provided at the end of Appendix S. On a normalized cost scale (0 to 5), the total present-worth cost of Alternative L-F earned a rating of 0.0; it is the most expensive alternative evaluated. (Rating = 0.0)

S.3 ANALYSIS OF ALTERNATIVES FOR UPPER CONTAMINANT PLUME

In this section, each of the six remedial alternatives for the upper contaminant plume is evaluated in detail, using the numerical scores presented in Table S-2. Conceptual designs and cost estimates for each remedial alternative are provided at the end of Appendix S.

Alternative U-A: No Action

Alternative U-A, the no action alternative, is used as a baseline to reflect current conditions without remediation. This alternative is used for comparison with each of the other alternatives. Although natural processes may result in reduction of contaminant concentrations to acceptable levels over time, this alternative does not include any long-term monitoring, modeling, or treatability studies to evaluate the effectiveness of these processes. This alternative is applicable to all contaminant types found in water, soil, and wetland environments.

CERCLA Criteria Scoring Results – Alternative U-A

Criteria	Score
Protection of Human Health and the Environment	No
Compliance With ARARs	No
Long-Term Effectiveness and Permanence	0
Reduction in Toxicity, Mobility, and Volume Through Treatment	0
Short-Term Effectiveness	1
Implementability	5
Costs	5
Total Score	11

Protection of Human Health and the Environment. Alternative U-A provides no control of exposure to the contaminated soil, groundwater, and surface water and no reduction in risk to human health and the environment posed by the site contamination. It also allows for continued migration of the contaminant plume and further degradation of the groundwater. (Rating = No)

Compliance With ARARs. Because no action is taken, Alternative U-A would not comply with ARARs such as the site specific ACL for PCE and its daughter products in soil and water. (Rating = No)

Long-Term Effectiveness and Permanence. This alternative includes no controls for exposure and no long-term management measures. Under this alternative, all current and potential future risks would remain. (Rating = 0)

Reduction in Toxicity, Mobility, and Volume Through Treatment. This alternative provides no reduction in toxicity, mobility, or volume of the contaminated soil or groundwater through treatment. (Rating = 0)

Short-Term Effectiveness. There would be no additional risks posed to the community, the workers, or the environment because of this alternative being implemented. However, release of contaminants from the subsurface environment to the Kenai River would continue for the foreseeable future. (Rating = 1)

Implementability. There are no implementability concerns posed by this remedy since no action would be taken. (Rating = 5)

Cost. The total present-worth cost of Alternative U-A is estimated to be $0 since there would be no action. (Rating = 5)

Alternative U-B: Intrinsic Remediation

Description. Intrinsic remediation would not involve active remedial technologies. Groundwater, soil, and surface water would be left in their current state, and natural processes would continue to reduce contaminant concentrations. Dilution, adsorption, volatilization, precipitation, complexation, and biological degradation of the contaminants occur in the groundwater and subsurface soils. Intrinsic remediation would allow these processes to continue to occur as they have in the past, without disturbances potentially caused by implementation of active remedial technologies.

Intrinsic remediation is not the same as "no action." Implementation of this alternative requires modeling and evaluation of contaminant attenuation. This alternative would also include a groundwater and surface-water monitoring program to confirm predicted results. The water samples would be collected periodically and analyzed for the contaminants of concern. The data generated would be used to monitor degradation and provide an early indication of possible impacts, allowing time for remedial response to mitigate the impact. Intrinsic remediation involves no excavation or handling of contaminated materials. Therefore, site workers are not at risk during implementation and there is no risk to the community from extraction and treatment of contaminated water.

The target contaminants for intrinsic remediation are usually nonhalogenated volatile and semivolatile organics and fuel hydrocarbons. Halogenated volatiles and semivolatiles can also be allowed to naturally attenuate, although the process may be less effective and may only be applicable to some compounds within these contaminant groups. The primary contaminants of concern at the River Terrace site are halogenated volatiles, which are more difficult to treat via intrinsic remediation.

PCE concentrations in groundwater within the property boundary are above the site-specific ACL. Because of the suspected source of contamination underneath the former dry cleaner building and its unknown quantity, it was assumed that site contamination will remain above the site specific ACLs for approximately another 15 years under naturally attenuating conditions. A detailed cost evaluation for this alternative is presented in the back of Appendix S.

CERCLA Criteria Scoring Results – Alternative U-B

Criteria	Score
Protection of Human Health and the Environment	No
Compliance With ARARs	Yes
Long-Term Effectiveness and Permanence	1
Reduction in Toxicity, Mobility, and Volume Through Treatment	1
Short-Term Effectiveness	2
Implementability	5
Costs	2.6
Total Score	11.6

Protection of Human Health and the Environment. Alternative U-B is not expected to provide protection of human health and the environment. Contaminant concentrations above those generally considered protective of human health and the environment will be allowed to persist on the property and may continue to migrate off the property, if only PCE contamination above the ACL is remediated. No detailed risk assessment has been performed to demonstrate that the ACLs are protective of human health and the environment. (Rating = No)

Compliance with ARARs. This alternative would meet site specific ACLs for groundwater exiting the property, but groundwater concentrations within the property boundary remain above the ACLs. Over time, intrinsic remediation is expected to reduce site contaminant concentrations below the ACLs. (Rating = Yes)

Long-Term Effectiveness and Permanence. Intrinsic remediation is effective in the long-term; however, there is continued risk of contaminant migration. (Rating = 1)

Reduction in Toxicity, Mobility, and Volume Through Treatment. By intrinsic remediation and institutional controls, Alternative U-B would provide a reduction in risk to human health and the environment posed by site contamination. However, potential exposure to vapor accumulation in underground utilities is a risk. No mitigation of the volatilized PCE vapors observed adjacent to the former dry cleaner building is provided by the alternative. (Rating = 1)

Short-Term Effectiveness. There would be no additional risks posed to the community or the environment because of this alternative being implemented. The potential for contaminant exposure remains within the property boundaries. (Rating = 2)

Implementability. This alternative has low implementability concerns; only a long-term monitoring plan must be implemented. (Rating = 5)

Cost. The total present-worth cost of Alternative U-B is estimated to range from \$314,000 to \$674,000. Costing details are provided in this Appendix S. On a normalized cost scale (0 to 5), the total present-worth cost of Alternative U-B earned a rating of 2.6. (Rating = 2.6)

Alternative U-C: Permeable Reactive Barrier

Description. A permeable reactive treatment wall is installed across the flow path of the upper contaminant plume, allowing the water portion of the plume to passively move through the wall (treatment wall portion of Figure S-5). This type of barrier allows the passage of water while removing dissolved contaminants by physical, chemical, and/or biological processes. The mechanically simple barriers may contain such agents as zero-valent iron, chelators (ligands selected for their specificity for a given metal), sorbents, microbes, and others. Successful application of this technology requires sufficient characterization of the groundwater hydrology and contamination.

An iron treatment wall consists of iron granules or other iron-bearing minerals for the treatment of chlorinated contaminants such as PCE, TCE, DCE, and VC. As the iron is oxidized, a chlorine atom is removed from the compound by one or more reductive dechlorination mechanisms, using electrons supplied by the oxidation of iron. The iron granules are dissolved by the process, but the metal disappears so slowly that the remediation barriers can be expected to remain effective for many years, possibly even decades. The effectiveness of the iron treatment varies depending on the contaminant properties. The reaction rates for TCE and PCE are more rapid than the reaction rates for DCE and VC (USEPA, 1998a). Typically, permeable reactive barriers are designed to provide adequate residence time for the degradation of the parent compound and all toxic intermediate products that are produced. It is estimated that an iron treatment wall will result in complete conversion of the site contaminants to non-toxic compounds, however, bench-scale studies will be required to predict system performance (verify degradation rates) and provide data for field design. Iron treatment wall vendors have also stated that downgradient impacts, such as iron staining, from the installation of an iron treatment wall are unlikely as this has not been observed at any of the sites where the technology has been applied (Personal Communication, EnviroMetal Technologies).

In situ treatment walls have several advantages over other treatment methods. *In situ* technologies do not require exposing contamination to the surface for remediation. Operation and maintenance costs are minimal; no energy input is required, because the treatment occurs under the natural groundwater gradient. The only operation and maintenance (O&M) costs associated with this technology would be periodic replacement or rejuvenation of the reaction medium, which may be necessary if the media becomes plugged or its reactive surface capacity is diminished. A permeable reactive barrier installed at the Borden Aquifer, Ontario, Canada, showed only minimal amounts of calcium carbonate precipitate in the wall after five years of operation and it was estimated that the wall should remain active for at least another five years (USEPA, 1999).

Vidic and Pohland (1996) present a summary on the status of treatment wall technology. Examples of pilot-, field-, and commercial-scale treatment walls for chlorinated organic compounds are provided in this summary. Most of the systems reviewed included slurry walls (or other impermeable barriers) on both sides of a permeable treatment wall. The treatment walls were charged with a range of sand/iron mixtures (from 100 percent granular iron to a minimum of 22 percent [by weight] iron filings mixed with 78 percent sand). Treatment wall widths varied from 0.6 meters to 3.2 meters and groundwater residence times within the wall varied between 2 days and 15 days. Influent TCE concentrations ranged from 0.05 mg/L to 250 mg/L; the walls consistently removed 90 percent or more of the influent TCE concentrations.

Full-Scale installations of permeable reactive barriers indicate removal efficiencies of 90 to 95 percent for PCE and TCE, respectively (USEPA, 1999). A former drycleaner site in Germany with initial maximum plume concentration of 20 mg/L for PCE had effluent concentrations for PCE of less than 100 µg/L after treatment with a granular iron permeable reactive barrier. A pilot-scale demonstration at the Borden Aquifer in Ontario, Canada, showed that a permeable reactive barrier reduced TCE concentrations by 90 percent and PCE concentration by 86 percent (USEPA, 1999). Initial site concentrations were 250,000 µg/L for TCE and 43,000 µg/L for PCE.

The RTRVP upper contaminant plume permeable reactive wall would run parallel to the northwest and northeast sides of the former dry cleaner building. The wall would be approximately 100-feet long by 20-feet deep with an active treatment layer of approximately 7 feet. The length of the treatment wall is based on treating groundwater near MW-16, which is the area in which PCE has been detected above the groundwater ACL. Additional details and assumptions used for the permeable reactive wall are provided in this Appendix S along with the estimated costs. An intermediate restoration timeframe of 15 years is expected for this technology. Treatment wall installation is expected to occur in the most contaminated section of the upper plume; therefore, this system functions as a treatment barrier with limited source removal.

An additional benefit of the permeable reactive wall is that the wall will likely be left in-place, and therefore, continuing to remediate site groundwater even after the ACLs have been reached. Since treatment wall operation requires no O&M costs, there is no reason to remove the system from the site. Although the iron will eventually deplete, the treatment wall will likely continue to have some beneficial effect after the 10-year remediation timeframe has been reached.

CERCLA Criteria Scoring Results – Alternative U-C

Criteria	Score
Protection of Human Health and the Environment	No
Compliance With ARARs	Yes
Long-Term Effectiveness and Permanence	5
Reduction in Toxicity, Mobility, and Volume Through Treatment	3
Short-Term Effectiveness	3
Implementability	1
Costs	1.9
Total Score	13.9

Protection of Human Health and the Environment. Alternative U-C is not expected to provide protection of human health and the environment. Contaminant concentrations above those generally considered protective of human health and the environment will be allowed to persist on the property and may continue to migrate off the property, if only PCE contamination above the ACL is remediated. No detailed risk assessment has been performed to demonstrate that the ACLs are protective of human health and the environment. (Rating = No)

Compliance With ARARs. ARARs compliance for dissolved PCE and its daughter products is expected downgradient of the reactive treatment wall shortly after installation. Intrinsic remediation is expected to adequately address the remaining groundwater and residual phase contaminants within the 10-year timeframe. (Rating = Yes)

Long-Term Effectiveness and Permanence. This alternative removes dissolved PCE from the groundwater as it passes through the reactive wall, and excavation and instrinsic remediation address the residual soil contamination. Residual soil contamination possibly located under the former dry cleaner building is not addressed by this option. Iron treatment walls have the potential for fouling and clogging through the precipitation of minerals in the groundwater, however, removal or mixing of the fouled material can often be done to rejuvenate the wall. This could range from as frequently as every five years in highly mineralized or oxygenated groundwater to a frequency of every 10 to 15 years in less mineralized waters (USEPA, 1998a). Reductions in groundwater and residual contaminant concentrations are considered permanent. (Rating = 5)

Reduction in Toxicity, Mobility, and Volume Through Treatment. This alternative provides a reduction in toxicity, mobility, and volume of contaminated groundwater passing through the treatment wall. (Rating = 3)

Short-Term Effectiveness. There should be only minimal additional risks posed to the community or the environment because of this alternative being implemented. However, worker exposure may occur during the reactive treatment wall installation. The reactive iron treatment wall is not an effective short-term technology for addressing on-site contamination; however, it treats groundwater leaving the site to ensure no downgradient migration of the dissolved contamination. (Rating = 3)

Implementability. This alternative has moderate implementability concerns, regarding planning and implementation of PCE treatment wall installation activities. Costs for installation of an iron permeable reactive barrier in the upper contaminant plume area, as with all subsurface construction in a contaminated area, may significantly fluctuate based on:

- The need for dewatering during excavation,
- The means and costs of contaminated groundwater and soil disposal,
- The structural stability of the soils and potential need for excavation support particularly below the water table,
- Underground utilities within the excavation area will need to be temporarily terminated and later reconnected or permanently relocated, and
- Health and safety concerns for construction personnel working in both a contaminated area and an excavation operation simultaneously.

Equipment, materials, and labor for this type of installation are generally available from larger construction firms. However, granular iron suitable for use will need to be purchased and shipped from the Midwest section of the United States. Excavation and placement of the granular iron may be problematic depending on sloughing of trench walls. Implementation of institutional controls and a long-term monitoring plan have a minor contribution to implementability concerns. (Rating = 1)

Cost. The total present-worth cost of Alternative U-C is estimated to range from $403,000 to $865,000. Costing details are provided at the end of Appendix S. It was assumed that no operation and maintenance costs would be associated with the reactive treatment wall other than monitoring. On a normalized cost scale (0 to 5), the total present-worth cost of Alternative U-C earned a rating of 1.9. (Rating = 1.9)

Alternative U-D: Air Sparging Grid

Description. This alternative would involve injecting air into the contaminated groundwater in the upper contaminant plume, creating an underground stripper that removes contaminants through volatilization. This process is designed to operate at high airflow rates in order to effect volatilization (as opposed to the lower airflow rates used to stimulate biodegradation). Air sparging is usually operated in tandem with SVE systems that capture volatile contaminants stripped from the saturated zone. The captured vapors are discharged to the atmosphere or treated. If necessary, activated carbon can be used to control emissions from an SVE system, although dispersion modeling and monitoring are often sufficient to prevent risk to human health.

The target contaminant groups for air sparging are halogenated and nonhalogenated volatile organic compounds and fuels. Air sparging technology is generally applicable to volatile compounds such as PCE, TCE, DCE, and VC.

Groundwater pump-and-treat combined with air sparging was used to cleanup PCE and TCE contamination at the Gold Coast Superfund Site in Miami, Florida (USEPA, 1998b). Initial PCE and TCE groundwater concentrations at the site were 100 mg/L and 48 mg/L, respectively. Remediation consisted of five extraction wells operating at a combined flow of 44 gpm or a total of 80 million gallons of water removal over a 4-year period. Groundwater cleanup was achieved in four years after excavation and air-sparging of the DNAPL source areas. A total of 1,961 pounds of TCE and PCE were removed from the site at a total cost of approximately $700,000 or $360 per pound of contaminant removed.

The River Terrace upper contaminant plume air-sparging grid system would consist of a grid of sparging wells across the entire region of the groundwater plume (Figure S-6). This sparging grid would consist of 32 air-sparging wells and 6 VES wells connected to blowers housed in a connex or small building. The air-sparging grid is located on the northwest side of the former dry cleaners building, extending out to approximately MW-25, which is the area in which PCE has been detected above its ACL. Six passive ventilation wells installed underneath the floor of the former dry cleaner building will assist in removing PCE soil contamination from beneath the building. This Appendix includes additional details and the estimated cost for implementing this alternative. Because this alternative includes sparging and vapor extraction of the source contamination area, it is expected that the restoration time will be shorter than that for intrinsic remediation. A restoration time of five years was assumed for the feasibility study.

Monitoring of the groundwater chemistry and contaminant concentrations would be required to document the effectiveness of this alternative and determine if the compliance objectives are being met.

CERCLA Criteria Scoring Results – Alternative U-D

Criteria	Score
Protection of Human Health and the Environment	No
Compliance With ARARs	Yes
Long-Term Effectiveness and Permanence	4
Reduction in Toxicity, Mobility, and Volume Through Treatment	4
Short-Term Effectiveness	3
Implementability	4
Costs	0.0
Total Score	15.0

Protection of Human Health and the Environment. Alternative U-D is not expected to provide protection of human health and the environment. Contaminant concentrations above those generally considered protective of human health and the environment will be allowed to persist on the property and may continue to migrate off the property, if only PCE contamination above the ACL is remediated. No detailed risk assessment has been performed to demonstrate that the ACLs are protective of human health and the environment. (Rating = No)

Compliance With ARARs. With aggressive remediation of dissolved and residual phase PCE and other contaminants, Alternative U-D is expected to meet ARARs within the 5-year remediation timeframe. However, the quantity of contamination that exists underneath the building is unknown and the actual remediation timeframe could be longer. (Rating = Yes)

Long-Term Effectiveness and Permanence. This alternative removes dissolved and residual phase PCE from the groundwater and soil, as the injected air passes through the groundwater into the vadose zone. Sparging wells are placed in the contaminant source area to assist the remediation process. The hydraulic conductivity values at the site are considered acceptable for air sparging and should not limit its effectiveness. Reductions in groundwater and residual-phase contaminant concentrations are considered permanent. (Rating = 4)

Reduction in Toxicity, Mobility, and Volume Through Treatment. This alternative provides a reduction in toxicity, mobility, and volume of contaminated groundwater and soil. Air sparging is often not completely effective in the removal of dissolved groundwater contaminants due to air channelization and heterogeneties within the subsurface. Sparging wells are placed in a grid pattern across the entire contaminant area in order to address source area contaminants. Mitigation of the volatilized PCE vapors observed adjacent to the former dry cleaner building and mitigation of potential exposure from vapor accumulation in underground utilities along the Sterling Highway is provided by this alternative. (Rating = 4)

Short-Term Effectiveness. There should be minor additional risks posed to the community or the environment because of the volatilization of contaminants. Worker exposure may occur during air sparging well installation. This is an active remedial technology resulting in an aggressive and rapid removal of dissolved PCE. (Rating = 3)

Implementability. This alternative has minor implementability concerns, primarily regarding planning and installation of the air sparging wells. Planning and implementation of institutional controls and a long-term monitoring plan have a minor contribution to implementability concerns. (Rating = 4)

Cost. The total present-worth cost of Alternative U-D is estimated to range from \$642,000 to \$1,375,000. Costing details are provided in the back of Appendix S. On a normalized cost scale (0 to 5), the total present-worth cost of Alternative U-D earned a rating of 0.0; it is the most expensive alternative evaluated. (Rating = 0.0)

Alternative U-E: In Situ Biological Treatment

Description. This alternative would involve injecting sodium lactate or HRC into the contaminated groundwater in the upper contaminant plume, creating a suitable anaerobic environment for removal of contaminants through biological activity. Once anaerobic conditions are achieved, the lactic acid is converted to hydrogen through biodegradation, this hydrogen can then be used by reductive dehalogenators that are capable of dechlorinating compounds such as PCE and its daughter products. However, other competing microbial processes (i.e., methanogenesis) may also consume the hydrogen.

Although anaerobic conditions favor PCE and TCE degradation, some daughter products like DCE and VC can be degraded faster under aerobic conditions. Given that VC accumulation is of particular concern due to its high toxicity, optimal results for chlorinated compound remediation may also require the addition of oxygen to the groundwater at a point downgradient of the lactate injection to promote aerobic biodegradation of VC.

Because the sodium lactate and HRC are consumed during the dechlorination process, these materials must be replenished for the chlorinated compound remediation to continue. Sodium lactate may require weekly applications whereas HRC is expected to last for several months due to its time-release feature. For this reason, it is assumed that HRC would be preferred method of application.

An HRC field demonstration conducted at a dry cleaning site in Wisconsin showed that the PCE plume mass declined by over 70 percent, and the DCE plume mass increased by over 3,500 percent 253 days after adding 240 pounds of HRC. Increases in the VC concentration were also observed although specific concentrations were not reported (regenesis.com/hrctb311.htm). Other case studies reported by Regenesis (the HRC vendor) showed similar results with declines in the PCE/TCE plume mass and increases in the DCE and VC plume masses.

The method of HRC application for the upper contaminant plume at River Terrace consists of an HRC injection grid. This HRC grid would be constructed using 90 HRC injection points during the first year, with 20 new HRC injection points being installed annually for reapplication at the remaining contaminated hot spots (Figure S-7). Additionally injections of liquid HRC or sodium lactate to the soils underneath the building will be performed to promote biodegradation of the PCE contamination found under the building. This Appendix S includes additional details and the estimated cost for implementing this alternative. Because this alternative includes injection of HRC into the source contamination area, it is expected that the restoration time will be shorter than that for intrinsic remediation. A restoration time of five years was assumed for the feasibility study.

Monitoring of the groundwater chemistry and contaminant concentrations would be required to document the effectiveness of this alternative and determine if the compliance objectives are being met.

CERCLA Criteria Scoring Results – Alternative U-E

Criteria	Score
Protection of Human Health and the Environment	No
Compliance With ARARs	Yes
Long-Term Effectiveness and Permanence	4
Reduction in Toxicity, Mobility, and Volume Through Treatment	4
Short-Term Effectiveness	4
Implementability	3
Costs	1.5
Total Score	16.5

Protection of Human Health and the Environment. Alternative U-E is not expected to provide protection of human health and the environment. Contaminant concentrations above those generally considered protective of human health and the environment will be allowed to persist on the property and may continue to migrate off the property, if only PCE contamination above the ACL is remediated. No detailed risk assessment has been performed to demonstrate that the ACLs are protective of human health and the environment. (Rating = No)

Compliance With ARARs. With the remediation of dissolved PCE downgradient of the HRC injection area, Alternative U-E would meet the ARARs in the near term. However, additional treatment may be required if unacceptable increases in the DCE or VC concentrations occur. In situ biological remediation of the source area contamination is expected to adequately address the remaining groundwater and residual phase contaminants within the 5-year timeframe. However, the quantity of contamination that exists underneath the building is unknown and the actual remediation timeframe could be longer. (Rating = Yes)

Long-Term Effectiveness and Permanence. This alternative removes dissolved PCE from the groundwater and soil through in-situ biological treatment as the HRC is dissolved and carried with the groundwater. Frequent applications of the HRC are required for continued effectiveness. Reductions in groundwater and residual-phase contaminant concentrations are considered permanent. However, there is a possibility for temporary accumulations of breakdown products, such as DCE and VC, to occur. (Rating = 4)

Reduction in Toxicity, Mobility, and Volume Through Treatment. This alternative provides a reduction in toxicity, mobility, and volume of contaminated groundwater and soil. An HRC injection grid is used to address the source area contaminants. In situ bioremediation also offers at least partial mitigation of the volatilized PCE vapors observed adjacent to the former dry cleaner building and partial mitigation of potential exposure from vapor accumulation in underground utilities along the Sterling Highway. (Rating = 4)

Short-Term Effectiveness. There should be no additional risks posed to the community or the environment because of this alternative being implemented. However, worker exposure may occur during HRC injection well installation. This is an active remedial technology resulting in an aggressive removal of contaminants. (Rating = 4)

Implementability. This alternative has a couple of implementability concerns. Numerous HRC injection points are required to ensure complete coverage of the contaminated area and frequent applications of the HRC are required for continued effectiveness. The remediation area will need to remain accessible for a drilling rig to install the HRC material. Biological treatment alternatives also require specific environmental site conditions and microorganisms for them to be effective. Implementation of a long-term monitoring plan has a minor contribution to implementability concerns. (Rating = 3)

Cost. The total present-worth cost of Alternative U-E is estimated to range from $443,000 to $949,000. Costing details are provided in the back of this Appendix S. On a normalized cost scale (0 to 5), the total present-worth cost of Alternative U-E earned a rating of 1.5. (Rating = 1.5)

Alternative U-F: Source Excavation and Groundwater Treatment

Excavation Description. This alternative would involve excavating upper plume contaminated soils adjacent to the former dry cleaner building, *ex situ* treatment of contaminated soils in treatment cells, and backfilling part of the excavation with a granular iron treatment system. Excavation and *ex situ* treatment of contaminated soil is a proven remedial technology.

This alternative would include the design, construction, and operation of a soil treatment cell. Soils in the treatment cell will be remediated by SVE. Blowers will aerate the soil, causing the VOCs (e.g., PCE and its degradation products) to volatilize. Vapors may be released to the atmosphere or treated with activated carbon. The soil treatment cell process is a full-scale process that has been used at numerous sites to remediate contaminated soil. This technology was used to successfully remediate contaminated soil removed during the October 1997 and June 1998 excavations at the RTRVP site. No soil monitoring would be performed as part of this alternative, except for performance monitoring to document the removal of contaminated soil from the excavation and performance monitoring of the soil treatment process.

The target contaminant groups for SVE are halogenated and nonhalogenated volatile organic compounds, and fuel hydrocarbons. SVE is a full-scale technology that has been applied at numerous sites for *in situ* and *ex situ* treatment of volatile contaminants.

As an *ex situ* remedy, the excavation associated with this alternative poses a potential health and safety risk to site workers through skin contact and air emissions. Personal protective equipment, at a level commensurate with the contaminants involved would be required during excavation operations.

Permeable Reactive Treatment Wall Description. A permeable reactive treatment wall is installed across the flow path of the contaminant plume, allowing the water portion of the plume to passively move through the wall. This type of barrier allows the passage of water while removing dissolved contaminants by physical, chemical, and/or biological processes. The mechanically simple barriers may contain such agents as zero-valent iron, chelators (ligands selected for their specificity for a given metal), sorbents, microbes, and others. Successful application of this technology requires sufficient characterization of the groundwater hydrology and contamination.

An iron treatment wall consists of iron granules or other iron-bearing minerals for the treatment of chlorinated contaminants such as PCE, TCE, DCE, and VC. As the iron is oxidized, a chlorine atom is removed from the compound by one or more reductive dechlorination mechanisms, using electrons supplied by the oxidation of iron. The iron granules are dissolved by the process, but the metal disappears so slowly that the remediation barriers can be expected to remain effective for many years, possibly even decades. The effectiveness of the iron treatment varies depending on the contaminant properties. The reaction rates for TCE and PCE are more rapid than the reaction rates for DCE and VC (USEPA, 1998a). Typically, permeable reactive barriers are designed to provide adequate residence time for the degradation of the parent compound and all toxic intermediate products that are produced. It is estimated that an iron treatment wall will result in complete conversion of the site contaminants to non-toxic compounds, however, bench-scale studies will be required to predict system performance (verify degradation rates) and provide data for field design. Iron treatment wall vendors have also stated that downgradient impacts, such as iron staining, from the installation of an iron treatment wall are unlikely as this has not been observed at any of the sites where the technology has been applied (Personal Communication, EnviroMetal Technologies).

In situ treatment walls have several advantages over other treatment methods. *In situ* technologies do not require exposing contamination to the surface for remediation. Operation and maintenance costs are minimal; no energy input is required, because the treatment occurs under the natural groundwater gradient. The only operation and maintenance (O&M) costs associated with this technology would be periodic replacement or rejuvenation of the reaction medium, which may be necessary if the media becomes plugged or its reactive surface capacity is diminished. A permeable reactive barrier installed at the Borden Aquifer, Ontario, Canada, showed only minimal amounts of calcium carbonate precipitate in the wall after five years of operation and it was estimated that the wall should remain active for at least another five years (USEPA, 1999).

Vidic and Pohland (1996) present a summary on the status of treatment wall technology. Examples of pilot-, field-, and commercial-scale treatment walls for chlorinated organic compounds are provided in this summary. Most of the systems reviewed included slurry walls (or other impermeable barriers) on both sides of a permeable treatment wall. The treatment walls were charged with a range of sand/iron mixtures (from 100 percent granular iron to a minimum of 22 percent [by weight] iron filings mixed with 78 percent sand). Treatment wall widths varied from 0.6 meters to 3.2 meters and groundwater residence times within the wall varied between 2 days and 15 days. Influent TCE concentrations ranged from 0.05 mg/L to 250 mg/L; the walls consistently removed 90 percent or more of the influent TCE concentrations.

Full-Scale installations of permeable reactive barriers indicate removal efficiencies of 90 to 95 percent for PCE and TCE, respectively (USEPA, 1999). A former drycleaner site in Germany with initial maximum plume concentration of 20 mg/L for PCE had effluent concentrations for PCE of less than 100 μg/L after treatment with a granular iron permeable reactive barrier. A pilot-scale demonstration at the Borden Aquifer in Ontario, Canada, showed that a permeable reactive barrier reduced TCE concentrations by 90 percent and PCE concentration by 86 percent (USEPA, 1999). Initial site concentrations were 250,000 μg/L for TCE and 43,000 μg/L for PCE.

Application of the Technology at the RTRVP site: The excavation will encompass an area of approximately 3,300 square feet adjacent to the former dry cleaner building, with an average depth of 20 feet (Figure S-8). Based on soil sample results, the 12 to 14 feet of soil above the water table is uncontaminated, and the bottom 6 to 8 feet of soil (below the water table) is considered contaminated. The contaminated material will be placed into a 100'x45'x5' SVE remediation cell located near the previous RTRVP remediation cells.

Installation of the granular iron treatment system at the RTRVP upper contaminant plume will occur when backfilling the excavation below the water table. Approximately 300 CY of a 50/50 mix of sand and reactive iron material will be placed adjacent to the west/northwest side of the old dry cleaning building, resulting in a sand/iron wall measuring approximately 10 feet wide by 100 feet long by 8 feet deep. This treatment wall will treat any remaining contaminants that may flow from beneath the facility. After the wall is placed, uncontaminated soil from above the water table will be returned to the hole and additional clean backfill material will be used to finish filling the excavation.

The advantage of this combination of technologies includes the direct removal of contaminated soils from a portion of the source area and continued groundwater treatment for any possible remaining source contamination. Disadvantages include higher costs, and the possibility of missing a large portion of the source contamination that may be below the existing facility or that may have penetrated deeper into the till layer. An additional benefit of the permeable reactive wall is that the wall will be permanently left in-place, and therefore, continuing to remediate site groundwater even after the site specific ACLs have been reached. Since treatment wall operation requires no O&M costs, there is no reason to remove the system from the site. Although the iron will eventually deplete, the treatment wall will likely continue to have some beneficial effect after the 5-year remediation timeframe has been reached.

Implementation of this alternative will also involve groundwater and surface water monitoring and institutional controls. It is estimated that this monitoring will be required for a period of 10 years, but the actual monitoring period may vary depending on how soon the remedial action objectives are met. Although some variations in monitoring techniques may occur between alternatives, the costs will not vary much between the options.

Appendix S includes additional details and the estimated cost for implementing this alternative. Because this alternative includes removal of contaminated soils, it is expected that the restoration time will be shorter than that for intrinsic remediation. A restoration time of five years was assumed for the feasibility study.

CERCLA Criteria Scoring Results – Alternative U-F

Criteria	Score
Protection of Human Health and the Environment	No
Compliance With ARARs	Yes
Long-Term Effectiveness and Permanence	5
Reduction in Toxicity, Mobility, and Volume Through Treatment	4
Short-Term Effectiveness	3
Implementability	1
Costs	0.7
Total Score	13.7

Protection of Human Health and the Environment. Alternative U-F is not expected to provide protection of human health and the environment. Contaminant concentrations above those generally considered protective of human health and the environment will be allowed to persist on the property and may continue to migrate off the property, if only monitoring data indicates that remedial objectives are not being met or will not be achieved within the desired timeframe then additional corrective measures or modifications may be required.

For the purposes of the feasibility study it was assumed that none of the excavated soils, removed groundwater, or investigation-derived wastes (IDW) would be classified as a RCRA hazardous waste. The EPA has provided a Contained-in Determination for investigation-derived wastes that have been or will be generated during remedial investigation work associated with the River Terrace site. This contained-in determination applies only to those wastes that comply with the Contained-in levels stated in the USEPA letter for the River Terrace site and that are to be disposed of on the RTRVP property. Other conditions contained in this letter must also be complied with for the contained-in determination to be applicable. The EPA will must also agree that wastes generated after the contained-in determination can still fall under its classification. To be exempt from the RCRA Subtitle C regulations, soils must also be shown not to exhibit any hazardous characteristic under 40 CFR Part 261 Subpart C.

If the assumption that excavated soils or removed groundwater are not classified as RCRA hazardous waste turns out to be incorrect, it could result in a major increase in the cost estimate for some alternatives depending on the amount of waste generated but especially with pump-and-treat alternatives.

S.5 SUMMARY

S.5.1 Lower Contaminant Plume

The feasibility study component of this report for the lower contaminant plume evaluated six alternative remediation technologies potentially appropriate for the site. All of the remedial alternatives were determined to not be protective of human health and the environment, since the ACL are above concentrations that are generally accepted to be protective of human health and the environment. Estimated costs include 10 years of operation and maintenance and 10 years of monitoring for the three barrier type alternatives (L-C through L-E) and the Intrinsic Remediation Alternative (L-B). Estimated costs include 5 years of operation and maintenance and 5 years of monitoring for the one alternative (L-F) that includes treatment of the contaminant source area. Each alternative and the estimated cost to implement it are listed below:

- L-B Intrinsic Remediation (for comparison) $275K to $590K
- L-C Permeable reactive barrier $508K to $1,089K
- L-D In-situ air sparging curtain $557K to $1,194K
- L-E Extraction wells with air stripping $569K to $1,220K
- L-F In-situ biological treatment $657K to $1,409K

Any of the alternatives selected will require institutional controls to prohibit installation of a well as a drinking water source or other intrusive activities that would not be appropriate during site remediation.

S.5.2 Upper Contaminant Plume

The feasibility study component of this report for the upper contaminant plume evaluated six alternative remediation technologies potentially appropriate for the site. All of the remedial alternatives were determined to not be protective of human health and the environment, since the ACL are above concentrations that are generally accepted to be protective of human health and the environment. Five remaining technologies were determined to be viable, and cost estimates (total present cost) were developed for each of these alternatives. Estimated costs include 15 years of operation and maintenance and 15 years of monitoring for the Intrinsic Remediation Alternative (U-B) and the Permeable Reactive Barrier Alternative (U-C). Estimated costs include 5 years of operation and maintenance and 5 years of monitoring for the three alternatives (U-D through U-F) that included treatment of the contaminant source area. Each alternative and the estimated cost to implement it are listed below:

- U-B Intrinsic Remediation $314K to $674K
- U-C Permeable Reactive Barrier $403K to $865K
- U-D In-situ air sparging grid $642K to $1,375K
- U-E In-situ biological treatment $443K to $949K
- U-F Source Excavation and Treatment $557K to $1,194K

Any of the alternatives selected will require institutional controls to prohibit installation of a well as a drinking water source or other intrusive activities that would not be appropriate during site remediation.

Table S-3
Comparative Analysis of Remedial Alternatives for Alternative Cleanup Level
Lower Contaminant Plume at River Terrace

Remedial Alternative		Effectiveness Scores						Cost					
Identifier	Dissolved PCE	Protection of Human Health and the Environment	Compliance with ARARs	Long-term Effectiveness and Permanence	Reduction in Toxicity, Mobility, and Volume through Treatment	Short-term Effectiveness	**Implementability**	Cost Score	Estimated Present Worth (in thousands of dollars)	**Total Score**	**Effectiveness to Cost Quotients**	**Estimated Restoration Time (Years)**	**Confidence that Remedial Alternative will meet RAO**
L-A	No Action	No	No	0	0	1	5	5.0	$0	11	NA	NA	NA
L-B	Intrinsic Remediation	No	No	1	1	2	5	2.9	$275 $590	11.9	14.55 6.78	10	Low
L-C	Permeable Reactive Barrier	No	Yes	5	3	3	1	1.1	$508 $1,089	13.1	21.65 10.10	10	High
L-D	In-Situ Air Sparging Curtain	No	Yes	3	2	3	4	0.8	$557 $1,194	12.8	14.36 6.70	10	Moderate
L-E	Extraction Wells with Air Stripping	No	Yes	4	2	2	3	0.7	$569 $1,220	11.7	14.06 6.56	10	Moderate
L-F	In-Situ Biological Treatment	No	Yes	4	4	4	2	0.0	$657 $1,409	14.0	18.26 8.52	5	Moderate

Notes: The ability of a remedial alternative to meet remedial action objectives is dependant on site specific conditions that may vary from site to site.
The confidence levels indicated assume that site conditions are acceptable for the application of the remedial alternative.

Table S-3 (Cont.)
Comparative Analysis of Remedial Alternatives for Alternate Cleanup Level
Upper Contaminant Plume at River Terrace

Remedial Alternative		Effectiveness Scores						Cost					
Identifier	Dissolved PCE	Protection of Human Health and the Environment	Compliance with ARARs	Long-term Effectiveness and Permanence	Reduction in Toxicity, Mobility, and Volume through Treatment	Short-term Effectiveness	**Implementability**	Cost Score	Estimated Present Worth (in thousands of dollars)	**Total Score**	**Effectiveness to Cost Quotients**	**Estimated Restoration Time (Years)**	**Confidence that Remedial Alternative will meet RAO**
U-A	No Action	No	No	0	0	1	5	5.0	$0 $0	11	NA	NA	NA
U-B	Intrinsic Remediation	No	Yes*	1	1	2	5	2.6	$314 $674	11.6	12.74 5.93	15	Low
U-C	Permeable Reactive Barrier	No	Yes	5	3	3	1	1.9	$403 $865	13.9	27.30 12.72	15	High
U-D	In-Situ Air Sparging Grid	No	Yes	4	4	3	4	0.0	$642 $1,375	15.0	17.13 8.00	5	High
U-E	In-Situ Biological Treatment	No	Yes	4	4	4	3	1.5	$443 $949	16.5	27.09 12.64	5	Moderate
U-F	Excavation and GW Treatment	No	Yes	5	4	3	1	0.7	$557 $1,194	13.7	21.54 10.05	5	High

Notes: The ability of a remedial alternative to meet remedial action objectives is dependant on site specific conditions that may vary from site to site.
The confidence levels indicated assume that site conditions are acceptable for the application of the remedial alternative.
* "Yes" values for this threshold criteria are based on the assumption that groundwater PCE concentrations detected in MW-25 remain below the groundwater ACL for PCE.

Table S-4
Comparative Analysis of Remedial Alternatives
MCL as RAO versus ACL as RAO
Lower Contaminant Plume at River Terrace

Remedial Alternative			Cost: MCL as RAO					Cost: ACL as RAO					
Identifier: MCL as RAO (Identifier: ACL as RAO)	Description	Meet Threshold Criteria?	Cost Score	Estimated Present Worth (in thousands of dollars)	Total Score: MCL as RAO	Estimated Restoration Time (Years): MCL as RAO	Confidence that Remedial Alternative will meet RAO (MCL)	Cost Score	Estimated Present Worth (in thousands of dollars)	Total Score: ACL as RAO	Estimated Restoration Time (Years)	Confidence that Remedial Alternative will meet RAO (ACL)	Present Worth Cost Difference (in thousands of dollars)
RT-A (L-A)	No Action	No	5.0	$0	11	NA	NA	5.0	$0	11	NA	NA	
RT-B (L-B)	Intrinsic Remediation	No	3.7	$314 $674	12.7	15	Low	2.9	$275 $590	11.9	10	Low	$39 $84
RT-C (L-C)	Permeable Reactive Barrier	Yes	1.5	$848 $1,818	13.5	15	High	1.1	$508 $1,089	13.1	10	High	$340 $729
RT-D (L-D)	In-Situ Air Sparging Curtain	Yes	1.8	$764 $1,637	13.8	15	Moderate	0.8	$557 $1,194	12.8	10	Moderate	$207 $443
RT-E	Funnel and Gate System	Yes	1.1	$934 $2,002	13.1	15	High	NE		NE		NE	
RT-F (L-E)	Extraction Wells with Air Stripping	Yes	1.7	$793 $1,699	12.7	15	Moderate	0.7	$569 $1,220	11.7	10	Moderate	$224 $479
RT-G (L-F)	In-Situ Biological Treatment	Yes	0.0	$1,195 $2,561	14.0	5	Moderate	0.0	$657 $1,409	14.0	5	Moderate	$538 $1,152

Notes: The ability of a remedial alternative to meet remedial action objectives is dependant on site specific conditions that may vary from site to site.
The confidence levels indicated assume that site conditions are acceptable for the application of the remedial alternative.
NE Alternative not evaluated
NA Not applicable

Table S-4 (Cont.)
Comparative Analysis of Remedial Alternatives
MCL as RAO versus ACL as RAO
Upper Contaminant Plume at River Terrace

Remedial Alternative			Cost: MCL as RAO					Cost: ACL as RAO					
Identifier: MCL as RAO (Identifier: ACL as RAO)	Description	Meet Threshold Criteria?	Cost Score	Estimated Present Worth (in thousands of dollars)	Total Score: MCL as RAO	Estimated Restoration Time (Years): MCL as RAO	Confidence that Remedial Alternative will meet RAO (MCL)	Cost Score	Estimated Present Worth (in thousands of dollars)	Total Score: ACL as RAO	Estimated Restoration Time (Years)	Confidence that Remedial Alternative will meet RAO (ACL)	Present Worth Cost Difference (in thousands of dollars)
UT-A (U-A)	No Action	No	5.0	$0	11	NA	NA	5.0	$0	11	NA	NA	
UT-B (U-B)	Intrinsic Remediation	No	3.9	$314 $674	12.9	15	Low	2.6	$314 $674	11.6	15	Low	$0 $0
UT-C (U-C)	Permeable Reactive Barrier	Yes	3.2	$522 $1,118	16.2	15	High	1.9	$403 $865	13.9	15	High	$119 $253
UT-D (U-D)	In-Situ Air Sparging Grid	Yes	1.2	$1,087 $2,330	16.2	10	High	0.0	$642 $1,375	15.0	5	High	$445 $955
UT-E	In-Situ Air Sparging Curtain	Yes	2.5	$730 $1,565	14.5	15	Moderate	NE		NE		NE	
UT-G (U-E)	In-Situ Biological Treatment	Yes	2.9	$602 $1,290	16.9	10	Moderate	1.5	$443 $949	16.5	5	Moderate	$159 $341
UT-F (U-F)	Excavation and GW Treatment	Yes	0.0	$1,433 $3,071	13.0	5	Moderate	0.7	$557 $1,194	13.7	5	Moderate/ High	

Notes: The ability of a remedial alternative to meet remedial action objectives is dependant on site specific conditions that may vary from site to site.
The confidence levels indicated assume that site conditions are acceptable for the application of the remedial alternative.
NE Alternative not evaluated
NA Not applicable

APPROACH USED FOR DEVELOPMENT OF COSTS

The development of costs for alternatives evaluated for River Terrace was based on best engineering judgement and experience, in a consistent manner that included the following steps:

1. An outline of the basic components of each alternative was assembled. Basic components included capital materials that would be purchased or constructed, services that would be purchased or rented, and labor.
2. Quantities of the basic components required were estimated. These estimates were based on previous experience with implementing remedial projects, vendor information, and best professional judgement.
3. The prices for the basic components were estimated using vendor information and existing pricing data. An accuracy range between +50 to –30 percent can be expected for the costs provided (USEPA, 1998).
4. A **Construction Cost Subtotal** was calculated from the estimated quantities and prices for the basic components of the alternatives.
5. A 10 to 15 percent charge for **Mobilization and Demobilization** was added to the Construction Cost Subtotal. This charge includes planning, expediting, transportation of personnel, per diem, and other mobilization costs not explicitly included in the basic component outline.
6. A variable percent charge for **Construction Contingencies** was applied to the Construction Cost Subtotal. The Construction Contingency is comprised of a scope contingency and a bid contingency. The scope contingency represents project risks associated with an incomplete design. These contingencies represent capital or O&M costs, unforeseeable at the time the feasibility study is prepared, which are likely to become known as the remedial design proceeds. The bid contingency includes variations caused by weather, unexpected site conditions, quantity overruns, modifications, etc. that occur during construction. A 15 percent bid contingency is generally recommended.
7. An **Administrative Charge** of 15 percent was applied to the Construction Cost Subtotal. This charge includes project management and construction management costs. The Administrative Charge also includes other services during construction including bid and contract administration, negotiations, and additional engineering and design during construction. Finally, this charge includes permitting and legal fees that include the cost of obtaining the required permits to implement the alternative (e.g., NPDES permits for discharges and permitting for wetland activity).
8. A 20 to 40 percent charge for **Engineering and Design** was applied to the Construction Cost Subtotal. The percentage was varied between 20 and 40 percent to determine a reasonable cost, based on the level of complexity of the design and engineering services required.
9. For some alternatives a **Site Technology Licensing** fee was applied to the Construction Cost Subtotal. The percentage was based on the Licensee's fee structure.
10. The items above were summed and added to the **Construction Cost Subtotal** to arrive at the **Capital Cost Total**.

11. **Annual Operation and Maintenance (O&M)** costs were developed for each alternative. The O&M components included recurring consumable materials that would be purchased or constructed, services that would be purchased or rented, sampling and analysis labor. Quantities of the required basic components were estimated. The estimate was based on previous experience with implementing remedial projects, vendor information, and best professional judgement.
12. A charge of 15 percent of the **Annual O&M Cost Subtotal** was added for annual mobilization and general requirement costs.
13. The **Annual O&M Cost Total** provides a total of the annual cost of O&M and does not include a present-worth analysis.
14. Present-worth analysis was applied to each O&M component sum. The present-worth analysis assumes that 7 percent annual interest can be made on money invested today. The duration of time used for present-worth analysis often varies depending on the remedial alternative. A 15-year duration was assumed for all of the remedial alternatives evaluated for the upper contaminant plume except the source treatment alternatives where a 5-year duration was assumed. A 10-year duration was assumed for all of the remedial alternatives evaluated for the lower contaminant plume except the source treatment alternatives where a 5-year duration was assumed.
15. The present-worth costs of each O&M component were summed to arrive at an O&M Cost Total (**Present Worth @ 15 Years @ 7%**).
16. The Capital Cost Total was added to the O&M Cost Total (Present Worth @ 15 years @ 7%) to arrive at a **Total Present Worth Cost**.

ALTERNATIVE L-A
NO ACTION (LOWER CONTAMINANT PLUME)

Capital Cost:	None
O&M Costs (Present Worth @ 10 years):	None
Total Present-Worth Cost:	None

Description:

No remedial actions or institutional controls would be implemented. Evaluation of the "no action" alternative is required by CERCLA to provide a baseline against which all other remedial alternatives can be compared. This alternative is applicable to all contaminant types found in water, soil, and wetland environments. Natural processes may eventually reduce contaminant concentrations to acceptable levels, but current and future risk to human health and the environment would remain above ARARs for an extended period of time. No monitoring of groundwater or soil would be conducted to confirm eventual compliance with ARARs. The "no action" alternative is not expected to achieve remedial action objectives.

ALTERNATIVE L-B
INTRINSIC REMEDIATION (LOWER CONTAMINANT PLUME)

Capital Cost:	$38,000 to $82,000
O&M Costs (Present Worth @ 10 years):	$237,000 to $509,000
Total Present-Worth Cost:	$275,000 to $591,000

Description:

Intrinsic remediation would not involve active remedial technologies. Dilution, absorption, volatilization, and biological degradation would naturally occur to continue attenuating dissolved PCE and its daughter products. Bioremediation of PCE generally occurs under reducing (anoxic) conditions. Groundwater monitoring at River Terrace has indicated the aquifer is anaerobic and empirical evidence indicates that the PCE is attenuating in areas of the lower contaminant plume as discussed in Section 7.

Implementation of this alternative will involve groundwater and surface water monitoring, periodic groundwater modeling, and institutional controls to ensure that the dissolved-phase PCE is not causing risk to human health or the environment. Groundwater monitoring is also proposed to monitor the intrinsic remediation progress.

The intrinsic remediation option is not expected to achieve remedial action objectives and is only included to provide a comparison to the other remedial alternatives.

Assumptions:

- Initial data analysis and modeling would be performed to evaluate the feasibility and restoration time period for intrinsic remediation to achieve remedial objectives.
- Five (5) and ten (10) years after initial event the data analysis and modeling efforts would be repeated to review the intrinsic remediation progress and determine if remedial action goals will be met in the desired timeframe.
- Fifteen wells will be sampled periodically for 10 years. Sampling will be quarterly for the first 3 years, semiannually for the next two years, and annually thereafter. Water samples will be analyzed for VOCs (8260) during each sampling event and annually for geochemical indicator parameters. The geochemical indicator parameters include pH, redox potential (Eh), alkalinity, dissolved oxygen, ferrous iron, sulfate or sulfide, chloride, and potentially, dissolved hydrogen.

River Terrace RV Park
Groundwater Monitoring Costs

Function	Unit	Quantity	Cost Per Unit	Total Cost	Total Cost (- 30%)	Total Cost (+ 50%)
1 Groundwater Monitoring						
Groundwater Monitoring Per Sampling Event						
1.1 Well Sampling	Well	15	$200	$3,000		
1.2 Analysis for VOCs (8260)	EA	20	$180	$3,600		
1.3 IDW Disposal	Drum	2	$800	$1,600		
1.1.4 Data Analysis and Reporting	HR	55	$75	$4,125		
1.1.5 Mobilization and General Requirements	%		15%	$1,849		
Total for Groundwater Monitoring				**$14,174**		
1.2. Annual Geochemical Analyses	EA	15	$150	**$2,250**		
1.3. Annual Well Maintenance	LS	1	$200	**$200**		
2. Mobilization / Demobilization	%	1	15%	**$2,126**		
Total Quarterly Monitoring Costs per Year				**$67,649**		
Total Semiannual Monitoring Costs per Year				**$35,050**		
Total Annual Monitoring Costs per Year				**$18,750**		
Present Worth Analysis						
Quarterly Monitoring for Years 1 - 3 @ 7%				**$177,533**		
Semiannual Monitoring for Years 4-5 @ 7%				**$51,729**		
Annual Monitoring for Years 6 - 10 @ 7%				**$54,813**		
Annual Monitoring for Years 6 - 15 @ 7%				**$93,894**		
Total Present Worth Cost (5 Yrs @ 7%)				**$229,262**	**$160,483**	**$343,893**
Total Present Worth Cost (10 Yrs @ 7%)				**$284,075**	**$198,853**	**$426,113**
Total Present Worth Cost (15 Yrs @ 7%)				**$323,156**	**$226,209**	**$484,734**

River Terrace RV Park						
Alternative L-B Intrinsic Remediaition						
Lower Contaminant Plume						
Function	**Unit**	**Quantity**	**Cost Per Unit**	**Total Cost**	**Total Cost (- 30%)**	**Total Cost (+ 50%)**
1. Base Construction Estimate						
1.1. Initial Intrinsic Evaluation						
1.1.1. Data Analysis	HR	100	$75	$7,500		
1.1.2. Groundwater Modeling	HR	200	$85	$17,000		
1.1.3. Reporting Effort	LS	1	$20,000	$20,000		
Total for Intrinsic Remediation Analysis				**$44,500**		
1.2. Administrative and Permitting	LS	1	$10,000	**$10,000**		
1.3.				**$0**		
Construction Cost Subtotal				**$54,500**	**$38,150**	**$81,750**
2. Mobilization / Demobilization	%	1	0%	$0		
3. Construction Contingency	%	1	0%	$0		
4. Administrative Charge	%	1	0%	$0		
6. Engineering and Design	%	1	0%	$0		
Capital Cost Total				**$54,500**	**$38,150**	**$81,750**
Annual O&M Costs						
			$0	$0		
	LS	1	$0	$0		
Mobilization and General Requirements	%	1	15%	$0		
Annual O&M Cost Total				**$0**		
Present Worth Analysis						
Intrinsic Analysis Review 5 and 10 @ 7%				$54,960		
Monitoring Cost for Years 1 - 10 @ 7%				$284,075		
Total O&M Cost (Present Worth - 10 yrs)				**$339,035**	**$237,325**	**$508,553**
Total Present Worth Cost (10 Yrs @ 7%)				**$393,535**	**$275,475**	**$590,303**

ALTERNATIVE L-C
PERMEABLE REACTIVE BARRIER (LOWER CONTAMINANT PLUME)

Capital Cost:	$301,000 to $646,000
O&M Costs (Present Worth @ 10 years):	$207,000 to $443,000
Total Present-Worth Cost:	$508,000 to $1,089,000

Description:

This alternative will require the installation of a permeable reactive barrier across the flow path of the lower contaminant plume. This type of barrier allows the passage of water while prohibiting the movement of contaminants by chemical reactions. The specific type of reaction wall proposed for River Terrace is a zero-valent iron treatment wall. It consists of iron filings mixed with sand. This type of treatment wall is applicable for treatment of chlorinated contaminants such as PCE, TCE, DCE, and VC. As the iron is oxidized, a chlorine atom is removed from the compound by one or more reductive dechlorination mechanisms, using electrons supplied by the oxidation of iron. The process dissolves the iron filings, but the metal disappears so slowly that the remediation barriers can be expected to remain effective for many years.

A 100-foot long treatment wall would be installed approximately parallel to the Kenai River to treat PCE-contaminated groundwater prior to its discharge into the river. Installation of the treatment wall will require a trench approximately 20 feet deep, with a 6-foot deep active treatment layer.

Due to the uncertainty of constructing a permeable reactive barrier by trenching and material placement alone, the use of temporary sheet pile walls to provide safety and geo-support were assumed necessary. Double rows of sheet piling would be used to allow safe vertical excavation to the 20-foot depth. Sheet piling would prevent trench sloughing and make is safer and easier to place the reactive iron material. However, several utilities run through this area and they would need to be relocated or at least temporarily terminated and reconnected after construction.

It was assumed that an iron treatment wall would not result in any aesthetic or deleterious impacts to the Kenai River (e.g., iron staining). A pilot study is recommended to evaluate the reactions of the site water chemistry with that of an iron filing mixture.

Implementation of this alternative will also involve groundwater and surface water monitoring, and institutional controls to ensure that the dissolved-phase PCE is not causing risk to human health or the environment. It is estimated that this monitoring will be required for a period of 10 years, but the actual monitoring period may vary depending on how soon the remedial action objectives are met. Although some variations in monitoring techniques may occur between alternatives, the costs will probably not vary much between the options.

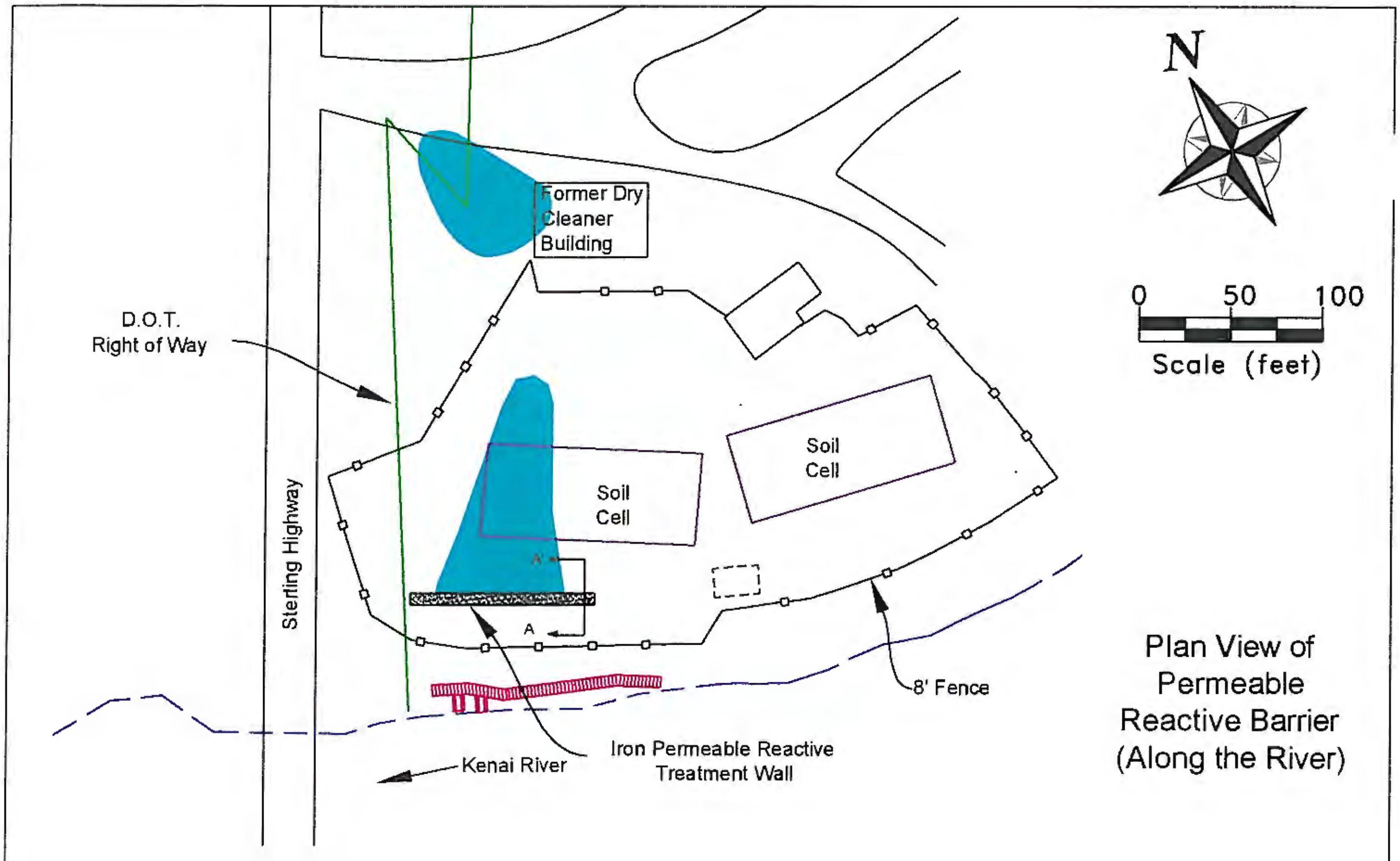
Assumptions:

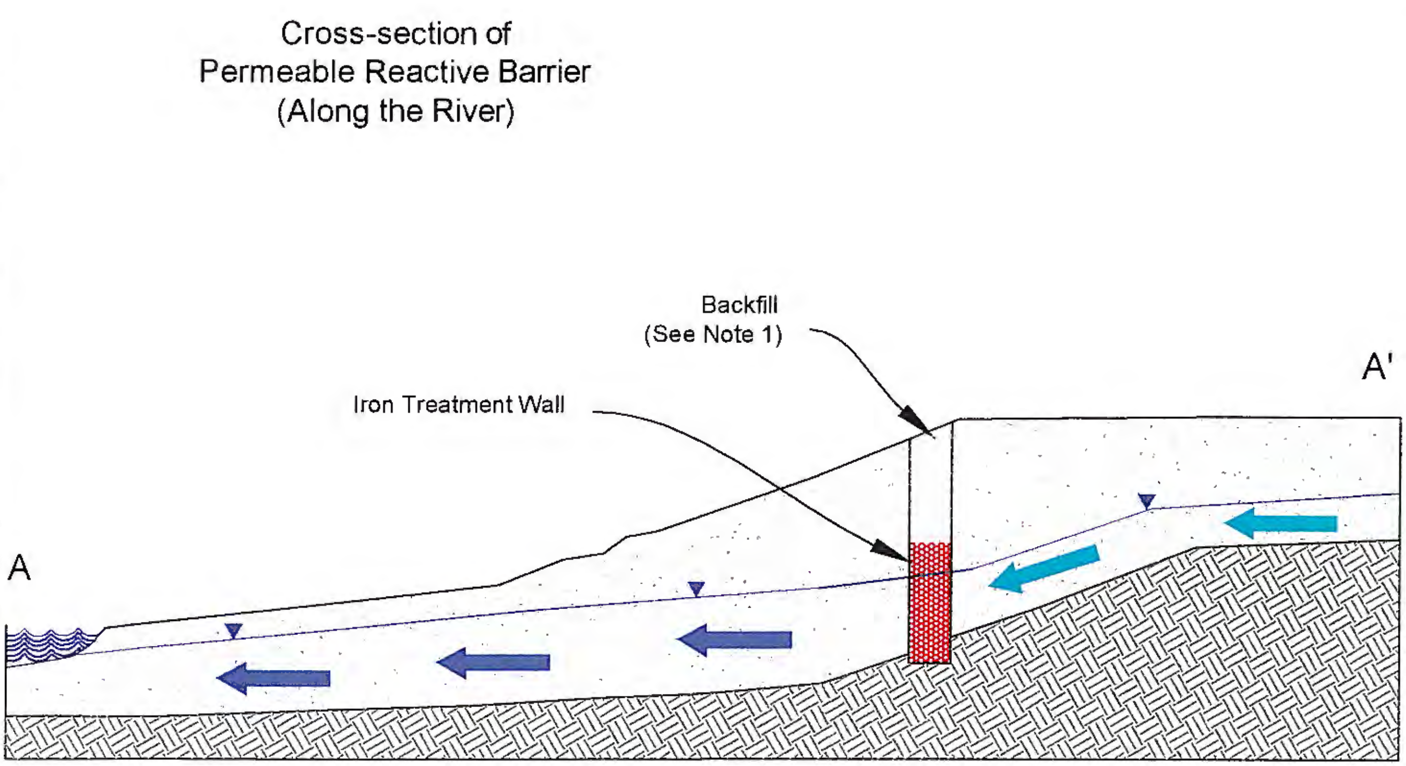
- Dimensions of the treatment wall will be approximately 100 feet long by 2.6 feet wide by 6 feet deep (volume = 1,560 cubic feet).

- Half of the 2.6-foot thick wall consists of granular iron, purchased and shipped from the continental United States. Shipment will be by train to Seattle, then by barge to Kenai.
- For construction reasons, the iron will be mixed with processed, cleaned, and screened sand at a 1:1 ratio, resulting in a 2.6-foot thick wall. The sand will be purchased from a local borrow source.
- Dimensions of the trench for installing the treatment wall will be approximately 100 feet long by 2.6 feet wide by 20 feet deep (5,200 cubic feet). The trench will most likely be constructed by backhoe or ladder type trenching equipment.
- Two temporary sheet pile walls approximately 100 feet long by 22 feet deep are required to assure safety, geo-support, and proper placement of the iron medium.
- After installing the iron reactive treatment wall, the trench will be backfilled 12 to14 feet deep with native soils. The approximate 1,560 cubic feet of soil that was replaced by the iron/sand mixture, and not placed back into the trench, will be taken from the upper soil zone. It is assumed that the upper soil zone PCE contamination levels are significantly below the site ACL for soil and that these soils may be spread on-site.
- A pilot test/treatability study is recommended prior to final design and installation. It is assumed that the iron reactive barrier will successfully transform the PCE and its daughter products to concentrations in the groundwater that comply with the remedial action objectives. This pilot study will assist in the design of a treatment wall that will be effective in achieving the remedial action objectives.
- Fifteen wells will be sampled periodically for 10 years. Sampling will be quarterly for the first 3 years, semiannually for the next two years, and annually thereafter. Water samples will be analyzed for VOCs (8260) during each sampling event and annually for geochemical indicator parameters. The geochemical indicator parameters include pH, redox potential (Eh), alkalinity, dissolved oxygen, ferrous iron, sulfate or sulfide, chloride, and potentially, dissolved hydrogen.
- The Reactive Iron Wall technology is proprietary and requires a licensing fee of 15 percent of the construction costs.

River Terrace RV Park						
Alternative L-C Reactive Treatment Wall						
Lower Contaminant Plume						
					Total Cost	Total Cost
Function	Units	Quantity	Cost Per Unit	Total Cost	(- 30%)	(+ 50%)
1. Base Construction Estimate						
1.1. Permeable Reactive Barrier						
1.1.1 Iron Medium with Installation	TON	100	$400	$40,000		
1.1.2. Shipping Costs for Iron Medium	TON	100	$180	$18,000		
1.1.3. Clean Sand for Medium Mix	CY	46	$15	$690		
1.1.4. Trench, Backfill, and Shoring	LF	100	$90	$9,000		
1.1.5. Install/Remove Sheet Pile Walls	SF	4,400	$25	$110,000		
Total for Permeable Reactive Barrier				$177,690		
1.2. Fencing	LF	450	$20	$9,000		
1.3. Dewatering/Waste Management	LS	1	$10,000	$10,000		
1.4. Bench Scale Study	LS	1	$30,000	$30,000		
Construction Cost Subtotal				$226,690	$158,683	$340,035
2. Mobilization / Demobilization	%	1	10%	$22,669		
3. Construction Contingency	%	1	20%	$45,338		
4. Administrative Charge	%	1	15%	$34,004		
6. Engineering and Design	%	1	30%	$68,007		
7. Site Technology Licensing	%	1	15%	$34,004		
Capital Cost Total				$430,711	$301,498	$646,067
Annual O&M Costs						
Maintenance Support (0.5 hrs per week)	HR	25	$65	$1,625		
Annual O&M Cost Total				$1,625		
Present Worth Analysis						
O&M Cost for Years 1 - 10 @ 7%				$11,413		
Monitoring Cost for Years 1 - 10 @ 7%				$284,075		
Total O&M Cost (Present Worth - 10 yrs)				$295,488	$206,842	$443,232
Total Present Worth Cost (10 Yrs @ 7%)				$726,199	$508,340	$1,089,299

Alternative L-C: Lower Plume





Note 1:
Backfill material is less permeable than native material in case the water table rises.

OASIS/BRISTOL JV	Conceptual Drawing River Terrace RV Park Feasibility Study Soldotna, Alaska	Date: April 2000	Figure S-1
ADEC Contract No: 18-2-12-12		Drawn By: JAS Checked By: ASN	Project No: 20019

ALTERNATIVE L-D
IN-SITU AIR SPARGING CURTAIN (LOWER CONTAMINANT PLUME)

Capital Cost:	$194,000 to $415,000
O&M Costs (Present Worth @ 10 years):	$363,000 to $779,000
Total Present-Worth Cost:	$557,000 to $1,194,000

Description:

This alternative consists of installation of an in-situ air-sparging curtain to treat the PCE impacted groundwater before it reaches the Kenai River. Air sparging involves the injection of air into the contaminated groundwater, creating an underground stripper that removes contaminants through volatilization. This process is designed to operate at high airflow rates in order to effect volatilization (as opposed to the lower airflow rates used to stimulate biodegradation). The area of focus will be at the downgradient edge of the plume, just prior to it entering the Kenai River. If required, soil vapor extraction piping would be used in conjunction with the air sparging wells to control the flow of volatilized PCE.

Implementation of this alternative will also involve groundwater and surface water monitoring and institutional controls to ensure that the dissolved-phase PCE is not causing risk to human health or the environment. It is estimated that this monitoring will be required for a period of 10 years, but the actual monitoring period may vary depending on how soon the remedial action objectives are met. Although some variations in monitoring techniques may occur between alternatives, the costs will not vary much between the options.

Assumptions:

System Installation

- Twenty 2-inch diameter air-sparging wells will be installed to an average depth of 15 feet bgs. Each air-sparging well is capable of injecting 5-10 SCFM of air at a maximum pressure of 10 psi, with an estimated radius of influence of 5-10 feet.
- Vapor recovery will be performed by two horizontally buried 3-inch diameter ADS slotted pipes, installed to a depth of 2 to 3 feet bgs. Each vacuum line well will be capable of drawing 100 SCFM. The air-sparging region will be overlaid with an impermeable liner material to prevent short-circuiting and extend the effective area of the vapor extraction lines.
- Installation of 300 lineal feet of horizontal HDPE piping for sparging lines, with associated valves, gauges, and meters.
- Installation of 200 lineal feet of perforated ADS piping for soil vapor extraction, with associated insulation, valves, gauges, and meters.
- Installation of 400 lineal feet of 4-foot deep, 4-foot wide trenching for sparging and extraction lines.
- Installation of prefabricated and weatherized equipment/blower buildings to house the air sparging blowers and vapor extraction blowers with associated controls, valves, and piping.
- The system will be winterized using insulation and heat trace for the piping.

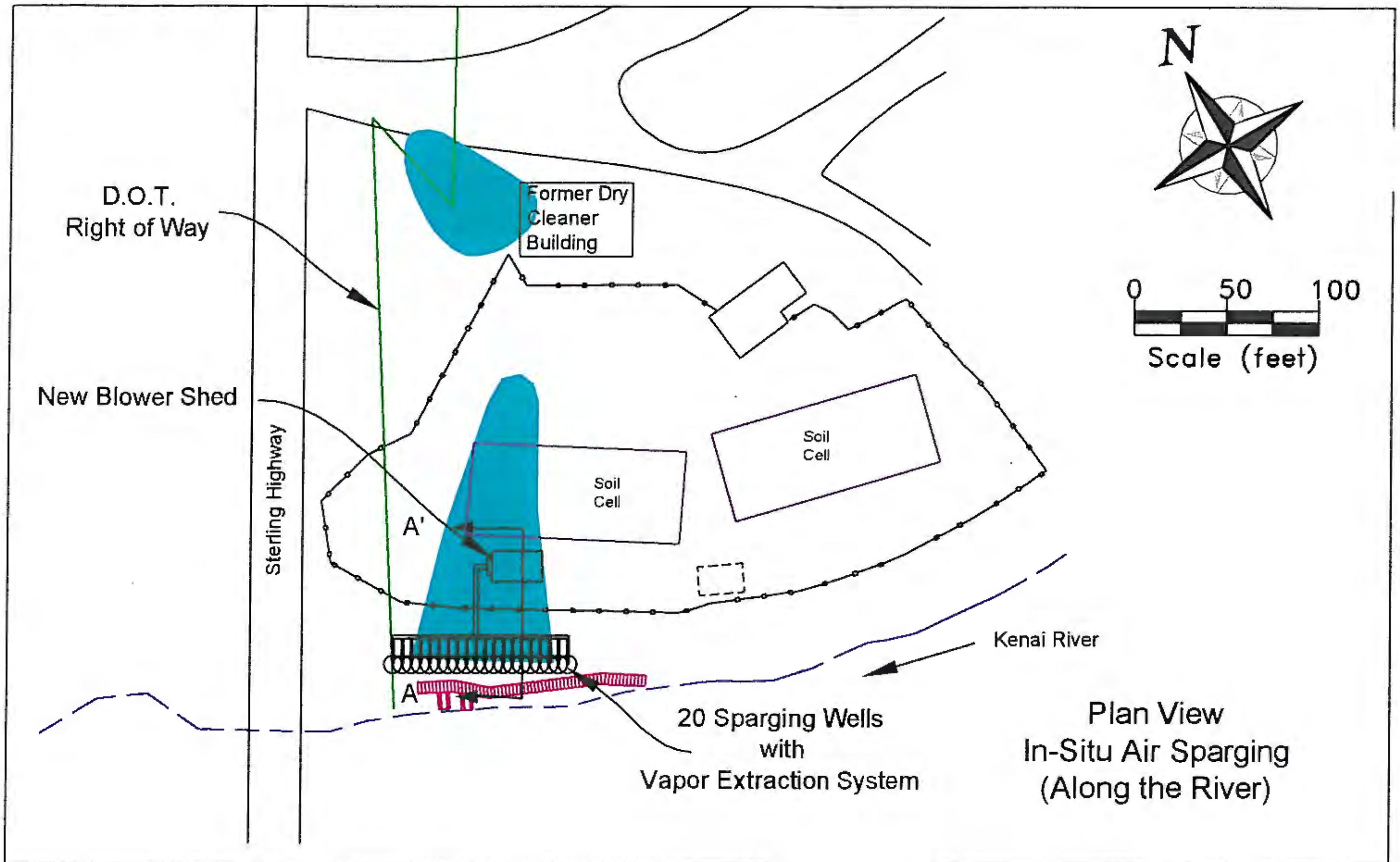
- A pilot test would be conducted prior to full-scale system design and implementation. A pilot test will assist in proper spacing of air sparging wells and will provide an indication of expected PCE removal rates.

System O&M

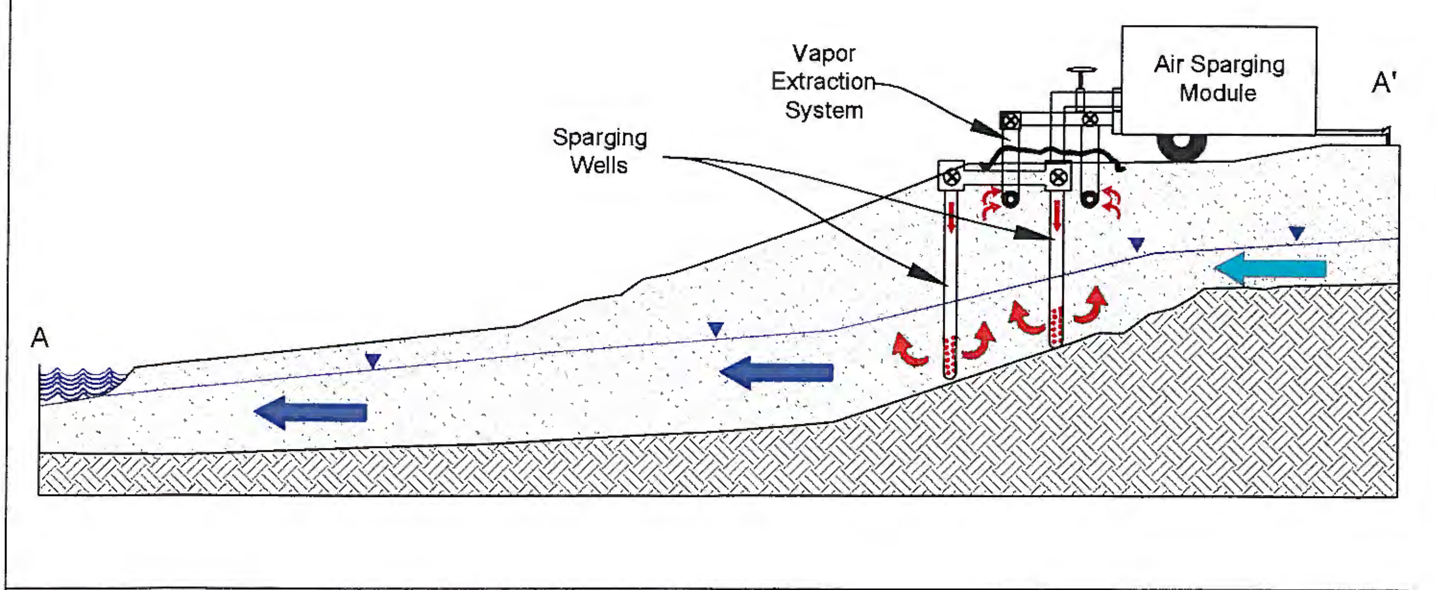
- The system will operate 365 days per year for 10 years.
- There will be no requirements for off-gas control or treatment.
- Exhaust stack air samples will be collected 4 times per year for 10 years. Air samples will be analyzed for VOCs using EPA TO-14 method.
- Fifteen wells will be sampled periodically for 10 years. Sampling will be quarterly for first 3 years, semiannually for next two years, and annually thereafter. Water samples will be analyzed for VOCs (8260) during each sampling event and annually for geochemical indicator parameters. The geochemical indicator parameters include pH, redox potential (Eh), alkalinity, dissolved oxygen, ferrous iron, sulfate or sulfide, chloride, and potentially, dissolved hydrogen.
- Annual reporting and data analysis will include a discussion on system O&M, groundwater monitoring results, and air monitoring results.

River Terrace RV Park						
Alternative L-D In-Situ Air Sparging Curtain						
Lower Contaminant Plume						
Function	**Unit**	**Quantity**	**Cost Per Unit**	**Total Cost**	**Total Cost (- 30%)**	**Total Cost (+ 50%)**
1. Base Construction Estimate						
1.1. Sparging Wells						
1.1.1.Trenching and backfill for piping	LF	150	$15	$2,250		
1.1.2. HDPE Piping	LF	300	$0.60	$180		
1.1.3. Sparging Wells	EA	20	$1,500	$30,000		
1.1.4. Installation Labor	MH	200	$40	$8,000		
Total for Sparging Wells				**$40,430**		
1.2 Soil Vaper Extraction System						
1.2.1.Trenching,heat trace, insulation	LF	250	$25	$6,250		
1.2.2. Perforated ADS Piping	LF	200	$2.00	$400		
1.2.3. Impermeable surface barrier	SF	2000	$1.00	$2,000		
Total for Soil Vaper Extraction System				**$8,650**		
1.3. Blower Building	EA	1	$50,000	**$50,000**		
1.4. Fencing	LS	450	$20	**$9,000**		
1.5. External Power Supply	LS	1	$15,000	**$15,000**		
1.6. Dewatering/Waste Management	LS	1	$5,000	**$5,000**		
1.7. Pilot Study	LS	1	$30,000	**$30,000**		
Construction Cost Subtotal				**$158,080**	**$110,656**	**$237,120**
2. Mobilization / Demobilization	%	1	10%	$15,808		
3. Construction Contingency	%	1	20%	$31,616		
4. Administrative Charge	%	1	15%	$23,712		
5. Engineering and Design	%	1	30%	$47,424		
Capital Cost Total				**$276,640**	**$193,648**	**$414,960**
Annual O&M Costs						
Maintenance Support (3 hrs per week)	HR	156	$65	$10,140		
Operating Power and Light	LS	1	$17,000	$17,000		
Routine Equip. Replacement and Repair	LS	1	$2,000	$2,000		
Mobilization and General Requirements	%	1	15%	$4,371		
Annual O&M Cost Total				**$33,511**		
Present Worth Analysis						
O&M Cost for Years 1 - 10 @ 7%				$235,367		
Monitoring Cost for Years 1 - 10 @ 7%				$284,075		
Total O&M Cost (Present Worth - 10 yrs)				**$519,442**	**$363,610**	**$779,163**
Total Present Worth Cost (10 Yrs @ 7%)				**$796,082**	**$557,258**	**$1,194,123**

Aternative L-D: Lower Plume



Plan View
In-Situ Air Sparging
(Along the River)



Cross-Section
In-Situ Air Sparging
(Along the River)

OASIS/BRISTOL JV	Conceptual Drawing River Terrace RV Park Feasibility Study Soldotna, Alaska	Date: April 2000	Figure S-2
ADEC Contract No: 18-2-12-12		Drawn By: JAS Checked By: ASN	Project No: 20019

ALTERNATIVE L-E
EXTRACTION WELLS WITH AIR STRIPPING (LOWER CONTAMINANT PLUME)

Capital Cost:	$170,000 to $364,000
O&M Costs (Present Worth @ 10 years):	$400,000 to $856,000
Total Present-Worth Cost:	$569,000 to $1,220,000

Description:

This alternative uses groundwater extraction wells to capture and direct shallow-groundwater flow to an above ground treatment system. The collected water will be pumped to the surface for treatment with air stripping equipment. Once treated, the water will probably be returned to a drainage gallery in the river alluvium along the Kenai River.

Air strippers work by introducing air into contaminated water to maximize the air-water interface and volatilize contaminants. Three general types of air strippers are: packed tower, low-profile tray, and diffused bubble air strippers.

In the packed tower air-stripping system, water is pumped to the top of a tower and allowed to trickle over packing inside. As the water flows downward over the packing, it spreads more thinly, creating a greater surface area. These thin films of water are met by a counter-flow of air blown in from the bottom of the tower. Packed towers are typically tall large units that must be stationary for operation. This is the oldest form of air stripping and is still widely used.

Low-profile tray air strippers represent a large portion of the air strippers used at newer remediation sites. The most common type of low-profile air stripper is the tray-type unit in which a shallow layer of water is allowed to flow along one or more trays. Air is blown through hundreds of holes in the bottom of the trays to generate a froth of bubbles that significantly enhance contaminant volatilization. Manufacturers often claim 99 percent removal rates from tray air strippers. Additionally, low-profile systems are much smaller than the packed tower type and are more resistant to media failure due to clogging (iron fouling). They are often configured on a mobile platform with all necessary ancillary devices to provide a complete portable water treatment solution.

Diffused air strippers are typically a series of tanks, or a single tank with a series of baffles. Air is introduced from the bottom by fine bubble diffusers to enhance volatilization. They are often more economical, since diffused air bubble type strippers may be built for a site-specific application using locally procured components. Such systems are probably less efficient than the prefabricated, packed tower or low profile type systems.

Of the three types of air-stripping systems mentioned above, the low-profile tray air stripping system appears to be the best choice for River Terrace because of its portability, ability to be housed, and efficiency. Several companies rent or lease self-contained trailers with all operational equipment included. These trailers can be kept at optimum operating temperature throughout the cold winter months. Packed towers can easily freeze at low temperatures, and insulating them is costly.

This system is intended to intercept the flow of contaminants into the Kenai River and aggressively treats the contaminated shallow ground water. Air strippers provide one of the most aggressive and controllable methods of treating contaminated water, and they are particularly effective at volatilizing the types of chemical contaminants found at this location.

It was assumed that off gases from the air stripping operations could be released to the atmosphere without treatment. If off gas concentrations are higher than anticipated, additional costs for off gas treatment will be required.

This alternative, unlike the other alternatives, may contain significant regulatory issues and costs associated with the above ground treatment and discharge of treated wastewater -- re-injection to shallow groundwater or, especially, into a storm water or sanitary sewer system. The use of extraction well will also not be as effective as an impermeable barrier in preventing the flow of contaminated groundwater towards the Kenai River.

Assumptions:

System Installation

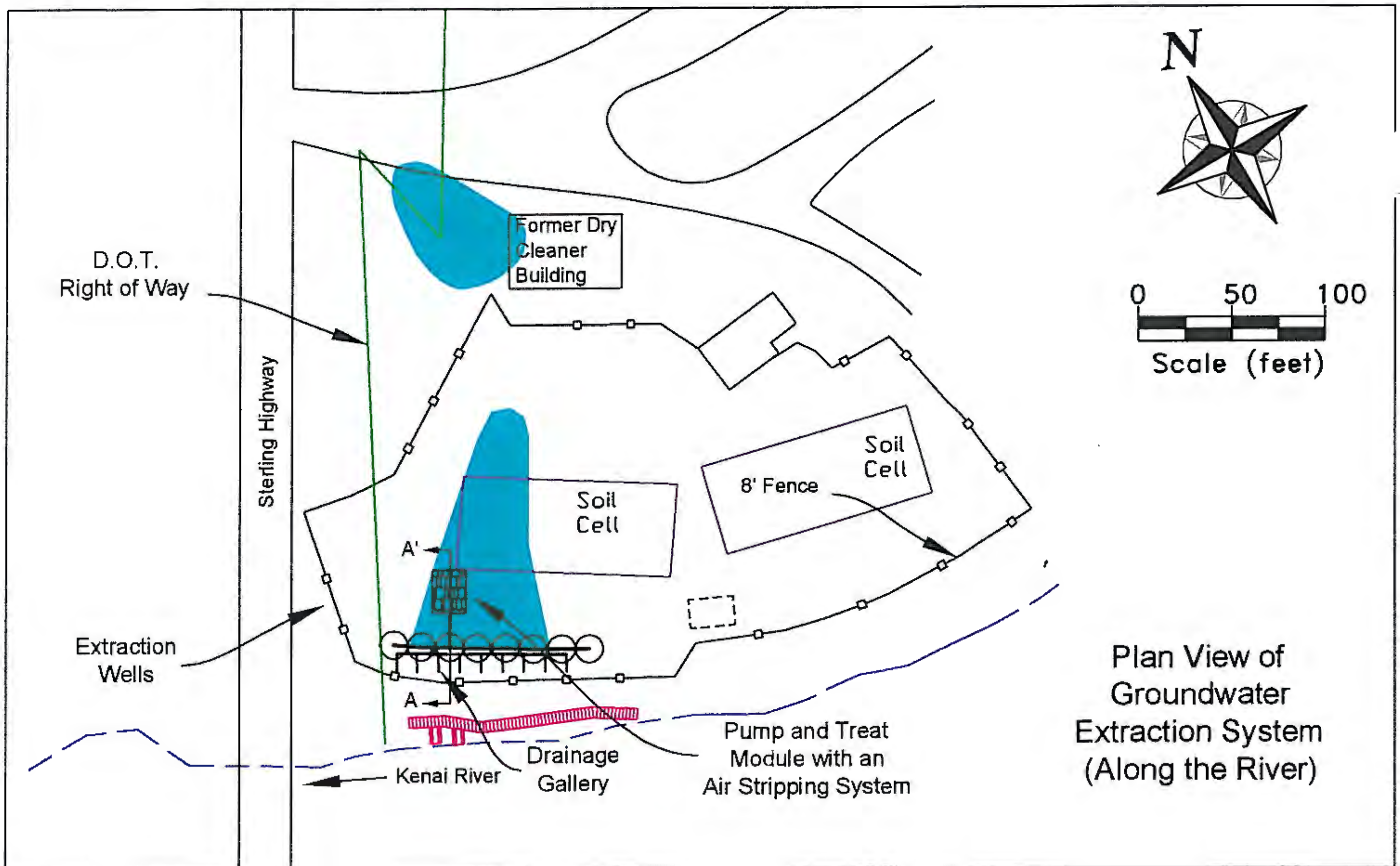
- Eight 2-inch diameter groundwater extraction wells will be installed to a depth of 15 feet bgs. Each well is estimated to produce approximately one gpm of water, with an estimated radius of influence of 15 feet.
- Two liquid ring pumps will be used to extract and pull groundwater from the extraction wells.
- Installation of 300 lineal feet of horizontal HDPE piping, with associated insulation, valves, gauges, and meters.
- Installation of 150 lineal feet of 4-foot deep, 4-foot wide trenching.
- Installation of a prefabricated and weatherized equipment building to house the liquid ring pumps, water holding tank, and tray air-stripper equipment.
- A drainage gallery will be required to disperse the treated water back into the groundwater table.
- The system will be winterized using insulation and/or heat trace where needed.
- The groundwater extraction wells will provide sufficient removal of contaminated groundwater to prevent any water that passes the extraction wall from exceeding the remedial action objectives. Special construction techniques, such as constructing a permeable trench in the till layer, may be required to minimize the amount of groundwater that escapes the extraction wells.

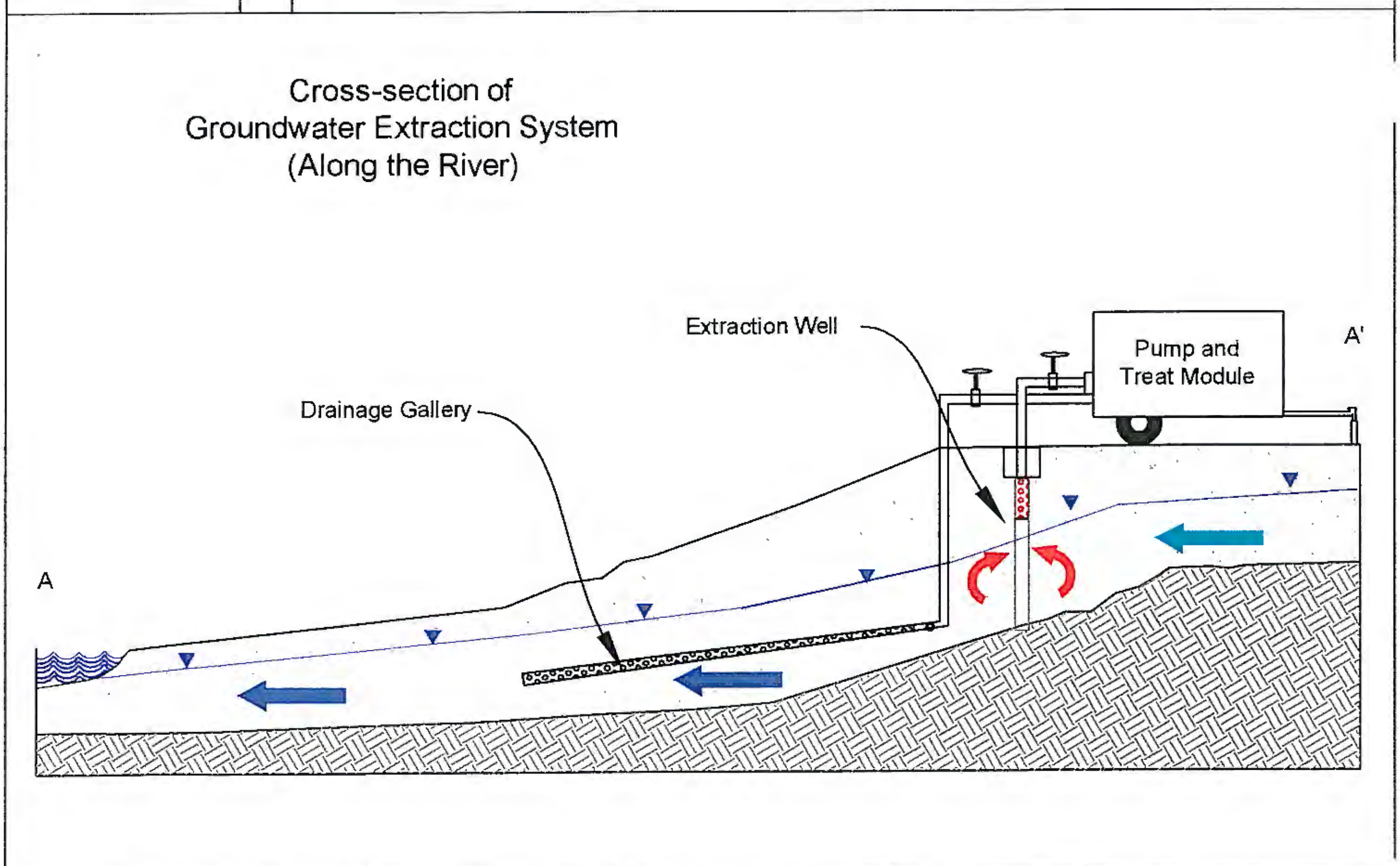
System O&M

- The system will operate 365 days per year for 10 years.
- There will be no requirements for off-gas control or treatment.
- Exhaust stack air samples will be collected 4 times per year for 10 years. Air samples will be analyzed for VOCs using EPA TO-14 method.
- Fifteen wells will be sampled periodically for 10 years. Sampling will be quarterly for the first 3 years, semiannually for the next two years, and annually thereafter. Water samples will be analyzed for VOCs (8260) during each sampling event and annually for geochemical indicator parameters. The geochemical indicator parameters include pH, redox potential (Eh), alkalinity, dissolved oxygen, ferrous iron, sulfate or sulfide, chloride, and potentially, dissolved hydrogen.
- Annual reporting and data analysis will include a discussion on system O&M, groundwater monitoring results, and air monitoring results.

River Terrace RV Park						
Alternative L-E Extraction Wells and Air Stripping						
Lower Contaminant Plume						
Function	Unit	Quantity	Cost Per Unit	Total Cost	Total Cost (- 30%)	Total Cost (+ 50%)
1. Base Construction Estimate						
1.1. Extraction Wells						
1.1.1.Trenching with insulation for piping	LF	150	$25	$3,750		
1.1.2. HDPE Piping	LF	300	$0.60	$180		
1.1.3. Wells	EA	8	$1,500	$12,000		
Total for Stripping Wells				**$15,930**		
1.2 Pumping and Stripping Facility						
1.2.1. Containerized Stripping System	EA	1	$80,000	$80,000		
1.2.2. Installation Labor	LS	1	$10,000	$10,000		
Total for Equipment Facility				**$90,000**		
1.3. Drainage Field	LF	100	$36	**$3,600**		
1.4. Fencing	LF	450	$20	**$9,000**		
1.5. External Power Supply	LS	1	$15,000	**$15,000**		
1.6. Dewatering/Waste Management	LS	1	$5,000	**$5,000**		
Construction Cost Subtotal				**$138,530**	**$96,971**	**$207,795**
2. Mobilization / Demobilization	%	1	10%	$13,853		
3. Construction Contingency	%	1	20%	$27,706		
4. Administrative Charge	%	1	15%	$20,780		
6. Engineering and Design	%	1	30%	$41,559		
Capital Cost Total				**$242,428**	**$169,699**	**$363,641**
Annual O&M Costs						
Maintenance Support (4 hrs per week)	HR	208	$65	$13,520		
Operating Power and Light	LS	1	$17,000	$17,000		
Routine Equip. Replacement and Repair	LS	1	$5,000	$5,000		
Mobilization and General Requirements	%	1	15%	$5,328		
Annual O&M Cost Total				**$40,848**		
Present Worth Analysis						
O&M Cost for Years 1 - 10 @ 7%				$286,899		
Monitoring Cost for Years 1 - 10 @ 7%				$284,075		
Total O&M Cost (Present Worth - 10 yrs)				**$570,974**	**$399,682**	**$856,461**
Total Present Worth Cost (10 Yrs @ 7%)				**$813,402**	**$569,381**	**$1,220,103**

Alternative L-E: Lower Plume





OASIS/BRISTOL JV	Conceptual Drawing River Terrace RV Park Feasibility Study Soldotna, Alaska	Date: April 2000	Figure S-3
ADEC Contract No: 18-2-12-12		Drawn By: JAS Checked By: ASN	Project No: 20019

ALTERNATIVE L-F
REDUCTIVE ANAEROBIC BIOLOGICAL IN-SITU TREATMENT TECHNOLOGY (RABITT)
(LOWER CONTAMINANT PLUME)

Capital Cost:	$321,000 to $687,000
O&M Costs (Present Worth @ 5 years):	$337,000 to $722,000
Total Present-Worth Cost:	$657,000 to $1,409,000

Description:

This alternative consists of in situ injection of Hydrogen Release Compound (HRC) through approximately 40 injection points and 40 monitoring wells that will initially be used for injection. HRC injection results in anaerobic bioremediation of chlorinated solvents such as PCE and TCE. HRC offers a passive and possibly low-cost approach to in-situ remediation. HRC is a moderately flowable material that can be injected under pressure into an aquifer using various drilling and direct push technologies. It can maintain dechlorinating conditions in the aquifer for six months or more, depending on site characteristics. HRC provides a time-release carbon source to accelerate the reduction of anaerobically degradable contaminants.

Advantages of this technology include the elimination of aboveground treatment and processing equipment. Since chlorinated hydrocarbon source locations are difficult to locate, a large number of injection wells, placed in a grid pattern, will most likely be required to address the entire source contamination area. An HRC barrier wall consisting of 40 4-inch diameter injection wells (2 rows of 20 wells each) used as injection points is recommended to ensure the halt of contaminants migrating towards the Kenai River. An additional 40 injection points will be placed up-gradient from the barrier wall to treat possible source locations. To ensure that this barrier wall remains active at all times, replacement of the HRC is recommended at least two times per year. It is expected that annual replacement of the HRC in the source treatment areas will be required to maintain reductive anaerobic biological treatment conditions for the source treatment area.

Because introduction of the HRC may lead to anaerobic impacts to the Kenai River, a series of 25 4-inch diameter injection wells located between the river and the HRC injection wells will be used to assist in re-oxygenating the groundwater. An Oxygen Release Compound (ORC) will be added to the wells at least two times per year during the same period that HRC injections are being conducted.

Because this alternative includes aggressive treatment of the contaminant source area, it is estimated that the RAOs can be achieved in five years. However, unknown contaminant source areas and site conditions may extend the required treatment time.

Implementation of this alternative will also involve groundwater and surface water monitoring and institutional controls to ensure that the dissolved-phase PCE is not causing risk to human health or the environment. It is estimated that this monitoring will be required for a period of 5 years, but the actual monitoring period may vary depending on how soon the remedial action objectives are met.

Assumptions:

System Installation

- Forty 4-inch diameter wells will be drilled to a depth of 15 to 20 feet below ground surface. The wells will be alternately spaced in two 20-well rows that will create a barrier wall for injection of HRC at the lower edge of the contaminant plume. Wells are used to allow for frequent replacement of the HRC. It was assumed that the HRC would be replaced two times per year. Each injection well will receive approximately 40 lbs of HRC per injection.
- Twenty-five 4-inch diameter wells will be drilled to a depth of 10 feet below ground surface. The wells will be located in a single row between the HRC barrier wells and the Kenai River. It was assumed that the ORC would be replaced two times per year. Each injection well will receive six 4-inch ORC socks per injection.
- Forty 2-inch diameter injection points will be drilled to a depth of 15 to 35 feet below ground surface. Each injection point will receive approximately 15 lbs of HRC, based on the assumption of an active layer of 10 foot deep.
- The design engineer will determine appropriate method of injection.
- HRC injection is a proprietary treatment method that requires a contract with Regenesis Corporation of California.

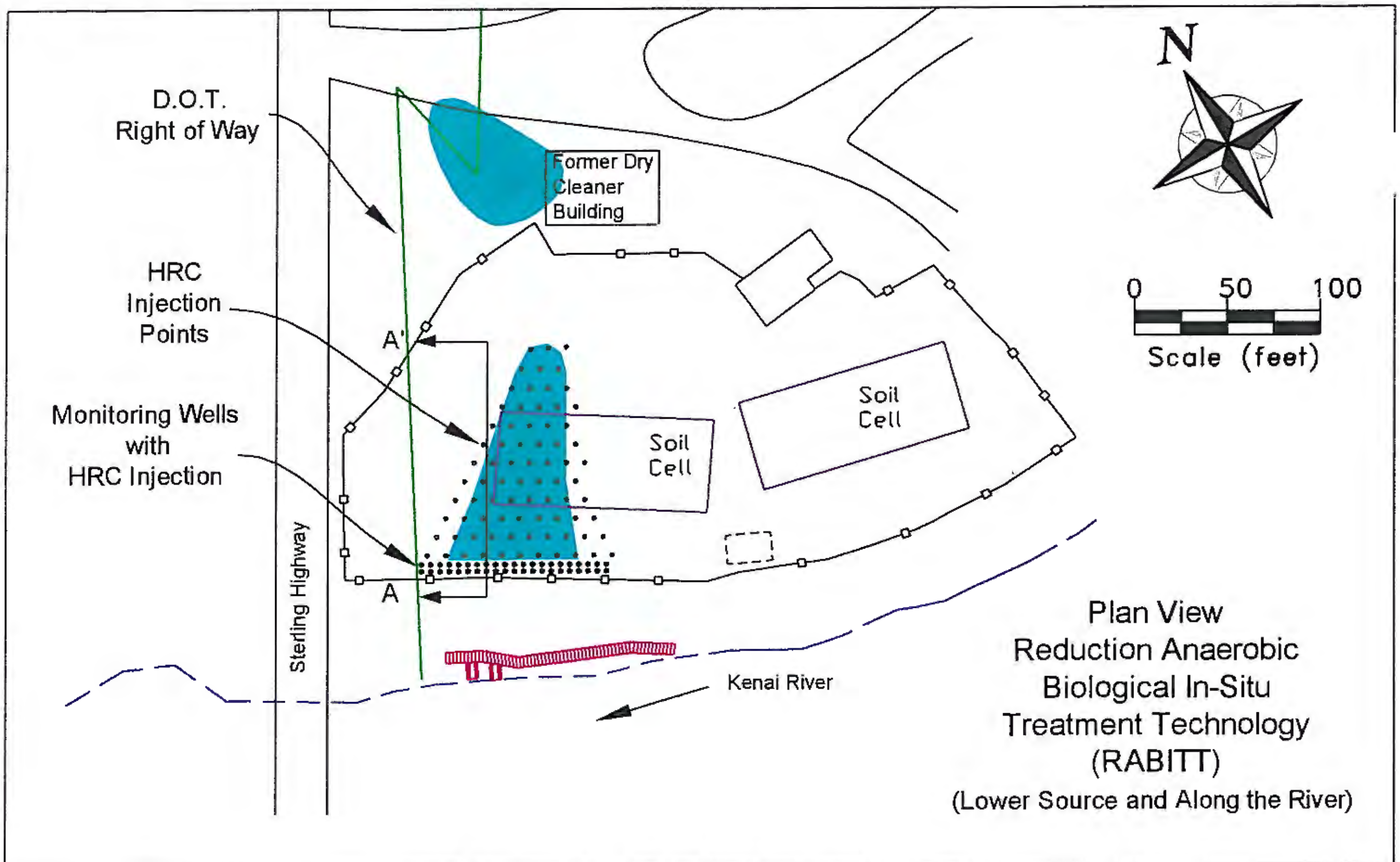
System O&M

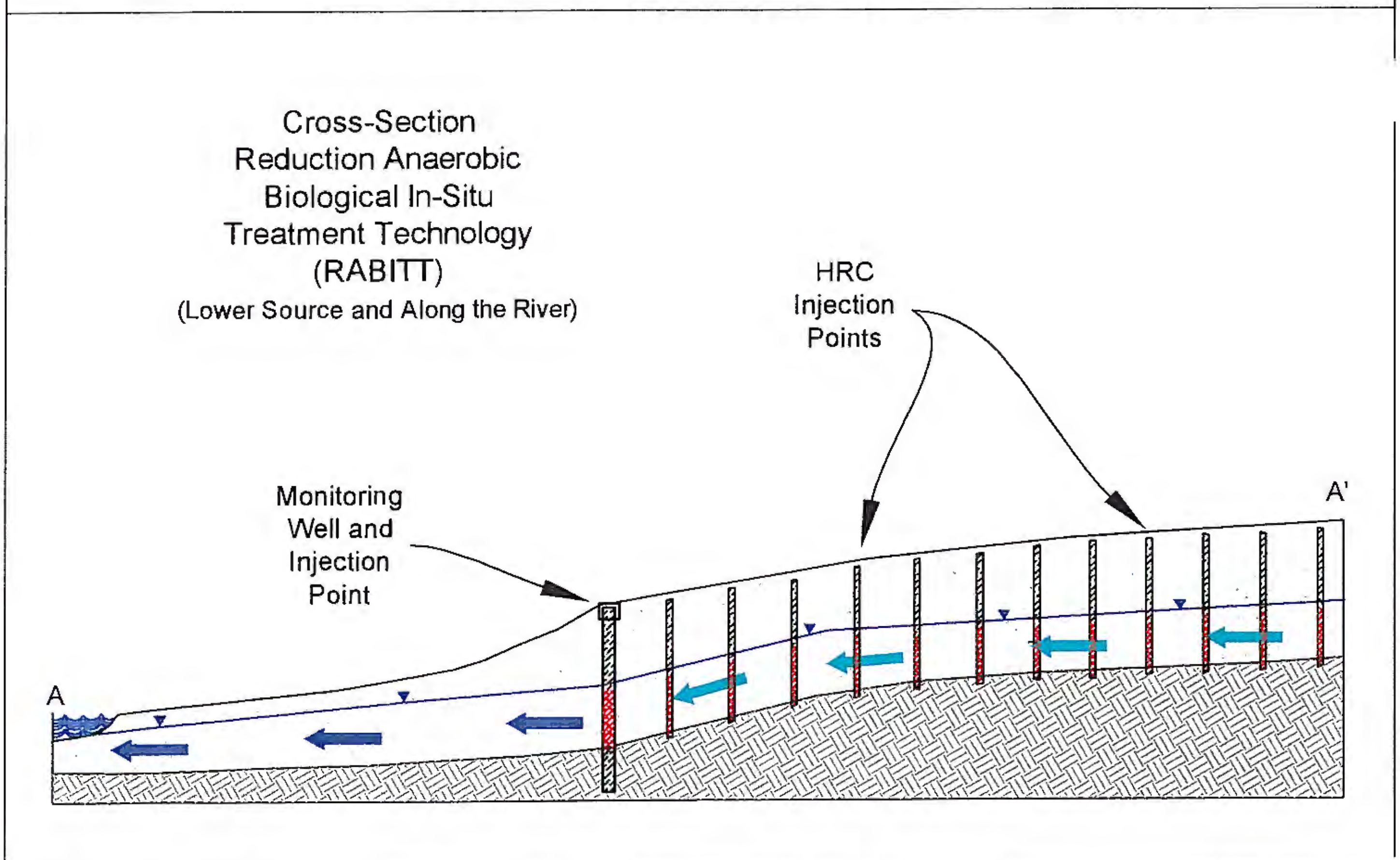
- Replacement of HRC in the 4-inch injection wells will be made two times per year. Each replacement requires the addition of 40 lbs of HRC per well.
- Replacement of ORC in the 4-inch injection wells will be made two times per year. Each replacement requires the addition of six 4-inch ORC socks per well.
- It was assumed the used ORC socks could be disposed of at the local municipal landfill without any added costs.
- Replacement of the HRC within the source treatment area will be required on an annual basis. It was assumed that 15 borings would be installed each year to replace the HRC in the areas of remaining contamination.
- Fifteen wells will be sampled periodically for 5 years. Sampling will be quarterly for the first 3 years, semiannually for the next two years, and annually thereafter. Water samples will be analyzed for VOCs (8260) during each sampling event and annually for geochemical indicator parameters. The geochemical indicator parameters include pH, redox potential (Eh), alkalinity, dissolved oxygen, ferrous iron, sulfate or sulfide, chloride, and potentially, dissolved hydrogen.
- Annual reporting and data analysis will include a discussion on system O&M, groundwater monitoring results, and air monitoring results.

River Terrace RV Park
Alternative L-F Reductive Anaerobic Biological In-Situ Treatment Technology (RABITT)
Lower Contaminant Plume

Function	Unit	Quantity	Cost Per Unit	Total Cost	Total Cost (- 30%)	Total Cost (+ 50%)
1. Base Construction Estimate						
1.1. HRC Injection						
1.1.1. Drill/install Injection Points	EA	40	$750	$30,000		
1.1.2. Drill/Install HRC Injection Wells	EA	40	$2,500	$100,000		
1.1.3. Hydrogen Release Compound	LBS	4000	$7	$28,000		
1.1.4 Drill/Install ORC Injection Wells	EA	25	$1,500	$37,500		
1.1.5 Oxygen Release Compound	Socks	300	$37.50	$11,250		
1.1.6. Installation Equip and Labor	LS	1	$20,000	$20,000		
Total for HRC/ORC Injection Wells				**$226,750**		
1.2. Dewatering/Waste Management	LS	1	$5,000	**$5,000**		
1.3. Pilot Study	LS	1	$30,000	**$30,000**		
Construction Cost Subtotal				**$261,750**	**$183,225**	**$392,625**
2. Mobilization / Demobilization	%	1	10%	$26,175		
3. Construction Contingency	%	1	20%	$52,350		
4. Administrative Charge	%	1	15%	$39,263		
6. Engineering and Design	%	1	30%	$78,525		
Capital Cost Total				**$458,063**	**$320,644**	**$687,094**
Annual O&M Costs						
Replacement of HRC in Wells (2 Times/Yr)	LBS	3200	$7	$22,400		
Replacement of ORC in Wells (2 Times/Yr)	Sock	300	$37.50	$11,250		
Replacement of HRC (10 Borings)	LS	1	$10,000	$10,000		
Labor Requirements (75 hrs per event)	HR	150	$65	$9,750		
Mobilization and General Requirements	%	1	15%	$8,010		
Annual O&M Cost Total				**$61,410**		
Present Worth Analysis						
O&M Cost for Years 1 - 5 @ 7%				**$251,793**		
Monitoring Cost for Years 1 - 5 @ 7%				$229,262		
Total O&M Cost (Present Worth - 5 yrs)				**$481,055**	**$336,739**	**$721,583**
Total Present Worth Cost (5 Yrs @ 7%)				**$939,118**	**$657,382**	**$1,408,677**

Alternative L-F: Lower Plume





OASIS/BRISTOL JV	Conceptual Drawing River Terrace RV Park Feasibility Study Soldotna, Alaska	Date: April 2000	Figure S-4
ADEC Contract No: 18-2-12-12		Drawn By: JAS Checked By: ASN	Project No: 20019

ALTERNATIVE U-A
NO ACTION (UPPER CONTAMINANT PLUME)

Capital Cost:	None
O&M Costs (Present Worth @ 15 years):	None
Total Present-Worth Cost:	None

Description:

No remedial actions or institutional controls would be implemented. Evaluation of the "no action" alternative is required by CERCLA to provide a baseline against which all other remedial alternatives can be compared. This alternative is applicable to all contaminant types found in water, soil, and wetland environments. Natural processes may eventually reduce contaminant concentrations to acceptable levels, but current and future risk to human health and the environment would remain above ARARs for an extended period of time. No monitoring of groundwater or soil would be conducted to confirm eventual compliance with ARARs. The "no action" alternative is not expected to achieve remedial action objectives.

ALTERNATIVE U- B
INTRINSIC REMEDIATION (UPPER CONTAMINANT PLUME)

Capital Cost:	$38,000 to $82,000
O&M Costs (Present Worth @ 15 years):	$276,000 to $592,000
Total Present-Worth Cost:	$314,000 to $674,000

Description:

Intrinsic remediation would not involve active remedial technologies. Dilution, absorption, volatilization, and biological degradation would naturally occur to continue attenuating dissolved PCE and its daughter products. Bioremediation of PCE generally occurs under reducing (anoxic) conditions. Groundwater monitoring at the River Terrace Upper Contaminant Plume indicates the aquifer is aerobic and no evidence exists to indicate that the PCE is biodegrading in this portion of the aquifer. However, other intrinsic remediation processes such as dispersion and sorption are present in all aquifer conditions.

Implementation of this alternative will involve groundwater and surface water monitoring, periodic groundwater modeling, and institutional controls to ensure that the dissolved-phase PCE is not causing risk to human health or the environment. Groundwater monitoring is also proposed to monitor the intrinsic remediation progress.

The intrinsic remediation option is not expected to achieve remedial action objectives and is only included to provide a comparison to the other remedial alternatives.

Assumptions:

- Initial data analysis and modeling would be performed to evaluate the feasibility and restoration time period for intrinsic remediation to achieve remedial objectives.
- Five (5), ten (10), and fifteen (15) years after initial event the data analysis and modeling efforts would be repeated to review the intrinsic remediation progress and determine if remedial action goals will be met in the desired timeframe.
- Fifteen wells will be sampled periodically for 15 years. Sampling will be quarterly for the first 3 years, semiannually for the next two years, and annually thereafter. Water samples will be analyzed for VOCs (8260) during each sampling event and annually for geochemical indicator parameters. The geochemical indicator parameters include pH, redox potential (Eh), alkalinity, dissolved oxygen, ferrous iron, sulfate or sulfide, chloride, and potentially, dissolved hydrogen.

ALTERNATIVE U-C
PERMEABLE REACTIVE BARRIER (UPPER CONTAMINANT PLUME)

Capital Cost:	$167,000 to $358,000
O&M Costs (Present Worth @ 15 years):	$237,000 to $507,000
Total Present-Worth Cost:	$403,000 to $865,000

Description:

This alternative will require the installation of a permeable reactive barrier across the flow path of the upper contaminant plume. This type of barrier allows the passage of water while prohibiting the movement of contaminants by chemical reactions. The specific type of reaction wall proposed for River Terrace is a zero-valent iron treatment wall. It consists of iron filings mixed with sand. This type of treatment wall is applicable for treatment of chlorinated contaminants such as PCE, TCE, DCE, and VC. As the iron is oxidized, a chlorine atom is removed from the compound by one or more reductive dechlorination mechanisms, using electrons supplied by the oxidation of iron. The process dissolves the iron filings, but the metal disappears so slowly that the remediation barriers can be expected to remain effective for many years.

A 100-foot long treatment wall would be installed approximately parallel to the northwest and northeast walls of the former dry cleaner building to treat PCE-contaminated groundwater emanating from the building vicinity. The wall will be installed in the vicinity of MW-25, approximately 50- to 75-feet from the building. Installation of the treatment wall will require a trench approximately 20 feet deep, with a 5-foot deep active treatment layer.

Due to the uncertainty of the cohesive strength and stability of the soil conditions (soils consist of cobbles and gravel), a one to one slope on the trench excavation was assumed down to 15 feet below ground surface. Construction of the permeable reactive barrier would be performed by excavating an additional 5 feet of material using trench boxes and supports where needed to stabilize the excavation. The upper 15 feet of soil that are above the water table are assumed uncontaminated and this material will be used to backfill the excavation.

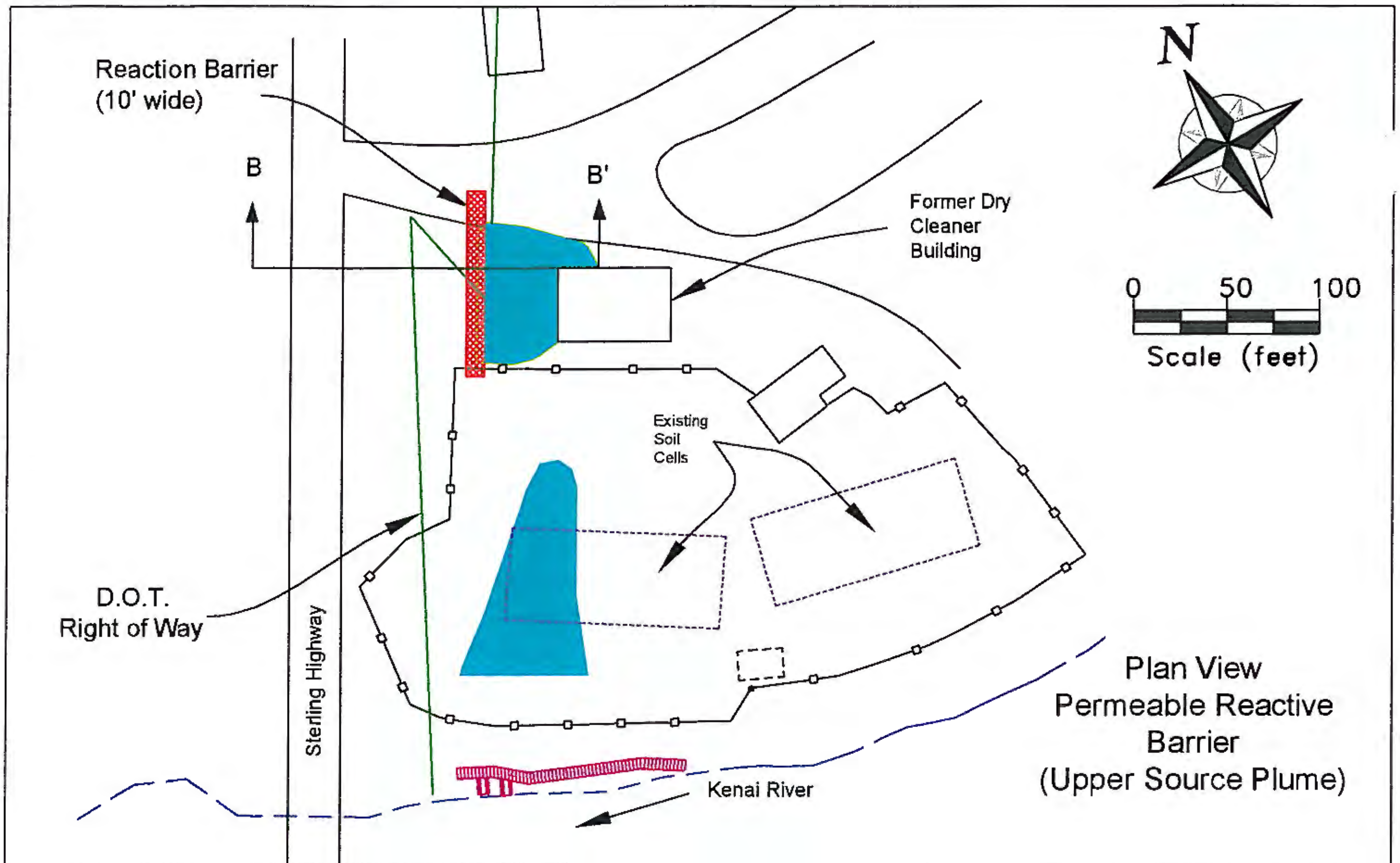
Implementation of this alternative will also involve groundwater and surface water monitoring, and institutional controls to ensure that the dissolved-phase PCE is not causing risk to human health or the environment. It is estimated that this monitoring will be required for a period of 15 years, but the actual monitoring period may vary depending on how soon the remedial action objectives are met.

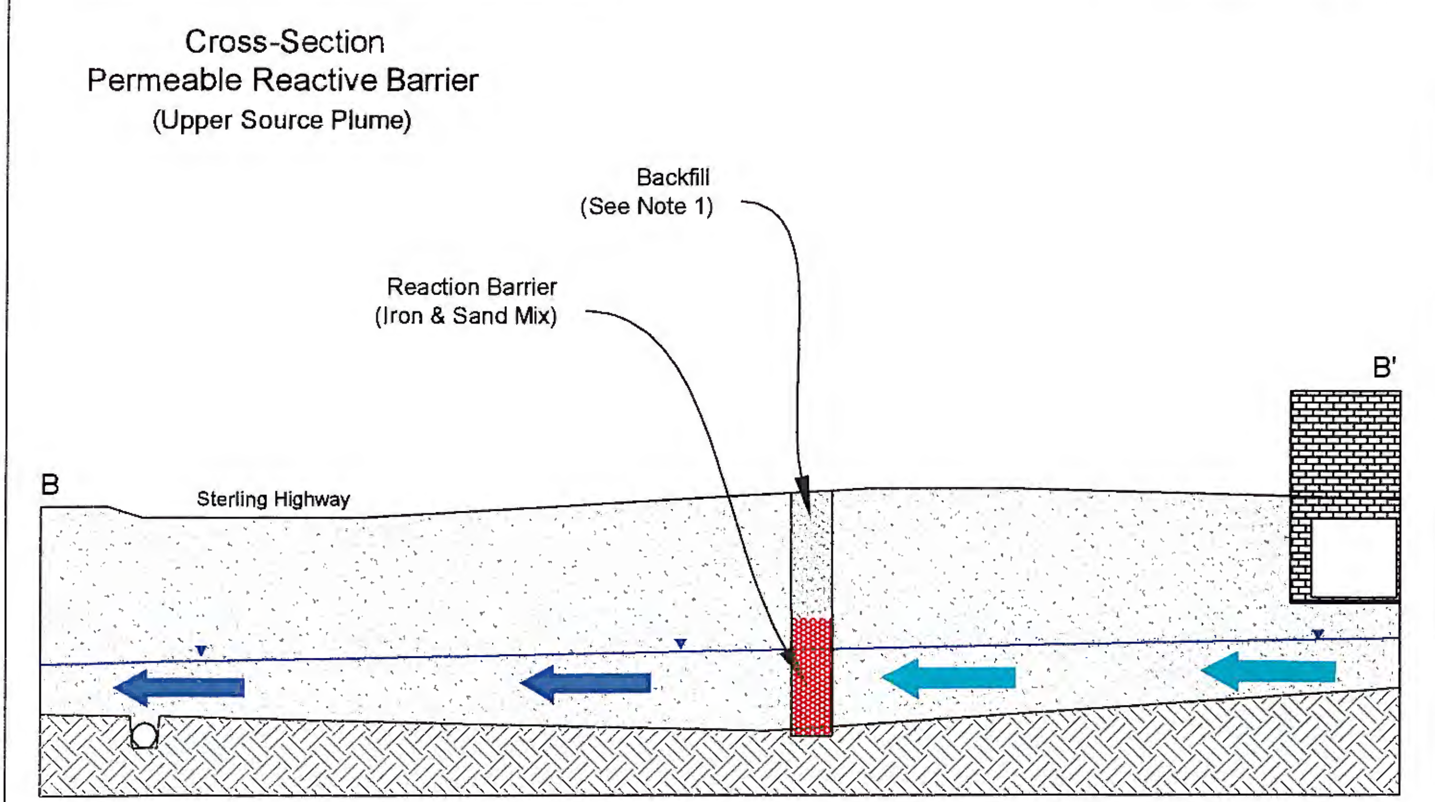
Assumptions:

- Dimensions of the treatment wall will be approximately 100 feet long by 3 feet wide by 7 feet deep (volume = 2,100 cubic feet).
- A mixture of sand and granular will be used to construct the 3-foot thick wall. The granular iron will be purchased and shipped from the continental United States. Shipment will be by train to Seattle, then by barge to Kenai.
- For construction reasons, the iron will be mixed with processed, cleaned, and screened sand at a 1:1 ratio, resulting in a 3-foot thick wall. The sand will be purchased from a local borrow source.
- Dimensions of the trench for installing the treatment wall will be approximately 100 feet long by 3 feet wide by 20 feet deep (6,000 cubic feet). The trench will most likely be constructed by backhoe or ladder type trenching equipment. Shoring, trench boxes, and even sheet piles may be required to assure safety and proper placement of the iron medium.
- The upper 15 feet of the trench walls will be slopped back at a one to one slope for stability and safety during excavation activities. Trench boxes and bracing will also be used to reduce trench sloughing and make it easier to place the iron material in a uniform matter during the permeable wall construction.
- After installing the iron reactive treatment wall, the remaining trench area will be backfilled with native soils. The approximate 2,100 cubic feet of soil that was replaced by the iron/sand mixture, and not placed back into the trench, will be taken from the upper soil zone. It is assumed that the upper soil zone PCE contamination levels are significantly below the site ACL for soil and that these soils may be spread on-site.
- A pilot test/treatability study is recommended prior to final design and installation. It is assumed that the iron reactive barrier will successfully transform the PCE and its daughter products to concentrations in the groundwater that comply with the remedial action objectives. This pilot study will assist in the design of a treatment wall that will be effective in achieving the remedial action objectives.
- Fifteen wells will be sampled periodically for 15 years. Sampling will be quarterly for the first 3 years, semiannually for the next two years, and annually thereafter. Water samples will be analyzed for VOCs (8260) during each sampling event and annually for geochemical indicator parameters. The geochemical indicator parameters include pH, redox potential (Eh), alkalinity, dissolved oxygen, ferrous iron, sulfate or sulfide, chloride, and potentially, dissolved hydrogen.
- The Reactive Iron Wall technology is proprietary and requires a licensing fee of 15 percent of the construction costs.

River Terrace RV Park						
Alternative U-C Reactive Treatment Wall						
Upper Contaminant Plume						
Function	Units	Quantity	Cost Per Unit	Total Cost	Total Cost (- 30%)	Total Cost (+ 50%)
1. Base Construction Estimate						
1.1. Permeable Reactive Barrier						
1.1.1 Iron Medium (including shipping)	TON	80	$400	$32,000		
1.1.2. Shipping Costs for Iron Medium	TON	80	$180	$14,400		
1.1.3. Clean Sand for Medium Mix	CY	38	$15	$570		
1.1.4. Trench, Backfill, and Shoring	LF	100	$60	$6,000		
Total for Permeable Reactive Barrier				**$52,970**		
1.2. Overburden Removal/Replacement						
1.2.1. Excavate uncontaminated soil above water table and slope walls 1:1	CY	1,125	$10	$11,250		
1.2.2. Replace uncontaminated soil	CY	1,125	$10	$11,250		
Total for Sheet Pile Wall				**$22,500**		
1.3	LS	1				
1.4. Dewatering/Waste Management	LS	1	$20,000	**$20,000**		
1.5. Bench Scale Study	LS	1	$30,000	**$30,000**		
Construction Cost Subtotal				**$125,470**	**$87,829**	**$188,205**
2. Mobilization / Demobilization	%	1	10%	$12,547		
3. Construction Contingency	%	1	20%	$25,094		
4. Administrative Charge	%	1	15%	$18,821		
6. Engineering and Design	%	1	30%	$37,641		
7. Site Technology Licensing	%	1	15%	$18,821		
Capital Cost Total				**$238,393**	**$166,875**	**$357,590**
Annual O&M Costs						
Maintenance Support (0.5 hrs per week)	HR	25	$65	$1,625		
Total Annual O&M Cost				**$1,625**		
Present Worth Analysis						
O&M Cost for Years 1 - 15 @ 7%				$14,800		
Monitoring Cost for Years 1 - 15 @ 7%				$323,156		
Total O&M Cost (Present Worth - 15 yrs)				**$337,956**	**$236,569**	**$506,934**
Total Present Worth Cost (15 Yrs @ 7%)				**$576,349**	**$403,444**	**$864,524**

Alternative U-C: Upper Plume





Note 1:
Backfill material is less permeable than native material in case the water table rises.

OASIS/BRISTOL JV	Conceptual Drawing River Terrace RV Park Feasibility Study Soldotna, Alaska	Date: APRIL 2000	Figure S-5
ADEC Contract No: 18-2-12-12		Drawn By: JAS Checked By: ASN	Project No: 20019

ALTERNATIVE U-D
IN-SITU AIR SPARGING AND VES GRID
(UPPER CONTAMINANT PLUME)

Capital Cost:	\$302,000 to \$646,000
O&M Costs (Present Worth @ 5 years):	\$340,000 to \$729,000
Total Present-Worth Cost:	\$642,000 to \$1,375,000

Description:

This alternative consists of in situ air sparging grid to treat the PCE impacted groundwater and soil at the contaminant source area. This alternative would involve injecting air into the contaminated groundwater, creating an underground stripper that removes contaminants through volatilization. This process is designed to operate at high airflow rates in order to effect volatilization (as opposed to the lower airflow rates used to stimulate biodegradation). Soil vapor extraction piping would be used in conjunction with the air sparging wells to control the flow of volatilized PCE. It is estimated that 32 sparging wells and 6 vapor extraction wells are required.

To promote enhanced remediation of the PCE contamination underneath the building, six passive venting wells will be placed through the floor of the building. Each well will have a one-way check valve that allows air to flow into the subsurface but not back into the building. By imposing a negative vacuum around the building with the vapor extractions wells air from inside the building would be drawn through the passive venting wells enhancing the subsurface volatilization of PCE underneath the building.

A pilot test would be conducted prior to full-scale system design and implementation. A pilot test will assist in proper spacing of air sparging wells and will provide an indication of expected PCE removal rates.

Because this alternative includes aggressive treatment of some of the contaminant source area, it is estimated that the ACLs can be achieved in five years. The potential for contaminant source material underneath the building and the possibility of PCE penetrating the till material may extend the required treatment time.

Implementation of this alternative will also involve groundwater and surface water monitoring and institutional controls to ensure that the dissolved-phase PCE is not causing risk to human health or the environment. It is estimated that this monitoring will be required for a period of 5 years, but the actual monitoring period may vary depending on how soon the remedial action objectives are met. Although some variations in monitoring techniques may occur between alternatives, the costs will probably not vary much between the options.

Assumptions:

System Installation

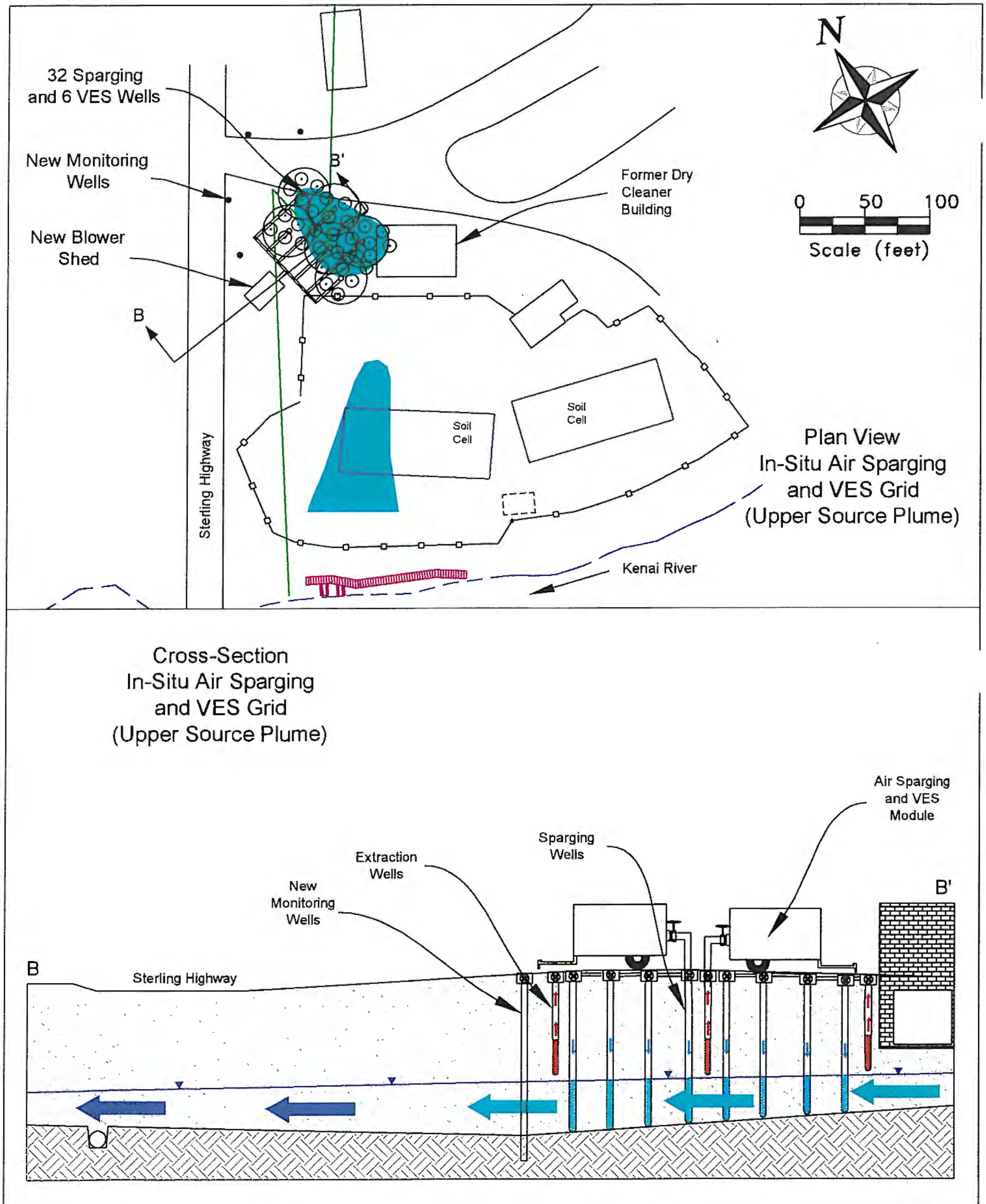
- A pilot test will be conducted prior to final design and installation.
- Thirty-two 2-inch diameter air-sparging wells will be installed to an average depth of 22 to 24 feet bgs. Wells will be spaced in a 10-foot by 15-foot grid pattern.
- Each air sparge well is capable of injecting 5 SCFM of air at a maximum pressure of 6 to 8 psi, with an estimated radius of influence of 5 feet. This will require approximately 4 blowers capable of 50 SCFM at these pressures.
- Six 2-inch diameter vacuum extraction wells installed to a depth of 15 to 17 feet bgs. Each well is estimated to be capable of extracting 50 to 100 SCFM with a radius of influence of 40 feet.
- Six 2-inch diameter passive venting wells with one-way check valves will be installed through the floor of the former dry cleaner building.
- Installation of 500 lineal feet of horizontal HDPE piping for the sparge and vacuum systems, with associated insulation, valves, gauges, and meters. A short section of heat resistant pipe is needed at the output of the air sparge blowers.
- Installation of 250 feet of heat trace and insulation for the vacuum system.
- 500 lineal feet of trenching and backfill, 4 feet deep, 4 feet wide, for the sparge and vacuum systems piping.
- Installation of one prefabricated and weatherized equipment building to house the air sparge blowers, vapor extraction blowers, and associated valves, pipes, and controls.
- The system will be winterized using insulation and heat trace of pipe.

System O&M

- The system will operate 365 days per year for 5 years.
- There will be no requirements of off-gas control or treatment.
- Exhaust stack air samples will be collected 4 times per year for 5 years. Air samples will be analyzed for VOCs using EPA TO-14 method.
- Fifteen wells will be sampled periodically for 5 years. Sampling will be quarterly for the first 3 years, semiannually for the next two years, and annually thereafter. Water samples will be analyzed for VOCs (8260) during each sampling event and annually for geochemical indicator parameters. The geochemical indicator parameters include pH, redox potential (Eh), alkalinity, dissolved oxygen, ferrous iron, sulfate or sulfide, chloride, and potentially, dissolved hydrogen.
- Annual reporting and data analysis will include a discussion on system O&M, groundwater monitoring results, and air monitoring results.

River Terrace RV Park						
Alternative U-D In-Situ Air Sparging - GRID						
Upper Contaminant Plume						
					Total Cost	Total Cost
Function	Unit	Quantity	Cost Per Unit	Total Cost	(- 30%)	(+ 50%)
1. Base Construction Estimate						
1.1 Sparging Wells						
1.1.1. Trenching and backfill for piping	LF	500	$15	$7,500		
1.1.2. HDPE Piping	LF	500	$0.60	$300		
1.1.3. Sparging Wells	EA	32	$1,500	$48,000		
1.1.4. Installaltion Labor	MH	300	$40	$12,000		
Total for Sparging Wells				$67,800		
1.2 Soil Vaper Extraction System						
1.2.1.Trenching,heat trace, insulation	LF	250	$25	$6,250		
1.2.2. HDPE Piping	LF	250	$0.60	$150		
1.2.3. VES Wells	EA	6	$1,500	$9,000		
1.2.4. Passive Vent Wells Under Bldg.	EA	6	$1,500	$9,000		
Total for Soil Vaper Extraction System				$24,400		
1.4 Blower Building(s)	EA	1	$100,000	$100,000		
1.5 Fencing	LF	200	$20	$4,000		
1.6. External Power Supply	LS	1	$15,000	$15,000		
1.7. Dewatering/Waste Management	LS	1	$5,000	$5,000		
1.8. Pilot Study	LS	1	$30,000	$30,000		
Construction Cost Subtotal				$246,200	$172,340	$369,300
2. Mobilization / Demobilization	%	1	10%	$24,620		
3. Construction Contingency	%	1	20%	$49,240		
4. Administrative Charge	%	1	15%	$36,930		
5. Engineering and Design	%	1	30%	$73,860		
Capital Cost Total				$430,850	$301,595	$646,275
Annual O&M Costs						
Maintenance Support (5 hrs per week)	HR	260	$65	$16,900		
Operating Power and Light	LS	1	$30,000	$30,000		
Routine Equip. Replacement and Repair	LS	1	$7,500	$7,500		
Mobilization and General Requirements	%	1	15%	$8,160		
Annual O&M Cost Total				$62,560		
Present Worth Analysis						
O&M Cost for Years 1 - 5 @ 7%				$256,508		
Monitoring Cost for Years 1 - 5 @ 7%				$229,262		
Total O&M Cost (Present Worth - 5 yrs)				$485,770	$340,039	$728,656
Total Present Worth Cost (5 Yrs @ 7%)				$916,620	$641,634	$1,374,931

Alternative U-D: Upper Plume



OASIS/BRISTOL JV	Conceptual Drawing River Terrace RV Park Feasibility Study Soldotna, Alaska	Date: April 2000	Figure S-6
ADEC Contract No: 18-2-12-12		Drawn By: JAS Checked By: ASN	Project No: 20019

ALTERNATIVE U-E
REDUCTIVE ANAEROBIC BIOLOGICAL IN-SITU TREATMENT TECHNOLOGY (RABITT)
(UPPER CONTAMINANT PLUME)

Capital Cost:	$177,000 to $379,000
O&M Costs (Present Worth @ 5 years):	$266,000 to $570,000
Total Present-Worth Cost:	$443,000 to $949,000

Description:

This alternative consists of in situ injection of Hydrogen Release Compound (HRC) through approximately 90 injection points. HRC injection results in anaerobic bioremediation of chlorinated solvents such as PCE and TCE. HRC offers a passive, and possibly low-cost approach to in-situ remediation. HRC is a moderately flowable material that can be injected under pressure into an aquifer using various drilling and direct push technologies. It can maintain dechlorinating conditions in the aquifer for six months to one year or more, depending on site characteristics. HRC provides a time-release hydrogen source to accelerate the reduction of anaerobically degradable contaminants.

Advantages of this technology include the elimination of aboveground treatment and processing equipment, and reduced disruption to the site. Since chlorinated hydrocarbon sources are difficult to locate, a large number of injection wells, placed in a grid pattern, will most likely be required to address the entire contaminated area. It is expected that annual replacement of the HRC will be required to maintain reductive anaerobic biological treatment conditions.

To promote enhanced remediation of the PCE contamination underneath the building, injections of sodium lactate or liquid HRC will be conducted. The solution will be prepared in a large tank and pumped through a hose to the sumps or other injection points placed in the floor of the building. Two injections are planned for the first year with annual injections being performed each year after that.

Because this alternative includes aggressive treatment of some of the contaminant source area, it is estimated that the ACLs can be achieved in five years. The potential for contaminant source material underneath the building and the possibility of PCE penetrating the till material may extend the required treatment time.

Implementation of this alternative will also involve groundwater and surface water monitoring and institutional controls to ensure that the dissolved-phase PCE is not causing risk to human health or the environment. It is estimated that this monitoring will be required for a period of 5 years, but the actual monitoring period may vary depending on how soon the remedial action objectives are met. Although some variations in monitoring techniques may occur between alternatives, the costs will not vary much between the options.

Assumptions:

System Installation

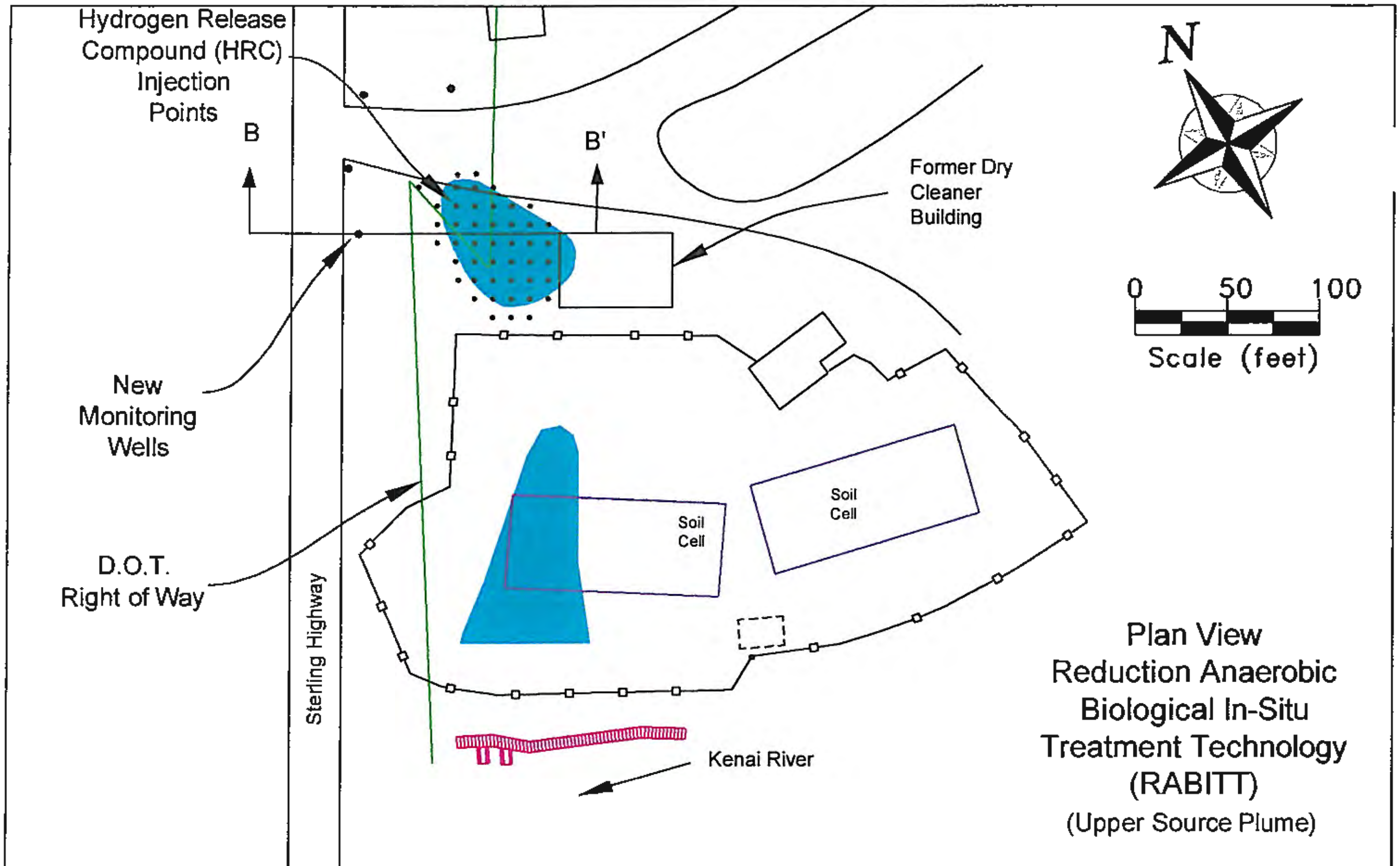
- Ninety 2-inch diameter injection points will be drilled to a depth of 20 to 25 feet below ground surface. Each injection point will receive approximately 12 lbs of HRC in the bottom six feet of the boring.
- Liquid batches of HRC or sodium lactate will be prepared and injected underneath the floor of the building to promote remediation of PCE contamination underneath the building. These injections would be conducted twice a year the first year and then annually for the next five years or until PCE contamination is reduced below the ACL.
- Appropriate method of injection will be determined by design engineer.
- HRC injection is a proprietary treatment method that requires a contract with Regenesis Corporation of California.

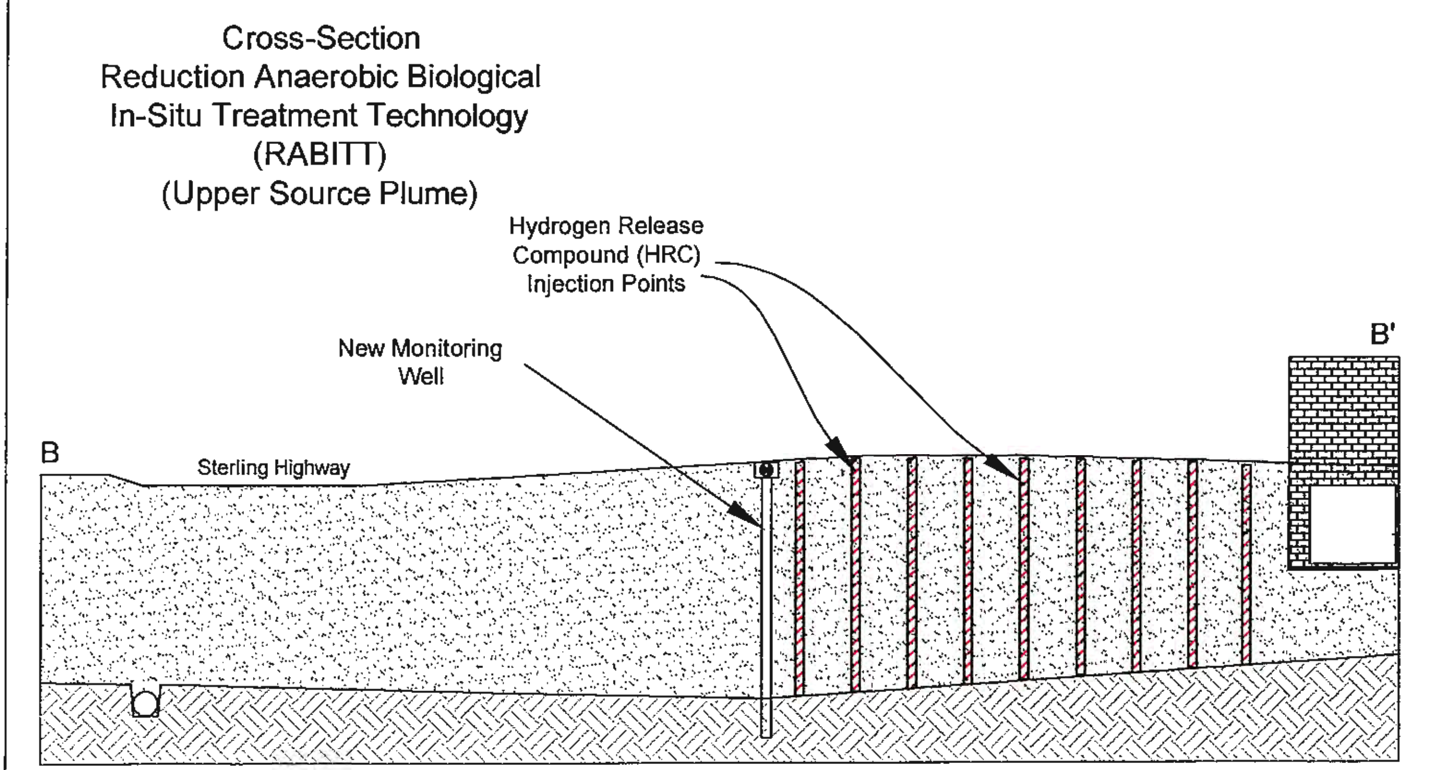
System O&M

- Replacement of the HRC will be required on an annual basis. It was assumed that 20 borings would be installed each year to replace the HRC.
- Annual injection of sodium lactate or liquid HRC underneath the building floor will be required on an annual basis. It was assumed that the equivalent of 1,000 lbs of HRC would be used during each injection.
- Fifteen wells will be sampled periodically for 5 years. Sampling will be quarterly for the first 3 years, semiannually for the next two years, and annually thereafter. Water samples will be analyzed for VOCs (8260) during each sampling event and annually for geochemical indicator parameters. The geochemical indicator parameters include pH, redox potential (Eh), alkalinity, dissolved oxygen, ferrous iron, sulfate or sulfide, chloride, and potentially, dissolved hydrogen.
- Annual reporting and data analysis will include a discussion on system O&M, groundwater monitoring results, and air monitoring results.

River Terrace RV Park						
Alternative U-E Reductive Anaerobic Biological In-Situ Treatment Technology (RABITT)						
Upper Contaminant Plume						
Function	Unit	Quantity	Cost Per Unit	Total Cost	Total Cost (- 30%)	Total Cost (+ 50%)
1. Base Construction Estimate						
1.1. HRC Injection						
1.1.1. Drill Injection Points	EA	90	$750	$67,500		
1.1.2. Hydrogen Release Compound	LBS	1100	$7	$7,700		
1.1.3. Installation Equip and Labor	LS	1	$10,000	$10,000		
Total for HRC Injection Wells				**$85,200**		
1.2. HRC Injection Under Building						
1.1.1. Sodium Lactate or HRC	LBS	2000	$7	$14,000		
1.1.2. Installation Equip and Labor	LS	1	$10,000	$10,000		
Total for Injection Under Building				**$24,000**		
1.3. Dewatering/Waste Management	LS	1	$5,000	**$5,000**		
1.4. Pilot Study	LS	1	$30,000	**$30,000**		
Construction Cost Subtotal				**$144,200**	**$100,940**	**$216,300**
2. Mobilization / Demobilization	%	1	10%	$14,420		
3. Construction Contingency	%	1	20%	$28,840		
4. Administrative Charge	%	1	15%	$21,630		
6. Engineering and Design	%	1	30%	$43,260		
Capital Cost Total				**$252,350**	**$176,645**	**$378,525**
Annual O&M Costs						
Replacement of HRC (20 borings)	LS	1	$20,000	$20,000		
Reinjection of HRC under Building	LS	1	$12,000	$12,000		
Mobilization and General Requirements	%	1	15%	$4,800		
Annual O&M Cost Total				**$36,800**		
Present Worth Analysis						
O&M Cost for Years 1 - 5 @ 7%				$150,887		
Monitoring Cost for Years 1 - 5 @ 7%				$229,262		
Total O&M Cost (Present Worth - 5 yrs)				**$380,149**	**$266,105**	**$570,224**
Total Present Worth Cost (5 Yrs @ 7%)				**$632,499**	**$442,750**	**$948,749**

Alternative U-E: Upper Plume





OASIS/BRISTOL JV	Conceptual Drawing River Terrace RV Park Feasibility Study Soldotna, Alaska	Date: April 2000	Figure S-7
ADEC Contract No: 18-2-12-12		Drawn By: JAS Checked By: ASN	Project No: 20019

ALTERNATIVE U-F
SOURCE AREA EXCAVATION AND GROUNDWATER TREATMENT
(UPPER CONTAMINANT PLUME)

Capital Cost:	$351,000 to $752,000
O&M Costs (Present Worth @ 5 years):	$206,000 to $442,000
Total Present-Worth Cost:	$557,000 to $1,194,000

Description:

This alternative consists of excavating the upper plume contaminated soil surrounding the old dry cleaning building and depositing the soil into treatment cells for remediation. The excavation will encompass a 3,300 sq ft area with an average depth of 20 feet. The bottom 6- to 8-feet of soil is in the water table and is considered contaminated (approximately 800 CY). Based on soil sample results, it is assumed that the 12 to 14 feet of soil above the water table is uncontaminated.

Using a large backhoe, excavation should start with removing the uncontaminated soil above the water table and piling it so that it can be easily placed into the excavation. Once below the water table, localized dewatering will be performed with a pump that will transport the contaminated water to an external air stripping treatment module. It is assumed that the treated water will be approved for disposal into the local sewer system. Dewatering will be kept to a minimum by excavating and filling small sections as the work progresses through the site.

When backfilling the excavation below the water table, approximately 300 CY of a 50/50 mix of sand and reactive iron material will be placed on the downgradient edge of the excavation along the west/northwest side of the old dry cleaning building. The 10'x100'x8' permeable iron wall will treat any remaining contaminants that may flow from beneath the facility. After the wall is placed, uncontaminated soil from above the water table will be returned to the excavation and additional clean backfill material will be used to finish filling the excavation.

The contaminated material will be transported approximately 200 feet and placed into a 100'x45'x5' treatment cell located near the previous treatment cells. The dump trucks will use plastic liners to prevent spillage of contaminated water during transport. The 5' tall cell will be constructed of soil and be completely lined and covered with impermeable geo-textile. A blower building will house the electrical controls and blowers that will feed air through a piping system to treat the contaminated soil.

Advantages of this technology include the direct removal of contaminated soils from a portion of the contaminated soil source. Disadvantages include the high costs, and the possibility of missing a large portion of contaminated soil that may be below the existing facility or within the till material underlying the site.

Implementation of this alternative will also involve groundwater and surface water monitoring and institutional controls to ensure that the dissolved-phase PCE is not causing risk to human health or the environment. It is estimated that this monitoring will be required for a period of 10 years, but the actual monitoring period may vary depending on how soon the remedial action objectives are met.

Assumptions:

System Installation

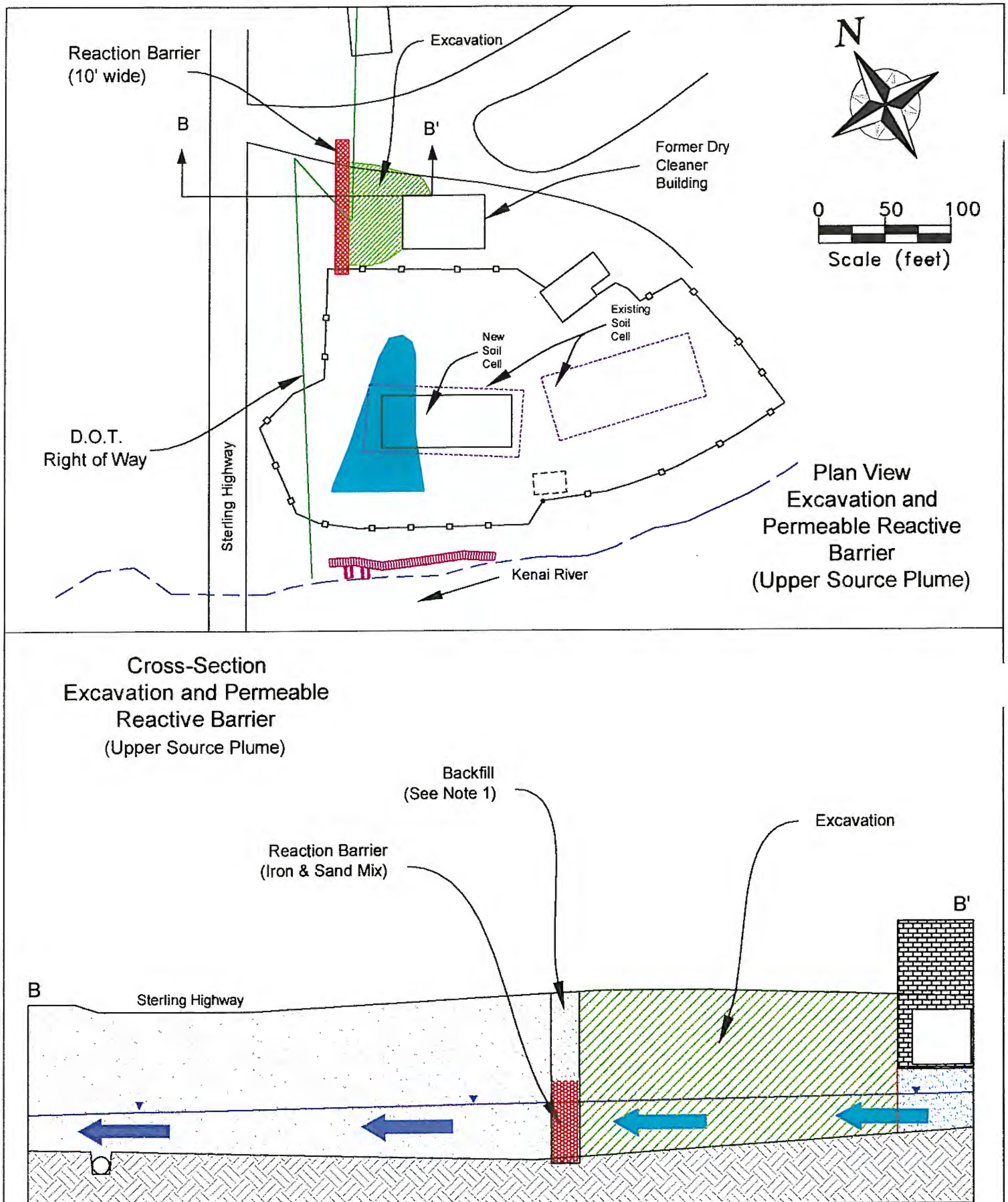
- Excavate approximately 1700 CY of uncontaminated soil and 800 CY of contaminated soil. Contaminated soil will be transported about 150-200 feet to a remediation cell. The cell will be created with soil berms and completely lined and covered with geo-textile.
- Soils above the water table (estimated at 18 feet below ground surface) are considered clean and will be used as backfill.
- Confirmation soil samples will be collected from the excavation floor at a frequency of one per every 150 SF. Confirmation soil samples will be collected from the excavation sidewalls at a frequency of every 25 feet. These samples will be analyzed by EPA method 8260.
- A permeable iron reactive wall will be used to provide treatment of groundwater emanating from any remaining contaminated soils that could not be excavated.
- Dewatering of the excavation will be necessary. The water will be treated on-site with a portable air stripper. The water will be discharged to the local sewer after on-site treatment.
- No utilities cross the planned excavation area.
- Contaminated soils can be treated on-site under the existing contained-in determination.
- The contaminated soils will be placed into one soil treatment cells located on the site. The treatment cell is capable of containing approximately 800 CY of contaminated soil.

System O&M

- Continual operation and maintenance of the treatment cells will be required. Electrical costs for blower operation, heating, and lights are expected for up to 5 years.
- The remediation cell will be sampled periodically for 5 years. There will be no requirements for off-gas control or treatment.
- Fifteen wells will be sampled periodically for 5 years. Sampling will be quarterly for the first 3 years, semiannually for the next two years, and annually thereafter. Water samples will be analyzed for VOCs (8260) during each sampling event and annually for geochemical indicator parameters. The geochemical indicator parameters include pH, redox potential (Eh), alkalinity, dissolved oxygen, ferrous iron, sulfate or sulfide, chloride, and potentially, dissolved hydrogen.
- Annual reporting and data analysis will include a discussion on system O&M, groundwater monitoring results, and air monitoring results.

River Terrace RV Park						
Alternative U-F Source Area Excavation and Permeable Iron Wall Upper Contaminant Plume						
					Total Cost	Total Cost
Function	Unit	Quantity	Cost Per Unit	Total Cost	(- 30%)	(+ 50%)
1. Base Construction Estimate						
1.1. Excavate, Backfill, and Transport						
1.1.1. Excavate uncontaminated soil above water table and backfill	CY	1700	$10	$17,000		
1.1.2. Excavate contaminated material below water table and transport	CY	800	$75	$60,000		
1.1.3. Furnish and place new backfill	TON	900	$14	$12,600		
1.1.4. Confirmation Soil Sampling	EA	35	$250	$8,750		
Total for Excavate, Backfill, and Transport				**$98,350**		
1.2. Permeable Reactive Barrier						
1.2.1. Iron Medium with Installation	TON	80	$400	$32,000		
1.2.2. Shipping Costs for Iron Medium	TON	80	$180	$14,400		
1.2.3. Clean Sand for Medium Mix	CY	38	$15	$570		
1.2.4. Soil / Iron Installation Barrier	LS	1	$12,000	$12,000		
Total for Permeable Reactive Barrier				**$58,970**		
1.3. Dewatering/Waste Management						
1.3.1. Pump and Stripping System	LS	1	$40,000	$40,000		
1.3.3. Holding Tank Rental	MO	1	$3,000	$3,000		
1.3.4. Decontamination Operations	LS	1	$10,000	$10,000		
Total for Dewatering/Waste Management				**$53,000**		
1.4 Construct Remediation Cells						
1.4.1. Soil Cell Structure	LS	1	$15,000	$15,000		
1.4.2. Cell Liner and Cover	SF	12,000	$2	$24,000		
1.1.2. Piping	LF	500	$1.50	$750		
1.4.3. Blower Building w/equip.	EA	1	$20,000	$20,000		
1.1.4. Installation Labor	MH	300	$40	$12,000		
Total for Construct Remediation Cells				**$71,750**		
Construction Cost Subtotal				**$282,070**	**$197,449**	**$423,105**
2. Mobilization / Demobilization	%	1	10%	$28,207		
3. Construction Contingency	%	1	30%	$84,621		
4. Administrative Charge	%	1	15%	$42,311		
5. Engineering and Design	%	1	30%	$21,525		
6. Site Technology Licensing	%	1	15%	$42,311		
Capital Cost Total				**$501,044**	**$350,731**	**$751,566**
Annual O&M Costs						
Mobilization and General Requirements	%	1	15%	$2,082		
Maintenance Support (1 hrs per week)	HR	52	$65	$3,380		
Operating Power	LS	1	$10,000	$10,000		
Routine Equip. Replacement and Repair	LS	1	$500	$500		
Annual O&M Cost Total				**$15,962**		
Present Worth Analysis						
O&M Cost for Years 1 - 5 @ 7%				$65,447		
Monitoring Cost for Years 1 - 5 @ 7%				$229,262		
Total O&M Cost (Present Worth - 5 yrs)				**$294,709**	**$206,297**	**$442,064**
Total Present Worth Cost (5 Yrs @ 7%)				**$795,753**	**$557,027**	**$1,193,630**

Alternative U-F: Upper Plume



Note 1:
Backfill material is less permeable than native material in case the water table rises.

OASIS/BRISTOL JV	Conceptual Drawing River Terrace RV Park Feasibility Study Soldotna, Alaska	Date: APRIL 2000	Figure S-8
		Drawn By: JAS	Project No:
ADEC Contract No: 18-2-12-12		Checked By: ASN	20019

APPENDIX S2

In this appendix, cost evaluations are presented for excavating the remaining source area at the River Terrace site. Three different excavation alternatives were evaluated: the lower contaminant plume source area, the upper contaminant plume source area, and excavating contaminated soil across the entire River Terrace site.

Detailed cost evaluations are provided on the pages of this appendix, along with a discussion of each excavation alternative and the assumptions used in estimating the costs.

APPROACH USED FOR DEVELOPMENT OF COSTS

The development of costs for alternatives evaluated for River Terrace was based on best engineering judgement and experience, in a consistent manner that included the following steps:

1. An outline of the basic components of each alternative was assembled. Basic components included capital materials that would be purchased or constructed, services that would be purchased or rented, and labor.
2. Quantities of the basic components required were estimated. These estimates were based on previous experience with implementing remedial projects, vendor information, and best professional judgement.
3. The prices for the basic components were estimated using vendor information and existing pricing data. An accuracy range between +50 to –30 percent can be expected for the costs provided (USEPA, 1998).
4. A **Construction Cost Subtotal** was calculated from the estimated quantities and prices for the basic components of the alternatives.
5. A 10 to 15 percent charge for **Mobilization and Demobilization** was added to the Construction Cost Subtotal. This charge includes planning, expediting, transportation of personnel, per diem, and other mobilization costs not explicitly included in the basic component outline.
6. A variable percent charge for **Construction Contingencies** was applied to the Construction Cost Subtotal. The Construction Contingency is comprised of a scope contingency and a bid contingency. The scope contingency represents project risks associated with an incomplete design. These contingencies represent capital or O&M costs, unforeseeable at the time the feasibility study is prepared, which are likely to become known as the remedial design proceeds. The bid contingency includes variations caused by weather, unexpected site conditions, quantity overruns, modifications, etc. that occur during construction. A 15 percent bid contingency is generally recommended.
7. An **Administrative Charge** of 15 percent was applied to the Construction Cost Subtotal. This charge includes project management and construction management costs. The Administrative Charge also includes other services during construction including bid and contract administration, negotiations, and additional engineering and design during construction. Finally, this charge includes permitting and legal fees that include the cost of obtaining the required permits to implement the alternative (e.g., NPDES permits for discharges and permitting for wetland activity).
8. A 20 to 40 percent charge for **Engineering and Design** was applied to the Construction Cost Subtotal. The percentage was varied between 20 and 40 percent to determine a reasonable cost, based on the level of complexity of the design and engineering services required.
9. For some alternatives a **Site Technology Licensing** fee was applied to the Construction Cost Subtotal. The percentage was based on the Licensee's fee structure.
10. The items above were summed and added to the **Construction Cost Subtotal** to arrive at the **Capital Cost Total**.

11. **Annual Operation and Maintenance (O&M)** costs were developed for each alternative. The O&M components included recurring consumable materials that would be purchased or constructed, services that would be purchased or rented, sampling and analysis labor. Quantities of the required basic components were estimated. The estimate was based on previous experience with implementing remedial projects, vendor information, and best professional judgement.
12. A charge of 15 percent of the **Annual O&M Cost Subtotal** was added for annual mobilization and general requirement costs.
13. The **Annual O&M Cost Total** provides a total of the annual cost of O&M and does not include a present-worth analysis.
14. Present-worth analysis was applied to each O&M component sum. The present-worth analysis assumes that 7 percent annual interest can be made on money invested today. The duration of time used for present-worth analysis often varies depending on the remedial alternative. A 15-year duration was assumed for all of the remedial alternatives evaluated for the upper contaminant plume except the source treatment alternatives where a 5-year duration was assumed. A 10-year duration was assumed for all of the remedial alternatives evaluated for the lower contaminant plume except the source treatment alternatives where a 5-year duration was assumed.
15. The present-worth costs of each O&M component were summed to arrive at an O&M Cost Total (**Present Worth @ 15 Years @ 7%**).
16. The Capital Cost Total was added to the O&M Cost Total (Present Worth @ 15 years @ 7%) to arrive at a **Total Present Worth Cost**.

ALTERNATIVE L-X
SOURCE AREA EXCAVATION (LOWER CONTAMINANT PLUME)

Capital Cost:	$665,000 to $1,426,000
O&M Costs (Present Worth @ 10 years):	$277,000 to $594,000
Total Present-Worth Cost:	$943,000 to $2,020,000

Description:

This alternative consists of excavating PCE contaminated soils in a "Hot Spot" around MW-4A. Excavated soils will be placed in on-site soil vapor extraction cells for treatment. Once treated, the soils will be spread on site. In addition, a permeable reactive barrier across the flow path of the lower contaminant plume will be installed.

Soil vapor extraction cells work by volatilizing the contaminants into the air that is forced through the soil. The air is then often discharged to the atmosphere or passed through a treatment system to remove the volatilized contaminants.

Soil treatment cells are constructed by placing contaminated soils into a lined cell (usually lined with 20-mil HDPE). The cell will have a piping network. This network is used to distribute air to the contaminated soils. Blowers are used to force atmospheric air through the piping network and into the contaminated soils. The blowers and system controls are typically housed in a conex or other temporary building.

Advantages of this technology include the direct removal of contaminated soils from a portion of the contaminated soil source. Disadvantages include the potential for high costs, and the possibility of missing a large portion of contaminated soil that may continue to act as a source for the groundwater contamination. Because only a portion of the soil contamination is being removed, it is necessary to include an additional treatment alternative to prevent contaminated groundwater from entering the Kenai River. A permeable reactive barrier was used for this purpose, since it represented the lowest cost alternative, although other barrier treatment alternatives could also be used.

Implementation of this alternative will also involve groundwater and surface water monitoring and institutional controls to ensure that the dissolved-phase PCE is not causing risk to human health or the environment. It is estimated that this monitoring will be required for a period of 10 years, but the actual monitoring period may vary depending on how soon the remedial action objectives are met.

Permeable Reactive Barrier:

This alternative will require the installation of a permeable reactive barrier across the flow path of the lower contaminant plume. This type of barrier allows the passage of water while prohibiting the movement of contaminants by chemical reactions. The specific type of reaction wall proposed for River Terrace is a zero-valent iron treatment wall. It consists of iron filings mixed with sand. This type of treatment wall is applicable for treatment of chlorinated contaminants such as PCE, TCE, DCE, and VC. As the iron is oxidized, a chlorine atom is removed from the compound by one or more reductive dechlorination mechanisms, using electrons supplied by the oxidation of iron. The process dissolves the iron filings, but the metal disappears so slowly that the remediation barriers can be expected to remain effective for many years.

A 220-foot long treatment wall would be installed approximately parallel to the Kenai River to treat PCE-contaminated groundwater prior to its discharge into the river. Installation of the treatment wall will require a trench approximately 20 feet deep, with a 6-foot deep active treatment layer.

It was assumed that an iron treatment wall would not result in any aesthetic or deleterious impacts to the Kenai River (e.g., iron staining). A pilot study is recommended to evaluate the reactions of the site water chemistry with that of an iron filing mixture.

Assumptions:

System Installation

- Excavate approximately 2,350 CY of contaminated soil. Excavation dimensions will be approximately 50 feet by 50 feet by 25 feet deep. Contaminated soil will be transported a remediation cell. The cell will be created with soil berms and completely lined and covered with geo-textile.
- The western edge of the excavation will be stabilized with sheet piles because of the steep existing slope leading in from the road to the planned excavation area.
- The excavation will be sloped at a 1:1 grade from the ground surface to the top of the glacial-till layer (on sides other than the side supported with sheet piles). The glacial-till layer is assumed cohesive enough to allow steeper vertical slopes.
- Safety fencing will be placed around the excavated areas.
- Confirmation soil samples will be collected from the excavation floor at a frequency of one per every 150 SF. Confirmation soil samples will be collected from the excavation sidewalls at a frequency of every 25 feet. These samples will be analyzed by EPA method 8260.
- Dewatering of the excavation will be necessary. The water will be treated on-site with a portable air stripper. The water will be discharged to the local sewer after on-site treatment.
- No utilities cross the planned excavation area.
- Contaminated soils can be treated on-site under the existing contained-in determination.
- The contaminated soils will be placed into two soil-vapor extraction treatment cells located on the site. A total (for both cells) of 1,200 lineal feet of piping will installed along with associated valves, gauges, and meters.
- A conex will house the vapor extraction system controls and blowers.

Permeable Reactive Barrier Installation

- Dimensions of the treatment wall will be approximately 220 feet long by 2.6 feet wide by 6 feet deep (volume = 3,500 cubic feet). Half of the 2.6-foot thick wall consists of granular iron, purchased and shipped from the continental United States. Shipment will be by train to Seattle, then by barge to Kenai.
- For construction reasons, the iron will be mixed with processed, cleaned, and screened sand at a 1:1 ratio, resulting in a 2.6-foot thick wall. The sand will be purchased from a local borrow source.
- Dimensions of the trench for installing the treatment wall will be approximately 220 feet long by 2.6 feet wide by 20 feet deep (11,500 cubic feet). The trench will most likely be constructed by backhoe or ladder type trenching equipment. Shoring, trench boxes, and even sheet piles may be required to assure safety and proper placement of the iron medium.

- After installing the iron reactive treatment wall, the trench will be backfilled 12 to 14 feet deep with native soils. The approximate 3,500 cubic feet of soil that was replaced by the iron/sand mixture, and not placed back into the trench, may require treatment in the soil vapor extraction cells.
- A pilot test/treatability study is recommended prior to final design and installation. It is assumed that the iron reactive barrier will successfully transform the PCE and its daughter products to concentrations in the groundwater that comply with the remedial action objectives. This pilot study will assist in the design of a treatment wall that will be effective in achieving the remedial action objectives.
- The Reactive Iron Wall technology is proprietary and requires a licensing fee of 15 percent of the construction costs.

System O&M

- Continual operation and maintenance of the treatment cells will be required. Electrical costs for blower operation, heating, and lights are expected for up to 5 years.
- There will be no requirements for off-gas control or treatment.
- After treatment, confirmation soil samples will be collected at a frequency of 30 samples per cell. These samples will be analyzed by EPA method 8260.
- Fifteen wells will be sampled periodically for 10 years. Sampling will be quarterly for the first 3 years, semiannually for the next two years, and annually thereafter. Water samples will be analyzed for VOCs (8260) during each sampling event and annually for geochemical indicator parameters. The geochemical indicator parameters include pH, redox potential (Eh), alkalinity, dissolved oxygen, ferrous iron, sulfate or sulfide, chloride, and potentially, dissolved hydrogen.
- Annual reporting and data analysis will include a discussion on system O&M.

ALTERNATIVE U-X
SOURCE AREA EXCAVATION (UPPER CONTAMINANT PLUME)

Capital Cost:	$1,188,000 to $2,547,000
O&M Costs (Present Worth @ 5 years):	$245,000 to $525,000
Total Present-Worth Cost:	$1,433,000 to $3,071,000

Description:

This alternative consists of excavating the upper plume contaminated soil surrounding and underneath the old dry cleaning building and depositing the soil into treatment cells for remediation. The excavation will encompass an area of approximately 9,000 sq ft with an average depth of 35 feet. Based on soil sample results, it is assumed that the 12 to 14 feet of soil above the water table is uncontaminated. Excavated soils will be placed in on-site soil vapor extraction cells for treatment. Once treated, the soils will be spread on site.

Using a large backhoe, excavation should start with removing the uncontaminated soil above the water table and piling it so that it can be easily placed into the excavation. Once below the water table, localized dewatering will be performed with a pump that will transport the contaminated water to an external air stripping treatment module. It is assumed that the treated water will be approved for disposal into the local sewer system. Dewatering will be kept to a minimum by excavating and filling small sections as the work progresses through the site.

The contaminated material will be transported approximately 200 feet and placed into several soil treatment cells located near the previous treatment cells. The dump trucks will use plastic liners to prevent spillage of contaminated water during transport. The treatment cell will be constructed using soil/concrete berms and be completely lined and covered with impermeable geo-textile (usually lined with 20-mil HDPE). The cell will have a piping network. This network is used to distribute air to the contaminated soils. Blowers are used to force atmospheric air through the piping network and into the contaminated soils. A blower building will house the electrical controls and blowers that will feed air through a piping system to treat the contaminated soil.

Soil vapor extraction cells work by volatilizing the contaminants into the air that is forced through the soil. The air is then often discharged to the atmosphere or passed through a treatment system to remove the volatilized contaminants.

Advantages of this technology include the direct removal of contaminated soils from a portion of the contaminated soil source. Disadvantages include the high costs, and the possibility of missing a large portion of contaminated soil.

Implementation of this alternative will also involve groundwater and surface water monitoring and institutional controls to ensure that the dissolved-phase PCE is not causing risk to human health or the environment. It is estimated that this monitoring will be required for a period of 5 years, but the actual monitoring period may vary depending on how soon the remedial action objectives are met.

Assumptions:

System Installation

- The former dry cleaner building will be demolished prior to excavation. No costs for building demolition are included in this estimate.
- Excavation dimensions will be 75 feet by 120 feet by 35 feet deep. Resulting in the excavation of approximately 9,500 CY of uncontaminated soil and 5,700 CY of contaminated soil. Contaminated soil will be transported about 200 feet to a remediation cell.
- Soils above the water table (estimated at 18 feet below ground surface) are considered clean and will be used as backfill.
- The excavation will be sloped at a 1:1 grade from the ground surface to the top of the glacial-till layer. The glacial-till layer is cohesive enough to allow for more vertical slopes. Safety fencing will be placed around the excavated area.
- Dewatering of the excavation will be necessary. The water will be treated on-site with a portable air stripper. The water will be discharged to the local sewer after on-site treatment.
- No utilities cross the planned excavation area.
- Confirmation soil samples will be collected from the excavation floor at a frequency of one per every 150 SF. Confirmation soil samples will be collected from the excavation sidewalls at a frequency of every 25 feet. These samples will be analyzed by EPA method 8260.
- Contaminated soils can be treated on-site under the existing contained-in determination.
- The contaminated soils will be placed into four soil treatment cells located on the site. Each treatment cell is capable of containing approximately 1,500 CY of contaminated soil.
- One large connex will house the soil treatment system controls and blowers for all treatment cells.

System O&M

- Continual operation and maintenance of the treatment cells will be required. Electrical costs for blower operation, heating, and lights are expected for up to 5 years.
- There will be no requirements for off-gas control or treatment.
- After treatment, confirmation soil samples will be collected at a frequency of 30 samples per cell. These samples will be analyzed by EPA method 8260.
- Fifteen wells will be sampled periodically for 5 years. Sampling will be quarterly for the first 3 years, semiannually for the next two years, and annually thereafter. Water samples will be analyzed for VOCs (8260) during each sampling event.
- Annual reporting and data analysis will include a discussion on system O&M, groundwater monitoring results, and air monitoring results.

ALTERNATIVE X
CONTAMINATED SOIL EXCAVATION (ENTIRE RIVER TERRACE SITE)

Capital Cost:	$9,013,000 to $19,314,000
O&M Costs (Present Worth @ 5 years):	$975,000 to $2,088,000
Total Present-Worth Cost:	$9,988,000 to $21,402,000

Description:

This alternative consists of excavating the contaminated soil surrounding the old dry cleaning building and contaminated soil remaining in the lower contaminant plume area where soil concentration exceed the ADEC cleanup criteria of 0.030 mg/Kg for PCE. The excavation will encompass an area of approximately 45,000 sq ft with an estimated excavation volume of approximately 62,000 CY. Excavated soils will be placed in on-site soil vapor extraction cells for treatment. Once treated, the soils will be spread on site.

Using a large backhoe, excavation should start with removing the uncontaminated soil above the water table and piling it so that it can be easily placed into the excavation. Once below the water table, localized dewatering will be performed with a pump that will transport the contaminated water to an external air stripping treatment module. It is assumed that the treated water will be approved for disposal into the local sewer system. Dewatering will be kept to a minimum by excavating and filling small sections as the work progresses through the site.

The contaminated material will be transported and placed into several soil treatment cells located near the previous treatment cells. The dump trucks will use plastic liners to prevent spillage of contaminated water during transport. The treatment cell will be constructed using soil/concrete berms and be completely lined and covered with impermeable geo-textile (usually lined with 20-mil HDPE). The cell will have a piping network. This network is used to distribute air to the contaminated soils. Blowers are used to force atmospheric air through the piping network and into the contaminated soils. A blower building will house the electrical controls and blowers that will feed air through a piping system to treat the contaminated soil.

Soil vapor extraction cells work by volatilizing the contaminants into the air that is forced through the soil. The air is then often discharged to the atmosphere or passed through a treatment system to remove the volatilized contaminants.

Advantages of this technology include the direct removal of contaminated soils from a portion of the contaminated soil source. Disadvantages include the high costs, and the possibility of missing a portion of contaminated soil that may be within the till material underlying the site.

Implementation of this alternative will also involve groundwater and surface water monitoring and institutional controls to ensure that the dissolved-phase PCE is not causing risk to human health or the environment. It is estimated that this monitoring will be required for a period of 5 years, but the actual monitoring period may vary depending on how soon the remedial action objectives are met.

Assumptions:

System Installation

- The former dry cleaner building will be demolished prior to excavation. No costs for building demolition are included in this estimate.
- Excavation dimensions will be approximately 150 feet by 300 feet by 35 feet deep. Resulting in the excavation of approximately 5,200 CY of uncontaminated soil and 62,000 CY of contaminated soil. Contaminated soil will be transported to a remediation cell for treatment.
- The excavation will be sloped at a 1:1 grade from the ground surface to the top of the glacial-till layer. The glacial-till layer is cohesive enough to allow for more vertical slopes. Safety fencing will be placed around the excavated area.
- Dewatering of the excavation will be necessary. The water will be treated on-site with a portable air stripper. The water will be discharged to the local sewer after on-site treatment.
- A 20-foot buffer zone between the edge of the Sterling Highway and the edge of the sloped portion (1:1 grade) of the excavation will be maintained.
- The southwestern edge of the excavation will be stabilized with sheet piles because of the slope leading from the road to the planned excavation area. In addition, the southern edge of the excavation along the Kenai River will be stabilized with sheet piles.
- All utilities that cross the planned excavation area will be terminated at the junction point between the main line and the branch (or "customer") line.
- Confirmation soil samples will be collected from the excavation floor at a frequency of one per every 150 SF. Confirmation soil samples will be collected from the excavation sidewalls at a frequency of every 25 feet. These samples will be analyzed by EPA method 8260.
- Contaminated soils can be treated on-site under the existing contained-in determination.
- The contaminated soils will be placed into 42 soil treatment cells located on the site. Each treatment cell is capable of containing approximately 1,500 CY of contaminated soil. (There is obviously no room on the property to construct this many cells).
- Five large connex will house the soil treatment system controls and blowers for all treatment cells.

System O&M

- Continual operation and maintenance of the treatment cells will be required. Electrical costs for blower operation, heating, and lights are expected for up to 5 years.
- There will be no requirements for off-gas control or treatment.
- After treatment, confirmation soil samples will be collected at a frequency of 30 samples per cell. These samples will be analyzed by EPA method 8260.
- Fifteen wells will be sampled periodically for 5 years. Sampling will be quarterly for the first 3 years, semiannually for the next two years, and annually thereafter. Water samples will be analyzed for VOCs (8260) during each sampling event.
- Annual reporting and data analysis will include a discussion on system O&M, groundwater monitoring results, and air monitoring results.

River Terrace RV Park Groundwater Monitoring Costs						
Function	Unit	Quantity	Cost Per Unit	Total Cost	Total Cost (- 30%)	Total Cost (+ 50%)
1 Groundwater Monitoring						
Groundwater Monitoring Per Sampling Event						
1.1 Well Sampling	Well	15	$200	$3,000		
1.2 Analysis for VOCs (8260)	EA	20	$180	$3,600		
1.3 IDW Disposal	Drum	2	$800	$1,600		
1.1.4 Data Analysis and Reporting	HR	55	$75	$4,125		
1.1.5 Mobilization and General Requirements	%		15%	$1,849		
Total for Groundwater Monitoring				**$14,174**		
1.2. Annual Geochemical Analyses	EA	0	$150	**$0**		
1.3. Annual Well Maintenance	LS	1	$200	**$200**		
2. Mobilization / Demobilization	%	1	15%	**$2,126**		
Total Quarterly Monitoring Costs per Year				**$65,399**		
Total Semiannual Monitoring Costs per Year				**$32,800**		
Total Annual Monitoring Costs per Year				**$16,500**		
Present Worth Analysis						
Quarterly Monitoring for Years 1 - 3 @ 7%				**$171,628**		
Semiannual Monitoring for Years 4-5 @ 7%				**$48,408**		
Annual Monitoring for Years 6 - 10 @ 7%				**$48,235**		
Annual Monitoring for Years 6 - 15 @ 7%				**$82,626**		
Total Present Worth Cost (5 Yrs @ 7%)				**$220,037**	**$154,026**	**$330,055**
Total Present Worth Cost (10 Yrs @ 7%)				**$268,272**	**$187,790**	**$402,408**
Total Present Worth Cost (15 Yrs @ 7%)				**$302,663**	**$211,864**	**$453,995**

River Terrace RV Park Alternative L-X Source Excavation Lower Contaminant Plume						
Function	Unit	Quantity	Cost Per Unit	Total Cost	Total Cost (- 30%)	Total Cost (+ 50%)
1. Base Construction Estimate						
1.1. Excavate, Backfill, and Transport						
1.1.1. Excavate contaminated material and transport	CY	2,350	$75	$176,250		
1.1.2. Furnish and place new backfill	TON	4,000	$14	$56,000		
1.1.3. Install Sheet Pile Wall for Support	SF	1,500	$25	$37,500		
1.1.4. Fencing	LF	240	$20	$4,800		
1.1.5. Confirmation Sampling	EA	18	$250	$4,500		
Total for Excavate, Backfill, and Transport				**$279,050**		
1.2. Permeable Reactive Barrier						
1.2.1. Iron Medium with Installation	TON	137	$400	$54,800		
1.2.2. Shipping Costs for Iron Medium	TON	137	$180	$24,660		
1.2.3. Clean Sand for Medium Mix	CY	64	$15	$960		
1.2.4. Trench, Backfill, and Shoring	LF	220	$60	$13,200		
Total for Permeable Reactive Barrier				**$93,620**		
1.3. Dewatering/Waste Management						
1.3.1. Pump and Stripping System	LS	1	$40,000	$40,000		
1.3.2. Holding Tank Rental	MO	1	$3,000	$3,000		
1.3.3. Decontamination Operations	LS	1	$5,000	$5,000		
Total for Dewatering/Waste Management				**$48,000**		
1.4 Construct Remediation Cells						
1.4.1. Soil Cell Structure	LS	2	$30,000	$60,000		
1.4.2. Cell Liner and Cover	SF	24,000	$0.50	$12,000		
1.4.3. Piping	LF	1,200	$2.00	$2,400		
1.4.4. Blower Building w/equip.	EA	1	$25,000	$25,000		
1.4.5. Installation Labor	MH	600	$40	$24,000		
1.4.6. Confirmation Sampling	EA	60	$250	$15,000		
Total for Construct Remediation Cells				**$138,400**		
Construction Cost Subtotal				**$559,070**	**$391,349**	**$838,605**
2. Mobilization / Demobilization	%	1	15%	$83,861		
3. Construction Contingency	%	1	20%	$111,814		
4. Administrative Charge	%	1	15%	$83,861		
5. Engineering and Design	%	1	20%	$111,814		
Capital Cost Total				**$950,419**	**$665,293**	**$1,425,629**
Annual O&M Costs						
Mobilization and General Requirements	%	1	15%	$2,082		
Maintenance Support (1 hrs per week)	HR	52	$65	$3,380		
Operating Power	LS	1	$10,000	$10,000		
Routine Equip. Replacement and Repair	LS	1	$500	$500		
Annual O&M Cost Total				**$15,962**		
Present Worth Analysis						
O&M Cost for Years 1 - 10 @ 7%				$112,110		
Monitoring Cost for Years 1 - 10 @ 7%				$284,075		
Total O&M Cost (Present Worth - 10 yrs)				**$396,185**	**$277,330**	**$594,278**
Total Present Worth Cost (10 Yrs @ 7%)				**$1,346,604**	**$942,623**	**$2,019,907**

River Terrace RV Park Alternative X Soil Contamination Excavation All River Terrace Site Contamination above Table 2 Levels						
Function	Unit	Quantity	Cost Per Unit	Total Cost	Total Cost (- 30%)	Total Cost (+ 50%)
1. Base Construction Estimate						
1.1. Excavate, Backfill, and Transport						
1.1.1. Excavate 1:1 slopes (uncontaminated soils)	CY	5,200	$10	$52,000		
1.1.2. Excavate contaminated material and transport	CY	62,000	$50	$3,100,000		
1.1.3. Furnish and place new backfill	TON	105,400	$14	$1,475,600		
1.1.4. Install sheet pile wall for support	SF	4,500	$25	$112,500		
1.1.5. Fencing	LF	1,000	$2	$2,000		
1.1.6. Confirmation Sampling	EA	230	$250	$57,500		
Total for Excavate, Backfill, and Transport				**$4,799,600**		
1.2. Dewatering/Waste Management						
1.2.1. Pump and Stripping System	LS	1	$40,000	$40,000		
1.2.2. Holding Tank Rental	MO	6	$3,000	$18,000		
1.2.3. Decontamination Operations	MO	6	$10,000	$60,000		
Total for Dewatering/Waste Management				**$118,000**		
1.3 Construct Remediation Cells						
1.3.1. Soil Cell Structure	LS	42	$30,000	$1,260,000		
1.3.2. Cell Liner and Cover	SF	504,000	$0.50	$252,000		
1.3.3. Piping	LF	25,200	$2.00	$50,400		
1.3.4. Blower Building w/equip.	EA	5	$55,000	$275,000		
1.3.5. Installation Labor	MH	12,600	$40	$504,000		
1.3.6. Confirmation Sampling	EA	1260	$250	$315,000		
Total for Construct Remediation Cells				**$2,656,400**		
Construction Cost Subtotal				**$7,574,000**	**$5,301,800**	**$11,361,000**
2. Mobilization / Demobilization	%	1	15%	$1,136,100		
3. Construction Contingency	%	1	20%	$1,514,800		
4. Administrative Charge	%	1	15%	$1,136,100		
5. Engineering and Design	%	1	20%	$1,514,800		
Capital Cost Total				**$12,875,800**	**$9,013,060**	**$19,313,700**
Annual O&M Costs						
Mobilization and General Requirements	%	1	15%	$37,293		
Maintenance Support (24 hrs per week)	HR	1248	$65	$81,120		
Operating Power	LS	1	$160,000	$160,000		
Routine Equip. Replacement and Repair	LS	1	$7,500	$7,500		
Annual O&M Cost Total				**$285,913**		
Present Worth Analysis						
O&M Cost for Years 1 - 5 @ 7%				$1,172,300		
Monitoring Cost for Years 1 - 5 @ 7%				$220,037		
Total O&M Cost (Present Worth - 5 yrs)				**$1,392,336**	**$974,635**	**$2,088,505**
Total Present Worth Cost (5 Yrs @ 7%)				**$14,268,136**	**$9,987,695**	**$21,402,205**