Impact Area Groundwater Study Program

Feasibility Study
Demo 1 Groundwater Operable Unit

Appendix B
Detailed Descriptions of Treatment Technologies

Camp Edwards
Massachusetts Military Reservation
Cape Cod, Massachusetts

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TABLE OF CONTENTS

1.0 Introduction

This Appendix provides background information on the treatment technologies: granular activated carbon (GAC), ion exchange (IX), and fluidized bed reactor (FBR). It is not intended to duplicate the sections of the report describing remedial technologies or remedial alternatives, but rather to provide information about the current state of each technology.

2.0 Granular Activated Carbon Adsorption

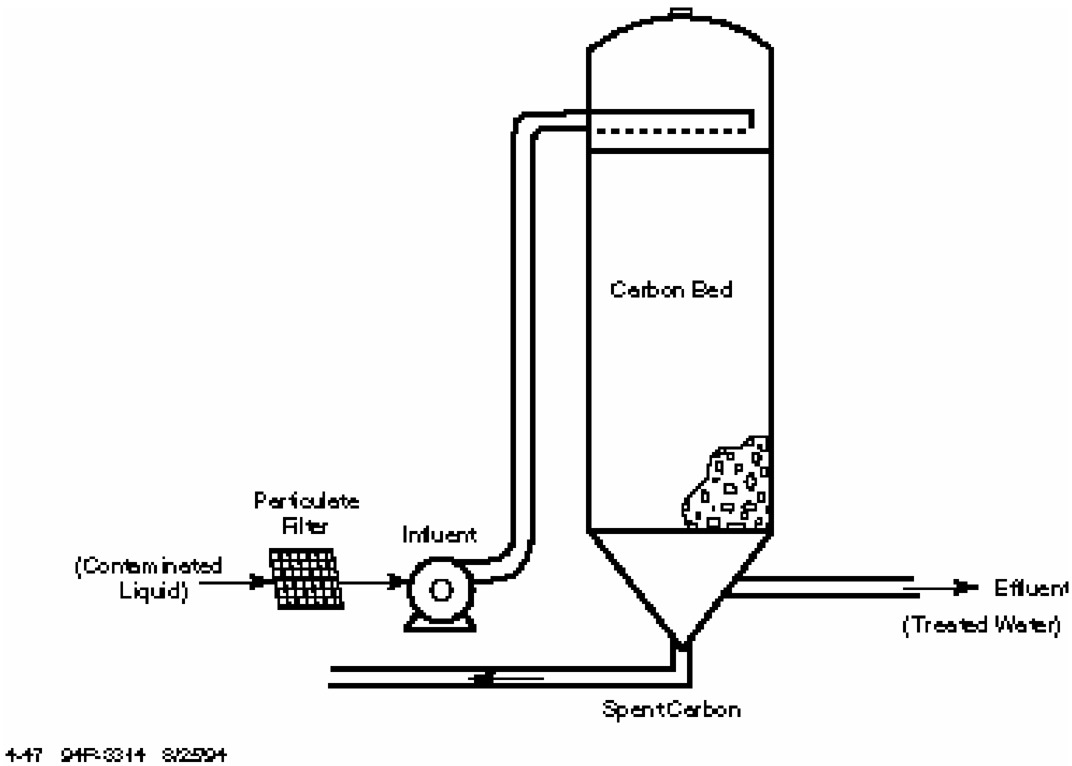
GAC is manufactured by crushing a material (such as coal, wood, coconut shells or nutshells) then roasting it to make charcoal. A second roasting step, in the presence of steam, creates highly porous granules. These pores provide the extremely high surface area that makes GAC an effective adsorbent. GAC is found in two forms: powdered and granular (Chermisnoff and Ellerbush, 1978). GAC can be generated from almost any material that possesses a high carbon content. Surface area is critical to the sorption characteristics of GAC. In general, the larger the surface area, the higher the sorption capacity of the GAC.

GAC is typically packed in a flow-through column designed to operate under pressure. Typically, contaminated water flows downward through the column. As the water flows through the unit, contaminants adsorb onto the GAC. Two GAC columns in series are frequently used to treat groundwater. Multiple units may be used in parallel to provide hydraulic capacity.

GAC units are sized to provide sufficient time for the contaminated groundwater to contact the GAC and contaminants to adsorb to the GAC. The sizing of GAC vessels and the design of GAC systems is typically based on empty bed contact time (EBCT). EBCT is the residence time of fluid flowing through an empty vessel (i.e., it does not account for the volume of the GAC). EBCT values typically range from 5 to 20 minutes per unit. The size is also based on the necessary bed depth; room needed for expansion during backwashing (discussed below); and the bed life, or frequency of GAC replacement. Liquid-phase GAC treatment units are available from many vendors, in a variety of sizes.

Solids in the influent gradually accumulate on the GAC bed, causing a pressure drop across the GAC. Large GAC adsorption units intended for long-term use are designed to permit periodic backwashing to remove particulates when the pressure drop becomes too high. When backwashing is to occur, treatment of contaminated groundwater must stop. Backwashing is accomplished by reversing the flow through the GAC unit, using clean water to expand the GAC bed and remove the solids. The wastewater generated from backwashing should be treated.

Figure 1 Schematic of Granular Activated Carbon System



(Marks et al. 1994)

When the GAC's adsorption capacity is used up, or spent, contaminant breakthrough occurs and contaminants are detected in the effluent from the GAC bed. The use of two columns in series to treat groundwater is intended to prevent discharge of unacceptable levels of contaminants when breakthrough occurs: when contaminants break through the first column (Column A) in series, the second column (Column B) adsorbs the contaminants. At that time, the GAC in the first bed (Column A) is replaced or regenerated to provide fresh GAC. The flow pattern is often reversed, so that the water flows first through Column B, then through Column A. (The cleanest GAC bed is last.)

Spent GAC may be landfilled or regenerated. Regeneration means that the GAC is thermally treated to remove and destroy adsorbed organic contaminants. Regeneration has limits, however:

- Metal contaminants are not removed.

- GAC used for high levels of explosives-contaminated groundwater is not regenerated; it must be properly disposed of (Marks et al., 1994 and American Norit Company, 1987).
- The initial adsorptive capacity is partially, although not completely restored. About 5 to 10% of the GAC is destroyed during regeneration.
- GAC can be regenerated on-site or off-site. On-site regeneration is generally not cost-effective unless more than 2,000 lb of GAC are used per day.

The potential performance of GAC in a specific application is predicted by performing bench-scale tests or by analogy to use at a similar site. Systems are optimized by conducting laboratory investigations consisting of equilibrium tests and continuous flow GAC tests. Equilibrium tests typically are conducted at constant temperature and are thus referred to as isotherm tests. Isotherm curves provide information on adsorption processes and the extent of surface coverage by the adsorbate. Isotherm curves provide a quick method for comparing the effectiveness of different GACs for various contaminants. The capacity of GAC to adsorb a contaminant varies with the concentration of that compound in solution; adsorption isotherms describe this variation at a constant temperature.

GAC units can foul as a result of bacterial growth or precipitation of naturally occurring metals in groundwater. They can also foul or lose capacity due to naturally occurring organics or contaminants other than the target compounds. Operating concerns include the following conditions (Sellers, 1999):

- *Suspended solids* $\geq$ 50 ppm require backwashing so frequently as to be impractical. Pretreatment (e.g., by sedimentation or filtration) would be required.
- *Iron and manganese* may precipitate and clog the GAC unit. Pretreatment may be required to remove iron and manganese if their total concentration exceeds approximately 10 milligrams per liter (mg/L).
- *Bacteria* may grow on the GAC bed if the groundwater contains high levels of biodegradable organics. This biological growth can clog the GAC bed.

2.1 Projected Pretreatment Requirements for Demo 1 Groundwater

Based on the projected groundwater characteristics of natural groundwater in the Demo 1 plume, as summarized in the RRA Plan, constituents (total suspended solids-TSS, iron, manganese, total dissolved solids-TDS) do not appear to be present at a level that would interfere with GAC adsorption processes (AMEC, MMR-7657). Therefore, minimal pretreatment would appear to be necessary in advance of GAC treatment.

2.2 Review of Granular Activated Carbon Treatment for COCs

2.2.1 Use of GAC for Removal of Perchlorate

Standard Granular Activated Carbon

The sorption chemistry of perchlorate onto GAC is not well understood. However, it is theorized that perchlorate adsorption in GAC differs from typical contaminant adsorption (such as explosives) in that perchlorate interacts with the positively charged surfaces of the GAC particles rather than adsorbing to the inner surfaces of pores in the GAC (Graham 2003). GAC beds exhausted from perchlorate adsorption are typically not regenerable.

Standard GAC has many highly desirable characteristics and its performance with respect to the treatment of perchlorate is becoming better understood. Numerous systems have used standard GAC, including a pilot test run at MMR on low concentrations of perchlorate (as summarized below).

Standard (non-tailored) GAC has been tested to treat perchlorate at a public water supply in Redlands California. The GAC pilot test system successfully reduced perchlorate concentrations from an average of 75 µg/L to less than 4 µg/L (the applicable drinking water standard in California). The Redlands treatment utilized an empty bed contact time (EBCT) of 20 minutes. The treatment system processes approximately 1,150 bed volumes until perchlorate breakthrough. Tailored GAC is currently being field tested on Redlands water (AMEC, MMR-8305).

Tailored Granular Activated Carbon

Research has shown that increasing the number of positive charges on the surface of the GAC improves adsorption of perchlorate and extends the bed life of the GAC (Cannon and Chongzheng, 2000). This can be accomplished by preloading the GAC with an NSF-approved organic polymer or a proprietary monomer (not approved by NSF) that has a strong positive charge. This tailored GAC appears to offer an economical alternative to conventional GAC for the treatment of perchlorate. An Innovative Technology Evaluation (ITE) study is ongoing at MMR to test the site-specific performance of this technology. Field Scale demonstrations by US Filter in Monterey Park, California were performed in February/March of 2003. Preliminary data from the ITE studies indicates that the tailored GAC is highly effective in treating the higher concentrations of perchlorate found at the Monterey Park site as described in Section 2.2.

2.2.2 Use of GAC for Removal of Explosives

Standard Granular Activated Carbon

Standard GAC can be effectively used to remove explosives such as RDX and HMX. Several reports have studied the adsorption of explosive compounds found in groundwater on GAC at munition facilities (Hinshaw et al. 1987; Wujcik, Lowe and Marks 1989; Dennis et al. 1990; and Calgon Carbon 1988).

Based on the results of the ITE studies (described below), with an EBCT of 9 minutes and influent concentrations of approximately 7 micrograms per liter (µg/L) explosives, a total of over 308,000 bed volumes can be processed before RDX breakthrough is observed. This translates to an operation life of a treatment vessel of over 60 months before change-out is required (AMEC, MMR-8615). It should be noted that for the detailed design and cost estimates, the change out frequency of a full-scale system was assumed to be more frequent to account for bed life limitations and for general conservative estimating.

Tailored Granular Activated Carbon

Based on the ITE study results, with an EBCT of 9 minutes, monomer-tailored GAC is ineffective in treating groundwater containing 7 µg/L explosives (AMEC, MMR-8615). It is hypothesized that the adsorption sites for RDX and other explosives would be covered by the cationic monomer, which was itself ineffective in adsorbing RDX. This is supported by the ITE results.

2.2.3 Field and Full-Scale Operations Conducted at MMR

GAC treatment of perchlorate and explosives has been field tested and implemented, on a limited basis, at MMR. In April 2002, AMEC, on behalf of the IAGWSP, conducted a field column test in the Central Impact Area (CIA). For this test, water was extracted from PW-1 at 5 gpm. The flow was split (approximately 2.5 gpm) and treated through two treatment trains of GAC columns. One treatment train consisted of two 200-pound GAC columns (both 20-minute EBCT) and the other treatment train consisted of one 50-pound (5-minute EBCT) column and one 200-pound column (20 min EBCT). The influent concentrations were 1-3 µg/L perchlorate and 2-5 µg/L RDX. The test was run for 72-hours continuously. Neither perchlorate nor RDX were detected at the mid-point (between GAC columns) or effluent sample locations. The results from this field column test were used to design the GAC system for an aquifer test conducted at PW-1 as described below.

In June 2002, AMEC, on behalf of the IAGWSP, conducted an aquifer test in the CIA at PW-1. For the aquifer test, water was pumped from PW-1 at 520 gpm and treated through two 3,500-pound GAC vessels in parallel, 7,000 pounds total. The GAC sizing was based on the column test described above. Influent concentrations were similar to those detected for the column test. The test was run for 72-hours continuous and no perchlorate or explosives were detected in the mid point or effluent samples.

In March and April 2003, a field scale pilot test system was operated at MW-80. Water was extracted from the monitoring well at an average rate of 5.6 gpm for 18 days. The water was treated through standard GAC vessels providing an EBCT of 8.2 minutes. A total of 145,320 gallons was processed for a total of approximately 3,100 bed volumes. Perchlorate was the only COC detected in the influent water with a concentration of approximately 1 ug/l (averaged 0.94 ug/l). Perchlorate was not detected in the effluent (i.e., breakthrough did not occur) (AMEC, MMR-7493).

2.2.4 Innovative Technology Evaluation Studies

In addition to the field scale operations described above, two sets of ITE studies have been overseen by AMEC, on behalf of IAGWSP. These studies were designed to test the efficacy of GAC to treat perchlorate and explosives. The first ITE study (ITE study #1) was conducted in July 2003 and the second study (ITE study #2) was conducted in November 2003. The results of these studies are summarized in AMEC MMR-8454 and AMEC MMR-8615.

Both ITE studies utilized Rapid Small Scale Column Tests (RSSCTs), which are used to predict the performance of a full-scale system by scaling the entire system down to a size suitable for laboratory study. RSSCTs results are used primarily to determine how many bed volumes of groundwater containing the contaminants of concern can be processed through the GAC before contaminant break through. Additionally, the RSSCTs are used to estimate design parameters, optimize EBCTs, and determine filter bed depth.

Two forms of GAC are considered for treatment, tailored and non-tailed GAC. Non-tailored GAC (or standard GAC) is the GAC that is utilized industry wide to treat various COCs in water. Tailored GAC is standard GAC that is treated with a surface coating (e.g., monomer). The coating alters the surface chemistry to increase the removal potential of specific compounds (i.e., perchlorate).

Innovative Technology Evaluation Study #1

The RSSCTs in this study were performed using groundwater from MW-80M1, located on Canal View Road at the intersection with Wheelock Road, and containing approximately 1.0 µg/L perchlorate. Approximately 220 gallons of water were pumped from MW-80M1 on February 27, 2003 and sent to Pennsylvania State University (PSU), College Park, Pennsylvania where the RSSCTs were performed. Studies were also performed using groundwater from MW-211M2, located on Pew Road approximately 1,200 feet north of the intersection with Estey Road and containing approximately 3 – 6 µg/L perchlorate. Approximately 550 gallons of water were pumped from MW-211M2, on March 16, 2003. An additional 220 gallons were collected and shipped on June 20, 2003.

Seven RSSCTs were operated in parallel. The studies were performed on various media and with varying simulated EBCTs. The media included two forms of a bituminous coal based GAC, US Filter Ultracarb 830 and US Filter Aquacarb 830, and two forms of GAC amendments, an NSF-approved cationic polymer and a proprietary cationic monomer. The tests are summarized in Table 1 below.

RSSCT influent and effluent samples were collected and analyzed for perchlorate. These results were used to determine the breakthrough isotherm for perchlorate and extrapolate the performance of a full-scale pilot plant. RSSCTs performed over several days in the laboratory simulate a test that would typically take several months in the field.

The results of the ITE Study #1 are summarized on Table 1.

Innovative Technology Evaluation Study #2

The RSSCTs in this study were performed using groundwater from PW-1, located in the Central Impact Area, and containing approximately 1 µg/L perchlorate, 6 µg/L RDX, and 0.6 µg/L HMX. Approximately 500 gallons of water were pumped from PW-1 on July 23, 2003 and sent to PSU, where the RSSCTs were performed. An additional 400 gallons of water were pumped from PW-1 on October 20, 2003.

Seven RSSCTs were operated in parallel. The studies were performed on various media and with varying simulated EBCTs. The media included two forms of a bituminous coal based GAC, US Filter Ultracarb 830 and US Filter Aquacarb 830, and the proprietary cationic monomer as a GAC amendment. Draft data from ITE study #1 were used to refine test protocols, such as EBCT, for ITE study #2.

RSSCT influent and effluent samples were collected and analyzed for perchlorate and explosives. These results were used to determine the breakthrough isotherm for the contaminants and extrapolate the performance of a full-scale pilot plant. RSSCTs performed over several days in the laboratory simulate a test that would typically take several months in the field.

The results of the ITE Study #2 are summarized on Table 1. As indicated, ITE study #2 demonstrated effective treatment at EBCTs lower than those tested in ITE study #1.

Table 1
Summary of Innovative Technology Evaluation Studies

RSSCT Results
ITE Study #1

Water Source	Test #	Influent Perchlorate (µg/L)	Type of GAC	Empty Bed Contact Time (min)	Bed Volumes (BV) to Perchlorate Detection
MW-80	3	0.85	US Filter Ultracarb	20	30,000[a]
MW-211	4	5.6	US Filter Ultracarb	20	20,000[a]
MW-211	5	5.6	US Filter Ultracarb	5	15,000[a]
MW-211	6	5.6	US Filter Aquacarb	20	31,000[a]
MW-211	6a	5.6	US Filter Aquacarb	7-8	25,000[a]
MW211	2	5.6	Polymer on Ultracarb	5 or 20*	40,000
MW211	1	5.6	Monomer on Ultracarb	5	210,000
MW211	7	5.6	Monomer post tailored	5	67,000[a]

RSSCT Results
ITE Study #2

Water Source	Test #	Influent Perchlorate (µg/L)	Type of GAC	Empty Bed Contact Time (min)	BV to Perchlorate Detection	BV to RDX Detection
PW-1	136	1	Aquacarb	9	46,000	>69,000
PW-1	137	1	Ultracarb	11	40,000	>62,000
PW-1	142	1	Ultracarb	9	NA	308,000
PW-1	138	1	Monomer Tailored Ultrcarb	9	270,000	8,000
PW-1	139	1	Monomer Tailored Ultrcarb	10		
PW-1	140	1	Monomer Post-Tailored Ultracarb followed by non-tailored Ultracarb	8.5 for each column	195,000	322,000

[a] Detection limit of 0.35 µg/L
* Test #2 in Study #1 began at 5 minute EBCT but was modified to 20 minute EBCT due to operational problems (AMEC MMR-8491).

Column tests used for control and quality assurance purposes are not included in table.

2.3 Design Considerations

A review of the previously described information indicates that standard GAC would be the optimal choice of treatment media at this time. Currently, standard GAC technology is better understood and accepted by regulators. Tailored GAC may prove to be useful in the future, however, the current state of the technology (lack of comprehensive testing and NFS approval) does not support its use. In addition, there is currently no supplier that can readily provided tailored GAC in quantities necessary to support a full-scale treatment system at Demo 1. Finally, tailored GAC would also need to be combined with standard GAC treatment for the treatment of explosive compounds.

When additional information becomes available and the state of the tailored GAC technology advances, it may, in the future, become feasible to utilize tailored GAC as a treatment method for the Demo 1 treatment systems.

It should be noted that based on the results of ITE studies and the low anticipated perchlorate concentrations, it appears that GAC alone will be sufficient to treat the influent stream at either the upgradient (Frank Perkins Road) or downgradient (Pew Road) location under any of the modeled pumping scenarios. However, input from the regulatory agencies indicates that GAC-only treatment will not be accepted and that additional perchlorate-specific treatment (i.e., IX) will be necessary as well (EPA 2003)

Perchlorate

Utilizing standard GAC, a 10 minute EBCT should be sufficient to treat low levels of perchlorate (i.e., less than 10 µg/L). Based on the anticipated perchlorate concentrations at one year for each of the up gradient design scenarios (reference detailed evaluation sections, maximum anticipated concentration is 9.5 µg/L), the 10-minute EBCT will be sufficient to treat perchlorate. This design parameter is applicable to the scenarios of the upgradient (Frank Perkins Road) treatment system as described in the Feasibility Study.

For the downgradient (Pew Road) treatment location, a 5-minute EBCT should be sufficient to treat perchlorate for each of the alternatives in the Feasibility Study. Very low concentrations (less than 5 µg/L) are anticipated at this location for all extraction/treatment alternatives (maximum anticipated concentration is 1.4 µg/L). This parameter is consistent with the test parameters and results of ITE study #1 as well as field scale tests conducted at MMR. This design is also consistent with the Pew Road RRA system which will extract from the down gradient portion of the plume (utilizing EW-

D1-2). Operational data from this RRA system will provide additional data for this location.

Explosives

Similar to perchlorate a 10 minute EBCT will be sufficient to treat explosives for the Frank Perkins Road treatment system at Demo 1. This parameter will provide adequate treatment for a wide range of concentrations. Based on the ITE study results for low concentrations of RDX, GAC change outs for RDX breakthrough would be spaced out over a frequency of years.

2.4 References

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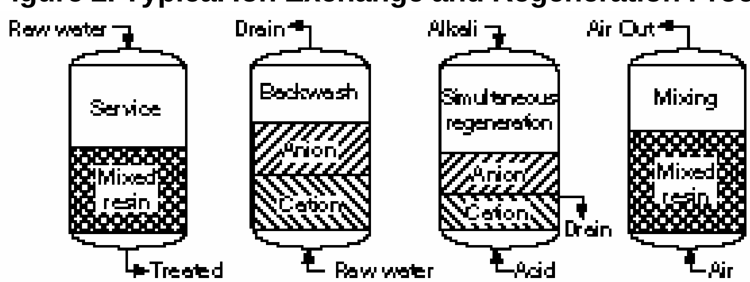
3.0 Ion Exchange and Synthetic Resins

Ion exchange is a physical-chemical process by which ions are transferred from the liquid phase to the solid phase. Ions held by electrostatic forces to charged functional groups on the surface of a solid are exchanged for ions of similar charge in a solution in contact with the solid (Mihelcic, 1999). Ion exchange removes ions from the aqueous phase by the exchange of cat ions or anions between a contaminated liquid and an exchange medium.

Ion exchange media are polymer resins with cross-linking (i.e., connections between long carbon chains in a polymer). The resin has active groups in the form of electrically charged sites. Ions of opposite charge are attracted to these sites, but may be replaced by other ions depending on their relative concentrations and affinities for the active sites. Different resins have different types of active sites, and may attract positively or negatively charged ions. To maximize the active sites, significant surface areas are generally desirable. The resins are usually cast in the form of porous beads.

Typically, ion-exchange resins are placed in columns (based on a pressure vessel similar to that used for a GAC vessel). As the water flows downward through the column, ions in the water exchange with ions on the resin. The column is sized based on the flow rate, the capacity of the resin under site-specific conditions, and the intended frequency of regeneration. It typically consists of a vertical cylindrical pressure vessel made of steel. The ion-exchange resin is supported on a screen. Influent water is distributed across the top of the resin bed. The unit may be plumbed to allow for regeneration through either downward flow or upward flow of a regenerant solution (Marks et al., 1994).

Figure 2. Typical Ion Exchange and Regeneration Process



Principle of mixed-bed ion exchange: *(a)* Service period. *(b)* Backwash period. *(c)* Simulteneous regeneration. (Illinois Water Treatment Co.)

Source: *Chemical Engineer's Handbook*, Perry & Chilton (5th Edition)

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When the ion-exchange capacity of the resin is exhausted, the column is backwashed if necessary to remove trapped solids and then regenerated. The resin is flushed free of the newly-exchanged ions and contacted with a solution of replacement ions. Regeneration is initiated after most of the active sites have been used and the ion exchange is no longer effective. Regeneration allows for the reuse of resin beads. The regeneration process produces a highly acidic or basic waste stream that contains concentrated contamination and which generally requires further treatment. The alternative to regeneration is to simply replace the resin with fresh material and dispose of the spent resin.

Operating concerns include (Sellers, 1999):

- treatment/disposal of concentrated regenerant;
- fouling due to high levels of suspended solids in the water (> 10 mg/L), which will clog or blind the resin; and
- a potential concern may be the concentration of exchanged ions in the treated water (e.g., sodium levels in drinking water).

3.1 Projected Pretreatment Requirements for Demo 1 Groundwater

Based on the projected groundwater characteristics, natural groundwater constituents (i.e., TSS, iron, manganese, TDS) do not appear to be present at a level that would interfere with ion exchange processes. Therefore, minimal pretreatment would appear to be necessary in advance of ion exchange treatment.

3.2 Review of Ion Exchange Treatment of COCs

3.2.1 Use of Ion Exchange to Remove Perchlorate

The perchlorate anion (ClO_4^-) originates as a contaminant in the environment primarily from the disposal of solid salts of ammonium or sodium perchlorate, which are very soluble in water. Although perchlorate is a strong oxidizing agent thermodynamically, this anion is known to be kinetically inert in many redox reactions and noncomplexing in interactions with metal ions typically found in the environment. For these reasons, the perchlorate ion is very mobile in the subsurface environment. It can persist for decades under typical groundwater conditions due to kinetic barriers to reactivity with other organic or inorganic constituents. Large volumes of perchlorate-containing compounds have been disposed of in the environment since the 1950s, although the extent of the problem was not fully realized until 1997 when a more sensitive ion chromatographic method for detecting perchlorate in water was developed. (Gu et al., 2000)

The recent discovery of perchlorate in groundwater wells in Nevada, California, and Utah has generated interest in potential treatment technologies to remove this contaminant. Extensive research has focused on the use of ion exchange processes for the removal of perchlorate from water. The initial challenge was to identify ion exchange resins that would selectively remove perchlorate when other anions (notably chloride, sulfate, and bicarbonate) were present at higher concentrations.

Strong-base ion-exchange resins have proven to be very effective in removing perchlorate from water. (Batista et al., 2000) However, regeneration of perchlorate-laden resins has proven difficult since perchlorate attaches very strongly to the resins and regeneration generates a large excess of brine that requires disposal.

Removal of perchlorate from water by strong-base anion exchange resins can be described by the following reaction:

$$\text{Resin-Cl}^- + ClO_4^- \leftrightarrow \text{Resin-}ClO_4^- + Cl^-$$

Once breakthrough occurs, the resin can potentially be regenerated with sodium chloride (NaCl) according to the reaction below:

$$\text{Resin-}ClO_4^- + NaCl \leftrightarrow \text{Resin-Cl}^- + Na^+ + ClO_4^-$$

Research conducted by Batista et al. 2000 indicate perchlorate is effectively removed from water by both acrylic and styrenic strong-base resins. Regeneration efficiency, however, was determined to be much higher for acrylic type resins than styrenic. (Batista et al, 2000).

IX resins have been widely used for perchlorate removal at sites in other states. A few locations are provided below, including influent perchlorate concentrations, cleanup levels for each site, and sources of information.

- 2000: La Puente. influent 200 µg/L, effluent <5 µg/L (http://www.perchlorateinfo.co./perchlorate-case-24.html)

- 2000: Henderson, NV. influent 80,000 µg/L to 110,000 µg/L, effluent <20,000 µg/L (http://www.perchlorateinfo.com/perchlorate-case-17.html)

- 2000: Edwards Air Force Base, CA. influent 50 µg/L, effluent <5 µg/L http://www.perchlorateinfo.com/perchlorate-case-10.html

- 1998: Los Angeles, CA (Big Dalton Site). influent averaging 50 µg/L, effluent <4 µg/L http://www.perchlorateinfo.com/perchlorate-case-15.html

- 1999: NASA/Jet Propulsion Laboratory, CA. influent 1200 µg/L http://www.perchlorateinfo.com/perchlorate-case-41.html

- 2003: Los Alamos, NM. influent 100 µg/L, effluent <4 µg/L http://www.lanl.gov/worldview/news/releases/archive/02-087.shtml

A paper prepared for *Water Conditioning and Purification* by US Filter evaluates four types of IX resins. The types of resins examined in the white paper included Type I Styrene Strong-Base Resins, Acrylic Strong-Base Resins, Nitrate-Selective Resins, and Perchlorate-Selective Resins (Boodoo, 2003).

The Type I Styrene Base Resin is a reliable IX resin in addition to being the standard by which all other IX resin performance is evaluated. It is estimated that with a full-scale treatment system, Styrenic Resins could operate at Demo 1 for 8 months to a year without replacement.

Acrylic Strong Base Resins were eliminated from consideration because of the resins' low affinity for perchlorate. With a low affinity for perchlorate, the Acrylic strong base resins are impractical for use in a non-regeneration style treatment system.

The removal efficiency of Perchlorate-Selective Resins is significantly higher than the Type I Styrenic Resins. Perchlorate-Selective Resin's strong affinity for perchlorate and much lower affinity for other competing anions allows the resin to operate for much longer than other resins for treating perchlorate contaminated groundwater. Perchlorate-Selective Resins are highly effective in groundwater containing concentrations of perchlorate in the hundreds of parts per billion (ppb) or higher. However, with the low concentrations of perchlorate and other ions in the Camp Edwards groundwater, the resin will operate to the point of physical exhaustion long before reaching the exhaustion of its chemical exchange capacity. Although the theoretical bed life of a vessel containing the Perchlorate-Selective Resins could be three years or more, the bed may experience biofouling, bed compaction, and/or particulate accumulation within approximately one year.

The Nitrate Selective Resins have up to four times the removal efficiencies than the Type I Styrenic Resins, at two to three times the cost. The Nitrate Selective Resins are also expected to provide the same effective throughput at a lower cost than the Perchlorate-Selective Resins, after the issues of biofouling, bed compaction, and/or particulate accumulation are taken into account.

After comparing removal efficiencies and cost effectiveness of the different resins, Type 1 Styrenic Base Resins and Nitrate Selective Resins were selected for inclusion in the Feasibility Study. It should be noted that perchlorate selective resins may be considered at a later date if the cost of the media decreases such that the treatment process will be cost effective over the functional bed life.

Information is not readily available on whether IX resins can remove perchlorate to the 0.35 µg/L method detection limit. An informal survey of sites using IX resins for remediation indicated reluctance to discuss whether IX resins are effective in removing perchlorate to concentrations of 0.35 µg/L. ITE studies are currently being conducted to provide this information.

3.2.2 Use of Ion Exchange for Removal of Explosives

After conducting a literature search, no information could be found on the use of ion exchange for the removal of explosives. Although some portion of an explosive molecule (RDX, HMX, TNT, 2,4-DNT, 2A-DNT, 4A-DNT) may exhibit some polarity, one would not expect the ion exchange process to be effective in removing explosives from water.

3.3 Design Considerations

The use of regenerable IX resins requires a medium to high capital cost when perchlorate concentrations are low. In addition, the regeneration process produces a briny waste stream containing a high concentration of perchlorate. The waste stream itself requires disposal, frequently performed using biological or thermal destruction of the concentrated waste.

Until recently, the cost of various non-regenerable IX resins was considered prohibitive for treatment of low concentrations of perchlorate. However, costs have decreased in the last year alone by fifty percent due to competitive market factors. These resins would likely be appropriate for treatment of low concentrations of perchlorate such as at the Frank Perkins Road ETR System.

Presently there is little information available on IX treatment of low levels of perchlorate (less than 10 µg/L). Available design information has been limited to vendor information provided to AMEC (Purolite, 2004). Based on this vendor information, the conceptual IX design was based on a minimum bed depth of 3 feet and a cross sectional area of 6 gpm/ft^2.

A conceptual IX treatment system designed to treat perchlorate would include a treatment train of two IX vessels (with the volume based on 3 foot bed depth and 6 gpm/ft^2) plumbed in series prior to a full scale GAC system of three GAC vessels (each with sizing based on the EBCT's previously summarized).

3.4 References

Batista, J. R., F. X. McGarbey, and A. R. Vieira, 2000. The Removal of Perchlorate from Waters Using Ion-Exchange Resins. Chapter 13 in: Urbansky, E. T., Perchlorate in the Environment. Kluwer Academic/Plenum Press, New York. Pp. 135-145.

Boodoo, Francis. POU/POE Removal of Perchlorate. Water Conditioning and Purification. August 2003.

Gu, B., G. M. Brown, S. D. Alexandratos, R. Ober, J. A. Dale, and S. Plant, 2000. Efficient Treatment of Perchlorate-Contaminated Groundwater with Bifunctional Anion Exchange Resins. Chapter 16 in: Urbansky, E. T., Perchlorate in the Environment. Kluwer Academic/Plenum Press, New York. Pp. 165-176.

Marks, P. J., W. J. Wujcik, A. F. Loncar, 1994. Remediation Technologies Screening Matrix and Reference Guide. Second Edition, U.S. Army Environmental Center, NTIS PB95-104782. October 1994.

Mihelcic, J. R. 1999. Fundamentals of Environmental Engineering. John Wiley & Sons, Inc., New York, NY, pp. 119-120

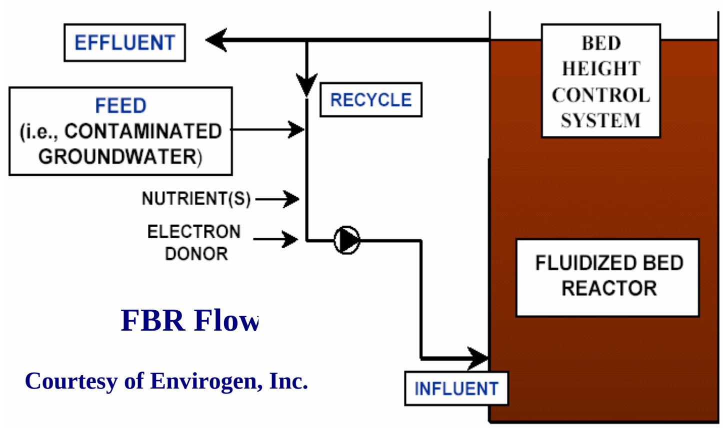
Purolite, 2004. Personal communication between Katherine Weeks of AMEC and Francis Boodoo of Purolite. February 10, 2004.

Sellers, K., 1999. Fundamentals of Hazardous Waste Site Remediation, CRC Press, Boca Raton, FL, pp. 135-150.

4.0 Fluidized Bed Reactor

An FBR treats contaminants in water by biodegradation. An FBR system consists of a reactor vessel containing a granular medium that is colonized with active bacterial biofilm. The medium is fluidized by the upward flow of groundwater through the vessel, and provides support for bacteria to attach and grow. A schematic of a typical FBR is presented in Figure 3.

Figure 3. General FBR System Process Schematic



FBR systems typically include the following features:

- An influent stream of impacted groundwater, which contains the contaminants of interest. At MMR, both perchlorate and explosives such as RDX act as electron acceptors that are critical to the growth of the biofilm;
- A granular medium (typically sand or granular activated carbon - GAC) that is colonized by active bacterial biomass. ITE studies used GAC as the bed medium;
- Controlled addition of a nutrient substrate, such as acetic acid (vinegar), denatured alcohol (ethanol), or molasses to provide an electron donor for the biofilm to interact with explosives and perchlorate;
- Controlled addition of growth nutrients (nitrogen, phosphorous), and pH control chemicals such as sulfuric acids and sodium hydroxide;
- Hydraulic control to maintain fluidization of the system, by suspending the GAC, and provide enough hydraulic retention time to treat the influent water to desired performance goals; and
- Treated water exiting the reactor, which is recycled or discharged (AMEC, MMR-6661).

Anaerobic FBR systems have been shown to successfully degrade perchlorate in the field. A bench-scale treatability study was performed at MMR (AMEC, MMR-6661) to determine whether FBR systems could degrade both perchlorate and explosives. The test showed that an anaerobic FBR with a nutrient substrate of acetic acid could successfully degrade perchlorate from approximately 90 µg/L to less than 1 µg/L and RDX from 190 µg/L to less than 2 µg/L, with a hydraulic residence time of 80 minutes. Influent concentrations at the Demo 1 Frank Perkins FS ETR System are projected to average approximately less than 10 µg/L for RDX for long-term operations. Based on an extrapolation of the study results, it was estimated that a FBR could degrade the perchlorate to less than 1 µg/L and the RDX to less than 2 µg/L with a hydraulic residence time of approximately 65 minutes (AMEC, MMR-6661). The effluent water from FBR systems usually contains low concentrations of biomass that have separated from the GAC substrate, which does not contain any contaminants. The biomass could be removed using a sand filter.

FBR systems have been successfully operated in other locations. A FBR system is currently operating at the Longhorn Army Ammunition Plant in Karnack, Texas. This system treats influent water with up to 22,000 µg/L perchlorate to below the reporting limit of 4 µg/L. The FBR system at GenCorp Aerojet Facility in Sacramento, California currently treats perchlorate in the influent water from 4,000 to 8,000 µg/L to below the reporting limit of 4 µg/L. A third FBR system at the Jet Propulsion Laboratory in Pasadena, California treats perchlorate in the water at concentrations of 300 to 800 µg/L to below the reporting limit of 4 µg/L (AMEC, MMR-6661).

4.1 Design Considerations

Although FBR treatment has been shown to be effective, it does not represent a cost effective technology when compared to IX, at current prices, or even GAC for very low concentrations of perchlorate. Currently, FBR has not been conducted on a full-scale basis on perchlorate concentrations as low as those expected at Demo 1. Therefore, FBR was not chosen as part of the treatment train in the detailed analysis.

4.2 References

AMEC, MMR-6661. Final ITE Study Summary Report - Fluidized Bed Reactor - AO3. September 2002.

IMPACT AREA GROUNDWATER STUDY PROGRAM

Feasibility Study
Demo 1 Groundwater Operable Unit

Appendix B
Detailed Descriptions of Treatment Technologies

Camp Edwards
Massachusetts Military Reservation
Cape Cod, Massachusetts

August 19, 2005

Prepared for:

U.S. Army Corps of Engineers
New England District
Concord, Massachusetts

U.S. Army / National Guard Bureau
Impact Area Groundwater Study Program
Camp Edwards, Massachusetts

Prepared by:

AMEC Earth & Environmental, Inc.
Westford, Massachusetts

MMR-9501

Impact Area Groundwater Study Program

Feasibility Study
Demo 1 Groundwater Operable Unit

Appendix C
Estimated Costs of Alternatives

Camp Edwards
Massachusetts Military Reservation
Cape Cod, Massachusetts

August 19, 2005

Prepared for:

U.S. Army Corps of Engineers
New England District
Concord, Massachusetts
for
U.S. Army / National Guard Bureau
Impact Area Groundwater Study Program
Camp Edwards, Massachusetts

Prepared by:

AMEC Earth & Environmental, Inc
Westford, Massachusetts
Contract No. DAHA92-01-D-0006

IMPACT AREA GROUNDWATER STUDY PROGRAM

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Appendix C
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Westford, Massachusetts

MMR-9501

Appendix C
Overview of Estimated Costs of Alternatives
Feasibility Study
Demo 1 Groundwater Operable Unit

Component costs for Alternative 1 (Minimal Action):

Capital Cost		$ 1,550,000
	1 Year	All Years*
Annual O&M	*$ 47,900*	$ 1,350,000
Total O&M		$ 1,350,000
Total Cost		**$ 2,900,000**

Component costs for Alternative 2 (Baseline):

Capital Cost		$ 3,640,000
	1 Year	All Years*
Annual O&M	*$ 364,000*	$ 10,200,000
Periodic O&M		$ 1,200,000
Total O&M		$ 11,400,000
Total Cost		**$ 15,000,000**

Component costs for Alternative 3 (Background):

Capital Cost		$ 6,370,000
	1 Year	All Years*
Annual O&M	*$ 612,000*	$ 12,800,000
Periodic O&M		$ 1,910,000
Total O&M		$ 14,700,000
Total Cost		**$ 21,100,000**

Component costs for Alternative 4 (10 Year):

Capital Cost		$ 10,200,000
	1 Year	All Years*
Annual O&M	*$ 1,380,000*	$ 14,300,000
Periodic O&M		$ 1,190,000
Total O&M		$ 15,500,000
Total Cost		**$ 25,700,000**

Component costs for Alternative 5 (Additional Alternative A):

Capital Cost		$ 8,340,000
	1 Year	All Years*
Annual O&M	*$ 879,000*	$ 12,000,000
Periodic O&M		$ 696,000
Total O&M		$ 12,700,000
Total Cost		**$ 21,000,000**

Component costs for Alternative 6 (Additional Alternative B):

Capital Cost		$ 9,870,000
	1 Year	All Years*
Annual O&M	*$ 994,000*	$ 15,700,000
Periodic O&M		$ 980,000
Total O&M		$ 16,700,000
Total Cost		**$ 26,600,000**

* Annual O&M for all years includes the Net Present Value of the cost, based on the number of years covered by the Alternative.

Note: Discrepancies between summary costs and detailed costs may occur due to rounding.

Alternative 1: Minimal Action

ITEM			TOTAL COST	
Capital (Direct and Indirect) Cost				
Direct Cost				
A. Monitoring well installation and development			$	1,090,000
Indirect Cost				
Contingency (20%)			$	219,000
Project Management (5%)			$	65,600
Remedial Design (7%)			$	91,900
Construction Management (6%)			$	78,800
Total Indirect Cost			$	455,000
Total Capital (Direct and Indirect) Cost			$	1,550,000
Operating and Maintenance Costs				
Total Annual Monitoring Costs for 50-Year Activities	$	38,300		
Contingency (25% of subtotal)	$	9,570		
Project Management (5%)	$	2,390		
Technical Support (15%)	$	7,180		
Present Worth of O&M Costs @ 3.5% for 50 years			$	1,350,000
Total Present Worth of Operating and Maintenance Costs			$	1,300,000
Total Cost of Alternative 1			**$**	**2,850,000**

Note: Discrepancies between summary costs and detailed costs may occur due to rounding.

Alternative 2: Baseline

ITEM				TOTAL COST
Capital (Direct and Indirect) Cost				
Direct Cost				
A. Treatment System - Frank Perkins Road (New facility = 7,000 sf)			$	2,570,000
B. Treatment System - Pew Road			$	-
Total Direct Cost			$	2,570,000
Indirect Cost				
Contingency (20%)			$	514,000
Project Management (5%)			$	154,000
Remedial Design (7%)			$	216,000
Construction Management (6%)			$	185,000
Total Indirect Cost			$	1,069,000
Total Capital (Direct and Indirect) Cost			$	3,640,000
Operating and Maintenance Costs				
Total Annual Operating and Maintenance Costs for 50-Year Activities	$	291,000		
Contingency (25% of subtotal)	$	72,800		
Project Management (5%)	$	18,200		
Technical Support (15%)	$	54,600		
Present Worth of O&M Costs @ 3.5% for 50 years			$	10,200,000
Total Operating and Maintenance Costs for Periodic Activities and Site Closeout	$	566,000		
Contingency (25% of subtotal)	$	142,000		
Project Management (5%)	$	35,400		
Technical Support (15%)	$	106,200		
Present Worth of O&M Costs @ 3.5% for Periodic Activities and Site Closeout			$	1,198,000
Total Present Worth of Operating and Maintenance Costs			$	11,400,000
Total Cost of Alternative 2			**$**	**15,000,000**

Note: Discrepancies between summary costs and detailed costs may occur due to rounding.

Alternative 3: Background

ITEM		TOTAL COST
Capital (Direct and Indirect) Cost		
Direct Cost		
A. Extraction well installation, development and pump installation		$ 449,000
B. Injection well installation and development		$ 215,000
C. Piping of wells to treatment system and to injection wells		$ 1,098,000
D. Treatment System - Frank Perkins Road (new facility = 7,000 sq ft)		$ 2,570,000
E. Treatment System - Pew Road		$ 170,000
Total Direct Cost		$ 4,500,000
Indirect Cost		
Contingency (20%)		$ 900,000
Project Management (5%)		$ 270,000
Remedial Design (7%)		$ 378,000
Construction Management (6%)		$ 324,000
Total Indirect Cost		$ 1,870,000
Total Capital (Direct and Indirect) Cost		$ 6,370,000
Operating and Maintenance Costs		
Total Annual Operating and Maintenance Costs for 27-Year Activities	$ 490,000	
Contingency (25% of subtotal)	$ 122,000	
Project Management (5%)	$ 30,600	
Technical Support (15%)	$ 91,800	
Present Worth of O&M Costs @ 3.4% for 27 years		$ 12,800,000
Total Operating and Maintenance Costs for Periodic Activities and Site Closeout	$ 1,050,000	
Contingency (25% of subtotal)	$ 262,000	
Project Management (5%)	$ 65,000	
Technical Support (15%)	$ 196,000	
Present Worth of O&M Costs @ 3.4% for Periodic Activities and Site Closeout		$ 1,910,000
Total Present Worth of Operating and Maintenance Costs		$ 14,700,000
Total Cost of Alternative 3		**$ 21,100,000**

Note: Discrepancies between summary costs and detailed costs may occur due to rounding.

Alternative 4: 10 Year Alternative

ITEM			TOTAL COST	
Capital (Direct and Indirect) Cost				
Direct Cost				
A. Road Construction			$	45,000
B. Extraction well installation, development and pump installation			$	674,000
C. Injection well installation and development			$	215,000
D. Piping of wells to treatment system and to injection wells			$	688,000
E. Treatment System - Frank Perkins Road (new facility = 15,000 sq ft)			$	5,410,000
F. Treatment System - Pew Road			$	170,000
Total Direct Cost			$	7,200,000
Indirect Cost				
Contingency (20%)			$	1,440,000
Project Management (5%)			$	432,000
Remedial Design (7%)			$	605,000
Construction Management (6%)			$	519,000
Total Indirect Cost			$	3,000,000
Total Capital (Direct and Indirect) Cost			$	10,200,000
Operating and Maintenance Costs				
Total Annual Operating and Maintenance Costs for 10-Year Activities	$	1,110,000		
Contingency (25% of subtotal)	$	276,000		
Project Management (5%)	$	69,000		
Technical Support (15%)	$	207,000		
Present Worth of O&M Costs @ 2.8% for 10 years			$	14,300,000
Total Operating and Maintenance Costs for Periodic Activities and Site Closeout	$	940,000		
Contingency (25% of subtotal)	$	235,000		
Project Management (5%)	$	58,700		
Technical Support (15%)	$	176,000		
Present Worth of O&M Costs @ 2.8% for Periodic Activities and Site Closeout			$	1,190,000
Total Present Worth of Operating and Maintenance Costs			$	15,500,000
Total Cost of Alternative 4			**$**	**25,700,000**

Note: Discrepancies between summary costs and detailed costs may occur due to rounding.

Alternative 5: Additional Alternative A

ITEM				TOTAL COST
Capital (Direct and Indirect) Cost				
Direct Cost				
A. Road Construction			$	45,000
B. Extraction well installation, development and pump installation			$	674,000
C. Injection well installation and development			$	215,000
D. Piping of wells to treatment system and to injection wells			$	688,000
E. Treatment System - Frank Perkins Road (new facility = 11,000 sq ft)			$	4,270,000
F. Treatment System - Pew Road			$	-
Total Direct Cost			$	5,890,000
Indirect Cost				
Contingency (20%)			$	1,180,000
Project Management (5%)			$	353,000
Remedial Design (7%)			$	494,000
Construction Management (6%)			$	424,000
Total Indirect Cost			$	2,450,000
Total Capital (Direct and Indirect) Cost			$	8,340,000
Operating and Maintenance Costs				
Total Annual Operating and Maintenance Costs for 14-Year Activities	$	703,000		
Contingency (25% of subtotal)	$	176,000		
Project Management (5%)	$	44,000		
Technical Support (15%)	$	132,000		
Present Worth of O&M Costs @ 2.9% for 14 years			$	12,000,000
Total Operating and Maintenance Costs for Periodic Activities and Site Closeout	$	609,000		
Contingency (25% of subtotal)	$	152,000		
Project Management (5%)	$	38,000		
Technical Support (15%)	$	114,000		
Present Worth of O&M Costs @ 2.9% for Periodic Activities and Site Closeout			$	696,000
Total Present Worth of Operating and Maintenance Costs			$	12,700,000
Total Cost of Alternative 5			**$**	**21,000,000**

Note: Discrepancies between summary costs and detailed costs may occur due to rounding.

Alternative 6: Additional Alternative B

ITEM				TOTAL COST
Capital (Direct and Indirect) Cost				
Direct Cost				
A. Road Construction			$	45,000
B. Extraction well installation, development and pump installation			$	899,000
C. Injection well installation and development			$	215,000
D. Piping of wells to treatment system and to injection wells			$	1,430,000
E. Treatment System - Frank Perkins Road (new facility = 11,000 sq ft)			$	4,270,000
F. Treatment System - Pew Road			$	110,000
Total Direct Cost			$	6,970,000
Indirect Cost				
Contingency (20%)			$	1,390,000
Project Management (5%)			$	418,000
Remedial Design (7%)			$	585,000
Construction Management (6%)			$	502,000
Total Indirect Cost			$	2,900,000
Total Capital (Direct and Indirect) Cost			$	9,870,000
Operating and Maintenance Costs				
Total Annual Operating and Maintenance Costs for 17-Year Activities	$	795,000		
Contingency (25% of subtotal)	$	199,000		
Project Management (5%)	$	49,700		
Technical Support (15%)	$	149,000		
Present Worth of O&M Costs @ 3.0% for 17 years			$	15,700,000
Total Operating and Maintenance Costs for Periodic Activities and Site Closeout	$	846,000		
Contingency (25% of subtotal)	$	211,000		
Project Management (5%)	$	52,900		
Technical Support (15%)	$	159,000		
Present Worth of O&M Costs @ 3.0% for Periodic Activities and Site Closeout			$	980,000
Total Present Worth of Operating and Maintenance Costs			$	16,700,000
Total Cost of Alternative 6			**$**	**26,600,000**

Note: Discrepancies between summary costs and detailed costs may occur due to rounding.

Description: Frank Perkins Road and Pew Road Feasibility Study Extraction Treatment Recharge (FP & PR FS ETR) No Action Alternative

This is the Minimal Action alternative which involves the installation of six additional monitoring wells and the monitoring of a total of 12 wells for 50 years.

Item	Units	Quantity	Unit Cost	Item Cost	Notes/Reference
I. Estimated Capital Cost of FS ETR System					
A. Monitoring well installation and development					
UXO Clearance	per well	6	$21,250	$127,500	Estimate
Well Installation	per well	6	$161,050	$966,300	Contractor estimate
Subtotal, direct capital costs				*$1,093,800*	
Contingency (20%)				$218,760	
			Subtotal	$1,312,560	
Project Management (5%)				$65,628	
Remedial Design (7%)				$91,879	
Construction Management (6%)				$78,754	
Total capital cost of extraction and discharge				***$1,550,000***	

References:
A Guide to Developing and Documenting Cost Estimates During the Feasibility Study, US Environmental Protection Agency, EPA 540-R-00-002, July 2000.
The Office of Management and Budget, The Executive Office of the President, Circular No. A-94, February 2004.

Item	Units	Quantity	Unit Cost	Item Cost	Notes/Reference

II. Estimated Operation and Maintenance Cost of ETR

A. Annual costs

Item	Units	Quantity	Unit Cost	Item Cost	Notes/Reference
Annual Sampling/Monitoring of wells					
Sampling event	each	1	$19,140	$19,140	12 wells sampled
Subtotal for one sampling event			*Subtotal*	$19,140	
Subtotal 2 sampling events				$38,280	2 sampling events per year
Contingency (25% of subtotal)				$9,570	
Subtotal annual sampling				$47,850	
Project Management (5%)				$2,393	
Technical Support (15%)				$7,178	
Subtotal, including project management and technical support				$57,420	
Present worth	(P/A, 3.5%, 50) =		23.456	$1,346,822	

Total present worth of operation and maintenance ***$1,300,000***

<u>Total Estimated Cost of Alternative 1 (No Action Alternative - 50 yrs):</u> ***<u>$2,850,000</u>***

Description: Frank Perkins Road and Pew Road Feasibility Study Extraction Treatment Recharge (FP & PR FS ETR) Baseline Alternative

This alternative is estimated to run for a total of 50 years (this alternative includes O&M for 50 years).
Initially, the RRA system consists of three mobile treatment containers with GAC/IX at the Frank Perkins Road location and one mobile treatment container with GAC at the Pew Road location. The Frank Perkins Road mobile treatment containers would be replaced by a full-scale treatment facility. The mobile treatment container would remain at the Pew Road location. It is assumed that the container would be changed out every 10 years at Pew Road.

Item	Units	Quantity	Unit Cost	Item Cost	Notes/Reference
I. Estimated Capital Cost of FS ETR System					
A. Treatment System - Frank Perkins Road					
New Facility (7,000 sq ft)					
GAC System	LS	1	$177,300	$177,300	Vendor quote 3-10,000 lb vessels (includes initial fill)
Filtration System	LS	1	$94,000	$94,000	Vendor quote
Ion Exchange (IX) System	LS	1	$133,000	$133,000	Vendor quote; two IX units; includes initial fill
Tanks	LS	1	$130,000	$130,000	Vendor quote; Equalization, Settling, Backwash
System Integrator	LS	1	$161,000	$161,000	Contractor quote
Mobilization	LS	1	$72,000	$72,000	Contractor quote
Earthwork	LS	1	$84,000	$84,000	Contractor quote
Chain Link Fence	LS	1	$11,000	$11,000	Contractor quote
Pavement	LS	1	$50,000	$50,000	Contractor quote
Pre-Cast Concrete	LS	1	$13,000	$13,000	Contractor quote
Unit Masonry	LS	1	$87,000	$87,000	Contractor quote
Pre-Fab Metal Building	LS	1	$560,000	$560,000	Contractor quote
Pumps	LS	1	$62,000	$62,000	Contractor quote
Process Piping and Valves	LS	1	$266,000	$266,000	Contractor quote
Air Compressor	LS	1	$13,000	$13,000	Contractor quote
Fire Protection	LS	1	$41,000	$41,000	Contractor quote
Electrical	LS	1	$469,000	$469,000	Contractor quote
LP Gas System	LS	1	$88,000	$88,000	Contractor quote
Installation of Misc. Items	LS	1	$38,000	$38,000	Contractor quote
Demobilization and Clean-Up	LS	1	$19,000	$19,000	Contractor quote
B. Treatment System - Pew Road					
Existing RRA Mobile Treatment Container	per container	1	$0	$0	Assume use of existing mobile treatment container system from RRA for Pew Road through year 6
Subtotal, direct capital costs				*$2,568,300*	
Contingency (20%)				$513,660	
			Subtotal	$3,081,960	
Project Management (5%)				$154,098	
Remedial Design (7%)				$215,737	
Construction Management (6%)				$184,918	
Total capital cost of extraction and discharge				***$3,640,000***	

References:

A Guide to Developing and Documenting Cost Estimates During the Feasibility Study, US Environmental Protection Agency, EPA 540-R-00-002, July 2000.
The Office of Management and Budget, The Executive Office of the President, Circular No. A-94, February 2004.

Item	Units	Quantity	Unit Cost	Item Cost	Notes/Reference
II. Estimated Operation and Maintenance Cost of ETR					
A. Annual costs					
Annual Treatment System Costs					
O&M of well pumps (labor & materials)	year	1	$14,000	$14,000	Contractor quote
Power for wells	per day-HP	15573	$2	$31,147	Engineering estimate; 365 days
Analytical for treatment building	ea	120	$330	$39,600	Up to 10 samples/month for perchlorate and explosives (ref. STL & Ceimic)
Carbon replacement FP FS ETR (labor + materials)	lb	20,000	$1	$26,667	Budgetary estimates from vendors, Replace/dispose 20,000 lbs GAC every 9 months
IX replacement FP FS ETR (labor + materials)	cf	220	$250	$73,333	Budgetary estimates from vendor, change out every 9 months; incineration of spent IX included.
Power for treatment building	per day-HP	11680	$2	$23,360	Engineering estimate; 365 days
Carbon replacement PR FS ETR (labor + materials)	lb	16,000	$1	$64,000	Budgetary estimates from vendors, Replace/dispose 4,000 lbs GAC every 3 months
Subtotal for annual treatment system costs			*Subtotal*	$272,107	
Contingency (25% of subtotal)				$68,027	
Subtotal annual treatment system costs				$340,133	
Annual Sampling/Monitoring of wells					
Sampling event	each	1	$9,570	$9,570	6 wells sampled 2 times/year
Subtotal for one sampling event			*Subtotal*	$9,570	
Subtotal 2 sampling events				$19,140	2 sampling events per year
Contingency (25% of subtotal)				$4,785	
Subtotal annual sampling				$23,925	
			Subtotal, including contingency	$364,058	
Project Management (5%)				$18,203	
Technical Support (15%)				$54,609	
			Subtotal, including project management and technical support	$436,870	
Present worth	(P/A, 3.5%, 50) =		23.456	$10,247,056	
B. Periodic costs					
Pump/motor replacement for extraction wells (EW)	EA	2	$6,500	$13,000	Lifespan of Pump 10 years; New pump/EW Year 6, 16, 26, 36, 46 for two EWs; Contractor quote.
Pew Road Container replacement	EA	1	$225,000	$225,000	Assume lifespan of container is 10 years; new container year 6, 16, 26, 36, 46; Vendor quote.
			Subtotal	$238,000	
Contingency (25% of subtotal)				$59,500	
			Subtotal, including contingency	$297,500	
Project Management (5%)				$14,875	
Technical Support (15%)				$44,625	
			Subtotal, including project management and technical support	$357,000	
Present worth	(P/F, 2.3%, 6) +(P/F, 3.%, 16) +(P/F, 3.4%, 26) +(P/F, 3.5%, 36) +(P/F, 3.5%, 46) =		2.410	$860,431	Present worth of well pump and container replacement at T=6, 16, 26, 36, 46 years
FPR Treatment Component Repairs	EA	1	$100,000	$100,000	Every 10 years; T=11,21,31,41 years
Contingency (25% of subtotal)				$25,000	
			Subtotal, including contingency	$125,000	
Project Management (5%)				$6,250	
Technical Support (15%)				$18,750	
			Subtotal, including project management and technical support	$150,000	
Present worth	(P/F, 2.8%, 11) +(P/F, 3.2%, 21) +(P/F, 3.5%, 31) +(P/F, 3.5%, 41)		1.842	$276,358	Present worth of FPR Treatment Component Repairs at T=11,21,31,41 years
C. Site Closeout					
Well Abandonment	EA	5	$5,690	$28,450	Contractor estimate
FPR building demolition	EA	1	$200,000	$200,000	
			Subtotal	$228,450	
Contingency (25% of subtotal)				$57,113	
			Subtotal, including contingency	$285,563	
Project Management (5%)				$14,278	
Technical Support (15%)				$42,834	
			Subtotal, including project management and technical support	$342,675	
Present worth	(P/F, 3.5%, 50) =		0.179	$61,357	50-years
Total present worth of operation and maintenance				***$11,400,000***	

<u>Total Estimated Cost of Alternative 2 (Baseline Alternative - 50 yrs):</u> ***<u>$15,000,000</u>***

Description: Frank Perkins Road and Pew Road Feasibility Study Extraction Treatment Recharge (FP & PR FS ETR) Background Alternative

This alternative involves groundwater treatment at two locations:
1. Frank Perkins Road (FP FS ETR): Extraction from two locations at a combined extraction rate of 264 gallons per minute. The wells would be located along the centerline of the plume at: Pocasset Forestdale Road and Frank Perkins Road. Groundwater would be pumped to a treatment facility located in the former GP-15 area. Extracted groundwater would enter an equilization tank, be pumped through an ion exchange (IX) system followed by a filtration system followed by granular activated carbon (GAC) system prior to being discharged. Discharged water would be re-injected into the subsurface at Demo 1 at two injection well, located to the north and south of the plume along Frank Perkins Road.
2. Pew Road (PR FS ETR): Extraction from two locations at a combined extraction rate of 208 gallons per minute. The wells would be located along the centerline of the plume at: Pew Road and Fredrikson Road. Groundwater would be pumped to three mobile treatment containers (similar to existing RRA system for Pew Road) located near EW-D1-2. It is assumed that the mobile treatment containers would be changed out every 10 years. Discharged water would be re-injected into the subsurface at Demo 1 at two injection well, located to the north and south of the plume along Pew Road.

Item	Units	Quantity	Unit Cost	Item Cost	Notes/Reference
I. Estimated Capital Cost of FS ETR System					
A. Extraction well installation, development and pump installation					
UXO Clearance	per well	2	$21,250	$42,500	Estimate
Well Installation (including drilling/well costs, pump, pump installation and testing)	per well	2	$188,400	$376,800	Contractor estimate
Well Vault and Completion	per well	2	$15,000	$30,000	Contractor estimate
B. Injection well installation and development					
UXO Clearance	per well	1	$21,250	$21,250	Estimate
Well Installation	per well	1	$161,050	$161,050	Contractor estimate
Chemical Analysis	per well	1	$17,500	$17,500	Estimate
Well Vault and Completion	per well	1	$15,000	$15,000	Contractor estimate
C. Piping of wells to treatment system and to injection wells					
Trenching, Subsurface Piping and Electrical Conduit	LF	8,135	$135	$1,098,225	Contractor estimate
D. Treatment System - Frank Perkins Road (new facility = 7,000 sq ft)					
GAC System	LS	1	$177,300	$177,300	Vendor quote 3-10,000 lb vessels (includes initial fill)
Filtration System	LS	1	$94,000	$94,000	Vendor quote
Ion Exchange (IX) System	LS	1	$133,000	$133,000	Vendor quote; two IX units; includes initial fill
Tanks	LS	1	$130,000	$130,000	Vendor quote; Equalization, Settling, Backwash
System Integrator	LS	1	$161,000	$161,000	Contractor quote
Mobilization	LS	1	$72,000	$72,000	Contractor quote
Earthwork	LS	1	$84,000	$84,000	Contractor quote
Chain Link Fence	LS	1	$11,000	$11,000	Contractor quote
Pavement	LS	1	$50,000	$50,000	Contractor quote
Pre-Cast Concrete	LS	1	$13,000	$13,000	Contractor quote
Unit Masonry	LS	1	$87,000	$87,000	Contractor quote
Pre-Fab Metal Building	LS	1	$560,000	$560,000	Contractor quote
Pumps	LS	1	$62,000	$62,000	Contractor quote
Process Piping and Valves	LS	1	$266,000	$266,000	Contractor quote
Air Compressor	LS	1	$13,000	$13,000	Contractor quote
Fire Protection	LS	1	$41,000	$41,000	Contractor quote
Electrical	LS	1	$469,000	$469,000	Contractor quote
LP Gas System	LS	1	$88,000	$88,000	Contractor quote
Installation of Misc. Items	LS	1	$38,000	$38,000	Contractor quote
Demobilization and Clean-Up	LS	1	$19,000	$19,000	Contractor quote
E. Treatment System - Pew Road					
Mobile Treatment Container	per container	3	$0	$0	Assume use of existing mobile treatment container system from RRA for Pew Road through year 6
Mobilization	per container	2	$10,000	$20,000	Mobilization from Frank Perkins Road RRA location to Pew Road location
Transformer, service cabinet, grounding upgrades	LS	1	$100,000	$100,000	Estimate
Site Work and Piping Connection	LS	1	$50,000	$50,000	Estimate
Subtotal, direct capital costs				*$4,500,625*	
Contingency (20%)				$900,125	
			Subtotal	$5,400,750	
Project Management (5%)				$270,038	
Remedial Design (7%)				$378,053	
Construction Management (6%)				$324,045	
Total capital cost of extraction and discharge				***$6,370,000***	

References:

A Guide to Developing and Documenting Cost Estimates During the Feasibility Study, US Environmental Protection Agency, EPA 540-R-00-002, July 2000.
The Office of Management and Budget, The Executive Office of the President, Circular No. A-94, February 2004.

Item	Units	Quantity	Unit Cost	Item Cost	Notes/Reference

II. Estimated Operation and Maintenance Cost of ETR

A. Annual costs

Item	Units	Quantity	Unit Cost	Item Cost	Notes/Reference
Annual Treatment System Costs					
O&M of well pumps (labor & materials)	year	1	$28,000	$28,000	Contractor quote
Power for wells	per day-HP	22971	$2	$45,941	Engineering estimate; 365 days
Analytical for treatment building	ea	168	$330	$55,440	Up to 14 samples/month for perchlorate and for explosives (ref. STL & Ceimic)
Carbon replacement FP FS ETR (labor + materials)	lb	20,000	$1	$26,667	Budgetary estimates from vendors, Replace/dispose 20,000 lbs GAC every 9 months
IX replacement FP FS ETR (labor + materials)	cf	264	$250	$88,000	Budgetary estimates from vendor, change out every 9 months; incineration of spent IX included.
Power for treatment building	per day-HP	17228	$2	$34,456	Engineering estimate; 365 days
Carbon replacement PR FS ETR (labor + materials)	lb	48,000	$1	$192,000	Budgetary estimates from vendors, Replace/dispose 4,000 lbs GAC every 3 months/container
Subtotal for annual treatment system costs			*Subtotal*	$470,504	
Contingency (25% of subtotal)				$117,626	
Subtotal annual treatment system costs				$588,130	
Annual Sampling/Monitoring of wells					
Sampling event	each	1	$9,570	$9,570	6 wells sampled 2 times/year
Subtotal for one sampling event			*Subtotal*	$9,570	
Subtotal 2 sampling events				$19,140	2 sampling events per year
Contingency (25% of subtotal)				$4,785	
Subtotal annual sampling				$23,925	
			Subtotal, including contingency	$612,055	
Project Management (5%)				$30,603	
Technical Support (15%)				$91,808	
	Subtotal, including project management and technical support			$734,466	
Present worth	(P/A, 3.4%, 27) =		17.487	$12,843,270	

B. Periodic costs

Item	Units	Quantity	Unit Cost	Item Cost	Notes/Reference
Pump/motor replacement for extraction wells (EW) EW-D1-1 and EW-D1-2	EA	2	$6,500	$13,000	Lifespan of Pump 10 years; New pump/EW Year 6 and 16 for two EWs; Assume last 2 pumps can last 11 years. Contractor quote.
Pew Road Container Replacements	EA	3	$225,000	$675,000	Lifespan of container 10 years; New container Year 6 and 16;Assume last 3 containers can last 11 years. Vendor quote.
			Subtotal	$688,000	
Contingency (25% of subtotal)				$172,000	
			Subtotal, including contingency	$860,000	
Project Management (5%)				$43,000	
Technical Support (15%)				$129,000	
	Subtotal, including project management and technical support			$1,032,000	
Present worth	(P/F, 2.3%, 6) (P/F, 3.0%, 16) =		1.496	$1,543,488	Present worth of well pump replacement at T=6, 16 years
Pump/motor replacement for extraction wells (EW) EW-D1-401 and EW-D1-402	EA	2	$6,500	$13,000	Lifespan of Pump 10 years; New pump/EW Year 11 and 21 for 2 EW. Contractor quote.
FPR Treatment Component Repairs	EA	1	$100,000	$100,000	Every 10 years; T=11,21 years
			Subtotal	$113,000	
Contingency (25% of subtotal)				$28,250	
			Subtotal, including contingency	$141,250	
Project Management (5%)				$7,063	
Technical Support (15%)				$21,188	
	Subtotal, including project management and technical support			$169,500	
Present worth	(P/F, 2.8%, 11) +(P/F, 3.2%, 21) =		1.254	$212,574	Present worth of well pump replacement at T=11, 21 years

C. Site Closeout

Item	Units	Quantity	Unit Cost	Item Cost	Notes/Reference
Well Abandonment	EA	8	$5,690.00	$45,520	Contractor estimate
FPR building demolition	EA	1	$200,000	$200,000	
			Subtotal	$245,520	
Contingency (25% of subtotal)				$61,380	
			Subtotal, including contingency	$306,900	
Project Management (5%)				$15,345	
Technical Support (15%)				$46,035	
	Subtotal, including project management and technical support			$368,280	
Present worth	(P/F, 3.4%, 27) =		0.405	$149,322	27-years

Total present worth of operation and maintenance ***$14,700,000***

Total Estimated Cost of Alternative 3 (Background - 27 yrs): ***$21,100,000***

Appendix C
Estimated Costs - Alternative 4: 10 Year
Feasibility Study
Demo 1 Groundwater Operable Unit

Description: Frank Perkins Road and Pew Road Feasibility Study Extraction Treatment Recharge (FP & PR FS ETR) 10 Year Risk-Based Alternative

This alternative involves groundwater treatment at two locations:
1. Frank Perkins Road (FP FS ETR): Extraction from four locations at a combined extraction rate of 1,196 gallons per minute. The wells would be located along the centerline of the plume: two wells along Pocasset Forestdale Road, one well at Frank Perkins Road, and one well between Frank Perkins Road and Pew Road. Groundwater would be pumped to a treatment system located in the former GP-15 area. Extracted groundwater would enter an equilization tank, be pumped through an ion exchange (IX) system followed by a filtration system followed by granular activated carbon (GAC) system prior to being discharged. Discharged water would be re-injected into the subsurface at Demo 1 at two injection well, located to the north and south of the plume along Frank Perkins Road.

2. Pew Road (PR FS ETR): Extraction from one location at an extraction rate of 221 gallons per minute. The well would be located along the centerline of the plume at Pew Road. Groundwater would be pumped to three mobile treatment containers (similar to existing RRA system for Pew Road) located near EW-D1-2. It is assumed that the mobile treatment containers would be changed out every 10 years. Discharged water would be re-injected into the subsurface at Demo 1 at two injection well, located to the north and south of the plume along Pew Road.

Item	Units	Quantity	Unit Cost	Item Cost	Notes/Reference
I. Estimated Capital Cost of FS ETR System					
A. Road Construction					
Road Construction, including clearing and UXO clearance	LF	625	$72	$45,000	Budgetary estimates from vendors for a semi-permanent road (e.g., not paved) (500' + 25%)
B. Extraction well installation, development and pump installation					
UXO Clearance	per well	3	$21,250	$63,750	Estimate
Well Installation (including drilling/well costs, pump, pump installation and testing)	per well	3	$188,400	$565,200	Contractor estimate
Well Vault and Completion	per well	3	$15,000	$45,000	Contractor estimate
C. Injection well installation and development					
UXO Clearance	per well	1	$21,250	$21,250	Estimate
Well Installation	per well	1	$161,050	$161,050	Contractor estimate
Chemical Analysis	per well	1	$17,500	$17,500	Estimate
Well Vault and Completion	per well	1	$15,000	$15,000	Contractor estimate
D. Piping of wells to treatment system and to injection wells					
Trenching, Subsurface Piping and Electrical Conduit	LF	5095	$135	$687,825	Contractor estimate
E. Treatment System - Frank Perkins Road (new facility = 15,000 sq ft)					
GAC System	LS	1	$610,000	$610,000	Vendor quote 2 sets of 3-20,000 lb vessels and one 3-10,000 lb vessels (includes initial fill)
Filtration System	LS	1	$470,000	$470,000	Vendor quote
Ion Exchange (IX) System	LS	1	$665,000	$665,000	Vendor quote; two IX units; includes initial fill
Tanks	LS	1	$166,000	$166,000	Vendor quote; Equalization, Settling, Backwash
System Integrator	LS	1	$195,800	$195,800	Contractor quote
Mobilization	LS	1	$154,000	$154,000	Contractor quote
Earthwork	LS	1	$180,000	$180,000	Contractor quote
Chain Link Fence	LS	1	$23,000	$23,000	Contractor quote
Pavement	LS	1	$107,000	$107,000	Contractor quote
Pre-Cast Concrete	LS	1	$19,000	$19,000	Contractor quote
Unit Masonry	LS	1	$122,000	$122,000	Contractor quote
Pre-Fab Metal Building	LS	1	$1,200,000	$1,200,000	Contractor quote
Pumps	LS	1	$124,000	$124,000	Contractor quote
Process Piping and Valves	LS	1	$532,000	$532,000	Contractor quote
Air Compressor	LS	1	$26,000	$26,000	Contractor quote
Fire Protection	LS	1	$87,000	$87,000	Contractor quote
Electrical	LS	1	$563,000	$563,000	Contractor quote
LP Gas System	LS	1	$106,000	$106,000	Contractor quote
Installation of Misc. Items	LS	1	$46,000	$46,000	Contractor quote
Demobilization and Clean-Up	LS	1	$19,000	$19,000	Contractor quote
F. Treatment System - Pew Road					
Mobile Treatment Container	per container	3	$0	$0	Assume use of existing mobile treatment container system from RRA for Pew Road through year 6
Mobilization	per container	2	$10,000	$20,000	Mobilization from Frank Perkins Road RRA location to Pew Road location
Transformer, service cabinet, grounding upgrades	LS	1	$100,000	$100,000	Estimate
Site Work and Piping Connection	LS	1	$50,000	$50,000	Estimate
Subtotal, direct capital costs				*$7,206,375*	
Contingency (20%)				$1,441,275	
			Subtotal	$8,647,650	
Project Management (5%)				$432,383	
Remedial Design (7%)				$605,336	
Construction Management (6%)				$518,859	
Total capital cost of extraction and discharge				***$10,200,000***	

Item	Units	Quantity	Unit Cost	Item Cost	Notes/Reference

References:
A Guide to Developing and Documenting Cost Estimates During the Feasibility Study, US Environmental Protection Agency, EPA 540-R-00-002, July 2000.
The Office of Management and Budget, The Executive Office of the President, Circular No. A-94, February 2004.

Item	Units	Quantity	Unit Cost	Item Cost	Notes/Reference
II. Estimated Operation and Maintenance Cost of ETR					
A. Annual costs					
Annual Treatment System Costs					
O&M of well pumps (labor & materials)	year	1	$35,000	$35,000	Contractor quote
Power for wells	per day-HP	68961	$2	$137,921	Engineering estimate; 365 days
Analytical for treatment building	ea	264	$330	$87,120	Up to 22 samples/month for perchlorate and for explosives (ref. STL & Ceimic)
Carbon replacement FP FS ETR (labor + materials)	lb	100,000	$1	$133,333	Budgetary estimates from vendors, Replace/dispose 100,000 lbs GAC every 9 months
IX replacement FP FS ETR (labor + materials)	cf	1194	$250	$398,000	Budgetary estimates from vendor, change out every 9 months; incineration of spent IX included.
Power for treatment building	per day-HP	51721	$2	$103,441	Engineering estimate; 365 days
Carbon replacement PR FS ETR (labor + materials)	lb	48,000	$1	$192,000	Budgetary estimates from vendors, Replace/dispose 4,000 lbs GAC every 3 months
Subtotal for annual treatment system costs			*Subtotal*	$1,086,816	
Contingency (25% of subtotal)				$271,704	
Subtotal annual treatment system costs				$1,358,520	
Annual Sampling/Monitoring of wells					
Sampling event	each	1	$9,570	$9,570	6 wells sampled 2 times/year
Subtotal for one sampling event			*Subtotal*	$9,570	
Subtotal 2 sampling events				$19,140	2 sampling events per year
Contingency (25% of subtotal)				$4,785	
Subtotal annual sampling				$23,925	
		Subtotal, including contingency		$1,382,445	
Project Management (5%)				$69,122	
Technical Support (15%)				$207,367	
	Subtotal, including project management and technical support			$1,658,934	
Present worth	(P/A, 2.8%, 10) =		8.618	$14,296,579	
B. Periodic costs					
Pump/motor replacement for extraction wells (EW) EW-D1-1 and EW-D1-2	EA	2	$6,500	$13,000	Lifespan of Pump 10 years; New pump/EW Year 6 for two EWs (EW-D1-1, EW-D1-2); Contractor quote.
Pew Road Container Replacements	EA	3	$225,000	$675,000	Lifespan of container 10 years; New container Year 6; Vendor quote.
			Subtotal	$688,000	
Contingency (25% of subtotal)				$172,000	
		Subtotal, including contingency		$860,000	
Project Management (5%)				$43,000	
Technical Support (15%)				$129,000	
	Subtotal, including project management and technical support			$1,032,000	
Present worth	(P/F, 2.3%, 6)		0.872	$900,380	present worth of well pump replacement at T=6 years
C. Site Closeout					
Well Abandonment	EA	9	$5,690	$51,210	Contractor estimate
FPR building demolition	EA	1	$200,000	$200,000	
			Subtotal	$251,210	
Contingency (25% of subtotal)				$62,803	
		Subtotal, including contingency		$314,013	
Project Management (5%)				$15,701	
Technical Support (15%)				$47,102	
	Subtotal, including project management and technical support			$376,815	
Present worth	(P/F, 2.8%, 10) =		0.759	$285,889	10-years
Total present worth of operation and maintenance				***$15,500,000***	

Total Estimated Cost of Alternative 4 (10-Year Alternative - 10 yrs): ***$25,700,000***

Description: Frank Perkins Road and Pew Road Feasibility Study Extraction Treatment Recharge (FP & PR FS ETR) Additional Alternative A

This alternative involves groundwater treatment at two locations:
1. Frank Perkins Road (FP FS ETR): Extraction from four locations at a combined extraction rate of 808 gallons per minute. The wells would be located along the centerline of the plume: two wells along Pocasset Forestdale Road, one well at Frank Perkins Road, and one well between Frank Perkins Road and Pew Road. Groundwater would be pumped to a treatment system located in the former GP-15 area. Extracted groundwater would enter an equilization tank, be pumped through an ion exchange (IX) system followed by a filtration system followed by granular activated carbon (GAC) system prior to being discharged. Discharged water would be re-injected into the subsurface at Demo 1 at two injection well, located to the north and south of the plume along Frank Perkins Road.

2. Pew Road (PR FS ETR): Extraction from one location at an extraction rate of 98 gallons per minute. The well would be located along the centerline of the plume at Pew Road. Groundwater would be pumped to one mobile treatment container (similar to existing RRA system for Pew Road) located near EW-D1-2. It is assumed that the mobile treatment container would be changed out every 10 years. Discharged water would be re-injected into the subsurface at Demo 1 at two injection well, located to the north and south of the plume along Pew Road.

Item	Units	Quantity	Unit Cost	Item Cost	Notes/Reference
I. Estimated Capital Cost of FS ETR System					
A. Road Construction					
Road Construction, including clearing and UXO clearance	LF	625	$72	$45,000	Budgetary estimates from vendors for a semi-permanent road (e.g., not paved) (500' + 25%)
B. Extraction well installation, development and pump installation					
UXO Clearance	per well	3	$21,250	$63,750	Estimate
Well Installation (including drilling/well costs, pump, pump installation and testing)	per well	3	$188,400	$565,200	Contractor estimate
Well Vault and Completion	per well	3	$15,000	$45,000	Contractor estimate
C. Injection well installation and development					
UXO Clearance	per well	1	$21,250	$21,250	Estimate
Well Installation	per well	1	$161,050	$161,050	Contractor estimate
Chemical Analysis	per well	1	$17,500	$17,500	Estimate
Well Vault and Completion	per well	1	$15,000	$15,000	Contractor estimate
D. Piping of wells to treatment system and to injection wells					
Trenching, Subsurface Piping and Electrical Conduit	LF	5,095	$135	$687,825	Contractor estimate
E. Treatment System - Frank Perkins Road (new facility = 11,000 sq ft)					
GAC System	LS	1	$432,000	$432,000	Vendor quote two sets of 3-20,000 lb vessels (includes initial fill)
Filtration System	LS	1	$376,000	$376,000	Vendor quote
Ion Exchange (IX) System	LS	1	$532,000	$532,000	Vendor quote; two IX units; includes initial fill
Tanks	LS	1	$166,000	$166,000	Vendor quote; Equalization, Settling, Backwash
System Integrator	LS	1	$178,000	$178,000	Contractor quote
Mobilization	LS	1	$113,000	$113,000	Contractor quote
Earthwork	LS	1	$132,000	$132,000	Contractor quote
Chain Link Fence	LS	1	$17,000	$17,000	Contractor quote
Pavement	LS	1	$78,000	$78,000	Contractor quote
Pre-Cast Concrete	LS	1	$16,000	$16,000	Contractor quote
Unit Masonry	LS	1	$105,000	$105,000	Contractor quote
Pre-Fab Metal Building	LS	1	$880,000	$880,000	Contractor quote
Pumps	LS	1	$93,000	$93,000	Contractor quote
Process Piping and Valves	LS	1	$399,000	$399,000	Contractor quote
Air Compressor	LS	1	$20,000	$20,000	Contractor quote
Fire Protection	LS	1	$54,000	$54,000	Contractor quote
Electrical	LS	1	$516,000	$516,000	Contractor quote
LP Gas System	LS	1	$97,000	$97,000	Contractor quote
Installation of Misc. Items	LS	1	$42,000	$42,000	Contractor quote
Demobilization and Clean-Up	LS	1	$19,000	$19,000	Contractor quote
F. Treatment System - Pew Road					
Mobile Treatment Container	per container	1	$0	$0	Assume use of existing mobile treatment container system from RRA for Pew Road through year 6
Subtotal, direct capital costs				*$5,886,575*	
Contingency (20%)				$1,177,315	
			Subtotal	$7,063,890	
Project Management (5%)				$353,195	
Remedial Design (7%)				$494,472	
Construction Management (6%)				$423,833	
Total capital cost of extraction and discharge				***$8,340,000***	

References:
A Guide to Developing and Documenting Cost Estimates During the Feasibility Study, US Environmental Protection Agency, EPA 540-R-00-002, July 2000.
The Office of Management and Budget, The Executive Office of the President, Circular No. A-94, February 2004.

Item	Units	Quantity	Unit Cost	Item Cost	Notes/Reference
II. Estimated Operation and Maintenance Cost of ETR					
A. Annual costs					
Annual Treatment System Costs					
O&M of well pumps (labor & materials)	year	1	$35,000	$35,000	Contractor quote
Power for wells	per day-HP	44092	$2	$88,184	Engineering estimate; 365 days
Analytical for treatment building	ea	168	$330	$55,440	Up to 14 samples/month for perchlorate and for explosives (ref. STL & Ceimic)
Carbon replacement FP FS ETR (labor + materials)	lb	80,000	$1	$106,667	Budgetary estimates from vendors, Replace/dispose 80,000 lbs GAC every 9 months
IX replacement FP FS ETR (labor + materials)	cf	806	$250	$268,667	Budgetary estimates from vendor, change out every 9 months; incineration of spent IX included.
Power for treatment building	per day-HP	33069	$2	$66,138	Engineering estimate; 365 days
Carbon replacement PR FS ETR (labor + materials)	lb	16,000	$1	$64,000	Budgetary estimates from vendors, Replace/dispose 4,000 lbs GAC every 3 months
Subtotal for annual treatment system costs			*Subtotal*	$684,095	
Contingency (25% of subtotal)				$171,024	
Subtotal annual treatment system costs				$855,119	
Annual Sampling/Monitoring of wells					
Sampling event	each	1	$9,570	$9,570	6 wells sampled 2 times/year
Subtotal for one sampling event			*Subtotal*	$9,570	
Subtotal 2 sampling events				$19,140	2 sampling events per year
Contingency (25% of subtotal)				$4,785	
Subtotal annual sampling				$23,925	
			Subtotal, including contingency	$879,044	
Project Management (5%)				$43,952	
Technical Support (15%)				$131,857	
			Subtotal, including project management and technical support	$1,054,853	
Present worth	(P/A, 2.9%, 14) =		11.373	$11,997,329	
B. Periodic costs					
Pump/motor replacement for extraction wells (EW) EW-D1-1 and EW-D1-2	EA	2	$6,500	$13,000	Lifespan of Pump 10 years; New pump/EW Year 6 for two EWs (EW-D1-1, EW-D1-2); Contractor quote.
Pew Road Container Replacements	EA	1	$225,000	$225,000	Lifespan of container 10 years; New container Year 6; Vendor quote.
			Subtotal	$238,000	
Contingency (25% of subtotal)				$59,500	
			Subtotal, including contingency	$297,500	
Project Management (5%)				$14,875	
Technical Support (15%)				$44,625	
			Subtotal, including project management and technical support	$357,000	
Present worth	(P/F, 2.3%, 6)		0.872	$311,469	Present worth of well pump replacement at T=6 years
Pump/motor replacement for extraction wells (EW) EW-D1-501, EW-D1-502, and EW-D1-503	EA	3	$6,500	$19,500	Lifespan of Pump 10 years; New pump/EW Year 11 for 3 EW. Contractor quote.
FPR Treatment Component Repairs	EA	1	$100,000	$100,000	Every 10 years; T=11 years
			Subtotal	$119,500	
Contingency (25% of subtotal)				$29,875	
			Subtotal, including contingency	$149,375	
Project Management (5%)				$7,469	
Technical Support (15%)				$22,406	
			Subtotal, including project management and technical support	$179,250	
Present worth	(P/F, 2.8%, 11)		0.738	$132,292	Present worth of well pump replacement at T=11 years
C. Site Closeout					
Well Abandonment	EA	9	$5,690	$51,210	Contractor estimate
FPR building demolition	EA	1	$200,000	$200,000	
			Subtotal	$251,210	
Contingency (25% of subtotal)				$62,803	
			Subtotal, including contingency	$314,013	
Project Management (5%)				$15,701	
Technical Support (15%)				$47,102	
			Subtotal, including project management and technical support	$376,815	
Present worth	(P/F, 2.9%, 14) =		0.670	$252,530	14-years
Total present worth of operation and maintenance				***$12,700,000***	
Total Estimated Cost of Alternative 5 (Additional Alternative A - 14 yrs):					***$21,000,000***

Description: Frank Perkins Road and Pew Road Feasibility Study Extraction Treatment Recharge (FP & PR FS ETR) Background Alternative B

This alternative involves groundwater treatment at two locations:
1. Frank Perkins Road (FP FS ETR): Extraction from four locations at a combined extraction rate of 808 gallons per minute. The wells would be located along the centerline of the plume: two wells along Pocasset Forestdale Road, one well at Frank Perkins Road, and one well between Frank Perkins Road and Pew Road. Groundwater would be pumped to a treatment system located in the former GP-15 area. Extracted groundwater would enter an equilization tank, be pumped through an ion exchange (IX) system followed by a filtration system followed by granular activated carbon (GAC) system prior to being discharged. Discharged water would be re-injected into the subsurface at Demo 1 at two injection well, located to the north and south of the plume along Frank Perkins Road.
2. Pew Road (PR FS ETR): Extraction from two locations at a combined extraction rate of 173 gallons per minute. The wells would be located along the centerline of the plume at: Pew Road and Fredrikson Road. Groundwater would be pumped to two mobile treatment containers (similar to existing RRA system for Pew Road) located near EW-D1-2. It is assumed that the mobile treatment containers would be changed out every 10 years. Discharged water would be re-injected into the subsurface at Demo 1 at two injection well, located to the north and south of the plume along Pew Road.

Item	Units	Quantity	Unit Cost	Item Cost	Notes/Reference
I. Estimated Capital Cost of FS ETR System					
A. Road Construction					
Road Construction, including clearing and UXO clearance	LF	625	$72	$45,000	Budgetary estimates from vendors for a semi-permanent road (e.g., not paved) (500' + 25%)
B. Extraction well installation, development and pump installation					
UXO Clearance	per well	4	$21,250	$85,000	Estimate
Well Installation (including drilling/well costs, pump, pump installation and testing)	per well	4	$188,400	$753,600	Contractor estimate
Well Vault and Completion	per well	4	$15,000	$60,000	Contractor estimate
C. Injection well installation and development					
UXO Clearance	per well	1	$21,250	$21,250	Estimate
Well Installation	per well	1	$161,050	$161,050	Contractor estimate
Chemical Analysis	per well	1	$17,500	$17,500	Estimate
Well Vault and Completion	per well	1	$15,000	$15,000	Contractor estimate
D. Piping of wells to treatment system and to injection wells					
Trenching, Subsurface Piping and Electrical Conduit	LF	10,620	$135	$1,433,700	Contractor estimate
E. Treatment System - Frank Perkins Road (new facility = 11,000 sq ft)					
GAC System	LS	1	$432,000	$432,000	Vendor quote two sets of 3-20,000 lb vessels (includes initial fill)
Filtration System	LS	1	$376,000	$376,000	Vendor quote
Ion Exchange (IX) System	LS	1	$532,000	$532,000	Vendor quote; two IX units; includes initial fill
Tanks	LS	1	$166,000	$166,000	Vendor quote; Equalization, Settling, Backwash
System Integrator	LS	1	$178,000	$178,000	Contractor quote
Mobilization	LS	1	$113,000	$113,000	Contractor quote
Earthwork	LS	1	$132,000	$132,000	Contractor quote
Chain Link Fence	LS	1	$17,000	$17,000	Contractor quote
Pavement	LS	1	$78,000	$78,000	Contractor quote
Pre-Cast Concrete	LS	1	$16,000	$16,000	Contractor quote
Unit Masonry	LS	1	$105,000	$105,000	Contractor quote
Pre-Fab Metal Building	LS	1	$880,000	$880,000	Contractor quote
Pumps	LS	1	$93,000	$93,000	Contractor quote
Process Piping and Valves	LS	1	$399,000	$399,000	Contractor quote
Air Compressor	LS	1	$20,000	$20,000	Contractor quote
Fire Protection	LS	1	$54,000	$54,000	Contractor quote
Electrical	LS	1	$516,000	$516,000	Contractor quote
LP Gas System	LS	1	$97,000	$97,000	Contractor quote
Installation of Misc. Items	LS	1	$42,000	$42,000	Contractor quote
Demobilization and Clean-Up	LS	1	$19,000	$19,000	Contractor quote
F. Treatment System - Pew Road					
Mobile Treatment Container	per container	2	$0	$0	Assume use of existing mobile treatment container system from RRA for Pew Road through year 6
Mobilization	per container	1	$10,000	$10,000	Mobilization from Frank Perkins Road RRA location to Pew Road location
Transformer, service cabinet, grounding upgrades	LS	1	$75,000	$75,000	Estimate
Site Work and Piping Connection	LS	1	$25,000	$25,000	Estimate
Subtotal, direct capital costs				*$6,967,100*	
Contingency (20%)				$1,393,420	
			Subtotal	$8,360,520	
Project Management (5%)				$418,026	
Remedial Design (7%)				$585,236	
Construction Management (6%)				$501,631	
Total capital cost of extraction and discharge				***$9,870,000***	

Item	Units	Quantity	Unit Cost	Item Cost	Notes/Reference
II. Estimated Operation and Maintenance Cost of ETR					
A. Annual costs					
Annual Treatment System Costs					
O&M of well pumps (labor & materials)	year	1	$42,000	$42,000	Contractor quote
Power for wells	per day-HP	47742	$2	$95,484	Engineering estimate; 365 days
Analytical for treatment building	ea	192	$330	$63,360	Up to 16 samples/month for perchlorate and for explosives (ref. STL & Ceimic)
Carbon replacement FP FS ETR (labor + materials)	lb	80,000	$1	$106,667	Budgetary estimates from vendors, Replace 80,000 lbs GAC every 9 months
IX replacement FP FS ETR (labor + materials)	cf	806	$250	$268,667	Budgetary estimates from vendor, change out every 9 months; incineration of spent IX included.
Power for treatment building	per day-HP	35807	$2	$71,613	Engineering estimate; 365 days
Carbon replacement PR FS ETR (labor + materials)	lb	32,000	$1	$128,000	Budgetary estimates from vendors, Replace 4,000 lbs GAC every 3 months
Subtotal for annual treatment system costs			*Subtotal*	$775,790	
Contingency (25% of subtotal)				$193,948	
Subtotal annual treatment system costs				$969,738	
Annual Sampling/Monitoring of wells					
Sampling event	each	1	$9,570	$9,570	6 wells sampled 2 times/year
Subtotal for one sampling event			*Subtotal*	$9,570	
Subtotal 2 sampling events				$19,140	2 sampling events per year
Contingency (25% of subtotal)				$4,785	
Subtotal annual sampling				$23,925	
			Subtotal, including contingency	$993,663	
Project Management (5%)				$49,683	
Technical Support (15%)				$149,049	
			Subtotal, including project management and technical support	$1,192,396	
Present worth	(P/A, 3.0%, 17) =		13.166	$15,699,220	
B. Periodic costs					
Pump/motor replacement for extraction wells (EW) EW-D1-1 and EW-D1-2	EA	2	$6,500	$13,000	Lifespan of Pump 10 years; New pump/EW Year 6 for two EWs (EW-D1-1, EW-D1-2); Contractor quote.
Pew Road Container Replacements	EA	2	$225,000	$450,000	Assume last 2 containers can last 11 year; New container Year 6; Vendor quote.
			Subtotal	$463,000	
Contingency (25% of subtotal)				$115,750	
			Subtotal, including contingency	$578,750	
Project Management (5%)				$28,938	
Technical Support (15%)				$86,813	
			Subtotal, including project management and technical support	$694,500	
Present worth	(P/F, 2.3%, 6)		0.872	$605,924	present worth of well pump replacement at T=10 years
Pump/motor replacement for extraction wells (EW) EW-D1-601, EW-D1-602, EW-D1-603, and EW-D1-604	EA	4	$6,500	$26,000	Lifespan of Pump 10 years; New pump/EW Year 11 for 4 EW. Contractor quote.
FPR Treatment Component Repairs	EA	1	$100,000	$100,000	Every 10 years; T=11 years
			Subtotal	$126,000	
Contingency (25% of subtotal)				$31,500	
			Subtotal, including contingency	$157,500	
Project Management (5%)				$7,875	
Technical Support (15%)				$23,625	
			Subtotal, including project management and technical support	$189,000	
Present worth	(P/F, 2.8%, 11)		0.738	$139,488	present worth of well pump replacement at T=11 years
C. Site Closeout					
Well Abandonment	EA	10	$5,690	$56,900	Contractor estimate
FPR building demolition	EA	1	$200,000	$200,000	
			Subtotal	$256,900	
Contingency (25% of subtotal)				$64,225	
			Subtotal, including contingency	$321,125	
Project Management (5%)				$16,056	
Technical Support (15%)				$48,169	
			Subtotal, including project management and technical support	$385,350	
Present worth	(P/F, 3.0%, 17) =		0.605	$233,143	17-years
Total present worth of operation and maintenance				***$16,700,000***	

Total Estimated Cost of Alternative 6 (Additional Alternative B - 17 yrs): ***$26,600,000***

Bid Form Notes

A. Mobilization, Demobilization, and Clean-Up. Payment for mobilization, demobilization, and clean-up is included in Item No. 1 and Item No. 16 of the Bid Form. Mobilization and demobilization includes assembly of all Contractor's equipment, personnel, and supplies on-site for the duration of the project, followed by removal from site after project completion. Included is providing temporary power to the construction site. Included is providing a crane and operator for removal of the treatment equipment components, pre-fabricated metal building, etc. from the delivery truck as required for successful installation of the said items.

B. Earthwork. Payment for earthwork is included in Item No. 2 of the Bid Form. Item No. 2 includes, at a minimum, the labor, tools, material, and equipment to furnish and install the following:
   - Site preparation. Limited site clearing and grubbing within the footprint of the proposed building and paved areas; erection of soil erosion and sedimentation control measures;
   - Excavating topsoil and stockpiling topsoil for later use. Excavating and segregating unsuitable material or refuse, if encountered;
   - Backfilling depressions if rock and boulder are encountered during excavation, as necessary;
   - Cut, fill and rough grade to the subgrade elevations necessary to prepare the site for the building foundation and the bituminous concrete parking lot as shown on the Design Sheets;
   - Excavating and replacing native soils with select fill material within the footprint of the building, if the existing soil does not meet the requirements for "structural fill" as defined in Specification 02200 – Earthwork;
   - Grading to proposed contours and compaction of earthwork materials as defined in Specification 02200 – Earthwork; and
   - Installation of all subsurface utilities (e.g., gas, electrical, drain) prior to construction of the foundation and erection of the pre-fabricated metal building.

C. Chain Link Fence. Payment for the chain link fence is included in Item No. 3 of the Bid Form. This item includes the labor, tools, material, and equipment to furnish and install the fence post in concrete; fence framework, fabric and accessories; manual gates and related hardware; and appurtenances.

D. Pavement. Payment for pavement is included in Item No. 4 of the Bid Form. This item includes labor, tools, material, and equipment to furnish and install the pavement (e.g., base course and bituminous binder course) as shown on the Design Sheets.

E. Cast-in-Place Concrete. Payment for cast-in-place concrete is included in Item No. 5 of the Bid Form. Cast-in-place concrete includes, at a minimum, the labor, tools, material, and equipment to furnish and install the following: footings, foundation walls, slabs, concrete pads, and concrete stairs; formwork; reinforcement; inspections; water stops; concrete testing; and miscellaneous related items such as sleeves, reglets, anchor bolts, inserts, and embedded items specified in the Contract Documents. Note that it is anticipated that the concrete foundation will be poured during the Winter 2003-2004.

F. Pre-Cast Concrete. Payment for pre-cast concrete is included in Item No. 6 of the Bid Form. Pre-cast concrete includes, at a minimum, the labor, tools, material, and equipment to furnish and install the following: pre-cast concrete hollow core planks; connection plates, brackets and associated embedded items; grouting plank keys; and associated items. Included is forming expansion, contraction and control joints; furnishing and installing waterstops; and furnishing and installing anchors and inserts. Included is furnishing and installing grout for filling joints and setting and anchoring items to masonry and concrete.

G. Unit Masonry. Payment for unit masonry is included in Item No. 7 of the Bid Form. Unit masonry includes, at a minimum, the includes labor, tools, material, and equipment to furnish and install the following: concrete masonry units, horizontal joint and vertical reinforcement, wall ties, anchoring devices, flashing, mortar, grout, insulation, and accessories. Included are mortar, grout, admixtures, and reinforcement for unit masonry.

H. Pre-Fabricated Metal Building. Payment for pre-fabricated metal building included in Item No. 8 of the Bid Form. Item No. 8 includes, at a minimum, the includes labor, tools, material, and equipment to design, manufacture, and install the following: framing; wall and roof covering; insulation; closure strips; fasteners; sealants; liner panels; doors; door frames; overhead doors (coiling and electrically operated), channel frames, and hardware; windows and glazing; acoustical ceilings; flashing; wall and roof jacks; gutters and downspouts; finishes (paint); anchor bolt and bearing plate materials; joint sealants; and any other component parts reasonably incidental to providing a complete metal building. Included are metal fabrications and wood for miscellaneous framing, furring, blocking and nailing strips to accommodate built-in equipment. Included are furnishing and installing shop fabricated glass fiber and resin grating, stair treads, supports, frames, ladders, safety cages and component parts. Included is furnishing and installing board insulation for cavity wall construction, perimeter foundation walls and underside of floor slabs.

I. Pumps. Payment for pumps is included in Item No. 9 of the Bid Form. Pumps include, at a minimum, the labor, tools, material, and equipment to furnish and install the following: centrifugal pump units (transfer pumps) complete with the pumps, motors, mounting bases; sump pump with lift out rail system; and appurtenances.

J. Process Piping and Valves. Payment for process piping, valves, and appurtenances is included in Item No. 10 of the Bid Form. Item No. 10 includes, at a minimum, the labor, tools, material, and equipment to furnish and install the following: valves, sample ports, flexible connections, relief valves, pressure gauges, regulators, and appurtences. Item No. 10 includes installation and testing of all mechanical process piping. This includes piping within the treatment equipment components as well as piping which connects the treatment equipment components.

K. Air Compressor. Payment for air compressor is included in Item No. 11 of the Bid Form. Item No. 11 includes, at a minimum, the labor, tools, material, and equipment to deliver, unload, install, and test the air compressor and associated components.

L. Fire Protection. Payment for fire protection is included in Item No.12 of the Bid Form. Item No. 12 includes, at a minimum, labor, tools, material, and equipment to design, furnish and install the wet pipe sprinkler system; fire pump; storz connections.

M. Electrical. Payment for electrical is included in Item No.13 of the Bid Form. Item No. 13 includes, at a minimum, the labor, tools, material, and equipment to furnish and install the following:
- Complete electric service including overhead primary, pad mounted transformer, primary and secondary duct banks, conductors, grounding, metering, etc.
- Complete power distribution systems including switchboards, panelboards, motor control centers, transformers, over current devices, wiring devices, raceway, cable, wire and etc.
- All motor wiring, safety disconnects, and motor starters unless integral with equipment.
- Complete emergency power system including generator, transfer switch, and associated equipment, at designated sites.
- Fire alarm system.
- Control and instrumentation wiring (instrumentation components provided under separate contract).
- Complete grounding and surge protection system.
- All support material and hardware for raceway, cable tray and electrical equipment.
- Underground system.
- Termination of all cable and wire unless otherwise noted. This includes, but is not limited to, final termination of all control and instrumentation wiring in treatment equipment and PLC control panels and consoles.
- Building wall, floor and roof penetrations for raceway and cable tray.
- Fire rated sealing of all electrical penetrations.
- Miscellaneous equipment.
- Start up, acceptance testing test reports and instruction of systems operation to AMEC.

N. LP Gas System. Payment for the LP gas system is included in Item No.14 of the Bid Form. Item No. 14 includes, at a minimum, the labor, tools, material, and equipment to furnish, design, and install the following: installation of above ground liquid propane gas tank(s) and concrete block vandal barrier in accordance with Specification 15600 – Mechanical Performance Specification. Includes is the propane fired unit and wall heaters, wall inlet louvers and wall mounted exhaust fans, and thru-the-wall type residential air conditioning unit (in the Office) within the building.

O. Installation of Items provided by others. Payment for installation of items provided by AMEC is included in Item No.15 of the Bid Form. Item No. 15 includes, at a minimum, the labor, tools, material, and equipment to furnish and install the following: installation of the treatment equipment, SCADA system components, and ancillary items (e.g., eye wash/shower stations, fire extinguishers, equipment cage, signage). Ancillary items, to be purchased by AMEC and installed by the Contractor, are indicated on Sheet G-1. Specifications and Design Sheets related to the treatment equipment to be installed by the Contractor are located in Attachment A.

P. Stand-By Time: Payment for stand-by time is included in Item No. 17 of the Bid Form. The Corps of Engineers had determined that the probability of encountering unexploded ordnance (UXO) in the area of the proposed construction activities is low. Therefore, only UXO safety support will be required and provided by others.

The UXO team will physically preview the proposed construction area with the Contractor and discuss visual observations and potential areas of concern. In the event surface UXO is discovered, the UXO team will place flagging adjacent to the discovery for subsequent visual reference, select a course around the item, and lead any on-site personnel out of the area. The AMEC UXO team will assess the condition of the UXO to determine if disposal action is required.

The UXO team will monitor all excavation activities in areas potentially contaminated with UXO. One member of the team will be positioned to the rear and upwind of the excavation equipment for continuous visual observation of activities. If the Contractor unearths or otherwise encounters suspect UXO, all excavation activities will cease.

Once UXO has been encountered in an excavation, no further excavation is allowed at that location until the UXO item has been removed. Once the item is removed, excavation may continue.

There will be a 200-foot exclusion zone for non-essential personnel. There will be no shielding requirements for the excavation equipment.

Appendix C

Estimated Costs of Alternatives

Supporting Information - Contractor Quotes

Item No.	General Description	Contractor Quote #1	Contractor Quote #2	Contractor Quote #3	Contractor Quote #4	Max	Min	Difference (Max-Min)
		Unit Cost	Unit Cost	Unit Cost	Unit Cost			
1	Mobilization	$120,000	$200,000	$140,000	$394,000	$394,000	$120,000	$274,000
2	Earthwork	$200,000	$98,700	$270,000	$250,000	$270,000	$98,700	$171,300
3	Chain Link Fence	$20,000	$20,000	$18,000	$20,000	$20,000	$18,000	$2,000
4	Pavement	$90,000	$103,750	$73,000	$78,000	$103,750	$73,000	$30,750
5	Cast-in-Place Concrete	$400,000	$423,575	$371,000	$515,000	$515,000	$371,000	$144,000
6	Pre-Cast Concrete	$25,000	$26,000	$25,000	$28,000	$28,000	$25,000	$3,000
7	Unit Masonry	$100,000	$130,900	$75,000	$88,000	$130,900	$75,000	$55,900
8	Pre-Fab Metal Building	$550,000	$409,300	$697,600	$660,000	$697,600	$409,300	$288,300
9	Pumps	$80,000	Included in Item No. 10	$85,000	$51,000	$85,000	$51,000	$34,000
10	Process Piping and Valves	$250,000	$485,000	$340,000	$244,000	$485,000	$244,000	$241,000
11	Air Compressor	$30,000	Included in Item No. 10	$18,500	$8,000	$30,000	$8,000	$22,000
12	Fire Protection	$100,000	$43,750	$68,000	$100,000	$100,000	$43,750	$56,250
13	Electrical	$600,000	$738,200	$685,000	$585,000	$738,200	$585,000	$153,200
14	LP Gas System	$100,000	Included in Item No. 10	$95,000	$120,000	$120,000	$95,000	$25,000
15	Installation of Items Provided by AMEC	$120,000	$324,000	$70,000	$38,000	$324,000	$38,000	$286,000
16	Demobilization and Clean-Up	$30,000	$7,575	$16,500	$10,000	$30,000	$7,575	$22,425
	Total =	**$2,815,000**	**$3,010,750**	**$3,047,600**	**$3,189,000**	$3,189,000	$2,815,000	$374,000

Contractor quotes received for original Frank Perkins Road Rapid Response Action Treatment Facility.

Impact Area Groundwater Study Program

Feasibility Study
Demo 1 Groundwater Operable Unit

Appendix D
Summary of Regulatory Considerations

Camp Edwards
Massachusetts Military Reservation
Cape Cod, Massachusetts

August 19, 2005

Prepared for:

U.S. Army Corps of Engineers
New England District
Concord, Massachusetts
for
U.S. Army / National Guard Bureau
Impact Area Groundwater Study Program
Camp Edwards, Massachusetts

Prepared by:

AMEC Earth & Environmental, Inc
Westford, Massachusetts
Contract No. DAHA92-01-D-0006

IMPACT AREA GROUNDWATER STUDY PROGRAM

Feasibility Study
Demo 1 Groundwater Operable Unit

Appendix D
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August 19, 2005

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Westford, Massachusetts

MMR-9501

Table D-1
Summary of Potential Regulatory Considerations
Alternatives 1 through 6
Final Feasibility Study
Demo 1 Groundwater Operable Unit

AUTHORITY/TYPE	PROVISION	SYNOPSIS	ACTION TO BE TAKEN IN CONSIDERATION
Federal/Action Specific	SDWA MCLs, 40 CFR 141.61 – 141.63	The EPA has promulgated SDWA MCLs (40 CFR 141-143) that are enforceable standards for public drinking water supplies. The standards protect drinking water quality by limiting the levels of specific contaminants that can adversely affect public health.	Cleanup goals for the alternatives in the FS considered federal MCLs.
State/Action Specific	MA Drinking Water Regulations, 310 CMR 22.00	These standards establish Massachusetts MCLs (MMCLs) for public drinking water systems (310 CMR 22.00 et. seq.).	Cleanup goals for the alternatives in the FS considered Massachusetts MCLs (MMCLs)
Federal/Action Specific	SDWA 47 FR 30282 Sole Source Aquifer	Pursuant to Section 1424(e) of the Safe Drinking Water Act, the EPA has determined that the Cape Cod aquifer is the sole or principal source of drinking water for Cape Cod, Massachusetts, and that the Cape Cod aquifer, if contaminated, would create a significant hazard to public health.	Groundwater will be treated in accordance with Federal/State Drinking Water Standards before recharge so that implementation of any remedy would not contaminate the aquifer through a recharge zone.

Table D-1
Summary of Potential Regulatory Considerations
Alternatives 1 through 6
Final Feasibility Study
Demo 1 Groundwater Operable Unit

AUTHORITY/TYPE	PROVISION	SYNOPSIS	ACTION TO BE TAKEN IN CONSIDERATION
Federal/Action Specific	Resource Conservation and Recovery Act (RCRA) [40 CFR 261; 40 CFR 262.34]	Resource Conservation and Recovery Act (RCRA) regulations at 40 CFR 261.24 identify the concentrations of contaminants that make a waste material a RCRA-characteristic hazardous waste for toxicity. 2,4-DNT is the only COC that has a Toxicity Characteristic Leaching Procedure (TCLP) limit, i.e., 130 µg/l. .	Spent activated carbon and other solid waste sent offsite for disposal will be analyzed, and if the results exceed the standards in §261.24, or otherwise constitute hazardous wastes, the material will be treated and/or disposed of offsite in a RCRA-permitted treatment storage and disposal facility. Hazardous wastes will be identified at the point of generation , and will be accumulated in accordance with requirements of 40 CFR 262.34(a) on-site for no greater than 90 days without a RCRA permit. If hazardous wastes are accumulated for greater than 90 days a RCRA permit would be required.
Federal/Action Specific	RCRA Land Disposal Restrictions [40 CFR 268]	These regulations restrict the disposal of any treatment wastes classified as hazardous waste.	Hazardous wastes generated from the treatment process, if any, may require treatment before offsite land disposal.
State/Action Specific	Solid Waste Management Regulations (RCRA Subtitle D), 310 CMR 19.000 et seq.	If a waste is determined to be a solid waste, it must be managed in accordance with the state regulations at 310 CMR 19.000 et seq.	Any solid wastes generated and determined to be non-hazardous will be managed in accordance with these regulations and disposed of appropriately.
State/Action Specific	Hazardous Waste Operations and Emergency Response, 29 CFR 1910.120	These regulations describe training, monitoring, planning, and other activities to protect the health of workers performing hazardous waste operations.	These worker protection standards would be followed to protect the health of workers if any primary or secondary wastes are determined to be RCRA characteristically hazardous.

Table D-1
Summary of Potential Regulatory Considerations
Alternatives 1 through 6
Final Feasibility Study
Demo 1 Groundwater Operable Unit

AUTHORITY/TYPE	PROVISION	SYNOPSIS	ACTION TO BE TAKEN IN CONSIDERATION
Federal/Action Specific	Underground Injection Control Program [40 CFR 114, 146, 147, 1000]	Underground Injection Control Program (40 CFR 114, 146, 147, 1000) regulations outline minimum program and performance standards for underground injection wells and prohibit any injection that may cause a violation of any primary drinking water regulation in the aquifer. Infiltration galleries fall within the broad definition of Class V wells. These regulations are administered by the State. See description of State regulations below.	Extracted groundwater will be treated to levels at or below federal and state primary drinking water standards (where they exist) to ensure that discharges to the aquifer will not cause any violation of these standards in the aquifer. The substantive components of the Massachusetts Contingency Plan, 310 CMR 40.0040, Management Procedures for Remedial Wastewater and Remedial Additives will be adequately addressed as part of the planned approach for operation and maintenance of the treatment systems.
Federal/Action Specific	RCRA Section 3020	EPA guidance concerning the “Applicability of RCRA Section 3020 to In Situ Treatment of Ground Water” (EPA 2000) could also pertain to this remedial action component. The extracted groundwater would not be a listed or characteristic hazardous waste, therefore this regulatory interpretation would not be legally applicable. It could, however, be relevant and appropriate to groundwater recharge.	Requirements will be taken into account in regulating discharge of treated groundwater.

Table D-1
Summary of Potential Regulatory Considerations
Alternatives 1 through 6
Final Feasibility Study
Demo 1 Groundwater Operable Unit

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Federal/Action Specific	National Environmental Policy Act of 1969 (NEPA; 42 USC 4321 et seq.) and CEQ Regulations (4 CFR 1500-1508)	"EPA believes that NGB is not required to follow NEPA procedures, as long as the NGB's actions are conducted in accordance with the administrative order, because of the provision in the CEQ regulations exempting enforcement actions from NEPA." (USEPA, 1 March 01) The Environmental Standard Operating Procedures (ESOP) Manual (AMEC, August 2001) establishes a standard procedure for identifying and minimizing impacts to environmental resources through siting of structures, careful installation, and scheduling of construction work. This procedure was developed in consideration of the National Environmental Policy Act (NEPA; 42 USC 4321 et seq.); Council on Environmental Quality (CEQ) Regulations Implementing the Procedural Provisions of NEPA (40 CFR 1500-1508); and Army Regulation (AR) 200-2.	As applicable, a Record of Action for remedial actions will be prepared for review by the Natural Heritage and Endangered Species Program, State Historic Preservation Office and Tribal Historic Preservation Office.

Table D-1
Summary of Potential Regulatory Considerations
Alternatives 1 through 6
Final Feasibility Study
Demo 1 Groundwater Operable Unit

AUTHORITY/TYPE	PROVISION	SYNOPSIS	ACTION TO BE TAKEN IN CONSIDERATION
Federal/Action Specific	CWA NDPES Stormwater Discharge Requirements, 40 CFR 122.26	Establishes requirements for stormwater discharges associated with construction activities that result in a land disturbance of equal to or greater than one acre of land. The requirements include good construction management techniques; phasing of construction projects; minimal clearing; and sediment, erosion, structural, and vegetative controls to mitigate stormwater run-on and runoff.	If stormwater runoff associated with this rapid response action discharges to a surface water body, including wetlands, the runoff will be controlled in accordance with these requirements.
State/Action Specific	Stormwater Discharge Requirements, 314 CMR 3.04 and 314 CMR 3.19	Requires that stormwater discharges associated with construction activities be managed in accordance with the general permit conditions of 314 CMR 3.19 so as not to cause a violation of Massachusetts surface water quality standards in the receiving surface water body (including wetlands).	If stormwater runoff associated with remedial action construction, operation or maintenance activities discharges to a surface water body, including wetlands, the runoff will be controlled in accordance with these requirements.
State/ Chemical Specific	Massachusetts Air Pollution Control Regulations [310 CMR 6.00 – 7.00]	Construction activities could trigger Massachusetts Air Pollution Control Regulations (310 CMR 6.00 – 7.00). These regulations set emission limits necessary to attain ambient air quality standards for fugitive emissions, dust and particulates.	Engineering controls, such as dust suppression, would be used as necessary to comply with these regulations for fugitive emissions, dust, and particulate emissions during site construction activities.

Table D-1
Summary of Potential Regulatory Considerations
Alternatives 1 through 6
Final Feasibility Study
Demo 1 Groundwater Operable Unit

AUTHORITY/TYPE	PROVISION	SYNOPSIS	ACTION TO BE TAKEN IN CONSIDERATION
State/Action Specific, Chemical Specific	310 CMR 40.0040 Construction and operation of a groundwater treatment plant	Regulations establish management procedures for remedial wastewater as well as the construction, installation, change, operation and maintenance of treatment works for Remedial Wastewater. Treatment works shall be inspected and the inspections documented. Treatment works shall be protected from vandalism and measures shall be taken to prevent system failure, contaminant pass through, interference, by-pass, upset, and other events likely to result in a discharge of oil and/or hazardous material to the environment.	The substantive components of the Massachusetts Contingency Plan, 310 CMR 40.0040, Management Procedures for Remedial Wastewater and Remedial Additives will be adequately addressed as part of the planned approach for operation and maintenance of the treatment systems.

Table D-1
Summary of Potential Regulatory Considerations
Alternatives 1 through 6
Final Feasibility Study
Demo 1 Groundwater Operable Unit

AUTHORITY/TYPE	PROVISION	SYNOPSIS	ACTION TO BE TAKEN IN CONSIDERATION
State/Action Specific, Chemical Specific	Discharge of Groundwater 310 CMR 40.0045	Regulations restrict remedial wastewater discharge to the ground surface or subsurface and/or groundwater. Such a discharge should not erode or impair the functioning of the surficial and subsurface soils, infiltrate underground utilities, building interiors or subsurface structures, result in groundwater mounding within two feet of the ground surface, or result in flooding or breakout to the ground surface. The concentrations of all pollutants discharged must be below the Massachusetts Groundwater Quality Standards established by 314 CMR 6.0. The concentrations must also be below the applicable Reportable Concentrations established by 310 CMR 40.0300 and 40.1600.	The substantive components of the Massachusetts Contingency Plan, 310 CMR 40.0040, Management Procedures for Remedial Wastewater and Remedial Additives will be adequately addressed as part of the planned approach for operation and maintenance of the treatment systems. The detailed plan for monitoring, inspecting and reporting on the performance of the extraction, treatment and recharge systems will be presented in the System Performance and Ecological Impact Monitoring (SPEIM) Plan, which will be submitted to the MADEP for review.

Table D-1
Summary of Potential Regulatory Considerations
Alternatives 1 through 6
Final Feasibility Study
Demo 1 Groundwater Operable Unit

AUTHORITY/TYPE	PROVISION	SYNOPSIS	ACTION TO BE TAKEN IN CONSIDERATION
State/Action Specific	Discharge of Groundwater 310 CMR 40.0300 and 310 CMR 40.1600	The MCP contains special provisions for the discharge of groundwater containing very low levels of oil or hazardous material. Groundwater containing oil and/or hazardous material in concentrations less than the applicable release notification threshold established by 310 CMR 40.0300 and 40.1600, can be discharged to the ground subsurface and/or groundwater only when following appropriate guidelines.	The substantive components of the Massachusetts Contingency Plan, 310 CMR 40.0040, Management Procedures for Remedial Wastewater and Remedial Additives will be adequately addressed as part of the planned approach for operation and maintenance of the treatment systems. The detailed plan for monitoring, inspecting and reporting on the performance of the extraction, treatment and recharge systems will be presented in the System Performance and Ecological Impact Monitoring (SPEIM) Plan, which will be submitted to the MADEP for review.

Table D-1
Summary of Potential Regulatory Considerations
Alternatives 1 through 6
Final Feasibility Study
Demo 1 Groundwater Operable Unit

AUTHORITY/TYPE	PROVISION	SYNOPSIS	ACTION TO BE TAKEN IN CONSIDERATION
State/Action Specific	Groundwater Discharge Regulations [314 CMR 5.00]	Recharge of effluent from some treatment works requires a permit under Groundwater Discharge Regulations at 314 CMR 5.00 unless the exemption allowing for actions taken in compliance with MGL C. 21E and regulations at 40 CMR 40.00 applies. The effluent discharged must not exceed any Massachusetts Groundwater Quality Standards and effluent limitations in 314 CMR 6.0. The MADEP has determined that effluent from the Demo 1 treatment system is “conditionally exempt” from obtaining the permit provided that the applicable or relevant provisions of the MCP 310 CMR 40 are complied with (as per letter from MADEP dated 13 February 2004).	The substantive components of the Massachusetts Contingency Plan, 310 CMR 40.0040, Management Procedures for Remedial Wastewater and Remedial Additives will be adequately addressed as part of the planned approach for operation and maintenance of the treatment systems. Treated effluent which is recharged to the aquifer will not exceed Massachusetts groundwater quality standards. The detailed plan for monitoring, inspecting and reporting on the performance of the extraction, treatment and recharge systems will be presented in the System Performance and Ecological Impact Monitoring (SPEIM) Plan, which will be submitted to the MADEP for review.

Table D-1
Summary of Potential Regulatory Considerations
Alternatives 1 through 6
Final Feasibility Study
Demo 1 Groundwater Operable Unit

AUTHORITY/TYPE	PROVISION	SYNOPSIS	ACTION TO BE TAKEN IN CONSIDERATION
State/Action Specific	Underground Injection Control [310 CMR 27.00]	These regulations prohibit injection of fluid containing any pollutant into underground sources of drinking water where such pollutant will, or is likely to, cause a violation of any state drinking water standard or adversely affect the health of persons.	The substantive components of the Massachusetts Contingency Plan, 310 CMR 40.0040, Management Procedures for Remedial Wastewater and Remedial Additives will be adequately addressed as part of the planned approach for operation and maintenance of the treatment systems. The detailed plan for monitoring, inspecting and reporting on the performance of the extraction, treatment and recharge systems will be presented in the System Performance and Ecological Impact Monitoring (SPEIM) Plan, which will be submitted to the MADEP for review. Extracted groundwater will be treated to levels at or below federal and state primary drinking water standards (i.e., MCLs) to ensure that discharges to the receiving aquifer will not cause any violations of these standards in the aquifer.