Final

Feasibility Study Addendum for Groundwater
TNT and Red Water Pond Areas
Former Plum Brook Ordnance Works
Sandusky, Ohio

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List of Acronyms

°F	degrees Fahrenheit
µg/L	micrograms per liter
ADNT	aminodinitrotoluene
2-ADNT	2-amino-4,6-dinitrotoluene
4-ADNT	4-amino-2,6-dinitrotoluene
AOC	area of concern
ARAR	applicable or relevant and appropriate requirements
BERA	baseline ecological risk assessment
bgs	below ground surface
BHHRA	baseline human health risk assessment
BSC	background screening concentration
BTEX	benzene, toluene, ethylbenzene, and xylene
CERCLA	Comprehensive Environmental Response, Compensation, and Liability Act
CFR	Code of Federal Regulations
COC	contaminant of concern
COPC	chemical of potential concern
DD	decision document
DNB	dinitrobenzene
D&M	Dames and Moore, Inc.
DNT	dinitrotoluene
DOD	U.S. Department of Defense
EPA	U.S. Environmental Protection Agency
FFS	focused feasibility study
FS	feasibility study
ft^2	square feet
GAC	granular activated carbon
gpm	gallons per minute
GSA	General Services Administration
H_2S	hydrogen sulfide
HI	hazard index
ICI	International Consultants Incorporated
ILCR	incremental lifetime cancer risk
ISCO	in situ chemical oxidation
ISEB	in situ enhanced bioremediation

List of Acronyms *(Continued)*

IT	IT Corporation
LNAPL	light nonaqueous-phase liquid
LTM	long-term monitoring
LUCIP	land-use control implementation plan
MCL	maximum contaminant level
mg/kg	milligrams per kilogram
mg/L	milligrams per liter
MK	Morrison Knudsen Corporation
MNA	monitored natural attenuation
mV	millivolt
NAC	nitroaromatic compound
NASA	National Aeronautics and Space Administration
NCP	National Oil and Hazardous Substances Pollution Contingency Plan
NPDES	National Pollutant Discharge Elimination System
O&M	operation and maintenance
ODNR	Ohio Department of Natural Resources
OEPA	Ohio Environmental Protection Agency
OMB	Office of Management and Budget
ORP	oxidation-reduction potential
P&T	pump and treat
PAH	polycyclic aromatic hydrocarbon
PBOW	Plum Brook Ordnance Works
PCB	polychlorinated biphenyl
PETN	pentaerythritol tetranitrate
POTW	publicly owned treatment works
PRRWP	Pentolite Road Red Water Pond
RAO	remedial action objective
RBRC	risk-based remedial concentration
RBSC	risk-based screening concentration
RCRA	Resource Conservation and Recovery Act
RG	remedial goal
RI	remedial investigation
RO	reverse osmosis
ROD	record of decision
SAIC	Science Applications International Corporation

SCS	Soil Conservation Services
Shaw	Shaw Environmental, Inc.
SLERA	screening-level ecological risk assessment
SMCL	secondary maximum contaminant level
SOD	soil oxidant demand
SVOC	semivolatile organic compound
TAL	target analyte list
TAT	triaminotoluene
TBC	to be considered
TCL	target compound list
TDS	total dissolved solids
TNB	trinitrobenzene
TNT	2,4,6-trinitrotoluene
TNTA	TNT Area A
TNTB	TNT Area B
TNTC	TNT Area C
TOC	total organic carbon
TSS	total suspended solids
UIC	underground injection control
USACE	U.S. Army Corps of Engineers
USGS	U.S. Geological Survey
VOC	volatile organic compound
WARWP	West Area Red Water Ponds
WTI	WasteTron, Inc.
WWTP	wastewater treatment plant
yd^3	cubic yard
ZVI	zero-valent iron

Executive Summary

This addendum is a supplement and partial revision to the final feasibility study (FS) for groundwater for the TNT and Red Water Pond Areas of the former Plum Brook Ordnance Works (PBOW) site in Sandusky, Ohio. The U.S. Army Corps of Engineers (USACE) contracted Shaw Environmental, Inc. to conduct this FS addendum under Modification No. 6 to Delivery Order DX02 of IDT Contract W912DR-05-D-0026.

The objectives of this FS addendum are as follows:

- Address comments raised by the USACE Environmental and Munitions Center of Expertise (CX) on the internal draft proposed plan related to the final FS.
- Revise applicable and relevant or appropriate requirements (ARAR).
- Modify Alternative GW-2 to include monitored natural attenuation as a component of the alternative.
- Add new Alternative GW-5, groundwater monitoring and/or institutional controls.

This information is presented as revised sections and associated tables of the FS. As such, these sections and tables are numbered according to their placement in the final FS.

This addendum is not intended as a stand-alone document. Please refer to the final FS for information on the site background (FS Chapter 1.0), site and groundwater use and characteristics (FS Chapter 2.0) and remedial action objectives (FS Sections 3.1 through 3.7). This FS addendum does not make changes to any of the figures and appendices in the final FS. Please refer to the final FS for this information.

This FS addendum focuses on the development and evaluation of remedial alternatives for groundwater at the TNT and Red Water Pond Areas.

Remedial Alternatives. A broad range of remedial alternatives was developed in the FS that allow the project risk managers to assess the relative cost effectiveness of different remedial strategies that employ varying degrees of active remediation. A site-specific leaching and groundwater flow model was critical in the development of these alternatives, as the predictions of the model were used to identify target areas for remediation. Note the results of the groundwater model are considered to be conservative (i.e., biased high). The following remedial alternatives were developed and evaluated for contaminated groundwater at PBOW:

- Alternative GW-1: No further action
- Alternative GW-2: Groundwater monitoring, monitored natural attenuation, and institutional controls
- Alternative GW-3: In situ enhanced bioremediation (ISEB)/pump and treat (P&T) for mitigation/protection of the limestone bedrock groundwater, groundwater monitoring, and institutional controls
- Alternative GW-4: ISEB/P&T for mitigation/protection of the overburden/shale and limestone bedrock groundwater, groundwater monitoring, and institutional controls
- Alternative GW-5: Groundwater monitoring and/or institutional controls.

Evaluation of Remedial Alternatives. The remedial alternatives were evaluated against the seven threshold and primary balancing criteria required by the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA). Some general conclusions are presented in the following paragraphs. Present value cost summaries are provided in Table ES-3.

Table ES-3

Estimated Present Value Cost Summaries and Contingencies
TNT and Red Water Pond Areas Groundwater Feasibility Study Addendum
Former Plum Brook Ordnance Works, Sandusky, Ohio

	Alternative					
	GW-1 No Further Action	GW-2 Monitoring/ICs	GW-3 Targeted ISEB/P&T	GW-4 ISEB/P&T	GW-5a Monitoring	GW-5b ICs
Present Value Estimate	$0	$1,742,000	$13,216,000	$16,947,000	$414,000	$36,000
Present Value Estimate (-30%)	$0	$1,219,000	$9,251,000	$11,863,000	$290,000	$25,000
Present Value Estimate (+50%)	$0	$2,613,000	$19,824,000	$25,421,000	$621,000	$54,000

IC = Institutional control; ISEB/P&T = In situ enhanced bioremediation/pump and treat.

Alternative GW-1 protects human health and the environment, because groundwater at the five areas of concern is not a potential source of drinking water, and groundwater contamination does not present a threat to off-site downgradient groundwater. No ARARs are identified for Alternative GW-1. Therefore, this alternative would meet the threshold criteria required under CERCLA. Alternative GW-1 does not reduce the toxicity, mobility, or volume of contamination through treatment, but natural attenuation processes in the limestone bedrock may remove contaminants of concern (COC) that migrate from the overburden/weathered shale. The alternative does not implement any controls to manage potential residual risk; even so, the potential residual risks associated with the alternative are acceptable. The alternative does not present any short-term risks to the community, site workers, or the environment. There are no implementation concerns with Alternative GW-1 because no further action would be taken. There are no costs associated with the alternative.

Alternative GW-2 protects human health and the environment. The alternative provides an additional measure to prevent human exposure in comparison to Alternative GW-1 by establishing groundwater use restrictions to prevent exposure to contaminated groundwater on site. Long-term groundwater monitoring would protect the surrounding community by providing advanced notice of any potential off-site movement of contamination, allowing remedial action to be taken if necessary. The alternative includes a monitored natural attenuation component that would evaluate the capacity of the limestone bedrock to remove COCs that may migrate from the overburden/weathered shale. No ARARs are identified for Alternative GW-2. Therefore, this alternative would meet the threshold criteria required under CERCLA. Alternative GW-2 does not reduce the toxicity, mobility, or volume of contamination through treatment, but natural attenuation processes in the limestone bedrock may remove COCs that migrate from the overburden/weathered shale. The alternative manages potential residual risk at the site through groundwater monitoring and institutional controls. Short-term risks to the community, site workers, and the environment during implementation are considered to be minimal. The components of the alternative could be implemented within 1year, but monitoring and controls would be required until remedial goals (RG) were met. A period of at least 150 years is projected based on the results of groundwater modeling. The actual remedial duration would likely be shorter than projected because data were not available to incorporate the effects of natural attenuation processes into the modeling. For cost estimating purposes, the remedial duration of Alternative GW-2 is assumed to be 30 years. There are no significant implementation concerns with the alternative. The total present value cost of the alternative is estimated to range from $1.2 to $2.6 million over 30 years.

Alternative GW-3 protects human health and the environment. Alternative GW-3 includes treatment of groundwater in the overburden/weathered shale and limestone bedrock aquifers. The objective of this treatment is to reduce the concentration of COCs in the limestone bedrock aquifer to RGs. No ARARs are identified for Alternative GW-3. Therefore, this alternative would meet the threshold criteria required under CERCLA. Alternative GW-3 reduces the toxicity, mobility and volume of contamination through a combination of ISEB in the overburden/weathered shale aquifer and P&T in the limestone bedrock aquifer. The alternative manages potential residual risk at the site through groundwater monitoring and institutional controls. Short-term risks to the community, site workers, and the environment during implementation are considered to be minimal. The components of the alternative could be implemented within four years or less, but O&M of the P&T system, groundwater monitoring, and institutional controls are projected to be required over a period of at least 150 years based on the results of groundwater modeling. The actual remedial duration would likely be shorter than projected because data were not available to incorporate the effects of natural attenuation processes into the modeling. For cost estimating purposes, the remedial duration of Alternative GW-3 is assumed to be 30 years. There are no significant implementation concerns with the alternative. The total present value cost of the alternative is estimated to range from $9.3 to $19.8 million over 30 years.

Alternative GW-4 protects human health and the environment. GW-4 includes treatment of groundwater in the overburden/weathered shale and limestone bedrock aquifers. Unlike Alternative GW-3, the objective of this treatment is to reduce the concentrations of COCs in both the overburden/weathered shale and limestone bedrock aquifer to RGs. No ARARs are identified for Alternative GW-4. Therefore, this alternative would meet the threshold criteria required under CERCLA. Alternative GW-4 reduces the toxicity, mobility, and volume of contamination through a combination of ISEB in the overburden/weathered shale aquifer and P&T in the limestone bedrock aquifer. The ISEB component in the overburden/weathered shale would be applied over a larger area than in Alternative GW-3. The alternative manages potential residual risk at the site through groundwater monitoring and institutional controls. Short-term risks to the community, site workers, and the environment during implementation are considered to be minimal. The components of the alternative could be implemented within eight years or less, but O&M of the P&T system, groundwater monitoring, and institutional controls are projected to require a period of at least 150 years based on the results of groundwater modeling. The actual remedial duration would likely be shorter than projected because data were not available to incorporate the effects of natural attenuation processes into the modeling. For cost estimating purposes, the remedial duration of Alternative GW-4 is assumed to be 30 years. There are no significant implementation concerns with the alternative. The total present value cost of the alternative is estimated to range from $11.9 to $25.4 million over 30 years.

Alternative GW-5 protects human health and the environment. The alternative provides an additional measure to prevent human exposure in comparison to Alternative GW-1 by establishing groundwater-use restrictions to prevent exposure to contaminated groundwater on site. Groundwater monitoring would protect the surrounding community by monitoring and evaluating the potential for contamination to migrate off site. No ARARs are identified for Alternative GW-5. Therefore, this alternative would meet the threshold criteria required under CERCLA. Alternative GW-5 does not reduce the toxicity, mobility, or volume of contamination through treatment, but natural attenuation processes in the limestone bedrock may remove COCs that migrate from the overburden/weathered shale. The alternative manages potential residual risk at the site through groundwater monitoring and/or institutional controls. Short-term risks to the community, site workers, and the environment during implementation are considered to be minimal. The components of the alternative could be implemented within one year. Groundwater would be monitored every 5 years for a period of 30 years. Institutional controls would be enforced by the National Aeronautics and Space Administration for the same period of time. There are no significant implementation concerns with the alternative. The total present value cost of the groundwater monitoring component of the alternative is estimated to range from $290,000 to $621,000. The total present value cost of the institutional controls component of the alternative is estimated to range from $25,000 to $54,000.

Conclusions. Alternatives GW-1 through GW-5 meet the protectiveness of human health and the environment criterion because the bedrock groundwater underlying the TNT and Red Water Pond Areas contains naturally occurring petroleum-related hydrocarbons and hydrogen sulfide, which results in off-gassing which renders this groundwater unsuitable for potable use. Alternatives GW-2 through GW-5 include institutional controls which serve as an additional measure to prevent human exposure. A monitoring program would be included in Alternatives GW-2 through GW-5 to verify that groundwater contamination will not migrate off site. Under Alternatives GW-3 and GW-4, it is expected that limestone bedrock groundwater would be remediated over a period of time, and further contamination to the limestone bedrock from the overburden/shale would be prevented both through overburden/shale groundwater remediation and the soil remediation activities that are already planned or completed in the respective areas of concern. Alternative GW-4 is intended to result in eventual remediation of all overburden/shale groundwater to RGs.

Given the demonstrated low quality of both the overburden/shale and limestone bedrock groundwater due to naturally occurring chemicals and the low yield of the overburden/shale, the benefits of remediating this groundwater seem negligible. Even if RGs were met, it is possible that other naturally occurring chemicals may not be cleaned up using active remediation (i.e., GW-3 or GW-4). Even if the groundwater were to meet RGs (including naturally occurring non-COCs) during active remediation, it is likely that once treatment was complete, the non-COCs would increase in concentration due to natural processes (e.g., groundwater flow from naturally contaminated upgradient sources). The estimated costs for implementing either GW-3 ($9.6million to $19.8 million) or GW-4 ($11.9 million to $25.4 million) are substantial. The costs of the other alternatives are much lower and would provide the same level of protection to human health.

3.0 Remedial Action Objectives

This chapter provides remedial action objectives (RAO) and other key information for the evaluation of groundwater underlying TNT Area A (TNTA), TNT Area B (TNTB), TNT Area C (TNTC), the Pentolite Road Red Water Pond (PRRWP) Area, and the West Area Red Water Pond (WARWP) Area. RAOs are developed during the feasibility study (FS) and finalized in the record of decision to protect human health and the environment. RAOs provide the basis for the identification, detailed analysis, and selection of remedial alternatives. RAOs specify contaminants of concern (COC) to be addressed; relevant exposure route(s) and receptor(s); and chemical concentration limits specific to COCs, environmental media, and specific locations at the site. RAOs for this FS pertain specifically to groundwater. This chapter includes only those sections of Chapter 3.0 of the final FS that require changes to fulfill the scope of the FS addendum.

3.1 Identification of Remedial Action Objectives

The following RAOs have been developed for the TNT and Red Water Ponds Areas:

- Prevent on-site human exposure to groundwater containing COCs at concentrations that exceed remedial goals (RG).
- Prevent human exposure to downgradient off-site groundwater containing COCs at concentrations that exceed RGs.

The groundwater RGs are provided in Table 3-1. A range of remedial alternatives has been developed to meet the RAOs listed.

3.8 Applicable or Relevant and Appropriate Requirements

Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) Section 121 requires that on-site remedial actions comply with applicable or relevant and appropriate requirements (ARAR) at the completion of the remedy. ARARs are defined in CERCLA regulation (40 Code of Federal Regulations [CFR] 300.5) as follows:

- “Applicable requirements” means those cleanup standards, standards of control, and other substantive environmental protection requirements, criteria, or limitations promulgated under federal environmental or state environmental or facility siting laws that specifically address a hazardous substance, pollutant, contaminant, remedial action, location, or other circumstance found at a CERCLA site.

- "Relevant and appropriate requirements" means those cleanup standards, standards of control, and other substantive environmental protection requirements, criteria, or limitations promulgated under federal or state law that, while not "applicable" to a hazardous substance, pollutant, contaminant, remedial action, location, or other circumstance at a CERCLA site, address problems or situations sufficiently similar to those encountered at the CERCLA site that their use is well suited to the particular site.

ARARs are identified at various points in the CERCLA cleanup process and are refined as additional information regarding site conditions is made available. When an analysis results in a determination that a requirement is both relevant and appropriate, compliance with that requirement is mandatory to the same extent as for applicable requirements.

This section identifies potential ARARs for five areas of concern (AOC) (TNTA, TNTB, TNTC, PRRWP, and WARWP), based on the current knowledge of site conditions. Federal and State of Ohio laws, regulations, guidance, and policy have been reviewed to determine the potential ARARs for these areas. Per the Department of the Army (2004) policy, federal regulations have priority over state statutes or regulations as ARARs when the requirements of the federal regulation are not less stringent than those presented in the state statutes or regulations.

3.8.1 Location-Specific Applicable or Relevant and Appropriate Requirements

Location-specific ARARs are those requirements that must be met at a site due solely to its physical location or protected status. Generally, such ARARs are limited to locations afforded special legal protection (e.g., wetlands, historically significant resources, wildlife refuges, and critical species habitat). There are no location-specific ARARs for the five AOCs.

3.8.2 Chemical-Specific Applicable or Relevant and Appropriate Requirements

Chemical-specific ARARs are those requirements that are specific to a chemical or group of chemicals (e.g., arsenic, polychlorinated biphenyls). These ARARs are concentrations of a chemical that may be found in, or discharged to, the environment. Chemical-specific ARARs typically consist of health- or risk-based values, modified as appropriate to reflect technological limitations of analysis or treatment. There are no chemical-specific ARARs for the five AOCs.

3.8.3 Action-Specific Applicable or Relevant and Appropriate Requirements

Action-specific ARARs are typically technology- or activity-based requirements or limitations placed on remedial actions. Such requirements are specific to the particular remedial action considered (e.g., excavation, in situ treatment). There are no action-specific ARARs for the five AOCs.

3.8.4 Other Criteria To Be Considered

Nonbinding advisories, criteria, or guidelines (known as to be considered [TBC]) may be applied in instances where an ARAR does not exist for a particular contaminant or when an ARAR does not adequately address specific site conditions. Because TBCs are generally not promulgated or enforceable, they do not have the same status as ARARs. TBCs should only be considered if they are identified as appropriate based on site circumstances, shown to be protective, and are not superseded by a legally binding ARAR. U.S. No TBCs have been identified for groundwater underlying the TNT and red water pond areas.

5.0 Development and Detailed Analysis of Remedial Alternatives for Groundwater

The goal of this chapter is to introduce, assess, and communicate the relative costs, benefits, and limitations of the remedial alternatives for groundwater selected for detailed analysis. Evaluation criteria for the detailed analysis of remedial alternatives are described by the EPA in *Guidance for Conducting Remedial Investigations and Feasibility Studies under CERCLA* (EPA, 1988). These are the nine evaluation criteria included in the National Oil and Hazardous Substances Pollution Contingency Plan (NCP), Title 40 CFR, Part 300.430 (EPA, 1990). The results of the detailed analysis of remedial alternatives for groundwater will be presented in the proposed plan, decision document (DD), and other public information documents following the consideration of the Ohio Environmental Protection Agency (OEPA) and community input. The comparison of remedial alternatives is presented in Chapter 6.0.

The nine evaluation criteria include the two threshold criteria, five primary balancing criteria, and two modifying criteria. These criteria cover regulatory, technical, cost, institutional, and community considerations. Generally, the two threshold criteria are as follows:

- Protection of human health and the environment
- Compliance with ARARs.

The five balancing criteria are as follows:

- Long-term effectiveness and permanence
- Short-term effectiveness
- Reduction in toxicity, mobility, and volume
- Technical and administrative implementability
- Alternative cost, including capital, operation and maintenance (O&M), and present value costs.

The final two criteria are the modifying criteria. These two criteria often are evaluated after the initial publication of the FS and are as follows:

- State acceptance
- Community acceptance.

The first seven criteria will be evaluated in this FS. The two modifying criteria will be evaluated through working-level discussions with OEPA, as well as through the solicitation of community input from public outreach activities. These activities include publication of a proposed plan and presentation of the proposed plan at a public meeting. The purpose of the proposed plan is to present the preferred alternative to the public and provide an opportunity to receive public input as part of the remedial decision process. Such comment would be received specifically during the public meeting and a public comment period of at least 30 days, in addition to comments received during regularly scheduled Plum Brook Ordnance Works (PBOW) Restoration Advisory Board meetings. The public comment would form the basis of the modifying criterion, community acceptance. Once all of the FS criteria have been adequately considered and a final remedy pathway is selected, a final remediation alternative will be presented in a DD. The DD will serve as the basis for additional remedial design and action.

In developing the groundwater alternatives, a range of remedial alternatives were developed and evaluated that meet remedial action objectives, but do so in either more or less aggressive fashions. This presents decision makers with an array of remedial approaches to consider when balancing the various evaluation criteria. The following remedial alternatives were selected for detailed evaluation:

- Alternative GW-1: No further action
- Alternative GW-2: Groundwater monitoring, monitored natural attenuation (MNA), and institutional controls
- Alternative GW-3: In situ enhanced bioremediation (ISEB)/pump and treat (P&T) for mitigation/protection of the limestone bedrock groundwater, groundwater monitoring, and institutional controls
- Alternative GW-4: ISEB/P&T for mitigation/protection of the overburden/shale and limestone bedrock groundwater, groundwater monitoring, and institutional controls
- Alternative GW-5: Groundwater monitoring and/or institutional controls.

The description and evaluation of each of these alternatives is presented in the following sections. Cost tables for Alternatives GW-2 through GW-5 are presented in Tables 5-1 through 5-4 (no costs are attributable to the no-further-action alternative). The present value of O&M costs for each alternative is calculated in Table 5-5, and a summary and comparison of total present value costs for the remedial alternatives are presented in Table 5-6.

5.1 Alternative GW-1 – No Action

5.1.1 Description

A no-action alternative is required by the NCP to be carried forward as a baseline for detailed comparison. Under this alternative, no further remedial action or monitoring would be conducted for contaminated groundwater at the site. Note that completed (TNTB and PRRWP Area) and planned (TNTA and TNTC) soil removal represent source removal actions with respect to protection of groundwater. Decontamination efforts, beginning in 1945, were also completed that removed potential groundwater sources. Therefore, GW-1 is a no-further-action alternative rather than a no-action alternative.

5.1.2 Overall Protection of Human Health and the Environment

Alternative GW-1 would protect human health and the environment, because groundwater at the five AOCs is not a potential source of drinking water, and on-site groundwater contamination does not present a threat to off-site downgradient groundwater. Groundwater within the overburden/shale is discontinuous, seasonally dependent, and of relatively low quality based on concentrations of chloride, sulfate, sodium, and total dissolved solids (TDS) that exceed secondary maximum contaminant levels (SMCL). While SMCLs are not regulatory enforceable, they are used as a guide to determine acceptable drinking water based on taste, smell, color, or appearance. Similarly, high concentrations of sulfate, as well as hydrogen sulfide and naturally occurring petroleum hydrocarbons, are present in the limestone bedrock, making it unsuitable as a source for potable water. A survey of current off-site use of groundwater was conducted by the USACE. The result of the survey indicated that, while private wells were present in downgradient areas, they are not used for potable water. Thus, the poor water quality and limited yield in the overburden/shale and poor water quality in the limestone in effect deter use as a potable source for drinking water. This results in an incomplete exposure pathway for off-site groundwater.

Contaminated groundwater does not present a threat to ecological receptors or other environmental media, because impacted groundwater does not discharge to surface water. The combination of strongly reducing conditions and naturally occurring organic carbon in the limestone bedrock may be contributing to the microbial degradation and transformation of nitroaromatic compounds (NAC). These conditions should prevent concentrations of COCs in the overburden/shale from contributing to downgradient bedrock groundwater contamination. Available groundwater analytical data indicate that site-related contamination is limited to on-site areas.

5.1.3 Compliance with Applicable or Relevant and Appropriate Requirements

There are no chemical- or location-specific ARARs for the five AOCs, and no action-specific ARARs are identified for Alternative GW-1. Drinking water standards are not identified as ARARs because the on-site groundwater is not a potential source of drinking water. EPA toxicity data, which are not ARARs, were used to develop risk-based RGs for COC in groundwater.

5.1.4 Long-Term Effectiveness

The potential residual risk at all five AOCs is low because groundwater is not a viable source of drinking water and groundwater contamination is unlikely to migrate off site. Note that site-related contaminants have not been detected in off-site groundwater. Alternative GW-1 does not implement any controls to manage potential residual risk.

5.1.5 Reduction of Toxicity, Mobility, or Volume

This alternative does not employ any remedial component that would reduce the toxicity, mobility, or volume of contaminants in groundwater.

5.1.6 Short-Term Effectiveness

This alternative does not involve implementation of a remedial action, so there would be no implementation-related impacts to workers, the environment, or the community.

5.1.7 Implementability

There are no technical implementation issues associated with this alternative.

5.1.8 Cost

There is no cost associated with this alternative.

5.2 Alternative GW-2 – Groundwater Monitoring, Monitored Natural Attenuation, and Institutional Controls

5.2.1 Description

Alternative GW-2 consists of the following remedial components:

- Institutional controls to restrict the use of groundwater on site. The objective of this component is to prevent the exposure of on-site receptors to contaminated groundwater as long as concentrations of COCs in groundwater remain above RGs.

- Groundwater monitoring. The objective of this component is to monitor groundwater quality across the site and assess its potential to affect off-site receptors.

- MNA. The objective of this component is to collect and evaluate the potential for natural attenuation to reduce the concentrations of COCs in the limestone bedrock.

Groundwater use restrictions would prevent use of all groundwater in on-site contaminated areas. These use restrictions would be in place as long as the concentrations of COCs were greater than the RGs. Land-use controls consist of legal mechanisms designed to control exposure to chemicals in soil and groundwater and can include deed notices, easements, well drilling prohibitions, and zoning restrictions. Land-use controls would be implemented and enforced under Ohio's Environmental Covenants Act. A land-use control implementation plan (LUCIP) would be required to implement and enforce the specific groundwater use prohibitions.

Additional monitoring wells would be required to accomplish the above monitoring objective. For cost estimating purposes, the following assumptions are made concerning groundwater monitoring:

- A total of 29 new wells would be constructed in the limestone bedrock aquifer.
- A total of 33 wells (29 new and 4 existing) in the limestone bedrock zone would be analyzed for COCs and MNA parameters once per year.
- The groundwater monitoring period is assumed to span 30 years.

There are 26 hotspots in limestone bedrock groundwater at the TNT areas. It is assumed each of these hotspots would be monitored with one well. In addition, it was anticipated that up to seven wells would be needed to monitor limestone bedrock groundwater in the Red Water Ponds areas. Preliminary evaluation indicates that 4 existing wells could be used for monitoring, hence the need for 29 new bedrock wells.

The actual monitoring requirements would be negotiated between the USACE and OEPA when a long-term monitoring (LTM) program was established, and these requirements may be different than the assumptions presented above. Monitoring requirements may change over time as well. For example, later in the remedial period, fewer wells might be sampled in the limestone bedrock or sampling frequency might be decreased if COC concentrations in groundwater exhibited a long-term decreasing trend. Alternatively, additional sampling may be required in areas if an increasing trend in COC concentrations were observed.

The presence of naturally occurring petroleum hydrocarbons in portions of the limestone bedrock aquifer may stimulate the anaerobic biodegradation of nitroaromatic COCs. Further evaluation of

MNA as a possible enhancement to the groundwater monitoring program is warranted based on the analytical data collected for the site. The data indicate that nitroaromatic constituents are only detected sporadically within the limestone bedrock and are generally not detected in bedrock wells that are also impacted by naturally occurring petroleum compounds. MNA could shorten the required monitoring period or decrease the frequency of monitoring in the future.

Natural attenuation potential would be evaluated by site capacity and biomarker tests. Site capacity tests are batch shaker or column tests that measure the potential of the limestone bedrock to adsorb or transform COCs from the overburden/shale. These tests quantify the removal of COCs from samples of rock/groundwater spiked with NACs (Pennington, et al., 1999a).

Biomarker tests are used to detect the involvement of microorganisms as biocatalysts for the degradation and/or transformation of NACs. Radiorespirometry measures the potential of microbes in the limestone bedrock to degrade NACs from the overburden/shale. The test quantifies a mineralization rate by measuring the production of $^{14}CO_2$ in anaerobic microcosms of rock/groundwater slurries spiked with ^{14}C-labeled NACs (Pennington, et al., 1999a). For cost estimating purposes, it is assumed that five samples of rock and groundwater from the limestone bedrock, including one sample from each AOC, would be collected for site capacity and radiorespirometry tests.

5.2.2 Overall Protection of Human Health and the Environment

Alternative GW-2 would protect human health and the environment. The groundwater at the five AOCs is not a potential source of drinking water, and the on-site groundwater contamination does not present a threat to off-site downgradient groundwater. Alternative GW-2 would provide an additional measure to prevent exposure to contaminated groundwater by prohibiting use of on-site groundwater while the concentrations of COCs exceed the RGs. Groundwater monitoring would protect off-site groundwater users by monitoring and evaluating limestone bedrock groundwater quality. MNA would provide evidence of the capacity of the limestone bedrock to attenuate COCs that may migrate from the overburden/shale.

Contaminated groundwater does not present a threat to ecological receptors or other environmental media, because impacted groundwater does not discharge to surface water.

5.2.3 Compliance with Applicable or Relevant and Appropriate Requirements

There are no chemical- or location-specific ARARs for the five AOCs, and no action-specific ARARs are identified for Alternative GW-2. Drinking water standards are not identified as an

ARAR because the on-site groundwater is not a potential source of drinking water. EPA toxicity data, which are not ARARs, were used to develop risk-based RGs for COC in groundwater.

5.2.4 Long-Term Effectiveness

The potential residual risk at all five AOCs is low because groundwater is not a viable source of drinking water and groundwater contamination is unlikely to migrate off site. Note that site-related contaminants have not been detected in off-site groundwater. Alternative GW-2 would manage potential residual risk through groundwater use restrictions to prevent on-site exposure and groundwater monitoring and MNA to further evaluate the potential for contaminated groundwater to migrate off site. Laboratory studies conducted in support of the MNA component of Alternative GW-2 would evaluate the capacity of the limestone bedrock to attenuate NACs that may migrate from the overburden/shale. The institutional controls, groundwater monitoring, and five-year reviews would continue until RGs were met at each AOC.

5.2.5 Reduction of Toxicity, Mobility, or Volume

COCs in overburden/shale groundwater that may migrate to the limestone bedrock should attenuate through adsorption, transformation, or microbial degradation reactions. Irreversible microbial degradation and transformation reactions are expected to dominate the processes that result in NAC attenuation. The reversible adsorption of NACs is expected to be much less significant in the limestone bedrock.

5.2.6 Short-Term Effectiveness

Impacts to the community, site workers, and the environment are expected to be minimal. On-site workers would be protected by groundwater use restrictions and compliance with the site health and safety plan. The potential effects of fugitive hydrogen sulfide emissions on workers and the public would be mitigated when locating and constructing new wells. Groundwater monitoring well construction would be completed and institutional controls established within one year.

Based on groundwater modeling results, it would take more than 150 years for the concentrations of COCs in the limestone bedrock aquifer to fall below RGs under this alternative. The groundwater modeling of contaminant transport is likely overly conservative because natural attenuation processes in the limestone bedrock aquifer should prevent COCs in the overburden/shale from contaminating downgradient bedrock groundwater.

5.2.7 Implementability

The monitoring and institutional control components of Alternative GW-2 are technically and administratively implementable. Natural attenuation mechanisms for NACs have been identified, but the biodegradation, transformation, and adsorption processes that attenuate NACs are complex, and the methods used to evaluate these processes are not as well developed as some other classes of contaminants, such as fuel compounds or chlorinated solvents. The USACE has developed a draft protocol for MNA of NACs, and the tests proposed in the protocol demonstrate the capacity of a groundwater unit to attenuate NACs. Research in this area is ongoing, and additional techniques will likely be available in the future. The synthesis of ^{14}C-labeled NACs and handling of radioisotopes during the radiorespirometry tests would require the services of specialized laboratories.

The implementation of institutional controls would require coordination with state and local authorities. Nothing in the implementation of the components of this alternative precludes additional action if necessary.

5.2.8 Cost

The capital and annual O&M costs for Alternative GW-2 are presented in Table 5-1. Table 5-6 shows the present value calculation of O&M costs using a 2.7 percent discount rate (USACE and EPA, 2000; Office of Management and Budget [OMB], 2009). Table 5-7 presents a summary of the estimates for capital cost, present value of O&M cost, and total present value cost. The capital cost of Alternative GW-2 is $539,000. The present value of annual O&M costs over the 30-year remedial duration is $1,203,000. The total present value of capital and O&M costs is $1,742,000, with an estimated range of $1, 219,000 (minus 30 percent) to $2,613,000 (plus 50 percent).

5.3 Alternative GW-3 – In Situ Enhanced Bioremediation/Pump and Treat for Mitigation/Protection of the Limestone Bedrock Aquifer

5.3.1 Description

Alternative GW-3 consists of the following remedial components:

- **ISEB within the overburden and weathered shale aquifer to reduce the concentrations of COCs within 12 targeted areas of the aquifer to RGs**. The objective of this component is to protect the underlying limestone bedrock aquifer from contamination in the overburden/weathered shale zone. Restoration of the entire overburden/shale aquifer to RGs is not an objective.

- **P&T in the WARWP and PRRWP Areas of the limestone bedrock aquifer to reduce the concentrations of COCs to RGs**. The objective of this component is to reduce the concentrations of COCs to RGs.

- **Long-term groundwater monitoring**. The objectives of this component are to verify the effectiveness of remedial technologies and assess groundwater quality across the site so that groundwater contamination does not threaten potential off-site drinking water supplies.

- **Institutional controls to restrict the use of groundwater at the site**. The objective of this component is to prevent the exposure of on-site receptors to contaminated groundwater as long as it poses a threat.

5.3.1.1 ISEB in Overburden/Shale Groundwater

The objective of ISEB under Alternative GW-3 is to protect limestone bedrock groundwater. This is accomplished by lowering the concentrations of COCs in the overburden/weathered shale to prevent the migration of COC to limestone bedrock groundwater at rates that would cause RGs to be exceeded in the lower groundwater unit. Groundwater modeling was used to define those areas within the overburden/weathered shale that would require treatment to sufficiently retard the migration of COCs to meet this objective. The objective of ISEB under Alternative GW-3 is more limited than Alternative GW-4, and therefore, the areas targeted for treatment under Alternative GW-3 are more limited. Unlike Alternative GW-4, ISEB is not implemented on a more widespread basis in the overburden/weathered shale with the objective of reducing the concentrations of COCs across the overburden/weathered shale to RGs.

The target area for remediation in the overburden/weathered shale zone for Alternative GW-3 is shown in Table 3-5 of the final FS. The total target area is 829,000 square feet (ft^2) over 12 separate overburden/shale plumes. The objective of this component of the remedial alternative is to prevent contaminants from migrating to the underlying limestone bedrock aquifer.

To simplify the preliminary design and cost estimation process for the FS, the overburden/shale plume areas within each site (i.e., TNTA, TNTB, TNTC, PRRWP Area, and WARWP Area) were combined and treated as one plume. A plume area-weighted average was calculated for plume thickness (Table 3-5 of the final FS) and contaminant concentrations (Appendix E of the final FS) were calculated accordingly as representative of groundwater across each site.

Although a number of substrates could be used as a carbon source to stimulate anaerobic biodegradation in the aquifer, the preliminary design of the ISEB technology is based on injection of emulsified vegetable oil. Emulsified vegetable oil is a suitable choice for plumes within these sites, because the concentrations of COCs within the overburden/weathered shale zone are relatively high and the oil would provide a dissolved source of carbon over an extended period of time. The injected oil initially adsorbs onto the soil within the treatment zone and gradually dissolves into groundwater. The use of emulsified oil makes it practical to treat only a portion of the plume (with the exception of the WARWP Area plume, as discussed below) and thereby minimize injection costs. Because the adsorbed oil is a reservoir of carbon substrate, the emulsified oil may be injected within a series of barriers oriented perpendicular to the direction of groundwater flow. Contaminants are treated as groundwater flows through the reaction barriers, where oil is released into solution.

The preliminary design basis of the ISEB component of Alternative GW-3 is presented in Table 5-6 of the final FS. Calculations supporting the preliminary design are presented in Appendix E of the final FS. Tables E-1 through E-5 present the plume area-weighted average concentrations of COCs by site. These values are used along with the average concentrations of the competing electron acceptors (Table E-6) to determine the emulsified vegetable oil required for biodegradation. For convenience, a spreadsheet provided by EOS Remediation, Inc., was used to estimate the quantity of emulsified oil required to effect remediation at each site (Tables E-7 through E-11). Table E-12 presents other supporting ISEB design calculations that supplement those in Tables E-7 through E-11.

The injection points along each barrier are assumed to be 10 feet apart. The number of barriers within each plume varies. An estimated 4,609 injection points are required to treat the plume areas under this alternative. The majority of these points are required within the PRRWP Area plume (81 percent of the total). Although this is the largest plume, the high number of injection points and large mass of emulsified oil required here (1,032,000 pounds) result principally from the high concentration of sulfate (5,263 milligrams per liter [mg/L]) present within this plume. The sulfate concentration in the PRRWP plume is almost an order of magnitude higher than in any other plume on PBOW. The nitrate concentration is also higher in the PRRWP Area plume (419 mg/L) than elsewhere. Although TNT is biodegradable by some bacteria under nitrate- and sulfate-reducing conditions, reaction rates are typically higher under methanogenic conditions (Krumholz, et al., 1997) and the degradation of sequential intermediate reaction products require increasingly lower reducing conditions (Spain, 1995). The emulsified oil requirement calculated here is a rough estimate, and a pilot test would be required to more accurately estimate substrate requirements.

For costing purposes, it is assumed that one injection crew would work full time until completion of the injection. Although the work could be completed more rapidly by using multiple crews, funding considerations may prevent a significantly expedited remediation schedule.

5.3.1.2 Pump and Treat with Reinjection in Limestone Bedrock Aquifer

The second component of Alternative GW-3 is groundwater extraction and treatment within the WARWP Area and PRRWP Area limestone bedrock plumes, shown on Figures 3-6 and 3-7 of the final FS. Groundwater extraction is targeted in these areas only because the groundwater modeling predicts that concentrations of COCs will not exceed RGs in other areas (Appendix A of the final FS). Therefore, the objective of this component is to eventually restore the bedrock aquifer to RGs so that the groundwater use restrictions may eventually be removed and the property released for unrestricted use. It is important to couple ISEB in the overburden/shale groundwater with P&T in the limestone bedrock, because the downward migration of untreated NACs in the upper aquifer otherwise could be accelerated by P&T.

Groundwater modeling was performed to estimate the number of groundwater extraction wells required and the sustained pumping rate that could be maintained at each well. Modeling of two groundwater extraction scenarios was completed for both the WARWP Area and PRRWP Area plumes to determine the sensitivity of contaminant concentrations in groundwater to the number of extraction wells (Appendix A of the final FS). The groundwater modeling indicated that contaminant reduction in the limestone bedrock plumes would not be significantly accelerated by the larger number of recovery wells. Therefore, for remedial costing purposes in this FS, the following recovery well configuration was selected based on the modeling work:

- WARWP Area plume: three recovery wells at 6 gallons per minute (gpm) total flow
- PRRWP Area plume: five recovery wells at 10.5 gpm total flow.

The analytical data for limestone bedrock wells BED-MW14 (WARWP Area) and BED-MW27 (PRRWP Area) were evaluated to determine what type of treatment would be required prior to disposal under various discharge scenarios. Publicly owned treatment works (POTW), surface water, and reinjection disposal scenarios were considered for treated groundwater. As discussed in Chapter 4.0 of the final FS, the reinjection option was retained because the POTW and surface water discharge options were not practical. A discussion of the constituents that would require treatment prior to reinjection is presented in Section 4.3.4.4 of the final FS.

The following treatment train is proposed for the WARWP Area treatment system (Figure 5-1 of final FS):

- Anoxic denitrification fluid bed reactor
- Aerobic bioreactor
- Coagulant metering system
- Flash mix tank with high-speed agitator
- Flocculation tank with low-speed agitator
- Parallel plate clarifier with clarified water pump and sludge pump
- Duplex bag filters with filter feed pump
- Sludge holding tank
- Filter press with feed pump
- Sump pump.

The anoxic denitrification fluid bed reactor would biologically reduce nitrate to nitrogen gas and may reduce nitroaromatic COCs to less toxic reaction products. The aerobic bioreactor would reduce the total organic carbon (TOC) concentration and may contribute to the further biodegradation of nitroaromatic COCs. The coagulant metering system, flash mix tank, flocculation tank, and parallel plate clarifier are used together to reduce the concentration of total suspended solids (TSS). The duplex bag filters would remove additional particulate matter that overflows the clarifier. The sludge holding tank is an accumulation point for settled solids from the clarifier. The sludge would be dewatered in the filter press and discharged into a hopper for off-site disposal. The filtrate from the press would drain to the area sump and be returned to the front end of the treatment process. The treated water would be pumped to reinjection wells for disposal in the limestone bedrock aquifer.

The following additional unit operation may be required for a WARWP Area groundwater treatment system:

- Dual-bed granular activated carbon (GAC) system.

GAC units are commonly used to remove low levels of NACs from water. The GAC unit would only be required if the anaerobic denitrification system and the aerobic bioreactor did not reduce the concentrations of nitroaromatic COCs below the RGs.

The following treatment train is proposed for the PRRWP Area treatment system (Figure 5-2 of final FS):

- Aeration tank (air stripper)
- Coagulant metering system

- Flash mix tank with high-speed agitator
- Flocculation tank with low-speed agitator
- Parallel plate clarifier with clarified water pump and sludge pump
- Duplex bag filters with feed pump
- Dual bed GAC system
- Sludge holding tank
- Filter press with feed pump
- Sump pump.

The aeration tank would strip volatile organic compounds (including benzene) from the water and oxidize iron in the influent. The aeration tank would also strip hydrogen sulfide (H_2S) (if present) from the groundwater. The coagulant metering system, flash mix tank, flocculation tank, and parallel plate clarifier are used together to reduce the concentration of TSS. The duplex bag filters would remove additional particulate matter that overflows the clarifier. The GAC system would remove low concentrations of nitroaromatic COCs, as well as absorbable TOC, in the groundwater influent. Adsorption of organic compounds that are not COCs would increase carbon utilization costs, but the TOC concentration in the PRRWP Area groundwater (2.6 to 3.7 mg/L) is much lower than in the WARWP Area plume. The sludge holding tank is an accumulation point for settled solids from the clarifier. The sludge would be dewatered in the filter press and discharged into a hopper for off-site disposal. The filtrate from the press would drain to the area sump and be returned to the front end of the treatment process. The treated water would be pumped to reinjection wells for disposal in the limestone bedrock aquifer.

The following additional unit operations may be required for a PRRWP Area groundwater treatment system:

- Oil/water separator
- H_2S wet scrubber.

A naturally occurring light nonaqueous-phase liquid (LNAPL) petroleum hydrocarbon has been detected during sampling of BED-MW27. The thickness of the LNAPL has ranged from a sheen to as much as 0.5 foot on the surface of the groundwater. Under constant pumping conditions, the LNAPL may disappear. If not, an oil/water separator may be required on the front end of the groundwater treatment train to remove free-phase petroleum hydrocarbons. H_2S has been detected in the vapor space of BED-MW27 at a concentration greater than 50 parts per million vapor in air. H_2S nuisance odors from the air stripper may be managed by appropriate design of the air stripper stack or by locating the PRRWP Area groundwater treatment system as far as practical from the PBOW property boundary. If the H_2S cannot be managed by these approaches, a wet scrubber may be required to remove the H_2S from the air stripper emissions. The concentration of H_2S in groundwater has not been measured, so H_2S emissions cannot be estimated at this time.

The reinjection system for the WARWP Area and PRRWP Area treatment systems would consist of five and seven reinjection wells, respectively, each pumping at approximately 2 gpm. The reinjection wells would be located upgradient and within 200 feet of the plumes. The reinjection system requirements have been estimated based on what is currently known about the hydrology using previous groundwater modeling at these sites, although no modeling has been performed to specify the reinjection system.

5.3.1.3 Groundwater Monitoring

The third component of Alternative GW-3 is groundwater monitoring. Groundwater monitoring under this alternative has two objectives. The first objective is to evaluate the performance of the active remedial systems implemented, ISEB and P&T. The second objective is to assess the overall quality of groundwater across PBOW in the limestone bedrock since it is the only groundwater unit that has the potential to directly impact off-site groundwater.

Additional monitoring wells would be required to accomplish these objectives. For cost estimating purposes, the following assumptions concerning groundwater monitoring are made:

- A total of 19 new wells would be constructed in the overburden/weathered shale zone in areas where remedial action is proposed.

- A total of 29 new wells would be constructed in the limestone bedrock.

- A total of 19 wells in the overburden/weathered shale zone would be analyzed for COCs and MNA parameters once per year for five years after ISEB implementation was complete. No additional monitoring is proposed in the overburden/weathered shale zone after the first five years.

- A total of 33 wells (29 new and 4 existing) in the limestone bedrock zone would be analyzed for COCs once per year for 30 years.

Eleven hotspots in the overburden/shale impact limestone bedrock groundwater at the TNT areas. In addition, due to the large areas of impact at the red water ponds, each area would require approximately four new overburden wells to monitor changes in groundwater quality (eight wells). The rationale for limestone bedrock wells is the same as described for Alternative GW-2.

The actual monitoring requirements would be negotiated between the USACE and OEPA when an LTM program was established. These requirements would likely be different from the assumptions presented previously. Monitoring requirements may change over time as well. For example, later in the remedial period, fewer wells might be sampled in the limestone bedrock, or sampling frequency might be decreased if COC concentrations in groundwater exhibited a long-term decreasing trend. Alternatively, additional sampling may be required in areas if an increasing trend in COC concentrations were observed.

MNA is not included formally as a component of long-term groundwater monitoring for Alternative GW-3 because not enough data are available to conclusively determine its effectiveness as a remedial technology. MNA analysis is only proposed for the ISEB target areas to help evaluate the technology's effectiveness immediately after the implementation period. However, the presence of naturally occurring petroleum hydrocarbons in portions of the bedrock aquifer may stimulate the anaerobic biodegradation of nitroaromatic COCs (Appendix B of the final FS). Further evaluation of MNA as a possible enhancement to the groundwater monitoring program may be warranted, if it would shorten the required monitoring period or significantly reduce the frequency of monitoring in the future.

5.3.1.4 Institutional Controls

The final component of Alternative GW-3 is groundwater use restrictions. These restrictions would prevent use of all groundwater in on-site contaminated areas until such time as the concentrations of COCs fall below the RGs. Land-use controls consist of legal mechanisms designed to control exposure to chemicals in soil and groundwater and can include deed notices, easements, well drilling prohibitions, and zoning restrictions. Land-use controls would be implemented and enforced under Ohio's Environmental Covenants Act. A LUCIP would be prepared to implement and enforce specific groundwater-use prohibitions.

5.3.2 Overall Protection of Human Health and the Environment

Alternative GW-3 would protect human health and the environment. The groundwater at the five AOCs is not a potential source of drinking water, and on-site groundwater contamination does not present a threat to off-site downgradient groundwater. Alternative GW-3 would provide an additional measure to prevent exposure to contaminated groundwater by prohibiting use of on-site groundwater while the concentrations of COCs exceeded the RGs. Groundwater monitoring would protect potential off-site groundwater users by monitoring and evaluating limestone bedrock groundwater quality. Targeted use of ISEB within the overburden/shale aquifer would reduce the concentrations of COCs and prevent the migration of COCs to the limestone bedrock aquifer. P&T within the bedrock aquifer of the WARWP and PRRWP Areas would reduce the concentration of COCs in these areas as an additional protection against the potential off-site migration of contaminated groundwater.

Contaminated groundwater does not present a threat to ecological receptors or other environmental media, because impacted groundwater does not discharge to surface water.

5.3.3 Compliance with Applicable or Relevant and Appropriate Requirements

There are no chemical- or location-specific ARARs for the five AOCs, and no action-specific ARARs are identified for Alternative GW-3. Drinking water standards are not identified as an ARAR because the on-site groundwater is not a potential source of drinking water. EPA toxicity data, which are not ARARs, were used to develop risk-based RGs for COCs in groundwater.

5.3.4 Long-Term Effectiveness

The potential residual risk at all five AOCs is low because groundwater is not a viable source of drinking water and groundwater contamination is unlikely to migrate off site. Note that site-related contaminants have not been detected in off-site groundwater. Alternative GW-3 would mitigate potential residual risk by reducing the concentrations of COCs in both the overburden/shale and limestone bedrock aquifers through treatment. While concentrations of COCs remain above RGs, the potential residual risks would be managed through groundwater use restrictions to prevent on-site exposure and groundwater monitoring to further evaluate the potential for contaminated groundwater to migrate off site. The institutional controls, groundwater monitoring, and five-year reviews would continue until RGs were met at each AOC.

5.3.5 Reduction of Toxicity, Mobility, or Volume

Remedial technologies used as part of Alternative GW-3 should irreversibly and permanently reduce the toxicity, mobility, and volume of COCs in groundwater. Injection of a carbon substrate into the overburden/shale groundwater during the implementation of ISEB would biologically convert nitrate and nitroaromatic COCs to less toxic or nontoxic reaction products. Nonmineralized reaction products may be incorporated into the soil matrix through subsequent irreversible transformation and covalent binding reactions.

The treatment operations of the P&T systems also provide irreversible and permanent treatment of COCs. The anoxic denitrification and aerobic bioreactors in the WARWP Area treatment system would biologically convert nitrate and nitroaromatic contaminants in extracted groundwater to nontoxic or less toxic reaction products. The carbon adsorption system in the PRRWP Area treatment system would remove NACs in extracted groundwater by adsorption onto GAC. The adsorbed organic contaminants would be thermally destroyed off site upon regeneration of the spent carbon by the GAC vendor. In addition to the spent carbon, both P&T systems would generate a nonhazardous filter cake that would require off-site disposal.

Alternative GW-3 would treat an estimated 23.4 million gallons of groundwater over an area of 968,000 ft^2 in the overburden/shale groundwater and 260 million gallons of groundwater over an area of 1,380,000 ft^2 in the limestone bedrock aquifer. It is estimated that groundwater treatment O&M activities will continue for 30 years.

5.3.6 Short-Term Effectiveness

Impacts to the community, site workers, and the environment are expected to be minimal. On-site workers would be protected by groundwater use restrictions that would remain in place until groundwater RGs were met. On-site workers would be protected during installation of monitoring wells by following the site health and safety plan and would be equipped with the necessary personal protective equipment. The work conducted would conform to all USACE safety requirements. The P&T systems are not projected to generate any emissions that would be a health risk to site workers or the public, but air emissions would be routinely evaluated to ensure air pollution controls were met and human endangerment was not a consequence. The long-term groundwater monitoring program would protect the community by providing advanced warning of any groundwater contamination that might threaten off-site water. The groundwater monitoring conducted immediately after implementation of ISEB to evaluate the performance of the technology in the overburden/shale aquifer would include analysis of naturally occurring, oxidation-reduction potential (ORP)-sensitive metals that can be mobilized under reducing conditions. Active groundwater remediation increases the carbon footprint of the alternative.

The estimated time to complete substrate injection in the overburden/weathered shale groundwater is approximately four years using one direct-push rig with a crew working full time. Direct-push technology is suitable for injection of substrates into both the overburden and the weathered shale (clay-like material). This work could be accomplished more rapidly using multiple rigs/crews, although funding constraints might preclude a more expedited schedule. The limestone bedrock aquifer P&T system could be designed and constructed in approximately two years. Additional groundwater characterization and technology pilot studies are recommended for both technologies before full-scale implementation. Therefore, the total elapsed time necessary to have the technologies completely implemented could be longer. Groundwater monitoring wells would be constructed and institutional controls established within the first year.

The initial five-year stage of the groundwater monitoring program would test the effectiveness of ISEB treatment in the overburden/shale groundwater after it was completed. After that period of time, it is assumed that groundwater monitoring would be restricted to the bedrock aquifer. Groundwater modeling has estimated that the P&T systems in the WARWP and PRRWP Areas would operate for about 150 years. The remedial period is extensive because the model predicts that there will continue to be some contribution to bedrock contamination from overlying zones. The groundwater modeling predictions about contaminant transport are likely overly conservative because natural attenuation processes in the limestone bedrock aquifer (Appendix B of the final FS) would likely reduce the operating period of the P&T systems. Therefore, a 30-year O&M period is assumed for Alternative GW-3. The estimated volumes of bedrock groundwater requiring treatment at the WARWP Area and PRRWP Area are 45 million and 61 million gallons, respectively. At the projected capture rates of the two P&T systems (6 gpm for WARWP Area and 10.5 gpm for PRRWP Area), the WARWP Area and PRRWP Area P&T systems would capture approximately 2.1 and 2.7 pore volumes, respectively, in 30 years.

5.3.7 Implementability

The components of Alternative GW-3 appear to be technically and administratively implementable, albeit at a potentially high cost. Additional data should be collected prior to full-scale implementation of the ISEB and P&T technologies to ensure that they will be effectively implemented. Groundwater plumes at target areas for groundwater remediation should have well-defined boundaries. The distribution of COCs and potential competing electron acceptors should be well understood so that the demand for carbon substrate can be predicted and the configuration of injection points can be designed effectively for ISEB areas. Of particular concern are the concentrations of sulfate and nitrate throughout the ISEB target area at the PRRWP Area overburden/shale plume. The available data indicate that sulfate would exert a high demand on carbon substrate within this plume, leading to a potentially costly ISEB implementation. The distribution of contaminants and competing electron acceptors should be better defined so that a cost-effective ISEB implementation can be performed. ISEB pilot test(s) are also recommended to optimize the injection requirements. In addition, the degradability of all contaminants would be confirmed because some of the nitroaromatics (e.g., dinitrotoluenes) are more easily degraded under aerobic conditions.

The unit operations proposed for the WARWP Area and PRRWP Area P&T systems are relatively complicated and costly for groundwater treatment systems with flow rates of 10 gpm or less. This is particularly true of the proposed WARWP Area P&T system. These systems are complicated because constituents other than the target contaminants for groundwater remediation require treatment to meet operational or discharge requirements. High levels of TOC, TSS, iron, and TDS increase the complexity of the treatment process or limit the options for discharge. The high TOC is assumed to consist of naturally occurring petroleum hydrocarbons. Given the potential cost of these systems, it is important that the type and distribution of groundwater constituents (including nontarget constituents) be well defined before the treatment system is designed and constructed. The groundwater quality within the WARWP Area and PRRWP Area plumes should be characterized under pumping conditions by sampling at the end of a pump test. The pump test would also verify aquifer characteristics and the sustainable groundwater pumping rate. The groundwater model could then be used to refine the number and location of groundwater extraction and reinjection wells. Treatability tests may be required to support the design of the treatment systems and confirm the biodegradability of the undefined organics in the groundwater.

As previously discussed, funding constraints may not allow the project to be executed all at one time. Nevertheless, the work could be easily broken into various phases. It may be preferable to complete the ISEB component before the groundwater treatment systems are operated to avoid drawing contamination from the upper aquifer into the limestone bedrock. A phased approach to remedial action would also facilitate the intermediate evaluation of individual stages or components. This would allow adjustments and fine tuning of later stages of remediation that could result in cost savings on the total project.

Injection of chemicals during ISEB would require coordination with OEPA underground injection control representatives. The implementation of institutional controls would require coordination with state and local authorities.

Nothing in the implementation of the components of this alternative precludes additional action if necessary.

5.3.8 Cost

The capital and annual O&M costs for Alternative GW-3 are presented in Table 5-2. Table 5-6 shows the present value calculation of O&M costs using a 2.7 percent discount rate (USACE and EPA, 2000; OMB, 2009). Table 5-7 presents a summary of the estimates for capital cost, present value of O&M cost, and total present value cost. The capital cost of Alternative GW-3 is $8, 834,000. The present value of annual O&M costs over the 30-year remedial duration is $4,382,000. The total present value of capital and O&M costs is $13,216,000, with an estimated range of $9,251,000 (minus 30 percent) to $19,824,000 (plus 50 percent).

5.4 Alternative GW-4 – In Situ Enhanced Bioremediation/Pump and Treat for Mitigation/Protection of the Overburden/Shale and Bedrock Aquifers

5.4.1 Description

Alternative GW-4 consists of the following remedial components:

- **ISEB within the overburden and weathered shale aquifer to reduce the concentrations of COCs within 27 contaminated areas of the aquifer to RGs.** The objective of this component is to reduce the concentrations of COCs in these areas to RGs.

- **P&T in the WARWP Area and PRRWP Area plumes in the limestone bedrock aquifer to reduce the concentrations of COCs to RGs**. The objective of this component is to reduce the concentrations of COCs to RGs .

- **Long-term groundwater monitoring**. The objectives of this component are to verify the effectiveness of remedial technologies and assess groundwater quality across the site so that groundwater contamination does not threaten potential off-site drinking water.

- **Institutional controls to restrict the use of groundwater at the site**. The objective of this component is to prevent the exposure of on-site receptors to contaminated groundwater.

5.4.1.1 ISEB in Overburden/Shale Groundwater

The objective of ISEB under Alternative GW-4 is to protect both overburden/shale and limestone bedrock groundwater. This is accomplished by reducing the concentrations of COCs in the overburden/weathered shale to RGs. This requires that ISEB under Alternative GW-4 be implemented over a larger area than required under Alternative GW-3. The implementation of ISEB under GW-3 is limited to the treatment of areas in the overburden/weathered shale that are required to protect limestone bedrock groundwater from overlying contamination. Alternative GW-3 does not reduce the concentrations of COC to RGs across the overburden/weathered shale groundwater unit.

The target area for remediation in the overburden/weathered shale zone for Alternative GW-4 is shown in Table 3-6 of the final FS. The total target area is 1,411,700 ft^2 over 27 separate plumes. The objective of this component is to reduce the concentrations of COCs to RGs in these areas so that the aquifer may eventually be released for unrestricted use.

To simplify the preliminary design and cost estimation process for the FS, the plume areas within each site (i.e., TNTA, TNTB, TNTC, PRRWP Area, and WARWP Area) were combined and treated as one plume. A plume area-weighted average was calculated for plume thickness, and contaminant concentrations (Appendix E of the final FS) were calculated accordingly as representative of groundwater across each site.

Although a number of substrates could be used as a carbon source to stimulate anaerobic biodegradation in the aquifer, the preliminary design of the ISEB technology is based on injection of emulsified vegetable oil. Emulsified vegetable oil is a suitable choice for plumes within these sites, because the concentrations of COCs within the overburden/weathered shale zone are relatively high and the oil would provide a dissolved source of carbon over an extended period of time. The injected oil initially adsorbs onto the soil within the treatment zone and gradually dissolves into groundwater. The use of emulsified oil makes it practical to treat only a portion of the plume (with the exception of the WARWP Area plume) and thereby minimize injection costs. Because the adsorbed oil is a reservoir of carbon substrate, the emulsified oil may be injected within a series of barriers oriented perpendicular to the direction of groundwater flow. Contaminants are treated as groundwater flows through the reaction barriers, where oil is released into solution.

The preliminary design basis of the ISEB component of Alternative GW-4 is presented in Table 5-7 of the final FS. Calculations supporting the preliminary design are presented in Appendix E of the final FS. Tables E-13 through E-17 present the plume area-weighted average concentrations of COCs by site. These values are used along with the average concentrations of the competing electron acceptors (Table E-6) to determine the emulsified vegetable oil required for biodegradation. For convenience, a spreadsheet provided by EOS Remediation, Inc., was used to estimate the quantity of emulsified oil required to effect remediation at each site (Tables E-18 through E-22). Table E-23 presents other supporting ISEB design calculations that supplement those in Tables E-18 through E-22.

The injection points along each barrier are assumed to be 10 feet apart. The number of barriers within each plume varies. An estimated total of 8,173 injection points are required to treat the plume areas under this alternative. The majority of these points are required within the PRRWP Area plume (84 percent of the total). Although this is the largest plume, the high number of injection points and large mass of emulsified oil required here (1,905,000 pounds) result principally from the high concentration of sulfate (5,263 mg/L) present within this plume. The sulfate concentration in the PRRWP plume is almost an order of magnitude higher than in any other plume on PBOW. The nitrate concentration is also higher in the PRRWP Area plume (253 mg/L) than elsewhere. Although TNT is biodegradable by some bacteria under nitrate- and sulfate-reducing conditions, reaction rates are typically higher under methanogenic conditions (Krumholz, et al., 1997) and the degradation of sequential intermediate reaction products require increasingly lower reducing conditions (Spain, 1995). The emulsified oil requirement calculated here is a rough estimate, and a pilot test would be required to more accurately estimate substrate requirements.

For costing purposes, it is assumed that one injection crew would work full time until completion of the injection. Although the work could be completed more rapidly by using multiple crews, funding considerations may prevent a significantly expedited remediation schedule.

5.4.1.2 Pump and Treat With Reinjection in Limestone Bedrock Aquifer

The second component of Alternative GW-4 is groundwater extraction and treatment within the PRRWP Area and WARWP Area limestone bedrock plumes (Figures 3-6 and 3-7 of the final FS). Groundwater extraction is targeted in these areas only because the groundwater modeling predicts that concentrations of COCs will not exceed RGs in other areas (Appendix A of the final FS). Therefore, the objective of this component is to eventually restore the overburden/shale zone and the limestone bedrock aquifer to RGs so that the groundwater use restrictions may be removed and the property eventually released for unrestricted use. It is important to couple ISEB in the overburden/shale groundwater with P&T in the limestone bedrocks because the downward migration of untreated NACs in the upper aquifer could otherwise be accelerated by P&T.

The P&T systems in this alternative are identical to those proposed for Alternative GW-3. Refer to Section 5.3.1.2 for a detailed discussion of the P&T component of this alternative.

5.4.1.3 Groundwater Monitoring

The third component of Alternative GW-4 is groundwater monitoring. Groundwater monitoring under this alternative has two objectives. The first objective is to evaluate the performance of the active remedial systems implemented, ISEB and P&T. The second objective is to assess the overall quality of groundwater across PBOW in the limestone bedrock since it is the only groundwater unit that has the potential to directly impact off-site groundwater.

Additional monitoring wells would be required to accomplish these objectives. For cost estimating purposes, the following assumptions are made concerning groundwater monitoring:

- A total of 35 new wells would be constructed in the overburden/weathered shale zone in areas where remedial action is proposed.
- A total of 29 new wells would be constructed in the limestone bedrock.

- A total of 35 wells in the overburden/weathered shale zone would be analyzed for COCs and MNA parameters once per year for five years after ISEB implementation was complete. No additional monitoring is proposed in the overburden/weathered shale zone after the first five years.

- A total of 33 (29 new and 4 existing) wells in the limestone bedrock zone would be analyzed for COCs once per year for 30 years.

To fully address all 26 hotspots affecting overburden groundwater, one well would be installed in each of these areas to monitor groundwater contamination. In addition, due to the larger areas of impact in both overburden and bedrock, nine additional overburden/shale wells would be required to monitor the effectiveness of treatment in the red water pond areas. The rationale for limestone bedrock wells is the same as described for Alternatives GW-2 and GW-3.

The actual monitoring requirements would be negotiated between the USACE and OEPA when an LTM program was established. These requirements would likely be different from the assumptions presented previously. Monitoring requirements may change over time as well. For example, later in the remedial period, fewer wells might be sampled in the bedrock, or sampling frequency might be decreased if COC concentrations in groundwater exhibited a long-term decreasing trend. Alternatively, additional sampling may be required in areas if an increasing trend in COC concentrations were observed.

MNA is not included formally as a component of long-term groundwater monitoring for Alternative GW-4 because not enough data are available to conclusively determine its effectiveness as a remedial technology. MNA analysis is only proposed for the ISEB target areas to help evaluate the technology's effectiveness immediately after the implementation period. However, the presence of naturally occurring petroleum hydrocarbons in portions of the limestone bedrock aquifer may stimulate the anaerobic biodegradation of nitroaromatic COCs (Appendix A of the final FS). Further evaluation of MNA as a possible enhancement to the groundwater monitoring program may be warranted if it would shorten the required monitoring period or significantly reduce the frequency of monitoring in the future.

5.4.1.4 Institutional Controls

The final component of Alternative GW-4 is groundwater use restrictions. These restrictions would prevent use of all groundwater in on-site contaminated areas until such time as the concentrations of COCs fall below the RGs. Land-use controls consist of legal mechanisms designed to control exposure to chemicals in soil and groundwater and can include deed notices, easements, well drilling prohibitions, and zoning restrictions. Land-use controls would be implemented and enforced under Ohio's Environmental Covenants Act. A LUCIP would be prepared to implement and enforce specific groundwater use prohibitions.

5.4.2 Overall Protection of Human Health and the Environment

Alternative GW-4 would protect human health and the environment. The groundwater at the five AOCs is not a potential source of drinking water, and on-site groundwater contamination does not present a threat to off-site downgradient groundwater. Alternative GW-4 would provide an additional measure to prevent exposure to contaminated groundwater by prohibiting use of on-site groundwater while the concentrations of COCs exceed the RGs. Groundwater monitoring would protect off-site groundwater users by monitoring and evaluating limestone bedrock groundwater quality throughout the plumes. Implementation of ISEB within the overburden/shale groundwater would reduce the concentrations of COCs across the aquifer and prevent the migration of COCs to the bedrock aquifer. P&T within the limestone bedrock aquifer of the WARWP and PRRWP Areas would reduce the concentrations of COCs in these areas as an additional protection against the potential off-site migration of contaminated groundwater.

Contaminated groundwater does not present a threat to ecological receptors or other environmental media, because impacted groundwater does not discharge to surface water.

5.4.3 Compliance with Applicable or Relevant and Appropriate Requirements

There are no chemical- or location-specific ARARs for the five AOCs, and no action-specific ARARs are identified for Alternative GW-4. Drinking water standards are not identified as an ARAR because the on-site groundwater is not a potential source of drinking water. EPA toxicity data, which are not ARARs, were used to develop risk-based RGs for COC in groundwater.

5.4.4 Long-Term Effectiveness

The potential residual risk at all five AOCs is low because groundwater is not a viable source of drinking water and groundwater contamination is unlikely to migrate off site. Note that site-related contaminants have not been detected in off-site groundwater. Alternative GW-4 would mitigate potential residual risk by reducing the concentrations of COCs in both the overburden/shale and limestone bedrock aquifers through treatment. While concentrations of COCs remained above RGs, the residual risks would be managed through groundwater use restrictions to prevent on-site exposure and groundwater monitoring to further evaluate the potential for contaminated groundwater to migrate offsite. The institutional controls, groundwater monitoring, and five-year reviews would continue until RGs were met at each AOC.

5.4.5 Reduction of Toxicity, Mobility, or Volume

Remedial technologies used as part of Alternative GW-4 should irreversibly and permanently reduce the toxicity, mobility, and volume of COCs in groundwater. Injection of a carbon substrate into the overburden/shale groundwater during the implementation of ISEB would biologically convert nitrate and nitroaromatic COCs to less toxic or nontoxic reaction products. Nonmineralized reaction products may be incorporated into the soil matrix through subsequent irreversible transformation and covalent binding reactions.

The treatment operations of the P&T systems also provide irreversible and permanent treatment of COCs. The anoxic denitrification and aerobic bioreactors in the WARWP Area treatment system would biologically convert nitrate and nitroaromatic contaminants in extracted groundwater to nontoxic or less toxic reaction products. The carbon adsorption system in the PRRWP Area treatment system would remove nitroaromatic contaminants in extracted groundwater by adsorption onto GAC. The adsorbed organic contaminants would be thermally destroyed off site upon regeneration of the spent carbon by the GAC vendor. In addition to the spent carbon, both P&T systems would generate a nonhazardous filter cake that would require off-site disposal. Further, the natural reducing conditions in the limestone bedrock aquifer may naturally attenuate the nitroaromatic COCs over time.

Alternative GW-4 would treat 38.4 million gallons of groundwater over an area of 1,411,700 ft^2 in the overburden/shale groundwater and 260 million gallons of groundwater over an area of 1,380,000 ft^2 in the limestone bedrock aquifer. It is estimated that groundwater treatment O&M activities will continue for 30 years.

5.4.6 Short-Term Effectiveness

Impacts to the community, site workers, and the environment are expected to be minimal. On-site workers would be protected by groundwater use restrictions that would remain in place until groundwater RGs were met in both the limestone and overburden/shale groundwater. Remediation workers would be equipped with the necessary personal protective equipment and would conform to all USACE safety requirements. The P&T systems are not projected to generate any emissions that would be a health risk to site workers or the public, but air emissions will be routinely evaluated to ensure air pollution controls were met and human endangerment was not a consequence. The long-term groundwater monitoring program would protect the community by providing advance warning of any groundwater contamination that might threaten off-site groundwater. The groundwater monitoring conducted immediately after implementation of ISEB to evaluate the performance of the technology in the overburden/shale aquifer would include analysis of naturally occurring ORP-sensitive metals that can be mobilized under reducing conditions. Active groundwater remediation increases the carbon footprint of the alternative.

The estimated time to complete substrate injection in the overburden/shale aquifer is approximately eight years using one direct-push rig with a crew working full time. This work could be accomplished more rapidly using multiple rigs/crews, although funding constraints might preclude a more expedited schedule. The limestone bedrock aquifer P&T system could be designed and constructed in approximately two years. Additional groundwater characterization and technology pilot studies are recommended for both technologies to optimize the treatment technologies before full-scale implementation. Therefore, the total elapsed time necessary to have the technologies completely implemented would be longer. Groundwater monitoring wells would be constructed and institutional controls established within the first year.

The initial five-year stage of the groundwater monitoring program would test the effectiveness of ISEB treatment in the overburden/shale groundwater after it was completed. After that period of time, it is assumed that groundwater monitoring would be restricted to the limestone bedrock aquifer. Groundwater modeling has estimated that the P&T systems in the WARWP and PRRWP Areas would have to operate for at least 150 years. The remedial period is extensive, because the model predicts that there would continue to be some contribution to bedrock contamination from overlying zones. The groundwater modeling predictions about contaminant transport are likely overly conservative because natural attenuation processes in the bedrock aquifer (Appendix D of the final FS) would likely reduce the operating period of the P&T systems. Therefore, a 30-year O&M period is assumed for Alternative GW-4. The estimated volumes of limestone bedrock groundwater requiring treatment at the WARWP Area and PRRWP Area are 45 million and 61 million gallons, respectively. At the projected capture rates of the two P&T systems (6 gpm for WARWP Area and 10.5 for PRRWP Area), the WARWP Area and PRRWP Area P&T systems would capture approximately 2.1 and 2.7 pore volumes, respectively, in 30 years.

5.4.7 Implementability

The components of Alternative GW-4 appear to be technically and administratively implementable, albeit at a potentially high cost. Additional data should be collected prior to full-scale implementation of the ISEB and P&T technologies to ensure that they would be effectively implemented. Groundwater plumes at target areas for groundwater remediation should have well-defined boundaries. The distribution of COCs and potential competing electron acceptors should be well understood so that the demand for carbon substrate can be predicted and the configuration of injection points can be designed effectively for ISEB areas. Of particular concern is the concentration of sulfate and nitrate throughout the ISEB target area at the PRRWP Area overburden/shale plume. The available data indicate that sulfate would exert a high demand on carbon substrate within this plume, leading to a potentially costly ISEB implementation. The distribution of contaminants and competing electron acceptors should be better defined so that a cost-effective ISEB implementation can be performed. ISEB pilot test(s) are also recommended to optimize the injection requirements. In addition, the degradability of all contaminants would be confirmed because some of the nitroaromatics (e.g., dinitrotoluenes) are more easily degraded under aerobic conditions.

The unit operations proposed for the WARWP Area and PRRWP Area P&T systems are relatively complicated and costly for groundwater treatment systems with flow rates of 10 gpm or less. This is particularly true of the proposed WARWP Area P&T system. These systems are complicated because constituents other than the target contaminants for groundwater remediation require treatment to meet operational or discharge requirements. High levels of TOC, TSS, iron, and TDS increase the complexity of the treatment process or limit the options for discharge. The high TOC is assumed to consist of naturally occurring petroleum hydrocarbons. Given the potential cost of these systems, it is important that the type and distribution of groundwater constituents (including nontarget constituents) be well defined before the treatment system is designed and constructed. The groundwater quality within the WARWP and PRRWP Area plumes should be characterized under pumping conditions by sampling at the end of a pump test. The pump test would also verify aquifer characteristics and the sustainable groundwater pumping rate. The groundwater model could then be used to refine the number and location of groundwater extraction and reinjection wells. Treatability tests may be required to support the design of the treatment systems and confirm the biodegradability of the undefined organics (i.e., TOC) in the groundwater.

As previously discussed, funding constraints may not allow the project to be executed all at one time. Nevertheless, the work could be easily broken into various phases. It may be preferable to complete the ISEB component before the groundwater treatment systems are operated to avoid drawing contamination from the upper aquifer into the limestone bedrock. A phased approach to remedial action would also facilitate the intermediate evaluation of individual stages or components. This would allow adjustments and fine tuning of later stages of remediation that could result in cost savings on the total project.

Injection of chemicals during ISEB would require coordination with OEPA underground injection control representatives. The implementation of institutional controls would require coordination with state and local authorities.

Nothing in the implementation of the components of this alternative precludes additional action if necessary.

5.4.8 Cost

The capital and annual O&M costs for Alternative GW-4 are presented in Table 5-3. Table 5-6 shows the present value calculation of O&M costs using a 2.7 percent discount rate (USACE and EPA, 2000; OMB, 2009). Table 5-7 presents a summary of the estimate for capital cost, present value of O&M cost, and total present value cost. The capital cost of Alternative GW-4 is $12,503,000. The present value of annual O&M costs over the 30-year remedial duration is $4,444,000. The total present value of capital and O&M costs is $16,947,000, with a range of $11,863,000 (minus 30 percent) to $25,421,000 (plus 50 percent).

5.5 Alternative GW-5 – Groundwater Monitoring and/or Institutional Controls

5.5.1 Description

Alternative GW-5 consists of one or more of the following remedial components:

- **Institutional controls to restrict the use of groundwater at the site**. The objective of this component is to prevent the exposure of on-site receptors to contaminated groundwater as long as the concentrations of COCs remain above RGs or a determination is otherwise made that the institutional controls can be discontinued.

- **Groundwater monitoring**. The objective of this component is to periodically assess groundwater quality across the site to confirm that the concentrations of COCs in bedrock groundwater are not increasing.

Alternative GW-5 allows for the implementation of either institutional controls or groundwater monitoring as a single, stand-alone technology, or both technologies in combination.

The groundwater use restrictions would prevent the use of all groundwater in on-site contaminated areas. These use restrictions would be in place and five-year site reviews would be conducted as long as the concentrations of COCs were greater than the RGs or until a decision was otherwise made that institutional controls could be discontinued. Land-use controls consist of legal mechanisms designed to control exposure to chemicals in soil and groundwater and can include deed notices, easements, well drilling prohibitions, and zoning restrictions. Land-use controls would be implemented and enforced under Ohio’s Environmental Covenants Act. A LUCIP would be required to implement and enforce the specific groundwater-use prohibitions.

Groundwater monitoring would include the construction of additional monitoring wells. For cost estimating purposes, the following assumptions are made concerning groundwater monitoring:

- A total of 15 new wells would be constructed in the limestone bedrock aquifer.
- A total of 15 wells in the limestone bedrock zone would be analyzed for COCs every 5 years.
- The groundwater monitoring period is assumed to span 30 years.

In general, there are three areas where potentially contaminated groundwater leaves the boundary; north of TNTA, north through the "groundwater trough" from the Pentolite Road area, and north and west from the WARWP. It was assumed that monitoring these areas would require five bedrock wells for each area.

For cost-estimating purposes in the FS addendum, it is assumed that institutional controls and groundwater monitoring would be performed for a period of 30 years. The groundwater monitoring data collected every five years would be used to support decisions made at the five-year reviews. The USACE believes that this frequency and duration of groundwater monitoring would be sufficient to confirm that COCs in groundwater do not pose a threat to human health or the environment.

The actual monitoring requirements would be negotiated between USACE and OEPA when a monitoring program was established, and these requirements may be different than the assumptions presented previously. Monitoring requirements may change over time as well. For example, later in the monitoring period, fewer wells might be sampled in the limestone bedrock or sampling frequency might be decreased if COC concentrations in groundwater exhibited a decreasing trend. Alternatively, additional sampling may be required in areas if an increasing trend in COC concentrations were observed. Statistical techniques would be used to evaluate the trend in groundwater concentrations, and the monitoring program could be terminated after enough data were gathered to show that groundwater concentrations in the bedrock aquifer were not increasing.

5.5.2 Overall Protection of Human Health and the Environment

Alternative GW-5 would protect human health and the environment. The groundwater at the five AOCs is not a potential source of drinking water, and on-site groundwater contamination does not present a threat to off-site downgradient groundwater. Alternative GW-5 would provide additional protection through the implementation of institutional controls and/or groundwater monitoring, either separately or in combination, for a period of 30 years. Groundwater use restrictions would prevent exposure by prohibiting the use of on-site groundwater. Groundwater monitoring would protect off-site groundwater users by monitoring and evaluating limestone bedrock groundwater quality.

Contaminated groundwater does not present a threat to ecological receptors or other environmental media, because impacted groundwater does not discharge to surface water.

5.5.3 Compliance with Applicable or Relevant and Appropriate Requirements

There are no chemical- or location-specific ARARs for the five AOCs, and no action-specific ARARs are identified for Alternative GW-5. Drinking water standards are not identified as ARARs because the on-site groundwater is not a potential source of drinking water. EPA toxicity data, which are not ARARs, were used to develop risk-based RGs for COCs in groundwater.

5.5.4 Long-Term Effectiveness

The potential residual risk at all five AOCs is low because groundwater is not a viable source of drinking water and groundwater contamination is unlikely to migrate off site. Note that site-related contaminants have not been detected in off-site groundwater. Alternative GW-5 would manage potential residual risk through groundwater use restrictions to prevent on-site exposure and/or groundwater monitoring to further evaluate the potential for contaminated groundwater to migrate off site. Groundwater monitoring would be performed every 5 years for a period of 30 years. Institutional controls would continue and five-year site reviews would be performed until RGs were met.

5.5.5 Reduction of Toxicity, Mobility, or Volume

Alternative GW-5 does not employ any active remedial component that would permanently or significantly reduce the toxicity, mobility, or volume of contaminants in groundwater, although the presence of naturally occurring petroleum hydrocarbons in the limestone bedrock may stimulate the microbial degradation and transformation of NACs that may migrate from the overburden/shale (Appendix B of the final FS).

5.5.6 Short-Term Effectiveness

Impacts to workers, the environment, or the community would be negligible under this alternative. On-site workers would be further protected by groundwater-use restrictions that would remain in place. On-site workers would be protected during installation of monitoring wells by following the site health and safety plan. The potential effects of fugitive H_2S emissions on workers and the public would be mitigated when locating and constructing new wells. The groundwater monitoring would be performed every 5 years for a period of 30 years. The groundwater monitoring program would protect the community by monitoring and assessing the potential impact of contaminants in on-site limestone bedrock groundwater on off-site downgradient groundwater quality. The presence of naturally occurring petroleum hydrocarbons in the limestone bedrock may protect downgradient groundwater by stimulating the microbial degradation and transformation of NACs that migrate from the overburden/shale. The natural petroleum hydrocarbon contamination in the limestone bedrock at PBOW also renders on-site groundwater unsuitable for use as a drinking water resource.

5.5.7 Implementability

The components of Alternative GW-5 are technically and administratively implementable. The implementation of institutional controls would require coordination with state and local authorities. Nothing in the implementation of the components of this alternative precludes additional action if necessary.

5.5.8 Cost

The capital and annual O&M costs for the groundwater monitoring and institutional controls components of Alternative GW-5 are presented separately in Tables 5-4 and 5-5. For cost estimating purposes, the groundwater monitoring component is referred to as Alternative 5a and the institutional controls component as Alternative 5b. Table 5-6 shows the present value calculation of O&M costs using a 2.7 percent discount rate (USACE and EPA, 2000; OMB, 2009). Table 5-7 presents a summary of the estimates for capital cost, present value of O&M cost, and total present value cost. The capital cost of Alternative GW-5a is $250,000. The present value of annual O&M costs for Alternative GW-5a is $164,000. The total present value of capital and O&M cost for Alternative GW-5a is $414,000, with an estimated range of $290,000 (minus 30 percent) to $621,000 (plus 50 percent). The capital cost of Alternative GW-5b is $30,000. The present value of annual O&M costs over the 15-year remedial duration for Alternative GW-5b is $6,000. The total present value of capital and O&M cost for Alternative GW-5b is $36,000, with an estimated range of $25,000 (minus 30 percent) to $54,000 (plus 50 percent).

6.0 Comparative Analysis of Remedial Alternatives

This chapter provides a comparative analysis of the remedial alternatives developed in Chapter 5.0. The comparisons are based on the first seven of the nine NCP evaluation criteria and the overall feasibility of the alternatives in achieving and maintaining RAOs for groundwater. These seven criteria are as follows:

- Threshold criteria
  - Overall protection of human health and the environment
  - Compliance with ARARs.

- Primary balancing criteria
  - Long-term effectiveness and permanence
  - Reduction of toxicity, mobility, or volume through treatment
  - Short-term effectiveness
  - Implementability
  - Cost.

Table 6-1 summarizes this analysis. The last two criteria, known as the modifying criteria, are state acceptance and community acceptance. These two criteria are typically determined after presentation to the state and community and thus are not discussed in this FS.

6.1 Protection of Human Health and the Environment

All of the alternatives provide adequate protection for human health and the environment. The groundwater at the five AOCs is not a potential source of drinking water, and groundwater contamination does not present a threat to off-site downgradient groundwater. Alternative GW-5 provides an additional measure to prevent groundwater exposure by implementing, either separately or in combination, institutional controls and groundwater monitoring. Alternative GW-2 includes these measures and also evaluates capacity of the limestone bedrock to naturally attenuate COCs that may migrate from the overburden/weathered shale. Groundwater use restrictions would prevent the use of on-site groundwater. Groundwater monitoring would monitor and evaluate limestone bedrock groundwater quality. Alternatives GW-3 and GW-4 would implement active groundwater remediation. The objective of groundwater remediation under Alternative GW-3 is to reduce the concentrations of COCs in the limestone bedrock groundwater to RGs. The objective of groundwater remediation under Alternative GW-4 is to reduce the concentrations of COCs in the overburden/shale and the limestone bedrock to RGs.

No unacceptable ecological risks are presented by groundwater contamination at the site.

6.2 Compliance with Applicable or Relevant and Appropriate Requirements

There are no chemical- or location-specific ARARs for the five AOCs, and no action-specific ARARs have been identified for any of the remedial alternatives. EPA toxicity data, which are not ARARs, were used to develop risk-based RGs for COC in groundwater.

6.3 Long-Term Effectiveness and Permanence

The potential residual risk associated with all the alternatives is minimal or negligible because groundwater at the five AOCs is not a viable source of drinking water and on-site groundwater contamination is unlikely to migrate off site. Alternative GW-4 provides the greatest degree of risk mitigation by treating contaminated groundwater above RGs in both the overburden/weathered shale and limestone bedrock aquifers. Alternative GW-3 provides less risk mitigation than Alternative GW-4 because not all areas above RGs in overburden/weathered shale groundwater would be treated. Alternatives GW-2 and GW-5 do not reduce the potential residual risk through treatment, but these alternatives manage the potential residual risk through groundwater-use controls and groundwater monitoring. Laboratory studies conducted in support of the MNA component of Alternative GW-2 would evaluate the capacity of the limestone bedrock to attenuate NACs that may migrate from the overburden/shale. Under Alternatives GW-2, GW-3, and GW-4, institutional controls and groundwater monitoring would continue until RGs were met at each AOC (assumed to be 30 years for cost estimates). Under Alternative GW-5, groundwater monitoring would be performed every 5 years for 30 years and institutional controls would continue until RGs were met at each AOC or until a determination was otherwise made that institutional controls were no longer required (assumed to be 30 years for cost estimates). Alternative GW-1 does not implement any controls to manage potential residual risk.

6.4 Reduction of Toxicity, Mobility, or Volume Through Treatment

Alternative GW-4 provides the greatest reduction of toxicity, mobility, or volume by treating 38.4 million gallons of overburden/weathered shale groundwater and 260 million gallons from the limestone bedrock groundwater. In comparison, Alternative GW-3 treats 23.7 million gallons of overburden/weathered shale groundwater and a 260 million gallons from the limestone bedrock groundwater. Alternatives GW-1, GW-2, and GW-5 do not employ any form of active treatment, although natural attenuation processes in the limestone bedrock may remove COCs that migrate from the overburden/weathered shale.

Alternatives GW-3 and GW-4 use ISEB to treat overburden/shale groundwater and a groundwater P&T system to contain, remove, and treat limestone bedrock groundwater. All of the treatment technologies result in the irreversible conversion or destruction of the COCs. The

P&T systems would generate bag filters, spent activated carbon, and filter cake that would require off-site disposal.

6.5 Short-Term Effectiveness

Alternative GW-1 has no short-term impact because no action would be taken. Alternatives GW-2 through GW-5 would not have a significant impact on the surrounding community. Treatment systems and monitoring wells would be located or constructed to mitigate H_2S odors. Site workers would be protected by compliance with health and safety plans and enforcement of groundwater use restrictions. Adverse short-term impacts to the environment are not expected during implementation of any of the alternatives.

Implementation of the treatment portions of Alternatives GW-3 and GW-4 are expected to require four and eight years, respectively. Groundwater monitoring wells would be constructed and institutional controls established for Alternatives GW-2 through GW-5 within one year.

The time needed to attain RGs under all the alternatives is uncertain, but a three-year remedial duration is assumed for cost estimating purposes.

6.6 Implementability

There are no implementation concerns associated with Alternative GW-1 because no further action would be taken. Alternatives GW-2 through GW-5 are all technically implementable. All of the technologies are well developed, and equipment, specialists, and materials are available. The synthesis of ^{14}C-labeled NACs and handling of radioisotopes during the radiorespirometry tests conducted as part of the MNA component of Alternative GW-2 would require the services of specialized laboratories. Alternatives GW-2 through GW-5 can be easily evaluated by periodic groundwater monitoring. Alternatives GW-3 and GW-4 would require coordination with OEPA to inject chemicals into the subsurface. The implementation of institutional controls under Alternatives GW-2 through GW-5 would require coordination with state and local authorities.

6.7 Cost

There is no cost associated with Alternative GW-1, as no action would be taken. The total present value costs of the remedial alternatives are presented below:

- Alternative GW-1: $0
- Alternative GW-2: $1,742,000
- Alternative GW-3: $13,216,000
- Alternative GW-4: $16,947,000

- Alternative GW-5a: $414,000
- Alternative GW-5b: $36,000.

Capital and annual O&M costs are detailed for each of the active groundwater alternatives in Tables 5-1 through 5-5. The present values of O&M costs for the various alternatives are calculated in Table 5-6. A summary of capital, O&M, and present value costs for the alternatives is presented in Table 5-7.

7.0 Conclusions

7.1 Remedial Action Objectives

This FS included an evaluation of pertinent information in the administrative record for groundwater underlying and associated with the TNT and Red Water Pond Areas. Based on this information, the following RAOs were identified for groundwater associated with these five AOCs:

1. Prevent on-site human exposure to groundwater containing COCs at concentrations that exceed RGs.

2. Prevent human exposure to downgradient off-site groundwater containing COCs at concentrations that exceed RGs.

Groundwater is not currently used on site, off-site migration of contamination has not been detected, and groundwater is not of potable quality and is not known to be used as drinking water in households surrounding PBOW. Therefore, no current exposure to contaminants in PBOW groundwater exists.

7.2 Development and Evaluation of Remedial Alternatives

A broad range of remedial alternatives that allow the project risk managers to assess the relative cost effectiveness of different remedial strategies that employ varying degrees of active remediation was developed in the FS.

These alternatives were developed and the targeted areas for groundwater remediation were identified using a site-specific leaching and groundwater fate and transport model as well as groundwater analytical results. The following remedial alternatives were developed and evaluated for contaminated groundwater at PBOW:

- Alternative GW-1: No further action

- Alternative GW-2: Groundwater monitoring, MNA, and institutional controls

- Alternative GW-3: ISEB/P&T for mitigation/protection of the limestone bedrock groundwater

- Alternative GW-4: ISEB/P&T for mitigation/protection of the overburden/shale and limestone bedrock groundwater

- Alternative GW-5: Groundwater monitoring and/or institutional controls.

For cost estimating purposes only, Alternative GW-5 is subdivided into Alternative GW-5a (groundwater monitoring) and Alternative GW-5b (institutional controls). These remedial alternatives were evaluated against seven criteria as described in Chapter 5.0, and some general conclusions are presented below.

Alternative GW-1 protects human health and the environment. The groundwater at the five AOCs is not a potential source of drinking water, and groundwater contamination does not present a threat to off-site downgradient groundwater. No ARARs are identified for Alternative GW-1. Therefore, this alternative would meet the threshold criteria required under CERCLA. Alternative GW-1 does not reduce the toxicity, mobility, or volume of contamination through treatment, but natural attenuation processes in the limestone bedrock may remove COCs that migrate from the overburden/weathered shale. The alternative does not implement any controls to manage potential residual risk; even so, the potential residual risks associated with the alternative are acceptable. The alternative does not present any short-term risks to the community, site workers, or the environment. There are no implementation concerns with Alternative GW-1 because no further action would be taken. There are no costs associated with the alternative.

Alternative GW-2 protects human health and the environment. The alternative provides an additional measure to prevent exposure to contaminated groundwater in comparison to Alternative GW-1 by establishing groundwater use restrictions to prevent exposure to contaminated groundwater on site. Long-term groundwater monitoring would protect the surrounding community by providing advanced notice of any potential off-site movement of contamination, allowing remedial action to be taken if necessary. The alternative includes an MNA component that would evaluate the capacity of the limestone bedrock to remove COCs that may migrate from the overburden/weathered shale. No ARARs are identified for Alternative GW-2. Therefore, this alternative would meet the threshold criteria required under CERCLA. Alternative GW-2 does not reduce the toxicity, mobility, or volume of contamination through treatment, but natural attenuation processes in the limestone bedrock may remove COCs that migrate from the overburden/weathered shale. The alternative manages potential residual risk at the site through groundwater monitoring and institutional controls. Short-term risks to the community, site workers, and the environment during implementation are considered to be minimal. The components of the alternative could be implemented within one year, but monitoring and controls are projected to be required over a period of at least 150 years based on the results of groundwater modeling. The remedial duration is likely overestimated because data were not available to incorporate the effects of natural attenuation processes into the modeling.

For cost estimating purposes, the remedial duration of Alternative GW-2 is assumed to be 30 years. There are no significant implementation concerns with the alternative. The total present value cost of the alternative is estimated to range from $1.2 to $2.6 million over 30 years.

Alternative GW-3 protects human health and the environment. Groundwater-use restrictions and a long-term groundwater monitoring program would be implemented as in Alternative GW-2. Alternative GW-3 includes treatment of groundwater in the overburden/weathered shale and limestone bedrock aquifers. The objective of this treatment is to reduce the concentration of COCs in the limestone bedrock aquifer to RGs. No ARARs are identified for Alternative GW-3. Therefore, this alternative would meet the threshold criteria required under CERCLA. Alternative GW-3 reduces the toxicity, mobility, and volume of contamination through a combination of ISEB in the overburden/weathered shale aquifer and P&T in the limestone bedrock aquifer. The alternative manages potential residual risk at the site through groundwater monitoring and institutional controls. Short-term risks to the community, site workers, and the environment during implementation are considered to be minimal. The components of the alternative could be implemented within four years or less, but O&M of the P&T system, groundwater monitoring, and institutional controls are projected to be required over a period of at least 150 years based on the results of groundwater modeling. The remedial duration is likely overestimated because data were not available to incorporate the effects of natural attenuation processes into the modeling. For cost estimating purposes, the remedial duration of Alternative GW-3 is assumed to be 30 years. There are no significant implementation concerns with the alternative. The total present value cost of the alternative is estimated to range from $9.3 to $19.8 million over 30 years.

Alternative GW-4 protects human health and the environment. Groundwater use restrictions and a long-term groundwater monitoring program would be implemented as in Alternatives GW-2 and GW-3. GW-4 includes treatment of groundwater in the overburden/weathered shale and limestone bedrock aquifers. Unlike Alternative GW-3, the objective of this treatment is to reduce the concentrations of COCs in both the overburden/weathered shale and limestone bedrock aquifer to RGs. No ARARs are identified for Alternative GW-4. Therefore, this alternative would meet the threshold criteria required under CERCLA. Alternative GW-4 reduces the toxicity, mobility, and volume of contamination through a combination of ISEB in the overburden/weathered shale aquifer and P&T in the limestone bedrock aquifer. The ISEB component in the overburden/weathered shale would be applied over a larger area than in Alternative GW-3. The alternative manages potential residual risk at the site through groundwater monitoring and institutional controls. Short-term risks to the community, site workers, and the environment during implementation are considered to be minimal. The components of the alternative could be implemented within eight years or less, but O&M of the P&T system, groundwater monitoring, and institutional controls are projected to be required over a period of at least 150 years based on the results of groundwater modeling. The remedial duration is likely overestimated because data were not available to incorporate the effects of natural attenuation processes into the modeling. For cost estimating purposes, the remedial duration of Alternative GW-4 is assumed to be 30 years. There are no significant implementation concerns with the alternative. The total present value cost of the alternative is estimated to range from $11.9 to $25.4 million over 30 years.

Alternative GW-5 protects human health and the environment. The alternative provides an additional measure in comparison to Alternative GW-1 by establishing groundwater use restrictions to further prevent exposure to contaminated groundwater on site. Groundwater monitoring would aid in evaluating the potential for contamination to migrate off site. No ARARs are identified for Alternative GW-5. Therefore, this alternative would meet the threshold criteria required under CERCLA. Alternative GW-5 does not reduce the toxicity, mobility, or volume of contamination through treatment, but natural attenuation processes in the limestone bedrock may remove COCs that migrate from the overburden/weathered shale. The alternative manages potential residual risk at the site through groundwater monitoring and/or institutional controls. Short-term risks to the community, site workers, and the environment during implementation are considered to be minimal. The components of the alternative could be implemented within one year. Groundwater would be monitored every 5 years for a period of 30 years. Institutional controls would be enforced by the National Aeronautics and Space Administration until RGs were met, a period of at least 150 years based on the results of groundwater modeling. The remedial duration is likely overestimated because data were not available to incorporate the effects of natural attenuation processes into the modeling. For cost estimating purposes, the remedial duration of Alternative GW-5 is assumed to be 30 years. There are no significant implementation concerns with the alternative. The total present value cost of the groundwater monitoring component of the alternative is estimated to range from $290,000 to $621,000. The total present value cost of the institutional controls component of the alternative is estimated to range from $25,000 to $54,000.

7.3 Other Considerations

The following general observations are presented to give the project risk managers some additional perspective on remedial action for groundwater at PBOW:

- One of the objectives of Alternatives GW-3 and GW-4 is to restore the limestone bedrock aquifer to RGs. However, the treatment system is designed to remove COCs.

Portions of the aquifer are contaminated by naturally occurring petroleum hydrocarbons and H_2S, and the concentration of TDS is elevated. These naturally occurring contaminants might not be adequately removed by the treatment system. Therefore, this aquifer would likely never be a viable drinking water source due to natural contamination that is unrelated to previous TNT manufacturing operations at PBOW.

- Even if treatment under GW-3 or GW-4 would reduce the concentration of COC to RGs (including naturally occurring non-COCs) during active remediation, it is likely that once treatment is complete, the non-COCs would increase due to natural processes (e.g., groundwater flow from naturally contaminated upgradient sources) and would recontaminate treated areas.

- The petroleum hydrocarbons present in the limestone bedrock aquifer and the anaerobic environment induced by this contamination have created conditions in the aquifer that are conducive to the natural biodegradation of nitrate and NACs without any human intervention.

- The ability of ISEB technology to reductively transform NACs is well documented. However, the ultimate effectiveness of any in situ technology is the ability to get complete contact between contaminants and chemical reagents. Although the implementation of ISEB in the overburden/weathered shale aquifer would significantly reduce the mass of contamination, it is uncertain whether the aquifer could be returned to conditions such that it would be suitable or desirable for use as drinking water.

- The relatively complicated nature of the proposed P&T systems for the limestone bedrock aquifer substantially result from the necessity to treat constituents that are not related to TNT manufacturing operations, such as petroleum hydrocarbons, iron, and TSS. The natural levels of TDS in the groundwater make the normally low-cost option of direct discharge to surface water essentially impractical.

- The target remedial areas for ISEB in Alternative GW-3 and P&T in Alternatives GW-3 and GW-4 were selected largely on the basis of groundwater modeling predictions. While groundwater modeling is a useful tool to help assess future contaminant transport, it is limited by the amount and type of data available. To overcome the inherent uncertainties present in any groundwater modeling effort, conservative assumptions are used to estimate values that may not be well defined. These assumptions tend to overestimate the transport of contamination, particularly when the model is projecting values over extended time frames. Some of the biases in estimating parameters are additive, causing a further bias in the results. Specifically, the leaching component of the model is likely biased high. When the leaching data are coupled with the groundwater fate and transport model, which lacks a degradation component, the simulations produce higher groundwater concentrations and larger plumes than are likely to occur. The areas projected to require treatment may, therefore, be overestimated. This is further substantiated by the fact that nitroaromatics have only been sporadically detected in the limestone bedrock groundwater.

8.0 References

Agrawal, Abinash, Paul G. Tratnyek, Patricia Stoffyn-Egli, and Liyuan Liang, 1995, ***Processes Affecting Nitro Reduction by Iron Metal: Mineralogical Consequences of Precipitation in Aqueous Carbonate Environments,*** presented before the Division of Environmental Chemistry, American Chemical Society, April.

Agrawal, Abinash, and Paul G. Tratnyek, 1994, ***Abiotic Remediation of Nitro-Aromatic Groundwater Contaminants by Zero-Valent Iron,*** presented before the Division of Environmental Chemistry, American Chemical Society, March.

Choe, S., Lee, S.-H., Chang, Y.-Y., Hwang, K.-Y., and Khim, J., 2001, "Rapid Reductive Destruction of Hazardous Organic Compounds by Nanoscale Fe^0," ***Chemosphere***, 42: 367-372.

Dames and Moore, Inc. (D&M), 1997a, ***Red Water Ponds, Focused Remedial Investigation, Final Report, Plum Brook Ordnance Works, Plum Brook Station/NASA, Sandusky, Ohio,*** prepared for U.S. Army Corps of Engineers, Nashville District/Huntington District, April.

Dames and Moore, Inc. (D&M), 1997b, ***Final Report, Sitewide Groundwater Investigation, Plum Brook Ordnance Works, Plum Brook Station/NASA, Sandusky, Ohio,*** prepared for U.S. Army Corps of Engineers, Nashville District/Huntington District, April.

Dames and Moore, Inc. (D&M), 1997c, ***TNT Areas Site Investigation, Final Report, Plum Brook Ordnance Works, Sandusky, Ohio,*** April.

Department of the Army, 2004, ***Environmental Quality, Formerly Used Defense Sites (FUDS) Program Policy***, ER-200-3-1, U.S. Army Corps of Engineers, May 10.

Esteve-Núñez, A., A. Caballero, and J. L. Ramos, 2001, "Biological Degradation of 2,4,6-Trinitrotoluene", ***Microbiology and Molecular Biology Reviews***, 65(3), 335-352.

Esteve-Núñez, A., G. Luchessi, B. Phillipps, B. Schink, and J.L. Ramos, 2000, "Respiration of 2,4,6-Trinitrotoluene by *Pseudomonas sp.* strain JLR11," ***Journal of Bacteriology***, 182:1352-1355.

French, C.E., E.S. Nicklin, and N.C. Bruce, 1998, "Aerobic Degradation of 2,4,6-Trinitrotoluene by *Enterobacter Cloacae* PB2 and by Pentaerythriol Tetranitrate Reductase," ***Applied and Environmental Microbiology***, 64:2864-2868.

Haïdour, A. and J.L. Ramos, 1996, "Identification of Products Resulting from the Biological Reduction of 2,4,6-Trinitrotoluene, 2,4-Dinitrotoluene, and 2,6-Dinitrotoluene by *Pseudomonas sp.*," ***Environmental Science and Technology***, 30:2365-2370.

Hayes, T., and Arthur, D., 2004, "Overview of Emerging Produced Water Treatment Technologies," presented at the 11th Annual International Petroleum Environmental Conference, Albuquerque, New Mexico, October 12-15.

International Consultants Incorporated (ICI), 1995, ***Site Management Plan, Plum Brook Ordnance Works, Sandusky, Ohio, Part B, Areas of Concern,*** U.S. Army Corps of Engineers, Huntington District, September.

IT Corporation (IT), 2002a, ***2001 Groundwater Remedial Investigation, Former Plum Brook Ordnance Works, Sandusky, Ohio***, March.

IT Corporation (IT), 2002b, ***Final Red Water Pond Areas Focused Feasibility Study for Soils, Former Plum Brook Ordnance Works, Sandusky, Ohio***, December.

IT Corporation (IT), 2001a, ***Final-TNT Areas A and C Remedial Investigation, Volume 1, Part 2, Report of Findings, Former Plum Brook Ordnance Works, Sandusky, Ohio***, November.

IT Corporation (IT), 2001b, ***Final, Volume IV, Feasibility Study, TNT Area B Remedial Investigation, Former Plum Brook Ordnance Works, Sandusky, Ohio***, July.

IT Corporation (IT), 2001c, ***Final-TNT Areas A and C Remedial Investigation, Volume 1, Part 3, Report of Findings, Former Plum Brook Ordnance Works, Sandusky, Ohio***, November.

IT Corporation (IT), 2001d, ***Final-TNT Areas A and C Remedial Investigation, Volume 1, Part 1, Report of Findings, Former Plum Brook Ordnance Works, Sandusky, Ohio***, November.

IT Corporation (IT), 2001e, ***Final-Redwater Pond Areas Baseline Ecological Risk Assessment, Former Plum Brook Ordnance Works, Sandusky, Ohio***, November.

IT Corporation (IT), 2001f, ***Final-TNT Areas A and C Remedial Investigation, Volume 3, Ecological Risk Assessment, Former Plum Brook Ordnance Works, Sandusky, Ohio***, November.

IT Corporation (IT), 2001g, ***Final-TNT Areas A and C Remedial Investigation Volume 2, Human Health Risk Assessment, Former Plum Brook Ordnance Works, Sandusky, Ohio***, November.

IT Corporation (IT), 2000a, ***Final Risk Assessment and Direct-Push Investigation of Red Water Pond Areas, Former Plum Brook Ordnance Works, Sandusky, Ohio, Volume 1***, August.

IT Corporation (IT), 2000b, ***Final TNT Area B Remedial Investigation, Volume I, Former Plum Brook Ordnance Works, Sandusky, Ohio,*** August.

IT Corporation (IT), 2000c, ***Final TNT Area B Remedial Investigation, Volume II – Baseline Human Health Risk Assessment, Volume III – Ecological Risk Assessment, Former Plum Brook Ordnance Works, Sandusky, Ohio,*** August.

IT Corporation (IT), 1999, ***Final - Summary Report, Site-Wide Groundwater Monitoring (1997-1998), Former Plum Brook Ordnance Works, Sandusky, Ohio,*** June.

IT Corporation (IT), 1997, ***Site-Wide Groundwater Investigation Report, Former Plum Brook Ordnance Works, Sandusky, Ohio,*** September.

IT Corporation (IT), 1991, ***Engineering Report of the Contamination Evaluation at the Former Plum Brook Ordnance Works, Sandusky, Ohio,*** January.

Krumholz, L.R., Li, J., Clarkson, W.W., and Suflita, J.M., 1997, "Transformations of TNT and Related Aminotoluenes in Groundwater Aquifer Slurries under Different Electron-Accepting Conditions," ***Journal of Industrial Microbiology and Biotechnology***, 18:161-169.

Martin, J. L., S. D. Comfort, P. J. Shea, T. A. Kokjohn, and R. A. Drijber, 1997, "Denitration of 2,4,6-Trinitrotoluene by *Pseudomonas Savastano*," ***Canadian Journal of Microbiology***, 43:447-455.

Martinez, M., G. Smith , J. Wright, and J. Conca, 2005, ***The Effect of Apatite II on the Biodegradation of TNT in Contaminated Soil Samples***, 2nd DOD Sustainable Ranges Initiative, San Antonio, Texas, August 22-25.

Morrison Knudsen Corporation (MK), 1994***, Site Inspection Report, Plum Brook Station, Sandusky, Ohio, Volume 1 (prepared for NASA),*** January.

Ninshino, S.F. and Spain, J.C., 2001, ***Technology Status Review: Bioremediation of Dinitrotoluene (DNT)***, prepared for the Strategic Environmental Research and Development Program, February.

Office of Management and Budget (OMB), 2009, ***Appendix C Revised, OMB Circular A-94, Discount Rates for Cost Effectiveness, Lease Purchase and Related Analyses***, The White House, December.

Ohio Department of Natural Resources (ODNR), 1962, ***Availability of Underground Water, Pickeral Creek – Pipe Creek Area***, as referenced in Dames and Moore, Inc. (D&M), 1997c, ***TNT Areas Site Investigation, Final Report, Plum Brook Ordnance Works, Sandusky, Ohio,*** April.

Pak, J.W., K.L. Knoke, D.R. Noguera, B.G. Fox, and G.H. Chambliss, 2000, "Transformation of 2,4,6-Trinitrotoluene by Purified Xenobiotic Reductase B from *Pseudomonas Flourescens* I-C," ***Applied and Environmental Microbiology***, 66:4742-4750.

Pennington, J.C., Bowen, R., Brannon, J.M., Zakikhani, M., M., Harrelson, D.W., Gunnison, D., Mahannah, J., Clark, J., Jenkins, T.F., and Gnewuch, S., 1999a, ***Draft Protocol for Evaluating, Selecting, and Implementing Monitored Natural Attenuation at Explosives Contaminated Sites,*** Technical Report EL-99-10, U.S. Army Engineer Research and Development Center, Vicksburg, MS, September.

Pennington, J.C., Miyares, P.H., Ringelberg, D.B., Zakikhani, M., Reynolds, C.M., Felt, D., Coffin, R.B., Gunnison, D., Cifuentes, L., Fredrickson, H.L., and Jenkins, T.F., 1999b, ***Natural Attenuation of Explosives in Soil and Water Systems at Department of Defense Sites,*** Technical Report SERDP-99-1, U.S. Army Engineer Research and Development Center, Vicksburg, MS, July.

Pennington, J.C., Zakikhani, M., and Harrelson, D.W., 1999c, ***Monitored Natural Attenuation of Explosives in Groundwater – ESTCP Completion Report***, Technical Report EL-99-, U.S. Army Engineer Waterways Experiment Station, Vicksburg, MS, April.

PIMS NW, Inc., http://www.pimsnw.com/, accessed July 24, 2006.

Science Applications International Corporation (SAIC), 2007

Science Applications International Corporation (SAIC), 2007, ***NASA Plum Brook Station Monitoring Well Product Determination Task,*** November 2.

Science Applications International Corporation (SAIC), 1991, ***Plum Brook Station Preliminary Assessment,*** June.

Shaw Environmental, Inc. (Shaw), 2008a, ***Addendum for TNT Area A, TNT Areas A and C Focused Feasibility Study for Soil and Sediment, Former Plum Brook Ordnance Works, Sandusky, Ohio***, May.

Shaw Environmental, Inc. (Shaw), 2008b, ***Addendum for TNT Area C, TNT Areas A and C Focused Feasibility Study for Soil and Sediment, Former Plum Brook Ordnance Works, Sandusky, Ohio***, May.

Shaw Environmental, Inc. (Shaw), 2006, ***Baseline Human Health Risk Assessment of Groundwater, Final, Former Plum Brook Ordnance Works, Sandusky, Ohio***, September.

Shaw Environmental, Inc. (Shaw), 2005, ***2004 Groundwater Data Summary and Evaluation Report, Final, Former Plum Brook Ordnance Works, Sandusky, Ohio***, April.

Shaw Environmental, Inc. (Shaw), 2004, ***Ninth Quarterly (March 2004) Background Groundwater Report, Final, Former Plum Brook Ordnance Works, Sandusky, Ohio***, June.

Shaw Environmental, Inc. (Shaw), 2003a, ***2002 Groundwater Data Summary and Evaluation Report, Former Plum Brook Ordnance Works, Sandusky, Ohio***, June.

Shaw Environmental, Inc. (Shaw), 2003b, ***TNT A&C, Remedial Investigation, Volume 4 – Focused Feasibility Study for Soil and Sediment, Former Plum Brook Ordnance Works, Sandusky, Ohio,*** October.

Soil Conservation Service (SCS), 1971, ***Soil Survey for Erie County, Ohio***, Ohio Department of Natural Resources, Division of Lands and Soil.

Spain, J.C.(editor), 1995, ***Biodegradation of Nitroaromatic Compounds***, Environmental Science Research, Volume 49, Plenum Press, New York, NY.

Tront, J., and J.B. Hughes, 2005, "Oxidative Microbial Degradation of 2,4,6-Trinitrotoluene via 3-Methyl-4,6-Dinitrocatechol," ***Environmental Science and Technology***, 39(12), 4540-4549.

U.S. Army Corps of Engineers (USACE), 2004a, ***Final Action Memorandum for TNT Area A Interim Removal Action at the Plum Brook Ordnance Works, Sandusky, Ohio,*** prepared for Huntington District, Huntington, West Virginia, May.

U.S. Army Corps of Engineers (USACE), 2004b, ***Final Action Memorandum for TNT Area C Interim Removal Action at the Plum Brook Ordnance Works, Sandusky, Ohio,*** prepared for Huntington District, Huntington, West Virginia, May.

U.S. Army Corps of Engineers (USACE), 2003a, ***Final Action Memorandum for TNT Area B Interim Removal Action at the Plum Brook Ordnance Works, Sandusky, Ohio,*** prepared for Huntington District, Huntington, West Virginia, June.

U.S. Army Corps of Engineers (USACE), 2003b, ***Final Action Memorandum for Interim Removal Action for Pentolite Road Red Water Ponds, Plum Brook Ordnance Works, Sandusky, Ohio,*** prepared for Huntington District, Huntington, West Virginia, June.

U.S. Army Corps of Engineers (USACE) and U.S. Environmental Protection Agency (EPA), 2000, ***A Guide to Developing and Documenting Cost Estimates During the Feasibility Study***, EPA-540-R-00-002, OSWER 9355.0-75, July.

U.S. Environmental Protection Agency (EPA), 2007, ***Integrated Risk Information System,*** National Center for Environmental Assessment**,** Cincinnati, Ohio, online at *www.epa.gov/iris*.

U.S. Environmental Protection Agency (EPA), 2006, ***2006 Edition of the Drinking Water Standards and Health Advisories***, Office of Water, August, EPA 822-R-06-013.

U.S. Environmental Protection Agency (EPA), 2004, ***Region 9 Preliminary Remediation Goals (PRG) Table,*** Region 9, San Francisco, California, October.

U.S. Environmental Protection Agency (EPA), 1999c, ***Use of Monitored Natural Attenuation at Superfund, RCRA Corrective Action, and Underground Storage Tank Sites***, Final OSWER Directive 9200.4-17P, April.

U.S. Environmental Protection Agency (EPA), 1997, ***Rules of Thumb for Superfund Remedy Selection***, Office of Solid Waste and Emergency Response, 540-R-97-013, August.

U.S. Environmental Protection Agency (EPA), 1992, ***Guidance on Implementation of the Superfund Accelerated Cleanup Model (SACM) under CERCLA and the NCP,*** OSWER Directive 9203.1-03, July.

U.S. Environmental Protection Agency (EPA), 1991, ***Role of the Baseline Risk Assessment in Superfund Remedy Selection Decisions***, OSWER Directive 9355.0-30, April 22.

U.S. Environmental Protection Agency (EPA), 1990, ***National Oil and Hazardous Substances Pollution Contingency Plan,*** 40 CFR Part 300.430.

U.S. Environmental Protection Agency (EPA), 1988, ***Guidance for Conducting Remedial Investigations and Feasibility Studies Under CERCLA,*** EPA/540/9-89-004.

U.S. Geological Survey (USGS), 1992, ***Hydraulic Properties of Three Types of Glacial Deposits in Ohio***, Water-Resources Investigation Report, Report 92-4135.

Vorbeck, C., H. Lenke, P. Fischer, J.C. Spain, and H.J. Knackmuss, 1998, "Initial Reductive Reactions in Aerobic Microbial Metabolism of 2,4,6-Trinitrotoluene," ***Applied and Environmental Microbiology***, 64, 246-252.

WasteTron, Inc., (WTI), 2005a, ***Draft Interim Soil Removal Action Report, Excavation, Ex-Situ Bioremediation, and Disposal of Contaminated Soil, Plum Brook Ordnance Works, Pentolite Road Red Water Ponds, Sandusky, Ohio,*** prepared for Huntington District, Corps of Engineers, Huntington, West Virginia, November.

WasteTron, Inc., (WTI), 2005b, ***Draft Interim Soil Removal Action Report, Excavation, Ex-Situ Bioremediation, and Disposal of Contaminated Soil, Plum Brook Ordnance Works, Pentolite Road Red Water Ponds, Sandusky, Ohio,*** prepared for Huntington District, Corps of Engineers, Huntington, West Virginia, November.

Zhang, C. and G.N. Bennett, 2005, "Biodegradation of Xenobiotics by Anaerobic Bacteria," ***Applied Microbiology and Biotechnology***, 67:600-618.

TABLES

Table 3-1

Remedial Goals for Groundwater
TNT Manufacturing and Red Water Pond Areas Groundwater Feasibility Study Addendum
Former Plum Brook Ordnance Works, Sandusky, Ohio

Chemicals of Concern for Both Limestone Bedrock and Overburden/Shale Groundwater[a]	**Remedial Goal (µg/L)**
2,4,6-Trinitrotoluene	*3*
2,4-Dinitrotoluene	*0.5*
2,6-Dinitrotoluene	*0.5*
2-Amino-4,6-dinitrotoluene	*1*
4-Amino-2,6-dinitrotoluene	*1*
2-Nitrotoluene	*0.6*
4-Nitrotoluene	*4*
Nitrobenzene	*0.5*
4,6-Dinitro-2-methylphenol	2
3-Nitroaniline	2
Nitrate	10,000
Additional Chemicals of Concern for Overburden/Shale Groundwater Only[b]	**Remedial Goal (µg/L)**
1,3,5-Trinitrotoluene	109
1,3-Dinitrobenzene	0.4
3-Nitrotoluene	122
2,4-Dinitrophenol	7.3
4-Nitrophenol	4.9
Dibenzofuran	1.2
Fluorene	24
Toluene	1,000

µg/L - Micrograms per liter.
RG - Remedial goal.

[a] RGs for the limestone bedrock chemicals of concern (COC) were derived based on back-calculations from the groundwater risk assessment (Shaw, 2006) as described in Section 3.4 of the text. The RG for nitrate equals the maximum contaminant level (MCL) for drinking water (EPA, 2006).
[b] RGs for the additional overburden/shale groundwater COCs are the risk-based screening concentrations found in the risk assessment (Shaw, 2006). The exception is the toluene RG, which equals the MCL (EPA, 2006).

Sources:
Shaw Environmental, Inc., 2006, *Baseline Human Health Risk Assessment of Groundwater* , Final, Plumbrook Ordnance Works, Sandusky, Ohio, September.

U.S. Environmental Protection Agency (EPA), 2006, *2006 Edition of the* Drinking Water Standards and Health Advisories, Office of Water, August, EPA 822-R-06-013.

Table 5-1

Alternative GW-2 Cost Estimate
TNT Manufacturing and Red Water Pond Areas Groundwater Feasibility Study Addendum
Former Plum Brook Ordnance Works, Sandusky, Ohio

Alternative GW-2	**Site:** PBOW
Groundwater Monitoring, MNA and Institutional Controls	Alternative GW-2
	Date: 03/21/11

Scope:
1 Groundwater Monitoring Plan and Procurement
2 Mobilization
3 Installation of Bedrock Monitoring Wells
4 Groundwater Use Controls
5 MNA Lab Tests
6 Total Capital Cost
7 Groundwater Monitoring, MNA Institutional Controls and Site Reviews: Years 1 - 30 (Annualized)

1.0 Groundwater Monitoring Plan and Procurement

Includes:
1 Prepare Long-Term Groundwater Monitoring Plan.
2 Procure equipment, materials, and subcontracts.

Service/Materials	Unit	Unit Cost		Subtotal	
Long-Term Groundwater Monitoring Plan	1	$40,000.00	/ea	$40,000.00	
Contractor Office Labor:					
Mrg, Contract Admin (E09)	40	$77.75	/hr	$3,110.00	
Procurement Coordinator (N07)	20	$35.80	/hr	$716.00	
				Subtotal	**$43,826.00**

2.0 Mobilization

Includes:
1 Mobilize personnel, equipment, and subcontractors.
2 Conduct preconstruction conference.

Assumptions:
1 Allow two days to mobilize personnel, equipment, and subcontractors.
5 Hours work per day = 10 hours
6 Schedule (10-hr workday) = 2 days
7 Schedule (5-day workweek) = 0.4 weeks

Service/Materials	Unit	Unit Cost		Subtotal	
Contractor Office Labor:					
Geologist (E08)	20	$68.82	/hr	$1,376.40	
Engineering Technician III (N08)	20	$ 46.80	/hr	$936.04	
Equipment Rental:					
Pressure washer (2000 psi)	1	$100.00	/mobe-demobe	$100.00	
Travel:					
Perdiem	4	$39.00	/day	$156.00	
Lodging	4	$91.00	/night	$364.00	
Air Fare	2	$800.00	/trip	$1,600.00	
Rental Car	4	$46.00	/day	$184.00	
Rental Car FOGM	4	$12.00	/day	$48.00	
				Subtotal	**$4,764.00**

Table 5-1

Alternative GW-2 Cost Estimate
TNT Manufacturing and Red Water Pond Areas Groundwater Feasibility Study Addendum
Former Plum Brook Ordnance Works, Sandusky, Ohio

3.0 Installation of Bedrock Monitoring Wells

Includes:

1 Installation of Additional Bedrock Monitoring Wells using Hollow-Stem Auger/Air Rotary
2 Rock and groundwater sample collection for MNA lab tests
3 Development of Monitoring Wells
4 Well Constructed of 2-inch PVC with 15-feet of 0.010 Slot Continuous Wrap PVC Screen

Assumptions:

1 Number of New Bedrock Monitoring Wells:			29
2 Construct and Develop One Well =			3 days
3 Well Installation Field Days =			87 days
4 Hours work per day =	10	hours	
5 Schedule (10-hr workday) =	87	days	
6 Schedule (5-day workweek) =	17	weeks	
7 Schedule (months) =	4.4	month	

Service/Materials		Unit	Unit Cost		Cost	
Contractor Office Labor:						
Engineer/Scientist III (E08)		20	$68.82	/hr	$1,376.35	
Procurement Coordinator (N07)		16	$35.80	/hr	$572.80	
Secretary III (N06)		16	$34.80	/hr	$556.80	
Contractor Field Labor:						
Geologist (E08)		870	$ 68.82	/hr	$59,871.31	
Engineering Technician III (N08)		870	$ 46.80	/hr	$40,717.57	
Drilling Subcontractor:						
Mobilization		1	$2,500.00	/ea	$2,500.00	
Demobilization		1	$2,500.00	/ea	$2,500.00	
Posthole first 5 feet	5'	29	$25.00	/ea	$725.00	
Decon pad construction		5	$750.00	/ea	$3,750.00	
Drill soil with 12" HSA to bedrock	15'	435	$50.00	/ft	$21,750.00	
Cut 5' bedrock with 10" tricone roller bit	5'	145	$41.00	/ft	$5,945.00	
Install 6" steel casing	35'	1015	$45.00	/ft	$45,675.00	
Cut bedrock with 6" OD tricone roller bit	35'	1015	$44.00	/ft	$44,660.00	
2-inch ID, Sch 40, PVC casing	47.5'	1378	$9.00	/ft	$12,397.50	
2-inch ID, Sch 40, PVC screen	'15	435	$12.00	/ft	$5,220.00	
2-inch Bedrock Well Construction		29	$1,200.00	/ft	$34,800.00	
Well Development		29	$1,200.00	/ea	$34,800.00	
Surface Completion		29	$425.00	/ea	$12,325.00	
Decontamination		29	$85.00	/ea	$2,465.00	
Site cleanup		29	$125.00	/ea	$3,625.00	
IDW disposal		29	$250.00	/ea	$7,250.00	
Surveying		29	$268.72	/ea	$7,792.88	
Travel:						
Per Diem		174	$39.00	/day	$6,786.00	
Lodging		174	$91.00	/day	$15,834.00	
Air Fare		17	$800.00	/trip	$13,920.00	
Rental Car		174	$46.00	/day	$8,004.00	
Rental Car FOGM		174	$12.00	/day	$2,088.00	
					Subtotal	**$397,907.00**

Table 5-1

Alternative GW-2 Cost Estimate
TNT Manufacturing and Red Water Pond Areas Groundwater Feasibility Study Addendum
Former Plum Brook Ordnance Works, Sandusky, Ohio

4.0 Groundwater Use Controls

Service/Materials	Unit	Unit Cost		Cost	
Land Use Control Implementation Plan	1	$30,000.00	/ea	$30,000.00	
				Subtotal	**$30,000.00**

5.0 Monitored Natural Attenuation (MNA) Lab Tests

Includes:
1 Site capacity tests for natural attenuation via adsorption and transformation.
2 Radiorespirometry tests for natural attenuation via enzymatic mineralization.
3 MNA report preparation

Assumptions:
1 Sampling included in well construction costs.
2 No of rock/groundwater samples for lab tests = 5 samples

Service/Materials	Unit	Unit Cost		Cost	
Office Labor:					
Project Manager II (E11)	24	$106.75	/hr	$2,562.00	
Senior Consultant I (E12)	160	$118.41	/hr	$18,945.60	
Data Entry Technician (E04)	5	$45.00	/hr	$225.00	
Chemist III (E06)	4	$54.20	/hr	$216.80	
Database Manager (E08)	8	$64.40	/hr	$515.20	
Secretary III (N06)	8	$34.80	/hr	$278.40	
Word Processor (N06)	4	$41.82	/hr	$167.28	
Analytical:					
Site Capacity & Radiorespirometry Tests[A]	5	$8,000.00	/ea	$40,000.00	
				Subtotal	**$62,910.00**

Table 5-1

Alternative GW-2 Cost Estimate
TNT Manufacturing and Red Water Pond Areas Groundwater Feasibility Study Addendum
Former Plum Brook Ordnance Works, Sandusky, Ohio

6.0 O&M: Groundwater Monitoring, MNA, Institutional Controls and Site Reviews: Years 1 - 15 (Annualized)

Includes:
1 Groundwater monitoring for COCs and MNA parameters.
2 Data management and validation
3 Annual monitoring report
4 Inspections and reporting for institutional controls
5 Annualized cost of 5-year review

Assumptions:

1 No. of wells sampled =	33	wells/event
2 Number of QA samples =	6	samples/event
3 Number of technicians in field crew =	2	personnel
4 Sampling time (per well) =	3	hrs/well
5 Number of well sampling events =	1	events/year
6 Well sampling time =	11	days
7 Hours work per day =	10	hours

Data Management and QA/QC Assumptions:

Data Entry Technician (E04)	1	hr/sample
Chemist III (E06)	0.75	hr/sample
Database Manager (E08)	1.5	hr/sample
Senior Consultant I (E12)	0.175	hr/sample

Service/Materials	Unit	Unit Cost		Cost	
Office Labor:					
Project Manager II (E11)	20	$106.75	/hr	$2,135.00	
Senior Consultant I (E12)	10	$118.41	/hr	$1,184.10	
Engineer/Scientist III (E08)	120	$68.82	/hr	$8,258.40	
Engineer/Scientist II (E06)	40	$57.06	/hr	$2,282.40	
Data Entry Technician (E04)	39	$45.00	/hr	$1,755.00	
Chemist III (E06)	30	$54.20	/hr	$1,626.00	
Database Manager (E08)	59	$64.40	/hr	$3,799.60	
Senior Consultant I (E12)	7	$118.41	/hr	$828.87	
Secretary III (N06)	8	$34.80	/hr	$278.40	
Draftsperson (N08)	32	$53.36	/hr	$1,707.52	
Word Processor (N06)	8	$41.82	/hr	$334.56	
Field Labor:					
Engineering Technician III (N08)	110	$46.80	/hr	$5,148.00	
Engineering Technician III (N08)	110	$46.80	/hr	$5,148.00	
Materials:					
Sampling Equipment	11	$353.00	/day	$3,883.00	
Supplies	1	$500.00	/event	$500.00	
RDW Treatment and Disposal	1	$1,250.00	/event	$1,250.00	
Analytical:					
NACs + Breakdown Products[B]	39	$168.00	/ea	$6,552.00	
SVOCs	8	$177.00	/ea	$1,416.00	
Nitrate	8	$22.00	/ea	$176.00	
Geochemical Parameters	33	$182.00	/ea	$6,006.00	
Travel:					
Per Diem	22	$39.00	/day	$858.00	
Lodging	22	$91.00	/day	$2,002.00	
Air Fare	2	$800.00	/trip	$1,600.00	
Rental Car	22	$46.00	/day	$1,012.00	
Rental Car FOGM	22	$12.00	/day	$264.00	
Institutional Controls and 5-Year Review:					
Inspection and Reporting	1	$1,500.00	/yr	$1,500.00	
5 -Year Review (Annualized)	1	$1,500.00	/yr	$1,500.00	
				Subtotal	**$63,005.00**

Table 5-1

Alternative GW-2 Cost Estimate
TNT Manufacturing and Red Water Pond Areas Groundwater Feasibility Study Addendum
Former Plum Brook Ordnance Works, Sandusky, Ohio

7.0 O&M: Groundwater Monitoring, Institutional Controls and Site Reviews: Years 16 - 30 (Annualized)

Includes:
1 Groundwater monitoring for COCs only.
2 Data management and validation
3 Annual monitoring report

Assumptions:

1 No. of wells sampled =	33	wells/event
2 Number of QA samples =	6	samples/event
3 Number of technicians in field crew =	2	personnel
4 Sampling time (per well) =	3	hrs/well
5 Number of well sampling events =	1	events/year
6 Well sampling time =	11	days
7 Hours work per day =	10	hours

Data Management and QA/QC Assumptions:

Data Entry Technician (E04)	1	hr/sample
Chemist III (E06)	0.75	hr/sample
Database Manager (E08)	1.5	hr/sample
Senior Consultant I (E12)	0.175	hr/sample

Service/Materials	Unit	Unit Cost		Cost	
Office Labor:					
Project Manager II (E11)	16	$106.75	/hr	$1,708.00	
Senior Consultant I (E12)	10	$118.41	/hr	$1,184.10	
Engineer/Scientist III (E08)	120	$68.82	/hr	$8,258.40	
Engineer/Scientist II (E06)	40	$57.06	/hr	$2,282.40	
Data Entry Technician (E04)	39	$45.00	/hr	$1,755.00	
Chemist III (E06)	30	$54.20	/hr	$1,626.00	
Database Manager (E08)	59	$64.40	/hr	$3,799.60	
Senior Consultant I (E12)	7	$118.41	/hr	$828.87	
Secretary III (N06)	8	$34.80	/hr	$278.40	
Draftsperson (N08)	20	$53.36	/hr	$1,067.20	
Word Processor (N06)	4	$41.82	/hr	$167.28	
Field Labor:					
Engineering Technician III (N08)	110	$46.80	/hr	$5,148.00	
Engineering Technician III (N08)	110	$46.80	/hr	$5,148.00	
Materials:					
Sampling Equipment	11	$353.00	/day	$3,883.00	
Supplies	1	$500.00	/event	$500.00	
RDW Treatment and Disposal	1	$1,250.00	/event	$1,250.00	
Analytical:					
NACs	39	$138.00	/ea	$5,382.00	
SVOCs	8	$177.00	/ea	$1,416.00	
Nitrate	8	$22.00	/ea	$176.00	
Travel:					
Per Diem	22	$39.00	/day	$858.00	
Lodging	22	$91.00	/day	$2,002.00	
Air Fare	2	$800.00	/trip	$1,600.00	
Rental Car	22	$46.00	/day	$1,012.00	
Rental Car FOGM	22	$12.00	/day	$264.00	
Institutional Controls and 5-Year Review:					
Inspection and Reporting	0	$1,500.00	/yr	$0.00	
5 -Year Review (Annualized)	1	$1,500.00	/yr	$1,500.00	
				Subtotal	**$53,094.00**

Table 5-1

Alternative GW-2 Cost Estimate
TNT Manufacturing and Red Water Pond Areas Groundwater Feasibility Study Addendum
Former Plum Brook Ordnance Works, Sandusky, Ohio

	Item	Unit	Unit Cost		Cost	
6.0	**Total Capital Cost**					
	Item	**Unit**	**Unit Cost**		**Cost**	
1	Groundwater Monitoring Plan and Procurement				$43,826.00	
2	Mobilization				$4,764.00	
3	Installation of Bedrock Monitoring Wells				$397,907.00	
4	Groundwater Use Controls				$30,000.00	
5	MNA Lab Tests				$62,910.00	
				Total		**539,407.00**
7.0	**Total O&M Cost**					
1	Years 1 - 15	15	$63,005.00 /yr		$945,075.00	
2	Years 16 - 30	15	$53,094.00 /yr		$796,410.00	
				Total		**$1,741,485.00**

Notes:
This is an 'order of magnitude' engineering cost estimate that is expected to be within + 50% to - 30% of actual project cost.
[A] Lab costs from: *Monitored Natural Attenuation of Explosives in Groundwater - ESTCP Completion Report* , April 1999.
[B] NACs + Breakdown products = 8330 analysis + DANTs. Standards are not readily available for TAT, HADNTs and AZOXYs.

Table 5-2

Alternative GW-3 Cost Estimate
TNT Manufacturing and Red Water Pond Areas Groundwater Feasibility Study Addendum
Former Plum Brook Ordnance Works, Sandusky, Ohio

Alternative GW-3	**Site:** PBOW
In-situ Enhanced Bioremediation (ISEB) and Pump and Treat	Alternative GW-3
for Mitigation / Protection of the Bedrock Groundwater	**Date: 03/21/11**

Scope:

1 Groundwater Modeling, Remedial Design, Work Plans, and Procurement
2 Mobilization
3 Site Preparation, Clearing, and Layout
4 Installation of Overburden Monitoring Wells
5 Installation of Bedrock Monitoring Wells
6 Extraction and Reinjection Well Installation
7 Installation of the Groundwater Treatment Systems
8 ISEB - Emulsified Vegetable Oil Injection
9 Site Restoration, Testing and Demobilization
10 Groundwater Use Controls
11 Total Capital Cost
12 Annual Pump and Treat Operation and Maintenance (O&M)
13 Annual Long Term O&M: Years 1 - 5 (Annualized)
14 Annual Long Term O&M: Years 6 - 30 (Annualized)

1.0 Groundwater Modeling, Remedial Design, Work Plans, and Procurement

Includes:

1 Perform groundwater modeling verifying placement of wells screen interval.
2 Mobilize drilling subcontractor and geologist to perform one 72-hour pump test at PRRWP and one at WARWP, two total.
3 Prepare RD/RA work plan, H&S work plan, and CQCP.
4 Procure equipment, materials, and subcontracts.

Assumptions:

1 The vertical well depth at PRRWP is 70 feet and the vertical well depth at WARWP is 54 feet.
2 The 72-hour pump test at PRRWP and WARWP shall include pumping from one well within the bedrock and sampling for characterization of the groundwater under pumping conditions. Assume the PRRWP and WARWP wells are installed as part of the scope for installation of the new Bedrock Monitoring Wells (Section 5.0).
3 Assume a Hydrogeologist on-site for a week at 10 hours per day to perform the 72-hour pump test.

Service/Materials	Unit	Unit Cost		Subtotal	
Contractor Office Labor:					
Senior Consultant I (E12)	30	$118.41	/hr	$3,552.30	
Sr. Geologist (E10)	60	$93.94	/hr	$5,636.40	
RD/RA Work Plan	1	$60,000.00	/ea	$60,000.00	
Health & Safety Plan	1	$5,000.00	/ea	$5,000.00	
CQCP	1	$9,000.00	/ea	$9,000.00	
Mrg, Contract Admin (E09)	60	$77.75	/hr	$4,665.00	
Procurement Coordinator (N07)	120	$35.80	/hr	$4,296.00	
GW Modeling	1	$25,000.00	/ls	$25,000.00	
Contractor Field Labor:					
Hydrogeologist (E08)	50	$68.82	/hr	$3,441.00	
Travel:					
Perdiem	5	$39.00	/day	$195.00	
Lodging	5	$91.00	/night	$455.00	
Air Fare	1	$500.00	/trip	$500.00	
Rental Car	5	$46.00	/day	$230.00	
Rental Car FOGM	5	$12.00	/day	$60.00	
				Subtotal	**$122,031.00**

Alternative GW-3 Cost Estimate
TNT Manufacturing and Red Water Pond Areas Groundwater Feasibility Study Addendum
Former Plum Brook Ordnance Works, Sandusky, Ohio

2.0 Mobilization

Includes:

1. Mobilize personnel, equipment, and subcontractors.
2. Conduct preconstruction conference.

Assumptions:

1. Setup Shaw Field office. The annual utilities and office supplies are covered within the Pump and Treat O&M (Section 11.0).
2. Allow five days to mobilize personnel, equipment, and subcontractors.
3. Mobilization/ demobilization charges for each piece of equipment is $300 round trip, unless noted otherwise.
4. Travel costs are included for a Site Manager, H&S coordinator, and QC engineer. Travel costs are reflected for each subsequent task.
5. Contractor Field Labor rotate home every 3 weeks.
6. Hours work per day = 10 hours
7. Schedule (10-hr workday) = 5 days
8. Schedule (5-day workweek) = 1 weeks

Service/Materials	Unit	Unit Cost		Subtotal	
Contractor Office Labor:					
Sr. Geologist (E10)	10	$93.94	/hr	$939.40	
Engineer/Scientist IV (E10)	10	$92.56	/hr	$925.60	
Geologist (E08)	20	$68.82	/hr	$1,376.40	
Engineer/Scientist III (E08)	20	$68.82	/hr	$1,376.40	
Contractor Field Labor:					
Site Manager (E06)	50	$57.06	/hr	$2,853.00	
H&S Coordinator (E09)	50	$86.13	/hr	$4,306.50	
QC/QA (E08)	50	$68.82	/hr	$3,441.00	
Subcontractor Field Labor:					
Equipment Operator	5	$327.00	/day	$1,635.00	
Equipment Operator	5	$327.00	/day	$1,635.00	
Equipment Operator	5	$327.00	/day	$1,635.00	
Equipment Operator	5	$327.00	/day	$1,635.00	
Laborer	5	$288.00	/day	$1,440.00	
Laborer	5	$288.00	/day	$1,440.00	
Laborer	5	$288.00	/day	$1,440.00	
Laborer	5	$288.00	/day	$1,440.00	
Laborer	5	$288.00	/day	$1,440.00	
Site Support Facilities					
Installed Site Trailer, 50' x 10'	1	$13,335.00	/ls	$13,335.00	
Installed Site Trailer, 50' x 10'	1	$13,335.00	/ls	$13,335.00	
Utility and Power Hook-Ip	1	$3,000.00	/ls	$3,000.00	
Equipment Rental:					
Excavator	1	$300.00	/mobe-demobe	$300.00	
Backhoe (85 hp)	1	$300.00	/mobe-demobe	$300.00	
Dozer (140 hp)	1	$300.00	/mobe-demobe	$300.00	
Trencher	1	$300.00	/mobe-demobe	$300.00	
Dump truck (14 cy)	1	$300.00	/mobe-demobe	$300.00	
Pressure washer (2000 psi)	1	$100.00	/mobe-demobe	$100.00	
Travel:					
Perdiem	15	$39.00	/day	$585.00	
Lodging	15	$91.00	/night	$1,365.00	
Air Fare	3	$800.00	/trip	$2,400.00	
Rental Car	15	$46.00	/day	$690.00	
Rental Car FOGM	15	$12.00	/day	$180.00	
				Subtotal	**$65,448.00**

3.0 Site Preparation, Clearing, and Layout

Includes:

1 Survey locations of monitoring wells, extraction wells, reinjection wells, PRRWP and WARWP groundwater treatment systems (WTP), and location of route for piping to and from the PRRWP WTP and WARWP WTP.
2 Install erosion controls, perform clearing and grubbing, and rehabilitate existing access roads at PRRWP and WARWP.

Assumptions:

1 Existing survey monuments adequate for locating new wells and pipe route.
Clearing and Grubbing
2 All clearing debris to be disposed on site.
3 Assume that 30% of pipe route length requires silt fencing and all well location perimeters require silt fencing.
4 Length of piping for extraction and reinjection wells to the WTPs = 8,000 linear feet [Note: See Section 6 for footage.]
5 Area of clearing along pipe route (20 feet width) = 3.7 acres
6 PRRWP shall have 3 extraction wells and 3 reinjection wells while WARWP shall have 5 extraction wells and 5 reinjection wells installed. In addition, 10 overburden monitoring wells and 29 bedrock monitoring wells shall be installed at specified locations at TNT A, TNT B, TNT C, PRRWP, and WARWP.
7 Total number of wells installed = 55 wells
8 Area of clearing for well , at 60' x 60' per site = 4.6 acres
9 Assume that each WTP (at PRRWP and WARWP) are centrally located within the said area and occupy two acres each.
10 Area of clearing for PRRWP and WARWP WTPs = 4.0 acres
11 TNT A, TNT B, TNT C, PRRWP, and WARP have an ISEB injection barrier at each site. So, this area requires clearing for injection point installation.
12 Assume an area of 25-foot wide times the length of the barrier at each site.
13 Area of clearing for ISEB injection barriers =

	Length (ft)	Width (ft)	Area (acres)
TNT A	344	25	0.2
TNT B	331	25	0.2
TNT C	245	25	0.1
PRRWP	663	25	0.4
WARWP	825	25	0.5
		Total	1.4

14 All areas shall require some tree removal and / or brush. Shall be performed Subcontractor.
Site Access Roads
15 PRRWP has an existing access road off of Pentolite Road, ~900 feet, and WARWP has an existing access road off of Patrol Road, ~1,100 feet. Both roads are currently mud/dirt. Thus, assume rehabilitation to a standard access road condition.
16 Length of existing access road at PRRWP, 6"depth x 12 ft. = 990 linear feet [Includes 10% for realignment.]
17 Length of existing access road at WARWP, 6"depth x 12 ft. = 1,210 linear feet [Includes 10% for realignment.]
Duration
18 Hours work per day = 10 hours
19 Schedule (10-hr workday) = 10 days
20 Schedule (5-day workweek) = 2 weeks
21 Schedule (months) = 0.5 month

[Note: Accounts for Shaw oversight, erosion control installation, and site access road rehabilitation.]

Service/Materials	Unit	Unit Cost		Subtotal
Contractor Office Labor:				
Sr. Geologist (E10)	8	$93.94	/hr	$751.52
Engineer/Scientist IV (E10)	8	$92.56	/hr	$740.48
Geologist (E08)	20	$68.82	/hr	$1,376.40
Engineer/Scientist III (E08)	20	$68.82	/hr	$1,376.40
Contractor Field Labor:				
Site Manager (E06)	100	$57.06	/hr	$5,706.00
H&S Coordinator (E09)	100	$83.18	/hr	$8,318.00
QC/QA (E08)	100	$68.82	/hr	$6,882.00
Subcontractor Field Labor:				
Equipment Operator	10	$327.00	/day	$3,270.00
Equipment Operator	10	$327.00	/day	$3,270.00
Equipment Operator	10	$327.00	/day	$3,270.00
Equipment Operator	10	$327.00	/day	$3,270.00
Laborer	10	$288.00	/day	$2,880.00
Laborer	10	$288.00	/day	$2,880.00
Laborer	10	$288.00	/day	$2,880.00
Laborer	10	$288.00	/day	$2,880.00
Laborer	10	$288.00	/day	$2,880.00
Subcontractor:				
Survey crew (2-man)	10	$1,100.00	/day	$11,000.00
Med. brush, avg. grub, some trees, clearing	12.30	$810.00	/acre	$9,963.00
Chipping medium brush	12.30	$1,940.00	/acre	$23,862.00
Med. brush, med. trees-clear/grub/haul	1.40	$8,100.00	/acre	$11,340.00
Equipment Rental:				
Excavator	0.5	$4,600.00	/month	$2,300.00
Backhoe (85 hp)	0.5	$1,650.00	/month	$825.00
Dozer (140 hp)	0.5	$4,350.00	/month	$2,175.00
Dump truck (14 cy)	0.5	$3,590.00	/month	$1,795.00
Trencher (diesel, 4 ft. deep, 12" width)	0.5	$6,550.00	/month	$3,275.00
Pressure washer (2000 psi)	0.5	$480.00	/month	$240.00
FOGM	0.5	$3,000.00	/month	$1,500.00
Chemical toilets (x2)	0.5	$300.00	/month	$150.00

Table 5-2

Alternative GW-3 Cost Estimate
TNT Manufacturing and Red Water Pond Areas Groundwater Feasibility Study Addendum
Former Plum Brook Ordnance Works, Sandusky, Ohio

3.0 Site Preparation, Clearing, and Layout, Continued…					
Service/Materials	**Unit**	**Unit Cost**		**Subtotal**	
Materials:					
Silt fencing	12,300	$0.75	/linear foot	$9,225.00	
Straw bales	400	$4.00	/ea	$1,600.00	
Geotextile for road underlayment	26,400	$0.42	/sf	$11,088.00	
Dense graded aggregate (delivered)	890.00	$17.00	/ton	$15,130.00	
Travel:					
Perdiem	36	$39.00	/day	$1,404.00	
Lodging	36	$91.00	/night	$3,276.00	
Air Fare	3	$800.00	/trip	$2,400.00	
Rental Car	36	$46.00	/day	$1,656.00	
Rental Car FOGM	36	$12.00	/day	$432.00	
				Subtotal	**$167,267.00**

4.0 Installation of Overburden Monitoring Wells

Includes:

1 Installation of Overburden Monitoring Wells using Hollow-Stem Auger Drilling
2 Installation of 10 wells to a total depth of 25 ft.
3 Development of Monitoring Wells
4 Well Constructed of 2-inch PVC with 10-feet of 0.010 Slot Continuous Wrap PVC Screen

Assumptions:

1 Number of New Overburden Monitoring Wells =	19	
2 Depth of overburden well =	25	feet
3 length of well screen =	10	feet
4 Drill, construct, and develop one well =	1.5	days
5 Well Installation Field Days =	29	days
6 Soil and bedrock (for this task) can be drilled using HSA.		
7 Hours work per day =	10	hours
8 Schedule (10 day on/4 days off) =	6	weeks
9 Contractor crew size =	2	workers
10 Length of extended work week =	10	days
11 No. of round trips to site =	3	trips
12 Travel days per worker =	3	days

Service/Materials	**Unit**	**Unit Cost**		**Cost**	
Contractor Office Labor:					
Engineer/Scientist III (E08)	16	$68.82	/hr	$1,101.08	
Procurement Coordinator (N07)	8	$35.80	/hr	$286.40	
Secretary III (N06)	8	$34.80	/hr	$278.40	
Contractor Field Labor:					
Geologist (E08)	320	$ 68.82	/hr	$22,021.63	
Engineering Technician III (N08)	320	$ 46.80	/hr	$14,976.58	
Drilling Subcontractor:					
Mobilization	1	$2,500.00	/ea	$2,500.00	
Demobilization	1	$2,500.00	/ea	$2,500.00	
Posthole first 5 feet	19	$25.00	/ea	$475.00	
Decon pad construction	5	$750.00	/ea	$3,750.00	
Average drilling cost in soil, per foot	475	$18.00	/ft	$8,550.00	
2-inch ID, Sch 40, PVC casing	285	$9.00	/ft	$2,565.00	
2-inch ID, Sch 40, PVC screen	190	$12.00	/ft	$2,280.00	
2-inch Overburden Well Construction	19	$1,200.00	/ea	$22,800.00	
Well Development	19	$1,200.00	/ea	$22,800.00	
Surface Completion	19	$425.00	/ea	$8,075.00	
Decontamination	19	$85.00	/ea	$1,615.00	
Site cleanup	19	$125.00	/ea	$2,375.00	
IDW disposal	19	$250.00	/ea	$4,750.00	
Surveying	19	$268.72	/ea	$5,105.68	
Travel:					
Perdiem	64	$39.00	/day	$2,496.00	
Lodging	64	$91.00	/night	$5,824.00	
Air Fare	6	$800.00	/trip	$4,800.00	
Rental Car	32	$46.00	/day	$1,472.00	
Rental Car FOGM	32	$12.00	/day	$384.00	
				Subtotal	**$143,781.00**

Table 5-2

Alternative GW-3 Cost Estimate
TNT Manufacturing and Red Water Pond Areas Groundwater Feasibility Study Addendum
Former Plum Brook Ordnance Works, Sandusky, Ohio

5.0 Installation of Bedrock Monitoring Wells

Includes:

1 Installation of 29 Additional Bedrock Monitoring Wells using Hollow-Stem Auger/Air Rotary to a total depth of 60 ft.
2 Development of Monitoring Wells
3 Well Constructed of 2-inch PVC with 15-feet of 0.010 Slot Continuous Wrap PVC Screen

Assumptions:

1	Number of New Bedrock Monitoring Wells:			29
2	Construct and Develop One Well =			3 days
3	Well Installation Field Days =			87 days
4	Hours work per day =	10	hours	
5	Schedule (10-hr workday) =	87	days	
6	Schedule (5-day workweek) =	17	weeks	
7	Schedule (months) =	4.1	month	

Service/Materials		Unit	Unit Cost		Cost	
Contractor Office Labor:						
Engineer/Scientist III (E08)		20	$68.82	/hr	$1,376.35	
Procurement Coordinator (N07)		16	$35.80	/hr	$572.80	
Secretary III (N06)		16	$34.80	/hr	$556.80	
Contractor Field Labor:						
Geologist (E08)		870	$ 68.82	/hr	$59,871.31	
Engineering Technician III (N08)		870	$ 46.80	/hr	$40,717.57	
Drilling Subcontractor:						
Mobilization		1	$2,500.00	/ea	$2,500.00	
Demobilization		1	$2,500.00	/ea	$2,500.00	
Posthole first 5 feet	5'	29	$25.00	/ea	$725.00	
Decon pad construction		5	$750.00	/ea	$3,750.00	
Drill soil with 12" HSA to bedrock	15'	435	$50.00	/ft	$21,750.00	
Cut 5' bedrock with 10" tricone roller bit	5'	145	$41.00	/ft	$5,945.00	
Install 6" steel casing	35'	1015	$45.00	/ft	$45,675.00	
Cut bedrock with 6" OD tricone roller bit	35'	1015	$44.00	/ft	$44,660.00	
2-inch ID, Sch 40, PVC casing	47.5'	1378	$9.00	/ft	$12,397.50	
2-inch ID, Sch 40, PVC screen	'15	435	$12.00	/ft	$5,220.00	
2-inch Bedrock Well Construction		29	$1,200.00	/ft	$34,800.00	
Well Development		29	$1,200.00	/ea	$34,800.00	
Surface Completion		29	$425.00	/ea	$12,325.00	
Decontamination		29	$85.00	/ea	$2,465.00	
Site cleanup		29	$125.00	/ea	$3,625.00	
IDW disposal		29	$250.00	/ea	$7,250.00	
Surveying		29	$268.72	/ea	$7,792.88	
Travel:						
Per Diem		174	$39.00	/day	$6,786.00	
Lodging		174	$91.00	/day	$15,834.00	
Air Fare		17	$800.00	/trip	$13,920.00	
Rental Car		174	$46.00	/day	$8,004.00	
Rental Car FOGM		174	$12.00	/day	$2,088.00	
					Subtotal	**$397,907.00**

Table 5-2

Alternative GW-3 Cost Estimate
TNT Manufacturing and Red Water Pond Areas Groundwater Feasibility Study Addendum
Former Plum Brook Ordnance Works, Sandusky, Ohio

6.0 Extraction and Reinjection Well Installation

Includes:

1 Installation of extraction and reinjection wells along with pumps, power, controls and surface completions.
2 Eight extraction wells, 3 at PRRWP and 5 at WARWP will be installed:

3 at PRRWP -	70	avgas depth (ft)	210	total depth (ft)
5 at WARWP -	54	avgas depth (ft)	270	total depth (ft)

3 Eight reinjection wells, 3 at PRRWP and 5 at WARWP:

3 at PRRWP -	70	avg depth (ft)	210	total depth (ft)
5 at WARWP -	54	avg depth (ft)	270	total depth (ft)

4 Average depth to bedrock estimated to be 50 ft at both PRRWP and WARWP.
5 Development of wells.
6 Install piping, valving, interim lift station, along with power and controls related with the PRRWP WTP and WARWP WTP.
7 Baseline sampling of the newly installed wells.

Assumptions:

1 Medium voltage distribution line is available in the proximity to each well cluster.
2 No other existing utilities require relocation.
3 Piping to the groundwater treatment systems shall be HDPE, SDR 21, single wall.
4 Assume each WTP is centrally located to the extraction and reinjection wells at said location, i.e., PRRWP and WARWP.
5 Assume that on average, 500 feet of pipe for each extraction well and each reinjection well.
6 Assume 250 linear of piping, fittings and valves can be installed per day.
7 Installation of wells using air rotary drilling methods.

8 Number of extraction wells =	8	each	
9 Construct and develop one well =	3	days	[Note: Does not incl. surface completion.]
10 Overburden drilling=	456	feet	
11 Bedrock drilling=	380	feet	
12 Total depth =	836	feet	
13 Well installation field days =	24	days	
14 Number of Reinjection Wells =	8	each	
15 Construct and develop one well =	3	days	[Note: Does not incl. surface completion.]
16 Overburden drilling=	320	feet	
17 Bedrock drilling=	160	feet	
18 Total depth =	480	feet	
19 Well installation field days =	24	days	
20 Total field days =	48.0	days	
21 Number of wells to be sampled =	16	each	
22 Total field days for sampling wells (3 dy) =	6.0	days	
23 Length of manifold piping from extraction wells =	3,000	linear feet	
24 Length of piping WTP to reinjection wells =	5,000	linear feet	
25 Assume 250 feet of pipe shall be installed per day. Duration =	32.0	days	

26 Assume Shaw Field Labor for installation of piping and utilization of a Drilling Subcontractor for well installation.

26 Hours work per day =	10	hours	
27 Schedule (10-hr workday) =	54	days	[Note: Based on well installation to have Shaw oversight.]
28 Schedule (5-day workweek) =	11	weeks	
29 Schedule (months) =	2.5	months	

Service/Materials	Unit	Unit Cost		Subtotal
Contractor Office Labor:				
Sr. Geologist (E10)	44	$93.94	/hr	$4,133.36
Engineer/Scientist IV (E10)	44	$92.56	/hr	$4,072.64
Geologist (E08)	108	$68.82	/hr	$7,432.56
Engineer/Scientist III (E08)	108	$68.82	/hr	$7,432.56
Chemist III (E06)	40	$54.20	/hr	$2,168.00
Data Entry Technician (E04)	40	$45.00	/hr	$1,800.00
Contractor Field Labor:				
Site Manager (E06)	540	$57.06	/hr	$30,812.40
H&S Coordinator (E09)	540	$83.18	/hr	$44,917.20
QC/QA (E08)	540	$68.82	/hr	$37,162.80
Subcontractor Field Labor:				
Equipment Operator	32	$327.00	/day	$10,464.00
Equipment Operator	32	$327.00	/day	$10,464.00
Equipment Operator	32	$327.00	/day	$10,464.00
Equipment Operator	32	$327.00	/day	$10,464.00
Laborer	32	$288.00	/day	$9,216.00
Laborer	32	$288.00	/day	$9,216.00
Laborer	32	$288.00	/day	$9,216.00
Laborer	32	$288.00	/day	$9,216.00
Laborer	32	$288.00	/day	$9,216.00
Baseline Sampling:				
Sampling, analytical, and reporting	16	$2,000.00	/well	$32,000.00

Table 5-2

Alternative GW-3 Cost Estimate
TNT Manufacturing and Red Water Pond Areas Groundwater Feasibility Study Addendum
Former Plum Brook Ordnance Works, Sandusky, Ohio

6.0 Extraction and Reinjection Well Installation

Service/Materials	Unit	Unit Cost		Subtotal	
Equipment Rental:					
Excavator	1.5	$4,600.00	/month	$6,900.00	
Backhoe (85 hp)	1.5	$1,650.00	/month	$2,475.00	
Dozer (140 hp)	1.5	$4,350.00	/month	$6,525.00	
Trencher (diesel, 4 ft. deep, 12" width)	1.5	$6,550.00	/month	$9,825.00	
Dump truck (14 cy)	1.5	$3,590.00	/month	$5,385.00	
Pressure washer (2000 psi)	1.5	$480.00	/month	$720.00	
FOGM	1.5	$3,000.00	/month	$4,500.00	
Chemical toilets (x2)	1.5	$300.00	/month	$450.00	
Materials:					
4" gw pump (<7 gpm, <800 ft head, 1.5 hp, cntrls)	8	$3,750.00	/ea	$30,000.00	
Reinjection wellhead completion & vault	8	$3,500.00	/ea	$28,000.00	
Control panel	7	$2,500.00	/ea	$17,500.00	
3" dia. HDPE, SDR 21 pipe (welder & machine only)	3,000	$7.19	/linear foot	$21,570.00	
4" dia. HDPE, SDR 21 pipe (welder & machine only)	5,000	$8.44	/linear foot	$42,200.00	
Buried utility marking tape (foil backing)	8,000	$0.15	/linear foot	$1,200.00	
Valving and fittings (10% of pipe total)	1	$6,377.00	/lump sum	$6,377.00	
Package lift station (18 gpm)	1	$4,000.00	/lump sum	$4,000.00	
Drilling Subcontractor:					
Mobilization/demobilization (10-day rotation)	5	$5,000.00	/ea	$25,000.00	
Minirae 2000 (10.6)	12	$225.00	/week	$2,700.00	
4-inch PVC, schedule 40, well casing	1,076	$18.00	/vf	$19,368.00	
4-inch PVC, schedule 40, well screen	240	$25.00	/vf	$6,000.00	
8" roller cone soil drilling, casing installation	776	$80.00	/vf	$62,080.00	
6" roller cone bedrock drilling	540	$44.00	/feet	$23,760.00	
Install well and materials	16	$675.00	/feet	$10,800.00	
Furnish and Install flush well and pad	16	$500.00	/ea	$8,000.00	
Well development	8	$250.00	/ea	$2,000.00	
Decontamination	16	$150.00	/ea	$2,400.00	
Cleanup	16	$85.00	/ea	$1,360.00	
IDW disposal	16	$500.00	/ea	$8,000.00	
Travel:					
Perdiem	162	$39.00	/day	$6,318.00	
Lodging	162	$91.00	/night	$14,742.00	
Air Fare	6	$800.00	/trip	$4,800.00	
Rental Car	162	$46.00	/day	$7,452.00	
Rental Car FOGM	162	$12.00	/day	$1,944.00	
				Subtotal	**$654,200.00**

7.0 Installation of the Groundwater Treatment Systems

Includes:

1 Installation of the PRRWP WTP and WARWP WTP.

Assumptions:

1 Non-equipment costs estimated by factoring based on total equipment costs.
2 Flow rate of PRRWP WTP = 10.5 gpm
3 Flow rate of WARWP WTP= 6 gpm

Service/Materials	Unit	Unit Cost		Cost	
Plant and Equipment:					
Anoxic FBR Denitrification System	1	$250,000.00	/ea	$250,000.00	Total installed cost
Aerobic Bioreactor	1	$660,000.00	/ea	$660,000.00	Total installed cost
Subtotal - Biological Treatment Systems				**$910,000.00**	Total installed cost
Air Stripper	1	$15,000.00	/ea	$15,000.00	
Polymer Feed System	2	$4,000.00	/ea	$8,000.00	
Coagulation/Flocculation Tanks w/ Agitators	2	$8,000.00	/ea	$16,000.00	
Parallel Plate Clarifier	2	$17,000.00	/ea	$34,000.00	
Duplex Bag Filter w/ Pump	2	$11,000.00	/ea	$22,000.00	
Dual Bed Carbon Adsorber	1	$12,000.00	/ea	$12,000.00	
Sludge Storage Tank	2	$8,000.00	/ea	$16,000.00	
Filter Press w/ Pump	2	$25,000.00	/ea	$50,000.00	
Subtotal - Non-Biological Treatment Systems				**$173,000.00**	
Subtotal Equipment Cost				**$1,083,000.00**	
Miscellaneous					
Site Improvements	1	$108,300.00	/ea	$108,300.00	
Buildings	1	$194,940.00		$194,940.00	
Equipment Installation	1	$81,310.00	/ea	$81,310.00	
Instrumentation and Controls (Installed)	1	$43,250.00	/ea	$43,250.00	
Piping (Installed)	1	$114,180.00	/ea	$114,180.00	
Electrical (Installed)	1	$19,030.00	/ea	$19,030.00	
Utilities (Installed)	1	$541,500.00	/ea	$541,500.00	
Engineering and Supervision	1	$57,090.00	/ea	$57,090.00	
Construction Expense	1	$70,930.00	/ea	$70,930.00	
Subtotal Other Costs				**$1,230,530.00**	
				Subtotal	**$2,313,530.00**

Table 5-2

Alternative GW-3 Cost Estimate
TNT Manufacturing and Red Water Pond Areas Groundwater Feasibility Study Addendum
Former Plum Brook Ordnance Works, Sandusky, Ohio

8.0 ISEB - Emulsified Vegetable Oil Injection

Includes:
1 DPT Injection of emulsified vegetable oil in plumes designated in Table 3-6.
2 DPT injection implemented in a series of parallel biobarriers per Table 5-2.

Assumptions:
1 DPT rig, field truck, water truck and substrate metering system purchased outright for long-term project.
2 All field personnel hired direct for duration of project, therefore expenses for travel, lodging and meals not incurred.
3 Office engineer travels to the site 3 days (including travel) per month for duration of project.

Total Plume Areas

1	Total number of injection points =	4609	points
2	Substrate demand =	1,161,600	pounds
3	Substrate density =	7.64	pounds/gal
4	Substrate demand per injection point =	252	pounds
5	Ratio substrate to water =	0.2	
6	Water required =	760	kgal
7	Injection points completed per day =	4	points/DPT crew*day
8	Estimated field duration =	1153	crew days
9	Number of DPT crews =	1	crews
10	Estimated field duration =	1153	work days
11	Work days per month =	22	work days/month
12	Estimated field duration =	52	months
13	Field workers per DPT crew =	2	workers/crew
14	Hours per Work Day =	8	hours/day
15	Number of supervisory crew =	2	workers

Service/Materials	Unit	Unit Cost		Cost	
Contractor Office Labor:					
Project Manager II (E11)	624	$106.75	/hr	$66,612.00	
Engineer Scientist IV (E10)	1,664	$ 92.56	/hr	$154,019.84	
Geologist (E08)	416	$68.82	/hr	$28,629.12	
Procurement Coordinator (N07)	416	$35.80	/hr	$14,892.80	
Contractor Field Labor:					
Site Manager (E06)	9,224	$ 57.06	/hr	$526,321.44	
Engineering Technician (N08)	9,224	$46.80	/hr	$431,683.20	
Equipment & Materials:					
EOS (incl. shipping)	1,161,600	$1.90	/lb	$2,207,040.00	
Dilution Water	760	$2.87	/kgal	$2,181.80	
Metering System	1	$25,000.00	/ea	$25,000.00	Purchased
Water truck	1	$30,000.00	/ea	$30,000.00	Purchased
Injection Supplies	52	$5,000.00	/month	$260,000.00	
Field Truck	1	$25,000.00	/ea	$25,000.00	Purchased
Rental Car FOGM	2,306	$12.00	/day	$27,672.00	
DPT Drilling Crew:					
DPT Rig	1	$140,000.00	/ea	$140,000.00	Purchased
Equipment Operator	2,306	$327.00	/day	$754,062.00	
Travel:					
Per Diem	156	$39.00	/day	$6,084.00	
Lodging	104	$91.00	/day	$9,464.00	
Air Fare	52	$800.00	/trip	$41,600.00	
Rental Car	156	$46.00	/day	$7,176.00	
				Subtotal	**$4,757,438.00**

Table 5-2

Alternative GW-3 Cost Estimate
TNT Manufacturing and Red Water Pond Areas Groundwater Feasibility Study Addendum
Former Plum Brook Ordnance Works, Sandusky, Ohio

9.0 Site Restoration, Testing and Demobilization

Includes:
1 Conduct hydrostatic pressure testing on pipe line and "shakedown/startup" testing of pumps and controls.
2 Site restoration including finish grading and seeding.
3 Demobilization

Assumptions:
1 Groundwater from wells will be used to hydrostatic test pipe lines, then it will be discharged to PRRWP WTP and WARWP WTP.
2 Dozer will finish grade areas as work is completed in line items above.
3 Testing and shakedown completed by contractor labor for one week duration.
4 Reference clearing areas in Section 3.0.
5 Demobilization of equipment was accounted for in Section 2.0.
6 Hours work per day = 10 hours
7 Schedule (10-hr workday) = 15 days
8 Schedule (5-day workweek) = 3 weeks
9 Schedule 0.7 months

Service/Materials	Unit	Unit Cost		Cost	
Office Labor:					
Sr. Geologist (E10)	12	$93.94	/hr	$1,127.28	
Engineer/Scientist IV (E10)	12	$92.56	/hr	$1,110.72	
Geologist (E08)	30	$68.82	/hr	$2,064.60	
Engineer/Scientist III (E08)	30	$68.82	/hr	$2,064.60	
Construction completion report	1	$12,500.00	/lump sum	$12,500.00	
LTM plan	1	$15,000.00	/lump sum	$15,000.00	
Contractor Field Labor:					
Site Manager (E06)	150	$57.06	/hr	$8,559.00	
H&S Coordinator (E09)	150	$83.18	/hr	$12,477.00	
QC/QA (E08)	150	$68.82	/hr	$10,323.00	
Engineer/Scientist III (E08) - Mechanical	50	$68.82	/hr	$3,441.00	
Engineer/Scientist III (E08) - Electrical	50	$68.82	/hr	$3,441.00	
Equipment Rental:					
Backhoe (85 hp)	1	$1,650.00	/month	$1,650.00	
Dozer (140 hp)	1	$4,350.00	/month	$4,350.00	
Pump for testing	1	$480.00	/month	$480.00	
Pressure washer (2000 psi)	1	$480.00	/month	$480.00	
FOGM	1	$3,000.00	/month	$3,000.00	
Subcontractor Field Labor:					
Equipment Operator	15	$327.00	/day	$4,905.00	
Equipment Operator	15	$327.00	/day	$4,905.00	
Laborer	15	$288.00	/day	$4,320.00	
Laborer	15	$288.00	/day	$4,320.00	
Subcontractor:					
Mob/Demob	1	$2,500.00	/ea	$2,500.00	
Seed, mulch, water	13.70	$4,700.00	/acre	$64,390.00	
Travel:					
Per diem	61	$39.00	/day	$2,379.00	
Lodging	61	$91.00	/day	$5,551.00	
Air Fare	5	$800.00	/trip	$4,000.00	
Rental Car	56	$46.00	/day	$2,576.00	
Rental Car FOGM	56	$12.00	/day	$672.00	
				Subtotal	**$182,586.00**

10.0 Groundwater Use Controls

Service/Materials	Unit	Unit Cost		Cost	
Land Use Control Implementation Plan	1	$30,000.00	/ea	$30,000.00	
				Subtotal	**$30,000.00**

Table 5-2

Alternative GW-3 Cost Estimate
TNT Manufacturing and Red Water Pond Areas Groundwater Feasibility Study Addendum
Former Plum Brook Ordnance Works, Sandusky, Ohio

11.0 Annual Pump and Treat Operation and Maintenance (O&M), Years 1-30

Includes:
1 Groundwater Treatment System O&M
2 Installed Wells, Piping, and Site Facilities

Assumptions:
1 Field labor is local; therefore no cost for travel is included.
2 Annual reporting cost sufficient to cover five-year reviews.

Note:
Cost for capital improvements to replace substantial portions of the groundwater treatment systems are not included in this evaluation.

Service/Materials	Unit	Unit Cost			Cost	
I. Groundwater Treatment System O&M - PRRWP WTP and WARWP WTP						
Labor:						
Operator labor	2	$26,000.00	/ls		$52,000.00	
Management	2	$1,500.00	/ls		$3,000.00	
Materials:						
Filter replacement	2	$200.00	/ls		$400.00	
Carbon for Polishing, at 2ppm	1	$3,800.00	/ls		$3,800.00	
Chemical/Flocculants, at 20 ppm	1	$2,800.00	/ls		$2,800.00	
Utilities:						
Electric Power for Treatment System 4 pumps + 1 blower (3 heaps each)	2	$8,900.00	/ls		$17,800.00	
Disposal:						
Filter Cake Solids, lb/day	204	$2.00	/lb/day		$408.00	
Sampling:						
Water Sample Analysis	2	$16,800.00	/ls		$33,600.00	
Anoxic and Aerobic Equipment:						
Anoxic FBR Denitrification System	1	$327.00	/ea		$327.00	
Aerobic Bioreactor	1	$19,457.00	/ea		$19,457.00	
Miscellaneous:						
Reporting	2	$5,000.00	/ls		$10,000.00	
Maintenance	2	$4,000.00	/ls		$8,000.00	
				Subtotal	**$151,592.00**	
II. Installed Wells, Piping, and Site Facilities						
Monitoring, Extraction, and Reinjection Well Repairs	1	$5,000.00	/ls		$5,000.00	
Miscellaneous Repairs to Pipeline	1	$1,000.00	/ls		$1,000.00	
Field Office Utilities	1	$7,332.00	/ls		$7,332.00	
				Subtotal	**$13,332.00**	
					Subtotal	**$164,924.00**

Table 5-2

Alternative GW-3 Cost Estimate
TNT Manufacturing and Red Water Pond Areas Groundwater Feasibility Study Addendum
Former Plum Brook Ordnance Works, Sandusky, Ohio

12.0 Groundwater Monitoring and Institutional Controls: Years 1 - 5 (Annualized)

Includes:
1 Groundwater Monitoring

Includes:
1 Annual monitoring of 19 wells in the overburden/weathered shale and 33 wells in the bedrock zone for COCs.
2 Data verification, evaluation, and preparation of annual report

3 No. of wells sampled =	52	wells/event
4 Number of technicians in field crew =	2	personnel
5 Sampling time (per well) =	3	hrs/well
6 Sampling time per seep =	1	hrs/seep
7 Number of well sampling events =	1	events/year
8 Well sampling time =	16	days
9 Hours work per day =	10	hours

Data Management and QA/QC Assumptions:

Data Entry Technician (E04)	1 hr/sample
Chemist III (E06)	0.75 hr/sample
Database Manager (E08)	1.5 hr/sample
Senior Consultant I (E12)	0.175 hr/sample

Service/Materials	Unit	Unit Cost		Cost
Office Labor:				
Project Manager II (E11)	20	$106.75	/hr	$2,135.00
Senior Consultant I (E12)	10	$118.41	/hr	$1,184.10
Engineer/Scientist III (E08)	40	$68.82	/hr	$2,752.80
Engineer/Scientist II (E06)	100	$57.06	/hr	$5,706.00
Data Entry Technician (E04)	52	$45.00	/hr	$2,340.00
Chemist III (E06)	39	$54.20	/hr	$2,113.80
Database Manager (E08)	78	$64.40	/hr	$5,023.20
Senior Consultant I (E12)	9	$118.41	/hr	$1,065.69
Secretary III (N06)	20	$34.80	/hr	$696.00
Draftsperson (N08)	40	$53.36	/hr	$2,134.40
Word Processor (N06)	20	$41.82	/hr	$836.40
Field Labor:				
Engineering Technician III (N08)	160	$46.80	/hr	$7,488.00
Engineering Technician III (N08)	160	$46.80	/hr	$7,488.00
Materials:				
Sampling Equipment	1	$500.00	/event	$500.00
Document Reproduction	1	$400.00	/ea	$400.00
RDW Treatment and Disposal	1	$1,250.00	/event	$1,250.00
Analytical:				
Analytical:	1	$11,147.00	/ls	$11,147.00
Travel:				
Per Diem	32	$39.00	/day	$1,248.00
Lodging	32	$91.00	/day	$2,912.00
Air Fare	2	$800.00	/trip	$1,600.00
Rental Car	32	$46.00	/day	$1,472.00
Rental Car FOGM	32	$12.00	/day	$384.00
Institutional Controls and 5-Year Review:				
Inspection and Reporting	1	$1,500.00	/yr	$1,500.00
5 -Year Review (Annualized)	1	$1,500.00	/yr	$1,500.00
				Subtotal **$64,876.00**

Table 5-2

Alternative GW-3 Cost Estimate
TNT Manufacturing and Red Water Pond Areas Groundwater Feasibility Study Addendum
Former Plum Brook Ordnance Works, Sandusky, Ohio

13.0 Groundwater Monitoring and Institutional Controls: Years 6 - 30 (Annualized)

Includes:
1 Groundwater Monitoring

Includes:
1 Annual monitoring of 33 wells in the bedrock zone for COCs.
2 Data verification, evaluation, and preparation of annual report

3 No. of wells sampled =	33	wells/event
4 Number of technicians in field crew =	2	personnel
5 Sampling time (per well) =	3	hrs/well
6 Sampling time per seep =	1	hrs/seep
7 Number of well sampling events =	1	events/year
8 Well sampling time =	10	days
9 Hours work per day =	10	hours

Data Management and QA/QC Assumptions:

Data Entry Technician (E04)	1	hr/sample
Chemist III (E06)	0.75	hr/sample
Database Manager (E08)	1.5	hr/sample
Senior Consultant I (E12)	0.175	hr/sample

Service/Materials	Unit	Unit Cost		Cost	
Office Labor:					
Project Manager II (E11)	20	$106.75	/hr	$2,135.00	
Senior Consultant I (E12)	10	$118.41	/hr	$1,184.10	
Engineer/Scientist III (E08)	40	$68.82	/hr	$2,752.80	
Engineer/Scientist II (E06)	100	$57.06	/hr	$5,706.00	
Data Entry Technician (E04)	33	$45.00	/hr	$1,485.00	
Chemist III (E06)	25	$54.20	/hr	$1,355.00	
Database Manager (E08)	50	$64.40	/hr	$3,220.00	
Senior Consultant I (E12)	6	$118.41	/hr	$710.46	
Secretary III (N06)	20	$34.80	/hr	$696.00	
Draftsperson (N08)	40	$53.36	/hr	$2,134.40	
Word Processor (N06)	20	$41.82	/hr	$836.40	
Field Labor:					
Engineering Technician III (N08)	100	$46.80	/hr	$4,680.00	
Engineering Technician III (N08)	100	$46.80	/hr	$4,680.00	
Materials:					
Sampling Equipment	1	$500.00	/event	$500.00	
Document Reproduction	1	$400.00	/ea	$400.00	
RDW Treatment and Disposal	1	$1,250.00	/event	$1,250.00	
Analytical:					
Analytical:	1	$5,124.00	/ls	$5,124.00	
Travel:					
Per Diem	20	$39.00	/day	$780.00	
Lodging	20	$91.00	/day	$1,820.00	
Air Fare	2	$800.00	/trip	$1,600.00	
Rental Car	20	$46.00	/day	$920.00	
Rental Car FOGM	20	$12.00	/day	$240.00	
Institutional Controls and 5-Year Review:					
Inspection and Reporting	0	$1,500.00	/yr	$0.00	
5 -Year Review (Annualized)	1	$1,500.00	/yr	$1,500.00	
				Subtotal	**$45,709.00**

14.0 Total Capital Cost

Item	Unit	Unit Cost	Cost	
1 Groundwater Modeling, Remedial Design, Work Plans, and Procurement			$122,031.00	
2 Mobilization			$65,448.00	
3 Site Preparation, Clearing, and Layout			$167,267.00	
4 Installation of Overburden Monitoring Wells			$143,781.00	
5 Installation of Bedrock Monitoring Wells			$397,907.00	
6 Extraction and Reinjection Well Installation			$654,200.00	
7 Installation of the Groundwater Treatment Systems			$2,313,530.00	
8 ISEB - Emulsified Vegetable Oil Injection			$4,757,438.00	
9 Site Restoration, Testing and Demobilization			$182,586.00	
10 Groundwater Use Controls			$30,000.00	
		Total		**$8,834,188.00**

15.0 Total O&M Cost

Item	Unit	Unit Cost		Cost	
1 Years 1 - 5	5	$229,800.00	/yr	$1,149,000.00	
2 Years 6 - 30	25	$210,633.00	/yr	$5,265,825.00	
			Total		**$6,414,825.00**

Note: This is an 'order of magnitude' engineering cost estimate that is expected to be within + 50% to - 30% of actual project cost.

Table 5-3

Alternative GW-4 Cost Estimate
TNT Manufacturing and Red Water Pond Areas Groundwater Feasibility Study Addendum
Former Plum Brook Ordnance Works, Sandusky, Ohio

Site: PBOW
Alternative GW-4
Date: 03/21/11

Alternative GW-4
In-situ Enhanced Bioremediation (ISEB) and Pump and Treat for Mitigation / Protection of the Overburden / Shale and Bedrock Groundwater

Scope:
1 Groundwater Modeling, Remedial Design, Work Plans, and Procurement
2 Mobilization
3 Site Preparation, Clearing, and Layout
4 Installation of Overburden Monitoring Wells
5 Installation of Bedrock Monitoring Wells
6 Extraction and Reinjection Well Installation
7 Installation of the Groundwater Treatment Systems
8 ISEB - Emulsified Vegetable Oil Injection
9 Site Restoration, Testing and Demobilization
10 Groundwater Use Controls
11 Total Capitol Cost
12 Annual Pump and Treat Operation and Maintenance (O&M)
13 Annual Long Term O&M: Years 1 - 5 (Annualized)
14 Annual Long Term O&M: Years 6 - 30 (Annualized)

1.0 Groundwater Modeling, Remedial Design, Work Plans, and Procurement

Includes:
1 Perform groundwater modeling verifying placement of wells screen interval.
2 Mobilize drilling subcontractor and geologist to perform one 72-hour pump test at PRRWP and one at WARWP, two total.
3 Prepare RD/RA work plan, H&S work plan, and CQCP.
4 Procure equipment, materials, and subcontracts.

Assumptions:
1 The vertical well depth at PRRWP is 70 feet and the vertical well depth at WARWP is 54 feet.
2 The 72-hour pump test at PRRWP and WARWP shall include pumping from one well within the bedrock and sampling for characterization of the groundwater under pumping conditions. Assume the PRRWP and WARWP wells are installed as part of the scope for installation of the new Bedrock Monitoring Wells (Section 5.0).
3 Assume a Hydrogeologist on-site for a week at 10 hours per day to perform the 72-hour pump test.

Service/Materials	Unit	Unit Cost		Subtotal	
Contractor Office Labor:					
Senior Consultant I (E12)	30	$118.41	/hr	$3,552.30	
Sr. Geologist (E10)	60	$93.94	/hr	$5,636.40	
RD/RA Work Plan	1	$60,000.00	/ea	$60,000.00	
Health & Safety Plan	1	$5,000.00	/ea	$5,000.00	
CQCP	1	$9,000.00	/ea	$9,000.00	
Mrg, Contract Admin (E09)	60	$77.75	/hr	$4,665.00	
Procurement Coordinator (N07)	120	$35.80	/hr	$4,296.00	
GW Modeling	1	$25,000.00	/ls	$25,000.00	
Contractor Field Labor:					
Hydrogeologist (E08)	50	$68.82	/hr	$3,441.00	
Travel:					
Perdiem	5	$39.00	/day	$195.00	
Lodging	5	$91.00	/night	$455.00	
Air Fare	1	$500.00	/trip	$500.00	
Rental Car	5	$46.00	/day	$230.00	
Rental Car FOGM	5	$12.00	/day	$60.00	
				Subtotal	**$122,000.00**

Table 5-3

Alternative GW-4 Cost Estimate
TNT Manufacturing and Red Water Pond Areas Groundwater Feasibility Study Addendum
Former Plum Brook Ordnance Works, Sandusky, Ohio

2.0 Mobilization

Includes:
1 Mobilize personnel, equipment, and subcontractors.
2 Conduct preconstruction conference.

Assumptions:
1 Setup Shaw Field office. The annual utilities and office supplies are covered within the Pump and Treat O&M (Section 11.0).
2 Allow five days to mobilize personnel, equipment, and subcontractors.
3 Mobilization/ demobilization charges for each piece of equipment is $300 round trip, unless noted otherwise.
4 Travel costs are included for a Site Manager, H&S coordinator, and QC engineer. Travel costs are reflected for each subsequent task.
5 Contractor Field Labor rotate home every 3 weeks.
6 Hours work per day = 10 hours
7 Schedule (10-hr workday) = 5 days
8 Schedule (5-day workweek) = 1 weeks

Service/Materials	Unit	Unit Cost		Subtotal	
Contractor Office Labor:					
Sr. Geologist (E10)	10	$93.94	/hr	$939.40	
Engineer/Scientist IV (E10)	10	$92.56	/hr	$925.60	
Geologist (E08)	20	$68.82	/hr	$1,376.40	
Engineer/Scientist III (E08)	20	$68.82	/hr	$1,376.40	
Contractor Field Labor:					
Site Manager (E06)	50	$57.06	/hr	$2,853.00	
H&S Coordinator (E09)	50	$86.13	/hr	$4,306.50	
QC/QA (E08)	50	$68.82	/hr	$3,441.00	
Subcontractor Field Labor:					
Equipment Operator	5	$327.00	/day	$1,635.00	
Equipment Operator	5	$327.00	/day	$1,635.00	
Equipment Operator	5	$327.00	/day	$1,635.00	
Equipment Operator	5	$327.00	/day	$1,635.00	
Laborer	5	$288.00	/day	$1,440.00	
Laborer	5	$288.00	/day	$1,440.00	
Laborer	5	$288.00	/day	$1,440.00	
Laborer	5	$288.00	/day	$1,440.00	
Laborer	5	$288.00	/day	$1,440.00	
Site Support Facilities					
Installed Site Trailer, 50' x 10'	1	$13,335.00	/ls	$13,335.00	
Installed Site Trailer, 50' x 10'	1	$13,335.00	/ls	$13,335.00	
Utility and Power Hook-Ip	1	$3,000.00	/ls	$3,000.00	
Equipment Rental:					
Excavator	1	$300.00	/mobe-demobe	$300.00	
Backhoe (85 hp)	1	$300.00	/mobe-demobe	$300.00	
Dozer (140 hp)	1	$300.00	/mobe-demobe	$300.00	
Trencher	1	$300.00	/mobe-demobe	$300.00	
Dump truck (14 cy)	1	$300.00	/mobe-demobe	$300.00	
Pressure washer (2000 psi)	1	$100.00	/mobe-demobe	$100.00	
Travel:					
Perdiem	15	$39.00	/day	$585.00	
Lodging	15	$91.00	/night	$1,365.00	
Air Fare	3	$800.00	/trip	$2,400.00	
Rental Car	15	$46.00	/day	$690.00	
Rental Car FOGM	15	$12.00	/day	$180.00	
				Subtotal	**$65,400.00**

Alternative GW-4 Cost Estimate
TNT Manufacturing and Red Water Pond Areas Groundwater Feasibility Study Addendum
Former Plum Brook Ordnance Works, Sandusky, Ohio

3.0 Site Preparation, Clearing, and Layout

Includes:

1 Survey locations of monitoring wells, extraction wells, reinjection wells, PRRWP and WARWP groundwater treatment systems (WTP), and location of route for piping to and from the PRRWP WTP and WARWP WTP.

2 Install erosion controls, perform clearing and grubbing, and rehabilitate existing access roads at PRRWP and WARWP.

Assumptions:

1 Existing survey monuments adequate for locating new wells and pipe route.

Clearing and Grubbing

2 All clearing debris to be disposed on site.

3 Assume that 30% of pipe route length requires silt fencing and all well location perimeters require silt fencing.

4 Length of piping for extraction and reinjection wells to the WTPs 8,000 linear feet [Note: See Section 6 for footage.]

5 Area of clearing along pipe route (20 feet width) = 3.7 acres

6 PRRWP shall have 3 extraction wells and 3 reinjection wells while WARWP shall have 5 extraction wells and 5 reinjection wells installed. In addition, 25 overburden monitoring wells and 29 bedrock monitoring wells shall be installed at specified locations at TNT A, TNT B, TNT C, PRRWP, and WARWP.

7 Total number of wells installed = 70 wells

8 Area of clearing for well , at 60' x 60' per site = 5.8 acres

9 Assume that each WTP (at PRRWP and WARWP) are centrally located within the said area and occupy two acres each.

10 Area of clearing for PRRWP and WARWP WTPs = 4.0 acres

11 TNT A, TNT B, TNT C, PRRWP, and WARP have an ISEB injection barrier at each site. So, this area requires clearing for injection point installation.

12 Assume an area of 25-foot wide times the length of the barrier at each site.

13 Area of clearing for ISEB injection barriers =

	Length (ft)	Width (ft)	Area (acres)
TNT A	344	25	0.2
TNT B	331	25	0.2
TNT C	245	25	0.1
PRRWP	663	25	0.4
WARWP	825	25	0.5
		Total	1.4

14 All areas shall require some tree removal and / or brush. Shall be performed Subcontractor.

Site Access Roads

15 PRRWP has an existing access road off of Pentolite Road, ~900 feet, and WARWP has an existing access road off of Patrol Road, ~1,100 feet. Both roads are currently mud/dirt. Thus, assume rehabilitation to a standard access road condition.

16 Length of existing access road at PRRWP, 6"depth x 12 ft. = 990 linear feet [Includes 10% for realignment.]

17 Length of existing access road at WARWP, 6"depth x 12 ft. = 1,210 linear feet [Includes 10% for realignment.]

Duration

18 Hours work per day = 10 hours

19 Schedule (10-hr workday) = 10 days [Note: Accounts for Shaw oversight, erosion control installation, and site access road rehabilitation.]

20 Schedule (5-day workweek) = 2 weeks

21 Schedule (months) = 0.5 month

Service/Materials	Unit	Unit Cost		Subtotal
Contractor Office Labor:				
Sr. Geologist (E10)	8	$93.94	/hr	$751.52
Engineer/Scientist IV (E10)	8	$92.56	/hr	$740.48
Geologist (E08)	20	$68.82	/hr	$1,376.40
Engineer/Scientist III (E08)	20	$68.82	/hr	$1,376.40
Contractor Field Labor:				
Site Manager (E06)	100	$57.06	/hr	$5,706.00
H&S Coordinator (E09)	100	$83.18	/hr	$8,318.00
QC/QA (E08)	100	$68.82	/hr	$6,882.00
Subcontractor Field Labor:				
Equipment Operator	10	$327.00	/day	$3,270.00
Equipment Operator	10	$327.00	/day	$3,270.00
Equipment Operator	10	$327.00	/day	$3,270.00
Equipment Operator	10	$327.00	/day	$3,270.00
Laborer	10	$288.00	/day	$2,880.00
Laborer	10	$288.00	/day	$2,880.00
Laborer	10	$288.00	/day	$2,880.00
Laborer	10	$288.00	/day	$2,880.00
Laborer	10	$288.00	/day	$2,880.00
Subcontractor:				
Survey crew (2-man)	10	$1,100.00	/day	$11,000.00
Med. brush, avg. grub, some trees, clearing	13.50	$810.00	/acre	$10,935.00
Chipping medium brush	13.50	$1,940.00	/acre	$26,190.00
Med. brush, med. trees-clear/grub/haul	1.40	$8,100.00	/acre	$11,340.00
Equipment Rental:				
Excavator	0.5	$4,600.00	/month	$2,300.00
Backhoe (85 hp)	0.5	$1,650.00	/month	$825.00
Dozer (140 hp)	0.5	$4,350.00	/month	$2,175.00
Dump truck (14 cy)	0.5	$3,590.00	/month	$1,795.00
Trencher (diesel, 4 ft. deep, 12" width)	0.5	$6,550.00	/month	$3,275.00
Pressure washer (2000 psi)	0.5	$480.00	/month	$240.00
FOGM	0.5	$3,000.00	/month	$1,500.00
Chemical toilets (x2)	0.5	$300.00	/month	$150.00

Table 5-3

Alternative GW-4 Cost Estimate
TNT Manufacturing and Red Water Pond Areas Groundwater Feasibility Study Addendum
Former Plum Brook Ordnance Works, Sandusky, Ohio

3.0 Site Preparation, Clearing, and Layout, Continued…					
Service/Materials	**Unit**	**Unit Cost**		**Subtotal**	
Materials:					
Silt fencing	15,000	$0.75	/linear foot	$11,250.00	
Straw bales	400	$4.00	/ea	$1,600.00	
Geotextile for road underlayment	26,400	$0.42	/sf	$11,088.00	
Dense graded aggregate (delivered)	890.00	$17.00	/ton	$15,130.00	
Travel:					
Perdiem	36	$39.00	/day	$1,404.00	
Lodging	36	$91.00	/night	$3,276.00	
Air Fare	3	$800.00	/trip	$2,400.00	
Rental Car	36	$46.00	/day	$1,656.00	
Rental Car FOGM	36	$12.00	/day	$432.00	
				Subtotal	**$172,600.00**

4.0 Installation of Overburden Monitoring Wells

Includes:

1 Installation of Overburden Monitoring Wells using Hollow-Stem Auger Drilling
2 Installation of 25 wells to a total depth of 25 ft.
3 Development of Monitoring Wells
4 Well Constructed of 2-inch PVC with 10-feet of 0.010 Slot Continuous Wrap PVC Screen

Assumptions:

1 Number of New Overburden Monitoring Wells =	35	
2 Depth of overburden well =	25	feet
3 length of well screen =	10	feet
4 Drill, construct, and develop one well =	1.5	days
5 Well Installation Field Days =	53	days
6 Soil and bedrock (for this task) can be drilled using HSA.		
7 Hours work per day =	10	hours
8 Schedule (10 day on/4 days off) =	11	weeks
9 Contractor crew size =	2	workers
10 Length of extended work week =	10	days
11 No. of round trips to site =	6	trips
12 Travel days per worker =	6	days

Service/Materials	**Unit**	**Unit Cost**		**Cost**	
Contractor Office Labor:					
Engineer/Scientist III (E08)	16	$68.82	/hr	$1,101.08	
Procurement Coordinator (N07)	8	$35.80	/hr	$286.40	
Secretary III (N06)	8	$34.80	/hr	$278.40	
Contractor Field Labor:					
Geologist (E08)	590	$ 68.82	/hr	$40,602.38	
Engineering Technician III (N08)	590	$ 46.80	/hr	$27,613.06	
Drilling Subcontractor:					
Mobilization	1	$2,500.00	/ea	$2,500.00	
Demobilization	1	$2,500.00	/ea	$2,500.00	
Posthole first 5 feet	35	$25.00	/ea	$875.00	
Decon pad construction	5	$750.00	/ea	$3,750.00	
Average drilling cost in soil, per foot	875	$18.00	/ft	$15,750.00	
2-inch ID, Sch 40, PVC casing	525	$9.00	/ft	$4,725.00	
2-inch ID, Sch 40, PVC screen	350	$12.00	/ft	$4,200.00	
2-inch Overburden Well Construction	35	$1,200.00	/ea	$42,000.00	
Well Development	35	$1,200.00	/ea	$42,000.00	
Surface Completion	35	$425.00	/ea	$14,875.00	
Decontamination	35	$85.00	/ea	$2,975.00	
Site cleanup	35	$125.00	/ea	$4,375.00	
IDW disposal	35	$250.00	/ea	$8,750.00	
Surveying	35	$268.72	/ea	$9,405.20	
Subtotal				**$228,561.53**	
Travel:					
Perdiem	118	$39.00	/day	$4,602.00	
Lodging	118	$91.00	/night	$10,738.00	
Air Fare	12	$800.00	/trip	$9,600.00	
Rental Car	59	$46.00	/day	$2,714.00	
Rental Car FOGM	59	$12.00	/day	$708.00	
				Subtotal	**$256,923.53**

Table 5-3

Alternative GW-4 Cost Estimate
TNT Manufacturing and Red Water Pond Areas Groundwater Feasibility Study Addendum
Former Plum Brook Ordnance Works, Sandusky, Ohio

5.0 Installation of Bedrock Monitoring Wells

Includes:

1 Installation of 29 Additional Bedrock Monitoring Wells using Hollow-Stem Auger/Air Rotary to a total depth of 60 ft.
2 Development of Monitoring Wells
3 Well Constructed of 2-inch PVC with 15-feet of 0.010 Slot Continuous Wrap PVC Screen

Assumptions:

1 Number of New Bedrock Monitoring Wells:			29
2 Construct and Develop One Well =			3 days
3 Well Installation Field Days =			87 days
4 Hours work per day =	10	hours	
5 Schedule (10-hr workday) =	87	days	
6 Schedule (5-day workweek) =	17	weeks	
7 Schedule (months) =	4.1	month	

Service/Materials		Unit	Unit Cost		Cost	
Contractor Office Labor:						
Engineer/Scientist III (E08)		20	$68.82	/hr	$1,376.35	
Procurement Coordinator (N07)		16	$35.80	/hr	$572.80	
Secretary III (N06)		16	$34.80	/hr	$556.80	
Contractor Field Labor:						
Geologist (E08)		870	$ 68.82	/hr	$59,871.31	
Engineering Technician III (N08)		870	$ 46.80	/hr	$40,717.57	
Drilling Subcontractor:						
Mobilization		1	$2,500.00	/ea	$2,500.00	
Demobilization		1	$2,500.00	/ea	$2,500.00	
Posthole first 5 feet	5'	29	$25.00	/ea	$725.00	
Decon pad construction		5	$750.00	/ea	$3,750.00	
Drill soil with 12" HSA to bedrock	15'	435	$50.00	/ft	$21,750.00	
Cut 5' bedrock with 10" tricone roller bit	5'	145	$41.00	/ft	$5,945.00	
Install 6" steel casing	35'	1015	$45.00	/ft	$45,675.00	
Cut bedrock with 6" OD tricone roller bit	35'	1015	$44.00	/ft	$44,660.00	
2-inch ID, Sch 40, PVC casing	47.5'	1378	$9.00	/ft	$12,397.50	
2-inch ID, Sch 40, PVC screen	'15	435	$12.00	/ft	$5,220.00	
2-inch Bedrock Well Construction		29	$1,200.00	/ft	$34,800.00	
Well Development		29	$1,200.00	/ea	$34,800.00	
Surface Completion		29	$425.00	/ea	$12,325.00	
Decontamination		29	$85.00	/ea	$2,465.00	
Site cleanup		29	$125.00	/ea	$3,625.00	
IDW disposal		29	$250.00	/ea	$7,250.00	
Surveying		29	$268.72	/ea	$7,792.88	
Total Well Cost					**$351,275.21**	
Travel:						
Per Diem		174	$39.00	/day	$6,786.00	
Lodging		174	$91.00	/day	$15,834.00	
Air Fare		17	$800.00	/trip	$13,920.00	
Rental Car		174	$46.00	/day	$8,004.00	
Rental Car FOGM		174	$12.00	/day	$2,088.00	
					Subtotal	**$397,907.00**

Alternative GW-4 Cost Estimate
TNT Manufacturing and Red Water Pond Areas Groundwater Feasibility Study Addendum
Former Plum Brook Ordnance Works, Sandusky, Ohio

6.0 Extraction and Reinjection Well Installation

Includes:

1 Installation of extraction and reinjection wells along with pumps, power, controls and surface completions.
2 Eight extraction wells, 3 at PRRWP and 5 at WARWP will be installed:

3 at PRRWP -	70	avgas depth (ft)	210	total depth (ft)
5 at WARWP -	54	avgas depth (ft)	270	total depth (ft)

3 Eight reinjection wells, 3 at PRRWP and 5 at WARWP:

3 at PRRWP -	70	avg depth (ft)	210	total depth (ft)
5 at WARWP -	54	avg depth (ft)	270	total depth (ft)

4 Average depth to bedrock estimated to be 50 ft at both PRRWP and WARWP.
5 Development of wells.
6 Install piping, valving, interim lift station, along with power and controls related with the PRRWP WTP and WARWP WTP.
7 Baseline sampling of the newly installed wells.

Assumptions:

1 Medium voltage distribution line is available in the proximity to each well cluster.
2 No other existing utilities require relocation.
3 Piping to the groundwater treatment systems shall be HDPE, SDR 21, single wall.
4 Assume each WTP is centrally located to the extraction and reinjection wells at said location, i.e., PRRWP and WARWP.
5 Assume that on average, 500 feet of pipe for each extraction well and each reinjection well.
6 Assume 250 linear of piping, fittings and valves can be installed per day.
7 Installation of wells using air rotary drilling methods.

8 Number of extraction wells =	8	each	
9 Construct and develop one well =	3	days	[Note: Does not incl. surface completion.]
10 Overburden drilling=	456	feet	
11 Bedrock drilling=	380	feet	
12 Total depth =	836	feet	
13 Well installation field days =	24	days	
14 Number of Reinjection Wells =	8	each	
15 Construct and develop one well =	3	days	[Note: Does not incl. surface completion.]
16 Overburden drilling=	320	feet	
17 Bedrock drilling=	160	feet	
18 Total depth =	480	feet	
19 Well installation field days =	24	days	
20 Total field days =	48.0	days	
21 Number of wells to be sampled =	16	each	
22 Total field days for sampling wells (3 dy) =	6.0	days	
23 Length of manifold piping from extraction wells =	3,000	linear feet	
24 Length of piping WTP to reinjection wells =	5,000	linear feet	
25 Assume 250 feet of pipe shall be installed per day. Duration =	32.0	days	

26 Assume Shaw Field Labor for installation of piping and utilization of a Drilling Subcontractor for well installation.

26 Hours work per day =	10	hours	
27 Schedule (10-hr workday) =	54	days	[Note: Based on well installation to have Shaw oversight.]
28 Schedule (5-day workweek) =	11	weeks	
29 Schedule (months) =	2.5	months	

Service/Materials	Unit	Unit Cost		Subtotal
Contractor Office Labor:				
Sr. Geologist (E10)	44	$93.94	/hr	$4,133.36
Engineer/Scientist IV (E10)	44	$92.56	/hr	$4,072.64
Geologist (E08)	108	$68.82	/hr	$7,432.56
Engineer/Scientist III (E08)	108	$68.82	/hr	$7,432.56
Chemist III (E06)	40	$54.20	/hr	$2,168.00
Data Entry Technician (E04)	40	$45.00	/hr	$1,800.00
Contractor Field Labor:				
Site Manager (E06)	540	$57.06	/hr	$30,812.40
H&S Coordinator (E09)	540	$83.18	/hr	$44,917.20
QC/QA (E08)	540	$68.82	/hr	$37,162.80
Subcontractor Field Labor:				
Equipment Operator	32	$327.00	/day	$10,464.00
Equipment Operator	32	$327.00	/day	$10,464.00
Equipment Operator	32	$327.00	/day	$10,464.00
Equipment Operator	32	$327.00	/day	$10,464.00
Laborer	32	$288.00	/day	$9,216.00
Laborer	32	$288.00	/day	$9,216.00
Laborer	32	$288.00	/day	$9,216.00
Laborer	32	$288.00	/day	$9,216.00
Laborer	32	$288.00	/day	$9,216.00
Baseline Sampling:				
Sampling, analytical, and reporting	16	$2,000.00	/well	$32,000.00

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Former Plum Brook Ordnance Works, Sandusky, Ohio

6.0 Extraction and Reinjection Well Installation

Service/Materials	Unit	Unit Cost		Subtotal	
Equipment Rental:					
Excavator	1.5	$4,600.00	/month	$6,900.00	
Backhoe (85 hp)	1.5	$1,650.00	/month	$2,475.00	
Dozer (140 hp)	1.5	$4,350.00	/month	$6,525.00	
Trencher (diesel, 4 ft. deep, 12" width)	1.5	$6,550.00	/month	$9,825.00	
Dump truck (14 cy)	1.5	$3,590.00	/month	$5,385.00	
Pressure washer (2000 psi)	1.5	$480.00	/month	$720.00	
FOGM	1.5	$3,000.00	/month	$4,500.00	
Chemical toilets (x2)	1.5	$300.00	/month	$450.00	
Materials:					
4" gw pump (<7 gpm, <800 ft head, 1.5 hp, cntrls)	8	$3,750.00	/ea	$30,000.00	
Reinjection wellhead completion & vault	8	$3,500.00	/ea	$28,000.00	
Control panel	7	$2,500.00	/ea	$17,500.00	
3" dia. HDPE, SDR 21 pipe (welder & machine only)	3,000	$7.19	/linear foot	$21,570.00	
4" dia. HDPE, SDR 21 pipe (welder & machine only)	5,000	$8.44	/linear foot	$42,200.00	
Buried utility marking tape (foil backing)	8,000	$0.15	/linear foot	$1,200.00	
Valving and fittings (10% of pipe total)	1	$6,377.00	/lump sum	$6,377.00	
Package lift station (18 gpm)	1	$4,000.00	/lump sum	$4,000.00	
Drilling Subcontractor:					
Mobilization/demobilization (10-day rotation)	5	$5,000.00	/ea	$25,000.00	
Minirae 2000 (10.6)	12	$225.00	/week	$2,700.00	
4-inch PVC, schedule 40, well casing	1,076	$18.00	/vf	$19,368.00	
4-inch PVC, schedule 40, well screen	240	$25.00	/vf	$6,000.00	
8" roller cone soil drilling, casing installation	776	$80.00	/vf	$62,080.00	
6" roller cone bedrock drilling	540	$44.00	/feet	$23,760.00	
Install well and materials	16	$675.00	/feet	$10,800.00	
Furnish and Install flush well and pad	16	$500.00	/ea	$8,000.00	
Well development	8	$250.00	/ea	$2,000.00	
Decontamination	16	$150.00	/ea	$2,400.00	
Cleanup	16	$85.00	/ea	$1,360.00	
IDW disposal	16	$500.00	/ea	$8,000.00	
Travel:					
Perdiem	162	$39.00	/day	$6,318.00	
Lodging	162	$91.00	/night	$14,742.00	
Air Fare	6	$800.00	/trip	$4,800.00	
Rental Car	162	$46.00	/day	$7,452.00	
Rental Car FOGM	162	$12.00	/day	$1,944.00	
				Subtotal	**$654,200.00**

7.0 Installation of the Groundwater Treatment Systems

Includes:
1 Installation of the PRRWP WTP and WARWP WTP.

Assumptions:
1 Non-equipment costs estimated by factoring based on total equipment costs.
2 Flow rate of PRRWP WTP = 10.5 gpm
3 Flow rate of WARWP WTP= 6 gpm

Service/Materials	Unit	Unit Cost		Cost	
Plant and Equipment:					
Anoxic FBR Denitrification System	1	$250,000.00	/ea	$250,000.00	Total installed cost
Aerobic Bioreactor	1	$660,000.00	/ea	$660,000.00	Total installed cost
Subtotal - Biological Treatment Systems				**$910,000.00**	Total installed cost
Air Stripper	1	$15,000.00	/ea	$15,000.00	
Polymer Feed System	2	$4,000.00	/ea	$8,000.00	
Coagulation/Flocculation Tanks w/ Agitators	2	$8,000.00	/ea	$16,000.00	
Parallel Plate Clarifier	2	$17,000.00	/ea	$34,000.00	
Duplex Bag Filter w/ Pump	2	$11,000.00	/ea	$22,000.00	
Dual Bed Carbon Adsorber	1	$12,000.00	/ea	$12,000.00	
Sludge Storage Tank	2	$8,000.00	/ea	$16,000.00	
Filter Press w/ Pump	2	$25,000.00	/ea	$50,000.00	
Subtotal - Non-Biological Treatment Systems				**$173,000.00**	
Subtotal Equipment Cost				**$1,083,000.00**	
Miscellaneous					
Site Improvements	1	$108,300.00	/ea	$108,300.00	
Buildings	1	$194,940.00		$194,940.00	
Equipment Installation	1	$81,310.00	/ea	$81,310.00	
Instrumentation and Controls (Installed)	1	$43,250.00	/ea	$43,250.00	
Piping (Installed)	1	$114,180.00	/ea	$114,180.00	
Electrical (Installed)	1	$19,030.00	/ea	$19,030.00	
Utilities (Installed)	1	$541,500.00	/ea	$541,500.00	
Engineering and Supervision	1	$57,090.00	/ea	$57,090.00	
Construction Expense	1	$70,930.00	/ea	$70,930.00	
Subtotal Other Costs				**$1,230,530.00**	
				Subtotal	**$2,313,500.00**

Table 5-3

Alternative GW-4 Cost Estimate
TNT Manufacturing and Red Water Pond Areas Groundwater Feasibility Study Addendum
Former Plum Brook Ordnance Works, Sandusky, Ohio

8.0 ISEB - Emulsified Vegetable Oil Injection

Includes:
1. DPT Injection of emulsified vegetable oil in plumes designated in Table 3-6.
2. DPT injection implemented in a series of parallel biobarriers per Table 5-2.

Assumptions:
1. DPT rig, field truck, water truck and substrate metering system purchased outright for long-term project.
2. All field personnel hired direct for duration of project, therefore expenses for travel, lodging and meals not incurred.
3. Office engineer travels to the site 3 days (including travel) per month for duration of project.

Total Plume Areas

1. Total number of injection points =	8,173	points
2. Substrate demand =	2,076,850	pounds
3. Substrate density =	7.64	pounds/gal
4. Substrate demand per injection point =	254	pounds
5. Ratio substrate to water =	0.2	
6. Water required =	1,359	kgal
7. Injection points completed per day =	4	points/DPT crew*day
8. Estimated field duration =	2,044	crew days
9. Number of DPT crews =	1	crews
10. Estimated field duration =	2,044	work days
11. Work days per month =	22	work days/month
12. Estimated field duration =	93	months
13. Field workers per DPT crew =	2	workers/crew
14. Hours per Work Day =	8	hours/day
16. Number of supervisory crew =	2	workers

Service/Materials	Unit	Unit Cost		Cost	
Contractor Office Labor:					
Project Manager II (E11)	1,116	$106.75	/hr	$119,133.00	
Engineer Scientist IV (E10)	2,976	$ 92.56	/hr	$275,459.00	
Geologist (E08)	744	$68.82	/hr	$51,202.00	
Procurement Coordinator (N07)	744	$35.80	/hr	$26,635.20	
Contractor Field Labor:					
Site Manager (E06)	16,352	$ 57.06	/hr	$933,045.12	
Engineering Technician (N08)	16,352	$46.80	/hr	$765,273.60	
Equipment & Materials:					
EOS (incl. shipping)	2,076,850	$1.90	/lb	$3,946,015.00	
Dilution Water	1,359	$2.87	/kgal	$3,901.00	
Metering System	1	$25,000.00	/ea	$25,000.00	Purchased
Water truck	1	$30,000.00	/ea	$30,000.00	Purchased
Injection Supplies	93	$5,000.00	/month	$465,000.00	
Field Truck	1	$25,000.00	/ea	$25,000.00	Purchased
Rental Car FOGM	4,088	$12.00	/day	$49,056.00	
DPT Drilling Crew:					
DPT Rig	1	$140,000.00	/ea	$140,000.00	Purchased
Equipment Operator	4,088	$327.00	/day	$1,336,776.00	
Travel:					
Per Diem	279	$39.00	/day	$10,881.00	
Lodging	186	$67.20	/day	$12,499.20	
Air Fare	93	$800.00	/trip	$74,400.00	
Rental Car	279	$46.00	/day	$12,834.00	
				Subtotal	**$8,302,100.00**

Table 5-3

Alternative GW-4 Cost Estimate
TNT Manufacturing and Red Water Pond Areas Groundwater Feasibility Study Addendum
Former Plum Brook Ordnance Works, Sandusky, Ohio

9.0 Site Restoration, Testing and Demobilization

Includes:

1 Conduct hydrostatic pressure testing on pipe line and "shakedown/startup" testing of pumps and controls.
2 Site restoration including finish grading and seeding.
3 Demobilization

Assumptions:

1 Groundwater from wells will be used to hydrostatic test pipe lines, then it will be discharged to PRRWP WTP and WARWP WTP.
2 Dozer will finish grade areas as work is completed in line items above.
3 Testing and shakedown completed by contractor labor for one week duration.
4 Reference clearing areas in Section 3.0.
5 Demobilization of equipment was accounted for in Section 2.0.
6 Hours work per day = 10 hours
7 Schedule (10-hr workday) = 15 days
8 Schedule (5-day workweek) = 3 weeks
9 Schedule 0.7 months

Service/Materials	Unit	Unit Cost		Cost	
Office Labor:					
Sr. Geologist (E10)	12	$93.94	/hr	$1,127.28	
Engineer/Scientist IV (E10)	12	$92.56	/hr	$1,110.72	
Geologist (E08)	30	$68.82	/hr	$2,064.60	
Engineer/Scientist III (E08)	30	$68.82	/hr	$2,064.60	
Construction completion report	1	$12,500.00	/lump sum	$12,500.00	
LTM plan	1	$15,000.00	/lump sum	$15,000.00	
Contractor Field Labor:					
Site Manager (E06)	150	$57.06	/hr	$8,559.00	
H&S Coordinator (E09)	150	$83.18	/hr	$12,477.00	
QC/QA (E08)	150	$68.82	/hr	$10,323.00	
Engineer/Scientist III (E08) - Mechanical	50	$68.82	/hr	$3,441.00	
Engineer/Scientist III (E08) - Electrical	50	$68.82	/hr	$3,441.00	
Equipment Rental:					
Backhoe (85 hp)	1	$1,650.00	/month	$1,650.00	
Dozer (140 hp)	1	$4,350.00	/month	$4,350.00	
Pump for testing	1	$480.00	/month	$480.00	
Pressure washer (2000 psi)	1	$480.00	/month	$480.00	
FOGM	1	$3,000.00	/month	$3,000.00	
Subcontractor Field Labor:					
Equipment Operator	15	$327.00	/day	$4,905.00	
Equipment Operator	15	$327.00	/day	$4,905.00	
Laborer	15	$288.00	/day	$4,320.00	
Laborer	15	$288.00	/day	$4,320.00	
Subcontractor:					
Mob/Demob	1	$2,500.00	/ea	$2,500.00	
Seed, mulch, water	14.90	$4,700.00	/acre	$70,030.00	
Travel:					
Per diem	61	$39.00	/day	$2,379.00	
Lodging	61	$91.00	/day	$5,551.00	
Air Fare	5	$800.00	/trip	$4,000.00	
Rental Car	56	$46.00	/day	$2,576.00	
Rental Car FOGM	56	$12.00	/day	$672.00	
				Subtotal	**$188,200.00**

10.0 Groundwater Use Controls

Service/Materials	Unit	Unit Cost		Cost	
Land Use Control Implementation Plan	1	$30,000.00	/ea	$30,000.00	
				Subtotal	**$30,000.00**

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TNT Manufacturing and Red Water Pond Areas Groundwater Feasibility Study Addendum
Former Plum Brook Ordnance Works, Sandusky, Ohio

11.0 Annual Pump and Treat Operation and Maintenance (O&M), Years 1-30

Includes:
1 Groundwater Treatment System O&M
2 Installed Wells, Piping, and Site Facilities

Assumptions:
1 Field labor is local; therefore no cost for travel is included.
2 Annual reporting cost sufficient to cover five-year reviews.

Note:
Cost for capital improvements to replace substantial portions of the groundwater treatment systems are not included in this evaluation.

Service/Materials	Unit	Unit Cost			Cost	
I. Groundwater Treatment System O&M - PRRWP WTP and WARWP WTP						
Labor:						
Operator labor	2	$26,000.00	/ls		$52,000.00	
Management	2	$1,500.00	/ls		$3,000.00	
Materials:						
Filter replacement	2	$200.00	/ls		$400.00	
Carbon for Polishing, at 2ppm	1	$3,800.00	/ls		$3,800.00	
Chemical/Flocculants, at 20 ppm	1	$2,800.00	/ls		$2,800.00	
Utilities:						
Electric Power for Treatment System 4 pumps + 1 blower (3 heaps each)	2	$8,900.00	/ls		$17,800.00	
Disposal:						
Filter Cake Solids, lb/day	204	$2.00	/lb/day		$408.00	
Sampling:						
Water Sample Analysis	2	$16,800.00	/ls		$33,600.00	
Anoxic and Aerobic Equipment:						
Anoxic FBR Denitrification System	1	$327.00	/ea		$327.00	
Aerobic Bioreactor	1	$19,457.00	/ea		$19,457.00	
Miscellaneous:						
Reporting	2	$5,000.00	/ls		$10,000.00	
Maintenance	2	$4,000.00	/ls		$8,000.00	
				Subtotal	**$151,592.00**	
II. Installed Wells, Piping, and Site Facilities						
Monitoring, Extraction, and Reinjection Well Repairs	1	$5,000.00	/ls		$5,000.00	
Miscellaneous Repairs to Pipeline	1	$1,000.00	/ls		$1,000.00	
Field Office Utilities	1	$7,332.00	/ls		$7,332.00	
				Subtotal	**$13,332.00**	
					Subtotal	**$164,900.00**

Table 5-3

Alternative GW-4 Cost Estimate
TNT Manufacturing and Red Water Pond Areas Groundwater Feasibility Study Addendum
Former Plum Brook Ordnance Works, Sandusky, Ohio

12.0 O&M - Groundwater Monitoring and Institutional Controls: Years 1 - 5 (Annualized)

Includes:
1 Groundwater Monitoring

Includes:
1 Annual monitoring of 35 wells in the overburden/weathered shale and 33 wells in the bedrock zone for COCs.
2 Data verification, evaluation, and preparation of annual report

3 No. of wells sampled =	68	wells/event
4 Number of technicians in field crew =	2	personnel
5 Sampling time (per well) =	3	hrs/well
6 Sampling time per seep =	1	hrs/seep
7 Number of well sampling events =	1	events/year
8 Well sampling time =	20	days
9 Hours work per day =	10	hours

Data Management and QA/QC Assumptions:

Data Entry Technician (E04)	1	hr/sample
Chemist III (E06)	0.75	hr/sample
Database Manager (E08)	1.5	hr/sample
Senior Consultant I (E12)	0.175	hr/sample

Service/Materials	Unit	Unit Cost		Cost	
Office Labor:					
Project Manager II (E11)	20	$106.75	/hr	$2,135.00	
Senior Consultant I (E12)	10	$118.41	/hr	$1,184.10	
Engineer/Scientist III (E08)	40	$68.82	/hr	$2,752.80	
Engineer/Scientist II (E06)	100	$57.06	/hr	$5,706.00	
Data Entry Technician (E04)	68	$45.00	/hr	$3,060.00	
Chemist III (E06)	51	$54.20	/hr	$2,764.20	
Database Manager (E08)	102	$64.40	/hr	$6,568.80	
Senior Consultant I (E12)	12	$118.41	/hr	$1,420.92	
Secretary III (N06)	20	$34.80	/hr	$696.00	
Draftsperson (N08)	40	$53.36	/hr	$2,134.40	
Word Processor (N06)	20	$41.82	/hr	$836.40	
Field Labor:					
Engineering Technician III (N08)	200	$46.80	/hr	$9,360.00	
Engineering Technician III (N08)	200	$46.80	/hr	$9,360.00	
Materials:					
Sampling Equipment	1	$500.00	/event	$500.00	
Document Reproduction	1	$400.00	/ea	$400.00	
RDW Treatment and Disposal	1	$1,250.00	/event	$1,250.00	
Analytical:					
Analytical:	1	$16,219.00	/ls	$16,219.00	
Travel:					
Per Diem	40	$39.00	/day	$1,560.00	
Lodging	40	$91.00	/day	$3,640.00	
Air Fare	2	$800.00	/trip	$1,600.00	
Rental Car	40	$46.00	/day	$1,840.00	
Rental Car FOGM	40	$12.00	/day	$480.00	
Institutional Controls and 5-Year Review:					
Inspection and Reporting	1	$1,500.00	/yr	$1,500.00	
5 -Year Review (Annualized)	1	$1,500.00	/yr	$1,500.00	
				Subtotal	**$78,467.62**

Table 5-3

Alternative GW-4 Cost Estimate
TNT Manufacturing and Red Water Pond Areas Groundwater Feasibility Study Addendum
Former Plum Brook Ordnance Works, Sandusky, Ohio

13.0 O&M - Groundwater Monitoring and Institutional Controls: Years 6 - 25 (Annualized)

Includes:
1 Groundwater Monitoring

Includes:
1 Annual monitoring of 33 wells in the bedrock zone for COCs.
2 Data verification, evaluation, and preparation of annual report

3 No. of wells sampled =	33	wells/event
4 Number of technicians in field crew =	2	personnel
5 Sampling time (per well) =	3	hrs/well
6 Sampling time per seep =	1	hrs/seep
7 Number of well sampling events =	1	events/year
8 Well sampling time =	10	days
9 Hours work per day =	10	hours

Data Management and QA/QC Assumptions:

Data Entry Technician (E04)	1	hr/sample
Chemist III (E06)	0.75	hr/sample
Database Manager (E08)	1.5	hr/sample
Senior Consultant I (E12)	0.175	hr/sample

Service/Materials	Unit	Unit Cost		Cost	
Office Labor:					
Project Manager II (E11)	20	$106.75	/hr	$2,135.00	
Senior Consultant I (E12)	10	$118.41	/hr	$1,184.10	
Engineer/Scientist III (E08)	40	$68.82	/hr	$2,752.80	
Engineer/Scientist II (E06)	100	$57.06	/hr	$5,706.00	
Data Entry Technician (E04)	33	$45.00	/hr	$1,485.00	
Chemist III (E06)	25	$54.20	/hr	$1,355.00	
Database Manager (E08)	50	$64.40	/hr	$3,220.00	
Senior Consultant I (E12)	6	$118.41	/hr	$710.46	
Secretary III (N06)	20	$34.80	/hr	$696.00	
Draftsperson (N08)	40	$53.36	/hr	$2,134.40	
Word Processor (N06)	20	$41.82	/hr	$836.40	
Field Labor:					
Engineering Technician III (N08)	100	$46.80	/hr	$4,680.00	
Engineering Technician III (N08)	100	$46.80	/hr	$4,680.00	
Materials:					
Sampling Equipment	1	$500.00	/event	$500.00	
Document Reproduction	1	$400.00	/ea	$400.00	
RDW Treatment and Disposal	1	$1,250.00	/event	$1,250.00	
Analytical:					
Analytical:	1	$5,124.00	/ls	$5,124.00	
Travel:					
Per Diem	20	$39.00	/day	$780.00	
Lodging	20	$91.00	/day	$1,820.00	
Air Fare	2	$800.00	/trip	$1,600.00	
Rental Car	20	$46.00	/day	$920.00	
Rental Car FOGM	20	$12.00	/day	$240.00	
Institutional Controls and 5-Year Review:					
Inspection and Reporting	0	$1,500.00	/yr	$0.00	
5 -Year Review (Annualized)	1	$1,500.00	/yr	$1,500.00	
				Subtotal	**$45,709.16**

14.0 Total Capital Cost

Item	Unit	Unit Cost		Cost	
1 Groundwater Modeling, Remedial Design, Work Plans, and Procurement	1	$122,000.00	/ls	$122,000.00	
2 Mobilization	1	$65,400.00	/ls	$65,400.00	
3 Site Preparation, Clearing, and Layout	1	$172,600.00	/ls	$172,600.00	
4 Installation of Overburden Monitoring Wells	1	$256,923.53	/ls	$256,923.53	
5 Installation of Bedrock Monitoring Wells	1	$397,907.00	/ls	$397,907.00	
6 Extraction and Reinjection Well Installation	1	$654,200.00	/ls	$654,200.00	
7 Installation of the Groundwater Treatment Systems	1	$2,313,500.00	/ls	$2,313,500.00	
8 ISEB - Emulsified Vegetable Oil Injection	1	$8,302,100.00	/ls	$8,302,100.00	
9 Site Restoration, Testing and Demobilization	1	$188,200.00	/ls	$188,200.00	
10 Groundwater Use Controls	1	$30,000.00	/ls	$30,000.00	
				Total	**$12,502,830.53**

15.0 Total O&M Cost

Item	Unit	Unit Cost		Cost	
1 Years 1 - 5	5	$243,367.62	/yr	$1,216,838.10	
2 Years 6 - 30	25	$210,609.16	/yr	$5,265,229.00	
				Total	**$6,482,067.10**

Note: This is an 'order of magnitude' engineering cost estimate that is expected to be within + 50% to - 30% of actual project cost.

Table 5-4

Alternative GW-5a Cost Estimate
TNT Manufacturing and Red Water Pond Areas Groundwater Feasibility Study Addendum
Former Plum Brook Ordnance Works, Sandusky, Ohio

Alternative GW-5a	**Site:** PBOW
Groundwater Monitoring	Alternative GW-5a
	Date: 03/21/11

Scope:
1 Groundwater Monitoring Plan and Procurement
2 Mobilization
3 Installation of Bedrock Monitoring Wells
4 Total Capital Cost
5 Groundwater Monitoring and Institutional Controls: Years 1 - 30 (Every 5 Years)

1.0 Groundwater Monitoring Plan and Procurement

Includes:
1 Prepare Long-Term Groundwater Monitoring Plan.
2 Procure equipment, materials, and subcontracts.

Service/Materials	Unit	Unit Cost		Subtotal	
Long-Term Groundwater Monitoring Plan	1	$30,000.00	/ea	$30,000.00	
Contractor Office Labor:					
Mrg, Contract Admin (E09)	40	$77.75	/hr	$3,110.00	
Procurement Coordinator (N07)	20	$35.80	/hr	$716.00	
				Subtotal	**$33,826.00**

2.0 Mobilization

Includes:
1 Mobilize personnel, equipment, and subcontractors.
2 Conduct preconstruction conference.

Assumptions:
1 Allow two days to mobilize personnel, equipment, and subcontractors.
5 Hours work per day = 10 hours
6 Schedule (10-hr workday) = 2 days
7 Schedule (5-day workweek) = 0.4 weeks

Service/Materials	Unit	Unit Cost		Subtotal	
Contractor Office Labor:					
Geologist (E08)	20	$68.82	/hr	$1,376.40	
Engineering Technician III (N08)	20	$ 46.80	/hr	$936.04	
Equipment Rental:					
Pressure washer (2000 psi)	1	$100.00	/mobe-demobe	$100.00	
Travel:					
Perdiem	4	$39.00	/day	$156.00	
Lodging	4	$91.00	/night	$364.00	
Air Fare	2	$800.00	/trip	$1,600.00	
Rental Car	4	$46.00	/day	$184.00	
Rental Car FOGM	4	$12.00	/day	$48.00	
				Subtotal	**$4,765.00**

Table 5-4

Alternative GW-5a Cost Estimate
TNT Manufacturing and Red Water Pond Areas Groundwater Feasibility Study Addendum
Former Plum Brook Ordnance Works, Sandusky, Ohio

3.0 Installation of Bedrock Monitoring Wells

Includes:

1 Installation of Additional Bedrock Monitoring Wells using Hollow-Stem Auger/Air Rotary
2 Rock and groundwater sample collection for MNA lab tests
3 Development of Monitoring Wells
4 Well Constructed of 2-inch PVC with 15-feet of 0.010 Slot Continuous Wrap PVC Screen

Assumptions:

1 Number of New Bedrock Monitoring Wells:			15
2 Construct and Develop One Well =			3 days
3 Well Installation Field Days =			45 days
4 Hours work per day =	10	hours	
5 Schedule (10-hr workday) =	45	days	
6 Schedule (5-day workweek) =	9	weeks	
7 Schedule (months) =	2.3	month	

Service/Materials		Unit	Unit Cost	Cost	
Contractor Office Labor:					
Engineer/Scientist III (E08)		20	$68.82 /hr	$1,376.35	
Procurement Coordinator (N07)		16	$35.80 /hr	$572.80	
Secretary III (N06)		16	$34.80 /hr	$556.80	
Contractor Field Labor:					
Geologist (E08)		450	$ 68.82 /hr	$30,967.92	
Engineering Technician III (N08)		450	$ 46.80 /hr	$21,060.81	
Drilling Subcontractor:					
Mobilization		1	$2,500.00 /ea	$2,500.00	
Demobilization		1	$2,500.00 /ea	$2,500.00	
Posthole first 5 feet	5'	15	$25.00 /ea	$375.00	
Decon pad construction		5	$750.00 /ea	$3,750.00	
Drill soil with 12" HSA to bedrock	15'	225	$50.00 /ft	$11,250.00	
Cut 5' bedrock with 10" tricone roller bit	5'	75	$41.00 /ft	$3,075.00	
Install 6" steel casing	35'	525	$45.00 /ft	$23,625.00	
Cut bedrock with 6" OD tricone roller bit	35'	525	$44.00 /ft	$23,100.00	
2-inch ID, Sch 40, PVC casing	47.5'	713	$9.00 /ft	$6,412.50	
2-inch ID, Sch 40, PVC screen	'15	225	$12.00 /ft	$2,700.00	
2-inch Bedrock Well Construction		15	$1,200.00 /ft	$18,000.00	
Well Development		15	$1,200.00 /ea	$18,000.00	
Surface Completion		15	$425.00 /ea	$6,375.00	
Decontamination		15	$85.00 /ea	$1,275.00	
Site cleanup		15	$125.00 /ea	$1,875.00	
IDW disposal		15	$250.00 /ea	$3,750.00	
Surveying		15	$268.72 /ea	$4,030.80	
Travel:					
Per Diem		90	$39.00 /day	$3,510.00	
Lodging		90	$91.00 /day	$8,190.00	
Air Fare		9	$800.00 /trip	$7,200.00	
Rental Car		90	$46.00 /day	$4,140.00	
Rental Car FOGM		90	$12.00 /day	$1,080.00	
				Subtotal	**$211,248.00**

Alternative GW-5a Cost Estimate
TNT Manufacturing and Red Water Pond Areas Groundwater Feasibility Study Addendum
Former Plum Brook Ordnance Works, Sandusky, Ohio

4.0 O&M - Groundwater Monitoring: Years 1 - 30 (Every 5 Years)

Includes:
1 Groundwater monitoring for COCs only.
2 Data management and validation
3 Monitoring report

Assumptions:

1 No. of wells sampled =	15	wells/event
2 Number of QA samples =	5	samples/event
3 Number of technicians in field crew =	2	personnel
4 Sampling time (per well) =	3	hrs/well
5 Number of well sampling events =	1	events/year
6 Well sampling time =	5	days
7 Hours work per day =	10	hours

Data Management and QA/QC Assumptions:

Data Entry Technician (E04)	1	hr/sample
Chemist III (E06)	0.75	hr/sample
Database Manager (E08)	1.5	hr/sample
Senior Consultant I (E12)	0.175	hr/sample

Service/Materials	Unit	Unit Cost		Cost
Office Labor:				
Project Manager II (E11)	16	$106.75	/hr	$1,708.00
Senior Consultant I (E12)	10	$118.41	/hr	$1,184.10
Engineer/Scientist III (E08)	120	$68.82	/hr	$8,258.40
Engineer/Scientist II (E06)	40	$57.06	/hr	$2,282.40
Data Entry Technician (E04)	20	$45.00	/hr	$900.00
Chemist III (E06)	15	$54.20	/hr	$813.00
Database Manager (E08)	30	$64.40	/hr	$1,932.00
Senior Consultant I (E12)	4	$118.41	/hr	$473.64
Secretary III (N06)	8	$34.80	/hr	$278.40
Draftsperson (N08)	20	$53.36	/hr	$1,067.20
Word Processor (N06)	4	$41.82	/hr	$167.28
Field Labor:				
Engineering Technician III (N08)	50	$46.80	/hr	$2,340.00
Engineering Technician III (N08)	50	$46.80	/hr	$2,340.00
Materials:				
Sampling Equipment	5	$353.00	/day	$1,765.00
Supplies	1	$500.00	/event	$500.00
RDW Treatment and Disposal	1	$1,250.00	/event	$1,250.00
Analytical:				
NACs	20	$138.00	/ea	$2,760.00
SVOCs	8	$177.00	/ea	$1,416.00
Nitrate	8	$22.00	/ea	$176.00
Travel:				
Per Diem	10	$39.00	/day	$390.00
Lodging	10	$91.00	/day	$910.00
Air Fare	2	$800.00	/trip	$1,600.00
Rental Car	10	$46.00	/day	$460.00
Rental Car FOGM	10	$12.00	/day	$120.00
Institutional Controls and 5-Year Review:				
Inspection and Reporting	0	$1,500.00	/event	$0.00
5 -Year Review	1.0	$7,500.00	/event	$7,500.00
			Subtotal	**$42,591.00**

5.0 Total Capital Cost

Item	Unit	Unit Cost	Cost	
1 Groundwater Monitoring Plan and Procurement			$33,826.00	
2 Mobilization			$4,765.00	
3 Installation of Bedrock Monitoring Wells			$211,248.00	
		Total		**249,839.00**

6.0 Total O&M Cost

1 Years 1 - 30	6	$42,591.00 /yr	$255,546.00	
		Total		**$255,546.00**

Notes:
This is an 'order of magnitude' engineering cost estimate that is expected to be within + 50% to - 30% of actual project cost.

Table 5-5

Alternative GW-5b Cost Estimate
TNT Manufacturing and Red Water Pond Areas Groundwater Feasibility Study Addendum
Former Plum Brook Ordnance Works, Sandusky, Ohio

Alternative GW-5b		**Site:**	PBOW	
Institutional Controls			Alternative GW-5b	
		Date:	**03/21/11**	

Scope:
1 Groundwater Use Controls
2 Total Capital Cost
3 Institutional Controls and Site Reviews: Years 1 - 30 (Every 5 Years)

1.0 Groundwater Use Controls

Service/Materials	Unit	Unit Cost	Cost	
Land Use Control Implementation Plan	1	$30,000.00 /ea	$30,000.00	
			Subtotal	**$30,000.00**

2.0 O&M: Institutional Controls and Site Reviews: Years 1 - 30 (Every 5 Years)

Includes:
1 Inspections and reporting for institutional controls
2 Annualized cost of 5-year review

Institutional Controls and 5-Year Review:

	Unit	Unit Cost	Cost	
Inspection and Reporting	0	$1,500.00 /yr	$0.00	
5 -Year Review	1	$1,500.00 /yr	$1,500.00	
			Subtotal	**$1,500.00**

3.0 Total Capital Cost

Item	Unit	Unit Cost	Cost	
4 Groundwater Use Controls			$30,000.00	
			Total	**30,000.00**

4.0 Total O&M Cost

	Unit	Unit Cost	Cost	
1 Years 1 - 30	6	$1,500.00 /yr	$9,000.00	
			Total	**$9,000.00**

Notes:
This is an 'order of magnitude' engineering cost estimate that is expected to be within + 50% to - 30% of actual project cost.

Table 5-6

Present Value of O&M Costs
Remedial Alternatives for Groundwater
TNT and RWP Areas Groundwater Feasibility Study Addendum
Former Plum Brook Ordnance Works, Sandusky, Ohio

	Discount Rate = 0.027										
	Years of O&M =	30		30		30		30		30	
Year	Discount DF	Alternative GW-2 xt	Alternative GW-2 PV	Alternative GW-3 x_t	Alternative GW-3 PV	Alternative GW-4 x_t	Alternative GW-4 PV	Alternative GW-5a x_t	Alternative GW-5a PV	Alternative GW-5b x_t	Alternative GW-5b PV
1	0.973709834	$63,005.00	$61,349.00	$229,800.00	$223,759.00	$243,367.62	$236,969.00	$0.00	$0.00	$0.00	$0.00
2	0.948110842	$63,005.00	$59,736.00	$229,800.00	$217,876.00	$243,367.62	$230,739.00	$0.00	$0.00	$0.00	$0.00
3	0.923184851	$63,005.00	$58,165.00	$229,800.00	$212,148.00	$243,367.62	$224,673.00	$0.00	$0.00	$0.00	$0.00
4	0.898914168	$63,005.00	$56,636.00	$229,800.00	$206,570.00	$243,367.62	$218,767.00	$0.00	$0.00	$0.00	$0.00
5	0.875281566	$63,005.00	$55,147.00	$229,800.00	$201,140.00	$243,367.62	$213,015.00	$42,591.00	$37,279.00	$1,500.00	$1,313.00
6	0.852270269	$63,005.00	$53,697.00	$210,633.00	$179,516.00	$210,609.16	$179,496.00	$0.00	$0.00	$0.00	$0.00
7	0.829863942	$63,005.00	$52,286.00	$210,633.00	$174,797.00	$210,609.16	$174,777.00	$0.00	$0.00	$0.00	$0.00
8	0.808046682	$63,005.00	$50,911.00	$210,633.00	$170,201.00	$210,609.16	$170,182.00	$0.00	$0.00	$0.00	$0.00
9	0.786803001	$63,005.00	$49,573.00	$210,633.00	$165,727.00	$210,609.16	$165,708.00	$0.00	$0.00	$0.00	$0.00
10	0.76611782	$63,005.00	$48,269.00	$210,633.00	$161,370.00	$210,609.16	$161,351.00	$42,591.00	$32,630.00	$1,500.00	$1,149.00
11	0.745976455	$63,005.00	$47,000.00	$210,633.00	$157,127.00	$210,609.16	$157,109.00	$0.00	$0.00	$0.00	$0.00
12	0.726364611	$63,005.00	$45,765.00	$210,633.00	$152,996.00	$210,609.16	$152,979.00	$0.00	$0.00	$0.00	$0.00
13	0.707268365	$63,005.00	$44,561.00	$210,633.00	$148,974.00	$210,609.16	$148,957.00	$0.00	$0.00	$0.00	$0.00
14	0.688674163	$63,005.00	$43,390.00	$210,633.00	$145,058.00	$210,609.16	$145,041.00	$0.00	$0.00	$0.00	$0.00
15	0.670568805	$63,005.00	$42,249.00	$210,633.00	$141,244.00	$210,609.16	$141,228.00	$42,591.00	$28,560.00	$1,500.00	$1,006.00
16	0.65293944	$53,094.00	$34,667.00	$210,633.00	$137,531.00	$210,609.16	$137,515.00	$0.00	$0.00	$0.00	$0.00
17	0.635773554	$53,094.00	$33,756.00	$210,633.00	$133,915.00	$210,609.16	$133,900.00	$0.00	$0.00	$0.00	$0.00
18	0.619058962	$53,094.00	$32,868.00	$210,633.00	$130,394.00	$210,609.16	$130,379.00	$0.00	$0.00	$0.00	$0.00
19	0.6027838	$53,094.00	$32,004.00	$210,633.00	$126,966.00	$210,609.16	$126,952.00	$0.00	$0.00	$0.00	$0.00
20	0.586936514	$53,094.00	$31,163.00	$210,633.00	$123,628.00	$210,609.16	$123,614.00	$42,591.00	$24,998.00	$1,500.00	$880.00
21	0.571505856	$53,094.00	$30,344.00	$210,633.00	$120,378.00	$210,609.16	$120,364.00	$0.00	$0.00	$0.00	$0.00
22	0.556480872	$53,094.00	$29,546.00	$210,633.00	$117,213.00	$210,609.16	$117,200.00	$0.00	$0.00	$0.00	$0.00
23	0.541850898	$53,094.00	$28,769.00	$210,633.00	$114,132.00	$210,609.16	$114,119.00	$0.00	$0.00	$0.00	$0.00
24	0.527605548	$53,094.00	$28,013.00	$210,633.00	$111,131.00	$210,609.16	$111,119.00	$0.00	$0.00	$0.00	$0.00
25	0.513734711	$53,094.00	$27,276.00	$210,633.00	$108,209.00	$210,609.16	$108,197.00	$42,591.00	$21,880.00	$1,500.00	$771.00
26	0.50022854	$53,094.00	$26,559.00	$210,633.00	$105,365.00	$210,609.16	$105,353.00	$0.00	$0.00	$0.00	$0.00
27	0.487077449	$53,094.00	$25,861.00	$210,633.00	$102,595.00	$210,609.16	$102,583.00	$0.00	$0.00	$0.00	$0.00
28	0.474272102	$53,094.00	$25,181.00	$210,633.00	$99,897.00	$210,609.16	$99,886.00	$0.00	$0.00	$0.00	$0.00
29	0.46180341	$53,094.00	$24,519.00	$210,633.00	$97,271.00	$210,609.16	$97,260.00	$0.00	$0.00	$0.00	$0.00
30	0.449662522	$53,094.00	$23,874.00	$210,633.00	$94,714.00	$210,609.16	$94,703.00	$42,591.00	$19,152.00	$1,500.00	$674.00
Total		$1,741,485.00	$1,203,134.00	$6,414,825.00	$4,381,842.00	$6,482,067.10	$4,444,135.00	$255,546.00	$164,499.00	$9,000.00	$5,793.00

Notes:

1. Discount factor (DF) = $[1 / (1 + i)^t]$, where i = discount rate and t = year of payment
2. Discount rate from OMB Circular A-94, Appendix C, 2010 = 2.70%
3. Present value (PV) = DF * x_t, where x_t = payment in year t

O&M - Operation and maintenance.

Table 5-7

Remedial Cost Summary for Groundwater Alternatives
TNT Manufacturing and Red Water Pond Areas Groundwater Feasibility Study Addendum
Former Plum Brook Ordnance Works, Sandusky, Ohio

Cost Element	Alternative GW-1 No Further Action	Alternative GW-2 Mon/MNA/ICs	Alternative GW-3 Targeted ISEB/P&T	Alternative GW-4 ISEB/P&T	Alternative GW-5a Monitoring	Alternative GW-5b ICs
Capital Cost	$0	$539,000	$8,834,000	$12,503,000	$250,000	$30,000
Present Value O&M	$0	$1,203,000	$4,382,000	$4,444,000	$164,000	$6,000
Total Present Value	**$0**	**$1,742,000**	**$13,216,000**	**$16,947,000**	**$414,000**	**$36,000**
Minimum Present Value (-30%)	**$0**	**$1,219,000**	**$9,251,000**	**$11,863,000**	**$290,000**	**$25,000**
Maximum Present Value (+50%)	**$0**	**$2,613,000**	**$19,824,000**	**$25,421,000**	**$621,000**	**$54,000**

Notes:

Alternative GW-1: No Action

Alternative GW-2: Groundwater Monitoring, Monitored Natural Attenuation and Institutional Controls

Alternative GW-3: ISEB and Pump & Treat for Mitigation / Protection of the Delaware Limestone Bedrock Groundwater

Alternative GW-4: ISEB and Pump & Treat for Mitigation / Protection of the Overburden / Weathered Shale and Limestone Bedrock Groundwater

Alternative GW-5a: Groundwater Monitoring

Alternative GW-5b: Institutional Controls

Range of present value (PV) cost presented in the table represents a -30% (minimum PV) to +50% (maximum PV) contingency on the calculated present value.

ISEB - In situ enhanced bioremediation.

Mon - Groundwater monitoring.

O&M - Operation and maintenance.

A discount rate of 2.7% was used to calculate the present value of O&M costs (does not include inflation).

Reference: OSWER 9355.0-75, July 2000.

Table 6-1

Comparative Analysis of Remedial Alternatives for Groundwater
TNT and Red Water Pond Areas Groundwater Feasibility Study
Former Plum Brook Ordnance Works, Sandusky, Ohio

Criteria	**Alternative GW-1:** No Further Action	**Alternative GW-2:** Groundwater Monitoring, Monitored Natural Attenuation and Institutional Controls	**Alternative GW-3:** In Situ Enhanced Bioremediation/Pump and Treat for Mitigation/Protection of the Bedrock, Groundwater Monitoring, and Institutional Controls	**Alternative GW-4:** In Situ Enhanced Bioremediation/Pump and Treat for Mitigation/Protection of the Overburden/Shale and Bedrock, Groundwater Monitoring, and Institutional Controls	**Alternative GW-5:** Groundwater Monitoring and/or Institutional Controls
Protection of Human Health and the Environment					
Human Health Protection	Protective. The USACE maintains that on-site groundwater is not a potential source of drinking water and that on-site contamination will not impact off-site groundwater.	Protective. Legally enforceable groundwater use restrictions would be implemented to prevent the use of groundwater on site. Long-term groundwater monitoring would be performed to ensure that potential off-site groundwater users would not be exposed to contaminated groundwater from the site. Remedial action for groundwater could be taken if COCs in groundwater threaten potential off-site groundwater.	Protective. Legally enforceable groundwater use restrictions would be implemented to prevent the use of groundwater on site while the concentrations of COCs exceed the RGs. Groundwater monitoring would be performed to ensure that potential off-site groundwater users would not be exposed to contaminated limestone bedrock groundwater from the site. Remedial action for groundwater could be taken if COCs in groundwater threaten potential off-site groundwater. Targeted use of ISEB would be implemented to reduce the concentrations of COCs and prevent migration of COCs to limestone bedrock groundwater. P&T within the bedrock aquifer in the WARWP and PRRWP Areas would reduce concentrations of COCs in these plumes and prevent off-site migration of contaminated groundwater in these areas.	Protective. Legally enforceable groundwater use restrictions would be implemented to prevent the use of groundwater on site while the concentrations of COCs exceed the RGs. Groundwater monitoring would be performed to ensure that potential off-site groundwater users would not be exposed to contaminated limestone bedrock groundwater from the site. Remedial action for groundwater could be taken if COCs in groundwater threaten potential off-site groundwater. Use of ISEB would be implemented to reduce the concentrations of COCs to remedial goals in the overburden/shale groundwater and prevent migration of COCs to limestone bedrock groundwater. P&T within the bedrock aquifer in the WARWP and PRRWP Areas would reduce concentrations of COCs in these plumes and prevent off-site migration of contaminated groundwater in these areas.	Protective. The USACE maintains that on-site groundwater is not a potential source of drinking water and that on-site contamination will not impact off-site groundwater. Groundwater monitoring or institutional controls would be implemented, either separately or in combination. Groundwater monitoring would confirm that groundwater concentrations are not increasing over time. Institutional controls would prevent the use of on-site groundwater.
Environmental Protection	Protective. Impacted groundwater does not discharge to surface water. Thus, contaminated groundwater does not present a threat to ecological receptors or other environmental media.	Protective. Impacted groundwater does not discharge to surface water. Thus, contaminated groundwater does not present a threat to ecological receptors or other environmental media.	Protective. Impacted groundwater does not discharge to surface water. Thus, contaminated groundwater does not present a threat to ecological receptors or other environmental media.	Protective. Impacted groundwater does not discharge to surface water. Thus, contaminated groundwater does not present a threat to ecological receptors or other environmental media.	Protective. Impacted groundwater does not discharge to surface water. Thus, contaminated groundwater does not present a threat to ecological receptors or other environmental media.
Compliance with ARARs					
Chemical-Specific ARARs	No chemical-specific ARARs.	No chemical-specific ARARs.	No chemical-specific ARARs.	No chemical-specific ARARs.	No chemical-specific ARARs.
Location-Specific ARARs	No location-specific ARARs.	No location-specific ARARs.	No location-specific ARARs.	No location-specific ARARs.	No location-specific ARARs.
Action-Specific ARARs	No action-specific ARARs.	No action-specific ARARs.	No action-specific ARARs.	No action-specific ARARs.	No action-specific ARARs.
Other Criteria and Guidance	Toxicity data used to calculate RGs.	Toxicity data used to calculate RGs.	Toxicity data used to calculate RGs.	Toxicity data used to calculate RGs.	Toxicity data used to calculate RGs.
Long-Term Effectiveness and Permanence					
Magnitude of Residual Risk	The USACE believes that the potential residual risk is minimal or negligible at all five AOCs because on-site groundwater is not a viable source of drinking water and groundwater contamination is unlikely to migrate off site.	The USACE believes that the potential residual risk is minimal or negligible at all five AOCs because on-site groundwater is not a viable source of drinking water and groundwater contamination is unlikely to migrate off site. Monitored natural attenuation, groundwater monitoring, and institutional controls are additional measures to manage potential residual risk.	The USACE believes that the potential residual risk is minimal or negligible at all five AOCs because on-site groundwater is not a viable source of drinking water and groundwater contamination is unlikely to migrate off site. Groundwater treatment, groundwater monitoring, and institutional controls are additional measures to mitigate or manage potential residual risk.	The USACE believes that the potential residual risk is minimal or negligible at all five AOCs because on-site groundwater is not a viable source of drinking water and groundwater contamination is unlikely to migrate off site. Groundwater treatment, groundwater monitoring, and institutional controls are additional measures to mitigate or manage potential residual risk.	The USACE believes that the potential residual risk is minimal or negligible at all five AOCs because on-site groundwater is not a viable source of drinking water and groundwater contamination is unlikely to migrate off site. Groundwater monitoring and institutional controls, implemented either separately or in combination, are additional measures to manage potential residual risk.

Comparative Analysis of Remedial Alternatives for Groundwater
TNT and Red Water Pond Areas Groundwater Feasibility Study
Former Plum Brook Ordnance Works, Sandusky, Ohio

Criteria	**Alternative GW-1:** No Further Action	**Alternative GW-2:** Groundwater Monitoring, Monitored Natural Attenuation and Institutional Controls	**Alternative GW-3:** In Situ Enhanced Bioremediation/Pump and Treat for Mitigation/Protection of the Bedrock, Groundwater Monitoring, and Institutional Controls	**Alternative GW-4:** In Situ Enhanced Bioremediation/Pump and Treat for Mitigation/Protection of the Overburden/Shale and Bedrock, Groundwater Monitoring, and Institutional Controls	**Alternative GW-5:** Groundwater Monitoring and/or Institutional Controls
Adequacy and Reliability of Controls	No controls.	Groundwater use restrictions would prevent exposure to on-site groundwater. Annual groundwater monitoring would further evaluate the potential of contaminants to migrate off site. Controls would be maintained until RGs were met.	Groundwater use restrictions would prevent exposure to on-site groundwater. Annual groundwater monitoring would assess the effectiveness of groundwater treatment and further evaluate the potential of contaminants to migrate off site. Controls would be maintained until RGs were met.	Groundwater use restrictions would prevent exposure to on-site groundwater. Annual groundwater monitoring would assess the effectiveness of groundwater treatment and further evaluate the potential of contaminants to migrate off site. Controls would be maintained until RGs were met.	Groundwater use restrictions would prevent exposure to on-site groundwater. Groundwater monitoring would further evaluate the potential of contaminants to migrate off site. Groundwater monitoring would be performed every 5 years for a period of 30 years. Institutional controls would remain until RGs were met or a determination was made that these controls are no longer needed.
Reduction of Toxicity, Mobility or Volume through Treatment					
Treatment Process Used	No active treatment. Natural attenuation processes in the limestone bedrock may remove COCs that migrate from the overburden/shale.	No active treatment. Natural attenuation processes in the limestone bedrock may remove COCs that migrate from the overburden/shale.	ISEB and P&T. Injection of a carbon substrate into the overburden/shale groundwater for ISEB. Biological treatment would be used in the WARWP Area treatment system. A carbon adsorption system would be used in the PRRWP Area treatment system.	ISEB and P&T. Injection of a carbon substrate into the overburden/shale groundwater for ISEB. Biological treatment would be used in the WARWP Area treatment system. A carbon adsorption system would be used in the PRRWP Area treatment system.	No active treatment. Natural attenuation processes in the limestone bedrock may remove COCs that migrate from the overburden/shale.
Amount Destroyed or Treated	None.	None.	23.7 million gallons of overburden/shale groundwater to be treated over an area of 968,000 ft^2 and 260 million gallons of limestone bedrock groundwater extracted and treated from an area of 1,380,000 ft^2.	38.4 million gallons of overburden/shale groundwater to be treated over an area of 1,411,700 ft^2 and 260 million gallons of limestone bedrock extracted and treated from an area of 1,380,000 ft^2.	None.
Irreversible Treatment	None.	None.	COCs would be biologically degraded or irreversibly transformed into less toxic and immobile reaction products.	COCs would be biologically degraded or irreversibly transformed into less toxic and immobile reaction products.	None.
Type and Quantity of Residuals Remaining after Treatment	None.	None.	Both P&T systems would generate bag filters, spent activated carbon, and filter cake that would require off-site disposal.	Both P&T systems would generate bag filters, spent activated carbon, and filter cake that would require off-site disposal.	None.
Short-Term Effectiveness					
Community Protection	No short-term threat to community because no action would be taken.	Monitoring wells would be constructed so that H_2S odors were mitigated.	P&T systems and monitoring wells would be constructed so that H_2S odors were mitigated.	P&T systems and monitoring wells would be constructed so that H_2S odors were mitigated.	Monitoring wells would be constructed so that H_2S odors were mitigated.
Worker Protection	No risk to workers because no action would be taken.	Site workers would be protected through implementation of remedial action health and safety plan and groundwater use restrictions.	Site workers would be protected through implementation of remedial action health & safety plan and groundwater use restrictions.	Site workers would be protected through implementation of remedial action health and safety plan and groundwater use restrictions.	Site workers would be protected through implementation of remedial action health and safety plan and groundwater use restrictions.
Environmental Impacts	No short-term environmental impact.	No short-term environmental impact.	No short-term environmental impact.	No short-term environmental impact.	No short-term environmental impact.

Comparative Analysis of Remedial Alternatives for Groundwater
TNT and Red Water Pond Areas Groundwater Feasibility Study
Former Plum Brook Ordnance Works, Sandusky, Ohio

Criteria	**Alternative GW-1:** No Further Action	**Alternative GW-2:** Groundwater Monitoring, Monitored Natural Attenuation and Institutional Controls	**Alternative GW-3:** In Situ Enhanced Bioremediation/Pump and Treat for Mitigation/Protection of the Bedrock, Groundwater Monitoring, and Institutional Controls	**Alternative GW-4:** In Situ Enhanced Bioremediation/Pump and Treat for Mitigation/Protection of the Overburden/Shale and Bedrock, Groundwater Monitoring, and Institutional Controls	**Alternative GW-5:** Groundwater Monitoring and/or Institutional Controls
Time Until Action is Complete	Not applicable. No action taken.	Groundwater monitoring well construction would be completed and institutional controls would be established within the first year. Groundwater monitoring would continue and institutional controls would remain in place for 30 years.	ISEB would be completed in about 4 years. P&T systems should be completed in about 2 years. Groundwater monitoring well construction would be completed and institutional controls would be established within the first year. The P&T system would operate, groundwater monitoring would continue and institutional controls would remain in place for 30 years.	ISEB would be completed in about 8 years. P&T systems should be completed in about 2 years. Groundwater monitoring well construction would be completed and institutional controls would be established within the first year. The P&T system would operate, groundwater monitoring would continue and institutional controls would remain in place for 30 years.	Groundwater monitoring well construction would be completed and institutional controls would be established within the first year. Groundwater monitoring would continue and institutional controls would remain in place for 30 years.
Implementability					
Ability to Construct and Operate	No construction or operation.	Construction of monitoring wells only. No operation of treatment systems.	Technology is readily implementable. Additional data should be collected prior to full-scale implementation of the ISEB and P&T technologies to ensure that they will be effectively implemented. The groundwater plumes at target areas should have well-defined boundaries. The distribution of COCs and potential competing electron acceptors should be well understood so that the demand for carbon substrate can be predicted and the configuration of injection points can be designed effectively for ISEB areas. Of particular concern is the concentration of sulfate and nitrate throughout the ISEB target area at the PRRWP plume. The available data indicate that sulfate would exert a high demand on carbon substrate within this plume, leading to potentially costly ISEB implementation.	Technology is readily implementable. Additional data should be collected prior to full-scale implementation of the ISEB and P&T technologies to ensure that they will be effectively implemented. The groundwater plumes at target areas should have well-defined boundaries. The distribution of COCs and potential competing electron acceptors should be well understood so that the demand for carbon substrate can be predicted and the configuration of injection points can be designed effectively for ISEB areas. Of particular concern is the concentration of sulfate and nitrate throughout the ISEB target area at the PRRWP plume. The available data indicate that sulfate would exert a high demand on carbon substrate within this plume, leading to potentially costly ISEB implementation.	Construction of monitoring wells only. No operation of treatment systems.
Ease of Doing More Action if Needed	No further action would be taken.	Does not preclude additional action.	ISEB may continue beyond projected time frame until short-term objectives related to protection of the limestone bedrock groundwater are met. Additional injection/extraction wells may be installed and treatment capacity augmented if needed. Alternative does not preclude additional action.	ISEB may continue beyond projected time frame until short-term objectives related to restoration of the overburden/shale groundwater are met. Additional injection/extraction wells may be installed and treatment capacity augmented if needed. Alternative does not preclude additional action.	Does not preclude additional action
Ability to Monitor Effectiveness	No monitoring required.	Effectiveness gauged through groundwater monitoring.	Effectiveness gauged through groundwater monitoring.	Effectiveness gauged through groundwater monitoring.	Effectiveness gauged through groundwater monitoring.
Ability to Obtain Approvals and Coordinate with Other Agencies	None required.	Coordination with state and local authorities on institutional controls.	Coordination with OEPA UIC representatives on ISEB activities. Coordination with state and local authorities on institutional controls.	Coordination with OEPA UIC representatives on ISEB activities. Coordination with state and local authorities on institutional controls.	Coordination with state and local authorities on institutional controls.

Comparative Analysis of Remedial Alternatives for Groundwater
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Availability of Equipment, Specialists, and Materials	None required.	Specialized laboratories are required for preparation of ^{14}C-labeled nitroaromatic compounds and completion of radiorespirometry tests.	Equipment, specialists and materials available. Scale of project may be difficult for USACE to fund entire scope. Remedial action may need to be implemented in a phased approach.	Equipment, specialists and materials available. Scale of project may be difficult for USACE to fund entire scope. Remedial action may need to be implemented in a phased approach.	Readily available.
Availability of Technologies	None required.	None required.	Available and well developed	Available and well developed	
Cost					
Capital Cost Estimate	$0	$539,000	$8,834,000	$12,503,000	$250,000 (GW-5a) $30,000 (GW-5b)
Present Value O&M Cost Estimate	$0	$1,203,000	$4,382,000	$4,444,000	$164,000 (GW-5a) $6,000 (GW-5b)
Present Worth Cost Estimate	$0	$1,742,000	$13,216,000	$16,947,000	$414,000 (GW-5a) $36,000 (GW-5b)
Present Worth Estimated Range (-30%/+50%)	$0	$1,219,000 to $2,613,000	$9,251,000 to $19,824,000	$11,863,000 to $25,421,000	$290,000 to $621,000 (GW-5a) $25,000 to $54,000 (GW-5b)
State Acceptance					
State Acceptance	To be determined.	To be determined.	To be determined.	To be determined.	To be determined.
Community Acceptance					
Community Acceptance	To be determined.	To be determined.	To be determined.	To be determined.	To be determined.

AOC – Area of concern.
ARAR – Applicable or relevant and appropriate requirement.
COC – Contaminant of concern.
ft^2 – Square feet.
GW – Groundwater.
H_2S – Hydrogen sulfide.
ISEB – In situ enhanced bioremediation.
OEPA – Ohio Environmental Protection Agency.
P&T – Pump and treat.
PBOW – Plum Brook Ordnance Works.
PRRWP – Pentolite Road Red Water Pond.
RG – Remedial goal.
UIC – Underground injection control.
USACE – U.S. Army Corps of Engineers.
WARWP – West Area Red Water Ponds.

RESPONSE TO COMMENTS

Response to External Comments
Draft Feasibility Study Addendum for Groundwater,
TNT and Red Water Pond Areas
Plum Brook Ordnance Works, Sandusky, Ohio,
Dated March 25, 2011
FUDS Project No. G05OH001826

Comments by Janusz Z. Byczkowski, Ph.D., received May 20, 2011.

Comment 1: **General Remark. I would suggest minor revision of the Document. All errors, already pointed out by the OEPA reviewers in the previous comments should be corrected also in this Addendum. This Document should be re-check for typos and errors.**

Response 1: **The document will be re-checked for errors. We note that the reviewer is the only OEPA reviewer who has submitted comments on this document.**

Comment 2: **Executive Summary, Page ES-3, line 1; Page 5-3, Section 5.1.2, Line 11; Page 5-5, Section 5.1.4, Line #11; Table 6-1, Column 2. This Document states: "*…The alternative does not implement any controls to manage potential residual risk* […] *The alternative does not present any short-term risks to the community, site workers, or the environment…*" "*…Alternative GW-1 would protect human health and the environment…*" "*…The USACE maintains that the potential residual risk at all five AOCs is low because groundwater is not a viable source of drinking water and groundwater contamination is unlikely to migrate off site…*" and then, in Table 6-1: "*…the potential residual risk is minimal or negligible at all five AOCs…*" .**

As written, these statements could be misleading to risk managers and/or to the public. Thus, the environmental and health protectiveness of the "*no further action*" alternative *GW-1* is not supported by the results of baseline risk assessment (BRA). Since the risk of exposure to contaminants detected in ground water for some on-site receptors (e.g., construction worker) was not quantified in BRA and the assumption of "*incomplete pathway*" for off-site residents was based on unverifiable self-declaration survey (in its conclusion, the document states: "*…while private wells were present in downgradient areas, they are not used for potable water…*"), the protectiveness of this alternative is simply unknown. Also, given the uncertainty inherent to modeling methodology, the BRA did not exclude the possibility of the ground water contaminants off-site migration, over time. Please emphasize, that the health protectiveness of alternative GW-1 is uncertain for off-site residents and unknown for some on-site receptors.

Response 2: The construction worker was quantitatively evaluated for exposure to bedrock groundwater in the baseline human health risk assessment (BHHRA) for the TNT and Red Water Pond (RWP) Areas (Shaw, 2006). Only at the West Area Red Water Pond (WARWP) site was exposure to groundwater found to pose a site-related risk or hazard that exceeded the PBOW criteria of a hazard index (HI) of 1 or an incremental lifetime cancer risk (ILCR) of 1E-5. The site-related hazard index for the construction worker at the WARWP was 9; the site-related HI at the other four sites was less than 1 for the construction worker. The site-related ILCR at all five TNT and RWP sites was less than 1E-5 for the construction worker. Please note that based on discussions between USACE and OEPA risk assessors, it was agreed that because of its discontinuous, seasonally dependent nature, the overburden groundwater did not yield enough water to be used as a viable groundwater source and was not quantitatively evaluated for direct exposure. As stated in the groundwater BHHRA work plan (Shaw, 2005), "… perched groundwater in the vicinity of the former TNT manufacturing areas and red water ponds is not regarded as a potential source of potable water because it is isolated, discontinuous, and seasonally dependent; these characteristics result in low (if any) and undependable yield. It is possible that a construction worker may be exposed to perched water via direct contact; however, such exposure would likely be sporadic and of short duration. Therefore, the BHHRA will not quantitatively evaluate exposure to perched groundwater. As mentioned in Section 1.3, the potential impact of nitroaromatics in perched overburden groundwater on the bedrock unit is being modeled." This approach was likewise followed in the BHHRA (2006).

Exposure to bedrock groundwater at three of the sites (TNTA and the two RWP sites) was shown in the BHHRA to result in site-related cancer risk and noncancer hazard levels that, in at least the resident receptor, exceeded the PBOW ILCR and HI criteria. It is also noted that all five TNT and RWP sites have at least one receptor where the non-site related risk and hazard exceed the PBOW ILCR and HI criteria. Moreover, no site-related risks or hazards were identified in TNTB or TNTC groundwater, and the site-related risks at TNTA and the Pentolite Road RWP Area were much lower than the risks associated with naturally occurring background constituents in the groundwater underlying these sites.

The USACE asserts that because naturally occurring groundwater underlying the TNT and RWP Areas is nonpotable due to naturally occurring petroleum and high hydrogen sulfide, with several locations that exceed the criterion of 250 milligrams per liter for Ohio potable water, there is no complete exposure pathway for groundwater underlying the TNT and RWP sites. This position was corroborated by the off-site groundwater survey conducted by the USACE in 2003, described in the following paragraph.

The preliminary results of the off-site groundwater survey were presented during the September 18, 2003 PBOW Team Meeting in Sandusky, Ohio. There is no record of the OEPA objecting to the survey method or commenting on the results. In summary, the survey was conducted within a 1-mile radius in the downgradient direction, arcing from west through north to east of the PBOW facility boundary. The survey essentially found that all nearby residents use municipal water as a potable source; none are known to use groundwater as a potable source. Of the six known private wells located within 1 mile of PBOW, the owners of five participated in the well survey/sampling event. Three of these wells were being used for watering lawns and gardens, one was being used to irrigate an herb farm, and the fifth well was not being used for any purpose. Essentially, nitroaromatics were not detected in any of these wells. It is noted that a duplicate sample initially reported a low concentration of 1,3-dinitrobenzene (1.3 µg/L). When resampled, no nitroaromatics were detected in this well at a practical quantitation limit of 0.25 µg/L. Please note that because no nitroaromatics were detected in off-site groundwater, this pathway is by definition incomplete.

Although the groundwater leaching model indicated a potential for nitroaromatics concentrations in the bedrock groundwater to increase substantially, detections of nitroaromatics in bedrock monitoring wells have been sporadic. When detected, nitroaromatics concentrations are low compared to those predicted by the leaching model. Reducing conditions in the groundwater have been discussed thoroughly. It appears that such reducing conditions are responsible for the paucity of nitroaromatics in bedrock groundwater.

In summary, the USACE agrees that uncertainties exist with respect to the potential concentrations of nitoraromatics in groundwater. However, given the reducing conditions and the fact that more than 65 years after site closure, little contamination is found in the on-site bedrock groundwater and no contamination has been found off site, it would appear that on-site groundwater concentrations are unlikely to increase and that any contamination will remain within the property boundary. Also, the poor quality of bedrock groundwater with respect to natural conditions represents the lack of a legal basis for groundwater remediation.

Comment 3: **This Document states: "…*The USACE maintains that the potential residual risk at all five AOCs is low because groundwater is not a viable source of drinking water and groundwater contamination is unlikely to migrate off site*…" See comment # 2 above. Please emphasize, that the health protectiveness of alternatives (especially without monitoring) may be uncertain for off-site residents and it is unknown for some potential on-site receptors.**

Response 3: Please see response to Comment No. 2.

References Used in Responses:

Shaw Environmental, Inc. (Shaw), 2006, ***Baseline Human Health Risk Assessment of Groundwater Work Plan, Final, Former Plum Brook Ordnance Works, Sandusky, Ohio***, September.

Shaw Environmental, Inc. (Shaw), 2005, ***Baseline Human Health Risk Assessment of Groundwater Work Plan, Final, Former Plum Brook Ordnance Works, Sandusky, Ohio***, October.