US Army Corps
of Engineers®
New York District

FUSRAP

Final Feasibility Study Report
Groundwater Operable Unit OU2

Middlesex Sampling Plant FUSRAP Site
Middlesex, New Jersey

October 2017

PREPARED BY:

U.S. Army Corps Of Engineers
Formerly Utilized Sites Remedial Action Program

ecology and environment, inc.

Completion of Independent Technical Review

Project: Middlesex Sampling Plant FUSRAP Site
Deliverable: Final Feasibility Study Report
Revision and Date: 08/18/17

Ecology and Environment, Inc. has completed the above referenced deliverable. Notice is hereby given that an independent technical review, that is appropriate to the level of risk and complexity inherent in the project, has been conducted as defined in the Contractor Quality Control Plan. During the independent technical review, compliance with established policy principles and procedures, utilizing justified and valid assumptions, was verified. This included review of: assumptions; methods, procedures, and material used in analyses; alternatives evaluated; the appropriateness of data used and level obtained; and reasonableness of the result, including whether the product meets the customer's needs consistent with law and existing USACE policy. The independent technical reviewers confirmed that all comments were responded to and the changes made in the documents as stated. The independent technical review was accomplished by following signatories. All comments resulting from ITR have been resolved.

Date: 08/18/17
Independent Technical Review Team Leader/Project Manager

Date: 08/18/17
Program Manager

As noted above, all concerns resulting from independent technical review of the project have been considered.

Jacquelyn C Gillings
Date: 08/18/17
Quality Control Manager

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ACRONYMS

°F	degrees Fahrenheit
1,1-DCE	1,1-dichloroethene
AEC	Atomic Energy Commission
ARAR	Applicable or Relevant and Appropriate Requirement
bgs	below ground surface
BNI	Bechtel National, Inc.
CEA	Classification Exception Area
CERCLA	Comprehensive Environmental Response, Compensation, and Liability Act
CFR	Code of Federal Regulations
COC	chemical of concern
COPC	chemical of potential concern
CSM	Conceptual Site Model
CT	carbon tetrachloride
DO	dissolved oxygen
EB	enhanced bioremediation
ES	environmental surveillance
ESV	ecological screening value
EZVI	emulsified zero valent iron
FS	Feasibility Study
FUSRAP	Formerly Utilized Sites Remedial Action Program
GAC	granular activated carbon
gpm	gallon per minute
GRA	General Response Action
GWQS	Groundwater Quality Standard
HAER	Historic American Engineering Record
HHRA	human health risk assessment
HI	Hazard Index
HRC©	hydrogen release compound
IC	institutional control
ISCO	in situ chemical oxidation
ISCR	in situ chemical reduction
ITRC	Interstate Technology & Regulatory Council
LTM	Long-Term Monitoring
LUC	land use control
MCL	maximum contaminant level
MED	Manhattan Engineering District
µg/L	micrograms per liter
mg/kg	milligram per kilogram
mg/L	milligrams/liter
MML	Middlesex Municipal Landfill
MNA	monitored natural attenuation

ACRONYMS (continued)

MPE	multiphase extraction
MSP	Middlesex Sampling Plant
MTBE	methyl-tert-butyl-ether
MW	monitoring well
NAPL	non-aqueous phase liquid
NCP	National Oil and Hazardous Substances Pollution Contingency Plan
NJAC	New Jersey Administrative Code
NJDEP	New Jersey Department of Environmental Protection
NJPDES	New Jersey Pollutant Discharge Elimination System
NPL	National Priorities List
NTU	nephelometric turbidity units
NWS	National Weather Service
O&M	operation and maintenance
ORNL	Oak Ridge National Laboratory
ORP	oxidation reduction potential
OU	Operable Unit
PCE	tetrachloroethene
pCi/g	picocuries per gram
POTW	publicly owned treatment works
PQL	practical quantitation limit
PRG	preliminary remediation goal
RA	remedial action
RAOs	remedial action objectives
RfD	reference dose
RI	Remedial Investigation
RI/FS	Remedial Investigation/Feasibility Study
RME	reasonable maximum exposure
ROD	Record of Decision
SCS	Soil Conservation Services
SE	sampling event
SLERA	screening level ecological risk assessment
SVOC	semi-volatile organic compound
TBA	tert-butyl-alcohol
TBC	to be considered
TCE	trichloroethene
TSS	total suspended solids
ULC	United Lead Company
USACE	U.S. Army Corps of Engineers
USDA	U.S. Department of Agriculture
USDOE	U.S. Department of Energy
USEPA	U.S. Environmental Protection Agency
USFWS	U.S. Fish and Wildlife Service
VOC	volatile organic compound

ACRONYMS (continued)

VP	Vicinity Property
Weston	Roy F. Weston
yd^3	cubic yard
ZVI	zero valent iron

EXECUTIVE SUMMARY

The U.S. Army Corps of Engineers (USACE) has initiated a remediation program at the Middlesex Sampling Plant (MSP or site) in Middlesex, New Jersey. The remedial effort at the site addresses soils, sediment, surface water, and groundwater impacted by radioactive and/or chemical materials. Remedial investigations (RI) of soil and groundwater at the MSP were addressed under two Operable Units (OUs) by the USACE from 1999 through 2016. OU1 addresses soil and OU2 addresses groundwater. The purpose of this Feasibility Study (FS) is to develop and evaluate a range of remedial action alternatives for groundwater (OU2) at the MSP site based on the nature and extent of contamination. The extent of groundwater contamination and the need to take a remedial action is documented in the *Groundwater Operable Unit Remedial Investigation Report, Middlesex Sampling Plant, Middlesex, New Jersey* (USACE, 2005a), a subsequent groundwater investigation conducted in the fall of 2004 to further delineate the extent of the contamination off-site (Appendix B, "Off-Site Groundwater Delineation Investigation"), and a supplementary bedrock groundwater investigation conducted between 2008 and 2016 (USACE, 2017). The Groundwater OU at the MSP includes sediment, surface water, and groundwater. The specific contamination addressed by this FS is groundwater contamination resulting from activities at the site, which includes Formerly Utilized Sites Remedial Action Program (FUSRAP)-related contamination.

The MSP was established in 1943 by the Manhattan Engineering District (MED) to sample, store, test, and transfer ores containing uranium, thorium, and beryllium. Over the years that the MSP was operational, the buildings, grounds, and nearby land parcels became contaminated predominantly with radium and uranium. The plant site is no longer operational and was placed on the U.S. Environmental Protection Agency's (USEPA) National Priorities List (NPL) in 1999 under the Federal Facilities Program. Cleanup of the site is being addressed under FUSRAP, with USACE as the lead agency for site activities, and USEPA Region II as the support agency with oversight responsibilities. Remedial plans and activities are also being coordinated with the appropriate New Jersey State agencies, including the New Jersey Department of Environmental Protection (NJDEP).

The MSP Soils OU has been addressed pursuant to the *Soils Operable Unit Feasibility Study Report Middlesex Sampling Plant, Middlesex, New Jersey* (USACE, 2005b). The Soils OU remedial action (RA) was conducted in accordance with the *Soils Operable Unit Record of Decision Middlesex Sampling Plant, Middlesex, New Jersey* (USACE, 2005c), which was the excavation of soil and debris contaminated with radioactive and chemical waste above the criteria for residential use of the site. The excavated material was subsequently transported and disposed of off-site at a licensed or permitted facility. Excavation and off-site disposal of radiologically and chemically contaminated soil as part of the Soils OU RA was completed in June 2008.

The development of this Groundwater FS relies on the results of the remedial action completion report indicating that on-site soil contaminants above action levels have been removed. Consequently, a major source of groundwater contamination has been removed, and no further contaminant migration/loading from the soils to the groundwater is anticipated. However, residual levels of groundwater contamination are expected to remain and thus, the reason to evaluate the need for possible alternatives for a final RA for groundwater located at the MSP. It is important to note that the Applicable or Relevant and Appropriate Requirements (ARARs) for the Soils OU remedy were developed to be protective of receptors of contaminated groundwater, and thus address the impact of contaminated soils on groundwater.

Early groundwater investigations conducted at the site included the Groundwater OU Remedial Investigation (RI) conducted in 2000 to 2002 (USACE, 2005a), and the environmental surveillance (ES) program conducted from 2000 through 2008. During these evaluations, groundwater samples were collected and analyzed to identify chemicals of potential concern (COPCs) that are present in groundwater at the site. Based on the Soils OU (OU1), a primary focus of the groundwater investigations was to determine the concentration and extent of total uranium, as well as examine specific parameters associated with natural attenuation of total uranium. In the fall of 2004, a supplemental investigation was conducted to further delineate the extent of the contamination off site (Appendix B). In 2009, groundwater samples from the MSP detected volatile organic compounds (VOCs) at concentrations that exceeded their respective comparison criteria (USEPA Maximum Contaminant Level [MCL] and/or the NJDEP Specific Ground Water Quality Criteria for Class IIA aquifers). This resulted in a supplementary bedrock groundwater investigation being conducted between 2010 and 2016 (USACE, 2017).

The primary medium addressed in this FS is groundwater. Analytical data from groundwater samples adequately characterize the site so remedial action alternatives can be identified and evaluated. Based on the findings presented in the groundwater investigation reports and the results of the risk assessments completed for the MSP, the surface water and sediment do not pose unacceptable risks. Therefore, surface water and sediments do not require further evaluation in this FS. However, contaminant concentrations were detected in both on-site and off-site groundwater samples at levels posing unacceptable risks, which have been established for protection of human health and the environment.

ES.1 RISK SUMMARY

Two human health risk assessments (HHRAs) were conducted for MSP groundwater. A Baseline HHRA was developed in 2005 as part of the Groundwater OU RI (USACE, 2005a). A Supplemental HHRA was completed using groundwater data collected during the 2014 through 2016 investigations; the Supplemental HHRA is included as Appendix A of the Groundwater Investigation Technical Memorandum, which is an addendum to the RI (USACE, 2017). All HHRAs evaluated hypothetical future groundwater pathways. Groundwater at the site is not currently used, and there are no current plans for its use in the future. Current USEPA guidelines for acceptable exposures are a reasonable maximum individual lifetime excess cancer risk in the range of $1x10^{-4}$ to $1x10^{-6}$ (corresponding to a 1 in 10,000 to 1 in 1,000,000 increase in the probability of cancer as opposed to a 1 in 3 normal background risk). For non-cancer health effects, a “Hazard Index” (HI) is calculated. The key concept for a non-cancer HI is that a “threshold level” (measured as an HI of 1) exists below which non-cancer health effects are not expected to occur.

Baseline HHRA

The Baseline HHRA evaluated the risks from contaminants (radionuclides, VOCs, semi-volatile organic compounds [SVOCs], and metals) in on-site groundwater to hypothetical future residential receptors at the site. This Baseline HHRA concluded that:

- The potential cancer risks associated with groundwater were approximately 1 x 10^{-4} for site-wide average concentrations, which is equal to the upper limit of USEPA's acceptable risk range. The potential cancer risk at the well showing the highest radiological contamination, well B18W24S, was 6 x 10^{-4}. Ingestion of uranium in drinking water was the greatest contributor to the risk.
- Hazard indices exceeded the non-cancer hazard index (HI) of 1 for the residential scenario for average site-wide groundwater exposure. The exceedance was primarily due to the concentration of manganese, which appeared to be present as a natural background constituent. Uranium and carbon tetrachloride (CT) contributed to HIs greater than 1 in two monitoring wells.
- The annual radiation dose from drinking water (i.e., groundwater) projected for a site resident was 10 mrems/year. The NJDEP (NJAC 7:28-12), all pathways, 15 mrem annual dose was exceeded in one well (B18W24S).
- Exposure to sediments and surface water at the MSP posed a cancer risk of 2 x 10^{-5}, which is within USEPA's acceptable risk range. Non-cancer health effects from sediments and surface water were considered unlikely.

Based on the cancer risks and health hazards calculated, the following contaminants were identified as significant contaminants in the Baseline HHRA: total uranium (as a toxic metal); uranium-238 and uranium-234 (as radiological contaminants); CT; and manganese. However, elevated manganese concentrations were determined to represent naturally occurring background conditions at the site (Serfes, 1994) and historical records of government activities at the site do not indicate its use or possible use. Therefore, manganese was not retained as a significant contaminant.

Supplemental HHRA

The Supplemental HHRA for the MSP site (see Groundwater Investigation Technical Memorandum, Appendix A) evaluated the risks associated with VOCs in groundwater to hypothetical future on-site workers and hypothetical future off-site residential receptors. Groundwater sample results for the two most recent sampling events (2014, 2015) from five wells within the core of the plume were used for the risk assessment. The results of the Supplemental HHRA are summarized below:

- For the adult worker, the reasonable maximum exposure (RME) total cancer risk of 1.4 x 10^{-3} exceeded EPA's acceptable risk range primarily due to CT. The central tendency exposure cancer risk was within the acceptable risk range. The HI for the adult worker was 17.3 for the RME scenario and was primarily due to CT and trichloroethene (TCE). The HI for the central tendency exposure scenario also exceeded 1.

- For the young child resident, the RME total cancer risk of 1.2×10^{-3} exceeded EPA's acceptable risk range primarily due to CT. The central tendency exposure cancer risk also exceeded the acceptable risk range at 2.5×10^{-4}. The HI for the child resident was 59.1 for the RME scenario and was primarily due to CT, chloroform, and TCE. The HI for the central tendency exposure scenario also exceeded 1.
- For the adult resident, the RME total cancer risk of 3.4×10^{-3} exceeded EPA's acceptable risk range primarily due to CT and chloroform. The central tendency exposure cancer risk also exceeded the acceptable risk range at 4.6×10^{-4}. The HI for the adult resident was 48.6 for the RME scenario and was primarily due to CT, chloroform, and TCE. The HI for the central tendency exposure scenario also exceeded 1.

The vapor intrusion screening evaluation associated with the Supplemental HHRA indicated concerns for the vapor intrusion pathway. However, after further review this pathway does not present a risk because the contaminants are not located at the water table and cannot be transported to the water table.

Based on the potential risks and hazards identified by the Supplemental HHRA, CT, TCE, and chloroform were identified as significant contaminants.

MSP is located in an industrial area where there are multiple contributors of contaminants to the bedrock aquifer and VOCs do not naturally occur in the environment; therefore, contamination from upgradient sources represent anthropogenic contamination rather than naturally occurring chemicals. A true background well does not exist for the site; however, monitoring well URS-MW-22D was considered for comparison of off-site contamination from upgradient sources to contamination from the core of the plume. Low levels of VOCs have been detected in URS-MW-22D, indicating that off-site, upgradient sources of VOCs could be impacting groundwater conditions at the MSP site. The USACE will address the VOC contaminants originating from on-site sources (TCE, CT, and chloroform) in consideration of future redevelopment of the site and potential future use of impacted groundwater on the property.

Screening Level Ecological Risk Assessment

A Screening Level Ecological Risk Assessment (SLERA) performed in 2005 (USACE 2005a) concluded that ecological impacts from contaminants in surface water and sediment were unlikely. Further, no sensitive habitat was identified on site, and it was determined that current and potential future land uses on site made it unlikely that the area would be a significant ecological habitat. Additional information collected during the recent supplemental groundwater sampling corroborated these conclusions.

ES.2 IDENTIFICATION OF COCS AND ARARS FOR THE MSP SITE

The contaminants identified in groundwater as COCs on the basis of potential risks include:

- Total uranium (as a toxic metal);
- Uranium-238 and Uranium-234 (as radiological contaminants);
- CT;

- TCE; and
- Chloroform.

Both the federal and the New Jersey governments have promulgated standards, requirements, criteria, and limitations that are potentially ARARs for groundwater. Federal cleanup criteria promulgated pursuant to the Federal Safe Drinking Water Act in the form of MCLs in water delivered to a user of a public water system may be an ARAR for groundwater. In addition to promulgating its own MCLs, New Jersey has also promulgated Ground Water Quality Standards (GWQS). Only state standards that are of general applicability and are more stringent than federal standards may be considered as ARARs.

The following requirements or standards were identified as potential ARARs:

- **USEPA: 40 Code of Federal Regulations (CFR) Part 141**; National Primary Drinking Water Regulations, 40 CFR § 141.66 (e);
- **NJDEP: New Jersey Administrative Code (NJAC) 7:9C**; New Jersey Ground Water Quality Criteria, NJAC 7:9C App. A Table 1; and
- **NJDEP: NJAC 7:10;** New Jersey Safe Drinking Water Regulations, NJAC 7:10-5.1.

The more stringent of the above promulgated values for each COC identified appears below as the ARAR for that COC at the MSP site. The uranium MCL of 30 micrograms per liter (µg/L) is protective of kidney toxicity and cancer risk associated with U-234 and U-238 radioactivity (USEPA, 2000a). Therefore, separate ARARs were not established for the uranium isotopes.

COC	**Groundwater ARARs (µg/L)[a]**	**Source for Cleanup Level**
Total uranium	30 µg/L	40 CFR § 141.66 (e)
Carbon tetrachloride	1 µg/L	New Jersey GWQC PQL
Trichloroethene	1 µg/L	New Jersey GWQC PQL
Chloroform	70 µg/L	New Jersey GWQC PQL

[a] The lowest of USEPA's MCLs (40 CFR Part 141), NJGWQC or PQL (NJAC 7:9C), or NJAC 7:10.

COC – chemical of concern

PQL – Practical Quantitation Limit

µg/L – microgram per liter

It is recognized that PCE, 1,1-dichloroethene (1,1-DCE), MTBE, and manganese may exceed comparison criteria, or may have been found to pose a risk in the HHRA, or both. PCE, 1,1-DCE, and MTBE found in on-site wells has been determined to originate from off-site sources and do not present an unacceptable risk in the most recent risk assessment using VOCs (USACE, 2017). Therefore, they will not be listed as COCs for the site. Manganese concentrations have been determined to represent naturally occurring background conditions and does not need to be included as a COC for the site (Serfes, 1994). Therefore, addressing these contaminants in the groundwater would only be considered during handling, treatment, and discharge of the groundwater, if necessary, as a result of addressing the COC-related contamination.

ES.3 REMEDIAL ACTION OBJECTIVE

The remedial action objective (RAO) is based on mitigating human exposure to COCs in groundwater that exceed ARARs. These exposures may occur by ingestion of groundwater; indoor use of groundwater, such as showering, cooking, washing clothes or dishes, *et cetera*. Exceedances of ARARs, which are generally considered to represent "safe" levels, are another criteria for unacceptable risks. The RAO for this FS is therefore to:

- Prevent human ingestion of the groundwater with contaminants of total uranium exceeding 30 µg/L; CT exceeding 1 µg/L; TCE exceeding 1 µg/L; and chloroform exceeding 70 µg/L.

ES.4 REMEDIAL ACTION ALTERNATIVES

The alternatives developed for the MSP Groundwater OU are:

- Alternative 1 – No Further Action
- Alternative 2 – Monitored Natural Attenuation and Land Use Controls
- Alternative 3 – In situ Chemical Reduction, Monitored Natural Attenuation, and Land Use Controls
- Alternative 4 – Pump and Treat, Monitored Natural Attenuation, and Land Use Controls

The development of these alternatives considers the fact that the on-site contaminated soil has been excavated and backfilled with clean soil during the Soils OU RA. The total volume of contaminated material removed from the MSP and shipped off site to a licensed disposal facility was 41,244 cubic yards (yd^3) of radiologically impacted soil and debris, and approximately 4,454 yd^3 of chemically impacted waste. The replacement of contaminated soil with clean soil is expected to eliminate further migration of radiological contaminants into the overburden groundwater. However, it is assumed that residual levels of groundwater contamination could remain, and would need to be addressed by a remedial action.

Alternatives developed in this FS also address VOC contamination that may be attributable to past site activities.

Alternative 1 – No Further Action

Alternative 1 has been considered in accordance with 40 CFR 300.430(e) (6) and is intended to provide a baseline comparison to the other alternatives. In this alternative, no remedial systems would be installed or operated, and no LUCs, such as a Classification Exception Area (CEA), would be used for groundwater. Any improvement of the groundwater would be through natural attenuation including dispersion, dilution, and adsorption. No long-term groundwater monitoring would be conducted, nor would any other measures be taken to limit groundwater use or migration.

Alternative 2 – Monitored Natural Attenuation and Land Use Controls

Alternative 2 relies upon monitoring of the groundwater contaminant plume to determine whether contamination is being reduced by natural environmental processes as defined in *EPA OSWER Directive 9200.4-17P-Use of Monitored Natural Attenuation at Superfund, RCRA Corrective Action and Underground Storage Tank Sites, dated April 21, 1999*. Monitored natural attenuation (MNA) processes applicable to the MSP site include dispersion, dilution, and adsorption. MNA relies on monitoring to determine whether contaminants are spreading beyond current boundaries at concentrations exceeding ARARs. The ultimate duration of the groundwater monitoring program would be based on the sample results that demonstrate whether the impacted groundwater has contaminant concentrations that meet the RAOs. Under this alternative, it would be expected that contaminant concentrations would decrease over time as a result of the source removal completed during the Soils OU RA in 2008 and the natural attenuation. Dispersion processes would be especially effective in diminishing contaminant plumes of limited extent and relatively low concentrations. In addition, this alternative contains provisions for implementing LUCs, such as well restrictions in a groundwater CEA, where groundwater contamination has been identified and construction worker warnings issued regarding dermal exposure. Since this alternative would take time (up to 30 years) to achieve the remedial goal, restrictions on the use of groundwater would be implemented until the goal is met. The Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) also requires that the remedial action as proposed for the MSP site be reviewed at least once every five years.

Alternative 3 – Treatment with In situ Chemical Reduction, Monitored Natural Attenuation, and Land Use Controls

Alternative 3 is a combination of remedial technologies to treat the various contaminants present at the site. ISCR technologies are proposed to treat the VOCs present in groundwater situated in the fractured bedrock on site at the source area. This treatment would eventually eliminate VOCs emanating from the site source area and isolate groundwater with low concentration VOCs in the downgradient portion of the plume. MNA processes would be applied to the downgradient portion of the VOC plume and to the total uranium present in the overburden as discussed in Alternative 2.

ISCR applications are anticipated to degrade site COCs with contact and enhance mass reduction. ISCR materials (such as zero valent iron [ZVI]) are strong reducing agents and have been successful in treating VOCs present in bedrock groundwater as site COCs (TCE, CT and chloroform). ISCR would be injected directly into the source area and the areas of elevated VOC concentrations. Further, ZVI has the capacity and is efficient in the removal of uranium through reductive precipitation and adsorption.

Alternative 4 – Pump and Treat, Monitored Natural Attenuation, and Land Use Controls

Alternative 4 is a combination of remedial technologies to treat the various contaminants present at the site. Removal of contaminated groundwater by pumping is proposed to address the VOCs present in groundwater situated in the fractured bedrock onsite. Extraction wells would be placed in the source area and along the downgradient property boundary to control and eventually eliminate VOCs emanating from the source area. This would effectively isolate the downgradient portion of the plume that contains low concentrations of VOCs. MNA processes would be applied to the downgradient portion of the VOC plume and to the total uranium present in the overburden as discussed in Alternative 2.

Pump and treat would involve the use of a conventional pump-and-treat system technology. Extraction wells would be placed strategically in the areas of higher concentrations to target contaminant removal as well as in downgradient areas to prevent further migration of the plume. Construction of the pump and treat system would be initiated by installing approximately five groundwater extraction wells in the source area and areas of elevated VOC concentrations to recover as much of the mass as possible in the first 15 years of operations, after which they could then be converted to low flowrate extraction wells (due to the low transmissivity of the aquifer units) with pneumatic pumps for the remaining operational period. The eight wells located downgradient would be low flowrate extraction wells because of the low transmissivity of the aquifer units. The extracted groundwater would then be treated using an air stripper followed by granular activated carbon polishing. The treated effluent would then be discharged to the local publicly owned treatment works (POTW).

ES.5 COMPARATIVE ANALYSIS OF ALTERNATIVES

The comparative analysis identified the advantages and disadvantages of the developed alternatives. The analytical framework, which is defined under CERCLA, uses nine evaluation criteria. The FS evaluates each potential remedial alternative based on the following criteria: (1) overall protection of human health and the environment; (2) compliance with ARARs; (3) long-term effectiveness and permanence; (4) short-term effectiveness; (5) reduction of toxicity, mobility, and volume through treatment; (6) implementability; and (7) cost. The final two criteria, (8) state acceptance and (9) community acceptance are formally evaluated in the Record of Decision (ROD) after the public comment period for the Proposed Plan.

Overall Protection of Human Health and the Environment

Alternative 1 does not provide protection of human health and the environment because no remedial action would be undertaken to address groundwater contamination. It should be noted that there would be no groundwater sampling and analysis documenting whether any natural processes were reducing contamination and no LUCs would be implemented reducing the potential for exposure.

Alternatives 2, 3, and 4 are considered to be adequately protective of human health. Although no active remedial treatment measures would occur under Alternative 2, protection could still be adequately achieved through implementation of LUCs. Additionally, for Alternative 2, a groundwater monitoring program would assess the attainment of the ARARs and monitor the progress and rate of natural degradation, albeit slowly.

Alternatives 3 and 4 would protect human health and the environment by combining active remediation with the implementation of LUCs and a MNA program, which would assess the attainment of ARARs.

Compliance with ARARs

While it is possible that Alternative 1 could eventually meet the ARARs for the MSP groundwater COCs, there would be no data and documentation to support the claim, and no LUCs would be in place to restrict access to impacted groundwater. Alternative 2 would eventually comply with the ARARs through natural environmental processes, and LUCs would restrict access to impacted groundwater until the ARARs are achieved. Alternative 3 would comply with the ARARs through the implementation of MNA for the total uranium in the overburden and ISCR technologies that would be designed to meet the COCs demand of electron donor/acceptor for degradation of VOCs in the bedrock. Alternative 4 would comply with the ARARs through the implementation of MNA for the total uranium in the overburden and pump and treat technology that would be designed to extract groundwater impacted by COCs in the bedrock and provide treatment of the contaminated groundwater. Alternatives 3 and 4 also implement LUCs to restrict access to impacted groundwater until the ARARs are achieved. Alternatives 2, 3, and 4 would provide a monitoring program to determine when groundwater ARARs are achieved for the saturated overburden unit and bedrock aquifer.

Long-Term Effectiveness and Permanence

Alternative 1 may provide long-term effectiveness as contaminant concentrations in groundwater are reduced due to natural attenuation, although there is no monitoring in place to document the potential effectiveness. Alternative 2 may provide long-term effectiveness similar to Alternative 1, but Alternative 2 would provide documentation as to whether MNA is occurring; LUCs would be in place for protectiveness of exposure to contaminated groundwater. Alternatives 3 and 4 may provide a higher degree of long-term effectiveness and permanence through the implementation of an active remedial technology that either degrades or removes the VOC contaminants. Alternatives 3 and 4 would implement MNA for the total uranium in the overburden. Alternative 3 would implement ISCR technologies designed to chemically reduce VOC contaminants. Long-term effectiveness would diminish over time as VOC concentrations rebound; however, long-term effectiveness could be enhanced by repeated ISCR injections. It is anticipated that permanent reduction of COCs below cleanup levels may be achieved within 10 years. Alternative 4 would implement pump-and-treat technology, designed to extract and treat groundwater impacted by VOCs (i.e., removal of VOC contaminants). Long-term effectiveness would remain high as long as the pump-and-treat system operates; however, permanence may not be achieved for up to 15 years for uranium and 30 years for VOCs. Alternatives 2, 3, and 4 also implement LUCs to restrict access to impacted groundwater until the ARARs are achieved, meeting long-term effectiveness and permanence.

Reduction of Toxicity, Mobility, and Volume through Treatment

This evaluation criterion is not applicable to Alternatives 1 and 2. Each of these alternatives would rely solely on natural processes such as adsorption and dispersion to achieve groundwater RAOs. Alternatives 3 and 4 would satisfy the statutory preference for treatment as a principal element and incorporate natural processes occurring under the MNA technology.

Short-Term Effectiveness

No changes in potential exposure to workers or negative impacts to the environment would occur under Alternative 1. Alternative 2 would pose little to no additional health risk to the community and workers in the short term because no significant remedial activities would take place. Alternatives 3 and 4 may pose a slight increase in risk to workers during the remedial activities. However, these impacts would be mitigated by health and safety measures. Alternative 3 is anticipated to produce a prompt reduction of the COCs in the short term since remedial construction and operation activities are designed to target the source area and areas of elevated COC concentrations; LUCs would be implemented within 1 year. Alternative 4 is anticipated to have a moderate timeframe in reduction of the COCs in the short term as the pump-and-treat applications impact zone contamination; LUCs would be implemented within 1 year.

Implementability

Implementability would not be an issue for Alternative 1, as no further action would be taken. The remedial actions and technologies presented under Alternatives 2, 3, and 4 are proven and no problems are anticipated with their implementation. Due to the limited actions presented under Alternative 2, implementation is assumed to be straightforward. Since active remediation is proposed under Alternatives 3 and 4, increased complexity and some uncertainty would exist with implementation. Technologies have been proven, problems with implementation are not anticipated, and materials are readily available. The attainment of necessary permits for potential off-site actions is anticipated to be achievable. Sampling and analysis to occur are straightforward. Some degree of difficulty may occur during the implementation of the remedial process, which would require careful assessment and engineering judgment to determine operating parameters, and these could create additional uncertainties.

Cost

The estimated present-worth cost for each alternative is listed on the following table:

Alternative	Estimated Cost
1: No Further Action	$0
2: Monitored Natural Attenuation and Land Use Controls	$2,711,000
3: Treatment with In situ Chemical Reduction, Monitored Natural Attenuation, and Land Use Controls	$7,106,000
4: Removal by Pumping, Monitored Natural Attenuation, and Land Use Controls	$11,951,000

Findings

The comparative analysis of alternatives based on the above-described criteria provides the basis for selecting the preferred alternative. The selected preferred alternative must meet the threshold criteria of Overall Protection of Human Health and the Environment and Compliance with

ARARs, while the other primary balancing and modifying criteria should be considered in the selection process.

The preferred alternative, which will be described in the proposed plan, will be selected from among these four alternatives. In accordance with the National Oil and Hazardous Substances Pollution Contingency Plan (NCP), the preferred alternative will be presented to the public for review and comment. Public input on the alternatives is paramount in the selection process. Based on the comments received, the preferred remedy may be modified. The final remedy will be selected by the USACE and USEPA, in coordination with NJDEP, and presented in a ROD.

1.0 INTRODUCTION

The U.S. Army Corps of Engineers (USACE) is implementing a remediation program at the Middlesex Sampling Plant (MSP or site) in Middlesex, New Jersey (Figure 1.1). The site includes soils, sediment, surface water, and groundwater impacted or potentially impacted by contaminants from site operational activities as shown in the Site Historical Records (Appendix A, "Site Historical Records"). Remedial investigations (RI) of soil and groundwater at the MSP were addressed under two Operable Units (OUs) by the USACE from 1999 through 2016. OU1 addresses soil and OU2 addresses groundwater. This Feasibility Study (FS) evaluates remedial action alternatives for groundwater (OU2) impacted by radioactive and/or chemical materials associated with past site activities.

The site groundwater, sediment, and surface water comprise the MSP OU 2 at the site. However, as presented in the *Groundwater Operable Unit Remedial Investigation Report, Middlesex Sampling Plant, Middlesex, New Jersey* (USACE, 2005a), impacts to the site sediments and surface water are within the U.S. Environmental Protection Agency's (USEPA) risk management range and do not require remediation. The MSP Soils OU1, which includes site soils and building slabs, was addressed in a remedial action where the remedy considered the impact from groundwater contamination on human health and the environment. Therefore, the development of the Groundwater OU2 in this FS is based on the fact that the saturated and unsaturated on-site contaminated soil has been removed in accordance with the *Soils Operable Unit Record of Decision (ROD) Middlesex Sampling Plant, Middlesex, New Jersey* (USACE, 2005c).

The selected remedy for the Soils OU (OU1) was the excavation of soil and debris contaminated with radioactive and chemical waste above the criteria for residential re-use of the site, and off-site disposal at a licensed or permitted facility. Excavation and off-site disposal of soil contaminated with radioactive constituents as part of the Soils OU remedial action (RA) was completed in June 2008.

The total volume of contaminated material removed from the MSP and shipped off site to a licensed disposal facility was 41,244 cubic yards (yd^3) of contaminated soil with radioactive constituents and debris, and approximately 4,454 yd^3 of chemically impacted waste. Accordingly, the ongoing source of groundwater contamination has been removed, and no further contaminant migration into the site groundwater should occur. Additionally, dewatering was conducted as part of the Soils OU RA to remove water from the soil excavation. The removal of contaminated water from the excavations is expected to reduce contamination from the overburden groundwater; however, residual levels of radioactive groundwater contamination remain. For this reason, and also due to detected elevated concentrations of volatile organic compounds (VOCs) in bedrock groundwater, a final RA for groundwater (OU2) is necessary at the MSP site.

Applicable or Relevant and Appropriate Requirements (ARARs) identified for the Soils OU remedy were selected to be protective of groundwater and were chosen with the consideration of the contaminated groundwater exposure scenario.

The media addressed in this FS includes site groundwater that has been separated into the overburden, or shallow groundwater zone; and the bedrock, or deep groundwater zone.

Groundwater investigations conducted at the site include the Groundwater OU RI conducted in 2000 to 2002 (USACE, 2005a), a supplementary groundwater investigation conducted in the fall of 2004 to further delineate the extent of the contamination (Appendix B, “Off-Site Groundwater Delineation Investigation”), and supplementary bedrock groundwater investigations conducted from 2008 to 2016 (USACE, 2017). Based on the findings presented in the groundwater investigation reports and the results of the risk assessments completed for the MSP, the surface water and sediment do not pose unacceptable risks. Therefore, surface water and sediments do not require further evaluation in this FS. The available data sufficiently characterize the groundwater at the MSP for the development and evaluation of remedial action alternatives.

During the groundwater investigations conducted from 2008 through 2016, groundwater samples from the monitoring wells were analyzed to evaluate the chemicals of potential concern (COPCs) at the site. Based on the Soils OU (OU1), the primary focus of this groundwater investigation was to identify the nature and extent of total uranium and specific parameters associated with the natural attenuation of total uranium. In 2009, VOCs were detected in groundwater samples at concentrations above the respective comparison criteria (USEPA Maximum Contaminant Level [MCL] and/or the New Jersey Department of Environmental Protection [NJDEP] Specific Ground Water Quality Criteria for Class IIA aquifers). Additional groundwater investigations were conducted to further define the nature and extent of VOC-impacted groundwater at the site, the most recent results are provided in the Groundwater Investigation Technical Memorandum, which is an addendum to the RI (USACE, 2017).

This FS report is based on the results of investigations conducted at the MSP by the U.S. Department of Energy (USDOE) and USACE in cooperation with and oversight provided by the USEPA Region II and the NJDEP. The necessity for the remedial actions presented in this FS report are based on the findings of the Baseline and Supplemental Human Health Risk Assessments (HHRA), as discussed in the Groundwater Investigation Technical Memorandum. These reports evaluated the impacts of the MSP Groundwater OU contamination on the environment if no additional remedial measures were implemented.

1.1 Purpose and Organization of the Report

The purpose of this FS is to develop and evaluate remedial action alternatives for the Groundwater OU (OU2) to address contaminant concentrations that pose unacceptable risks (e.g., radiological and toxicological) to human health and the environment. The specific contamination addressed by this FS is contamination resulting from activities at the site, which includes Formerly Utilized Sites Remedial Action Program (FUSRAP)-related contamination. This FS is organized in a format similar to the outline suggested in the *Guidance for Conducting Remedial Investigations and Feasibility Studies under CERCLA* (USEPA, 1988).

This FS report:

- Provides a discussion of purpose and scope, a site description, site history (background and operational history), environmental setting (a summary of the ES program, land use, topography, and geology), the nature and extent of contamination, contaminant fate and transport, a summary of the Groundwater

Investigation Technical Memorandum, and the results of the additional data collection (Section 1);

- States the ARARs and remedial action objectives (RAO)s for the MSP Groundwater OU2, identifies the General Response Actions (GRA)s for each RAO, and identifies feasible remedial technologies and process options associated with each GRA (Section 2.0);
- Develops (assembles) the remedial technologies and process options evaluated into remedial alternatives, describes each remedial alternative and the basis for its development, screens the alternatives based on short-term and long term analysis of effectiveness, implementability, and cost; and selects alternatives for further evaluation and analysis (Section 3.0);
- Provides an analysis of selected remedial alternatives with respect to volumes of impacted media, technologies recommended, and performance requirements; evaluates and compares alternatives with respect to overall protection of human health and the environment, compliance with ARARs, long-term effectiveness and permanence, reduction of toxicity, mobility, or volume through treatment, short-term effectiveness, implementability, and cost (Section 4.0); and
- Presents the list of references cited in this FS (Section 5.0).

1.2 Site Description

The MSP is located at 239 Mountain Avenue in the Borough of Middlesex, New Jersey (Figure 1.1). The MSP is bordered to the east by residential and commercial properties, to the north and west by a railroad right-of way and a scrap metal facility, and to the south by a small parcel of vacant land (Figure 1.2). The MSP site is currently undeveloped, vacant land covered with grass and zoned for industrial use. The property is fenced and public access is restricted.

The site ground surface slopes gently toward the south at approximately a one percent grade. Stormwater flows over the site surface in drainage swales and as sheet flow to the south and is collected and discharged off-site into the South Drainage Ditch (Figure 1.3). The property to the south consists of a marshy land and fields. South Drainage Ditch carries surface water runoff from the site into Main Stream and is approximately 1,150 feet long. Main Stream flows intermittently in a southwesterly direction for approximately 2,100 feet to where it discharges into Ambrose Brook (Figure 1.4).

1.3 Site History and Environmental Setting

This section describes the background and operational history of the MSP. It also summarizes the environmental setting and physical characteristics of the site, such as land use, geological setting, groundwater characteristics, ecology, etc.

1.3.1 Background and Operational History

The MSP was established in 1943 as part of the Manhattan Engineering District (MED) to sample, store, test, and transfer ores containing uranium, thorium, and beryllium. Over the years that the

MSP was operational, the buildings, grounds, and nearby land parcels became contaminated, predominantly with radium and uranium. The site, no longer operational, is being addressed under FUSRAP.

The U.S. Atomic Energy Commission (AEC), a predecessor to the USDOE, established FUSRAP in 1974 to identify, remediate, or otherwise control sites contaminated with residual radioactivity resulting from activities of the MED and early operations of the AEC. The goal of FUSRAP is remediation of sites contaminated as a result of the nation's early atomic energy program in accordance with the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA), as amended by the Superfund Amendments and Reauthorization Act. Responsibility for execution of response actions on sites included in FUSRAP was transferred from USDOE to USACE by Public Law 105-62, October 13, 1997, and long term programmatic authority was specifically provided to USACE in Public Law 106-60, Section 611, on September 29, 1999. On February 18, 1999, the MSP was added to the National Priorities List (NPL) in the Federal Facilities Section. Furthermore, Public Laws 105-245 and 106-60 clarified Congressional intent that response actions taken by USACE under FUSRAP should be performed subject to the provisions of the CERCLA and the National Oil and Hazardous Substances Pollution Contingency Plan (NCP). Under CERCLA, NPL sites must undergo a detailed two-part study called a Remedial Investigation/Feasibility Study (RI/FS). The RI describes the nature and extent of contamination, its fate and transport, and its impact on baseline risk assessments. That information is then used in the FS to evaluate remedial action alternatives.

Industrial operations at the Middlesex site began in 1910 with the construction of a plant for the manufacture of asphalt paint. At this time, the plant included a brick warehouse, a boiler house, a garage, an administrative building, a dye warehouse, and four smaller buildings (USDOE, 1997). The original company (name unknown) was purchased in 1913 by the American Marietta Company with products sold under the American Asphalt Company label.

In October 1943, the MED leased the brick warehouse from American Marietta Corporation and converted it into the former Process Building to sample, store, test, and transfer ores containing uranium, thorium, and beryllium (as well as a chemical precipitate, magnesium diuranate, supplied by African Metals Corporation beginning in 1950). Between 1943 and 1955, uranium assay analysis, conducted by the United Lead Company (ULC) under contract with the AEC, was the primary operation.

In 1946, MED was deactivated and MSP operations were continued under the direction of AEC. The leased facility was purchased through condemnation by AEC from American Marietta Corporation, and various new buildings were constructed (USDOE, 1997). These new structures included a replacement for the administrative building, a replacement garage, a thaw house, and a storage house. A chain-link fence was installed around the site and approximately 7.9 acres of the 9.6 acres were paved with asphalt for use as a drum storage area.

Throughout the late 1940s and early 1950s, the site received and shipped various research and decontamination wastes. In addition, low-level combustible waste was incinerated on the site. The incinerated ashes and noncombustible scrap were reportedly placed in drums and transported off-site for disposal. The MSP was also used to prepare contaminated wastes for shipment and disposal at sea.

During 1951 and 1952, the MSP became the intermediate point for the shipment of uranium bars from the Lake Ontario Ordnance Works in Niagara Falls, New York, to the American Machine and Foundry Company in Brooklyn, New York, where the bars were experimentally machined into slugs. Scraps from this operation were then returned to the MSP for shipment to a uranium recovery processor. Before operations ceased, they also included assaying beryllium ore for shipment to Brush Beryllium in Luckey, Ohio.

During the years that the MSP was operational, the buildings, grounds, and nearby land parcels became contaminated with uranium and its associated decay progeny (radium). It is unlikely that the magnesium diuranate processing had significantly impacted the ground surface or adjacent properties due to the more controlled handling of the material. The handling of uranium ore sacks likely resulted in spillage, and subsequent migration mechanisms caused localized radiological contamination, both on and off-site. It should be noted, however, that the facility management practices used at the MSP were standard industry techniques, considered appropriate at the time. Data obtained during recent groundwater investigations indicate a source area located in the vicinity of the former sump within the Process Building. This sump was used to dispose of wastewater and may have been used for the disposal of non-water residuals, although site records do not indicate the use of solvents as part of site operations. VOCs were detected within shallow bedrock, which due to their potential to migrate downward, indicates that the release occurred on-site.

AEC terminated primary operations at the MSP in 1955. However, it continued to be used for storage and limited sampling of thorium residues. AEC activities at the site ended in September 1967, after decontamination of the structures and certification of the site for unrestricted release was complete. Decontamination activities included sandblasting, vacuuming, detergent and acid washing, concrete chipping, and equipment removal. In cases of severe contamination, parts of buildings were removed. In addition, a portion of the paved yard and underlying gravel and soil was transported by rail to the Nuclear Fuel Services licensed burial site at West Valley, New York (Ford, Bacon, & Davis, 1979a). In 1968, AEC returned the MSP property to the General Services Administration, which transferred the site to the U.S. Department of the Navy. The site served as a U.S. Marine Corps reserve training center from 1969 to 1979 before being placed back in the custody of USDOE in 1980.

1.3.1.1 Early Cleanup Actions and Recent Remedial Action

During 1976, due to changes in radiological standards and release guidelines, the MSP was re-evaluated for residual radioactive contamination (Oak Ridge National Laboratory [ORNL], 1977). The site was placed back in USDOE custody in 1980 after contamination above then current guidelines was found at the MSP and at surrounding Vicinity Properties (VPs), both residential and commercial guidance levels were exceeded. Residual contamination that originated from the MSP was also identified at the Middlesex Municipal Landfill (MML). This contaminated landfill material resulted from construction activities in 1948 when excess soil from grading operations at the MSP containing small amounts of pitchblende ore (high-grade uranium ore) was taken to the MML. The contaminated material was subsequently covered to varying depths during landfill operations.

Cleanup of the VPs and the MML was initiated by USDOE in 1981 and completed in 1986 (Bechtel National, Inc. [BNI], 1985a; BNI, 1985b). The excavated materials generated from these actions were temporarily stored on specially constructed pads at the MSP in two piles, the VP and MML interim storage piles. As their names imply, the VP pile contained the excavated materials from the cleanup of the VPs (a total of 35,200 yd^3), and the MML pile contained the excavated materials from the cleanup of the MML (a total of 31,200 yd^3). The VPs and MML piles were the subject of CERCLA removal actions conducted by USACE, which resulted in transportation of the waste materials to off-site licensed or permitted disposal facilities pursuant to an Action Memorandum by USACE officials in 1997 and 1999 (USACE, 1997; USACE, 1999).

Cleanup of contamination under the Soils OU ROD at the MSP began in September 2006 and was completed in Spring 2008. The site RI identified radium-226, uranium, poly-aromatic hydrocarbons and lead as site soil contaminants.

The Soils OU ROD for the MSP estimated approximately 24,600 yd^3 of radiological soil and debris and approximately 23,200 yd^3 of non-radiological soil and debris to be remediated. During the RA, a revised estimate of 48,000 yd^3 of radiological waste and 10,000 yd^3 of non-radiological waste was expected to be excavated and transported to an off-site permitted or licensed disposal facility. The final totals were approximately 41,244 yd^3 of radiological waste and 4,454 yd^3 of non-radiological waste excavated and transported to an off-site permitted or licensed disposal facility during the soils RA. Additionally, clean backfill material was placed in excavation areas. No remedial/removal actions were conducted for groundwater at the MSP, however, approximately 1.5 million gallons of water was removed from the excavation, treated, and discharged in accordance with the Soils OU ROD during the soils RA.

1.3.1.2 Archaeological and Historical Significance

The MSP (including the demolished process building, the demolished boiler house, the administrative building, and the garage) is eligible for the National Register of Historic Places because of the MSP's important role in the sampling and assaying of ores for the development and manufacture of atomic weapons between 1943 and 1955. Per the Memorandum of Agreement between USDOE and the New Jersey State Historic Preservation Office in July 1996, Historic American Engineering Record (HAER) documentation was completed to evaluate the adverse effects of remedial actions at the site (USDOE, 1997). The HAER includes documentation on the site operations, buildings, and site facilities. The MSP HAER documentation is included in the USACE Administrative Record file for the Middlesex Site and the Historic American Building Survey/HAER Collection of the Library of Congress.

1.3.2 Environmental Surveillance Program

An Environmental Surveillance (ES) Program was established at the MSP to monitor the effect of site activities on the surrounding environment and public health in order to assess whether both are adequately protected from site contamination. The ES program included the routine sampling of groundwater. Additionally, prior to the completion of the 2008 Soils OU RA, in addition to groundwater, the ES program included sampling of air, surface water, and sediment. A listing of the specific procedures and the data quality objectives for the surveillance program is provided in the *Environmental Surveillance Work Plan* (USACE, 2000), *Field Sampling Plan and Quality*

Assurance Project Plan of the Overburden Monitoring Well Installation Work Plan, Formerly Utilized Sites Remedial Action Program, MSP, Middlesex, New Jersey (USACE, 2008) and the *Overburden and Bedrock Monitoring Well Installation, Testing, Sampling and Analysis Work Plan, Formerly Utilized Sites Remedial Action Program, Middlesex Sampling Plant, Middlesex, New Jersey* (USACE, 2010a).

The data collected from the ES program were originally designed to estimate potential radiation doses to the general public and to a maximally exposed individual from radioactive material at the MSP. The direct gamma radiation pathway, drinking water pathway, and air pathway are used to calculate a conservative dose to a maximally exposed individual assumed to reside 100 feet from the site, as well as an annual collective dose to the general population living within 50 miles of the site. These estimated doses are reported in the annual environmental monitoring reports for the site. Results from ES events indicate that the environmental conditions at the ES locations are consistent with site background conditions.

The environmental surveillance program ended in 2008 and was replaced with groundwater monitoring sampling events (SE), which evaluated both the uranium and VOCs detected in groundwater. A total of 16 SEs were conducted from August 2008 (SE 1) to January 2016 (SE 16). VOCs detected in groundwater have generally been identified in the bedrock units and are discussed in detail in the Groundwater Investigation Technical Memorandum (USACE, 2017) and Section 1.5.

1.3.3 Current Land Use

The population of New Jersey as estimated by the U.S. Census Bureau on July 1, 2015, is 8,958,013, with 840,900 residing in Middlesex County. The population of Middlesex County has steadily increased over the past 30 years with an overall growth of about 21 percent. Population projections for Middlesex County over the next 20 years indicate an increase of approximately 13 percent (Bureau of Census, 1998). Approximately 96 percent of the county is urban or suburban in character. The area within a half-mile of the MSP is a mixture of residential homes, commercial and industrial properties, and undeveloped land. The residential population within a half-mile of the MSP is approximately 1,150 people. The preceding demographic data have been derived from U.S. Census Bureau Population Estimates.

The MSP site is currently undeveloped, vacant land covered with grass and zoned for Industrial use by the Borough of Middlesex Planning Commission. This Industrial-zoned area is surrounded by a Heavy Industrial zone approximately 3,000 feet to the west, Commercial/Light Manufacturing/Wholesale 200 feet to the north, and Attached Residential Cluster 2,100 feet to the east. The property to the south of the MSP is part of Piscataway Township. This property is zoned Residential and Light Industrial by Piscataway Township. The master plans for Middlesex and Piscataway Township do not recommend changes in zoning for the MSP and vicinity. However, to the south of the site, recent significant residential development is approaching the southern MSP boundary.

1.3.4 Topography, Soils, Geology and Groundwater

1.3.4.1 Topographic Setting

The MSP study area is in the Newark Basin portion of the Piedmont Physiographic Province. Most of this province is a maturely dissected peneplain, sloping gently toward the coast. The regional topography is hilly to rolling, with a few high ridges. In central New Jersey, the Newark Basin, a broad, structural basin that forms a lowland plain, crosses the province southwest to northeast. The primary geomorphic processes operating at the MSP are fluvial erosion, transportation and deposition, and mass wasting (U.S. Department of Agriculture [USDA], 1999). The elevation in Middlesex County ranges from nearly sea level to a maximum of approximately 240 feet above mean sea level.

Located in northwest Middlesex County, the 9.6-acre, predominantly asphalt-paved MSP slopes from north to south. A site survey conducted in November 2000 by GEOD, Inc., of Newfoundland, New Jersey, indicated that site elevations range from approximately 58 feet above mean sea level at its north end to 49 feet above mean sea level at its south end. This translates to an average slope of approximately 1 percent.

1.3.4.2 Soils and Overburden

The USDA Soil Conservation Service (SCS) (now known as the Natural Resources Conservation Service) in Middlesex County has identified soils to be silty to sandy loams of the Ellington Variant-Urban Land Complex in the northern part of the site and the Reaville-Urban Land Complex in the southern part of the site. The soils of the Ellington Variant-Urban Land complex are moderately well drained and the Reaville-Urban Land soils are poorly drained. Both soil types have slopes that range from 0 to 5 percent (USDA SCS, 1987). Due to the urban development of the area, these native soils have also probably been disturbed, stripped, or altered (Ford, Bacon & Davis, 1979b).

As observed during completion of soil borings as part of the Soils OU RI field activities, non-native fill material in the form of gravel and historic fill was observed directly beneath the asphalt pads, former building foundations and ground surface. Historic fill material was observed to be clay and fine sand with trace amounts of gravel and concrete debris. Underlying the non-native fill material were the clayey fine sands to silty sands of the native soils. The non-native fill material was observed as deep as 0.5 to 4.5 feet below ground surface (bgs). The native soils underlying the MSP were observed to be reddish brown, fine to medium sands with trace amounts of silt and coarse sand and some gravel. The thickness of these soils over bedrock ranged from 1.5 to 11 feet.

1.3.5 Geology

Geology of the MSP is discussed in terms of structural setting (stratigraphy) and groundwater (hydrologic setting, groundwater geochemistry, and groundwater usage).

1.3.5.1 Structural Setting

The site is located within the Newark Basin, which formed as a result of Triassic and Early Jurassic tectonic activities. Covering over 2,700 square miles, the Newark Basin is the largest in a series of rift basins in eastern North America. It is approximately 118 miles long by 31 miles wide and extends southwest from the Hudson River Valley of New York to southeastern Pennsylvania. The rift basin, a half graben bounded on the northwest by a series of major faults, is broken into five northwest-tilted fault blocks (Olsen, 1980). Following a series of rifting events, the basin was subsequently filled with stream and lacustrine deposits. At some locations these deposits are over 10,000 feet thick. Between 230 million and 187 million years ago, these deposits were intruded and overlain by three distinct basaltic lava flows.

Geologic maps of the northern Newark Basin show the MSP on the eastern flank of the Watchung Syncline, a major northeast-southwest trending syncline (Parker, 1993; Drake et al., 1996). The geologic maps also indicate that the MSP is in an area of extensive reverse faults that trend essentially north-south, in general orientation with the axis of the Watchung Syncline. Several fault features occur within a 2.9-mile radius of the MSP. The beds of the Passaic Formation have a general northeast-southwest strike and a dip of 10 degrees to the northwest. Observations made during BNI's 1994 and 1996 field efforts concluded that bedrock at the site has an apparent dip of 5 to 10 degrees from horizontal; however, no determination of true strike direction was made (SAIC, 1995; BNI, 1997).

1.3.5.1.1 Stratigraphy

The bedrock strata in the Newark Basin make up lithologic units known as the Newark Supergroup. The Newark Supergroup may be divided into Jurassic and Triassic units. The Triassic units are, from older to younger, the Stockton Formation, a mostly buff and red conglomerate, arkose, and mudstone unit; the Lockatong Formation, a mostly gray mudstone unit; and the Passaic Formation. The Passaic Formation of the Brunswick Group is the thickest and most extensive formation in the Newark Basin. Lithologies of the Passaic Formation consist primarily of interlayered dark to reddish brown, gray, green, and purple lacustrine clastics (mudstone, shale, and siltstone) with minor fluvial sandstone.

The Jurassic units of the Brunswick Group consist of three basalt flow units, each made up of two to four individual flows, and three sedimentary rock sequences overlying the basalts. From older to younger, the Jurassic units consist of the Orange Mountain Basalt; the Feltville Formation, a mostly red and buff gray siltstone with minor limestone, shale, and sandstone; the Preakness Basalt; the Towaco Formation, a red to buff to gray sandstone and calcareous siltstone; the Hook Mountain Basalt; and the Boonton Formation, a purplish to brownish-red fine sandstone and siltstone. Above the Mesozoic bedrock are often unconsolidated Pleistocene and Recent deposits of varying thickness (Olsen, 1980).

The Jurassic units and the Triassic Passaic Formation of the Brunswick Group, Newark Supergroup, underlie the MSP. The Passaic sediments consist mostly of reddish-brown feldspathic mudstone and micaceous siltstone with some claystone and fine-grained sandstone.

Stratigraphic units underlying the MSP are identified in the following order, from more shallow to deeper: overburden material, weathered bedrock of the Passaic Formation, and fractured bedrock of the Passaic Formation.

The classification of overburden material included the gravel base associated with the asphalt pads, the historic fill material, the clayey fine sands to silty sands of the native soils, and the backfill material associated with the sub-grade stormwater collection system. The weathered and fractured bedrock of the Passaic Formation was observed in core to be reddish brown to gray mud/siltstone and shale. Overburden materials range from 0.5 to 11 feet bgs across the site. Top of bedrock was observed to be in the range of 5 to 11 bgs across the site.

1.3.5.2 Groundwater

This section provides an overview of groundwater underlying and in the vicinity of the MSP. Additional information on the MSP groundwater flow system is presented in the Groundwater OU RI (USACE, 2005a).

1.3.5.2.1 Hydrogeologic Setting

The Passaic Formation is the major bedrock aquifer throughout a large part of central and northeastern New Jersey occurring throughout the Newark Group. Aquifer conditions generally exist as unconfined to partially confined in the upper 200 feet and confined at greater depths. Regionally, the depth range of the Passaic Formation aquifer is 30 to 1,500 feet below existing grade. The common well yield rate of the aquifer is 40 to 1,900 liters per minute, or 10 to 500 gallons per minute (gpm). Well yields have been known to exceed 1,500 gpm. Water, generally hard, may have high concentrations of iron and sulfate (USGS, 1999).

The Passaic Formation aquifer is used for domestic, municipal, and industrial water supply in Middlesex County and surrounding counties, with pumping rates ranging from approximately 2.6 to 317 gpm (Michalski, 1990). Groundwater flow is controlled by secondary porosity associated with fractures and joints in the formation. Observations made throughout the outcrop area of the Passaic Formation in New Jersey indicate one set of vertical joints that roughly parallels the strike of the beds and a second set oriented generally perpendicular to the strike (Vecchioli and Miller, 1974). Systematic fractures, both near-vertical joints and partings along bedding, are generally believed to provide the principal passages for groundwater flow in the Passaic Formation.

Observed movement of water under pumping conditions, and presumably under natural conditions, is preferentially along strike. Numerous pumping tests of wells completed in the Passaic Formation, where drawdown has been recorded in more than one direction, indicate that the aquifer has anisotropic hydraulic properties. The degree of anisotropy varies, even to the point of approaching isotropy. Where mildly anisotropic conditions exist, drawdown is always greatest along strike (Vecchioli et al., 1969).

The Passaic Formation aquifer has been described as consisting of a series of alternating tabular aquifers and aquitards several tens of feet thick. The water-bearing fractures of each tabular aquifer are more or less continuous, but hydraulic connection between individual tabular aquifers has been described as poor. These tabular aquifers extend down-dip for a few hundred feet and are continuous along strike for thousands of feet (Carswell, 1976).

Near-surface groundwater at the MSP occurs within the shallow overburden material that underlies the site and the weathered and fractured bedrock of the Passaic Formation. Roy F. Weston (Weston) performed the earliest study of the groundwater system at the MSP (Weston, 1980).

During this study, groundwater velocity was found to be greater in the deeper fractured bedrock than in the shallower overburden material and weathered bedrock. The low hydraulic conductivity and low hydraulic gradient (0.017) were considered to be representative of the weathered shale and silts of the Passaic Formation at an approximate depth of 10 feet bgs. In weathered bedrock, the calcareous zones and solution cavities that were observed in the core samples, along with changes in drilling characteristics, suggested an increase in transmissivity at the 15 to 25 foot depth. The deep bedrock zone also showed a steeper groundwater hydraulic gradient (0.11) that, coupled with the higher hydraulic conductivity, resulted in a higher groundwater flow velocity.

In the overburden, a groundwater mound or divide is typically observed in the vicinity of the former Process Building slab. Overburden groundwater flow is generally radial from this area. North of the slab, flow is typically to the north; east of the slab, flow is toward the east; and south of the slab, flow is to the south and southeast. A downward gradient was found to be present at the site. Groundwater elevations in the overburden are generally 12 to 15 feet higher than groundwater elevations in the shallow bedrock. Once groundwater enters the unweathered bedrock, flow patterns at some depth are different from the overlying shallow bedrock, following fractures and bedding planes primarily along strike. In the shallow bedrock, a groundwater mound is also observed near the former Process Building slab, with flow radial from this area. In the southern portion of the site, though, flow is from the southwest corner of the site toward the northeast. The site conceptual model is discussed in further detail in Section 1.6.1.

The conceptual groundwater flow model of the Passaic Formation aquifer in the Newark Basin has evolved over recent years. Recently published scientific articles (Michalski and Britton, 1997; Morin et al., 1997) provide a different model of groundwater flow in the Passaic Formation bedrock at a site approximately 4 miles along strike from the MSP. This model, which could be applicable to the MSP, consists of a leaky, multiunit aquifer system overlain by a weathered zone and overburden. In this model, bedding plane partings or fractures control permeability distribution and groundwater flow direction within discrete aquifer units. A near-vertical set of joints or fractures provides leakage between the discrete aquifer units. Lower permeability and greater storage could exist in the weathered bedrock than in the deeper bedrock (Michalski and Britton, 1997).

1.3.5.2.2 Middlesex Sampling Plant Hydrogeology and Site Hydrostratigraphic Units

The overburden water table is present between approximately two feet and eight feet bgs. This water-bearing unit is a perched unit sitting on top of the bedrock at the interface with the overburden and is up to several feet thick. A shallow groundwater divide causes the shallow groundwater to flow to the north and south from the area near monitoring well MW-OB-8. North of this groundwater divide, shallow groundwater flows in a northwesterly direction and discharges within a deep cut 8 to 10 feet into the subsurface along the railroad tracks. In the southern two-thirds of the site, groundwater in the overburden generally flows to the south-southeast. Groundwater flowing south discharges into the South Drainage Ditch and Main Stream, which flow through a wetland area prior to discharging into Ambrose Brook one-half mile west of the site.

The shallow bedrock at the MSP is defined as a leaky, multi-unit aquifer system (USACE, 2017). Within the shallow bedrock, groundwater occurs at 10 to 15 feet below the surface and flows generally to the north-northeast and north-northwest in the northern one-third of the site. Groundwater in the shallow bedrock over the southern two thirds of the site flows east-southeast. Based on results of several investigative methods used to identify and characterize transmissive bedrock fractures, three bedding-parallel bedrock aquifer units were identified and labeled Unit B, Unit C, and Unit D. The relationships between these units are shown on the cross-section in Figure 1.5.

Six bedrock MWs (ECC-MW-25C, ECC-MW-25D, ECC-MW-26C, ECC-MW-26D, ECC-MW-27C, and ECC-MW-27D) were installed during October 2010. The "C" wells were completed in the same hydrostratigraphic unit (Unit C) of the bedrock and the "D" wells were completed in a deeper hydrostratigraphic unit (Unit D) of the bedrock. After a review of the data collected from these six initial bedrock MWs, additional bedrock MWs were deemed necessary to complete the hydrogeologic study of the shallow portion of the bedrock aquifer system and to further characterize the nature and extent of contamination. Wells installed as part of the additional study are discussed in the Groundwater Investigation Technical Memorandum (USACE, 2017) and are identified on Figure 1.2.

1.3.5.2.3 Groundwater Usage

The Passaic Formation beneath the MSP is part of an aquifer used for domestic, municipal and industrial water supplies in Middlesex and surrounding counties. As of 1992, approximately 140 private water-supply wells had been identified within 1 mile of the MSP. Most of these wells draw from the deeper parts of the aquifer (ATSDR, 2000). Also, 19 municipal wells were identified within a 4-mile radius of the site. The nearest public well field is the Elizabethtown Water Company's Sebring's Mills well field, approximately 1.25 miles northwest of the site. This well field has not operated since 1978 (SAIC, 1995).

Unless otherwise designated, waters of New Jersey are classified as a Class II-A (N.J.A.C. 7:9) (drinking water aquifer). The primary designated use for Class II-A groundwater is potable water and conversion (through conventional water supply treatment, mixing, or other similar technique) to potable water. Class II-A secondary designated use includes agricultural water and industrial water.

In 2010, USACE conducted an updated well survey to determine the number of registered wells within a half-mile of the MSP. USACE used several resources to identify and locate supply wells that may still be in service for providing potable water to residents or local businesses. The on-line NJDEP well search resource was used to identify registered wells within a half-mile of the MSP, which resulted in the identification of 12 properties with records of existing potable water wells. To investigate additional properties within the search area that may exist, but were not registered with the state, the USACE consulted with either the Middlesex Department of Health to request a list of properties with a water well or a record of on-site contamination. This resulted in a small number of properties already on the list obtained from NJDEP.

In order to provide a more comprehensive assessment, Middlesex, New Jersey tax maps were searched to identify addresses within a half-mile radius of the MSP that could potentially be impacted by contamination from the MSP. Over 300 properties were identified. After cross-checking the address list with the New Jersey-American Water Company to eliminate properties on public water supply, 42 properties could not be verified as being supplied by a public water source and, therefore, might have a potable well. A field reconnaissance was conducted to investigate these 42 properties, which included drive-by inspections and door-to-door interviews to inquire whether or not the property had a potable well.

The document search and field reconnaissance resulted in a list of nine properties that were potential candidates for collecting groundwater samples; Figure 1.6 shows the locations of nine properties where residential wells were identified in the vicinity of the MSP. Table 1-1 lists seven properties, where groundwater samples were collected, along with the sampling dates and the VOC analytical detections. Samples collected from these seven properties exhibited VOC detections below the NJDEP drinking water criteria, and, therefore, are not discussed further in this report. One additional groundwater sample was collected from a potable water well located 233 Mountain Avenue, adjacent to the MSP (number 2 on Figure 1.6).

Table 1-2 presents the 233 Mountain Avenue Domestic Well analytical results for August 2010, September 2010, and October 2010. The analytical test result indicated VOCs concentrations above the NJDEP drinking water criteria; therefore, the property was connected to the City water supply line and the well was converted into a monitoring well.

1.3.5.2.4 Groundwater Geochemistry

Regional groundwater geochemistry is highly dependent upon the minerals that the water comes in contact with as it moves through the aquifer. The Passaic Formation consists primarily of reddish-brown feldspathic mudstone and micaceous siltstone with some claystone and fine-grained sandstone. Groundwater ultimately begins as precipitation, which percolates into the subsurface. As the precipitation percolates through the subsurface, it generally becomes more alkaline, mineralized and reducing through chemical interactions with aquifer materials. This occurs in Newark Group groundwater. In a study of over 90 groundwater samples collected from wells completed in the Brunswick Group, the median pH increased to 7.6, the alkalinity increased to a median of 141 milligrams/liter (mg/L) and conductivity increased to a median of 450 microSiemens/centimeter (Serfes, 1994).

Dissolved oxygen in rainwater is typically near saturation (8.5 to 14 mg/L; American Water Works Association, 1975). As groundwater migrates through the subsurface, dissolved oxygen concentration decreases and the groundwater becomes more reducing. Groundwater in the Newark Group has a median dissolved oxygen concentration of 2.9 mg/L.

In general, groundwater in the Newark Group is slightly alkaline. It has low dissolved solids (median 340 mg/L) and is hard (median hardness of 200 mg/L). The ions present at measurable concentrations include (in order of decreasing median concentration) calcium (50 mg/L), sulfate (44 mg/L), silica (22 mg/L), chloride (18 mg/L), magnesium (16 mg/L), sodium (15 mg/L), and potassium (1.3 mg/L; Serfes, 1994). Iron and manganese are also commonly detected in waters in the Newark Group. Unlike what would typically be expected, dissolved solids concentrations in the Brunswick Group do not appear to decrease with depth. Cation concentrations and chemical properties show variation within the Newark Group (including the Passaic Formation). These variations are due primarily to heterogeneities in the aquifer materials which the groundwater contacts.

The geochemistry of groundwater at the MSP was evaluated through samples collected from monitoring wells. Groundwater geochemistry can affect the fate and transport of contaminants. Changes in groundwater geochemistry may also be indicative of the presence of contaminants. The groundwater anion and other parameters analyzed include carbonate alkalinity, bicarbonate alkalinity, chloride, phosphorus, sulfate, total suspended solids (TSS), and total dissolved solids.

Overall, the groundwater anion data did not vary significantly between the overburden and bedrock wells. The values from the on-site wells are similar to those reported for the Brunswick Group bedrock groundwater (Serfes, 1994). The bicarbonate alkalinity was very similar in most of the overburden and bedrock wells sampled at the MSP. Overburden wells completed in the backfill material along the former pipe chases had a somewhat lower alkalinity. This could be due to the nature of the Pipe Chase material, which consists of relatively coarse-grained sand and gravel. The saturated overburden unit and bedrock aquifer materials consist of similar clay and silt mineralogy. The chloride concentrations in MSP wells are slightly higher than those measured in wells in the Brunswick Group. Elevated chloride levels in the unconsolidated materials may be the result of anthropogenic activity, such as pavement salting. Sulfate concentrations, similar among the overburden and bedrock wells, are within the range of those measured in wells in the Brunswick Group. Phosphorus concentrations are generally low to non-detected in wells. TSS was only measured in the overburden wells and was only detected in a small percentage of the samples analyzed. On the other hand, total dissolved solids was detected in most samples analyzed at similar concentration among the overburden and bedrock wells.

1.3.6 Ecology

Flora, fauna, and wetlands present in the region of the site are presented in this section.

1.3.6.1 Flora and Fauna

The MSP is in the glaciated area (Tedrow, 1986) of a Mixed Mesophytic Forest (Kricher, 1988) in the Northern Appalachian Piedmont Ecoregion (USDA, 1997). Past and current land use within the region has transformed the landscape by converting most of the forest and open habitat to residential and commercial/industrial uses. Forest corridors, islands and peninsulas characteristic of a Mixed Mesophytic Forest are the dominant habitat type in natural areas, in maturing successional forests and even, in a variant form, on some developed properties.

Two qualitative wildlife species and habitat surveys of the MSP and vicinity have been conducted. The first qualitative wildlife species and habitat survey of the MSP and the area along the South drainage ditch, Main Stream, and the developed properties to the north and east was conducted on February 3, 2001. This survey found no environmentally sensitive areas per NJAC 7:1E-1.8 within the fenced borders of the MSP. At the time, asphalt, buildings, or former building foundations/pads covered most of the site. A small lawn was to the north of the buildings along Mountain Avenue. The area south of the MSP consisted of a successional forested to shrub-scrub habitat with wetlands generally occurring adjacent to the South Drainage Ditch and along Main Stream. These areas may be considered a wetland per NJAC 7:7A-2.4.

The second qualitative wildlife species and habitat survey of the site and surrounding areas was conducted on July 10, 2002. As expected, wildlife and habitat observed during this survey included species not observed during the winter months of the first survey. This survey also found no environmentally sensitive areas within the fenced borders of the MSP per NJAC 7:1E-1.8. Most of the site was still covered with asphalt, concrete, gravel, buildings, or former building foundations/pads. The small grass-covered area around the existing buildings along Mountain Avenue was also in place at the time of the survey.

1.3.6.2 Wetlands

Wetlands have been identified to the south of the MSP on a U.S. Fish and Wildlife Service (USFWS) Map, National Wetlands Inventory Quadrangle; Plainfield, NJ (1979) and an NJDEP Freshwater Wetlands Quarter Quadrangle; Plainfield NW (1991). These documents identify areas likely to have wetlands based on ground surveys, topography, soils information and infrared photography. They are delineated on these documents, but have not been verified by NJDEP and may not coincide with actual wetland limits on the ground.

The USFWS Map and the NJDEP Freshwater Wetlands Quarter Quadrangle both identify several areas of wetlands to the south of the MSP. Both maps are generally consistent with each other in the extent and classification of the wetlands. These wetlands are identified as Palustrine Forested and Palustrine Scrub/Shrub.

1.3.7 Meteorology

Meteorological data presented in this report were obtained from the National Weather Service station at Newark International Airport in Newark, New Jersey (National Oceanic and Atmosphere Administration, 2002), which is approximately 12 miles from the MSP.

The regional climate is humid with a mean annual precipitation of 43.04 in and an average temperature of 54.1 degrees Fahrenheit (°F). Most precipitation occurs between March and May and, due to summer thunderstorms, also between July and September. The average annual maximum temperature for the Middlesex area is 17.0 degrees Celsius (62.7°F), and the average annual minimum temperature is 7.6°C (45.7°F). The annual average relative humidity recorded over the past 30 years was 64%, with the average minimum occurring in April (58%) and average maximum in September (68%). During the past 26 years, the annual average barometric pressure observed in the surrounding area was 30.01 in of mercury.

Winds are predominantly from the northwest at average speeds of 8.9 to 14.1 miles per hour. Middlesex County is in attainment for all criteria pollutants except for ozone, for which it is in non-attainment.

1.3.8 Site Features

This section presents a summary of the existing and former features at the MSP. They include the buildings and pads, the stormwater discharge system (i.e., the Pipe Chases) that includes the underground site stormwater control system, and the South Drainage Ditch that accepts the stormwater discharge from the site.

1.3.8.1 Buildings and Pads

The six site buildings that existed during the AEC's operations were the Process Building, administrative building, thaw house, boiler house, equipment storage building, and garage (Figure 1.3). The Process Building was a brick warehouse in which sampling and assay of uranium ore was conducted. The thaw house was a concrete block building used to store ore that needed to be thawed prior to processing. The boiler for heating the Process Building was in the boiler house. The concrete-block administrative building contained offices, a laundry, shower, lunchroom, two locker rooms, a health and safety dispensary, and a waste disposal unit (solid waste incinerator). The equipment storage building was a Quonset hut made of steel and corrugated metal. The garage was a wood-frame building covered with corrugated metal. During site operations, a seventh structure was used as a dumping station, where uranium ore would be transported via conveyor to the assay equipment in the Process Building (Cahalane, 1958).

The thaw house was demolished and buried on-site prior to construction of the MML pile asphalt pad, and the equipment storage building was demolished in the early 1980s. A series of underground fuel tanks and surface pumps were located near the center of the site (Ford, Bacon, and Davis, 1979a). These tanks and pumps were removed during construction activities in 1980. The Process Building and boiler house were demolished in 1996 (USDOE, 1996).

During site operations, a sump in the ore Process Building floor used for the disposal of wastewater was likely a disposal point for other wastes. The sump, which measured 12 feet by 6 feet by 10 feet, extended into the water table. As part of Process Building demolition in 1996, the sump was drained and plugged with concrete.

In 2000, preliminary activities related to the demolition of the AB were initiated. During these activities, low levels of radiological contamination were found on the building's roof. In 2005 this building, along with the garage, was subsequently demolished and the demolition materials were removed from the MSP. The site no longer contains structures or evidence of structures on the property.

1.3.8.2 Pipe Chases (Subsurface Stormwater Drainage System)

Surface stormwater runoff (e.g., rainfall, snowmelt, etc.) at the MSP was diverted into a subsurface storm drainage system, which then directed it to the South Drainage Ditch. As is typical of subsurface drainage systems, the pipes are surrounded by non-native bedding backfill material. This backfill is usually granular in nature and more porous than the surrounding soil. USACE historically identifies this subsurface pipe and backfill feature on the site as the Pipe Chase. This FS continues to refer to the subsurface piping and backfilled area as the "Pipe Chase" to be consistent with historical descriptions of this feature.

Prior to 1980, the site stormwater system consisted of a 12- to 14-inch diameter below-grade line (hereinafter called the Main Line) that extended through the approximate center of the site from the administrative building southward to the southern property boundary. This Main Line received roof runoff from the administrative building and garage as well as runoff collected by a sump in the former ore Process Building. The sump in the ore Process Building was connected to the Main Line by an 8-inch diameter feeder line. A second 8-inch diameter feeder line joined the Main Line just north of the southern site boundary. This feeder line drained the area on the west side of the property, south of the former thaw house. A series of catch basins were also located at turns and bends along the feeder and Main lines. Water collected by this system was subsequently discharged through a concrete headwall into the South Drainage Ditch.

In support of the VPs and MML cleanup actions, a portion of the above lines (Main Line and feeder lines) were plugged and abandoned with concrete at both ends in 1980. The remainder of the site system was plugged in 1996. The former Process Building sump and most of the catch basins were also plugged and abandoned with concrete at that time. Replacement of the below-grade drainage lines in 1980 consisted of the installation of a surface trench drain system around the areas of the former VP and MML piles, and a settling basin and granular activated carbon filtration system in the southern portion of the site (USACE, 2010a).

1.3.8.3 South Drainage Ditch

Stormwater flows over the site surface as sheet flow to the south and is collected and discharged off-site into the South Drainage Ditch. ULC, USDOE's FUSRAP Program Management Contractor at that time, conducted a remediation effort, involving the excavation and removal of contaminated sediments from this ditch in September and October 1981. However, phased investigations of the drainage ditch conducted between 1990 and 1996 (BNI, 1993; BNI, 1996) showed that radioactive contaminants were once again present in the sediments. In 1996, a second remediation effort was initiated and approximately 70 yd^3 of radioactive sediments from the South Drainage Ditch were excavated and added to the VP pile. An in situ granular activated carbon (GAC) filter was installed on the site behind the drainage ditch headwall to help reduce further off-site migration of radionuclides via groundwater seepage into the ditch. During installation of the filter, 160 yd^3 of radioactive material were excavated from the MSP property; this material was also added to the VP pile. The Wood Avenue portion of the stormwater drainage system was rerouted in 1996 to avoid re-contamination of the drainage ditch. The unused portion of the stormwater system was sealed. Stormwater entering the re-routed Wood Avenue drainage system is not contaminated and currently discharges to an area east of the South Drainage Ditch (Figure 1.3).

The nature and extent of sediment contamination in the South Drainage Ditch is addressed in the Groundwater OU RI report (USACE, 2005a).

1.4 Site Investigations

This section of the FS summarizes previous site investigations and historical results of groundwater contamination at the MSP that is based on the results of the following:

- Historical Investigations
- Soils OU RI (2000-2001)
- Groundwater OU RI (2000-2001)
- Environmental Surveillance results (from 2000 through 2008)
- Supplemental Off-Site Groundwater Delineation Investigation (2004)

- Supplemental Bedrock Groundwater Investigation (2010-2013)
- Additional Data Gathering for Groundwater OU (2014-2016)

Site characterization was previously described in other reports following investigations performed in 1976, 1980, 1983, 1991, and 1996 (referred to in this FS as "historical" investigations). Since the quality of the historical results could not be verified, they were not used in defining the nature or extent of site contamination. The following presents an overview of the nature and extent of contamination based on the results from past MSP investigations.

1.4.1 Historical Investigations

Prior to 1991, the analytical data collected at the MSP focused on radiological contamination, and only later was sampling for both radiological and chemical constituents performed. The nature of radiological contamination in MSP soil and groundwater is well documented, with the primary contaminants being uranium and radium.

Prior to the groundwater and soil RIs conducted in 2000, six significant historical investigations were conducted at the site to define the nature and extent of contamination. These historical investigations have included building material, air, soil, sediment, groundwater, and surface water sampling and analysis, and they provide information used as a basis for conducting RIs for the Soils and Groundwater OUs. Due, however, to uncertainty of sample locations and/or validity of the data, the data generated were not used to assess the nature and extent of soil and groundwater contamination.

As previously mentioned, due to a lack of documentation of the radiological status of the property after its release by AEC in 1967, the site was resurveyed in 1976 by ORNL. This study identified contamination above then-current guidelines on both the MSP property and vicinity properties. In support of the ensuing remediation of selected VPs, the site was re-graded and paved in 1980 to accommodate an interim storage pile generated from the cleanup. As such, the point of reference for the elevation of soil samples collected in 1976 changed. Due to the uncertainties associated with the location of the 1976 samples, the data were not used in the Soils OU RI report for identification of site-related contaminants.

In May 1980, Weston conducted a radiological study on MSP soils in conjunction with a groundwater investigation (Weston, 1980).

Weston also initiated a groundwater monitoring program with the installation of 20 monitoring wells. Six additional monitoring wells were installed in July 1981 as part of an environmental surveillance program. Heavy truck traffic during the 1980 remedial action activities resulted in silting and partial collapse of some of those wells. Apparently, the monitoring wells installed in 1980 and 1981 did not have grout between the casing and the surrounding formation (National Lead Company of Ohio, 1981). In addition, three of the bedrock monitoring wells installed in 1980 had casing set at an undocumented elevation in the bedrock with open-hole completions set to 50 feet. For these reasons, the groundwater data generated from these wells, including the environmental surveillance data obtained prior to 1994, may not be representative of current site groundwater conditions. Due to the well construction methods and the uncertainties associated with data from these wells, several monitoring wells were replaced in 1994. Of the 1980-1981 monitoring wells, it is understood that only one (MSP-12) remains; the others were abandoned (i.e., sealed).

BNI, on behalf of the USDOE, conducted a soils investigation in 1991 that provided an evaluation of chemical contamination of soils at the site. Groundwater was not evaluated in this investigation.

Seven new monitoring wells (B18W24 through B18W30S or SR) were installed in 1994. Well MSP-12 had been left in place to monitor groundwater elevations in the shallow groundwater flow system. However, a comparison of the groundwater elevation data from this well to the groundwater elevations in the other new (1994) wells showed that the elevations in MSP-12 fluctuated in a manner inconsistent with the other adjacent newly installed wells. Because the other wells installed in 1980/81 were of questionable integrity, it was suspected that MSP-12 was not providing reliable data. The inconsistent fluctuations may also have been due to the presence of fill material or surface water infiltration, causing water levels in this well that were not representative of the groundwater levels in this portion of the site. For these reasons, groundwater elevation data from MSP-12 were not included in the Groundwater RI. The monitoring wells that were installed in 1994 now comprise the groundwater-monitoring network that has been sampled as part of recent environmental surveillance activities.

To obtain localized groundwater data for installation of the in situ granular activated carbon filter, additional wells and borings/piezometers were installed during the shallow groundwater investigation conducted in 1996 (BNI, 1997). These wells and piezometers have not been sampled as part of the environmental surveillance program.

In total, there remained 13 groundwater monitoring wells and four piezometers at the MSP that were installed through 1996. With the exception of the seven wells installed in 1994, which are currently used as part of the environmental surveillance program, none of the remaining wells/piezometers have provided analytical data used in site characterization efforts. Data from these remaining wells, collected prior to the 2000 RI activities, were not included in the RI because the respective sampling methodologies and validation protocols are not available. Comparing data collected by others without knowledge or confirmation of the protocols to the 2000 RI data could result in inaccurate comparisons.

As concluded in the 2002 Public Health Assessment (ATSDR, 2002), which is a summary and evaluation of the historical data available through 1999, the results of the investigations indicate that the groundwater beneath the MSP is contaminated with radium, uranium, metals (e.g., arsenic, chromium, and lead), and VOCs (e.g., benzene and methyl-tert-butyl-ether [MTBE]). However, based on its evaluation, ATSDR determined that no exposures to contaminated groundwater immediately beneath the site are occurring or are expected to occur in the future.

1.4.2 Soils OU Remedial Investigation

In 2000, 50 boreholes were drilled and sampled on-site as part of the USACE's Soils OU RI. The soil boreholes were drilled to depths ranging from 6 to 11 feet bgs. At these soil-boring locations, one soil sample was collected from the shallow zone and two samples were collected from the deep zone. The samples collected from boreholes were analyzed for chemical and radiological parameters.

A background soil sampling program was implemented in January 2001. This sampling effort consisted of the installation of eight boreholes in six off-site (non-impacted) locations within a 2-mile radius of the MSP. Soil samples from these background soil-boring locations were collected from similar depths as on-site soil borings.

The following subsections present a summary of the results of the Soils OU RI based on the type of contamination detected at various depths. For more detail on the RI and its results, refer to the Soils RI report (USACE, 2004). It is important to note that the majority of these contaminated soils have been removed as part of the Soils OU RA, which was completed in 2008.

1.4.2.1 Summary of VOCs in Soil

The results of VOC testing on 59 surface (0 to 2 feet) and subsurface (2 to 6 feet) soil samples were used to complete the characterization of these compounds for MSP soils. Nine VOCs were detected in surface soil samples, and twelve in subsurface samples. Only one VOC sample exceeded its respective USEPA Region 9 Preliminary Remediation Goal (PRG): the surface soil sample at location BB-31 had detected a concentration for 1,1,2-trichloroethane of 4.96 milligram per kilogram (mg/kg), which exceeds the PRG value of 0.73 mg/kg.

Acetone, a common laboratory and field artifact, was detected in numerous surface and subsurface sample locations. The maximum detected concentration was 0.211 mg/kg, which is below the USEPA Region 9 PRG used for screening (1,600 mg/kg).

1.4.2.2 Summary of SVOCs in Soil

Twenty-two semi-volatile organic compound (SVOC)s were detected in the surface and subsurface soils at the site and were most likely present as a result of the burial of asphalt, cinders, or slag or of past operations of the asphalt-manufacturing plant formerly occupying the site. However, only the following SVOCs were identified as contaminants of potential concern based on the results of the risk assessment and hazard evaluation performed as part of the Soils RI:

- Benzo(a)pyrene
- Benzo(b)fluoranthene
- Benzo(a)anthracene
- Indeno(1,2,3-c,d)pyrene
- Dibenzo(a,h)anthracene

1.4.2.3 Summary of Metals in Soil

Twenty-three metals were detected in the soil samples. Of these metals, aluminum, calcium, copper, iron, manganese, potassium, silver, and zinc are common, naturally occurring metals that did not show specific trends in distribution or concentrations across the site. Also, from the sample information shown, no specific trends occurred in concentrations of antimony, beryllium, cobalt, magnesium, mercury, nickel, selenium, or vanadium. One sample detected a significant level of lead, which resulted in lead being listed as a contaminant of potential concern for the soils. The respective sample was co-located with radiological contamination, which resulted in its being addressed along with the radiological contamination.

Both surface and subsurface data indicated that metals were widespread at the MSP, although no clear pattern of their occurrence was discernible from the data. It is therefore difficult to relate the metals detected above applicable background criteria to specific past MSP operations or waste management practices.

1.4.2.4 Summary of Radionuclides in Soil

RI data indicated that radioactive material was present above background levels across most of the site. This was particularly the case for the radionuclide Ra-226, which was widely dispersed in both the surface and subsurface soil layers (e.g., detected in 101 soil samples with activity ranging between 0.314 and 222 picocuries per gram [pCi/g]). In addition, U-238 was detected in 99 soil samples, with activity ranging between 0.243 and 399 pCi/g, and Th-232 was detected in 97 soil samples with activity ranging between 0.204 and 11.5 pCi/g.

Elevated activities were also present in soil samples collected from beneath the former VP pile and the former MML pile. Samples collected from the areas around the former process building pad and the former AB showed less contamination than the former VP and MML areas. The soils around the Pipe Chases also indicated radiological contamination. Finally, the samples collected from the areas east of the former process building pad showed radionuclide levels above background.

The radionuclides that were identified as contaminants of potential concern through the screening process in the Soils OU RI report are the following, which are included in the uranium and actinium series:

- Radium-226
- Thorium-230
- Uranium-234
- Uranium-235
- Uranium-238

Note that Th-232 is not listed as a radionuclide of potential concern for the soils because it is included in the thorium series decay chain, the concentrations of which were not found to be significantly different at the MSP when compared to background data. See the Soils OU RI, FS, and Proposed Plan for more information on the nature and extent of soil contamination at the MSP.

1.4.3 Summary of the Groundwater OU RI, Environmental Surveillance, and Off-Site Delineation Investigation Data

As previously mentioned, the data from the Groundwater OU RI, ES (2000 through 2013), an off-site delineation investigation from 2004 (Appendix B), and a supplemental bedrock groundwater investigation from 2008 to 2016 (USACE, 2017) were used to define the nature and extent of the groundwater contamination at the MSP. The following presents a summary of the activities and results for each of these events.

1.4.3.1 Activities

MSP groundwater characterization efforts have historically focused on the overburden and slightly into the underlying bedrock. More recently, with the detection of VOCs in groundwater from samples collected within the bedrock units, groundwater investigations have focused on both the overburden and fractured bedrock. The following are brief summaries of activities associated with the sampling events. For more information on the Environmental Surveillance and Groundwater OU RI, refer to the respective reports (USACE, 2000-2005).

1.4.3.1.1 Environmental Surveillance (ES)

Environmental surveillance groundwater samples were collected from a monitoring network of seven wells beginning in 1994 to 2008. Thirteen additional wells were installed in the first water bearing zone in 2008 after the completion of the soils RA. Three rounds of sampling were conducted after the thirteen wells were installed. The last eight years of data demonstrate that although fluctuations in uranium concentrations in groundwater are observed, these fluctuations appear to be seasonal and typically do not differ by an order of magnitude. Additionally, only one well shows a steep significant increasing trend for the past eight years and the results for the past five sampling events for that well are lower than the highest recorded concentration for that well, indicating a downward trend for the past two years. Additionally, three deep bedrock wells were sampled for VOCs. Five rounds of sampling have been conducted since 2001. Elevated concentrations of carbon tetrachloride (CT) and trichloroethene (TCE) in groundwater were detected at two of the three deep bedrock wells. Surface water and sediment samples were also collected as part of this program from four locations at the site. Analytical results from these sampling events are presented in their respective environmental surveillance technical memoranda that were submitted to NJDEP and USEPA on a quarterly basis (2000 to 2003) and then an annual basis (2004-2007). Groundwater samples collected during each of the environmental surveillance events were analyzed for VOCs, SVOCs, metals, and radionuclides. Surface water and sediment samples collected during environmental surveillance events were analyzed for SVOCs, metals, and radionuclides. In 2008, quarterly sampling of groundwater was implemented after completion of the Soils RA. Analytical results from these sampling events are presented in data summary reports and submitted to NJDEP and USEPA on a quarterly basis. Groundwater samples collected during these quarterly events were analyzed for total uranium and VOCs.

1.4.3.1.2 Groundwater OU RI

From February to September 2001, groundwater samples were collected from 17 overburden and seven bedrock monitoring wells as part of the Groundwater OU RI. Samples were analyzed for VOCs, SVOCs, metals, and radionuclides. In addition to the samples collected from the monitoring wells, two overburden groundwater samples were collected within the South Drainage Ditch area from temporary well points using Hydropunch® technology. These samples were analyzed for the same parameters as the monitoring well samples.

Two background groundwater monitoring wells (URS-MW-20S and URS-MW-20D) were installed off-site and sampled as part of the Groundwater OU RI program. The samples were analyzed for the same suite of parameters as the on-site groundwater samples.

1.4.3.1.3 Off-Site Delineation Investigation

In November 2004, a supplemental off-site delineation investigation was performed (Appendix B). This investigation included the following:

- The installation and sampling of eight temporary well points (Hydropunch®) for VOC and radionuclide analysis.
- The installation and sampling of nine piezometers (two of which were subsequently turned into monitoring wells) for VOC and radionuclide analysis.
- The installation and sampling of four monitoring well clusters, each containing one overburden well and one bedrock well (total of eight new wells), as well as five additional perimeter wells. The samples were analyzed for VOCs, SVOCs, metals, and radionuclides.

1.4.3.1.4 Supplemental Bedrock Groundwater Investigation

The groundwater remedial investigation initially defined the nature and extent of radioactive groundwater contamination (USACE, 2005a). However, the groundwater data collected during environmental surveillance program indicated persistent elevated levels of VOCs in two of three bedrock wells being monitored during that program. After evaluating this data, USACE determined that installation of additional bedrock monitoring wells and sampling for VOCs would be necessary to further characterize the vertical and horizontal extent of the MSP contamination. This supplemental investigation was conducted between 2010 and 2016. The detail of the activities and results of this investigation are presented in the Groundwater Investigation Technical Memorandum (USACE, 2017). This work was conducted between 2010 and 2016 and resulted in the installation of 30 additional bedrock wells (ECC-MW24B through EE-MW-45S). Monitoring wells installed as part of these efforts are presented on Figure 1.2.

Groundwater within the bedrock aquifer moves primarily within dipping bedding planes and fracture aquifer units and minor movement of groundwater occurs between these aquifer units vertically (Michalski, 1990). This aquifer concept is presented in Figure 1.5. Therefore, groundwater is carried deeper vertically into the subsurface as it moves horizontally downgradient off site. The initial phase of the investigation focused on determining the site-specific hydrogeologic characteristics. This was accomplished by installing bedrock test holes, conducting various geophysical tests within the boreholes, converting the test holes to monitoring wells, collecting depth-discrete samples for analysis, and installing additional bedrock wells based on these results during the field work in 2010. The 2010 work identified three main aquifer units that the VOC contamination was located within and these were defined, from shallowest to deepest, as Unit B, Unit C, and Unit D. These aquifer units were found to dip downward to the northwest at an 11° angle. Subsequent field efforts conducted in 2012 through 2013 focused on installing bedrock monitoring wells within these units to define the vertical and horizontal extent of the VOC contamination onsite and on the adjacent properties to the northwest, north, and northeast. The vertical extent of the VOC contamination was defined during this work and the primary mass was found to be in the shallowest aquifer unit, Unit B.

From 2014 through January 2016, the objective of the investigation was to determine the downgradient horizontal extent of the contamination in the most highly contaminated aquifer unit, Unit B, and to further delineate the source area onsite. The onsite source area was further delineated by installing temporary borings and collecting discrete samples within the northern portion of the site and installing four shallow wells at the top of the bedrock water table surface. The focus of the downgradient investigation was offsite to the northwest in the direction of aquifer units dip. A series of five wells was installed in the right of way along Voorhees Avenue in the direction of the bedding dip (MW-36B through MW-39B and MW-43B). These wells were installed to depths between 225 to 340 feet deep below ground surface into Unit B. An additional well was installed at the northern end of Clarendon Street, MW-42B, to act as a control point outside of the zone of contaminated groundwater. Discrete groundwater samples, predicted depths using dipping angle calculations, drilling characteristics, and borehole gamma logging were used to help identify Unit B to determine the appropriated depth of each of these monitoring wells. The potentiometric surface contours for Unit B are presented on Figures 1.7a and 1.7b.

1.5 Nature and Extent of Contamination

Contaminant data collected prior to the FS were compared to the more stringent criterion of the New Jersey Class II-A Groundwater Quality Criteria and the National Primary Drinking Water Standards, referred throughout this document as *comparison criteria*. Analytical results used in the characterization of the Groundwater OU were obtained from the Groundwater RI (USACE, 2005a) and the Groundwater Investigation Technical Memorandum (USACE, 2017). Plume maps for CT and TCE are presented in Figure 1.8. The remaining VOC COC found on-site, chloroform, is co-located with CT but in lower concentrations. Review and analysis of the data collected during sampling events shows that the COCs have been adequately characterized for evaluating feasible remedial alternatives.

Specific analytical data used to evaluate the nature and extent of contamination include the following:

- Groundwater sampling and analysis of seven monitoring wells in the South Drainage Ditch area in July 2001.
- Two rounds of groundwater sampling and analysis referred to as the "RI sampling" events. Round 1 took place between May and June 2001 and Round 2 was completed between December and January 2002. Groundwater samples were collected from 17 overburden wells and 7 bedrock wells.
- Groundwater sampling and analysis of URS-MW-17S and URS-MW-18S in March 2002.
- Groundwater sampling and analysis of eight temporary well points and 9 piezometers in the overburden in July 2004.
- Groundwater sampling and analysis of five perimeter overburden wells and 8 bedrock wells in October and November 2004.

- Results of groundwater sampling and analysis during ES monitoring in 2000-2009.
- Groundwater sampling, geophysical results, and off-site groundwater delineation results are reported in the Groundwater Investigation Technical Memorandum (USACE, 2017).

Analytical data were validated using guidelines and procedures described in the Groundwater OU RI. Overall, the data are acceptable, usable, and, for the most part, in compliance with the Full CLP Data Deliverable Format. Less than one percent of the entire data set has been rejected as unreliable. The quality assurance review did identify aspects of the analytical data that required qualification. Data qualifiers, when applicable, are placed next to the results in tables and on figures so that the data user might assess the qualitative and/or quantitative reliability of the reported concentration.

1.5.1 Radionuclides in Groundwater

Concentrations of groundwater samples evaluated for the primary radionuclide of concern, total uranium, suggests that the OU1 Soils Removal Action has greatly improved MSP groundwater quality for radionuclides. Prior to the OU1 Soils Removal Action, total uranium concentrations exceeded the MCL criteria by a factor of 10. Since completion of the OU1 Soils Removal Action, total uranium exceedances have been limited to four wells (MW-OB-7, MW-OB-8, MW-OB-10, and MW-OB-12), with results marginally above criteria and only one exceedance at MW-OB-7 in the 2012 sampling event. No exceedances were detected in the most recent sampling events (2014 and 2015). The October 2014 and December 2015 total uranium detections for the overburden MWs are presented in Figure 1.9. The overburden wells potentiometric surface contours for December 2015 are presented in Figure 1.10.

Total uranium in former source area well MW-OB-8, marginally exceeded USEPA's MCL during the first sampling event following the soils removal and since has remained below USEPA's MCL. Total uranium in MW-OB-7, also located in the former source area, marginally exceeded criteria during the first three sampling events, dropping below the criteria in SE 4, SE 5, SE 7, SE 8, SE 9, SE 11, and SE 12, with an increase above the criteria in SE 6, SE 10,and SE 13.

Since the OU1 Removal Action, all overburden monitoring wells cross-gradient and downgradient south of the former source area (south of the groundwater divide) have been below the MCL, trending towards background levels or non-detections. Overburden monitoring wells north of the groundwater divide, cross-gradient and downgradient of the former source area have been below criteria, except for MW-OB-12 with a result above the USEPA criteria in SE 7 and MW-OB-10 with results above USEPA's MCL in SE 11 and SE 12. Table 1-3 presents a summary of the overburden monitoring well total uranium detections.

Monitoring wells MW-OB-7 and MW-OB-10 are the only wells with a detection of total uranium above criteria more than once. MW-OB-7 has shown six of thirteen sample results above criteria. MW-OB-10 has only shown two of twelve sample results above criteria, both in recent sampling events (SE 11 and SE 12). The well was not sampled during SE 13, SE 14, or SE 15 because it was dry. Both of these wells have exhibited very low yields. During sampling of MW-OB-7, establishment of a stable water level within USEPA Region 2 and NJDEP low-flow sampling guidelines was not accomplished while using low purge rates (120 milliliters per minute) due to very low yield of the well. This creates uncertainty in the validity of these samples results. MW-OB-10 has typically held a low water column averaging only 4.6 feet during the first twelve sampling events. While sampling in 2012, MW-OB-10 had a 3.2-foot water column or less within the well and was found to be dry during SE 13. Purging could not be established in this well because of the low water column and lack of yield. Only grab samples were collected, which creates uncertainty in the validity of these results. Both of these wells were abandoned, and MW-OB-07 was re-drilled within 10 feet of its previous location in an attempt to establish greater well yields as silts may have fouled the sand pack. MW-OB-10 was not replaced given the proximity of other overburden monitoring wells.

For all overburden wells (MW-OB), the geochemical parameters indicate favorable conditions for natural attenuation by sorption onto iron oxyhydroxides, as indicated by the high oxidation reduction potential (ORP) values and low ferrous iron levels.

1.5.2 VOCs in Groundwater

VOCs detected in samples collected from groundwater at the MSP are evaluated for the overburden and bedrock zones.

1.5.2.1 VOCs in Overburden Groundwater Prior to Soils OU-1 RA

VOCs were detected in a sample collected from a single piezometer installed in the overburden and sampled once in 2004. This result indicated there may have been minor isolated CT (89 µg/L), chloroform (30 µg/L), and TCE (3.8 µg/L) contamination in the saturated overburden unit near the north-central part of the site (Appendix B). Sample results prior to and after this sampling event indicate that these contaminants are not widely distributed or moving off site through the saturated overburden unit. Other VOCs detected at concentrations exceeding comparison criteria were chloroform, MTBE, methylene chloride, and tert-butyl-alcohol [TBA]. Of these compounds, methylene chloride, a potential laboratory contaminant, was eliminated from further consideration in the RI and will not be discussed further in this FS.

MTBE, a fuel additive that was not in use at the time the MSP was operating, was detected in groundwater in the southern portion of the site, specifically in the monitoring wells on the southwest and southern edge of the site near the South Drainage Ditch. Four samples showed MTBE concentrations exceeding the comparison criteria value of 70 µg/L from the overburden wells B18W27S (1,300 and 687 µg/L), B18W28S (74.6 µg/L), and PZ-8 (280 µg/L).

TBA, a breakdown product of MTBE, was also reported in groundwater from the southwestern portion of site at concentrations that exceeded the comparison criteria value of 100 µg/L. The maximum concentration of TBA was detected in the overburden well B18W27S (with eleven samples above the criteria value and a maximum of 3,170 µg/L). Note that this is the same location where the maximum MTBE concentration was detected. TBA concentrations above the comparison criteria value were also reported at locations PZ-8 (290 µg/L) and in the bedrock well URS-MW-9D (470 and 434 µg/L). A review of historical activities at the site indicates that MTBE and TBA would not be related to site activities. These are compounds generally associated with gasoline and other petroleum-related hydrocarbons that came into widespread use in the late 1970s.

The distribution of MTBE and TBA in the groundwater at the MSP is in the southwest corner and along the western property boundary of the site, which adjoins a property occupied by an automobile salvage yard. The presence of MTBE and TBA in the shallow groundwater may therefore indicate the migration of these compounds from an off-site non-FUSRAP source.

1.5.2.2 VOCs in the Overburden and the Bedrock Groundwater

CT and TCE are the most prevalent VOCs detected at MSP and the surrounding area, although other chlorinated compounds and their breakdown components and petroleum-related compounds have been detected in samples collected from the monitoring well network. The presence of chloroform and dichloroethene (1,1-DCE and cis-1,2-DCE) in site MWs is likely the result of degradation of CT and 1,1,1-TCA, respectively. Shallow wells containing CT on-site and bordering the site have typically exhibited a much higher concentration of CT than TCE. No other VOCs were detected in on-site monitoring wells at concentrations that indicated a potential that they had been released to the environment on-site.

No shallow sources of CT and/or TCE were detected on-site in overburden groundwater screening or monitoring well samples. The highest groundwater concentrations of CT and TCE were detected in samples collected from Unit B and shallow bedrock wells.

The Unit B bedrock MWs, CT/TCE concentrations, and CT/TCE iso-concentration contours for the most recent sampling event (SE 16) are presented on Figure 16 of the Groundwater Investigation Technical Memorandum (USACE, 2017) and on Figures 3.1 and 3.2. The highest concentrations of CT, TCE, and chloroform have been detected in ECC-MW30B, but the concentrations have been decreasing consistently and significantly since this well was first sampled in 2012. The concentrations in the well during SE 11 were 13,000 µg/L (CT), 600 µg/L (chloroform), and 430 µg/L (TCE); concentrations decreased to 1,200 µg/L (CT), 75 µg/L (chloroform), and 50 µg/L (TCE) during SE 16 in 2015 (see Table 1-4). EE-MW-41S showed a similar trend between the only two times this well was sampled (SE 15 and SE 16). The concentrations detected in this well were 2,460 µg/L (CT), 222 µg/L (chloroform), and 62 µg/L (TCE) during the first sampling event, and the concentrations dropped to 32 J µg/L (CT), 4.1 J µg/L (chloroform), and 0.61 J µg/L (TCE) in the following event.

Both of these wells, ECC-MW-30B and EE-MW-41S, were installed within the bedrock aquifer beneath the overburden unit to depths of 53 feet BGS and 30 feet BGS, respectively, with 10-foot well screens. Samples collected from wells installed at these depths would be expected to have lower VOC concentrations than samples collected from shallower or upgradient wells nearer to release areas (surface). Upgradient screening samples collected from Unit B and overburden groundwater did not exhibit significant concentrations of these VOCs. The significant reduction in CT, chloroform, and TCE concentrations seen in on-site wells ECC-MW-30B and EE-MW-41S indicates that the initial elevated concentrations of these contaminants may have been a secondary effect of drilling through minor residual contaminants in the unsaturated portion of the weathered bedrock, beneath the limits of the remedial excavation of site soils (OU1 remedial action). Thus, groundwater screening samples and monitoring well samples collected from Unit B and the top of bedrock aquifer (shallow bedrock wells) indicate that residual materials may be contained in the unsaturated portion of the weathered bedrock but are limited to a small area on the northern-central portion of the site, around ECC-MW-30B, EE-MW-41S, and the former sump of the Process

Building. The sump was 12 feet long, 6 feet wide, and 10 feet deep. Although the sump was built to accept wastewater from the building, it may have been used as a disposal point for other wastes. The location of the sump is indicated on Figure 1.3.

Concentration trends for CT and TCE in other site bedrock wells are relatively stable. The concentrations of VOCs detected in Units C and D at the same location of Unit B are lower as a result of minor downward vertical leakage through fractures.

1.5.3 SVOCs in Groundwater Prior to Soils OU1 RA

The SVOCs detected in groundwater at the site above the comparison criterion were bis(2)ethylhexyl-phthalate and 1,2,4-trichlorobenzene. Bis(2)ethylhexyl-phthalate was, however, also detected in the off-site background well and is a common laboratory contaminant. 1,2,4-trichlorobenzene was detected in two adjacent overburden wells (B18W28SR and B18W28S) at the south end of the site. Four samples from December 2000 to December 2001 had positive detections, but only one exceeded the MCL of 9 μg/L (11 μg/L) and it has not been detected since. For these reasons, SVOCs are not considered a contaminant of potential concern for the MSP.

1.5.4 Metals in Groundwater Prior to Soils OU1 RA

Samples collected at the MSP contained numerous metals that exceeded comparison criteria values, including aluminum, arsenic, chromium, lead, nickel, iron, manganese, antimony, and sodium. A groundwater sample collected from URS-MW-18S contained numerous metals in excess of the comparison criteria values. The turbidity of this sample, however, was noted to be greater than 800 nephelometric turbidity units (NTU). This indicates that the concentrations of metals reported at this location are likely to be biased high and not representative of site groundwater quality. Other groundwater samples (with lower NTU values) collected from the same location contained concentrations of these metals below comparison criteria values. Metals, such as aluminum, iron, and manganese, are distributed in the groundwater throughout the site.

As described in Section 1.3.5, the Passaic Formation, which underlies the MSP, is rich in minerals such as feldspar, hematite, and other trace minerals that contain aluminum, iron and manganese. The presence of these metals at the MSP is therefore considered to be part of the natural setting, and the concentrations representative of regional background. Other metals, such as chromium, nickel, antimony, and lead, were detected in excess of comparison criteria values in groundwater from monitoring wells in the southern and southeastern portion of the site. None of these metals were found to exceed comparison criteria values in samples collected from groundwater monitoring wells in the northern portions of the site.

1.6 Contaminant Fate and Transport

As described in Section 6.0 of the Groundwater OU RI (USACE, 2005a), a summary of contaminant fate and transport processes has been developed. Available data have been used to characterize and develop a conceptual understanding of the flow systems at work at the MSP. The Conceptual Site Model (CSM) is presented in Figure 1.11. Mathematical models have been established and calibrated to represent site conditions using available hydraulic and contaminant data. Simulations for U-238, U-234, Ra-226, Ra-228, MTBE, TCE, and CT were performed. The models provided a quantification of fate and transport processes of contaminants that exceed limits of the groundwater quality comparison criteria outlined in Section 6.3.1 of the RI. This section presents an overview of the results of the modeling effort performed in support of the RI. The CSM presented in the Groundwater OU 1 RI (USACE, 2005a) was reevaluated with the current understanding of the site based on data collected during the recent groundwater investigation (USACE, 2017): the current understanding of the CSM is consistent with previous presentations, as described below.

1.6.1 Conceptual Site Model

A CSM is a statement of our understanding of site conditions. The hydrogeologic conceptual model for the MSP was developed using data and information generated during the Groundwater OU RI (USACE, 2005a), and to a lesser extent, data from past reports. The model incorporates hydrologic data, site physical characteristics, infiltration/recharge, and surface water drainage patterns. The conceptual model provides a mechanism where observations can be compared and predictions can be made for potential exposure locations. The predictive function of the site conceptual model, of primary importance to contaminant fate and transport analysis, relies on known information and assumptions about the site.

The conceptual hydrogeological model for the MSP indicates that since the site was paved (1946), infiltration of precipitation is not a significant pathway for mobilization of contaminants. However, the coarse material surrounding the stormwater lines (the Pipe Chases) may serve as a localized preferential flow path for precipitation and water leaking from the stormwater lines to reach overburden groundwater.

Two subsurface flow systems are present at the MSP. Groundwater flow in the overburden in the northern one-third of the site is generally north to northeast and northwest, toward a railroad right-of-way, with a typical gradient of 0.008 to 0.016. In the southern two-thirds of the site, shallow groundwater flow is generally to the south to southeast, with a gradient of 0.01 to 0.02 and a hydraulic conductivity of 2.7 feet/day. Closer to the southern boundary of the site, groundwater in the overburden may discharge to the South Drainage Ditch.

The groundwater aquifer in the shallow bedrock at the MSP occurs 15 to 50 feet below grade and is at least 50 feet thick. The bedrock unit also has a low hydraulic conductivity (1.5×10^{-1} feet/day), and a low hydraulic gradient (0.008 to 0.012). The shallow bedrock is separated from the overburden flow system by the extremely weathered bedrock, which serves as a leaky aquitard, with many of its fractures filled with silt and clay.

South of the site, potential receptors of groundwater from the overburden system include the South Drainage Ditch, the wetlands area adjacent to the South Drainage Ditch, and Main Stream. Once groundwater discharges to these receptors, it can move via overland flow to Ambrose Creek, which in turn discharges to the Raritan River, approximately 1 mile from the MSP. Groundwater in the overburden is not used for water supply. To the north, groundwater in the overburden may discharge to a drainage ditch in the railroad right-of-way, which in turn, during periods of heavy runoff, flows to Ambrose Creek and eventually to the Raritan River. Groundwater in the shallow bedrock flows south-southeast, with no surface water bodies or topographic features in the area to serve as a potential receptor. Some local area residents do use groundwater from the deeper bedrock as a source of water. However, these supply wells are many hundreds of feet deep and are not likely to be influenced by the shallow bedrock groundwater at the MSP.

The release area for the CT and TCE (and the breakdown product chloroform) appears to be limited to a small sump that was located in the former Process Building (Figure 1.3). This sump was used to dispose of wastewater and may have been used for the disposal of non-water residuals, although site records do not indicate the use of solvents as part of site operations. This sump was 12 feet long, 6 feet wide, and 10 feet deep and had a feeder line leading from it to the main pipe chase line. Records indicate that the sump was open and in communication with groundwater (overburden). The bottom of the sump would have been near the interface of the overburden groundwater unit and on top of the unsaturated weathered bedrock, providing a migration pathway directly to the bedrock aquifer. Residuals disposed of at this depth would have spread downward and outward from this point along fractures and partings within the unsaturated bedrock before reaching the water table. CT and TCE were not detected in groundwater samples collected from the overburden wells or overburden screening samples during the most recent sampling events (SE 15 and SE 16).

Based on historical analytical data gathered as part of the RI and the 2016 Groundwater Investigation Technical Memorandum (USACE, 2017), groundwater contamination associated with activities at the MSP is located in the shallow overburden groundwater unit that generally lies within 10 feet of the ground surface (total uranium). The overburden groundwater contamination came from a release at the surface with the contaminant, uranium, leaching from soils that were removed during the soils remedial action in 2008. The Groundwater Investigation Technical Memorandum (USACE, 2017) describes the total uranium concentrations trending below MCLs.

1.7 Human Health Risk Assessment Summary

This section presents summaries for two HHRAs that were conducted for MSP groundwater. Section 1.7.1 summarizes the results of the Baseline HHRA performed in 2005 as part of the Groundwater OU RI (USACE, 2005a). Section 1.7.2 summarizes the Supplemental HHRA completed following the soils removal action, installation and sampling of a network of monitoring wells, and additional data collection. The Supplemental HHRA report is included as Appendix A to the Groundwater Investigation Technical Memorandum, an addendum to the RI (USACE, 2017).

Current USEPA guidelines for acceptable exposures are a reasonable maximum individual lifetime excess cancer risk in the range of 1×10^{-4} to 1×10^{-6} (corresponding to a 1 in 10,000 to 1 in 1,000,000 increase in the probability of cancer as opposed to a 1 in 3 normal background risk).

For non-cancer health effects, a “Hazard Index” (HI) is calculated. An HI represents the sum of the individual exposure levels compared to their corresponding reference doses (RfDs). The key concept for a non-cancer HI is that a “threshold level” (measured as an HI of 1) exists below which non-cancer health effects are not expected to occur.

Groundwater containing site related contaminants is not currently used as a potable water source or for other purposes. Though there are no known plans to use the groundwater in the future, use of this aquifer for a water source still presents a potential future risk. The primary designated use for groundwater in the area is a provision of potable groundwater with conventional treatment at current water quality (Class II-A). Therefore, the risk assessment assumed the best use of groundwater to be potable while determining exposure scenarios. Contaminated groundwater emanating from the site migrate beneath residential (offsite) and commercial/industrial properties (onsite and offsite) and therefore both exposure scenarios were evaluated in the risk assessment.

1.7.1 Baseline Human Health Risk Assessment

The Baseline HHRA performed in 2005 evaluated the risks from contaminants (radionuclides, VOCs, SVOCs, and metals) in on-site groundwater to hypothetical future residential receptors at the site. The COPCs that were carried through the Baseline HHRA process included nine radionuclides, six VOCs, two SVOCs, and 13 metals. It should be noted that this Baseline HHRA was performed prior to the soil removal action as part of the OU1 remedial action and concentrations of uranium in groundwater have decreased significantly since this action. The results of the Baseline HHRA are summarized below:

- The potential cancer risk associated with groundwater use by a hypothetical future on-site resident was approximately 1 x 10^{-4} for a site-wide average concentration, which is equal to the upper limit of USEPA's acceptable risk range. Uranium contributed 7 x 10^{-5} of the risk and radium contributed 2 x 10^{-5} of the risk. Chemical exposure from VOCs comprised 2 x 10^{-5} of the risk. The potential cancer risk at the well showing the highest radiological contamination, well B18W24S, was approximately 6 x 10^{-4}, primarily due to ingestion of uranium in drinking water.
- Hazard indices exceeded 1 for the resident (HI of 5) and child resident (HI of 14) for average site-wide groundwater exposure. The exceedance of the noncancer benchmark was primarily based on the concentration of manganese. For the well with the highest radiological contamination (B18W24S), the HI for the child resident was 15 due to the uptake of uranium. For the well with the highest chemical risk (URSMW2D), the HI for the child resident was 6, primarily due to CT concentrations.
- Exposure to sediments and surface water at the MSP posed a cancer risk of 2 x 10^{-5}, which is within USEPA's acceptable risk range. Non-cancer health effects from sediments and surface water are unlikely.

Based on the cancer risks and health hazards calculated for the COPCs, the following contaminants were identified as significant contaminants in the Baseline HHRA: total uranium (as a toxic metal); uranium-238 and uranium-234 (as radiological contaminants); CT; and manganese. The detected concentrations of the radium isotopes were comparable to background concentrations and below the established drinking water standards, therefore they were not classified as significant contaminants. Manganese was identified in the risk assessment as posing a non-cancer health hazard but is not a site contaminant. Historical records of site activities do not indicate its use or possible use. Elevated manganese has been documented for groundwater in the Newark Group (Serfes, 1994). Therefore, manganese is considered to be part of the natural background at this site rather than a result of government activities at the site and is not further addressed in this FS.

1.7.2 Supplemental Human Health Risk Assessment

The Supplemental HHRA for the MSP site (Appendix A of the Groundwater Investigation Technical Memo [USACE, 2017]) evaluated the risks associated with VOCs in groundwater to hypothetical future on-site workers and hypothetical future off-site residential receptors. Groundwater sample results for the two most recent sampling events (2014, 2015) from five wells within the core of the plume were used for the risk assessment. Based on the potential risks and hazards identified by the Supplemental HHRA, CT, TCE, and chloroform were identified as significant contaminants (see Table 1-5 through Table 1-10). The results of the Supplemental HHRA are summarized below:

- For the adult worker exposure to groundwater, the reasonable maximum exposure (RME) cancer risk exceeded EPA's acceptable risk range. The total cancer risk of 1.4 x 10^{-3} was primarily due to CT. The central tendency exposure (CTE) cancer risk was within the acceptable risk range at 9.0 x 10-^{5}. The HI for the adult worker exposure to groundwater was 17.3 for the RME scenario primarily due to CT and TCE. The HI for the CTE scenario was 4.2, primarily due to CT.
- For the child residential exposure to groundwater, the RME cancer risk exceeded EPA's acceptable risk range. The total cancer risk of 1.2 x 10-^{3} was primarily due to CT. The CTE cancer risk also exceeded the acceptable risk range at 2.5 x 10-^{4}. The HI for the child resident exposure to groundwater was 59.1 for the RME scenario primarily due to CT, chloroform, and TCE. The HI for the CTE scenario was 17.9 due to CT and TCE.
- For the adult residential exposure to groundwater, the RME cancer risk exceeded EPA's acceptable risk range. The total cancer risk of 3.4 x 10^{-3} was primarily due to CT and chloroform. The CTE cancer risk also exceeded the acceptable risk range at 4.6 x 10^{-4}. The HI for the adult resident exposure to groundwater was 48.6 for the RME scenario primarily due to CT, chloroform, and TCE. The HI for the CTE scenario was 15.9 due to CT and TCE.

Low levels of VOCs have been found in an upgradient well indicating that off-site VOCs could be impacting groundwater conditions at the MSP site. However, the USACE will address VOC contamination in consideration of future redevelopment of the site and potential future use of impacted groundwater on the property.

The vapor intrusion screening evaluation associated with the Supplemental HHRA indicated concerns for the vapor intrusion pathway. These concerns are addressed further in Section 1.7.3 of this FS.

Risks are typically expressed as total of all contaminants for particular pathways and receptors. A total risk from all contaminants (radiological, VOCs, metals) is provided in the Baseline HHRA discussion above. However, as a conservative measure, the Baseline HHRA evaluated a hypothetical on-site residential receptor and the Supplemental HHRA evaluated risk from VOCs to a hypothetical future on-site worker because the land is zoned for industrial use. Therefore, the risks from the Baseline HHRA and Supplemental HHRA were not added because the receptor populations differed.

1.7.3 Vapor Intrusion Addendum

VOCs present in unsaturated soil or in the dissolved phase in groundwater can act as a source for contaminant vapors that have the potential to migrate into indoor air. Vapors migrating upward can accumulate beneath relatively impermeable structures such as buildings and potentially migrate into buildings, posing a health risk. For a health risk to be present, a source, a receptor, and a pathway must be present. Although a groundwater source and existing and potential future receptors are present, there is no pathway for vapor intrusion into indoor air, rendering potential human health risk non-existent. Although site records do not indicate the use of VOCs at the MSP site, bedrock wells contain concentrations of VOCs, with CT, TCE, and chloroform detected at the highest concentrations. The potential release point of these substances is believed to be a sump in the former Process Building that was used to dispose of wastewater. The sump was 12 feet long, 6 feet wide, and 10 feet deep. The bottom of this sump was below the saturated overburden water table surface. Further discussions of the source, receptors, and pathway are provided below.

Sources for vapor intrusion may include:

- Soils: VOCs were not detected in soils during the OU1 remedial investigation in sufficient concentrations or frequency to consider them site COCs (USACE, 2004). In addition, unsaturated site soils were removed during the OU1 remedial excavation in 2008 and backfilled using clean fill (USACE, 2010b). Therefore, there is no source of VOCs in site unsaturated soils on the MSP property that could produce vapors, and this potential pathway does not exist and will not exist in the future on this site.
- Groundwater: VOCs were not detected in the saturated overburden unit at concentrations greater than USEPA Vapor Intrusion Screening Levels or NJDEP Generic Vapor Intrusion Screening Levels for groundwater in the saturated overburden unit (USEPA, 2016a; NJDEP, 2013). VOCs were detected in the bedrock aquifer at concentrations above both federal and state groundwater screening levels for vapor intrusion.

Potential vapor intrusion receptors may include:

- MSP site: There are currently no buildings on the MSP property; thus, there are no current risks. Buildings could be placed on the site in the future as the site is zoned for commercial and industrial use; therefore, the potential for future receptors exists.
- Off-site: Residential, commercial, and industrial buildings are located within 200 feet of the MSP site boundaries. Therefore, current potential receptors exist.

Pathway Analysis

VOCs are not present in site soils; therefore, this pathway does not exist at the MSP site.

Groundwater pathways include:

- The hydrogeologic model of the site includes two distinct groundwater flow regimes consisting of a perched saturated overburden unit sitting atop a deeper multi-unit bedrock aquifer system. The saturated overburden unit provides recharge to the bedrock aquifer system. The primary groundwater flow within the bedrock is downward along bedding planes that dip 11 degrees to the northwest. Water within the bedrock that is contaminated with VOCs follows this path, and as this water moves further from the source area it is carried deeper into the subsurface with the most contaminated bedding plane (Unit B) at a depth of more than 75 feet bgs at the site boundary. Three primary bedding planes were identified during the supplemental groundwater investigation (USACE, 2017). These planes were called Units B, C, and D (Figure 1.12).
- VOCs present as site significant contaminants have not been detected in monitoring wells in the saturated overburden unit. The VOCs detected in this unit, MTBE and PCE, are not COCs and were detected at levels 1/100 (MTBE) and 1/20 (PCE) below the NJDEP screening levels (NJDEP, 2013). The saturated overburden unit meets the criteria for a clean water lens as described in the NJDEP Vapor Intrusion Guidance (NJDEP, 2013), with an average thickness of 3 to 5 feet. This clean water lens provides a barrier through which VOCs cannot migrate to unsaturated soils above..
- The aquifer units containing VOCs at concentrations greater than groundwater screening levels occur within the bedrock bedding planes (Figure 1.12). Competent, low-permeability bedrock overlaying the VOC-contaminated bedding planes further inhibits potential upward migration of vapors.

Since both a clean water lens is present and low-permeability bedrock inhibits migration of vapors, there is no migration pathway from the areas of VOC contamination to potential current or future receptors, either on the MSP site or off-site.

1.8 Screening-Level Ecological Risk Assessment

A SLERA (USACE, 2005a) was conducted for the MSP groundwater in 2005 for the site contaminants identified at that time. This SLERA, which was completed as part of the OU2 Groundwater Remedial Investigation, evaluated the potential for harmful effects to ecological receptors exposed to chemicals and radionuclides released from the facility to surface water and sediments. Maximum concentrations of metals, organic compounds, and radionuclides were used to assess potential risk to these receptors. The conclusions from the MSP Groundwater OU RI SLERA were:

- Historic water and sediment sampling demonstrate that site related concentrations decrease with distance from the MSP. Sediment and surface water samples collected to support this SLERA were collected from the drainage way leading from the MSP outfall to the Main Stream at Cedar Avenue (near the confluence with Ambrose Brook). Concentrations at the Cedar Avenue monitoring location in water and sediments were found to be within background levels. Limited sampling of Ambrose Brook sediments has been conducted during past investigations at the MSP. Results have been within the typical range of background concentrations. The most significant sampling effort of Ambrose Brook was when the USDOE conducted an investigation of the nearest and sediment accumulation point of Ambrose Brook in Willow Lake (now known as Lake Creighton). The investigation concluded that the lake sediments were within typical background levels for MSP contaminants (ORNL, 1981).

- A number of metals were present in surface water at maximum detected levels above background concentrations and ecological screening values (ESVs). Average concentrations of these metals were below the ESVs. Ecological impacts from constituents in surface water are unlikely.
- A single organic detection in surface water (benzo[a]anthracene) was below the practical quantitation limit, but above the ESV. Based on the limited extent of detected contamination, ecological impacts from this contaminant are unlikely.
- Radionuclide doses were projected for aquatic and benthic organisms, taking into account external and internal exposure routes. The total doses projected for these receptors were less than 0.1 rad per day, the ESV adopted for the SLERA. On the basis of these calculations, no radionuclides were identified as COPCs.
- Concentrations of metals in the sediments are similar to the distribution in the background samples. Maximum detections of some metals were above the ESV and background levels. Cadmium, copper, lead, manganese, and zinc each have mean concentrations greater than background, with the average concentration of each contaminant no more than 2.5 times its respective background. Ecological impacts from contaminated sediments are unlikely.
- Sensitive habitat has not been identified on-site, and the current and likely future land uses make it unlikely that this area would be a significant ecological habitat.

Additional information on VOCs collected during the supplemental groundwater sampling and documented in the Groundwater Investigation Technical Memorandum (USACE, 2017) indicated that site-related VOCs are migrating off-site via bedrock bedding planes that do not discharge into surface water systems (USACE, 2017). In addition, no ecological habitats have been identified at the MSP site.

1.9 Basis for Conducting the MSP Groundwater OU Feasibility Study

Results of the Groundwater OU characterization program identified elevated levels of uranium and select VOCs in groundwater that originate from the MSP site. In addition, the results of the HHRAs using these elevated levels indicate that the groundwater would present unacceptable risks if future residential use of the site were to include groundwater use. Therefore, to assist in attaining beneficial reuse of the site, it was necessary to a conduct a Feasibility Study to evaluate remedial alternatives for the groundwater at this OU.

2.0 IDENTIFICATION AND SCREENING OF TECHNOLOGIES

Section 2.0 describes the site screening process information to support the various technologies recommended for the response action at the MSP. Section 2.0 also presents ARARs, RAOs, and GRAs to support the initial development and screening of remedial action technologies and process options for the MSP. The result is the development of a range of management options to be considered further or grouped together into potential remedial alternatives as presented in Section 3.0.

The purpose of the screening process is to identify a range of suitable remedial action technologies and process options to build remedial alternatives capable of reducing the risks to human health and the environment at the MSP to acceptable levels.

2.1 Introduction

USEPA's *Guidance for Conducting Remedial Investigations and Feasibility Studies under CERCLA* (USEPA, 1988) has established a structured process for identifying and screening relevant technologies and process options for determining methods for remediation of contaminated sites.

The screening process proceeds in a series of steps designed to condense available technology types and process options into a subset of viable alternatives from which a final remedy may be selected. This development process involves:

- Developing appropriate ARARs (Section 2.2);
- Identifying RAOs specific to the contaminated environmental media, including the presentation of potential COCs (Section 2.3);
- Identifying GRAs that are likely to attain the RAOs for the site (Section 2.4);
- Identifying broad categories of technologies and specific process options applicable to the GRAs, and performing an initial screening based on technical implementability (Section 2.5);
- Evaluating the retained process options further based on effectiveness, implementability, and cost (Section 3); and
- Selecting the representative process options for the various technology types and combining them with the GRAs to form remedial alternatives (Sections 3.1 and 4).

2.2 Identification of ARARs

Remedial actions for this site shall attain a degree of cleanup that assures protection of human health and the environment. Fulfilling this requirement includes identifying and meeting ARARs. Although the FS identifies environmental standards that may be considered ARARs, the final determination of ARARs will be presented in the ROD for the site.

2.2.1 ARARs Defined

Section 121 of CERCLA specifies that remedial actions must comply with requirements or standards under federal, or more stringent, state environmental laws that are applicable or relevant and appropriate to the hazardous substances or particular circumstances at the site.

Applicable requirements are defined by 40 CFR § 300.5 as, "…those cleanup standards, standards of control, and other substantive 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 are also defined by 40 CFR § 300.5 as, "…those cleanup standards, standards of control, and other substantive requirements, criteria, or limitations promulgated under federal environmental or state environmental or facility siting laws 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."

Where state environmental statutes or regulations are promulgated that are more stringent than federal regulations, those state standards may be ARARs. To be ARARs, state statutes or regulations must be (1) promulgated so that they are of general applicability and legally enforceable, (2) identified by a state in a timely manner, and (3) more stringent than federal requirements. Thus, subject to the previous three conditions for consideration of state environmental statutes and regulations, if a federal cleanup standard for a contaminant does not exist, or where the state of New Jersey has identified a promulgated cleanup standard that is more stringent, the New Jersey regulations shall be evaluated as a potential ARAR for the MSP.

In addition to applicable requirements and relevant and appropriate requirements, the NCP identifies a third category, termed information "to be considered" (TBC). TBCs are non-promulgated guidelines or advisories issued by the federal or a state government that are used to ensure protection of public health and the environment. Because they are not promulgated, such guidelines and advisories cannot be ARARs, and are not legally binding. TBCs are considered when ARARs are not available for a particular circumstance at a CERCLA site.

2.2.2 Types of ARARs

Hazardous substances present at the site influence the selection of ARARs, the characteristics and location of the site, and the planned actions for remediating the site. Thus, requirements may be chemical-, location-, or action-specific. These categories are not necessarily mutually exclusive and may overlap conceptually.

Chemical-specific ARARs are generally health- or risk-based concentration values set for specific hazardous substances or other contaminants potentially found in environmental media. Chemical-specific ARARs provide protective cleanup levels or a basis for calculating cleanup levels for chemicals or contaminants in environmental media. Chemical-specific ARARs can also be used to assess the effectiveness of a remedial alternative.

Location-specific ARARs consist of restrictions or requirements for substances or activities based primarily on their physical location. A remedial alternative may be restricted or precluded based on federal, state or facility siting laws that address proximity to wetlands, flood plains, or man-made features (such as existing landfills, disposal areas, and local historic buildings). Location-specific ARARs provide a basis for assessing restrictions during the formulation and evaluation of potential site-specific remedies. No location-specific ARARs are pertinent to this remediation.

Action-specific ARARs are generally technology or activity-based requirements on actions taken with respect to cleanup of hazardous substances at a site. These requirements are triggered by the particular activity that is selected to accomplish a remedy. Therefore, action-specific requirements do not determine the remedial action; rather, they indicate how a selected alternative must be achieved. No action-specific ARARs are pertinent to this remediation.

2.2.3 ARAR Waivers

CERCLA Section 121 stipulates compliance with ARARs established by federal law and, where they are more stringent, state laws. However, there may be certain site conditions that preclude the attainment of ARARs. For these situations, CERCLA identifies six circumstances under which ARARs may be waived:

- The alternative is an interim measure and would become part of a total remedial action that would attain the applicable or relevant and appropriate federal or state requirement.
- Compliance with a requirement would result in greater risk to human health and the environment than other alternatives.
- Compliance with a requirement is technically impracticable from an engineering perspective.
- The alternative would attain a standard of performance that is equivalent to that required under the otherwise applicable standard, requirement, or limitation through the use of another method or approach.
- The ARAR is a state requirement that the state has neither consistently applied, nor demonstrated the intention to consistently apply in similar circumstances.
- For Fund-financed (i.e., Hazardous Substance Response Fund established by section 221 of CERCLA) response actions only, an alternative that attains the ARAR would not provide a balance between the need for protection of human health and the environment at the site and the availability of Fund monies to respond to other sites that may present a threat to human health and the environment.

None of these requirements apply to the MSP; therefore, an ARAR waiver is not pertinent.

2.2.4 Designated Groundwater Use

Chemical-specific ARARs for groundwater are highly dependent upon the use, or potential use, of the groundwater at issue. Under the Federal Clean Water Act, each state must specify appropriate water uses to be achieved and protected. Under New Jersey Law (discussed in more detail below), groundwater is classified as Class I, II, or III. The designated use for Class I groundwater is the maintenance of special ecological resources. Secondary uses include potable, agricultural, and industrial. The designated use of Class II groundwater is to provide potable water using conventional treatment. Both existing and potential potable water uses are included. Class III groundwater can be used for anything other than for potable water. The designated use of groundwater at the MSP site is Class II.

2.2.5 Cleanup Standards for Potable Water

Both the federal and New Jersey governments have promulgated standards, requirements, criteria and limitations that are potential ARARs for groundwater remediation. Federal cleanup criteria for groundwater are found in the rules promulgated pursuant to the Federal Safe Drinking Water Act in the form of MCLs allowable in water delivered to a user of a public water system (40 CFR § 141.2). In addition to promulgating its own MCLs, New Jersey has also promulgated Groundwater Quality Standards (GWQS) at NJAC 7:9C. As stated above, however, only substantive state standards of general applicability that are more stringent than Federal standards are considered as potential ARARs. The following requirements or standards were evaluated as potential ARARs or TBCs:

- **USEPA: 40 Code of Federal Regulations (CFR) Part 141**; National Primary Drinking Water Regulations, 40 CFR § 141.66 (e);
- **NJDEP: New Jersey Administrative Code (NJAC) 7:9C**; New Jersey Ground Water Quality Criteria, NJAC 7:9C App. A, Table 1; and
- **NJDEP: NJAC 7:10;** New Jersey Safe Drinking Water Regulations, NJAC 7:10-5.1.

These requirements or standards are discussed in detail below:

USEPA, 40 CFR Part 141 – National Primary Drinking Water Regulations
The National Primary Drinking Water Regulations are relevant and appropriate because the groundwater under the MSP is classified as potable water. Although the groundwater at the MSP is not presently used as potable water, its classification as Class II groundwater means that the National Primary Drinking Water Regulations are pertinent. These regulations address criteria and standards for pollutants in drinking water and thus address levels that would be obtained from groundwater wells. These regulations contain MCLs for selected COCs at the site (e.g., VOCs and radionuclides) in groundwater. The National Primary Drinking Water Regulations are not applicable because there is no public water supply present at the site (more than 15 connections or 25 people served), nor is one likely in the future because of the low sustainable yield of the overburden and bedrock units at the site.

NJDEP, NJAC 7:9C– New Jersey Groundwater Quality Standards
The GWQS specify the quality criteria and designated uses for groundwater in New Jersey. The criteria are maximum allowable concentrations assigned to each constituent (pollutant). The GWQS also contain technical and general policies to ensure that the designated uses can be adequately protected. Under New Jersey Law, groundwater is classified as Class I, II, or III. These

classifications are broken down further within each class (i.e., Class I-A, I-PL, II-A, II-B, III-A, and III-B). The groundwater at the MSP is classified as Class II-A, which is defined as groundwater of the state, except for groundwater designated in Class I, II-B, and III. The primary designated use for Class II-A groundwater is potable water or for conversion through conventional treatment to potable water. Secondary uses include agricultural and industrial.

The GWQS serve as the basis for setting groundwater discharge standards under the New Jersey Pollutant Discharge Elimination System (NJPDES) program, and establishing standards for groundwater cleanups under the New Jersey Site Remediation Program.

The GWQS lists the original health-based criteria and Practical Quantitation Limits (PQLs) for Class II-A groundwater. Since ARARs must be “attainable”, the PQLs play an important role in determining what criteria to cite. PQLs are commonly used as cleanup goals in place of the criteria when the health-based criteria are below the PQLs. The state can also establish interim specific criteria on an as-needed basis for constituents where there are no current criteria in the GWQS. In addition, where the state believes that the existing specific criteria found are no longer appropriate in light of current scientific information, the state may develop interim specific criteria.

The state can also define an area of temporary noncompliance with specific constituent standards, known as a Classification Exception Area (CEA). A CEA is described in the NJAC 7:9C as *“The Department may establish a Classification Exception Area only when the Department determines that constituent standards for a given classification are not being met or will not be met in a localized area due to: natural quality; localized effects of a discharge approved through a NJPDES permit action; pollution caused by human activity within a contaminated site as defined by the Department in the context of an applicable regulatory program (for example, Site Remediation Program); or an ACL* (Alternative Concentration Limit) *as approved by the Department pursuant to NJPDES. In the context of an applicable regulatory program, the Department shall determine or describe appropriate boundaries for each Classification Exception Area and include the written description of the boundaries in the appropriate permit action along with specifications as to which constituents the exception applies. Classification Exception Areas may only be established when constituent standards are not being met or will not be met due to the conditions set forth above and shall not be established for the purpose of sanctioning violations of constituent standards.”* (NJAC 7:9C-1.6).

The state exercises its authority by utilizing a provision that requires restrictions on existing wells and permits prior to the construction of any groundwater well. Thus, the state administratively controls the drinking water well exposure pathway for those areas classified as a CEA. The groundwater at the MSP is classified as a Class II-A groundwater and is not currently in a CEA.

NJDEP: NJAC 7:10 – New Jersey Safe Drinking Water Regulations

These regulations contain standards for pollutants in drinking water. They are based on the federal standards in 40 CFR Part 141 and pertain if they include an applicable substantive standard not included in the federal regulations, or a substantive standard that is more stringent than that contained in the federal regulations. New Jersey promulgated regulations with substantive standards that are more stringent for the designated COCs than those identified in the USEPA’s MCL (see table below).

2.2.6 Identification of COCs and ARARs

In order to identify the contaminants posing unacceptable risks or exceeding ARARs within the groundwater, a characterization program and HHRAs were performed as described in Section 1.7. Unacceptable risks were identified for contaminants only in the groundwater media of OU2. No unacceptable risks were identified for chemicals detected in the surface water or sediment.

Contaminants identified in groundwater as COCs on the basis of potential risks to future residents (off-site) and/or on-site workers and carried through the FS process are:

- Total uranium (as a toxic metal);
- Uranium-238 and Uranium-234 (as radiological contaminants);
- CT
- TCE; and
- Chloroform

The more stringent of the promulgated values described in Section 2.2.5, for each COC identified for the MSP appears below as the ARAR for that COC at the MSP site. The total uranium MCL of 30 µg/L is protective of kidney toxicity and cancer risk associated with U-234 and U-238 radioactivity (USEPA, 2000a). Therefore, separate ARARs were not established for the uranium isotopes. Though the NJ GWQC for CT is 0.4 µg/L, the ARAR selected for this site is 1 µg/L because 0.4 µg/L is below the reportable level for most analytical methods.

COC	Groundwater ARARs (µg/L)[a]	Source for Cleanup Level
Total uranium	30 µg/L	40 CFR § 141.66 (e)
Carbon tetrachloride	1 µg/L	New Jersey GWQC PQL
Trichloroethene	1 µg/L	New Jersey GWQC PQL
Chloroform	70 µg/L	New Jersey GWQC PQL

[a] The lowest of USEPA's MCLs (40 CFR Part 141), NJGWQC or PQL (NJAC 7:9C), or NJAC 7:10.

COC – contaminants of concern
PQL – practical quantitation limit
µg/L – microgram per liter

It is recognized that PCE, 1,1-DCE, MTBE, and manganese, may exceed comparison criteria, or may have been found to pose a risk in the HHRA, or both. PCE, 1,1-DCE, and MTBE found in on-site wells has been determined to originate from off-site sources and the results of the risk assessment conclude that these contaminants do not present an unacceptable risk at concentrations found on-site. Therefore, they will not be listed as COCs for the site. Elevated manganese concentrations have been determined to represent naturally occurring background conditions and does not need to be included as a COC for the site (Serfes, 1994). Therefore, addressing these contaminants in the groundwater would only be considered during handling, treatment, and discharge of the groundwater, if necessary, as a result of addressing the COC-related contamination.

2.3 Remedial Action Objectives

As required by the NCP, site-specific RAOs were established that take into account the nature and extent of contamination, resources that are currently and potentially threatened, and potential for human and environmental exposure (USEPA, 1990).

RAOs are based on the chemicals exceeding ARARs, receptors, and probable exposure pathways for the contaminated site groundwater. The RAO established for the site is:

- Prevent human ingestion of the groundwater with contaminants of total uranium exceeding 30 µg/L; CT exceeding 1 µg/L; TCE exceeding 1 µg/L; and chloroform exceeding 70 µg/L.

2.4 General Response Actions

GRAs are broad categories of remedies that are capable of remediating contamination at a particular site. Each GRA may include several technologies or process options, some of which might be extensive enough to satisfy the RAO and ARARs on their own, while others have to be combined with additional technologies and/or process options to achieve ARARs and RAOs for the site.

Knowledge of the degree of contamination, estimated groundwater contaminant migration, potential foreseeable receptor, and site-specific conditions were the basis for identifying GRAs at the MSP. A brief description of each GRA follows.

2.4.1 Land Use Controls (LUCs)

LUCs include physical, legal, and/or administrative mechanisms that restrict the use of, or limit access to, real property to prevent or reduce risks to human health and the environment. Physical mechanisms encompass a variety of engineered remedies to contain or reduce contamination and physical barriers to limit access to property, such as fences or signs. The legal mechanisms are generally the same as those used for institutional controls (ICs) as discussed in the NCP. ICs are a subset of LUCs and are primarily legal mechanisms imposed to ensure the continued effectiveness of land use restrictions imposed as part of a remedial decision. Legal mechanisms include restrictive covenants, negative easements, and institutional controls or notices. Administrative mechanisms include public notices, adopted local land use plans and ordinances, construction permitting, or other existing land use management systems that may be used to ensure compliance with use restrictions. LUCs can be an effective means of eliminating possible pathways of exposure and restricting access to contaminated media. LUCs do not reduce the toxicity, mobility, or volume of contamination by engineered action, but are implemented to reduce the probability of physical contact with contaminated media while natural processes are occurring. The primary purpose of LUCs for MSP groundwater would be to control the human exposure to contaminated groundwater for drinking purposes for the period of time until the remedial action cleanup levels have been satisfied according to the groundwater RAO. LUCs are often used in combination with other general response actions.

The MSP is owned by the United States Government, and LUCs during United States Government ownership are entirely within Federal agency control. Deed covenants, or negative easements that would prevent drinking water use of the groundwater on the MSP, are readily available to be included in a deed transferring real property out of the United States Government ownership. Currently, the MSP is restricted by fencing, and access is controlled. If the property is sold by the United States Government at some future time, provisions to continue implementing LUCs would have to be made.

2.4.2 Monitored Natural Attenuation

MNA refers to the reliance on natural attenuation processes to reduce the contaminant concentrations and monitoring to document this reduction. Mechanisms that may result in natural attenuation at the MSP site include: dispersion, diffusion, dilution, and sorption. Based on data presented in the Groundwater Investigation Technical Memorandum (USACE, 2017), a key MNA mechanism, biodegradation, is not likely to be occurring within the groundwater plume at the MSP site. However, the other mechanisms are still relevant to the site, thereby, allowing MNA to still be a viable treatment technology.

MNA as defined in USEPA Office of Solid Waste and Emergency Response *"Use of Monitored Natural Attenuation at Superfund, RCRA Corrective Action and Underground Storage Tank Sites,"* (Directive 9200.4-17P; USEPA, 1999) as the reliance on natural processes (i.e., biodegradation, dispersion, adsorption and dilution) and monitoring to achieve site RAOs. This process option is generally recommended when active treatment measures are not cost-effective, not practical due to time constraints, or not necessary because the groundwater is not a source of drinking water. Dispersion and dilution processes would be especially effective in diminishing contaminant plumes of limited extent and relatively low concentrations. Site conditions at the MSP that favor the use of MNA include contaminants with low mobility (e.g., total uranium), low concentrations of contaminants, low potential for exposure, and low probability for use as a drinking water source.

2.4.3 Containment

This GRA includes technologies that produce physical or hydrologic restrictions on contaminant movement to reduce public and environmental contact with the contaminants.

Although containment involves little or no treatment, it can protect human health and the environment by eliminating or reducing exposure and/or mobility of COCs. Containment is effective in minimizing exposure pathways by isolating the contaminated media from receptors. The containment technologies evaluated for the MSP are in situ stabilization/solidification and physical barriers.

In situ stabilization/solidification, also known as chemical immobilization, involves the binding of inorganic and organic contamination through the injection of stabilizing agents into the subsurface. Contaminants in groundwater become physically bound to the underlying soils or become stabilized and less mobile through chemical reactions.

Physical barriers are used to block a contaminant migration pathway. Containment measures for contaminated groundwater typically include caps and vertical barriers.

Pumping systems (i.e., hydraulic gradient controls or “pump-and-treat”) are sometimes considered part of a “containment” GRA, although in this FS considered a “removal” GRA.

2.4.4 In situ Treatment

Treatment is USEPA’s preferred action under the NCP. This preference is satisfied when treatment is used to reduce the principal threats at a site through destruction of toxic contaminants, reduction of total mass of toxic contaminants, irreversible reduction in contaminant mobility, or reduction of total volume of contaminated media. Treatment options considered for the MSP include physical, chemical, and biological processes.

In-situ treatment methods destroy or convert groundwater contaminants to less toxic compounds or forms in the subsurface. By treating contaminants in place (i.e., contaminant mass not brought to the surface) significant cost savings can be achieved. Treatment methods evaluated for the MSP include recirculation wells, treatment walls, injection of in situ chemical reduction (ISCR) reagent, injection of in situ chemical oxidation (ISCO) agents, phytoremediation, and enhanced bioremediation.

2.4.5 Removal

Removal actions are used in conjunction with supplemental process options (e.g., disposal or ex situ treatment). Removal methods discussed for the MSP include multiphase extraction and pumping of well or sump/trench system (i.e., “pump-and-treat” technologies). Permeability enhancement techniques may be used in conjunction with removal technologies to increase the rate of contaminant removal.

Supplemental process options associated with removal actions include disposal and ex situ treatment. Disposal without treatment does not reduce the toxicity, mobility, or volume of the contamination, although removes the contamination from the site. Disposal options considered for groundwater include discharging extracted groundwater to a publicly owned treatment works (POTW) or transporting it to an industrial treatment facility. Ex-situ treatment technologies provide a reduction in toxicity, mobility, and/or volume of contaminants. Treatment can involve physical or chemical processes such as adsorption/absorption, oxidation, ion exchange, separation, and precipitation/coagulation/flocculation. The main advantages of ex situ treatment include (1) treatment generally occurs quickly and (2) there is a high certainty about the uniformity of treatment because treatment inflow and outflow can be continuously monitored. Extracted groundwater that undergoes ex-situ treatment may also requires disposal or reinjection of treated water, if the treated water does not meet surface water discharge standards.

2.5 Identification and Initial Screening of Technologies

Remedial technologies and process options are identified and screened in this section based on GRAs presented in Section 2.4. The remedial technologies and process options selected for evaluation were chosen based on common industry practices and research performed by federal agencies involved in hazardous waste site cleanup, such as the USDOE and USEPA.

Technologies considered to remediate contaminated groundwater are presented in Table 2-1 with a notation indicating whether the technology or process option was retained or eliminated. In the case of an eliminated technology, the reasons the technology did not pass the screening are stated. Additional comments regarding the feasibility of the retained technologies are also included. Individual technologies are often combined for application at a contaminated site. For instance, in situ treatment used to remediate groundwater contamination could be combined with LUCs to prevent future use of groundwater. The following questions were considered during the screening process:

- Is the technology effective at removing, containing, or treating the COC at the site, or by contrast, does it facilitate its migration?
- Does interference from other elements found in the groundwater prevent the technology from effectively removing, containing, or treating the COC?
- Are site conditions optimal for proper operation of process options based on the technology?
- Has the effectiveness of the technology been demonstrated in the field or has it not progressed beyond laboratory experimentation?
- Does the basis for the technology focus on remediating the media of concern (i.e., groundwater) or does it relate to other media?
- Is the technology effective within a reasonable time frame?

During this screening process, those technologies and process options that are not applicable to this remedial project based on one or more of the above factors have been removed from further consideration as a remedial option.

The concerns presented by the presence of COCs in groundwater may be viewed in terms of health, safety and environmental concerns. The presence of potential downgradient receptors of the groundwater contamination, such as surface water and potable water wells, may increase these concerns.

2.5.1 Land Use Controls

LUCs is not a CERCLA term, but rather a Department of Defense term that includes physical, legal, or administrative mechanism that restricts the use of, or limits access to, real property to reduce risks to human health and the environment. Physical mechanisms encompass a variety of engineered remedies, such as physical barriers to limit access to property (e.g., fences and signs). Legal mechanisms used for LUCs are generally the same as those used for institutional controls (ICs). ICs are a subset of LUCs and are primarily legal mechanisms imposed to provide the continued effectiveness of land use restrictions imposed as part of a remedial decision. Legal mechanisms include restrictive covenants, negative easements, equitable servitudes, CEAs and deed notices. Administrative mechanisms include notices, adopted local land use plans and ordinances, construction permitting or other existing land use management systems, that may be used to ensure compliance with land-use restrictions.

On-site LUCs would be implementable and easy to maintain while the government remains in control of the MSP site. The MSP is currently restricted by fencing and access is controlled. LUCs in the form of deed restrictions on the use of groundwater would be more difficult to implement on off-site properties. Enforcement on the use of groundwater under a CEA would become the obligation of the local government or the NJDEP through issuance of well permits or zoning. Maintaining ongoing funding for enforcement, and a mechanism for performing the required maintenance of controls, would be the major requirement to ensure continued implementability. The typical cost for enforcement and maintenance of LUCs is usually minimal compared to the cost of actual remediation. Further development of LUCs would be documented through remedial planning and decision documents (i.e., Proposed Plan, Record of Decision, and Remedial Design). This would be completed in accordance with the Department of Defense's "Policy on Land Use Controls (LUCs) Associated with Environmental Restoration Activities" (USDOD, 2001). LUCs are retained for further evaluation.

2.5.2 Monitored Natural Attenuation

Monitored natural attenuation (MNA) is a non-invasive remediation technology that relies on natural processes to clean up or attenuate contamination in soil and/or groundwater and monitoring to document process progress. Natural attenuation includes a variety of natural processes which work together to reduce the concentration of contaminants and their impact on the environment. Attenuation of contaminants occurs whether active remedial measures are implemented or not, so a systematic approach of monitoring and measuring the rate of attenuation of contaminants is implemented to demonstrate that RAOs are achieved through this technology. Natural attenuation at the MSP site would include remediation of groundwater through sorption, dilution, and dispersion. When used as a remedial technology, a formal monitoring program is established and the action is termed "MNA." Because conditions at the MSP may be suitable for these processes, MNA has been retained for further consideration.

As discussed in the Groundwater Investigation Technical Memorandum (USACE, 2017) one key natural attenuation mechanism for VOCs that is not occurring at a measurable rate is biodegradation. MNA is a viable process option for total uranium in the overburden.

2.5.3 Containment

The purpose of containment is to minimize contact with the contaminated groundwater, reduce exposure to the COCs, and control the release of groundwater contamination. Containment technologies discussed include stabilization and solidification, and physical barriers.

2.5.3.1 Stabilization and Solidification (Eliminated)

The most effective technology under the containment action response is stabilization and solidification. Although stabilization may be effective for total uranium, it is not technically feasible for the other COCs (VOCs) at this site. For total uranium, this process option has no known contaminant or chemical interferences. The ambiguous nature of the groundwater contamination boundaries and the variable permeabilities throughout the subsurface could limit its effectiveness. Immobilization technologies are best suited for use in a consistently moderate to highly permeable aquifer that contains a localized plume, which is not the case at the MSP. As a result, stabilization and solidification was eliminated from further consideration.

2.5.3.2 Physical Barriers (Eliminated)

Containment measures for contaminated groundwater may include caps, vertical barriers, and horizontal barriers. Capping and vertical barriers would reduce precipitation infiltration through contaminated soil and potentially prevent recharge to groundwater in source areas, thus limiting vertical migration of contaminated groundwater. However, sources would remain at and below the groundwater table and would continue to affect groundwater in the source areas; therefore, RAOs would not be achieved in the source areas using caps alone. Vertical barriers would limit the horizontal movement of groundwater, although they typically need to be keyed into an impermeable unit (e.g., bedrock with low permeability). Since the primary COCs (VOCs) are present in the bedrock units underlying the saturated overburden unit, vertical barriers would not be a recommended alternative at the site.

2.5.4 In situ Treatment

The technologies and process options addressed for treatment of groundwater at the MSP include a variety of in situ physical, chemical, and biological processes. In situ technologies include a number of processes that can effectively treat contaminants while also reducing waste generation and mitigating disposal problems. Two in situ physical processes screened in this FS are recirculation wells and treatment walls. Two in situ chemical processes considered in this FS are injection of ISCR reagent, and injection of ISCO agents. Two in situ biological processes considered in this FS are phytoremediation and enhanced bioremediation.

In situ treatment technologies may be enhanced using secondary technologies, such as permeability enhancement. Permeability enhancement increases the permeability in the subsurface allowing for a greater contact of the injected reagents with contaminants in the subsurface.

2.5.4.1 Recirculation Wells

Recirculation wells include a variety of process options, such as air stripping and in-well aeration. Recirculation wells treat contaminated groundwater by creating an artificial flow regime in the subsurface, usually between two different depths (e.g., screen intervals) along a single well. Groundwater or air is pumped into the lower screen interval while simultaneously being pumped out of the upper screen interval. Although the principal purpose of air injection is to strip off volatile contaminants, the process can also enhance inorganic fixation, sorption, and complexation processes by using the circulation "cell" technology. Also, the use of injected materials into a recirculation well system can create a greater interaction of the injected material with the contaminant mass in the subsurface to enhance degradation of the contaminants in place. The zone of influence created by a single recirculation well is typically a doughnut-shaped cell. Since recirculation wells are potentially applicable to the groundwater OU, this technology will be retained for further evaluation.

2.5.4.2 Treatment Walls (Eliminated)

Treatment walls, also known as permeable reactive barriers, are in-ground trenches installed across a groundwater flow path. Trenches are filled with reactive media (e.g., zero valent iron [ZVI]), where contaminated groundwater is treated when it passively interacts with the treatment wall as the groundwater naturally flows through. Treatment wall technologies can precipitate/adsorb (total uranium) or degrade (VOCs) the COCs in the groundwater at the MSP using various agents. The hydrogeologic setting is very critical for effective use of treatment walls. Permeable reactive barriers work well when the contamination is relatively shallow (i.e., physical limitations of trenching equipment). Since contaminated groundwater is present within the fractured bedrock unit and the source is likely in the unsaturated portion of the fractured bedrock, interaction with a treatment wall would be limited. This process option will not be retained for further evaluation.

2.5.4.3 Injection of In situ Chemical Reduction Reagent

Injection of ISCR materials is used to chemically reduce contaminants in the dissolved phase. ISCR is designed to (a) create a reducing condition in the groundwater that leads to uranium precipitation and (b) abiotic reductive dechlorination of VOCs. A common type of ISCR is ZVI, which will reduce dissolved VOCs such as CT to chloroform, and PCE, TCE, and 1,1-DCE to ethane. ISCR ZVI constituents are commonly composed of food-grade surfactant, biodegradable oil, water, and ZVI particles (either nano- or micro-scale iron), which form emulsion particles. The oil in the emulsion typically acts as an electron donor that limits formation of breakdown products. The remediation system is typically designed to inject ISCR materials in zones with elevated levels of contaminant concentrations. Once injection occurs, this technology is passive, requires no energy, and relies on transport of the dissolved COCs to the treatment zone. This technology was retained and will be evaluated further.

2.5.4.4 Injection of In situ Chemical Oxidation Agents (Eliminated)

Liquid or gas oxidization agents, also known as ISCO, can be injected into groundwater contamination zones through wells, which creates a treatment zone that can precipitate, immobilize, or render insoluble many redox sensitive radionuclides and is often used for the destruction and degradation of organic compounds (i.e., VOCs). ISCO applications have been determined not to be effective for CT in groundwater (Interstate Technology & Regulatory Council [ITRC], 2005) and will not be carried forward for further discussion.

2.5.4.5 Phytoremediation (Eliminated)

Phytoremediation involves the use of plants for the extraction, destruction, absorption, and stabilization of organic and inorganic contamination. Subsequent harvesting and off-site disposal of the plants or their ashes may or may not be necessary, depending upon the method used. This process can be quite effective in removal of large quantities of a wide range of low-concentration contaminants, leaving only residual levels of contaminant concentrations in the source area. Although interferences from other elements in the groundwater and soil are not anticipated, site conditions are not optimal for this process option due to the variable locations of groundwater contamination of total uranium in the overburden, which can compromise effective treatment. Remediation of radioactive metals through phytoremediation processes is still in its pilot- and bench-scale stages. Phytoremediation of chemical constituents (VOCs) in the bedrock is not considered to be appropriate due to depth constraints of the root zone and the preferential growth of roots in the alluvial zone (i.e., roots will not extend into the fractured bedrock). Because of these concerns, phytoremediation has been removed from further consideration.

2.5.4.6 Enhanced Bioremediation (Eliminated)

Enhanced bioremediation is a process option where existing or newly established microorganisms can create favorable subsurface conditions to adsorb total uranium or dechlorinate VOCs in groundwater.

Inorganic contamination (total uranium) can be rendered immobile under the proper pH and oxidation/reduction potential (FRTR, 1991). Natural biodegradation processes are typically accelerated using enhancements such as oxygen, hydrogen peroxide, and nitrate, depending upon the contaminants to be degraded and the intrinsic conditions within the subsurface.

Enhanced bioremediation of VOCs can take place under aerobic or anaerobic conditions. Under aerobic conditions, microorganisms consume oxygen in order to function. Under anaerobic conditions, little or no oxygen is present and the microorganisms break down chemical compounds in the soil or groundwater to provide the energy they need. One of the processes by which TCE is destroyed is called reductive dechlorination. Reductive dechlorination is most favorable under anaerobic conditions, but in some cases occurs under aerobic conditions. Products such as hydrogen release compound (HRC$^{©}$) can be injected to create anaerobic conditions and promote reductive dechlorination. Based on data collected at the site, the dissolved oxygen (DO) is high, meaning HRC$^{©}$ or similar product would be required under such aerobic conditions.

Bioremediation is an effective technology to treat CT and TCE (and the breakdown product, chloroform) contamination in groundwater. Implementation would be limited due to the low permeability of the aquifer, which limits the ability to inject the products due to their viscous nature.

The ability to inject these products into the aquifer at this site is unknown. The cost of this technology would be high due to large amounts of product needed to bring the aquifer to reducing conditions due to the high DO. Given that the source zone is an unsaturated zone, the biota is likely to disperse before dechlorinating the VOCs present or creating subsurface conditions that would adsorb uranium. Therefore, this technology has been removed from further consideration.

2.5.5 Removal

Removal (i.e., groundwater extraction, in situ flushing) of contaminated groundwater can be used to contain and/or control the movement of contamination. The groundwater extraction process, when properly designed and implemented, can be used to both remove the contaminant and to control additional spreading of the dissolved phase plume by shaping the groundwater flow pattern. Groundwater can be withdrawn using conventional vertical wells, horizontal wells and/or recovery trenches. The associated technology options considered may include permeability enhancement to increase the volume of contaminated groundwater removed. Removal designs may include groundwater removal by pumping a single well, a system of wells, or collection in a sump and trench system.

If removal technologies are used to remediate contaminated groundwater at the MSP, then secondary treatment technologies (e.g., disposal and/or ex situ treatment) would be required. This technology is retained for further consideration.

2.5.5.1 In situ Flushing (Eliminated)

In situ flushing, also referred to as in situ soil washing, is a two-step process that involves the pumping or injection of a solution into a groundwater contamination zone while simultaneously extracting the contaminant-solution mix downgradient. Extracted groundwater would require ex situ treatment. This process can use many different well configurations and solutions to flush a wide range of organic contaminants and may have some application to inorganic contaminants. However, the variability of the hydraulic conductivity of the subsurface media at the MSP is likely to reduce the effectiveness of the flushing process. In many cases, the injection solution used could also be considered a contaminant source, especially if it is not recovered properly. This process option has therefore been removed from further consideration.

2.5.5.2 Multiphase Extraction (Eliminated)

Multiphase extraction (MPE) includes in-situ remediation technologies that simultaneously extract more than one fluid phase from wells or trenches. These phases generally include air (i.e., gaseous phase including organic vapor) and water (i.e., aqueous phase including dissolved constituents), and may include Non-Aqueous Phase Liquids. One of the concerns at the MSP is the potential for vapor intrusion to the adjacent residences. The MPE provides groundwater flow direction and plume migration control and vapor extraction. Because COCs present at this site have not been identified in phases other than groundwater, multiphase extraction is not a recommended technology.

2.5.5.3 Pumping of Well or Sump/Trench System

Groundwater extraction by pumping of wells or a sump/trench system is a process where contaminated groundwater is extracted from an aquifer and brought to the surface where it can be treated more readily. There are a number of treatment systems that can be used for treating COCs identified in groundwater at the site. The most prevalent treatment technologies are air stripping and carbon adsorption. The treated water can be reinjected into the aquifer, discharged to the surface or sent to a POTW.

Groundwater extraction systems are effective at addressing contaminant plumes. Site surface features (i.e., residential homes, buildings) limit implementability of this technology. Well locations would be restricted by access to electricity and piping construction constraints. The cost of this technology is high due to long treatment duration and anticipated high operation and maintenance (O&M) cost. Because of the proven effectiveness of groundwater extraction technologies, this technology has been retained for further consideration.

If removal technologies are used to remediate contaminated groundwater at the MSP, then secondary treatment technologies (e.g., disposal and/or ex situ treatment) would be required. Ex situ physical treatment options include adsorption/absorption and separation processes. Ex situ chemical treatment options include oxidation, ion exchange, and precipitation, coagulation and flocculation processes.

2.6 Development of Technologies

Technologies and process options retained after the screening process presented in Section 2.5 undergo further evaluation using the three criteria of effectiveness, implementability, and cost in relation to site-specific conditions. Based on USEPA guidance (USEPA, 1988), this evaluation focuses on the effectiveness criterion, with less emphasis on implementability and relative cost. Those technologies and process options, either alone or in combination with other technologies or process options, that pass this level of screening are anticipated to achieve the RAOs for the site. Since descriptions of the technologies were presented in the previous section, only the evaluation and results are presented here. The evaluation criteria are defined below.

Effectiveness – This evaluation criterion focuses on whether or not the process options protect human health and the environment during and after implementation; achieve the RAOs, given the nature and estimated volume of contamination; and are proven and effective both in the short- and long-term timeframe with respect to COCs at the site. Accordingly, evaluating this criterion would address the capacity of the technology or process option to reduce contaminant concentrations or exposure levels, recover contaminated media for subsequent treatment (where applicable), and perform its intended function in a reasonable length of time. Lastly, evaluating the reliability of each process option would include a review of the O&M requirements, which can be significant for some technologies, to continually protect human health and the environment.

Implementability – This evaluation criterion encompasses both the technical and administrative feasibility of the process option or technology. Technical implementability was used as the initial screening criterion in the previous section. Therefore, this detailed evaluation focuses more on administrative or institutional implementability, which addresses the availability of treatment and disposal facilities, the availability of workers/contractors to implement the technology, and the likelihood of obtaining approval from the appropriate government agency. Approval by the governing agency is based upon their stance on employing the technology, which can be influenced by additional steps that may be necessary for implementation of a certain technology, such as pretreatment requirements or the need for management of residual wastes.

Cost – This criterion plays a limited role in this evaluation process prior to the development of technologies. Relative capital and O&M costs rather than detailed estimates are considered. The cost analysis is based on engineering judgment, and each process is evaluated as to whether the costs are higher, about the same, or lower relative to other process options with the same remedial technology.

The following sections present the results of this evaluation for each technology by screening criteria.

2.6.1 Land Use Controls

LUCs include physical, legal, or administrative mechanisms that restrict the use of, or limit access to, real property to reduce risks to human health and the environment. LUCs are usually considered in combination with other remedial alternatives.

2.6.1.1 Effectiveness

The actions carried out under a LUC remedial alternative (e.g., legal mechanism-Classification Exception Area) are considered effective in limiting exposure and provide some level of protection to public health and the environment in the short- and long-term duration as long as the controls remain in place. Legal LUCs, such as deed restrictions, would prevent the public from using groundwater. However, there would be no reduction in the toxicity, mobility, or volume through treatment.

2.6.1.2 Implementability

LUCs would be implementable and easy to continue while the government remains in control of the MSP. LUC enforcement would become the obligation of the property owner, local government, or the NJDEP. Maintaining ongoing funding for enforcement, and a mechanism for performing the required maintenance of controls, would be the major requirements to assure continued implementability.

2.6.1.3 Cost

Typical costs for initiation, enforcement, and maintenance of LUCs are usually minimal compared to remediation costs.

2.6.1.4 Results of Evaluation

LUCs are retained for consideration during the development of the alternatives.

2.6.2 Monitored Natural Attenuation

Natural attenuation is a non-invasive remediation method that relies on natural processes to attenuate contamination in soil or groundwater and monitoring to document the achievement of these processes.

MNA involves refining site-specific degradation rates, obtaining hydrogeologic and lithologic data, defining plumes and exposure pathways, and determining distances to receptors of the groundwater. Contour maps of contaminant concentrations, electron acceptors, and groundwater elevations would be developed. Fate-and-transport modeling refines predictions about the fate of contaminants over time. These procedures would be presented in a Long-Term Monitoring (LTM) Plan.

As discussed in the Groundwater Investigation Technical Memorandum (USACE, 2017) one key natural attenuation mechanism for VOCs, biodegradation, is not occurring at measurable rates. However, the other mechanisms associated with MNA are still occurring; thereby allowing for this process option to be viable for both VOCs in bedrock and total uranium in the overburden.

2.6.2.1 Effectiveness

Under optimal subsurface conditions, natural attenuation can be effective at reducing concentrations of volatile organic compounds, and certain natural subsurface conditions may prevent migration of radionuclides through immobilization. MNA has the potential to be protective of human health and the environment and to meet the RAOs in the long term, and would have minimal impacts on the community, site workers, and the environment. The concentration of contaminants in groundwater would be reduced through dilution, dispersion and sorption which in turn reduce the toxicity of groundwater. Sorption would also reduce the mobility of VOCs and uranium in the groundwater. As discussed in Section 1.5.1, effectiveness is further supported by the fact that the geochemical parameters for the OB wells indicate favorable conditions for natural attenuation by sorption onto iron oxyhydroxides, as indicated by the high ORP values and low ferrous iron levels. Monitoring at the site would be part of the MNA technology to assess current and future site conditions and contaminant concentrations.

2.6.2.2 Implementability

Natural attenuation is technically feasible and would be easy to implement. Implementation of the remedy includes the placement of groundwater monitoring wells at strategic locations of elevated contaminant concentrations, within the plume, along the plume boundary and between the plume edge and exposure points. This technology includes establishing a LTM groundwater sampling plan that presents a contingency plan in the event of unforeseen plume expansion. LTM would be conducted to monitor the attenuation of contamination to determine when cleanup levels have been achieved and to verify that contaminants are not migrating from the site at levels harmful to public health and the environment. The collection and analysis of groundwater samples from a network of monitoring wells would be required periodically until ARARs have been achieved.

2.6.2.3 Cost

Costs for this option are associated with the development of work plans, groundwater monitoring, and data evaluation. These costs are estimated to be low compared to an in situ or more traditional groundwater remedy (i.e., pump and treat).

2.6.2.4 Results of Evaluation

Low concentrations of radionuclide contaminants in the groundwater and aquifer conditions that limit its migration make this a viable option for uranium at the site. Although biodegradation of VOC contaminants in the site aquifer would be limited, MNA mechanisms such as dispersion, sorption, and dilution would reduce concentrations over time. Because of the low cost, ease of implementation, and the likelihood that this option could be effectively used in conjunction with other remedial measures, it has been retained for alternative development.

2.6.3 In situ Treatment

The technologies and process options addressed for treatment of groundwater at the MSP includes a variety of in situ physical, chemical, and biological processes. In situ technologies include a number of processes that can effectively treat contaminants while also reducing waste generation and mitigating disposal problems.

2.6.3.1 Recirculation Wells (Eliminated)

Recirculation wells include a variety of process options, such as air stripping and in-well aeration to strip off volatile contaminants or enhance inorganics fixation, sorption, and complexation processes.

2.6.3.1.1 Effectiveness

Circulating well technology is most effective on VOCs and would need modification or to be combined with other options to be effective on the total uranium present in the overburden. Because this technology is not likely effective for total uranium, the following discussion focuses on VOCs present at the site. VOCs present at the site primarily occur in zones of increased permeability of the fractured bedrock, therefore contact of injected air with VOC contamination would be limited, thus reducing the effectiveness of this technology for VOC remediation.

2.6.3.1.2 Implementability

The major issue with implementability would be the uncertainty of interaction between the injected air and the VOCs present in the subsurface. Recirculation wells require good interaction between the screen intervals that air or groundwater is being injected into the screen interval that is extracting air or groundwater, so the media of concern is able to "recirculate". Since VOCs are primarily found in fractured zones within the bedrock at the site, recirculation of groundwater within fractured zones of the bedrock would be technically difficult, if not infeasible.

2.6.3.1.3 Cost

The costs associated with this option are uncertain and depend on the number of wells used, if a supplemental technology is identified, and the length of time for operation to meet ARARs. At this point in the evaluation the cost would include moderate to high capital expenditures and low O&M costs.

2.6.3.1.4 Result of Evaluation

Due to the uncertainty of effectiveness, implementability, and potentially high costs, this option is eliminated from further consideration.

2.6.3.2 Injection of In situ Chemical Reduction Reagent

ISCR is designed to (a) create a reducing condition in the groundwater that leads to uranium precipitation and (b) facilitate reductive dechlorination of VOCs.

2.6.3.2.1 Effectiveness

ISCR can be used to precipitate mobile uranium in groundwater and enhance the destruction of VOCs. With injection of ISCR materials into targeted zones of the subsurface that exhibit high VOC COC concentrations, contact is achieved between the contaminant plume and the ISCR particles (e.g., ZVI). VOCs can be observed to have significant and rapid decreases in concentrations in the aqueous phase. In addition, many ISCR products include oil components that may act as an electron donor to promote biodegradation of VOCs that are not degraded by the ISCR. Further, ISCR has been proven effective in removing uranium from groundwater and reducing mobilization by surface adsorption or complexation processes. The technology would reduce the toxicity, mobility, or volume of the contaminants.

2.6.3.2.2 Implementability

ISCR implementability requires the installation of injection points (e.g., direct push locations, injection wells) and the injection of the ISCR product. Because VOCs in the subsurface are present in bedrock, typical direct push injection methods may not be successful. Injection wells would likely be required for ISCR implementation. The implementation of this technology is feasible and can be implemented using standard drilling technology.

2.6.3.2.3 Cost

Typical costs for implementing ISCR would consist of the installation of injections points, cost of ISCR product, injections, and post-injection monitoring. Drilling into bedrock would be required to address VOCs. Therefore, the cost to implement is moderate to high.

2.6.3.2.4 Results of Evaluation

Although the cost of implementing ISCR is higher when compared to other technologies, it provides a means to treat the complete list of COCs at the site; therefore, this technology has been retained for alternative development.

2.6.3.3 Enhanced Bioremediation

Enhanced bioremediation is a process option where existing or newly established microorganisms can create favorable subsurface conditions to adsorb total uranium or dechlorinate VOCs in groundwater.

2.6.3.3.1 Effectiveness

In order for natural attenuation to be effective in certain situations, the addition of electron donors and nutrients, or enhanced bioremediation (EB), may be necessary to increase the effectiveness of biological processes. Employing this process in the overburden for total uranium would not be appropriate at the MSP because the enhancement of biological processes would not increase the long-term effectiveness and permanence of uranium removal nor sufficiently reduce the mobility of total uranium to comply with the ARAR. EB would be an effective treatment of the VOCs in the groundwater associated with the bedrock units.

As discussed in the Groundwater Investigation Technical Memorandum (USACE, 2017) the natural attenuation mechanisms for VOCs (i.e., reductive dechlorination) are not occurring at measureable rates. However, biological amendments can be added to stimulate and subsequently enhance biological degradation of the VOCs. The technology would reduce the toxicity, mobility, and/or extent of the contaminants.

2.6.3.3.2 Implementability

Unlike some in situ chemical processes that require addition of hazardous oxidative or immobilization solutions to be effective, enhanced bioremediation requires the addition of less hazardous materials, such as a carbon source and nutrients, and is therefore likely to be more administratively feasible. However, implementation would be limited due to the viscous nature of the products and difficulty associated with injection into fractured bedrock.

2.6.3.3.3 Cost

Costs for this process option, which may be effectively used as a supplemental technology with other process options, would not be prohibitive. The costs would consist of the installation of injections point, cost of EB product, injections, and post-injection monitoring. The cost to implement would be moderate and the O&M costs in the low range.

2.6.3.3.4 Results of Evaluation

Enhanced biodegradation would not improve the effectiveness of natural attenuation processes to remediate total uranium. Since natural attenuation is not currently happening at measureable rates for the VOCs (USACE, 2017), enhanced bioremediation may require large volumes of product to initiate biodegradation of VOCs at the MSP. As a result, this technology is removed from further consideration.

2.6.4 Removal

Removal technologies are used in conjunction with supplemental process options (e.g., disposal or ex situ treatment) to physically remove the contaminated groundwater from the subsurface.

2.6.4.1 Pumping of Well or Sump/Trench System

Removal (i.e., groundwater extraction) of contaminated groundwater can be used to contain and/or control the movement of contamination. Extracted groundwater from the site that does not meet state or federal discharge regulations would require treatment applications.

2.6.4.1.1 Effectiveness

If removal of groundwater is chosen as the preferred remedial action for the MSP, pumping using a well or sump and trench system would need to be implemented. Under optimal hydrogeologic conditions, pumping can also be very effective in preventing groundwater contamination from migrating off-site. However, pumping could potentially draw off-site contamination into the pumping well or sump. This option on its own would be effective in protection of human health and the environment in the short term by reducing the mobility of the contamination.

Any groundwater collected that does not meet local, state, or federal discharge standards would have to either be pretreated (on- or off-site) before discharge to the sewer system or be transported to an off-site treatment facility. When combined with a treatment process, the result would be a reduction of toxicity and volume. With ex situ treatment, both the mass of contaminants removed from the ground and treated can be quantified by monitoring influent and effluent concentrations of ex situ treatment applications. The following ex situ process options, which include both physical and chemical processes, can be applied: adsorption/absorption (physical process), separation (physical process), oxidation (chemical process), ion exchange (chemical process), and precipitation/coagulation/flocculation (chemical process).

2.6.4.1.2 Implementability

Due to the common use of removal techniques, few implementability issues are anticipated. Other important considerations in the implementation of this technology include the number of wells that are required to achieve capture zone. If ex situ treatment were required, construction of an above-ground treatment system would be necessary. Relatively long timeframes are associated with removal techniques, which therefore include long-running O&M and monitoring. If disposal methods are required, then precautions regarding traffic and spills would need to be in place. Without proper installation, extracted groundwater would be preferentially ‘pulled’ from areas with higher permeabilities (e.g., overburden); therefore, removal of VOCs from the bedrock may be limited. If this technology is selected for the remediation of VOCs, a thorough understanding of the zone of influence for the extraction well would be needed.

2.6.4.1.3 Cost

Based on the assumptions that a complex extraction well/trench system would not be required, that pumping rates would be low, and that this technology would be used in combination with a treatment process, the relative capital costs would be in the moderate range. On its own, the system would need to be operational for an extended period; resulting in potentially high O&M costs.

2.6.4.1.4 Results of Evaluation

Pumping of a well or sump and trench system would be effective when combined with treatment, and costs are estimated to be moderate under these conditions. Due to the distribution of the COCs at the site and heterogeneous conditions of the subsurface this technology may be limited. This technology has been retained for alternative development.

3.0 DEVELOPMENT OF REMEDIAL ALTERNATIVES

Section 3 presents the remedial technologies and process options that have been retained after the screening and evaluation processes in Section 2 and that have been developed into site-specific remedial action alternatives.

As previously discussed, the focus of the remedial actions presented in this FS was to meet the RAOs associated with low-level radionuclides (total uranium) in the overburden groundwater unit and VOCs in the underlying unsaturated bedrock and bedrock aquifer, primarily Unit B.

Low-level radionuclide impacts to groundwater are assumed to be derived from impacted soils that were historically present above the groundwater. Remediation of these radionuclide-impacted soils was completed in accordance with the Soils Operable Unit ROD for the Middlesex Sampling Plant (USACE, 2005c). With the likely source of the contamination removed, residual contamination in the groundwater is addressed by this FS.

Moderate to high levels of VOCs (Table 1-4) have been found in zones of higher permeability (i.e., fractures) within the bedrock at concentrations greater than their respective USEPA MCLs and New Jersey GWQCs. Sampling results indicate a source in the unsaturated weathered bedrock above Unit B of the underlying bedrock aquifer. This source is limited to a small area on the north-central portion of the site in the areas of the former sump and wells ECC-MW-30B and EE-MW-41S.

3.1 Development of Alternatives

The GRAs, technologies and process options considered applicable to the groundwater at the MSP include the following:

- LUCs
- MNA
- In situ treatment
- Injection of ISCR
- Removal
- Extraction using trenches/wells and sumps

To assemble viable remedial alternatives, these GRAs, technologies and process options are combined and developed to focus specifically on remediating COCs present in groundwater at the MSP (i.e., the contamination identified as being a result of site activities at the MSP). USEPA specifies requirements for developing alternatives in general and with respect to groundwater response actions in the NCP (40 CFR 300.430[e]). These requirements are as follows:

- Alternatives should be developed that protect human health and the environment by recycling waste or by eliminating, reducing, or controlling risks posed through each exposure pathway at the site.

- Alternatives should be developed that attain site-specific remediation levels within different time frames using different technologies.
- As appropriate, alternatives should be developed involving innovative treatment technologies that offer the potential for comparable or superior performance or implementability, fewer or lesser adverse impacts, or lower costs for similar levels of performance when compared to demonstrated treatment technologies.
- A no action alternative should be developed that may be no further action if some removal or remedial action has already occurred at the site.
- As appropriate, the short- and long-term aspects of effectiveness, implementability, and cost should be used to guide the alternatives screening process.

The alternatives developed for the MSP Groundwater OU are:

- Alternative 1 – No Further Action
- Alternative 2 – Monitored Natural Attenuation and Land Use Controls
- Alternative 3 – Treatment with In situ Chemical Reduction, Monitored Natural Attenuation, and Land Use Controls
- Alternative 4 – Pump and Treat, Monitored Natural Attenuation, and Land Use Controls

The following subsections contain descriptions of each alternative, and Table 3-1 illustrates a flowchart of the development of the remedial action alternatives to the assembling of the following potential alternatives.

3.1.1 Alternative 1 – No Further Action

The No Further Action alternative is considered in accordance with the NCP requirements of 40 CFR 300.430(e)(6), and is intended to provide a baseline comparison to the other alternatives. This action is referred to as a “No Further Action” alternative as opposed to a “No Action” alternative because of the previous removal actions that occurred at the site pursuant to the *Soils Operable Unit ROD, MSP* (USACE, 2005c). In this alternative, no groundwater remedial systems are proposed, and no LUCs are to be implemented. Improvement of the groundwater quality would be through natural attenuation including dispersion, adsorption and dilution. Groundwater monitoring would not be conducted; therefore, improvement or further degradation of water quality would not be documented.

3.1.2 Alternative 2 – Monitored Natural Attenuation and Land Use Controls

Alternative 2 includes components from both MNA and LUC process options. This alternative contains provisions for implementing LUCs to create restrictions on the use of groundwater until RAOs are achieved, as documented by monitoring natural attenuation processes.

MNA refers specifically to the use of natural attenuation processes as part of overall site remediation. This alternative would rely upon monitoring and natural environmental processes to determine that cleanup goals have been achieved and whether groundwater contamination is spreading beyond current boundaries at concentrations exceeding acceptable risks or ARARs. Natural attenuation processes (dispersion, sorption and dilution) affect the fate and transport of contaminants in hydrologic systems. When natural attenuation processes illustrate capabilities of attaining site-specific remediation objectives in a location and period that are reasonable compared to other alternatives, it may be selected as the preferred remedial alternative.

As discussed in the Groundwater Investigation Technical Memorandum (USACE, 2017) MNA is a viable process option for total uranium in the overburden and the following discussion is focused on MNA for total uranium. While the data indicate that in situ biodegradation of VOCs is not occurring at the site, other MNA mechanisms such as dispersion and sorption are still applicable. Therefore, MNA can assist in the reduction of VOC concentrations.

Alternative 2 would be recommended when active treatment measures are not cost-effective, not practical due to time constraints, or not necessary because the groundwater is not a source of drinking water. Dispersion and dilution processes would be especially effective in diminishing contaminant plumes of limited extent and relatively low concentrations. Site conditions at the MSP that favor the use of MNA include contaminants with low mobility (e.g., total uranium), low concentrations of contaminants, low potential for exposure, and low probability for use as a drinking water source.

An integral part of this alternative is the implementation of a groundwater monitoring program, which would be conducted within and immediately adjacent to the perimeter of the site to assess potential contaminant migration and whether or not remedial goals are being met. A long-term monitoring program would be developed and the progress of MNA would be documented in reports for each monitoring event.

Key elements of a monitoring program include the location, frequency, and type of samples and measurements necessary to evaluate remedy performance as well as define the anticipated performance. Additional groundwater wells are anticipated to monitor remedy performance. The location of these wells would be determined during the Remedial Design phase.

The monitoring well network would consist of existing monitoring wells and new monitoring wells installed in Year 1 of implementation.

Based on USEPA guidance and for cost purposes, a present worth using a 30-year duration was calculated. The exact number of wells, design of the well network, and type of parameter analyses to be performed would be determined during the Remedial Design process. However, for cost-estimating purposes, a total of 32 samples (23 existing well samples, 6 new well samples, and 3 duplicate samples) would be collected annually. The duration of the groundwater-monitoring program would be based on attainment of the cleanup goals. In order to develop a cost estimate, it was assumed that for the first two years of the monitoring program, groundwater samples would be collected quarterly. After two years, the data would be reviewed to determine whether seasonal variation occurs and, if it does, to identify the season in which maximum concentrations occur. If a particular season were identified as giving elevated detection levels relative to the rest of the year, the wells would be sampled annually during that season. It was assumed that after the initial two years of monitoring, seasonal trends would be identified and that groundwater sampling would be conducted on an annual basis. Decisions related to monitoring well closure and monitoring frequency would be made in coordination with the USEPA and NJDEP. In general, during the first two years of sampling, four consecutive quarterly samples from a well with no exceedances of the cleanup goal for the COCs would justify the decision to close that well. For monitoring wells that remain in the annual monitoring program thereafter, three consecutive annual sampling rounds with concentrations at or below the cleanup level for the COCs would justify the decision to close that well. Implementation of the remedial alternative would be considered complete when the long-term average concentrations of the COCs at each monitoring well no longer exceed their remedial goals for three consecutive sampling rounds.

It is important to note that the compliance for the stated number of sampling results would not be the sole criteria on which a decision to close the well would be based. Other factors, such as seasonal variations that could affect contaminant concentrations during the period in question or whether the well is in a location that could be impacted by high concentrations of contaminants upgradient in the future, would also be considered.

The location and number of monitoring wells would be reviewed on an annual basis. Wells used for environmental monitoring that become damaged or require removal due to construction or other activities would be replaced or repaired, as needed. The need for continuing the monitoring at the location would be evaluated based on existing and expected future groundwater conditions. Water quality results, and the results of the review, would be provided in the annual monitoring report.

Under this alternative, LUCs would be implemented, such as well restrictions in a CEA, deed restriction or land use designation to restrict access to groundwater for uses as drinking water in areas where VOCs exceed groundwater cleanup levels. However, well restrictions in a groundwater CEA are preferable over deed restrictions and land use designations, since the Federal Government does not own all of the affected property. CEAs are administered by the State of New Jersey. The state exercises its authority by utilizing a statute that requires the issuance of permits prior to the construction of any groundwater well. Thus, the drinking water well exposure pathway is administratively controlled by the state in areas classified as a CEA. The USACE would request the NJDEP to establish a CEA in the affected areas associated with the MSP site. The USACE would submit the information listed in NJAC 7:26E-8.3 to assist the NJDEP in establishing the CEA. The CEA would remain in effect until the concentrations of VOCs in the aquifer are below the ARARs.

Because this alternative would result in contaminants remaining on the MSP site above proposed cleanup levels, CERCLA requires that the site be reviewed at least once every five years to evaluate the protectiveness of the remedy.

3.1.3 Alternative 3 – Treatment with In situ Chemical Reduction, Monitored Natural Attenuation, and Land Use Controls

Alternative 3 is a combination of remedial technologies to treat the various contaminants present at the site. ISCR technologies are proposed to treat the VOCs present in groundwater situated in the fractured bedrock on site at the source area. This treatment would eventually eliminate VOCs emanating from the site source area and isolate groundwater with low concentration VOCs in the downgradient portion of the plume. MNA processes would be applied to the downgradient portion of the VOC plume and to the total uranium present in the overburden as discussed in Alternative 2. While data indicate that in situ biodegradation is not occurring at the site, other MNA mechanisms such as dispersion and sorption are still applicable. A LUC, in the form of a groundwater CEA as described under Alternative 2, would be utilized in areas of groundwater contamination present at the site until cleanup goals are achieved.

ISCR applications are anticipated to degrade site COCs with contact and enhance mass reduction. ISCR is typically applied by injecting chemically reductive additives in liquid form into the contaminated area. The ISCR reagent ultimately facilitates the breaking of chemical bonds, eventually transforming groundwater contaminants into less harmful chemical species. The type and physical form of the reduction reagent indicates the general materials-handling and injection requirements. The persistence of the reagent in the subsurface is important since this affects the contact time for advective and diffusive transport and ultimately the delivery of reagent to targeted zones within the groundwater contaminant plume.

The selected reduction reagent would reduce groundwater contaminants such that residual contaminant concentrations are less than the ARARs established for the site. It should be noted that, depending on the type of reagent selected, additives or contaminants in the reagent itself may have their own cleanup requirements. In addition, ISCR reactions need to be controlled such that the heat of exothermic reactions and potential volatile emissions do not endanger nearby building occupants. During the remedial design, mass-balance calculations would be performed to better determine the potential for these contaminants to require additional process modifications. If a reagent with such additives is selected, these compounds would be added to the groundwater monitoring program.

ZVI is a proven technology and is the metal most commonly used as a reductant in ISCR. The use of zinc- and/or other metal-based reagents with other zero valent metals is not well established. Therefore, this FS focuses on ZVI.

Several technologies are available that involve injecting nano- or micro-scale reactive ZVI to remediate groundwater contaminated with VOCs such as those present at the MSP site. These are typically delivered in powder or slurry form. One example is the use of emulsified ZVI, which is typically composed of a food-grade surfactant, biodegradable vegetable oil, water, and ZVI. The final reagent consists of emulsion droplets that contain iron particles in water surrounded by an oil-liquid membrane. In addition to the abiotic degradation, the vegetable oil and surfactant would cause a sequestration of chlorinated ethenes into the oil, and biodegradation of dissolved chlorinated ethenes would occur. Chlorinated solvents would preferentially dissolve into the oil component, thereby reducing the aqueous-phase concentrations. The ZVI then degrades the chlorinated solvents. The vegetable oil and surfactant can also act as electron donors to promote anaerobic biodegradation of the chlorinated solvents. For example, abiotic degradation resulting from the ZVI in the emulsified zero valent iron (EZVI) was shown to be a very fast process in laboratory studies conducted at the University of Central Florida (Quinn et al., 2005). If the amount of ISCR is not sufficient to degrade VOCs, the vegetable oil and surfactant can act as a slow-release electron donor for biodegradation processes at the site (Major et al., 2002).

Emulsified oil is not the only substrate that can be mixed or injected with ZVI to achieve both a biological and chemical reactive zone. Several commercial products (e.g., EHC® and ABC® Plus ZVI) provide a carbon substrate along with ZVI. While the formulas differ, these products are designed to take advantage of the synergistic abiotic and biotic reduction reactions created by the combination. In addition to combined products, ZVI can be mixed or injected separately with common substrates (e.g., lactate, molasses, alcohol) appropriate to the contaminant and hydrogeological setting (ITRC, 2011). In addition to reduced contaminant concentrations of VOCs anticipated, studies have demonstrated that ISCR is effective in removing UO_2^{2+} from the aqueous solution under reducing conditions. The major reaction pathway is the reduction of UO_2^{2+} by Fe to form insoluble U(IV) species on iron surfaces. Uranium is then removed by iron oxide through the surface adsorption or complexation processes, which often exhibit relatively fast reaction kinetics. Therefore, the use of ISCR would not mobilize total uranium if it were to be exposed to the overburden material.

In order to develop a cost estimate for this alternative, a ZVI reagent was selected for application. A ZVI reagent was chosen because the use of iron filings in remediation of chlorinated solvents is a proven practice, the reagents can be readily obtained, and they can be injected by local suppliers and vendors without specialized training or handling. Although ZVI is a representative ISCR technology, a more thorough analysis of available ISCR reagents would be completed during the remedial design to ensure selection of the most efficient and economical reagent. Bench-scale and/or pilot tests would be completed to determine the effectiveness, the appropriate concentrations, and the specific volumes of the reagent necessary to be injected. In addition, if this alternative is selected, the cost analysis would be further refined to ensure the most economical reagent is chosen. To actively address VOC contamination, and depending on the geology present at the location of an injection, ISCR materials would be injected using one or more of the following technologies:

- Direct injection
- Pneumatic injection
- Pressure pulse injection
- Hydraulic permeability enhancement
- Injection wells

Based on presence of fractured bedrock at the site where elevated concentrations of VOCs exist, the ability to inject ISCR material and the subsequent limited and/or slow migration of the injected material may create design difficulties. Permeability enhancement would likely be the most successful technique for injection. Once injection points are installed to the desired depth and the seals are cured, an injection cap would be attached to the top of the injection point. A grout pump may be used to inject ISCR material and water into the formation. Pump pressures should be monitored and logged during injection events.

ISCR would be applied to remediate contamination in the on-site source area. Additional site data would be collected during the remedial design phase to determine the numbers of injection events and injection points and the depths of the injection wells. Most sites require multiple injections due to preferential treatment zones, the release of organically partitioned contamination, desorption from soil media, and NAPL dissolution.

ISCR would be implemented through injection wells placed at the source area near the sump, the areas of elevated VOC concentrations near ECC-MW-30B and along the downgradient property boundary (Figure 3.1). The source area and the areas of higher VOC concentrations injection well system would be configured in a grid of six wells by nine wells (54 wells) and a well spacing of 20 feet. The injection points in the two North-South (N-S) grid lines nearest to the source area and monitoring well EE-MW-41S would be drilled to a depth of 15 feet. Every subsequent two N-S grid lines would be drilled 5 feet deeper (20 feet, 25 feet, 30 feet), with the last three N-S lines of the grid drilled to a depth of 30 feet.

The injection well systems along the downgradient property boundaries would be configured in three lines totaling 500 feet in length; all of these wells would be drilled to a depth of 50 feet. The lines would be oriented perpendicular to the groundwater flow. Wells would be spaced every 20 feet for a total of 25 wells. The total number of injection wells at the source area, areas of elevated VOC concentrations near ECC-MW-30B and at the downgradient property boundary would be 79.

During ISCR injection, the injection area would be monitored for surface heave and evidence of daylighting or blow-by using a graduated heave rod and a surveyor’s transit. Daylighting occurs when a vertical fracture or other features such as casings or old boreholes provide a preferential pathway for fluid to surface. Blow-by occurs when injection fluid travels upwards along the side of the injection point well or injection assembly and dissipates at ground surface adjacent to the injection point. Further, measurements of pressure in select wells would be recorded using pressure gauges at the wellhead.

ISCR injection would not target off-site wells with elevated concentrations further from the source (e.g., EE-MW-37B). Contaminant concentrations are lower at these locations, and the locations are spread over a much larger area, which would require multiple rounds of injection. In addition, the contamination is located beneath a densely populated area, which would present significant access difficulties. As a result, the cost would be too high, and implementability and accessibility would be too difficult to obtain to justify injections at these off-site locations. The wells at these locations would be included as part of the long-term monitoring program.

Additional injections may be warranted to treat downgradient plumes or areas that may be identified to have a potential impact on receptors. Prior to the injection, monitoring wells located in the target zone (e.g., Unit B of bedrock aquifer) would be monitored for the following parameters:

- Contaminant levels
- Total Organic Carbon, ORP, pH
- Manganese, iron, chloride, sulfate
- Dissolved hydrocarbon gases (e.g., ethene, ethane, methane)
- Reagent additives or by-products, as necessary

The amount of VOC reduction would be assessed by comparing results of pre-injection (baseline) and post-injection groundwater samples. Based on the result of the post-injection sampling, subsequent injections may be required. For estimating purposes, it has been assumed that following 3 rounds of injections, 10 years of MNA would be required. Additional information associated with the assumptions used to develop costs for this alternative are presented in Section 4.

3.1.4 Alternative 4 – Pump and Treat, Monitored Natural Attenuation, and Land Use Controls

Alternative 4 is a combination of remedial technologies to treat the various contaminants present at the site. Removal of contaminated groundwater by pumping is proposed to address the VOCs present in groundwater situated in the fractured bedrock onsite. Extraction wells would be placed in the source area and along the downgradient property boundary to control and eventually eliminate VOCs emanating from the source area. This would effectively isolate the downgradient portion of the plume that contains low concentrations of VOCs. MNA processes would be applied to the downgradient portion of the VOC plume and to the total uranium present in the overburden as discussed in Alternative 2. While data indicate that in situ biodegradation is not occurring at the site, other MNA mechanisms such as dispersion and sorption are still applicable. A LUC in the form of a groundwater CEA would be utilized in areas of groundwater contamination present at the site until cleanup goals are achieved.

This alternative would involve the use of a conventional pump-and-treat system for groundwater contaminated with VOCs. Given the widespread nature of the contaminant plume, the use of a French drain collection system was deemed too passive and would not allow for optimal control and collection of the plume. Additionally, French drain systems are not effective at collecting groundwater in fractured bedrock. Therefore, extraction wells were chosen as a preferred option.

If Alternative 4 is selected, additional groundwater modeling would be performed to further refine the number of extraction wells that would be needed. For the purposes of costing this alternative, the specific well design and numbers of wells were assumed based on the size of the plume and assumed aquifer characteristics. Due to the presence of VOCs in fractured bedrock where transmissivities are low, groundwater extraction rates would be limited, thus creating a relatively small capture zone and requiring dense well spacing. The final location, depth, and number of wells would be proposed in the remedial design. For reasons described in Alternative 3, this alternative will not target off-site wells.

A total of 13 extraction wells would be installed. Eight of these extraction wells would be installed in a line along and inside of the downgradient property boundary to a depth of 70 feet (Figure 3.2), pumping at approximately 1 gpm. These wells would capture the width of the plume moving off-site.

The remaining five extraction wells would be installed at the source area (near the sump and EE-MW-41S) and the areas of elevated VOC concentrations near ECC-MW-30B until the concentrations there have been sufficiently reduced, at which time these wells would be converted to low flowrate extraction wells to be operated for the remainder of the operational period. These wells will be drilled to a depth of 30 feet. Further evaluation of the depths of all remedial wells would be completed during the remedial design phase.

Pump-and-treat systems are widely used to remediate groundwater and are, therefore, relatively straight forward to design, construct, and operate. Provided that the extraction system and treatment equipment is appropriately sized, ARARs established for site groundwater and discharge effluent would be met. During the remedial design, groundwater modeling and mass balance calculations would need to be performed to determine the appropriate well locations, extraction rates, equipment size, and operation and maintenance needs.

Many installation methods can be used to install the extraction wells. Based on the bedrock present at the site, air or mud rotary drilling techniques would be anticipated. Equipment decontamination would be required after use, and therefore, a light-duty decontamination pad of approximately 300 square feet would need to be constructed.

Based on the sampling results, it is assumed that extracted groundwater would exhibit levels of contamination that exceed local discharge permit levels. Therefore, extracted groundwater would be pumped to a treatment system, and the treated effluent would be tested and discharged to a POTW.

There are multiple methods for removing VOCs from the influent groundwater stream. Air stripping, GAC, reverse osmosis, ion exchange, and biological reactors are the technologies most commonly used for removing VOCs. While reverse osmosis, ion exchange, and biological reactors are proven technologies, they are expensive, require excessive maintenance, and provide no significant advantage when compared to purchasing and operating an air stripper and/or GAC systems to remove VOCs.

The treatment system proposed for this alternative would consist of a multi-stage operation involving two distinct processes. While both air stripping and GAC could be used individually to achieve the desired effluent requirements, for the development of this alternative, it is proposed that air stripping followed by GAC treatment be implemented. In the event that either process experiences an equipment malfunction, there would be a backup system to reduce the potential for exceeding the effluent limitations.

Pilot testing in the remedial design phase may be necessary to ensure the optimal process and actual design for treatment, where contact time and actual flow capacities would be determined. The treatment system would be designed for the anticipated flow rate of extracted groundwater and would be presented in the remedial design. A more thorough description of the proposed treatment system for this alternative is described in Section 4, with the associated cost estimate presented in Table 4-5.

Once groundwater monitoring indicates that contaminant concentrations are consistently meeting the cleanup objectives, the pump-and-treat system would be shut down, and the groundwater table would be allowed to equilibrate back to pre-remedial effort levels. The implementation of the remedial alternative would be considered complete when the long-term average concentrations of total uranium and VOCs at each individual well do not exceed their cleanup values for three consecutive sampling rounds after system shutdown. For cost estimating purposes, it has been assumed that 15 years of MNA would be needed to address the uranium plume, and the treatment system would be in operation for 30 years.

4.0 DETAILED ANALYSIS OF ALTERNATIVES

In this section, the alternatives that were defined in Section 3 are individually assessed with respect to the nine CERCLA evaluation criteria, and comparatively analyzed against each other to evaluate relative performance. Section 4.1 provides an overview of the evaluation criteria and some background on the context and purpose of the detailed analysis. Section 4.2 presents each alternative's individual analyses with an accompanying summary table. Section 4.3 includes a narrative discussion on the comparative analysis of alternatives that describes their strengths and weaknesses.

The alternatives presented may combine one or more technologies discussed in the previous sections. Utilizing more than one technology for an alternative may present a more focused approach in one area (e.g., source zone) and a less focused approach in another area (e.g., downgradient plume).

4.1 Evaluation Criteria

The requirements (40 CFR 300.430[f][1][ii][A-E]; USEPA, 1988) that guide the evaluation of alternatives in an FS are that a remedial action must:

- Protect human health and the environment;
- Attain ARARs or define criteria for invoking a waiver;
- Be cost-effective;
- Use permanent solutions and alternative treatment technologies to the maximum extent practicable; and
- Satisfy the preference for treatment that reduces toxicity, mobility, or volume as a principal element (or explain why this is not obtainable).

USEPA has established nine evaluation criteria, as presented in 40 CFR 300.430(e)(9)(iii), to address these statutory requirements and provide decision makers sufficient information to adequately compare the alternatives (USEPA, 1988). The results of the analysis and the comparison support the final selection of the recommended alternative, and thus, the foundation for the ROD. The nine criteria used throughout this detailed analysis are classified into the following three groups.

Threshold Criteria – requirements that each alternative must meet in order to be eligible for selection

1) Overall protection of human health and the environment
2) Compliance with ARARs

Primary Balancing Criteria – used to distinguish the relative effectiveness between alternatives, so that the alternative's strengths and weaknesses can be evaluated

3) Long-term effectiveness and permanence

4) Reduction of toxicity, mobility, and volume through treatment
5) Short-term effectiveness
6) Implementability
7) Cost

Modifying Criteria – evaluated following public comment on RI/FS report and proposed plan, and addressed when the ROD is being prepared

8) State acceptance
9) Community acceptance

The following subsections define each of the nine CERCLA criteria in detail.

4.1.1 Overall Protection of Human Health and the Environment

This criterion provides an assessment of whether or not the alternative reduces, controls, or eliminates both short- and long-term unacceptable risk and doses from COCs identified at the MSP by controlling exposures to levels at or below the developed remedial goal. This criterion is correlated with and dependent upon the evaluation of compliance with the ARAR, long-term effectiveness and permanence, and short-term effectiveness.

4.1.2 Compliance with ARARs

The capacity of each alternative to meet Federal and state ARARs identified in Section 2.2 or provide justification for invoking a waiver under Section 121 of CERCLA was assessed for each alternative in this section. Compliance with chemical-specific ARARs must be attained by the alternative to be considered. If compliance is not achieved, then this section must describe how the alternative meets the requirement or justification for an ARAR waiver.

4.1.3 Long-Term Effectiveness and Permanence

Under this criterion, each alternative is evaluated with respect to the magnitude of residual risk and dose that the remaining waste (untreated or residual waste) could pose. This criterion also focuses on the adequacy and reliability of the required controls to manage the risk from the remaining waste. Both of these components must be addressed during the evaluation of long-term effectiveness and permanence.

4.1.4 Reduction of Toxicity, Mobility, and Volume through Treatment

The statutory preference is to select a remedial action that employs treatment technologies to reduce the toxicity, mobility or volume of COCs present at the site. This evaluation assesses the performance of the alternative in achieving this preference. Relevant factors in this criterion include the treatment process and target materials, the amount of hazardous materials destroyed or treated, the degree of reduction in toxicity, mobility or volume, the irreversibility of the treatment process, the type and quantity of residual wastes, and the degree to which treatment is used as the principal element of the alternative.

4.1.5 Short-Term Effectiveness

The short-term effectiveness criterion addresses the effects to human health and the environment that the alternative would have during construction and implementation. Some factors considered in this evaluation are the protection of workers, the protection of the community, environmental impacts, and time until RAOs are achieved.

4.1.6 Implementability

The analysis of implementability deals with the technical and administrative feasibility of implementing the alternatives, as well as the availability of goods and services. This criterion addresses items such as constructability, reliability, and ability to operate the technology; ability to obtain services, materials, equipment, and specialists; ability to monitor the performance and effectiveness of the technology; and need to obtain regulatory approval or permits from other offices or agencies.

4.1.7 Cost

Costs included in the estimates are direct and indirect capital costs, and annual O&M costs. Direct capital costs include expenditures for the necessary materials, labor, and equipment for installation or construction of the remedial effort. Beyond the basic construction and equipment costs associated with the technology, direct capital costs might include site preparation expenses, utility and service expenses, and disposal costs. Indirect capital costs include expenditures for engineering, financial, and other required services not part of the actual remedial activities. For example, expenses for administration, design, licenses, and startup would be considered indirect capital costs.

Annual O&M costs are those expenditures associated with the continued effort required to allow the remedial activities to be effective once installation or construction of the technology has been completed. O&M costs to consider include, but are not limited to, post-installation expenses such as O&M labor, material and energy costs, sampling and analysis costs, periodic site review expenditures, and residual waste disposal costs.

FS cost estimates, typically in the plus 50 percent to minus 30 percent accuracy range, can be refined using characterization and treatability information, when necessary. For single-figure comparison purposes, it is convenient to have any future costs associated with the alternatives evaluated based on present worth. Accordingly, assumptions on the discount rate (usually 5 to 8 percent) and performance time (less than or equal to 30 years) would also be made. A sensitivity analysis may be recommended if variations in design exist that can have a significant cost impact or when interdependent design parameters require optimization. Costs developed in support of this FS are based on information obtained from a variety of sources, including cost-estimating guides, similar and comparative past project experience, and vendor estimates. The actual costs of the project would depend on true labor and material charges, site conditions, competitive market conditions, final project scope, engineering design, the implementation schedule, and other variables.

For the purpose of this FS, the following general assumptions were made for all alternatives:

- All present worth costs were determined using an interest rate of 7% per year;
- Yearly reporting was assumed to be $50,000 per event;
- An 8% contingency of the total cost was added to cover ownership costs (i.e., internal costs incurred by the USACE associated with running the job);
- A 20% contingency cost was added to cover miscellaneous items and/or potential overruns associated with implementing the alternative;
- Costs were multiplied by a factor of 1.12, obtained from RSMeans City Cost Indexes 2016, to account for higher construction costs in the nearby municipality of New Brunswick, New Jersey; and
- Estimates from 2013 were multiplied by a historical cost index of 1.03, as taken from RSMeans Historical Cost Indices 2016, to calculate amounts in 2016 dollars.

4.1.8 State and Community Acceptance

State and community acceptance of the remedial action alternatives are formally addressed in the ROD, following comments on the RI/FS and Proposed Plan. The assessment of state acceptance involves the evaluation of technical and administrative issues and concerns with respect to each alternative. The assessment of community acceptance includes issues and concerns the public may have regarding each alternative.

4.2 Individual Analysis of Alternatives

In this section, the alternatives from Section 3 are briefly summarized (i.e., details of each are presented in Section 3) and then evaluated. The evaluation of alternatives is conducted using seven of the nine evaluation criteria and in accordance with the process outlined in CERCLA and NCP. Tables 4-1 and 4-2 summarize the evaluation of alternatives, and Tables 4-3 through 4-8 present a brief summary of capital, annual O&M, and present worth costs for the alternatives.

4.2.1 Alternative 1 – No Further Action

The No Further Action Alternative makes no provisions for containment, removal, treatment, or disposal of impacted groundwater and no LUCs would be implemented. Any improvement of the groundwater quality would be through natural attenuation processes including dispersion, adsorption and dilution. However, groundwater monitoring would not be conducted; therefore, any improvement or further degradation of water quality would not be documented.

4.2.1.1 Overall Protection of Human Health and the Environment

This alternative is not considered protective of human health or the environment in the short or long term because it does nothing to reduce risk or exposure from COCs in groundwater. It also allows the continued existence of exposure pathways and even allows them potentially to increase over time as current control measures deteriorate. It should be noted that groundwater is neither currently used at this site nor is it likely to be used in the future.

4.2.1.2 Compliance with ARARs

It is anticipated that Alternative 1 could eventually meet the ARARs for the MSP groundwater COCs through natural attenuation. Although contaminant concentrations in groundwater would decrease through time due to natural attenuation processes, there would be no documentation of this decrease because of the absence of monitoring.

4.2.1.3 Long-Term Effectiveness and Permanence

This alternative provides no added control of exposure to contaminants and no long-term engineering or control measures through LUCs. Therefore, this alternative provides no long-term effectiveness or permanence, and current and potential future risks remain.

4.2.1.4 Reduction of Toxicity, Mobility, and Volume through Treatment

No treatment processes or remedial activities are proposed under this alternative. Therefore, a reduction in the toxicity, mobility, or volume of contaminated groundwater would not occur and the existing contamination would remain on-site. Natural processes could alter the toxicity, mobility, and volume of the COCs in groundwater over time, although this would not be achieved through active treatment and documentation through monitoring would not be achieved.

4.2.1.5 Short-Term Effectiveness

Under the No Further Action Alternative, no additional exposure risks would result to workers or the community from remediation activities, transportation, or disposal, since no remedial action would take place. There would also be no construction- or implementation-related impacts on the environment if this alternative were implemented. Time to achieve Remedial Action Objectives would be unknown for Alternative 1 since no further action would be taken and no LUCs would be implemented.

4.2.1.6 Implementability

The No Further Action Alternative would be readily implemented because there would be no further action undertaken.

4.2.1.7 Cost

There is no capital or present-worth O&M cost involved with this alternative, since there would be no further action. The MSP site would remain unchanged, with USACE no longer maintaining a permanent presence at the site, letting existing land use controls expire. A summary of costs associated with all alternatives is presented in Table 4-1.

4.2.2 Alternative 2 – Monitored Natural Attenuation and Land Use Controls

MNA involves the remediation of groundwater through adsorption, dilution, and dispersion. However, dispersion and dilution processes would be especially effective in diminishing contaminant plumes of limited extent and relatively low concentrations, as is the case of total uranium present in the alluvial aquifer at the MSP. Additional monitoring wells are anticipated to monitor remedy performance. The location of these wells would be determined during the Remedial Design phase. The main activity performed under this alternative would be monitoring. Evaluation of contaminant mobility and degradation would also be required. Accordingly, MNA would require specific design, construction, and operation of an efficient and effective monitoring network.

Under this alternative, a network of existing wells would be monitored. The monitoring well network would be comprised of the overburden and bedrock aquifer monitoring wells. The implementation of the remedial alternative would be considered complete when the long-term average concentrations of the COCs at each individual well do not exceed the ARARs for four consecutive sampling events.

In addition, this alternative contains provisions for implementing LUCs. LUCs may include physical mechanisms, such as fences or signs; legal mechanisms, such as restrictive covenants, negative easements, deed restrictions and notices, and CEAs; and administrative mechanisms, such as public notices, adopted local land use plans and ordinances, construction permitting, or other existing land use management systems that may be used to ensure compliance with use restrictions. Since this alternative may take some time to achieve the remedial goal, restrictions on the use of groundwater would have to be implemented until the goal is met.

4.2.2.1 Overall Protection of Human Health and the Environment

This alternative is expected to be protective of human health and the environment in the short- and long-term. Implementation of LUCs would restrict access to the contaminated groundwater that may remain until the RAOs are met. In addition, groundwater would be monitored and evaluated to measure the attainment of RAOs and to ensure that exposure to COCs are at an acceptable level. Natural processes would be expected to restore the groundwater and to mitigate the potential for future contaminant exposures.

4.2.2.2 Compliance with ARARs

The ARARs for the COCs would be met under this alternative by using LUCs to eliminate/minimize exposure until total uranium and VOC concentrations are reduced to below the cleanup levels by MNA processes. Additionally, LUCs would be implemented within one year.

4.2.2.3 Long-Term Effectiveness and Permanence

This alternative could provide an acceptable degree of long-term effectiveness in preventing exposure to groundwater contaminants that may remain above the ARAR through the implementation of LUCs. The monitoring well system, supported by data evaluation, would provide a greater level of confidence in the remedy's effectiveness.

4.2.2.4 Reduction of Toxicity, Mobility, and Volume through Treatment

Since no treatment processes or similar remedial activities are proposed under this alternative, there would be no immediate reduction in toxicity mobility, or volume of the contaminated groundwater through treatment technology.

4.2.2.5 Short-Term Effectiveness

This alternative would pose little to no additional health risk to the community and workers in the short term because no significant remedial activities would take place. There may be potential impacts on workers responsible for performing well installation and environmental monitoring, but this risk would be low, and protective measures could be taken to mitigate exposure to the COC or damage caused by traffic or area disturbances. The negative effects of equipment operations and the emission of criteria pollutants should be low, and measures can be taken to mitigate resultant worker or community health impacts.

This alternative would achieve the RAOs by reducing total uranium, and VOC concentrations in the groundwater to less than or equal to the MCLs through natural attenuation, and implementing LUCs within 1 year. While it would take approximately 1 year to implement LUCs under this alternative, it is anticipated that the alternative would require an additional 30 years at a minimum to achieve the cleanup objectives.

4.2.2.6 Implementability

The techniques involved with monitoring well design, installation, sampling, and analysis are proven technologies and straightforward. Problems with implementation are not anticipated. In addition, this alternative would not require any special permits or materials, and the concepts involved are proven and reliable.

4.2.2.7 Cost

This alternative involves capital costs associated with the development of a Project Work Plan, Health & Safety Plan, Quality Assurance Project plan, LUC Maintenance Plan, and the installation of additional monitoring wells.

Annual costs for long-term monitoring and LUCs were also included in the estimate for Alternative 2. Monitoring will consist of the sampling and analysis of a total 30 groundwater monitoring wells plus the collection of two duplicate samples. The total well count includes six new wells that would be screened in the bedrock. This cost is based on previous monitoring well installations at the site adjusted for inflation. Preparation of an annual report presenting the results of the previous year's sampling events is also included. The frequency of the monitoring events was assumed to be quarterly for the first 2 years, then annually through the remainder of the 30-year estimation period.

The costs for groundwater analysis were based on recent vendor laboratory pricing, and costs for sample collection, vendor laboratory supervision, and data validation were based on past project experience.

Capital costs, estimated at $1,233,000 primarily include engineering design and installation of new monitoring wells. An average annual O&M cost of $149,000 would be attributed to the groundwater monitoring program, annual report, maintenance activities, and comprehensive data evaluation. The 30-year present-worth cost for this alternative was estimated to be $2,711,000. Although the total cost is for a 30-year period, costs could be incurred beyond this timeframe due to monitoring that would continue until RAOs are met. A more detailed description of the cost and net present worth is presented in Tables 4-3 and 4-6.

4.2.3 Alternative 3 – Treatment with In situ Chemical Reduction, Monitored Natural Attenuation, and Land Use Controls

Alternative 3 is a combination of remedial technologies to treat the various contaminants present at the site. ISCR technologies are proposed to treat the VOCs present in groundwater situated in the fractured bedrock on site at the source area. This treatment would eventually eliminate VOCs emanating from the site source area and isolate groundwater with low concentration VOCs in the downgradient portion of the plume. MNA processes would be applied to the downgradient portion of the VOC plume and to the total uranium present in the overburden as discussed in Alternative 2. While data indicate that in situ biodegradation does not occur at the site, other MNA mechanisms such as dispersion and sorption are still applicable. A LUC, in the form of a groundwater CEA as described under Alternative 2, would be utilized in areas of groundwater contamination present at the site until cleanup goals are achieved.

This alternative would involve the injection of an ISCR material, such as EZVI. In order to develop an estimated cost for implementing an in situ reduction remedy, this evaluation assumes that EZVI would be the selected ISCR technology. EZVI is an innovative remediation technology used to enhance the destruction of chlorinated solvents in source zones by creating intimate contact between the contaminant and the ZVI particles. The EZVI is composed of food-grade surfactant, biodegradable oil, water, and ZVI particles that form emulsion particles. The ZVI provides rapid abiotic degradation of COCs, and the oil provides an immediate sequestration of the chlorinated constituents as well as a long-term electron donor source to enhance further biodegradation.

ZVI is a strong reducing agent and has been successful in treating VOCs present in bedrock groundwater as site COCs (TCE, CT, and chloroform). ZVI is ideally suited for treating chlorinated organic compounds through injection directly into the contamination plume.

Further, ZVI has the capacity and is efficient in the removal of uranium through reductive precipitation and adsorption (Gu et al., 1998). Studies indicate that iron filings are effective in removing UO_2^{2+} from the aqueous solution with an efficiency of approximately 97% removal rate. Although this remedy is not being recommended to specifically treat the total uranium present in the overburden, inadvertent interaction of ZVI with total uranium would not mobilize previously precipitated total uranium.

To deliver the ISCR materials into the subsurface, a number of injection points would be installed within the source area, areas indicating elevated VOC concentrations and downgradient of the areas indicating elevated VOC concentrations. These injection points would not target off-site wells with elevated concentrations further from the source (e.g., EE-MW-37B). Not only are contaminant concentrations lower at these locations, they are also spread over a much larger area that would require multiple rounds of injection. In addition, the contamination is located beneath a densely populated area, which would present significant access difficulties. As a result, the cost would be too high and implementability and accessibility would be too difficult to obtain to justify injections at these off-site locations. The wells at these locations would be included as part of the long-term monitoring program. A diagram of the injection point layout is presented on Figure 3.1 and a detailed description is presented in Section 3.1.3.

After the installation of the injection points, a round of groundwater samples would be collected from the monitoring well network to establish a baseline. During the delivery of the ISCR materials, a mixture of the ISCR material and water would be injected into the installation points utilizing a grout pump. Concurrently, the area and the monitoring wells adjacent to the injection point would be monitored to observe evidence of daylighting or blow-by and to evaluate the distribution of the injected material. At full-scale, the substantive requirements of an underground injection control permit would be met.

COC degradation trends would be determined by the implementation of a monitoring program. Because this alternative would result in contaminants remaining on the MSP site above proposed cleanup levels, CERCLA requires that the site be reviewed at least once every five years to evaluate the protectiveness of the remedy.

4.2.3.1 Overall Protection of Human Health and the Environment

This alternative would protect both human health and the environment. The use of LUCs would eliminate or minimize the potential for human exposure at unacceptable levels by direct contact or ingestion of groundwater. The use of ISCR materials injected into the groundwater would reduce concentrations of VOCs and expedite the timeframe required for MNA processes to attain cleanup levels. The monitoring program would be similar to the procedures outlined under Alternative 2.

4.2.3.2 Compliance with ARARs

This alternative is an active remediation; therefore, compliance with the ARARs can be achieved. It complies with ARARs by degrading VOCs present in the bedrock aquifer. The primary technology to be applied to the total uranium in the overburden is MNA. LUCs would be implemented within 1 year to protect human health and the environment since the reduction of the COCs to concentrations below the ARARs would be gradual.

4.2.3.3 Long-Term Effectiveness and Permanence

This alternative could provide an acceptable degree of long-term effectiveness in preventing exposure to groundwater contaminants that may remain above the ARAR through the implementation of LUCs. The monitoring well system, supported by data evaluation, would provide a greater level of confidence in the remedy's effectiveness.

4.2.3.4 Reduction of Toxicity, Mobility, and Volume through Treatment

This alternative would satisfy the statutory preference for using treatment as a principal element of remediation. It would also reduce the toxicity, mobility, or volume of the COCs through treatment. Groundwater contamination of VOCs would be treated in situ with the use of the ISCR materials. Additionally, ZVI may reduce the toxicity of the groundwater contaminated with radioactive constituents by reductive precipitation and adsorption of uranium.

4.2.3.5 Short-Term Effectiveness

A slight increase in risk to workers could occur during the remedial activities. Certain monitoring and safety techniques would be in place during injection activities to minimize any unexpected releases or daylighting of the injected ISCR material. Implementing this alternative is anticipated to have little impact on geology, water resources, or biotic resources. This alternative is anticipated to produce a prompt reduction of the COCs in the short term since remedial activities are designed to target the source area and areas of elevated COC concentrations.

This alternative would achieve the RAOs by reducing total uranium, CT, TCE, and chloroform in the groundwater to less than or equal to the MCLs through ISCR and natural attenuation, and by implementing LUCs within 1 year. While it would take approximately 1 year to implement LUCs under this alternative, it is anticipated that the alternative would require an additional 10 years to achieve the cleanup objectives.

4.2.3.6 Implementability

This alternative is technically feasible, and services and materials are readily available. ISCR is a proven technology, although it would require frequent monitoring to assess effectiveness. Equipment that would be used is reliable, but control over the operating conditions would be necessary to maximize effectiveness. Since the alternative would be implemented using a multi-component system, careful engineering evaluation and design would be required to determine the injection parameters, including mixing rate, injection depth and injection pressure.

4.2.3.7 Cost

Alternative 3 contains the monitoring well installation, sampling, and analysis components of Alternative 2. All costs and estimating methods used under Alternative 2 were used to calculate the monitoring costs of this alternative.

The EZVI application assumes EZVI material will be injected into approximately 54 injection points in the source and areas with elevated VOC concentrations. The number of injection wells is based on the site geology and assumes a 20-foot-on-center spacing. Three additional lines of injection wells would be located downgradient along the property boundary (Figure 3.1). This approach assumes that there are 10 open fractures per hole and that the actual fracture aperture for liquid is about 0.01 foot (3 millimeter) thick, or a total vertical opening per hole = 0.05 foot, resulting in a 10-foot radius of influence.

The impact of the EZVI injections would be monitored using downgradient monitoring wells screened within the target zone. The downgradient monitoring wells would be sampled on a quarterly basis for a period of 2 years following EZVI injection activities to assess the effect of source area treatment and natural attenuation of the VOC plume.

Two injection events will be conducted at all the injection wells and an extra injection event will be conducted at some wells to treat any residual contamination that would remain. Furthermore, it was assumed that daylighting of EZVI is not a concern.

The capital cost for the ISCR technology using direct injection is approximately $5,471,000. The average annual long-term monitoring cost is estimated to be $212,000 per year and represents a net present worth of $7,106,000 over a 10-year monitoring period. This includes the cost to implement MNA activities and LUCs. A more detailed description of the cost and net present worth is presented in Tables 4-4 and 4-7.

4.2.4 Alternative 4 – Pump and Treat, Monitored Natural Attenuation and Land Use Controls

Alternative 4 is a combination of remedial technologies to treat the various contaminants present at the site. Removal of contaminated groundwater by pumping is proposed to address the VOCs present in groundwater situated in the fractured bedrock on site. Extraction wells would be placed in the source area and along the downgradient property boundary to control and eventually eliminate VOCs emanating from the source area. This would effectively isolate the downgradient portion of the plume that contains low concentrations of VOCs. MNA processes would be applied to the downgradient portion of the VOC plume and to the total uranium present in the overburden as discussed in Alternative 2. While data indicate that in situ biodegradation does not occur at the site, other MNA mechanisms such as dispersion and sorption are still applicable. A LUC in the form of a groundwater CEA would be utilized in areas of groundwater contamination present at the site until cleanup goals are achieved.

As extracted groundwater would exhibit levels of contamination that exceed local discharge permit levels, the groundwater would be pumped to a treatment system (e.g., GAC, air stripper, etc.), and the treated effluent would be tested and discharged to a POTW. The treatment system would potentially consist of a multi-stage operation involving physical and chemical processes, depending upon the extent of remediation necessary. For costing purposes, the treatment system would consist of an air stripper to remove VOCs and a GAC unit for polishing prior to being discharged to the local POTW.

Pump and treat systems are widely used to remediate groundwater, and therefore, relatively straightforward to design. Many installation methods can be used to install the extraction wells. Based on the bedrock present at the site, air or mud rotary drilling techniques would be anticipated. Equipment decontaminated would be required after use, and therefore, a light-duty decontamination pad of approximately 300 square feet would have to be constructed.

Due to the presence of fractured bedrock where VOCs are located, groundwater extraction rates may be limited, thus creating a relatively small capture zone for an individual extraction well. Therefore, multiple extraction wells may be needed. The final location, depth, and number of wells would be presented in the remedial design. For costing purposes, a total of 13 extraction wells would be installed.

Eight of these extraction wells would be installed in a line along and inside of the downgradient property boundary to a depth of 70 feet (Figure 3.2), pumping at approximately 1 gpm. These wells would capture the width of the plume moving off-site.

The five remaining extraction wells would be installed at the source area (near the sump and EE-MW-41S) and the areas of elevated VOC concentrations near ECC-MW-30B until the concentrations there have been sufficiently reduced, at which time these wells would be converted to low flowrate extraction wells to be operated for the remainder of the operational period. These wells will be drilled to a depth of 30 feet. Further evaluation of the depths of all remedial wells would be completed during the remedial design phase.

As described in Alternative 2, additional extraction wells would not be installed off-site.

The implementation of the remedial alternative would be considered complete when the long-term average concentrations of total uranium and VOCs at each individual well do not exceed their cleanup values for three consecutive sampling rounds.

Because this alternative would result in contaminants remaining on the MSP site above proposed cleanup levels, CERCLA requires that the site be reviewed at least once every five years to evaluate the protectiveness of the remedy.

4.2.4.1 Overall Protection of Human Health and the Environment

This alternative would protect both human health and the environment. The pump and treat system included in this alternative would reduce risk to human health by treating the extracted groundwater that is contaminated above ARAR levels (i.e., prevention or limitation of ingestion of contaminated groundwater). Groundwater in the subsurface should be monitored and evaluated to measure the attainment of RAOs and to ensure that exposure to COCs is at an acceptable level. In addition, LUCs would be implemented under this Alternative in order to restrict access to the contaminated groundwater that may remain until cleanup goals are achieved.

4.2.4.2 Compliance with ARARs

This alternative would comply with ARARs for COCs by removing and treating groundwater that exceeds cleanup levels. LUCs would be implemented within one year. Additionally, the groundwater treatment system would be designed to meet the action-specific requirements for POTW discharge standards.

4.2.4.3 Long-Term Effectiveness and Permanence

This alternative is anticipated to achieve long-term effectiveness. Long-term human health risks would be reduced due to the reduction of COCs to the cleanup-goal, thus preventing ingestion of contaminated groundwater. In addition, LUCs would restrict access to contaminated groundwater that may remain until the cleanup goals are achieved. This alternative may result in contaminants remaining on the MSP above the proposed cleanup level for a certain period of time and therefore, CERCLA requires that the site be reviewed at least once every five years.

4.2.4.4 Reduction of Toxicity, Mobility, and Volume through Treatment

This alternative would satisfy the statutory preference for using treatment as a principal element of remediation. It would also reduce the toxicity, mobility, or volume of the COC through treatment. Contaminant concentrations in groundwater are anticipated to decline with the implementation of the extraction well system to the respective ARAR level.

4.2.4.5 Short-Term Effectiveness

A slight increase in risk to workers could occur during the implementation of remedial activities. Certain monitoring and safety techniques would be in place during the installation of the pump-and-treat technology. Implementing this alternative is anticipated to have little impact on geology, water resources, or biotic resources. This alternative is anticipated to produce a prompt reduction of the VOCs in the short term since extraction activities are designed to target the source area and areas of elevated VOC concentrations. Construction activities could result in minimal noise, equipment emissions, and dust disturbances, but this would occur only over a short period. Watering and other containment methods would suppress any particulate generation, if necessary.

A slight increase in risk to workers could occur if the extraction or treatment system fail, and a release of contaminated groundwater occurred. Certain monitoring and safety techniques would be in place during pump and treat activities to minimize any unexpected releases. Other risks to workers include physical hazards during installation of the wells, underground piping, and treatment system, although these hazards would also be minimized through adherence to mandatory monitoring and safety techniques.

This alternative would achieve the RAOs by reducing COC concentrations in the groundwater to less than or equal to their respective ARARs, and by implementing LUCs within 1 year. While it would take approximately 1 year to implement LUCs under this alternative, it is anticipated that this alternative would require an additional 30 years to achieve the cleanup objectives.

4.2.4.6 Implementability

This alternative is technically feasible, and services and materials are readily available. The pumping and treatment processes that could be used are proven technologies. Equipment that would be used is reliable, but control over the operating conditions would be necessary to maximize effectiveness. A permit would be necessary to release treated effluent to a POTW, but should be obtainable. Since the alternative would be implemented using a multi-component system, accurate engineering judgment would be required to determine operating parameters.

Since the MSP is located near other industrial facilities with known VOC contamination in groundwater, the design of a pump-and-treat system would require a thorough understanding of the interaction of the radius of influence of the system and nearby plumes. This system's design must not impact the flow regime and contaminant extent of nearby off-site plumes.

4.2.4.7 Cost

Alternative 4 contains all of the monitoring well installation, sampling, and analysis components of Alternative 2. All costs and estimating methods used under Alternative 2 were used to calculate the monitoring costs of this alternative.

Eight extraction wells would be installed near the downgradient property boundary and five extraction wells would be installed near the source area (in the vicinity of the sump and EE-MW-41S) and the areas of elevated VOC concentration near ECC-MW-30B.

Following the initial extraction, the five wells near the source area and ECC-MW-30B would be converted to low flowrate extraction wells for the remainder of the operational period (30 years). The effectiveness of this alternative would be monitored using downgradient monitoring wells screened within the target zone. The downgradient monitoring wells would be sampled on a quarterly basis for a period of 2 years following system installation to assess the effect of source area removal on the VOC plume.

The capital costs for pump-and-treat technology is approximately $3,039,000. The average annual long-term monitoring and operation cost is estimated to be $608,000 per year and represents a net present worth of $11,951,000 over a 30-year monitoring period. This includes the cost to construct the pump-and-treat system, annual O&M costs, MNA activities, and LUC costs. A more detailed description of the cost and net present worth is presented in Tables 4-5 and 4-8.

4.3 Comparative Analysis of Alternatives

The purpose of the comparative analysis is to identify the advantages and disadvantages of the alternatives when compared with each other. The comparative analysis allows identification of items that can be compared and contrasted during the final selection of a preferred alternative. The results of this analysis are summarized on Tables 4-1 and 4-2.

4.3.1 Overall Protection of Human Health and the Environment

Alternative 1 does not provide protection of human health and the environment because there would be no documentation that natural processes are reducing contamination and LUCs would not be implemented.

Alternatives 2, 3, and 4 would be considered adequately protective of human health. Although no active remedial treatment measures would occur under Alternative 2, adequate protection in the short-term could still be achieved through implementation of LUCs. Additionally for Alternative 2, a groundwater monitoring program would assess the attainment of the ARARs and monitor the progress and rate of natural degradation, albeit slow.

Alternatives 3 and 4 would protect human health and the environment by combining active remediation with the implementation of LUCs and a MNA program, which would assess the attainment of ARARs.

4.3.2 Compliance with ARARs

It is anticipated that Alternative 1 could eventually meet the ARARs for the MSP groundwater COCs. However, the achievement would not be documented, and LUCs would not be in place to restrict access to impacted groundwater. Alternative 2 would eventually comply with the ARARs through natural environmental processes and LUCs would restrict access to impacted groundwater until the ARARs are achieved. Alternative 3 would comply with the ARARs through the implementation of MNA for the total uranium in the overburden and ISCR that would be designed to meet the COCs demand of electron donor/acceptor for degradation of VOCs in the bedrock. Alternative 4 would comply with the ARARs through the implementation of MNA for the total uranium in the overburden and pump-and-treat technology that would be designed to extract groundwater impacted by COCs in the bedrock. Alternatives 3 and 4 would also implement LUCs to restrict access to impacted groundwater until the ARARs are achieved. Alternatives 2, 3, and 4 would provide a monitoring program to determine when groundwater ARARs are achieved for both the saturated overburden unit and bedrock aquifer.

4.3.3 Long-Term Effectiveness and Permanence

Alternative 1 may provide long-term effectiveness as contaminant concentrations in groundwater are reduced due to natural attenuation, although there is no monitoring in place to document this potential effectiveness. Alternative 2 may provide long-term effectiveness as contaminant concentrations in groundwater are reduced due to natural attenuation processes and monitoring would be in place to document this effectiveness; LUCs would be in place for protection against exposure to groundwater contamination. Alternatives 3 and 4 would offer a higher degree of long-term effectiveness and permanence through the implementation of remedial technologies. Alternative 3 would implement MNA for the total uranium in the overburden and ISCR that would be designed to meet the COCs demand of electron donor/acceptor for degradation of VOCs in the bedrock. Alternative 4 would implement MNA for the total uranium in the overburden and pump-and-treat technology that would be designed to extract groundwater impacted by COCs in the bedrock. Alternatives 3 and 4 also implement LUCs to restrict access to impacted groundwater until the ARARs are achieved, meeting long-term effectiveness and permanence.

4.3.4 Reduction of Toxicity, Mobility, and Volume through Treatment

This evaluation criterion is not applicable to Alternatives 1 and 2. Each of these alternatives would rely solely on natural processes such as biodegradation, adsorption, and dilution to remediate the groundwater at the MSP. Alternatives 3 and 4 would satisfy the statutory preference for treatment as a principal element and incorporate natural processes occurring under the MNA technology.

4.3.5 Short-Term Effectiveness

No changes in potential exposure to workers or negative impacts to the environment would occur under Alternative 1. Alternative 2 would pose little to no additional health risk to the community and workers in the short term because no significant remedial activities would take place. Alternatives 3 and 4 may have a slight increase in risk to workers during the remedial activities. However, these impacts would be mitigated by health and safety measures. Alternative 3 is anticipated to produce a prompt reduction of the COCs in the short term since remedial construction and operation activities are designed to target the source area and areas of elevated COC concentrations; LUCs would be implemented within 1 year. Alternative 4 is anticipated to have a moderate time frame in reduction of the COCs in the short term as the pump-and-treat applications impact zones of contamination; LUCs would be implemented within 1 year.

4.3.6 Implementability

Alternative 1 involves No Further Action, and is therefore easily implemented.

Applications presented under Alternatives 2, 3, and 4 are proven and no major hindrances have been identified nor are anticipated with their implementation. Due to the limited actions presented under Alternative 2, it is assumed to be the most straightforward alternative to implement.

Since active remediation is proposed under Alternatives 3 and 4, increased complexity and some uncertainty would exist with their implementation. Their technologies have been proven, problems with implementation are not anticipated, and materials are readily available. The attainment of necessary permits for potential off-site actions is anticipated to be achievable. Sampling and analysis to occur are straightforward. Some degree of difficulty may occur during the implementation of the remedial process, which would require careful assessment and engineering judgment to determine operating parameters, and these could create additional uncertainties.

4.3.7 Cost

Alternatives 3 and 4 would have significantly higher present-worth and capital costs than Alternative 2. The technology employed under Alternative 4 would be the most expensive, and the limited actions involved with Alternative 2 would be the least expensive, excluding Alternative 1. Detailed costs for alternatives are presented on Tables 4-3 to 4-5. A summary of the present worth cost for each alternative is presented below.

Alternative	Estimated Cost
1: No Further Action	$0
2: Monitored Natural Attenuation and Land Use Controls	$2,711,000
3: Treatment with In situ Chemical Reduction, Monitored Natural Attenuation, and Land Use Controls	$7,106,000
4: Removal by Pumping, Monitored Natural Attenuation, and Land Use Controls	$11,951,000

4.4 Findings

The comparative analysis of alternatives based on the above criteria provides the basis for selecting the preferred alternative. The selected preferred alternative must meet the threshold criteria of Overall Protection of Human Health and the Environment and Compliance with ARARs, while the other primary balancing and modifying criteria should be considered in the selection process.

The preferred alternative, which will be described in the proposed plan, will be selected from among these four alternatives. In accordance with the NCP, the preferred alternative will be presented to the public for review and comment. Public input on the alternatives is paramount in the selection process. Based on the comments received, the preferred remedy may be modified. The final remedy will be selected by USACE and USEPA, in consultation with NJDEP, and presented in a ROD.

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TABLES

Table 1-1
Analytical Results for Residential Well and Private Water Supply Well Samples
November 2010 and January 2011
Middlesex Sampling Plant
Middlesex, New Jersey

			Sample ID:	MSP-202F-DW-111810 (Well No. 4 on Figure 1.6)	MSP-160 FARRAGUT (Well No. 3 on Figure 1.6)	MSP-110 BLACKFORD (Well No. 6 on Figure 1.6)	MSP-107 BLACKFORD (Well No. 5 on Figure 1.6)
			Sample Date:	11/18/2010	11/19/2010	11/23/2010	11/29/2010
			SDG:	680-63319-1	680-63373-1	680-63488-1	680-63555-1
Volatile Organic Compounds	**NJDEP Drinking Water Standards**	**MCL**	**units**				
Benzene		5	µg/L	0.50 U	0.50 U	0.50 U	0.50 U
Bromobenzene			µg/L	0.50 U	0.50 U	0.50 U	0.50 U
Bromoform	See Trihalomethanes	See Trihalomethanes	µg/L	0.50 U	0.50 U	0.50 U	0.50 U
Bromomethane			µg/L	1.0 U	1.0 U	1.0 U	1.0 U
Carbon Tetrachloride	2	5	µg/L	0.50 U	0.50 U	0.50 U	0.50 U
Chlorobenzene	50	100	µg/L	0.50 U	0.50 U	0.50 U	0.50 U
Chlorodibromomethane	See Trihalomethanes	60	µg/L	0.50 U	0.50 U	0.50 U	0.50 U
Chloroethane			µg/L	1.0 U	1.0 U	1.0 U	1.0 U
Chloroform	See Trihalomethanes	70	µg/L	0.50 U	0.50 U	0.50 U	0.50 U
Chloromethane			µg/L	0.50 U	0.50 U	0.50 U	0.50 U
2-Chlorotoluene			µg/L	0.50 U	0.50 U	0.50 U	0.50 U
4-Chlorotoluene			µg/L	0.50 U	0.50 U	0.50 U	0.50 U
cis-1,2-Dichloroethene	70	70	µg/L	0.50 U	0.50 U	0.50 U	0.50 U
cis-1,3-Dichloropropene			µg/L	0.50 U	0.50 U	0.50 U	0.50 U
Dibromomethane			µg/L	0.50 U	0.50 U	0.50 U	0.50 U
1,2-Dichlorobenzene	600	600	µg/L	0.50 U	0.50 U	0.50 U	0.50 U
1,3-Dichlorobenzene	600		µg/L	0.50 U	0.50 U	0.50 U	0.50 U
1,4-Dichlorobenzene	75	75	µg/L	0.50 U	0.50 U	0.50 U	0.50 U
Dichlorobromomethane	See Trihalomethanes	See Trihalomethanes	µg/L	1.0 U	1.0 U	1.0 U	1.0 U
1,1-Dichloroethane	50		µg/L	0.50 U	0.50 U	0.50 U	0.50 U
1,2-Dichloroethane	2	5	µg/L	0.50 U	0.50 U	0.50 U	0.50 U
1,1-Dichloroethene	2	7	µg/L	0.50 U	0.50 U	0.50 U	0.50 U
1,2-Dichloropropane	5	5	µg/L	0.50 U	0.50 U	0.50 U	0.50 U
1,3-Dichloropropane			µg/L	0.50 U	0.50 U	0.50 U	0.50 U
1,1-Dichloropropene			µg/L	0.50 U	0.50 U	0.50 U	0.50 U
2,2-Dichloropropane			µg/L	0.50 U	0.50 U	0.50 U	0.50 U
Ethylbenzene	700	700	µg/L	0.50 U	0.50 U	0.50 U	0.50 U
Methylene Chloride	3	5	µg/L	0.50 U	0.50 U	0.50 U	0.50 U
Methyl tert-butyl Ether (MTBE)	70		µg/L	0.50 U	0.50 U	0.50 U	0.50 U
m-Xylene & p-Xylene	See Total	See Total	µg/L	0.50 U	0.50 U	0.50 U	0.50 U
o-Xylene	See Total	See Total	µg/L	0.50 U	0.50 U	0.50 U	0.50 U
Styrene	100	100	µg/L	0.50 U	0.50 U	0.50 U	0.50 U
1,1,1,2-Tetrachloroethane			µg/L	0.50 U	0.50 U	0.50 U	0.50 U
1,1,2,2-Tetrachloroethane	1		µg/L	0.50 U	0.50 U	0.50 U	0.50 U
Tetrachloroethene	1	5	µg/L	0.50 U	0.50 U	0.50 U	0.50 U
Toluene	1,000	1,000	µg/L	0.50 U	0.50 U	0.50 U	0.50 U
trans-1,2-Dichloroethene	100	100	µg/L	0.50 U	0.50 U	0.50 U	0.50 U
trans-1,3-Dichloropropene			µg/L	0.50 U	0.50 U	0.50 U	0.50 U
1,2,4-Trichlorobenzene	9	70	µg/L	0.50 U	0.50 U	0.50 U	0.50 U
1,1,1-Trichloroethane	30	200	µg/L	0.50 U	0.50 U	0.50 U	0.50 U
1,1,2-Trichloroethane	3	5	µg/L	0.50 U	0.50 U	0.50 U	0.50 U
Trichloroethene	1	5	µg/L	0.50 U	0.50 U	0.50 U	0.50 U
1,2,3-Trichloropropane			µg/L	0.50 U	0.50 U	0.50 U	0.50 U
Vinyl Chloride	2	2	µg/L	0.50 U	0.50 U	0.50 U	0.50 U
Total Xylenes	1,000	10,000	µg/L	0.50 U	0.50 U	0.50 U	0.50 U
Trihalomethanes (total of 4 individual THMs)	80	80	µg/L	1.0 U	1.0 U	1.0 U	1.0 U

Notes:

Detections exceeding the MCL and/or the NJDEP DW Standards are highlighted in blue.

Detections are in BOLD font.

Only analytes with bold numbers to the right were detected (present at a level that modern technology can detect).

Concentrations between the RL and MDL are considered to be less than the RL and estimated (J).

ID = identification
µg/L = micrograms per liter
MCL = Federal Maximum Contaminant Level Standard
MDL = Method Detection Limit (the lowest level that can be detected)
NJDEP = New Jersey Department of Environmental Protection Standard
RL = Reporting Limit (the lowest level that can be quantified accurately)
THMs = Trihalomethanes
U = Not Detected. Analyte is not present at a level greater than the method MDL.
UJ = Not Detected, Estimated Reporting Limit

Table 1-1
Analytical Results for Residential Well and Private Water Supply Well Samples
November 2010 and January 2011
Middlesex Sampling Plant
Middlesex, New Jersey

			Sample ID:	MSP-90WOOD-11711 (Well No. 9 on Figure 1.6)	MSP-430VOOR-11711 (Well No. 7 on Figure 1.6)	MSP-796WIL-11711 (Well No. 8 on Figure 1.6)
			Sample Date:	1/17/2011	1/17/2011	1/17/2011
			SDG:	680-64857-1	680-64857-1	680-64857-1
Volatile Organic Compounds	**NJDEP Drinking Water Standards**	**MCL**	**units**			
Benzene		5	µg/L	0.50 U	0.50 U	0.50 U
Bromobenzene			µg/L	0.50 U	0.50 U	0.50 U
Bromoform	See Trihalomethanes	See Trihalomethanes	µg/L	0.50 U	0.50 U	0.50 U
Bromomethane			µg/L	1.0 U	1.0 U	1.0 U
Carbon Tetrachloride	2	5	µg/L	0.50 U	0.50 U	0.50 U
Chlorobenzene	50	100	µg/L	0.50 U	0.50 U	0.50 U
Chlorodibromomethane	See Trihalomethanes	60	µg/L	0.50 U	0.50 U	0.50 U
Chloroethane			µg/L	1.0 U	1.0 U	1.0 U
Chloroform	See Trihalomethanes	70	µg/L	0.50 U	0.50 U	0.50 U
Chloromethane			µg/L	0.50 U	0.50 U	0.50 U
2-Chlorotoluene			µg/L	0.50 U	0.50 U	0.50 U
4-Chlorotoluene			µg/L	0.50 U	0.50 U	0.50 U
cis-1,2-Dichloroethene	70	70	µg/L	0.50 U	0.50 U	0.50 U
cis-1,3-Dichloropropene			µg/L	0.50 U	0.50 U	0.50 U
Dibromomethane			µg/L	0.50 U	0.50 U	0.50 U
1,2-Dichlorobenzene	600	600	µg/L	0.50 U	0.50 U	0.50 U
1,3-Dichlorobenzene	600		µg/L	0.50 U	0.50 U	0.50 U
1,4-Dichlorobenzene	75	75	µg/L	0.50 U	0.50 U	0.50 U
Dichlorobromomethane	See Trihalomethanes	See Trihalomethanes	µg/L	1.0 U	1.0 U	1.0 U
1,1-Dichloroethane	50		µg/L	0.50 U	0.50 U	0.50 U
1,2-Dichloroethane	2	5	µg/L	0.50 U	0.50 U	0.50 U
1,1-Dichloroethene	2	7	µg/L	0.50 U	0.50 U	0.50 U
1,2-Dichloropropane	5	5	µg/L	0.50 U	0.50 U	0.50 U
1,3-Dichloropropane			µg/L	0.50 U	0.50 U	0.50 U
1,1-Dichloropropene			µg/L	0.50 U	0.50 U	0.50 U
2,2-Dichloropropane			µg/L	0.50 U	0.50 U	0.50 U
Ethylbenzene	700	700	µg/L	0.50 U	0.50 U	0.50 U
Methylene Chloride	3	5	µg/L	0.83 UJ	0.71 UJ	0.73 UJ
Methyl tert-butyl Ether (MTBE)	70		µg/L	**1.9**	**0.29 J**	0.50 U
m-Xylene & p-Xylene	See Total	See Total	µg/L	0.50 U	0.50 U	0.50 U
o-Xylene	See Total	See Total	µg/L	0.50 U	0.50 U	0.50 U
Styrene	100	100	µg/L	0.50 U	0.50 U	0.50 U
1,1,1,2-Tetrachloroethane			µg/L	0.50 U	0.50 U	0.50 U
1,1,2,2-Tetrachloroethane	1		µg/L	0.50 U	0.50 U	0.50 U
Tetrachloroethene	1	5	µg/L	0.50 U	0.50 U	0.50 U
Toluene	1,000	1,000	µg/L	**0.36 J**	0.50 U	0.50 U
trans-1,2-Dichloroethene	100	100	µg/L	0.50 U	0.50 U	0.50 U
trans-1,3-Dichloropropene			µg/L	0.50 U	0.50 U	0.50 U
1,2,4-Trichlorobenzene	9	70	µg/L	0.50 U	0.50 U	0.50 U
1,1,1-Trichloroethane	30	200	µg/L	0.50 U	0.50 U	0.50 U
1,1,2-Trichloroethane	3	5	µg/L	0.50 U	0.50 U	0.50 U
Trichloroethene	1	5	µg/L	0.50 U	**0.38 J**	0.50 U
1,2,3-Trichloropropane			µg/L	0.50 U	0.50 U	0.50 U
Vinyl Chloride	2	2	µg/L	0.50 U	0.50 U	0.50 U
Total Xylenes	1,000	10,000	µg/L	0.50 U	0.50 U	0.50 U
Trihalomethanes (total of 4 individual THMs)	80	80	µg/L	1.0 U	1.0 U	1.0 U

Notes:

Detections exceeding the MCL and/or the NJDEP DW Standards are highlighted in blue.

Detections are in BOLD font.

Only analytes with bold numbers to the right were detected (present at a level that modern technolo

Concentrations between the RL and MDL are considered to be less than the RL and estimated (J).

ID = identification
µg/L = micrograms per liter
MCL = Federal Maximum Contaminant Level Standard
MDL = Method Detection Limit (the lowest level that can be detected)
NJDEP = New Jersey Department of Environmental Protection Standard
RL = Reporting Limit (the lowest level that can be quantified accurately)
THMs = Trihalomethanes
U = Not Detected. Analyte is not present at a level greater than the method MDL.
UJ = Not Detected, Estimated Reporting Limit

Table 1-2
Results for Domestic Well Samples Collected From Property Adjacent to MSP Site
Middlesex Sampling Plant
Middlesex, New Jersey

			Sample ID:	MSP-233M-GW-081610	MSP-233M-INF-090710 (influent)	MSP-233M-MID-090710 (mid-point)	MSP-233M-EFF-090710 (effluent)
			Sample Date:	8/16/2010	9/7/2010	9/7/2010	9/7/2010
			SDG:	680-60531-1	680-61043-1	680-61043-1	680-61043-1
Volatile Organic Compounds	**NJDEP Drinking Water Standards**	**MCL**					
Benzene		5	µg/L	1.0 U	0.50 U	0.50 U	0.50 U
Bromobenzene			µg/L	1.0 U	0.50 U	0.50 U	0.50 U
Bromoform	See Trihalomethanes	See Trihalomethanes	µg/L	1.0 U	0.50 U	0.50 U	0.50 U
Bromomethane			µg/L	2.0 U	1.0 U	1.0 U	1.0 U
Carbon Tetrachloride	2	5	µg/L	**19**	**19**	0.50 U	0.50 U
Chlorobenzene	50	100	µg/L	1.0 U	0.50 U	0.50 U	0.50 U
Chlorodibromomethane	See Trihalomethanes	60	µg/L	1.0 U	0.50 U	0.50 U	0.50 U
Chloroethane			µg/L	2.0 U	1.0 U	1.0 U	1.0 U
Chloroform	See Trihalomethanes	70	µg/L	**1.4**	**1.4**	0.50 U	0.50 U
Chloromethane			µg/L	1.0 U	0.50 U	0.50 U	0.50 U
2-Chlorotoluene			µg/L	1.0 U	0.50 U	0.50 U	0.50 U
4-Chlorotoluene			µg/L	1.0 U	0.50 U	0.50 U	0.50 U
cis-1,2-Dichloroethene	70	70	µg/L	**1.1**	**0.92**	0.50 U	0.50 U
cis-1,3-Dichloropropene			µg/L	1.0 U	0.50 U	0.50 U	0.50 U
Dibromomethane			µg/L	1.0 U	0.50 U	0.50 U	0.50 U
1,2-Dichlorobenzene	600	600	µg/L	1.0 U	0.50 U	0.50 U	0.50 U
1,3-Dichlorobenzene	600		µg/L	1.0 U	0.50 U	0.50 U	0.50 U
1,4-Dichlorobenzene	75	75	µg/L	1.0 U	0.50 U	0.50 U	0.50 U
Dichlorobromomethane	See Trihalomethanes	See Trihalomethanes	µg/L	2.0 U	1.0 U	1.0 U	1.0 U
1,1-Dichloroethane	50		µg/L	**4.3**	**4.2**	0.50 U	0.50 U
1,2-Dichloroethane	2	5	µg/L	1.0 U	**0.29 J**	0.50 U	0.50 U
1,1-Dichloroethene	2	7	µg/L	**62**	**54**	0.50 U	0.50 U
1,2-Dichloropropane	5	5	µg/L	1.0 U	0.50 U	0.50 U	0.50 U
1,3-Dichloropropane			µg/L	1.0 U	0.50 U	0.50 U	0.50 U
1,1-Dichloropropene			µg/L	1.0 U	0.50 U	0.50 U	0.50 U
2,2-Dichloropropane			µg/L	1.0 U	0.50 U	0.50 U	0.50 U
Ethylbenzene	700	700	µg/L	1.0 U	0.50 U	0.50 U	0.50 U
Methylene Chloride	3	5	µg/L	1.0 U	0.50 U	**0.71**	**1.1**
Methyl tert-butyl Ether (MTBE)	70		µg/L	1.0 U	0.50 U	0.50 U	0.50 U
m-Xylene & p-Xylene	See Total	See Total	µg/L	1.0 U	0.50 U	0.50 U	0.50 U
o-Xylene	See Total	See Total	µg/L	1.0 U	0.50 U	0.50 U	0.50 U
Styrene	100	100	µg/L	1.0 U	0.50 U	0.50 U	0.50 U
1,1,1,2-Tetrachloroethane			µg/L	1.0 U	0.50 U	0.50 U	0.50 U
1,1,2,2-Tetrachloroethane	1		µg/L	1.0 U	0.50 U	0.50 U	0.50 U
Tetrachloroethene	1	5	µg/L	**13**	**13**	0.50 U	0.50 U
Toluene	1,000	1,000	µg/L	1.0 U	0.50 U	0.50 U	0.50 U
trans-1,2-Dichloroethene	100	100	µg/L	1.0 U	0.50 U	0.50 U	0.50 U
trans-1,3-Dichloropropene			µg/L	1.0 U	0.50 U	0.50 U	0.50 U
1,2,4-Trichlorobenzene	9	70	µg/L	1.0 U	0.50 U	0.50 U	0.50 U
1,1,1-Trichloroethane	30	200	µg/L	**0.86 J**	**0.80**	0.50 U	0.50 U
1,1,2-Trichloroethane	3	5	µg/L	1.0 U	0.50 U	0.50 U	0.50 U
Trichloroethene	1	5	µg/L	**8.3**	**8.6**	0.50 U	0.50 U
1,2,3-Trichloropropane			µg/L	1.0 U	0.50 U	0.50 U	0.50 U
Vinyl Chloride	2	2	µg/L	1.0 U	0.50 U	0.50 U	0.50 U
Total Xylenes	1,000	10,000	µg/L	1.0 U	0.50 U	0.50 U	0.50 U
Trihalomethanes (total of 4 individual THMs)	80	80	µg/L	**1.4**	**1.4**	1.0 U	1.0 U

Notes:

Detections exceeding the MCL and/or the NJDEP DW Standards are highlighted in blue.

Detections are in BOLD font.

Only analytes with bold numbers to the right were detected (present at a level that modern technology can detect).

Concentrations between the RL and MDL are considered to be less than the RL and estimated (J).

*Samples on this table were collected from Well No. 2 on Figure 1.6.

ID = Identification
µg/L = Micrograms per Liter
MCL = Federal Maximum Contaminant Level Standard
MDL = Method Detection Limit (the lowest level that can be detected)
NJDEP = New Jersey Department of Environmental Protection Standard
RL = Reporting Limit (the lowest level that can be quantified accurately)
THMs = Trihalomethanes
U = Not Detected. Analyte is not present at a level greater than the method MDL.
UJ = Not Detected, Estimated Reporting Limit

Table 1-2
Results for Domestic Well Samples Collected From Property Adjacent to MSP Site
Middlesex Sampling Plant
Middlesex, New Jersey

			Sample ID:	MSP-233M-2EFF-090710 (effluent)	MSP-233M-INF-101210 (influent)	MSP-233M-MID-101210 (mid-point)	MSP-233M-EFF-101210 (effluent)
			Sample Date:	9/7/2010	10/12/2010	10/12/2010	10/12/2010
			SDG:	680-61043-1	680-62130-1	680-62130-1	680-62130-1
Volatile Organic Compounds	**NJDEP Drinking Water Standards**	**MCL**					
Benzene		5	µg/L	0.50 U	0.50 U	0.50 U	0.50 U
Bromobenzene			µg/L	0.50 U	0.50 U	0.50 U	0.50 U
Bromoform	See Trihalomethanes	See Trihalomethanes	µg/L	0.50 U	0.50 U	0.50 U	0.50 U
Bromomethane			µg/L	1.0 U	1.0 U	1.0 U	1.0 U
Carbon Tetrachloride	2	5	µg/L	0.50 U	**14**	0.50 U	0.50 U
Chlorobenzene	50	100	µg/L	0.50 U	0.50 U	0.50 U	0.50 U
Chlorodibromomethane	See Trihalomethanes	60	µg/L	0.50 U	0.50 U	0.50 U	0.50 U
Chloroethane			µg/L	1.0 U	1.0 U	1.0 U	1.0 U
Chloroform	See Trihalomethanes	70	µg/L	0.50 U	**1.2**	0.50 U	0.50 U
Chloromethane			µg/L	0.50 U	0.50 U	0.50 U	0.50 U
2-Chlorotoluene			µg/L	0.50 U	0.50 U	0.50 U	0.50 U
4-Chlorotoluene			µg/L	0.50 U	0.50 U	0.50 U	0.50 U
cis-1,2-Dichloroethene	70	70	µg/L	0.50 U	**0.84**	0.50 U	0.50 U
cis-1,3-Dichloropropene			µg/L	0.50 U	0.50 U	0.50 U	0.50 U
Dibromomethane			µg/L	0.50 U	0.50 U	0.50 U	0.50 U
1,2-Dichlorobenzene	600	600	µg/L	0.50 U	0.50 U	0.50 U	0.50 U
1,3-Dichlorobenzene	600		µg/L	0.50 U	0.50 U	0.50 U	0.50 U
1,4-Dichlorobenzene	75	75	µg/L	0.50 U	0.50 U	0.50 U	0.50 U
Dichlorobromomethane	See Trihalomethanes	See Trihalomethanes	µg/L	1.0 U	1.0 U	1.0 U	1.0 U
1,1-Dichloroethane	50		µg/L	0.50 U	**4.7**	0.50 U	0.50 U
1,2-Dichloroethane	2	5	µg/L	0.50 U	**0.27 J**	0.50 U	0.50 U
1,1-Dichloroethene	2	7	µg/L	0.50 U	**65**	0.50 U	0.50 U
1,2-Dichloropropane	5	5	µg/L	0.50 U	0.50 U	0.50 U	0.50 U
1,3-Dichloropropane			µg/L	0.50 U	0.50 U	0.50 U	0.50 U
1,1-Dichloropropene			µg/L	0.50 U	0.50 U	0.50 U	0.50 U
2,2-Dichloropropane			µg/L	0.50 U	0.50 U	0.50 U	0.50 U
Ethylbenzene	700	700	µg/L	0.50 U	0.50 U	0.50 U	0.50 U
Methylene Chloride	3	5	µg/L	**0.72**	1.5 UJ	1.2 UJ	0.88 UJ
Methyl tert-butyl Ether (MTBE)	70		µg/L	0.50 U	0.50 U	0.50 U	0.50 U
m-Xylene & p-Xylene	See Total	See Total	µg/L	0.50 U	0.50 U	0.50 U	0.50 U
o-Xylene	See Total	See Total	µg/L	0.50 U	0.50 U	0.50 U	0.50 U
Styrene	100	100	µg/L	0.50 U	0.50 U	0.50 U	0.50 U
1,1,1,2-Tetrachloroethane			µg/L	0.50 U	0.50 U	0.50 U	0.50 U
1,1,2,2-Tetrachloroethane	1		µg/L	0.50 U	0.50 U	0.50 U	0.50 U
Tetrachloroethene	1	5	µg/L	0.50 U	**13**	0.50 U	0.50 U
Toluene	1,000	1,000	µg/L	0.50 U	0.50 U	0.50 U	0.50 U
trans-1,2-Dichloroethene	100	100	µg/L	0.50 U	0.50 U	0.50 U	0.50 U
trans-1,3-Dichloropropene			µg/L	0.50 U	0.50 U	0.50 U	0.50 U
1,2,4-Trichlorobenzene	9	70	µg/L	0.50 U	0.50 U	0.50 U	0.50 U
1,1,1-Trichloroethane	30	200	µg/L	0.50 U	**0.93**	0.50 U	0.50 U
1,1,2-Trichloroethane	3	5	µg/L	0.50 U	0.50 U	0.50 U	0.50 U
Trichloroethene	1	5	µg/L	0.50 U	**8.3**	0.50 U	0.50 U
1,2,3-Trichloropropane			µg/L	0.50 U	0.50 U	0.50 U	0.50 U
Vinyl Chloride	2	2	µg/L	0.50 U	0.50 U	0.50 U	**0.35 J**
Total Xylenes	1,000	10,000	µg/L	0.50 U	0.50 U	0.50 U	0.50 U
Trihalomethanes (total of 4 individual THMs)	80	80	µg/L	1.0 U	**1.2**	1.0 U	1.0 U

Notes:

Detections exceeding the MCL and/or the NJDEP DW Standards are highlighted in blue.

Detections are in BOLD font.

Only analytes with bold numbers to the right were detected (present at a level that modern technology can detect).

Concentrations between the RL and MDL are considered to be less than the RL and estimated (J).

*Samples on this table were collected from Well No. 2 on Figure 1.6.

ID = Identification

µg/L = Micrograms per Liter

MCL = Maximum Contaminant Level

MDL = Method Detection Limit (the lowest level that can be detected)

NJDEP = New Jersey Department of Environmental Protection

RL = Reporting Limit (the lowest level that can be quantified accurately)

THMs = Trihalomethanes

U = Not Detected. Analyte is not present at a level greater than the method MDL.

UJ = Not Detected, Estimated Reporting Limit

TABLE 1-3
Summary of Overburden Monitoring Well Total Uranium Detections
Sampling Events 1 Through 16
Middlesex Sampling Plant
Middlesex, New Jersey

WELL ID	Units	SE 1 Aug-08	SE 2 Nov-08	SE 3 Feb-09	SE 4 Dec-09	SE 5 Apr-10	SE 6 Nov-10	SE 7 May-11	SE 8 Aug-11	SE 9 Nov-11	SE 10 Feb-12	SE 11 June-12	SE 12 Aug-12	SE 13 Nov-12	SE 15 Oct-14	SE 16 Nov-15
MW-OB-1	µg/L	3.63	1.83	1.89	1U	1U	1.60	1.20	1U	1U	0.67 J	0.96 J	0.74 J	1.2	0.317	0.321
MW-OB-2	µg/L	3.55	1U	2.98	1U	1U	1.40	1U	1U	1U	1U	1U	0.77 J	0.27 J	0.350	0.112J
MW-OB-3	µg/L	10.40	14.00	7.49	2.59	3.16	5.50	1.40	1.7	1.9	1.6	2.1	0.60 J	3.0	2.62	3.62
MW-OB-4	µg/L	1U	2.98	1.50	1U	1U	0.34	1.2	1U	1U	1U	1U	2.9	1U	0.975	2.04
MW-OB-5	µg/L	7.67	4.78	2.81	2.02	1.99	3.10	1.2	1.4UJ	1.9	2.9	0.79 J	1.8	3.4	0.418	1.94
MW-OB-6	µg/L	3.31	2.75	3.72	1U	1U	9.60	0.65	1U	0.49 J	0.93 J	0.24 J	1U	0.54 J	0.698	2.82
MW-OB-7*	µg/L	**35.10**	**36.10**	**38.10**	10.70	11.10	**41.10**	15	5.8	10.4	**32.3**	9.0	10	**44**	--	--
MW-OB-7R	µg/L	--	--	--	--	--	--	--	--	--	--	--	--	--	8.64	9.14
MW-OB-8	µg/L	**34.20**	6.89	2.55	1.24	5.69	25.80	1.7	1U	4.4	1.6	4.4	18	11	3.39	2.78
MW-OB-9	µg/L	18.20	6.36	10.50	2.80	4.53	1U	0.72	1U	1.2	0.60 J	0.57 J	4.2	2.3	Dry	0.780
MW-OB-10*	µg/L	4.30	7.23	23.60	19.20	NS	3.60	5.5	1.2	13.2	5.9	**51**	**40**	NS	--	--
MW-OB-11	µg/L	3.38	2.71	3.64	1.12	1.44	0.27	0.81	1U	0.39 J	0.45 J	1U	1U	0.31 J	0.479	0.447
MW-OB-12	µg/L	1U	2.98	4.03	3.03	4.54	8.50	**43.5**	9.3	17.7	5.5	8.4	5.9	7.8	Dry	3.08
MW-OB-13	µg/L	7.15	5.74	2.79	4.03	2.84	3.10	1.9	2.6	2.0	1.8	1.8	2.6	1.8	2.14	2.27
B18W29SR	µg/L	7.65	14.00	7.86	8.72	7.38	1.90	7.9	6.4	10.6	2.2	3.2	0.82 J	3.3	0.738	1.15

Notes: **Bold Font/Blue Cell** - value meets or exceeds the USEPA Maximum Contaminant Level (MCL) of 30 micrograms per liter (µg/L)

Samples were not collected for total uranium during SE 14, only VOCs.

*Wells MW-OB-7 and MW-OB-10 were abandoned in October 2014. MW-OB-7 was replaced with MW-OB-7R near the original location.

Key: µg/L - micorgrams per liter

J - estimated value

U - not detected. Analyte is not present at a level greater than the reporting limit.

UJ - not detected. The reporting limit is estimated.

NS - no sample was collected for analysis due to insuffient water

TABLE 1-4
Summary of Bedrock Monitoring Well Volatile Organic Compound Detections
Sampling Events 1 Through 16
Middlesex Sampling Plant
Middlesex, New Jersey

Volatile Organic Compound	USEPA MCL	NJDEP Criteria	Units	URS-MW-2D																ECC-MW-21D
				SE 1 8/2008	SE 2 11/2008	SE 3 2/2009	SE 4 12/2009	SE 5 4/2010	SE 6 11/2010	SE 7 5/2011	SE 8 8/2011	SE 9 11/2011	SE 10 2/2012	SE 11 6/2012	SE 12 8/2012	SE 13 11/2012	SE 14 2/2013	SE 15 10/2014	SE 16 11/2015	SE 9 11/2011
Chloroform (CF)	80	70	µg/L	6.6	5U	1.9	1.3	3.1	0.93	2.5	ND	1.1	1.1	2.6	1.2	0.79	NS	1.78	0.69J	1U
1,1-Dichloroethene (1,1-DCE)	7	1	µg/L	5U	5U	1U	1U	0.7	0.6	1U	0.27	1U	0.29	0.36	0.32	0.31	NS	0.30U	0.57UJ	1U
Carbon Tetrachloride (CT)	5	0.4	µg/L	**12**	**18**	**19**	**15**	**8.3**	**14**	**8**	**7.7**	**20.0**	**14**	**11**	**10**	**15**	NS	**6.28**	**7.4J**	1U
Tetrachloroethene (PCE)	5	0.4	µg/L	5U	5U	1U	1U	1U	0.15	0.15	0.20	1U	0.23	0.23	0.29	0.21	NS	0.30U	0.30UJ	1U
Trichloroethene (TCE)	5	1	µg/L	**25**	**29**	**26**	**27**	**24**	**23**	**23**	**28**	**32**	**26**	**31**	**37**	**27**	NS	**22.8**	**24J**	1U

Volatile Organic Compound	USEPA MCL	NJDEP Criteria	Units	URS-MW-22D																ECC-MW-23D
				SE 1 8/2008	SE 2 11/2008	SE 3 2/2009	SE 4 12/2009	SE 5 4/2010	SE 6 11/2010	SE 7 5/2011	SE 8 8/2011	SE 9 11/2011	SE 10 2/2012	SE 11 6/2012	SE 12 8/2012	SE 13 11/2012	SE 14 2/2013	SE 15 10/2014	SE 16 11/2015	SE 9 11/2011
Chloroform (CF)	80	70	µg/L	5U	5U	1UJ	1U	1U	1U	1U	1.8UJ	1.1	0.099	1U	1U	1U	NS	0.30U	0.25UJ	1U
1,1-Dichloroethene (1,1-DCE)	7	1	µg/L	5U	1	1.6	1.6	2.4	2.6	5	4.3	**7.5**	5.9	**9.5**	**7.6**	**9.1**	NS	5.14	**10J**	1U
Carbon Tetrachloride (CT)	5	0.4	µg/L	5U	5U	1U	1U	1U	1U	1U	1U	1U	1U	1U	1U	1U	NS	0.30U	0.45UJ	1.4
Tetrachloroethene (PCE)	5	0.4	µg/L	5U	5U	1U	1U	1UJ	0.37	**0.63**	**0.43**	**0.78**	**0.64**	**0.85**	**0.72**	**0.81**	NS	**0.42J**	**0.64J**	1U
Trichloroethene (TCE)	5	1	µg/L	5U	5U	1U	0.8	1.1	0.99	1.6	1.4	1.7	1.6	2.2	1.9	1.8	NS	1.04	1.7J	1U

Volatile Organic Compound	USEPA MCL	NJDEP Criteria	Units	ECC-MW-24B						URS-MW-24D															
				SE 11 6/2012	SE 12 8/2012	SE 13 11/2012	SE 14 2/2013	SE 15 10/2014	SE 16 11/2015	SE 1 8/2008	SE 2 11/2008	SE 3 2/2009	SE 4 12/2009	SE 5 4/2010	SE 6 11/2010	SE 7 5/2011	SE 8 8/2011	SE 9 11/2011	SE 10 2/2012	SE 11 6/2012	SE 12 8/2012	SE 13 11/2012	SE 14 2/2013	SE 15 10/2014	SE 16 11/2015
Chloroform (CF)	80	70	µg/L	6.2	4.9	5	NS	4.64	4.3J	47	48	37	32	37	29	26	25	46	19	26	27	19	NS	21.8	19
1,1-Dichloroethene (1,1-DCE)	7	1	µg/L	**9.5**	2.7	4.7	NS	**10.4**	**13**	5U	5U	1U	1.1	1.4	3U	0.4	0.95	1.6	0.72	1.6	13U	13U	NS	0.82J	0.91J
Carbon Tetrachloride (CT)	5	0.4	µg/L	**67**	**30**	**38**	NS	**6.29**	**7.6**	**280**	**270**	**270**	**120**	**220**	**210**	**300**	**220**	**310**	**87**	**230**	**220**	**240**	NS	**206**	**150**
Tetrachloroethene (PCE)	5	0.4	µg/L	2.2	1.1	1.6	NS	1.14	0.92J	5U	5U	1U	1U	1U	1.5U	0.25	0.29	0.37	1U	0.34	13U	13U	NS	0.30U	0.30U
Trichloroethene (TCE)	5	1	µg/L	**11**	**6.6**	**7.3**	NS	**6.37**	**5.2**	**19**	**23**	**20**	**24**	**18**	**17**	**22**	**19**	**23**	**11**	**19**	**19**	**17**	NS	**17.5**	**13**

Volatile Organic Compound	USEPA MCL	NJDEP Criteria	Units	ECC-MW-25C											ECC-MW-25D										
				SE 6 11/2010	SE 7 5/2011	SE 8 8/2011	SE 9 11/2011	SE 10 2/2012	SE 11 6/2012	SE 12 8/2012	SE 13 11/2012	SE 14 2/2013	SE 15 10/2014	SE 16 11/2015	SE 6 11/2010	SE 7 5/2011	SE 8 8/2011	SE 9 11/2011	SE 10 2/2012	SE 11 6/2012	SE 12 8/2012	SE 13 11/2012	SE 14 2/2013	SE 15 10/2014	SE 16 11/2015
Chloroform (CF)	80	70	µg/L	5U	1.1	1.1	1.5	1.1	1.2	1.3	0.86	NS	0.98J	0.97J	10U	0.28	0.24	0.48	0.35	0.46	10U	2U	NS	0.60U	0.39J
1,1-Dichloroethene (1,1-DCE)	7	1	µg/L	**81**	**150**	**110**	**200**	**140**	**180**	**120**	**110**	NS	**95.5**	**110J**	**8**	**16**	**14**	**32**	**26**	**44**	**31**	**8.1**	NS	**39.2**	**50J**
Carbon Tetrachloride (CT)	5	0.4	µg/L	**7.4**	**11**	**8.8**	**15**	**9.1**	**12**	**11**	**8.1**	NS	**9.73**	**6.7**	1.4U	0.65	0.43	0.82	0.58	0.92	10U	0.34	NS	0.60U	0.66J
Tetrachloroethene (PCE)	5	0.4	µg/L	**15**	**26**	**20**	**31**	**28**	**32**	**22**	**22**	NS	**16.9**	**15**	1.5U	1.4	1.1	1.9	1.8	2	2.3	0.49	NS	1.66J	1.7J
Trichloroethene (TCE)	5	1	µg/L	**12**	**17**	**16**	**21**	**19**	**21**	**19**	**14**	NS	**16.5**	**15**	**150**	**160**	**120**	**220**	**170**	**190**	**160**	**50**	NS	**108**	**82**

Volatile Organic Compound	USEPA MCL	NJDEP Criteria	Units	ECC-MW-26B										ECC-MW-26C										
				SE 7 5/2011	SE 8 8/2011	SE 9 11/2011	SE 10 2/2012	SE 11 6/2012	SE 12 8/2012	SE 13 11/2012	SE 14 2/2013	SE 15 10/2014	SE 16 11/2015	SE 6 11/2010	SE 7 5/2011	SE 8 8/2011	SE 9 11/2011	SE 10 2/2012	SE 11 6/2012	SE 12 8/2012	SE 13 11/2012	SE 14 2/2013	SE 15 10/2014	SE 16 11/2015
Chloroform (CF)	80	70	µg/L	2.9	2.7	3.4	2.6	1.1	1.8	0.83	NS	0.74J	0.41J	9.6	6.6	5.7	6	5.2	5.1	4.8	4.8	NS	3.63	3.5J
1,1-Dichloroethene (1,1-DCE)	7	1	µg/L	1U	1U	1U	1U	1U	1U	1U	NS	0.30U	0.57U	4.3	**8.6**	**11**	**13**	**18**	**26**	**23**	**29**	NS	**48.8**	**63**
Carbon Tetrachloride (CT)	5	0.4	µg/L	**41**	**18**	**27**	**10**	**11**	**21**	**6**	NS	**5.93**	3.2J	**110**	**88**	**78**	**87**	**69**	**80**	**79**	**43**	NS	**48.7**	**31**
Tetrachloroethene (PCE)	5	0.4	µg/L	1U	1U	1U	1U	1U	1U	1U	NS	0.30U	0.30U	2.7	3.1	3.4	4.5	4.9	**6**	**5.8**	**6.8**	NS	**8.34**	**8.4**
Trichloroethene (TCE)	5	1	µg/L	2.9	2.3	3	2.2	1.4	2.1	0.85	NS	0.50J	0.32J	**9.6**	**8.4**	**8.5**	**10**	**8.8**	**9.2**	**8.8**	**8.4**	NS	**7.41**	**7.2**

Volatile Organic Compound	USEPA MCL	NJDEP Criteria	Units	ECC-MW-26D											ECC-MW-27B			
				SE 6 11/2010	SE 7 5/2011	SE 8 8/2011	SE 9 11/2011	SE 10 2/2012	SE 11 6/2012	SE 12 8/2012	SE 13 11/2012	SE 14 2/2013	SE 15 10/2014	SE 16 11/2015	SE 13 11/2012	SE 14 2/2013	SE 15 10/2014	SE 16 11/2015
Chloroform (CF)	80	70	µg/L	0.46	0.42	1U	1U	0.3	0.4	0.25	0.24	NS	0.30U	0.25U	3.7	NS	3.29	2.9J
1,1-Dichloroethene (1,1-DCE)	7	1	µg/L	1U	1U	1U	1U	0.17	0.29	1U	1U	NS	0.30U	0.57U	**9.7**	NS	**23.4**	**27J**
Carbon Tetrachloride (CT)	5	0.4	µg/L	3.1	1.7	1.4	1.8	1.3	1.9	2.1	0.71	NS	0.68J	0.48J	**45**	NS	**31.2**	**22J**
Tetrachloroethene (PCE)	5	0.4	µg/L	1.3	0.91	0.67	1.1	0.85	1.2	1.2	0.38	NS	0.38J	0.51J	2.4	NS	2.68	3.5J
Trichloroethene (TCE)	5	1	µg/L	**14**	**8.7**	**7.8**	**11**	**9.4**	**11**	**13**	4.5	NS	**6.37**	**6.4**	**12**	NS	**16.7**	**17J**

Volatile Organic Compound	USEPA MCL	NJDEP Criteria	Units	ECC-MW-27C										
				SE 6 11/2010	SE 7 5/2011	SE 8 8/2011	SE 9 11/2011	SE 10 2/2012	SE 11 6/2012	SE 12 8/2012	SE 13 11/2012	SE 14 2/2013	SE 15 10/2014	SE 16 11/2015
Chloroform (CF)	80	70	µg/L	1.6	1.5	1.4UJ	1.9	1.5	1.3	1.3	1.1	NS	1.1	1.2J
1,1-Dichloroethene (1,1-DCE)	7	1	µg/L	2.1	3.4	3.2	5.6	5	**7**	6.8	**7.8**	NS	**13.2**	**14J**
Carbon Tetrachloride (CT)	5	0.4	µg/L	**16**	**14**	**12**	**18**	**13**	**13**	**16**	**12**	NS	**10.1**	**6.7J**
Tetrachloroethene (PCE)	5	0.4	µg/L	1.6	2	1.8	2.3	2	2.1	2.2	2.1	NS	2.21	1.7J
Trichloroethene (TCE)	5	1	µg/L	**21**	**28**	**26**	**32**	**30**	**31**	**36**	**32**	NS	**36.4**	**30J**

Volatile Organic Compound	USEPA MCL	NJDEP Criteria	Units	ECC-MW-27D											ECC-MW-28B									
				SE 6 11/2010	SE 7 5/2011	SE 8 8/2011	SE 9 11/2011	SE 10 2/2012	SE 11 6/2012	SE 12 8/2012	SE 13 11/2012	SE 14 2/2013	SE 15 10/2014	SE 16 11/2015	SE 7 5/2011	SE 8 8/2011	SE 9 11/2011	SE 10 2/2012	SE 11 6/2012	SE 12 8/2012	SE 13 11/2012	SE 14 2/2013	SE 15 10/2014	SE 16 11/2015
Chloroform (CF)	80	70	µg/L	1.3	0.65	1U	0.71	0.41	0.53	0.51	0.41	NS	0.34J	0.40J	1.1	2.2	2	1.2	1.2	1.4	1.2	NS	1.29	1.1J
1,1-Dichloroethene (1,1-DCE)	7	1	µg/L	1U	1U	1U	1U	1U	1U	1U	1U	NS	0.30U	0.57UJ	1.3	2.3	1.9	1.5	1.5	0.9	0.75	NS	0.47J	0.60J
Carbon Tetrachloride (CT)	5	0.4	µg/L	4.5	2.5	1.8	3.2	1.7	2.4	2.9	2.8	NS	2.44	2.0J	4	**8.9**	**10**	**6.4**	**8**	**12**	**9.8**	NS	**8.57**	4.5J
Tetrachloroethene (PCE)	5	0.4	µg/L	0.32	1U	1U	0.28	1U	0.23	0.41	0.33	NS	0.41J	0.57J	0.37	0.46	0.57	0.42	0.32	0.25	1U	NS	0.30U	0.30U
Trichloroethene (TCE)	5	1	µg/L	**5.3**	4.6	4	**6.1**	4.4	**5.7**	**7.5**	**6.9**	NS	**10.2**	**14J**	0.54	1.3	1.4	0.86	0.79	0.9	0.63	NS	0.67J	0.68J

Volatile Organic Compound	USEPA MCL	NJDEP Criteria	Units	ECC-MW-29B										ECC-MW-30B						ECC-MW-30D					
				SE 7 5/2011	SE 8 8/2011	SE 9 11/2011	SE 10 2/2012	SE 11 6/2012	SE 12 8/2012	SE 13 11/2012	SE 14 2/2013	SE 15 10/2014	SE 16 11/2015	SE 11 6/2012	SE 12 8/2012	SE 13 11/2012	SE 14 2/2013	SE 15 10/2014	SE 16 11/2015	SE 11 6/2012	SE 12 8/2012	SE 13 11/2012	SE 14 2/2013	SE 15 10/2014	SE 16 11/2015
Chloroform (CF)	80	70	µg/L	3	2.8	2.8	2.9	3.1	2.6	2.7	NS	2.48	2.8J	**600**	**380**	**270**	**190**	**161J**	75	2.1	1.7	0.57	NS	0.30U	0.31J
1,1-Dichloroethene (1,1-DCE)	7	1	µg/L	1.1	1.2	1.3	1.9	3	2.7	3	NS	6.66	**11J**	100U	750U	500U	100U	0.30U	0.57U	**8.7**	**7.3**	**9.9**	NS	**12.8**	**18**
Carbon Tetrachloride (CT)	5	0.4	µg/L	**40**	**35**	**42**	**32**	**42**	**36**	**39**	NS	**31**	**23**	**13,000**	**8,000**	**6,100**	**3,600**	**2,360**	**1,200**	**5.6**	3.1	0.7	NS	0.30U	0.45U
Tetrachloroethene (PCE)	5	0.4	µg/L	2.1	2	2.5	2.1	2.5	2.1	2	NS	2.01	2.4J	100U	750U	500U	100U	0.82J	0.52J	0.98	0.76	1.1	NS	0.88J	1.3J
Trichloroethene (TCE)	5	1	µg/L	**12**	**12**	**13**	**14**	**15**	**16**	**14**	NS	**15.9**	**14**	**430**	**230**	**180**	**130**	**121J**	**50**	**51**	**37**	**49**	NS	**53**	**52**

Volatile Organic Compound	USEPA MCL	NJDEP Criteria	Units	ECC-MW-31B				ECC-MW-32B				ECC-MW-32C				ECC-MW-33B				ECC-MW-34B				ECC-MW-35	
				SE 13 11/2012	SE 14 2/2013	SE 15 10/2014	SE 16 11/2015	SE 13 11/2012	SE 14 2/2013	SE 15 10/2014	SE 16 11/2015	SE 13 11/2012	SE 14 2/2013	SE 15 10/2014	SE 16 11/2015	SE 13 11/2012	SE 14 2/2013	SE 15 10/2014	SE 16 11/2015	SE 13 11/2012	SE 14 2/2013	SE 15 10/2014	SE 16 11/2015	SE 14 2/2013	SE 15 10/2014
Chloroform (CF)	80	70	µg/L	1U	NS	0.30U	0.25U	0.22	NS	0.30U	0.25U	23	NS	8.47	14J	1U	NS	0.30U	0.25U	1U	NS	0.30U	2.8J	1.7	0.53J
1,1-Dichloroethene (1,1-DCE)	7	1	µg/L	1U	NS	0.30U	0.57U	1U	NS	0.30U	0.57U	2.2	NS	1.05	1.5J	1U	NS	0.30U	0.57U	1U	NS	0.30U	**11J**	1.4	2.56
Carbon Tetrachloride (CT)	5	0.4	µg/L	1U	NS	0.30U	0.45U	1U	NS	0.30U	0.45U	**12**	NS	**61.9**	**47J**	1U	NS	0.30U	0.45U	1U	NS	0.30U	**22**	**5.7**	2.85
Tetrachloroethene (PCE)	5	0.4	µg/L	1U	NS	0.30U	0.30U	1U	NS	0.30U	0.30U	0.46	NS	0.30U	0.30U	1U	NS	0.30U	0.30U	1U	NS	0.30U	2.2J	3	0.48J
Trichloroethene (TCE)	5	1	µg/L	1U	NS	0.30U	0.22U	0.81	NS	0.30U	0.45J	**6.5**	NS	4.89	**5.8**	1U	NS	0.30U	0.22U	0.15	NS	0.30U	**14**	**11**	**26.2**

Volatile Organic Compound	USEPA MCL	NJDEP Criteria	Units	ECC-MW-35C			EE-MW-36B		EE-MW-37B		EE-MW-38B		EE-MW-39B		EE-MW-40B		EE-MW-41S		EE-MW-42B	EE-MW-43B	EE-MW-44S	EE-MW-45S
				SE 14 2/2013	SE 15 10/2014	SE 16 12/2015	SE 15 10/2014	SE 16 12/2015	SE 15 10/2014	SE 16 12/2015	SE 15 10/2014	SE 16 12/2015	SE 15 10/2014	SE 16 12/2015	SE 15 10/2014	SE 16 12/2015	SE 15 10/2014	SE 16 12/2015	SE 16 1/2016	SE 16 11/2015	SE 16 11/2015	SE 16 11/2015
Chloroform (CF)	80	70	µg/L	0.8	15.0U	0.25U	0.30U	0.25UJ	0.62J	0.64J	3.02	3.4J	1.49	1.5J	0.30U	0.25U	**222**	4.1J	0.44J	0.25U	0.27J	5.6
1,1-Dichloroethene (1,1-DCE)	7	1	µg/L	1.2	15.0U	3.8J	0.90J	0.57UJ	0.30U	0.57UJ	0.30U	0.57UJ	0.90J	0.67J	0.30U	0.57U	15.0U	0.57UJ	0.57U	**18**	0.57U	0.57U
Carbon Tetrachloride (CT)	5	0.4	µg/L	0.24	15.0U	0.45U	0.30U	0.45UJ	**5.57**	3.9J	**29.0**	**7.7J**	**14.6**	**6.9J**	0.30U	0.45U	**2,460**	**32J**	0.45U	0.45U	0.95J	**46**
Tetrachloroethene (PCE)	5	0.4	µg/L	1.3	15.0U	0.36J	0.30U	0.30UJ	1.04	0.30UJ	1.28	0.54J	2.84	1.3J	0.30U	0.30U	0.30U	0.30UJ	0.30U	0.30U	0.30U	0.30U
Trichloroethene (TCE)	5	1	µg/L	**8.3**	**33.0J**	**25**	4.10	1.2J	2.47	0.78J	3.17	2.1J	2.92	1.8J	0.30U	0.22U	**62.0**	0.61J	0.22U	0.80J	0.22U	0.97J

Notes: **Bold Font** - value meets or exceeds the USEPA Maximum Contaminant Level (MCL)
Blue Cell - value meets or exceeds the New Jersey Department of Environmental Protection (NJDEP) criteria.

MCL = Maximum Contaminant Level
NJDEP = New Jersey Department of Environmental Protection
NS = not sampled
µg/L = micrograms per liter
U = Not detected. Analyte is not present at a level greater than the reporting limit.
UJ = Not detected. The reporting limit is estimated.
J= Estimated value.

Table 1-5
On-Site Groundwater Cancer Risks - Worker
Middlesex Sampling Plant
Groundwater Operable Unit Feasibility Study

Exposure Point	Total Cancer Risk	Primary Contributors to Total Cancer Risk		Notes
RME On-Site Groundwater	1.4E-03	CT	1.3E-03	
CTE On-Site Groundwater	9.0E-05	NA	NA	Risks from all COPCs were either within or less than EPA's risk range.

Table 1-6
Off-Site Groundwater Cancer Risks - Resident Child
Middlesex Sampling Plant
Groundwater Operable Unit Feasibility Study

Exposure Point	Total Cancer Risk	Primary Contributors to Total Cancer Risk		Notes
RME On-Site Groundwater	1.2E-03	CT	1.1E-03	
CTE On-Site Groundwater	2.5E-04	CT	2.2E-04	

Table 1-7
Off-Site Groundwater Cancer Risks - Resident Adult
Middlesex Sampling Plant
Groundwater Operable Unit Feasibility Study

Exposure Point	Total Cancer Risk	Primary Contributors to Total Cancer Risk		Notes
RME On-Site Groundwater	3.4E-03	CT chloroform	3E-03 4E-04	
CTE On-Site Groundwater	4.6E-04	CT	3.9E-04	

KEY:

CT = carbon tetrachloride

CTE = central tendency exposure

NA = not applicable

RME = reasonable maximum exposure

Table 1-8
On-Site Groundwater Hazard Indices - Worker
Middlesex Sampling Plant
Groundwater Operable Unit Feasibility Study

Exposure Point	Hazard Index	Primary Contributors to Total Hazard Index		Notes
RME On-Site Groundwater	17.3	CT	13.2	
		TCE	3.7	
CTE On-Site Groundwater	4.2	CT	3.2	

Table 1-9
On-Site Groundwater Hazard Indices - Resident Child
Middlesex Sampling Plant
Groundwater Operable Unit Feasibility Study

Exposure Point	Hazard Index	Primary Contributors to Total Hazard Index		Notes
RME Off-Site Groundwater	59.1	CT	41.6	
		chloroform	1.2	
		TCE	16.2	
CTE Off-Site Groundwater	17.9	CT	11.8	
		TCE	5.7	

Table 1-10
On-Site Groundwater Hazard Indices - Resident Adult
Middlesex Sampling Plant
Groundwater Operable Unit Feasibility Study

Exposure Point	Hazard Index	Primary Contributors to Total Hazard Index		Notes
RME Off-Site Groundwater	48.6	CT	30.0	
		chloroform	1.1	
		TCE	17.4	
CTE Off-Site Groundwater	15.9	CT	8.9	
		TCE	6.6	

KEY:

CT = carbon tetrachloride

CTE = central tendency exposure

RME = reasonable maximum exposure

TCE = trichloroethylene

Table 2-1
Initial Screening of Remedial Technologies and Process Options
Middlesex Sampling Plant
Groundwater Operable Unit Feasibility Study

General Response Action	Technology	Process Option	Description	Screening Comments*
Land Use Controls	Land Use Controls	Deed Restrictions/Zoning	Site access restrictions, environmental monitoring and land use controls on future land use.	Potentially applicable in combination with other technologies.
Monitored Natural Attenuation	MNA	MNA	Relies on natural processes to reduce or control contaminants in groundwater.	MNA is a potentially viable process option for total uranium in the alluvium. Also works for chlorinated solvent contaminants.
Containment	Stabilization and Solidification	In situ stabilization/solidification	Injection of stabilizing chemicals into the subsurface to decrease contaminant mobility.	These technologies best suited for consistently moderate to highly permeable aquifers with
	Physical Barriers	Physical Barriers	Containment measures such as caps, hydraulic gradient controls, and vertical barriers.	Not recommended. Primary COCs (VOCs) are in bedrock units underlying alluvial aquifer.
In Situ Treatment	Physical Processes	Recirculation Wells	Processes are based upon air injection into contaminated groundwater causing air/water	Potentially applicable to the groundwater OU.
		Treatment Walls	Permeable reactive barriers. Treatment wall technologies can precipitate/adsorb (total uranium) or degrade (VOCs) the COCs in groundwater using	MSP has no continuous and homogenous plume. This process option not retained for further evaluation.
	Chemical Processes	ISCO	Injection of ISCO agents.	ISCO applications determined to be not effective for CT in groundwater.
		ISCR	Injection of ISCR reagent.	Potentially applicable under favorable subsurface conditions.
	Natural/Biological Processes	Phytoremediation	Plant up take of contaminants; the vegetation is then harvested and/or disposed.	Effectiveness compromised by depth and variability of groundwater VOC contamination.
		Enhanced Bioremediation	Injection of materials to stimulate biodegradation.	The high concentration of DO and shallow contamination depth reduces effectiveness of this treatment.

Table 2-1
Initial Screening of Remedial Technologies and Process Options
Middlesex Sampling Plant
Groundwater Operable Unit Feasibility Study

General Response Action	Technology	Process Option	Description	Screening Comments*
Removal	Extraction	In Situ Flushing	Two step process. Pumping/injection of solution into groundwater with simultaneous extraction of the contaminant-solution mix.	Hydraulic conductivity variability at MSP likely to reduce effectiveness of flushing process. Injection solution could be considered a contaminant source. This option removed from consideration.
		Multiphase Extraction	Technologies that simultaneously extract more than one fluid (gaseous and aqueous) phase from wells.	Potential at MSP for vapor intrusion to adjacent residences. COCs at this Site identified in phases other than groundwater. This technology not recommended.
		Well and Trench Systems	Uses pumping technology to extract groundwater and bring it to the surface to be treated.	Due to the proven effectiveness of groundwater extraction, this technology will be carried through as a remedial alternative.

▨ Hatched technologies or process options were screened out.

* Comments based on the following aspects of the process options:
1. Effective at removing contamination and/or treating site COCs.
2. Interferences from co-located elements is not a concern.
3. Site conditions are optimal.
4. Effectiveness has been demonstrated previously, outside of laboratory.
5. Focuses on remediation of the media of concern (groundwater).
6. Effective in a reasonable time.

Notes:

COC - contaminants-of-concern
ISCO - in situ chemical oxidation
ISCR - in situ chemical reduction
MNA - Monitored Natural Attenuation
VOC - volatile organic compound

Table 3-1
Remedial Action Alternatives
Middlesex Sampling Plant
Groundwater Operable Unit Feasibility Study

Remedial Action Alternatives	Remedial Technology	Process Options	Potential Alternatives
No Further Action	None	None	1. No Further Action
Limited Action	Land Use Controls	Deed Restrictions/Zoning	2. Monitored Natural Attenuation and Land Use Controls
Monitored Natural Attenuation	MNA	MNA	3. Treatment with In situ Chemical Reduction, Monitored Natural Attenuation and Land Use Controls
In Situ Treatment	Chemical Processes	ISCR	4. Removal by Pumping, Monitored Natural Attenuation and Land Use Controls
Removal	Extraction	Well and Trench Systems	

Table 4-1
Comparison of Alternatives
Middlesex Sampling Plant
Groundwater Operable Unit Feasibility Study

Evaluation Criteria	Alternative 1 - No Further Action	Alternative 2 - MNA and Land Use Controls	Alternative 3 - Treatment with In situ Chemical Reduction, MNA and Land Use Controls	Alternative 4 - Pump and Treat, MNA and Land Use Controls
Overall protection of human health	Not considered protective of human health or the environment in the short or long-term.	Expected to be protective of human health and the environment in the short and long-term.	Would protect both human health and the environment. Use of ISCR materials reduces risk to human health by treating contaminated groundwater above ARAR level.	Would protect both human health and the environment. The pump-and-treat system reduces risk to human health by treating the extracted groundwater contaminated above ARAR levels.
Compliance with ARARs	Could eventually meet the ARARs through natural attenuation. No documentation of this decrease in concentration would be available due to absence of monitoring.	The ARARs for the COCs could be met. The time requirement would be approximately 30 years.	Active remediation process. Compliance with the ARARs is expected. Complies with ARARs by degrading bedrock aquifer COCs. MNA is the primary technology applied to total uranium in the alluvium. Implementation of LUCs within 1 year. The time requirement for this alternative would be 10 years.	Active remediation process. This alternative would comply with ARARs for COCs by removal and treatment of groundwater exceeding cleanup levels. Implementation of LUCs within 1 year. The time requirement for this alternative would be 30 years.
Short-term Effectiveness	Risk to workers and community is not anticipated. However, continued impact to the community from contamination left in place.	Potential low risk risks to workers and community during MNA process implementation. Implementation of LUCs within 1 year. Reduction of target COCs in groundwater would be monitored.	Anticipated to produce prompt reduction of COCs in the short-term. Slight increase in risk to workers during remedial activities. Monitoring and safety techniques would be implemented to minimize unexpected exposure.	Anticipated to produce prompt reduction of COCs in the short-term. Slight increase in risk to workers during remedial activities. Monitoring and safety techniques would be implemented to minimize unexpected exposure. Construction activities could result in minimal disturbances.

Table 4-1
Comparison of Alternatives
Middlesex Sampling Plant
Groundwater Operable Unit Feasibility Study

Evaluation Criteria	Alternative 1 - No Further Action	Alternative 2 - MNA and Land Use Controls	Alternative 3 - Treatment with In situ Chemical Reduction, MNA and Land Use Controls	Alternative 4 - Pump and Treat, MNA and Land Use Controls
Long-term Effectiveness	No long-term effectiveness or permanence.	LUC implementation provides some long-term effectiveness in exposure prevention to groundwater contaminants that remain above the ARAR. MNA remedy monitored for effectiveness through well system sampling and data evaluation.	Long-term effectiveness is anticipated. Long-term human health risks reduced due to reduction of COCs to cleanup-goals. LUCs would restrict access to contaminated groundwater. Contaminants remain on the MSP above proposed cleanup level for a certain period of time. CERCLA required the site to be reviewed at least once every five years.	Long-term effectiveness is anticipated. Long-term human health risks reduced due to reduction of COCs to cleanup-goals. LUCs would restrict access to contaminated groundwater. Contaminants remain on the MSP above proposed cleanup level for a certain period of time. CERCLA required the site to be reviewed at least once every five years.
Reduction of toxicity, mobility, or volume	Aside from natural attenuation processes, reduction in the toxicity, mobility, or volume of contaminated groundwater would not occur.	MNA is a natural treatment process. No direct reduction in toxicity, mobility, or volume of the contaminated groundwater.	Would reduce the toxicity, mobility, or volume of the COCs through treatment. Injection of ISCR materials (such as EZV1) may reduce total uranium in alluvium by precipitation and adsorption. Satisfies statutory preference for using treatment as principal remediation element.	Would reduce the toxicity, mobility, or volume of the COCs through treatment. Groundwater contaminant concentrations anticipated to decline to respective ARAR levels. Satisfies statutory preference for using treatment as principal remediation element.
Implementability	No action will be taken, therefore easily implemented.	Well design, installation, sampling, and analyis are proven technologies. No implementation problems anticipated. No special permits or materials required; readily implementable.	Technically feasible. Services and materials readily available. Proven technology requiring frequent monitoring to assess effectiveness. Accurate engineering judgment required to determine injection parameters.	Technically feasible. Services and materials readily available. The pumping and treatment processes are proven technologies. Permit necessary to release treated effluent to POTW, but should be obtainable. Accurate engineering judgment required to determine operating parameters.

Table 4-1
Comparison of Alternatives
Middlesex Sampling Plant
Groundwater Operable Unit Feasibility Study

Evaluation Criteria	Alternative 1 - No Further Action	Alternative 2 - MNA and Land Use Controls	Alternative 3 - Treatment with In situ Chemical Reduction, MNA and Land Use Controls	Alternative 4 - Pump and Treat, MNA and Land Use Controls
Capital Cost	$0	$1,233,000	$5,471,000	$3,039,000
Average Annual O&M Cost	$0	$149,000	$212,000	$608,000
Present Worth	$0	$2,711,000	$7,106,000	$11,951,000

Table 4-2
Qualitative Comparison of Alternatives
Middlesex Sampling Plant
Groundwater Operable Unit Feasibility Study

Abili+A18+A1:J18+A1:J19+A18+A1:J18+A1:J25+A1:J18	Alternative 1 - No Further Action	Alternative 2 - MNA and Land Use Controls	Alternative 3 - Treatment with In situ Chemical Reduction, MNA and Land Use Controls	Alternative 4 - Pump and Treat, Monitored Natural Attenuation and Land Use Controls
Overall protection of human health[1]	Fail	Pass	Pass	Pass
Compliance with ARARs[1]	Fail	Pass	Pass	Pass
Short-term Effectiveness	None	Low to Medium	High	High
Long-term Effectiveness	None	Low to Medium	High	Medium
Reduction of toxicity, mobility, or volume	None	Low	High	Medium to High
Implementability	NA	High	High	Medium to High
Cost (present worth)	$0	$2,711,000	$7,106,000	$11,951,000

Notes:

1. Pass/Fail Score - Alternatives are graded as pass/fail for the threshold criteria (Overall Protection of Human Health and Compliance with ARARs), and eliminated from consideration if one/both criterial fail.
2. High - Alternative provides the technical capability and feasibility to implement remedial activities, effective in short term and long term and monitor chemicals of potential concern (COPCs) in groundwater;
3. Medium - Alternative provides the ability to monitor COPCs in groundwater but limited technical capability and feasibility to implement remedial activities, has limited short term and long term effectiveness;
4. Low - Alternative has limited ability to monitor COPCs in groundwater and has limited technical capability or feasibility to implement remedial activities, has limited short term and long term effectiveness;
5. None - Alternative provides no measurable ability to monitor COPCs in groundwater; timeframe for meeting remedial objectives indeterminate.
6. NA: No action will be taken, therefore easily implemented.

Table 4-3
Detailed Cost Analysis
Alternative 2 MNA - Middlesex Sampling Plant
Groundwater Operable Unit Feasibility Study

Middlesex MNA Operational Costs					
Cost Item	**Unit**	**Quantity**	**Unit Cost**	**Sub Total**	**Comment**
Plans & Field Work					
Work Plan	Each	1	$ 25,000	$ 25,000	
HASP		1	$ 10,000	$ 10,000	
QAPP		1	$ 45,000	$ 45,000	
Engineering Design	LS	1	$ 350,000	$ 350,000	
MW Installation & LUCs					
Dill Rig Mob/Demob	LS	1	$ 5,000	$ 5,000	
Drilling and completion	Foot	420	$ 50	$ 21,000	Install 6 wells in bedrock - Air rotary
Technician	Hour	40	$ 65	$ 2,600	Assume 1 well per hour
Project Manager	Hour	40	$ 65	$ 2,600	Assume 1 well per hour
VOCs	Each	7	$ 100	$ 700	Includes QC
MNA Parameters	Each	7	$ 150	$ 1,050	Includes QC
Uranium Analysis	Each	7	$ 50	$ 350	Includes QC
Purge Water Disposal	LS	1	$ 500	$ 500	
Data Validation	HR	40	$ 65	$ 2,600	
Data Validation Report	HR	60	$ 65	$ 3,900	
Institutional Controls Plan	LS	1	$ 15,000	$ 15,000	
			Total	**$ 485,300**	
LTM monitoring Year - Quarterly					
Sampling Events per year:	**4**				
# Wells per event	**32**				
# Years O&M Monitoring	**1**				
Technician	Hour	107	$ 65	$ 6,933	
VOCs	Each	32	$ 100	$ 3,200	
MNA Parameters	Each	32	$ 150	$ 4,800	
Uranium Analysis	Each	32	$ 50	$ 1,600	
Purge Water Disposal	LS	1	$ 750	$ 750	
Data Validation	HR	80	$ 65	$ 5,200	
Data Validation Report	HR	80	$ 65	$ 5,200	
Engineer	HR	60	$ 110	$ 6,600	
CAD	HR	20	$ 75	$ 1,500	
Hydrogeologist	HR	20	$ 110	$ 2,200	
			Total	**$ 37,983**	
LTM monitoring Year - Project for 28 years					
Sampling Events per year:	**1**				
# Wells per event	**32**				
# Years O&M Monitoring	**28**				
Technician	Hour	107	$ 65	$ 6,933	Assume 3 wells per day
VOCs	Each	32	$ 100	$ 3,200	
MNA Parameters	Each	32	$ 150	$ 4,800	
Uranium Analysis	Each	32	$ 50	$ 1,600	
Purge Water Disposal	LS	1	$ 750	$ 750	
Data Validation	HR	80	$ 65	$ 5,200	
Data Validation Report	HR	80	$ 65	$ 5,200	
Engineer	HR	60	$ 110	$ 6,600	
CAD	HR	20	$ 75	$ 1,500	
Hydrogeologist	HR	20	$ 110	$ 2,200	
			Total	**$ 37,983**	
Annual Report	LS	30	$ 50,000	**$ 1,500,000**	
5-year review	LS	6	$ 25,000	**$ 150,000**	
			Capital Cost Subtotal	$ 1,069,184	
			Capital Cost	**$ 1,233,411**	Updated for location and historical costs
			Average Periodic O&M Subtotal	$ 128,742	
			Average Periodic O&M Cost	**$ 148,517**	Updated for location and historical costs
			Net Present Worth Subtotal	$ 2,350,000	
			Net Present Worth Total	**$ 2,710,960**	Updated for location and historical costs

Notes:
1. Update factors taken from RS Means 2016 Cost Indexes: City Cost for New Brunswick, NJ (1.12) and Historical Cost Index for 2016 from 2013 (1.03)
2. Costs are multiplied by an 8% ownership fee and 20% contingency fee to determine subtotals.

Table 4-4
Detailed Cost Analysis
Alternative 3 In Situ (ISCR) - Middlesex Sampling Plant
Groundwater Operable Unit Feasibility Study

Middlesex In Situ (ISCR) Operational Costs

Cost Item	Unit	Quantity	Unit Cost	Sub Total	Comment
Plans & Field Work					
Work Plan/Design	Each	1	$ 350,000	$ 350,000	
HASP		1	$ 10,000	$ 10,000	
QAPP		1	$ 45,000	$ 45,000	
Injection Well Install					
Dill Rig Mob/Demob	LS	1	$ 5,000	$ 5,000	
Drilling and completion	Foot	2,510	$ 50	$ 125,500	Install 79 wells in bedrock - Air rotary
Geologist (2)	Hour	400	$ 80	$ 32,000	
Per Diem	Day	40	$ 150	$ 6,000	
Airfare	Each	2	$ 700	$ 1,400	
MW Installation & LUCs	LS	1	$ 135,300.00	$ 135,300.00	Cost of MW Installation & LUCs from Table 4-3
			Total	**$ 710,200.00**	
Amendment injection - assume 1 month per injection					
# Injections	**2.5**				
Geologist (2)	Hour	540	$ 80	$ 43,200	Assume 2 people full time for 27 work days (Average 3 wells per day)
Per Diem	Day	70	$ 150	$ 10,500	
Airfare	Each	4	$ 700	$ 2,800	Switch out geologists
EZVI (gal)	gal	32,560	$ 31	$ 1,017,500	Amendment - Assumes 440 gal per well. Cost quote from Tersus Environmental in Wake Forest, NC, 25% markup for shipping and transport.
Amendment Shipping	Lot	14	$ 2,650	$ 37,100	
Injection system shipping	LS	2	$ 7,000	$ 14,000	
Generator rental - 4 weeks	Week	2	$ 2,000	$ 4,000	
Field Personnel (3)	Hour	600	$ 80	$ 48,000	50 hour weeks
Airfare	Each	5	$ 700	$ 3,500	Switch Out
			Subtotal, cost per injection	$ 1,180,600	
			Total	**$ 2,951,500**	
Analytical to support construction					
Misc. parts	LS	1	$ 1,000	$ 1,000	
VOCs	Each	15	$ 100	$ 1,500	Includes QC
MNA Parameters	Each	15	$ 150	$ 2,250	Includes QC
Uranium Analysis	Each	15	$ 50	$ 750	Includes QC
Purge Water Disposal	LS	1	$ 500	$ 500	
Data Validation	HR	40	$ 65	$ 2,600	
Data Validation Report	HR	60	$ 65	$ 3,900	
Injection system fee	LS	1	$ 5,000	$ 5,000	
			Subtotal, cost per injection	$ 17,500	
			Total	**$ 43,750**	
LTM monitoring Year - Project for 2 years					
Sampling Events per year:	**4**				
# Wells per event	**32**				
# Years O&M Monitoring	**2**				
Technician	Hour	240	$ 65	$ 15,600	Assume 3 wells per day
VOCs	Each	36	$ 100	$ 3,600	Includes QC
MNA Parameters	Each	36	$ 150	$ 5,400	Includes QC
Uranium Analysis	Each	36	$ 50	$ 1,800	Includes QC
Purge Water Disposal	LS	1	$ 500	$ 500	
Data Validation	HR	80	$ 65	$ 5,200	
Data Validation Report	HR	125	$ 65	$ 8,125	
Engineer	HR	140	$ 110	$ 15,400	
CAD	HR	40	$ 75	$ 3,000	
Hydrogeologist	HR	40	$ 110	$ 4,400	
			Total	**$ 63,025**	
LTM monitoring Year - Project for 10 years	LS	10	$ 37,983.3	**$ 379,833.3**	LTM costs taken from Table 4-3
Annual Report	LS	10	$ 50,000	**$ 500,000**	
5-year review	LS	2	$ 25,000	**$ 50,000**	
			Capital Cost Subtotal	$4,742,976	
			Capital Cost	**$ 5,471,497**	Updated for location and historical costs
			Average Periodic O&M Subtotal	$183,556	
			Average Periodic O&M Cost	**$ 211,751**	Updated for location and historical costs
			Net Present Worth Subtotal	$ 6,160,000	
			Net Present Worth Total	**$ 7,106,176**	Updated for location and historical costs

Notes:
1. Update factors taken from RS Means 2016 Cost Indexes: City Cost for New Brunswick, NJ (1.12) and Historical Cost Index for 2016 from 2013 (1.03)
2. Costs are multiplied by an 8% ownership fee and 20% contingency fee to determine subtotals.

Table 4-5
Detailed Cost Analysis
Alternative 4 Pump Treat - Middlesex Sampling Plant
Groundwater Operable Unit Feasibility Study

Middlesex P&T Installation and Operational Costs					
Cost Item	**Unit**	**Quantity**	**Unit Cost**	**Sub Total**	**Comment**
Concept Design Costs					
Engineer	Hour	400	$ 150	$ 60,000	
AutoCad	Hour	300	$ 95	$ 28,500	
Principal Engineer	Hour	200	$ 200	$ 40,000	
Admin Asst	Hour	200	$ 45	$ 9,000	
Production Costs	LS	1	$ 5,000	$ 5,000	
			Total	**$ 142,500**	
90% and 100% Design Costs (Structural, Electrical, Process and Mechanical Details)					
AutoCAD	Hour	1200	$ 95	$ 114,000	
Engineer	Hour	2000	$ 150	$ 300,000	
Electrical Engineer	Hour	100	$ 175	$ 17,500	
Admin Asst	Hour	800	$ 45	$ 36,000	
Production Costs	LS	1	$ 10,000	$ 10,000	
			Total	**$ 477,500**	
Work Plan Development Costs					
Work Plan	Each	1	$ 35,000	$ 35,000	
HASP		1	$ 10,000	$ 10,000	
QAPP		1	$ 45,000	$ 45,000	
Analytical data to support construction					
VOCs	Each	15	$ 100	$ 1,500	Includes QC
MNA Parameters	Each	15	$ 150	$ 2,250	Includes QC
Uranium Analysis	Each	15	$ 50	$ 750	Includes QC
Purge Water Disposal	LS	1	$ 500	$ 500	
Data Validation	HR	40	$ 65	$ 2,600	
Data Validation Report	HR	60	$ 65	$ 3,900	
MW Installation & LUCs	LS	1	$ 135,300	$ 135,300	Cost of MW Installation & LUCs from Table 4-3
			Total	**$ 236,800**	
P&T Installation Costs (Labor, Equipment and Materials)					
PVC Piping Installation	Feet	4000	$ 40	$ 160,000	
Extraction Well Installation	Each	13	$ 18,000	$ 234,000	Well depth is between 30 and 70 feet
Treatment Building	Sq Feet	900	$ 500	$ 450,000	Includes architectural, structural, HVAC and electrical
LGAC Vessels	Each	2	$ 8,000	$ 16,000	3000 pounds each
VPGAC Vessels	Each	2	$ 6,000	$ 12,000	1500 pounds each
Consumables (carbon)	Pounds	9000	$ 3	$ 27,000	Initial Charge
Bag Filter and Chemical System	Each	1	$ 5,000	$ 5,000	Includes initial charge
Air Stripper	Each	1	$ 35,000	$ 35,000	
Influent and Effluent Storage Tanks	Each	2	$ 7,500	$ 15,000	9000 gallon tanks
Backwash Tank	Each	1	$ 6,000	$ 6,000	5000 gallon tank
Well Vault Construction	Each	6	$ 1,000	$ 6,000	
Exterior Electrical Conduit and Wiring	LS	1	$ 7,500	$ 7,500	
Electrical Utility Hook Up	LS	1	$ 5,000	$ 5,000	Local Utility company
Process Equipment Integration	LS	1	$ 150,000	$ 150,000	Includes treatment and well pumps, electrical, piping, programming
Startup Costs	LS	1	$ 75,000	$ 75,000	Includes labor, lab costs, operators for two months etc.
Site access/Grading	LS	1	$ 10,000	$ 10,000	Access road rock and soil grading
General utilities, office setup	LS	1	$ 3,000	$ 3,000	
H&S Oversight	Hour	900	$ 100	$ 90,000	90 days
QC Oversight	Hour	900	$ 100	$ 90,000	90 days
Project Manager	Hour	240	$ 150	$ 36,000	
Project Engineer	Hour	900	$ 125	$ 112,500	Part time
Cost/Schedule Controls	Hour	160	$ 80	$ 12,800	
Surveyor	Hour	80	$ 120	$ 9,600	
Geotechnical Testing	LS	1	$ 10,000	$ 10,000	
ODCs	Months	3	$ 50,000	$ 150,000	
Final Report	LS	1	$ 50,000	$ 50,000	
			Total	**$1,777,400**	
P&T O&M Yearly Costs					
Plant Operator	Hour	832	$ 60	$ 49,920	16 hours a week
Plant Operator	Hour	52	$ 60	$ 3,120	2 hours every other week for call outs
Project Manager	Hour	104	$ 125	$ 13,000	2 hours a week
Project Engineer	Hour	312	$ 100	$ 31,200	6 hours a week
Contracts	Hour	40	$ 80	$ 3,200	Initial Setup and any PO mods
Cost/Schedule Controls	Hour	52	$ 80	$ 4,160	1 hour a week
ODCs	Month	12	$ 500	$ 6,000	Primarily mileage for visits/emergency response
Lawn Maintenance	LS	1	$ 2,500	$ 2,500	
Carbon Consumables	Pounds	21000	$ 3	$ 63,000	4 LGAC change outs and 6 VPGAC change outs - carbon characterized as non-hazardous
Chemical Consumables	LS	1	$ 7,000	$ 7,000	Assuming metals precipitation
Solids Disposal	CY	300	$ 40	$ 12,000	From Backwash and Metals Precipitation Operations
Plant Operator	Event	80	$ 60	$ 4,800	10 Events at 8 hours a event for carbon change out

Table 4-5
Detailed Cost Analysis
Alternative 4 Pump Treat - Middlesex Sampling Plant
Groundwater Operable Unit Feasibility Study

Middlesex P&T Installation and Operational Costs					
Cost Item	**Unit**	**Quantity**	**Unit Cost**	**Sub Total**	**Comment**
Electrical Usage	Month	12	$ 1,700	$ 20,400	
Plant Utilities	Month	12	$ 800	$ 9,600	Bottled Water, Phone, Internet, Safety Supplies
Maintenance/Pump Repair	Year	1	$ 25,000	$ 25,000	
Well Rehab	Each	4	$ 10,000	$ 40,000	
Spare Parts/Instrumentation	LS	1	$ 8,000	$ 8,000	Flow Meters, Bags for filters, Electrical Parts like fuses
Sampling/Analysis/Shipping	Month	12	$ 1,500	$ 18,000	Typically CLP Lab but costs need to be accounted for
Total Yearly O & M	Year	30	$ 320,900	$ 9,627,000	
LTM monitoring Year - Project for 2 years	LS	8	$ 63,025.00	$ 504,200	Quarterly LTM costs taken from Table 4-4
LTM monitoring Year - Project for 15 years	LS	15	$ 37,983.33	$ 569,750	LTM costs taken from Table 4-3
Annual Reporting	LS	30	$ 50,000.00	$ 1,500,000	
5-Year Report	LS	6	$ 25,000.00	$ 150,000	
			Capital Cost Subtotal	$ 2,634,200	
			Capital Cost	**$ 3,038,813**	Updated for location and historical costs
			Average Periodic O&M Subtotal	$ 526,974	
			Average Periodic O&M Cost	**$ 607,917**	Updated for location and historical costs
			Net Present Worth Subtotal	$ 10,360,000	
			Net Present Worth Total	**$ 11,951,296**	Updated for location and historical costs

Notes:

1. Update factors taken from RS Means 2016 Cost Indexes: City Cost for New Brunswick, NJ (1.12) and Historical Cost Index for 2016 from 2013 (1.03)
2. Costs are multiplied by an 8% ownership fee and 20% contingency fee to determine subtotals.

Table 4-6
Present Worth Determination
Alternative 2 MNA - Middlesex Sampling Plant
Groundwater Operable Unit Feasibility Study

Present Worth Analysis

Year	Capital Costs	Periodic Costs	Total Annual Expenditure	Discount Factor (7%)	Present Worth
0	$621,184	$0	$621,184	1.0000	$621,184
1	$0	$258,475	$258,475	0.9346	$241,570
2	$0	$258,475	$258,475	0.8734	$225,752
3	$0	$112,619	$112,619	0.8163	$91,931
4	$0	$112,619	$112,619	0.7629	$85,917
5	$0	$144,619	$144,619	0.713	$103,113
6	$0	$112,619	$112,619	0.6663	$75,038
7	$0	$112,619	$112,619	0.6227	$70,128
8	$0	$112,619	$112,619	0.582	$65,544
9	$0	$112,619	$112,619	0.5439	$61,253
10	$0	$144,619	$144,619	0.5083	$73,510
11	$0	$112,619	$112,619	0.4751	$53,505
12	$0	$112,619	$112,619	0.444	$50,003
13	$0	$112,619	$112,619	0.415	$46,737
14	$0	$112,619	$112,619	0.3878	$43,674
15	$0	$144,619	$144,619	0.3624	$52,410
16	$0	$112,619	$112,619	0.3387	$38,144
17	$0	$112,619	$112,619	0.3166	$35,655
18	$0	$112,619	$112,619	0.2959	$33,324
19	$0	$112,619	$112,619	0.2765	$31,139
20	$0	$144,619	$144,619	0.2584	$37,369
21	$0	$112,619	$112,619	0.2415	$27,197
22	$0	$112,619	$112,619	0.2257	$25,418
23	$0	$112,619	$112,619	0.2109	$23,751
24	$0	$112,619	$112,619	0.1971	$22,197
25	$0	$144,619	$144,619	0.1842	$26,639
26	$0	$112,619	$112,619	0.1722	$19,393
27	$0	$112,619	$112,619	0.1609	$18,120
28	$0	$112,619	$112,619	0.1504	$16,938
29	$0	$112,619	$112,619	0.1406	$15,834
30	$0	$144,619	$144,619	0.1314	$19,003
				Total	**$2,350,000**

Note: Total represents 2013 costs before location adjustment.

Table 4-7
Present Worth Determination
Alternative 3 In Situ (ISCR) - Middlesex Sampling Plant
Groundwater Operable Unit Feasibility Study

Present Worth Analysis					
Year	**Capital Costs**	**Periodic Costs**	**Total Annual Expenditure**	**Discount Factor (7%)**	**Present Worth**
0	$4,742,976	$0	$4,742,976	1.0000	$4,742,976
1	$0	$435,307	$435,307	0.9346	$406,838
2	$0	$435,307	$435,307	0.8734	$380,197
3	$0	$112,619	$112,619	0.8163	$91,931
4	$0	$112,619	$112,619	0.7629	$85,917
5	$0	$144,619	$144,619	0.713	$103,113
6	$0	$112,619	$112,619	0.6663	$75,038
7	$0	$112,619	$112,619	0.6227	$70,128
8	$0	$112,619	$112,619	0.582	$65,544
9	$0	$112,619	$112,619	0.5439	$61,253
10	$0	$144,619	$144,619	0.5083	$73,510
				Total	**$6,160,000**

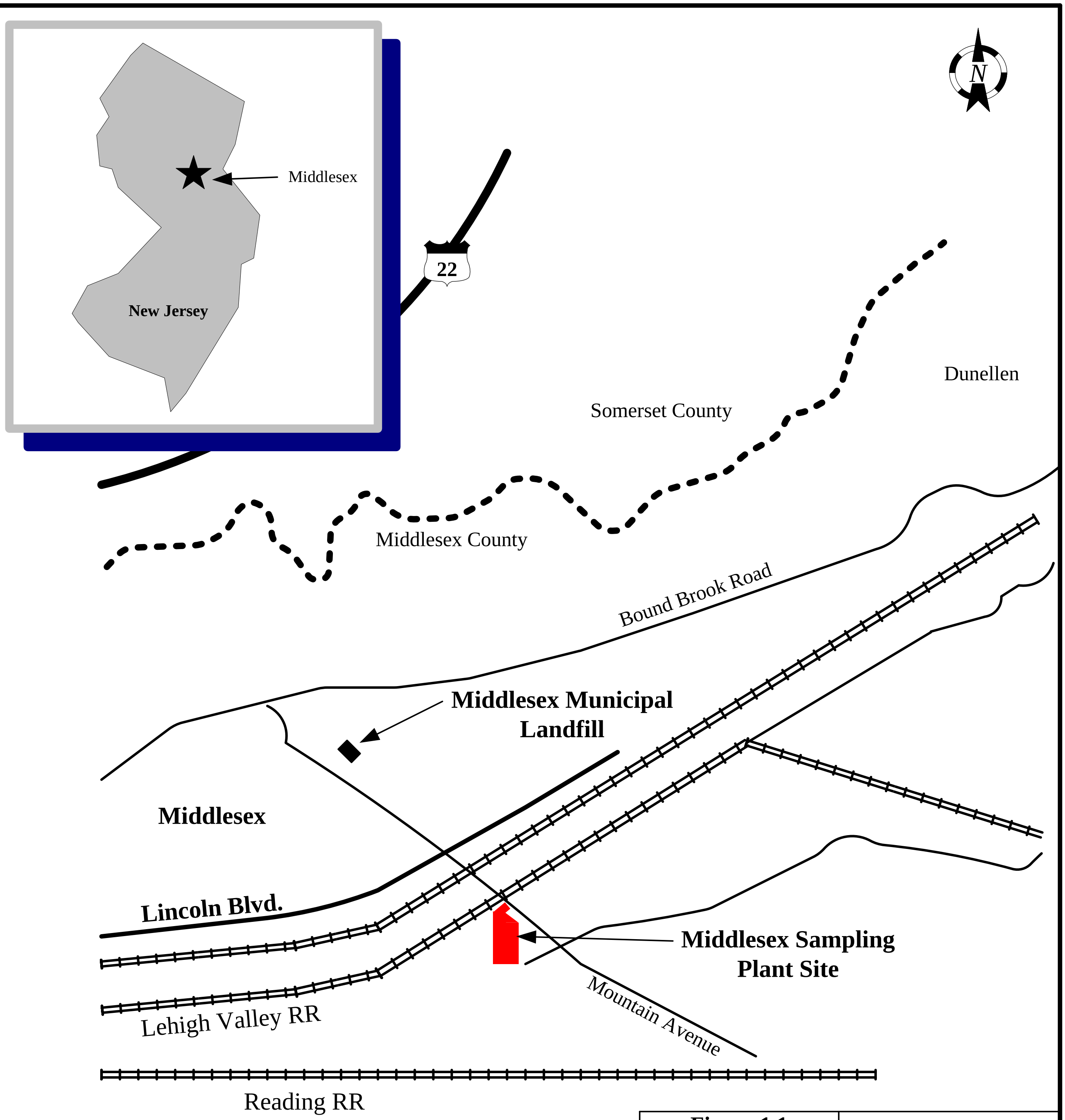
Note: Total represents 2013 costs before location adjustment.

Table 4-8
Present Worth Determination
Alternative 4 Pump and Treat - Middlesex Sampling Plant
Groundwater Operable Unit Feasibility Study

Present Worth Analysis					
Year	**Capital Costs**	**Periodic Costs**	**Total Annual Expenditure**	**Discount Factor (7%)**	**Present Worth**
0	3,371,776	0	3,371,776	1.0000	$3,371,776
1	0	846,059	846,059	0.9346	$790,726
2	0	846,059	846,059	0.8734	$738,948
3	0	523,371	523,371	0.8163	$427,227
4	0	523,371	523,371	0.7629	$399,279
5	0	555,371	555,371	0.713	$395,979
6	0	523,371	523,371	0.6663	$348,722
7	0	523,371	523,371	0.6227	$325,903
8	0	523,371	523,371	0.582	$304,602
9	0	523,371	523,371	0.5439	$284,661
10	0	555,371	555,371	0.5083	$282,295
11	0	523,371	523,371	0.4751	$248,653
12	0	523,371	523,371	0.444	$232,377
13	0	523,371	523,371	0.415	$217,199
14	0	523,371	523,371	0.3878	$202,963
15	0	555,371	555,371	0.3624	$201,266
16	0	474,752	474,752	0.3387	$160,799
17	0	474,752	474,752	0.3166	$150,306
18	0	474,752	474,752	0.2959	$140,479
19	0	474,752	474,752	0.2765	$131,269
20	0	506,752	506,752	0.2584	$130,945
21	0	474,752	474,752	0.2415	$114,653
22	0	474,752	474,752	0.2257	$107,152
23	0	474,752	474,752	0.2109	$100,125
24	0	474,752	474,752	0.1971	$93,574
25	0	506,752	506,752	0.1842	$93,344
26	0	474,752	474,752	0.1722	$81,752
27	0	474,752	474,752	0.1609	$76,388
28	0	474,752	474,752	0.1504	$71,403
29	0	474,752	474,752	0.1406	$66,750
30	0	506,752	506,752	0.1314	$66,587
				Total	**10,360,000**

Note: Total represents 2013 costs before location adjustment.

FIGURES



Legend

- County Boundary
- Creeks
- Roads
- Railroads

Not to Scale

Figure 1.1	Date: 4/15/2008
Drawn By: ROW	**Checked By: DMM**

Middlesex Sampling Plant
Middlesex, New Jersey

Site Location Map

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Path: L:\Buffalo\Middlesex\2016\Maps\MXD\FS\2016_July\Figure_1-2_Groundwater_MW_Location_Map_SizeD.mxd

LEGEND:

- ✦ Overburden Monitoring Well
- ✦ Shallow Bedrock Monitoring Well
- ✦ Unit B Monitoring Well
- ✦ Unit C Monitoring Well
- ✦ Unit D Monitoring Well
- ✦ Monitoring Well Not Sampled
- ━ Property Line
- - -► Former Location of Subsurface Pipe Chase with Flow Direction
- - - Approximate Location of Unit Subcrop Fracture/Bedding Plane
- - - Cross Section Location A-A'/Direction of Bedding Dip
- ······ Fenceline
- -·-· Matchline
- 🟩 Sump
- 🟦 Former Administration Building
- 🟨 Former Garage
- 🟥 Former Process Building
- *Well is abandoned

Matchline location shown on Figure 1.5

N

0 250 500 1,000 Feet

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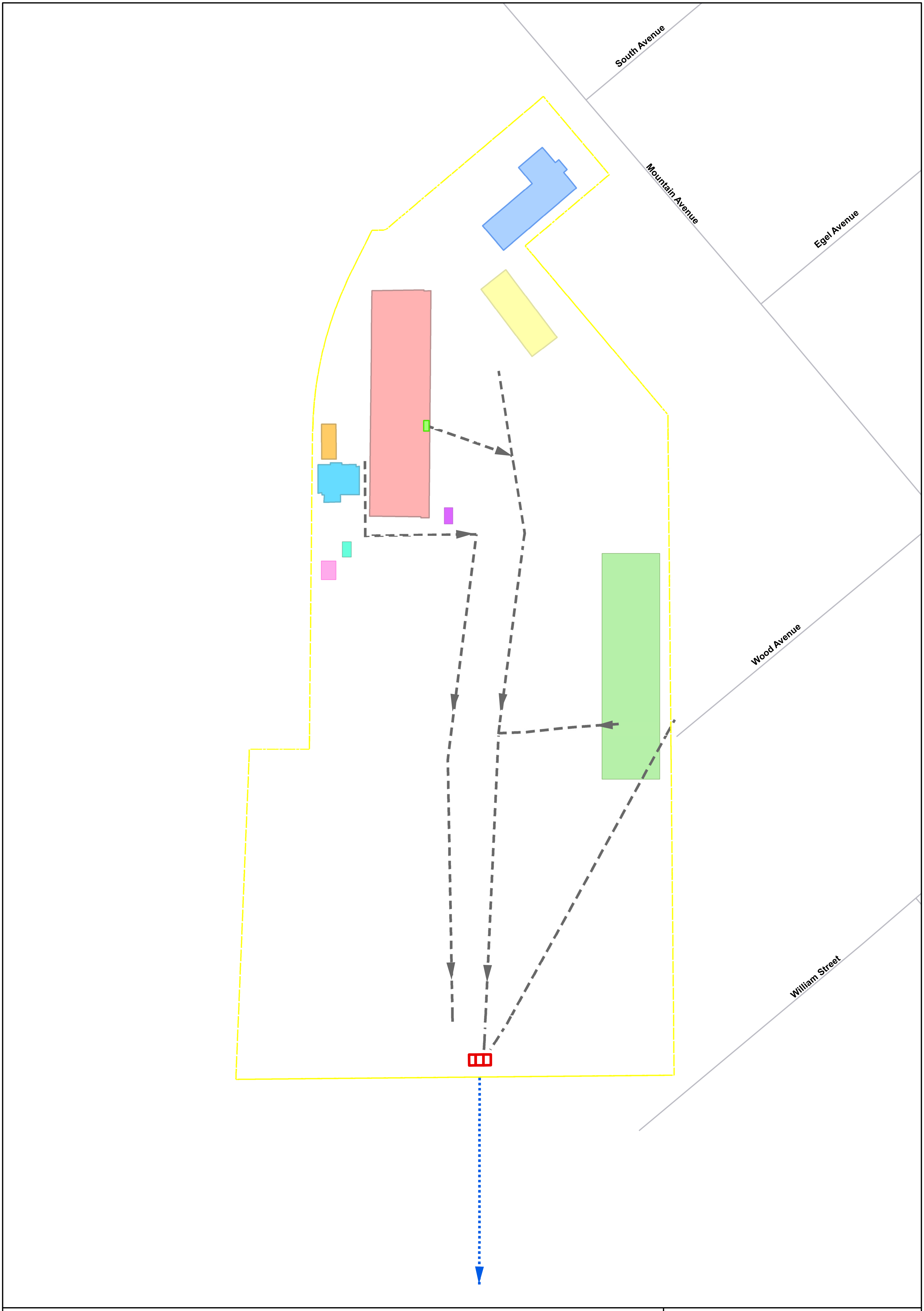
Middlesex Sampling Plant
Middlesex, New Jersey

Figure 1.2
Groundwater Monitoring Well Location Map

Path: L:\Buffalo\Middlesex\2016\Maps\MXD\Tech_Memo\2016_06\Figure_2_Former_Layout_Middlesex_Sampling_Plant.mxd



LEGEND:

- Property Line
- Subsurface Pipe Chase with Flow Direction
- South Drainage Ditch
- 🟥 Settling Basin with Carbon Filter
- 🟧 Aboveground Storage Tank Slab
- 🟩 Sump
- 🟦 Boiler House Slab
- 🟦 Administration Building
- 🟩 Equipment Storage Building
- 🟨 Garage
- 🟪 Gasoline Pumps
- 🟦 Ore Dumping Station
- 🟥 Process Building
- 🟪 Thaw House

N

0 25 50 100 Feet

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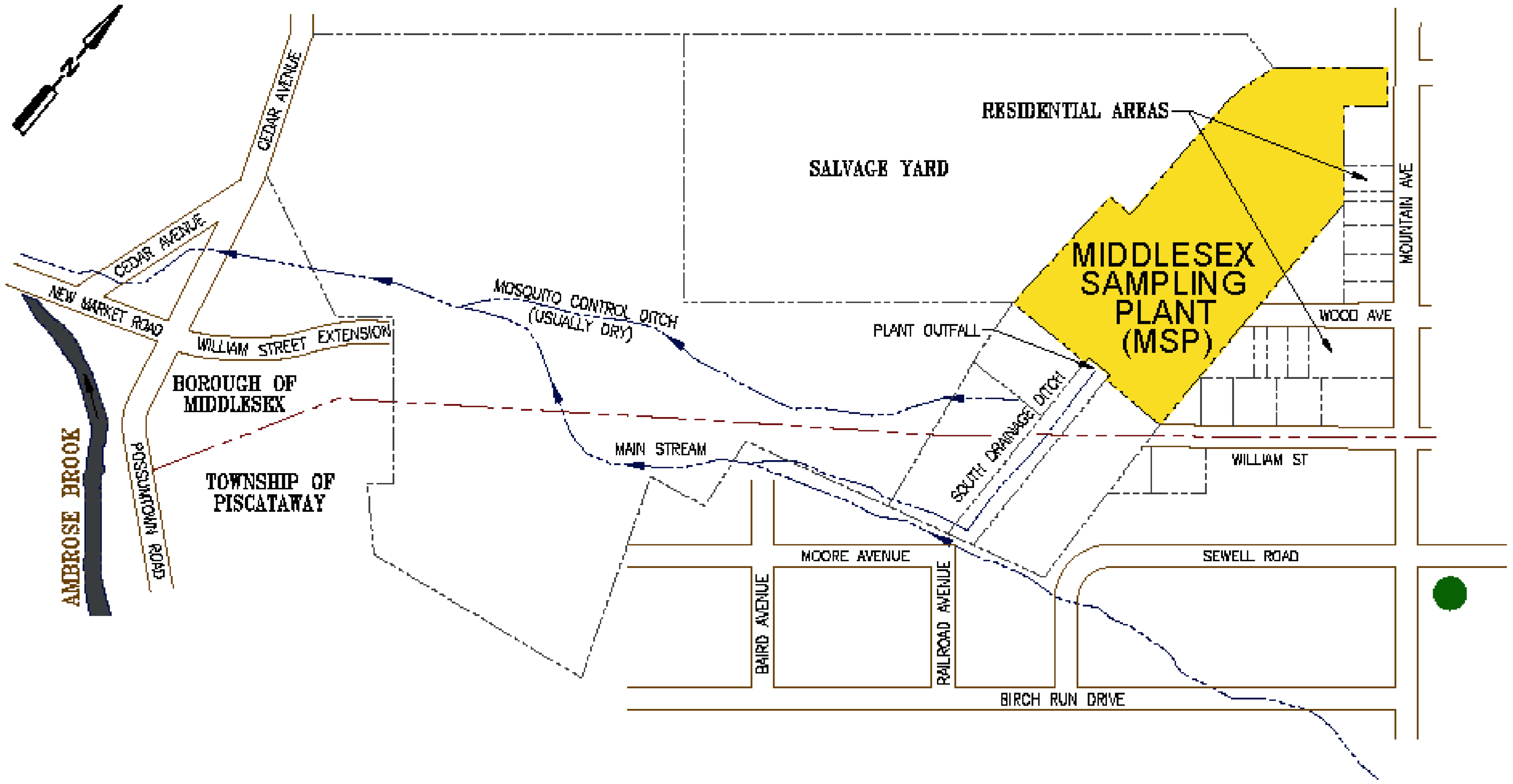
Middlesex Sampling Plant
Middlesex, New Jersey

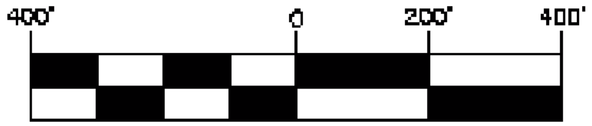
Figure 1.3
Historic Layout of Middlesex Sampling Plant (1958)



LEGEND:

- TOWN BOUNDARY
- SITE BOUNDARY
- PARCEL BOUNDARY
- ROAD RIGHT OF WAY
- CREEK OR STREAM
- DITCH LINE
- ● PARK LOCATION

GRAPHIC SCALE

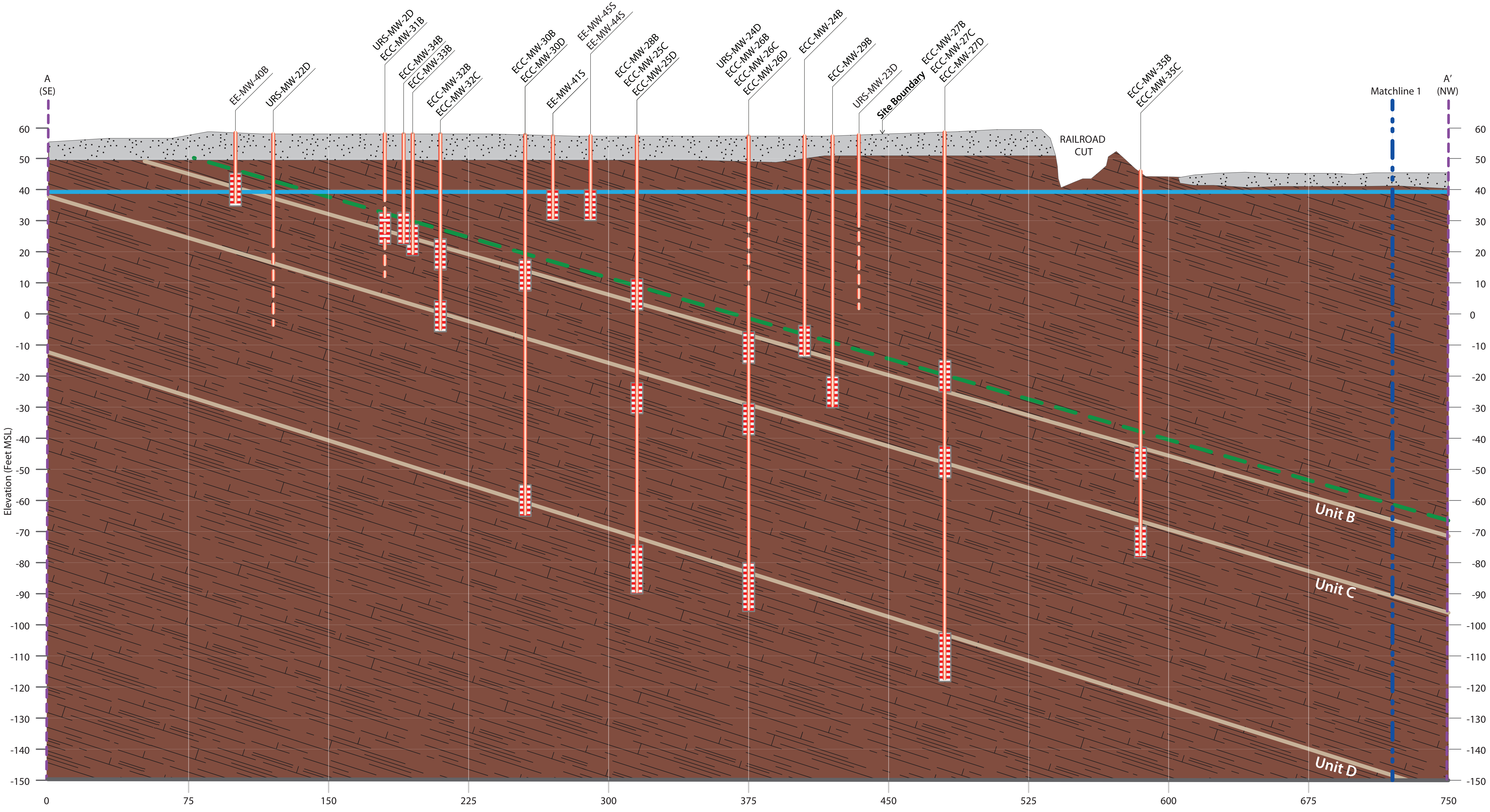


REFERENCES:

1.) BNI, DRAWING NO. R99F001.DGN

Drawn by: MGJ	UNITED STATES ARMY CORPS OF ENGINEERS
Date: 02/14/2013	Middlesex Sampling Plant Middlesex, New Jersey
Checked by: ROW	
Date: 03/22/2013	**Figure 1.4** **Vicinity Map**
Revised (Date/Initials):	

02:003239.0004.03\Figure 1.5 Cross Section.ai-7/26/16-GRA



LEGEND

- Monitoring Well with Well Screen
- Monitoring Well with Open Hole Completion
- Average Bedrock Aquifer Water Table Surface
- Unit Boundary
- Gamma Marker Bed
- Matchline
- Cross Section Location A-A'
- ▨ Overburden
- ▨ Bedrock (Passaic Formation: Red Siltstone and Shale)

Vertical Exaggeration = 1.5X
Approximate Horizontal Scale: 1.5 inch = 75 feet
MSL = Mean Sea Level
Cross Section Location shown on Figure 1.2

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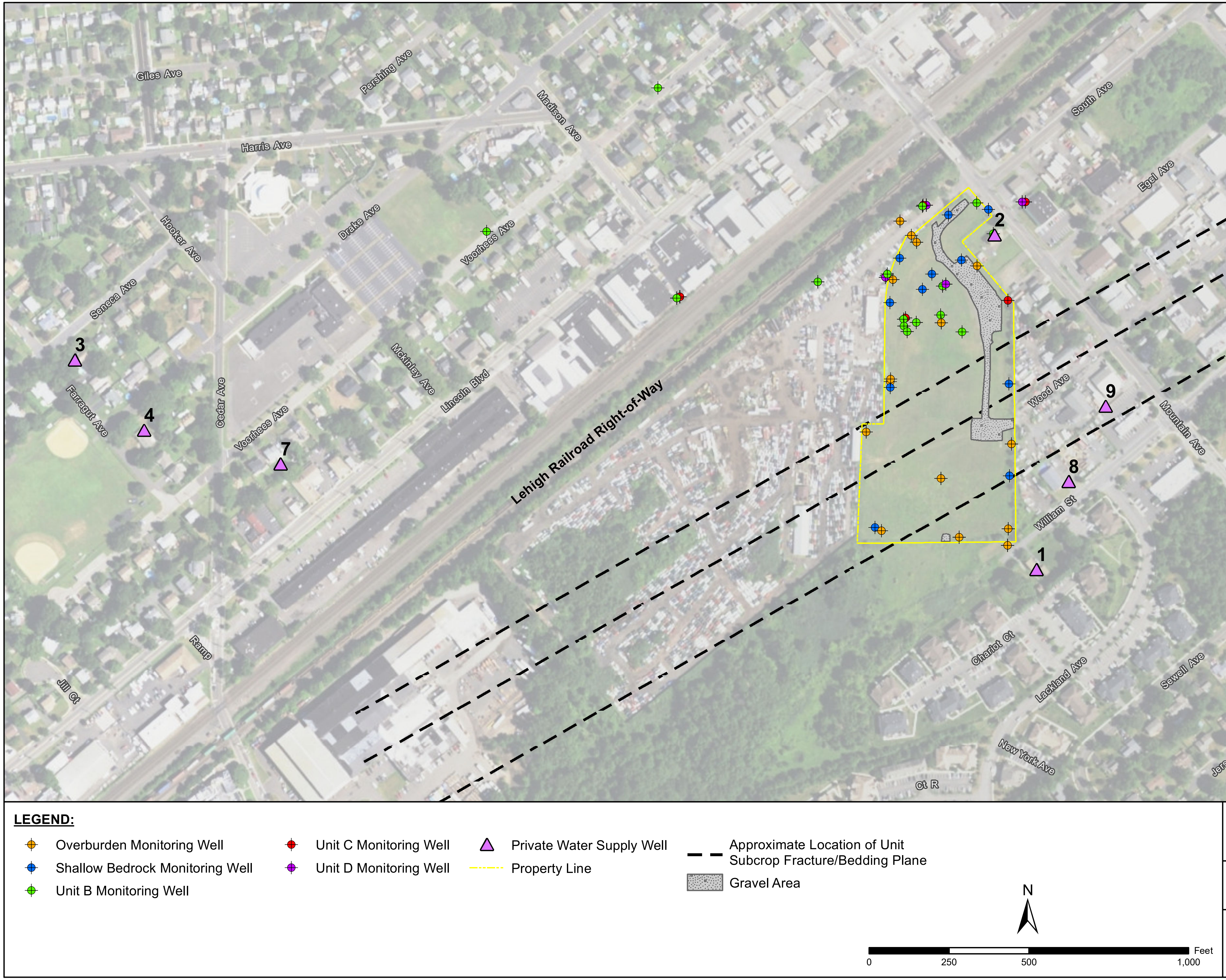
Middlesex Sampling Plant
Middlesex, New Jersey

Figure 1.5
Geologic Cross Section - Onsite Wells

Path: L:\Buffalo\Middlesex\2016\Maps\MXD\Tech_Memo\2017_08\Figure_1-6_Potable_Water_Well_Sample_Locations.mxd



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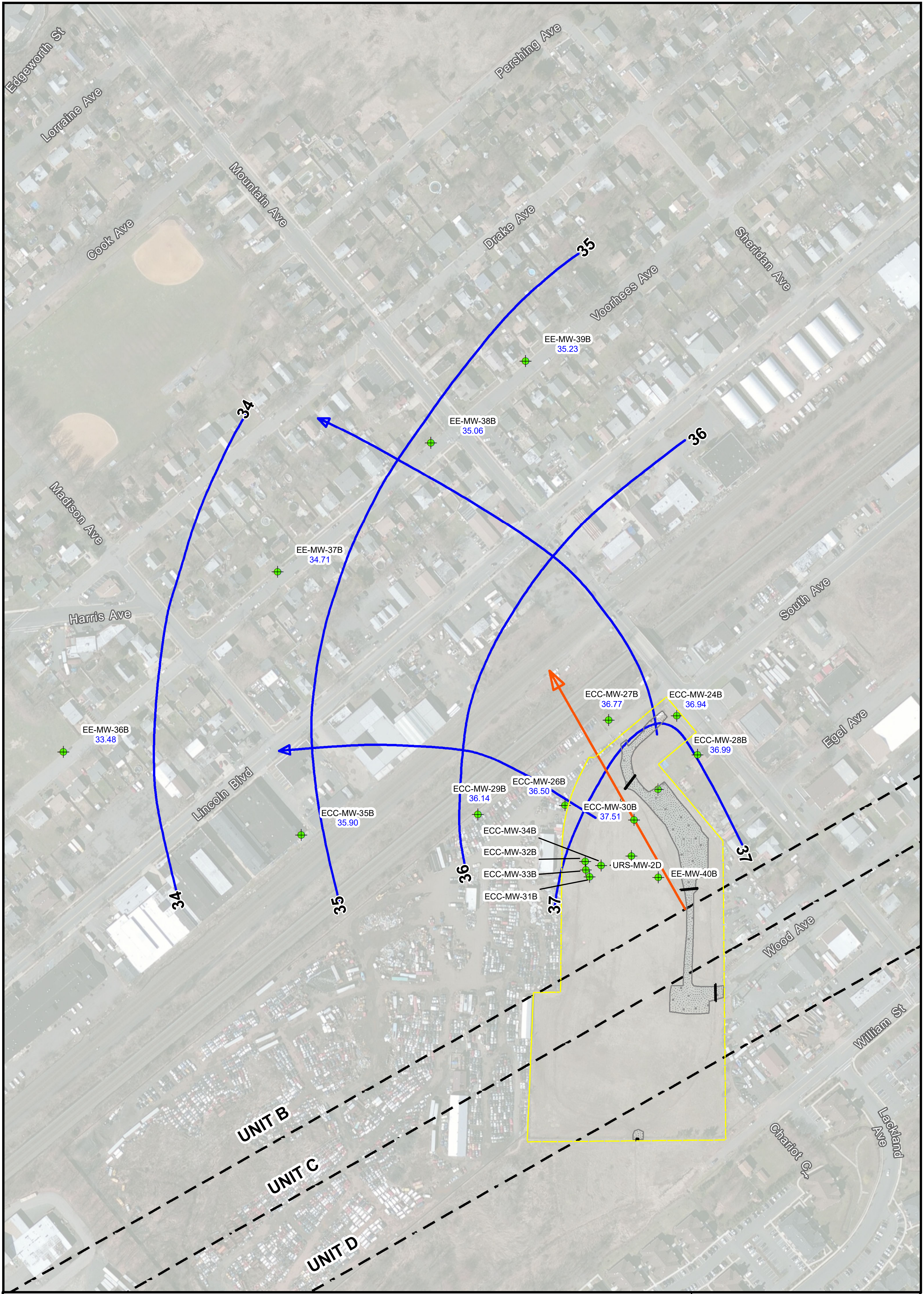
Middlesex Sampling Plant
Middlesex, New Jersey

Figure 1.6
Private Potable Water Well Sample Locations



Legend

-·-·- Property Line

- - - Elevation Contours (feet AMSL)

— Storm Drains

▨ Gravel Areas

⊕ 34.71 Unit B Monitoring Well with Groundwater Elevation

— Potentiometric Surface Contours for Unit B Wells

— — Approximate Location of Unit Subcrop Fracture/Bedding Plane

→ Direction of Groundwater Flow

→ Direction of Bedding Dip

NOTE:
*Wells not used to determine groundwater flow direction.

Coordinate System:
North American Datum 1983 HARN
New Jersey State Plane FIPS 2600
Units: Feet

AMSL = above Mean Sea Level

N

Feet
0 50 100 200

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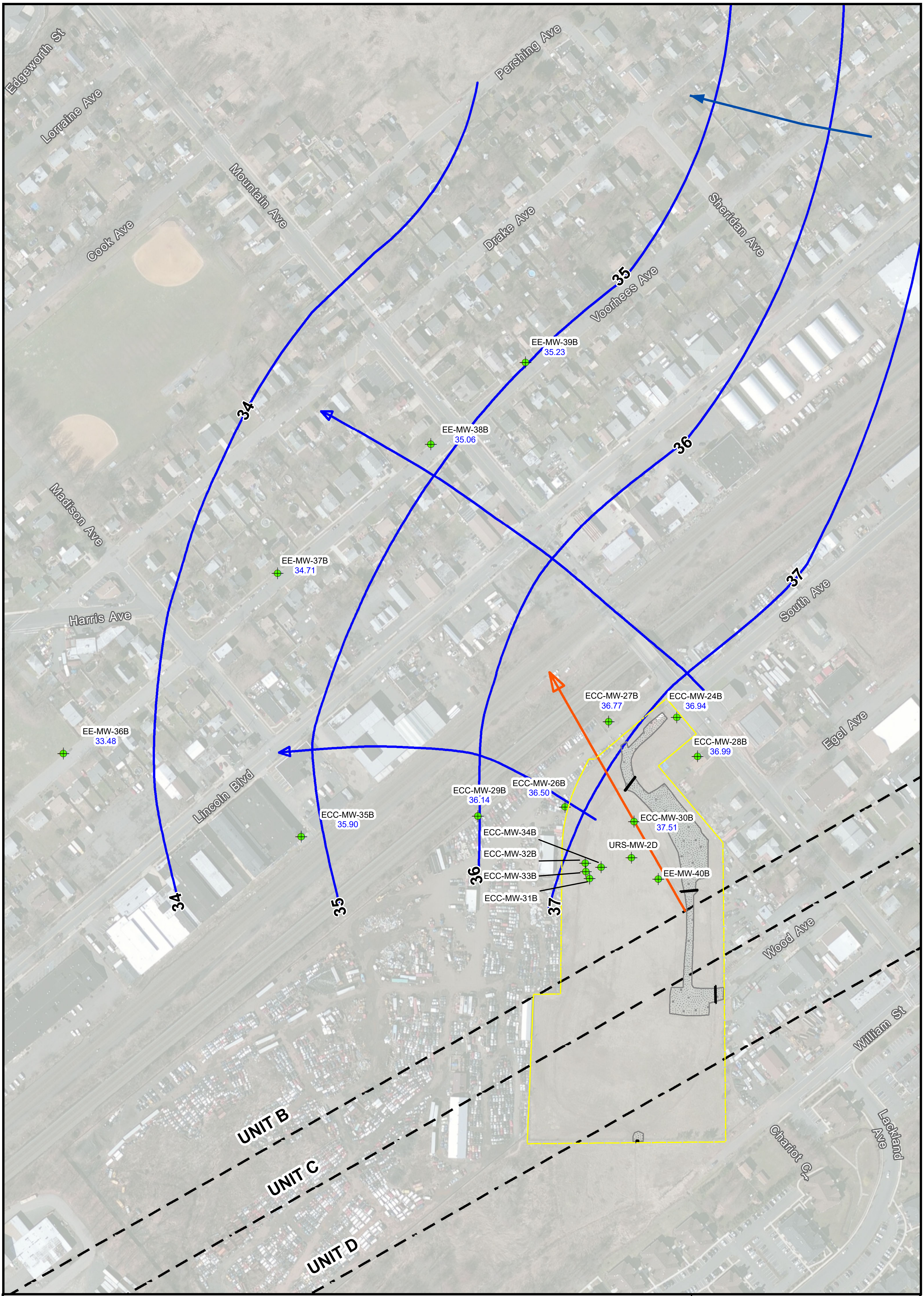
Middlesex Sampling Plant
Middlesex, New Jersey

Figure 1.7a
Potentiometric Surface Contours
for Unit B Wells (October 2014)

Document Path: L:\Buffalo\Middlesex\2016\Maps\MXD\FS\2016_July\Figure_1-7b_Potentiometric_Surface_Contours_for_Unit_B_Wells.mxd



Legend

- Property Line
- Elevation Contours (feet AMSL)
- Storm Drains
- ▨ Gravel Areas
- 34.16 Unit B Monitoring Well with Groundwater Elevation
- Potentiometric Surface Contours for Unit B Wells
- Approximate Location of Unit Subcrop Fracture/Bedding Plane
- Direction of Groundwater Flow
- Direction of Bedding Dip

NOTE:
*Wells not used to determine groundwater flow direction.

Coordinate System:
North American Datum 1983 HARN
New Jersey State Plane FIPS 2600
Units: Feet

AMSL = above Mean Sea Level

N

0 50 100 200 Feet

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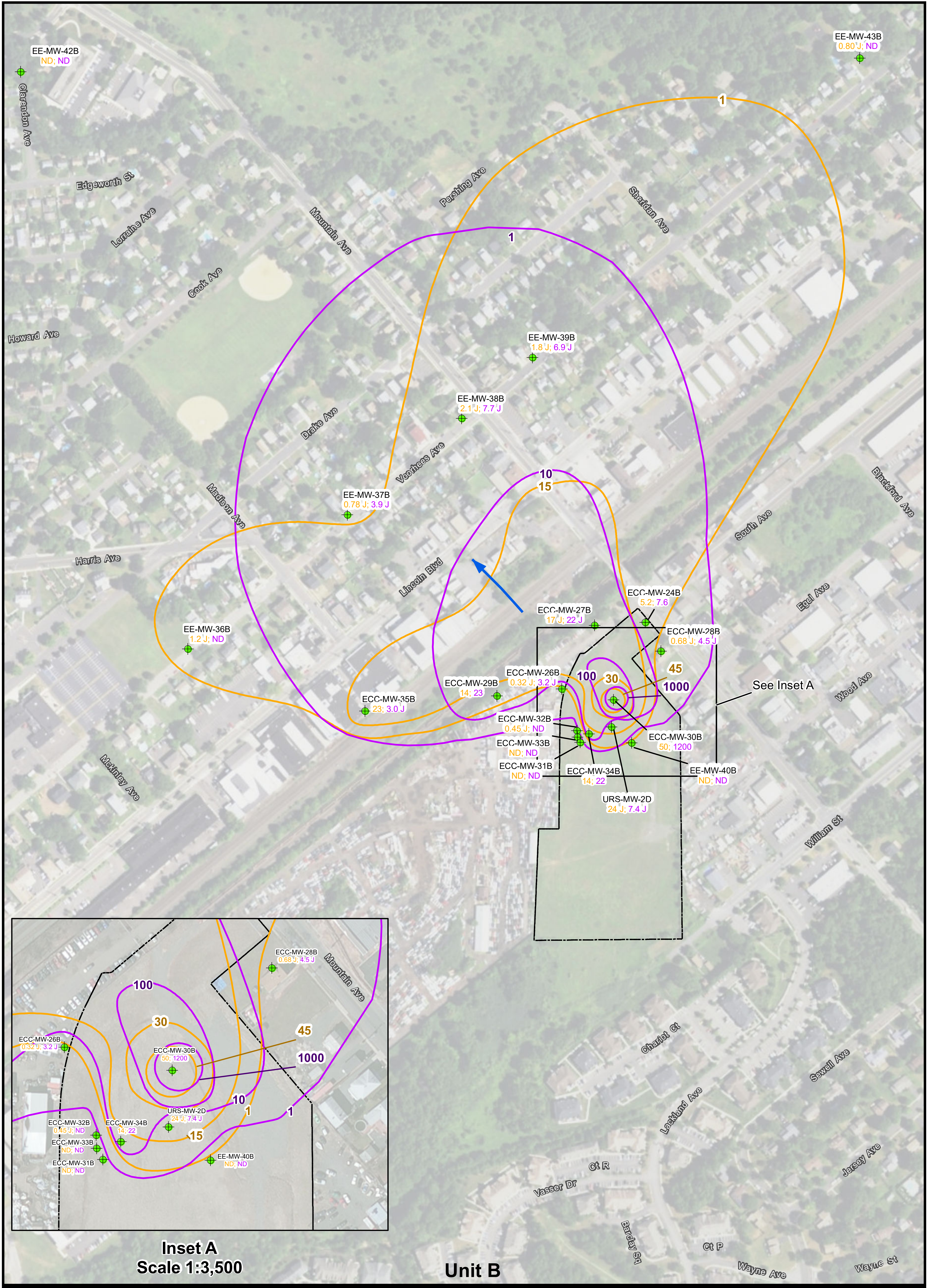
Middlesex Sampling Plant
Middlesex, New Jersey

Figure 1.7b
Potentiometric Surface Contours for Unit B Wells (December 2015)



Legend

⊕ Unit B Monitoring Well with CT and TCE Concentrations
-·-·- Property Line
→ General Direction of Groundwater Flow - Unit B
— Carbon Tetrachloride Concentration - Unit B
— Trichloroethene Concentration - Unit B

N

0 100 200 400 Feet

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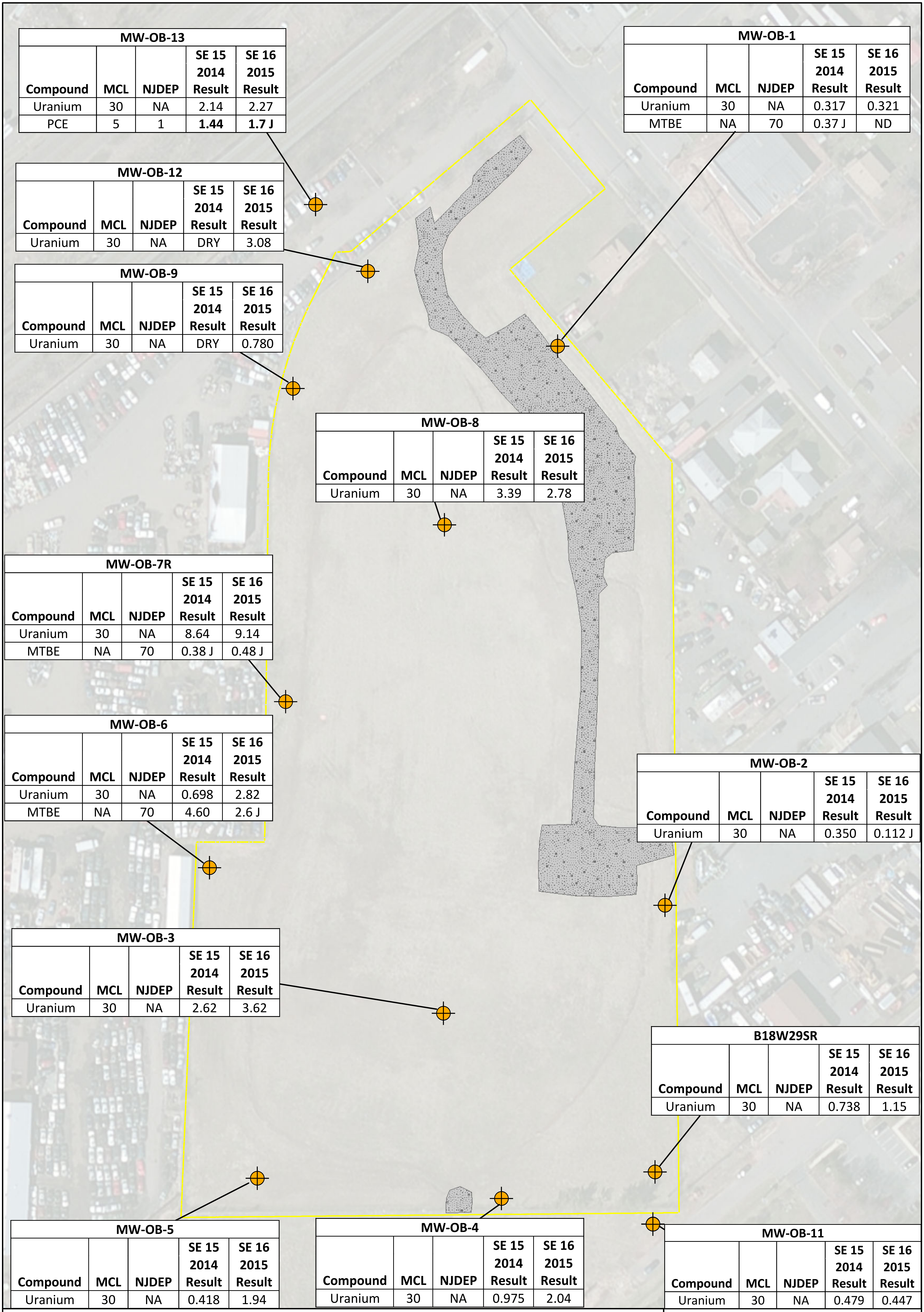
Middlesex Sampling Plant
Middlesex, New Jersey

Figure 1.8
Unit B
Trichloroethene and Carbon Tetrachloride Concentration Contours
SE16 2015 - 2016

Path: L:\Buffalo\Middlesex\2016\Maps\MXD\FS\2017_July\Figure_1-9_Nov_2012_Uranium_Detections_in_Overburden_Wells.mxd



MW-OB-13

Compound	MCL	NJDEP	SE 15 2014 Result	SE 16 2015 Result
Uranium	30	NA	2.14	2.27
PCE	5	1	**1.44**	**1.7 J**

MW-OB-1

Compound	MCL	NJDEP	SE 15 2014 Result	SE 16 2015 Result
Uranium	30	NA	0.317	0.321
MTBE	NA	70	0.37 J	ND

MW-OB-12

Compound	MCL	NJDEP	SE 15 2014 Result	SE 16 2015 Result
Uranium	30	NA	DRY	3.08

MW-OB-9

Compound	MCL	NJDEP	SE 15 2014 Result	SE 16 2015 Result
Uranium	30	NA	DRY	0.780

MW-OB-8

Compound	MCL	NJDEP	SE 15 2014 Result	SE 16 2015 Result
Uranium	30	NA	3.39	2.78

MW-OB-7R

Compound	MCL	NJDEP	SE 15 2014 Result	SE 16 2015 Result
Uranium	30	NA	8.64	9.14
MTBE	NA	70	0.38 J	0.48 J

MW-OB-6

Compound	MCL	NJDEP	SE 15 2014 Result	SE 16 2015 Result
Uranium	30	NA	0.698	2.82
MTBE	NA	70	4.60	2.6 J

MW-OB-2

Compound	MCL	NJDEP	SE 15 2014 Result	SE 16 2015 Result
Uranium	30	NA	0.350	0.112 J

MW-OB-3

Compound	MCL	NJDEP	SE 15 2014 Result	SE 16 2015 Result
Uranium	30	NA	2.62	3.62

B18W29SR

Compound	MCL	NJDEP	SE 15 2014 Result	SE 16 2015 Result
Uranium	30	NA	0.738	1.15

MW-OB-5

Compound	MCL	NJDEP	SE 15 2014 Result	SE 16 2015 Result
Uranium	30	NA	0.418	1.94

MW-OB-4

Compound	MCL	NJDEP	SE 15 2014 Result	SE 16 2015 Result
Uranium	30	NA	0.975	2.04

MW-OB-11

Compound	MCL	NJDEP	SE 15 2014 Result	SE 16 2015 Result
Uranium	30	NA	0.479	0.447

LEGEND:

⊕ Overburden Monitoring Well

--- Property Line

▨ Gravel Area

PCE: Tetrachloroethylene
MTBE: Methyl Tert-Butyl Ether
ND: Not Detected
NA: Not Applicable
J: Estimated Value
MCL: Federal Drinking Water Maximum Contaminant Level Standard
NJDEP: New Jersey Department of Environmental Protection Standard

Notes: 1) Bold values exceeded the NJDEP criteria.
2) All results are shown in micrograms per literl (ug/L).
3) Monitoring well locations MW-OB-12 and MW-OB-9 were dry and could not be sampled during SE 15 in 2014.

N

Feet
0 25 50 100

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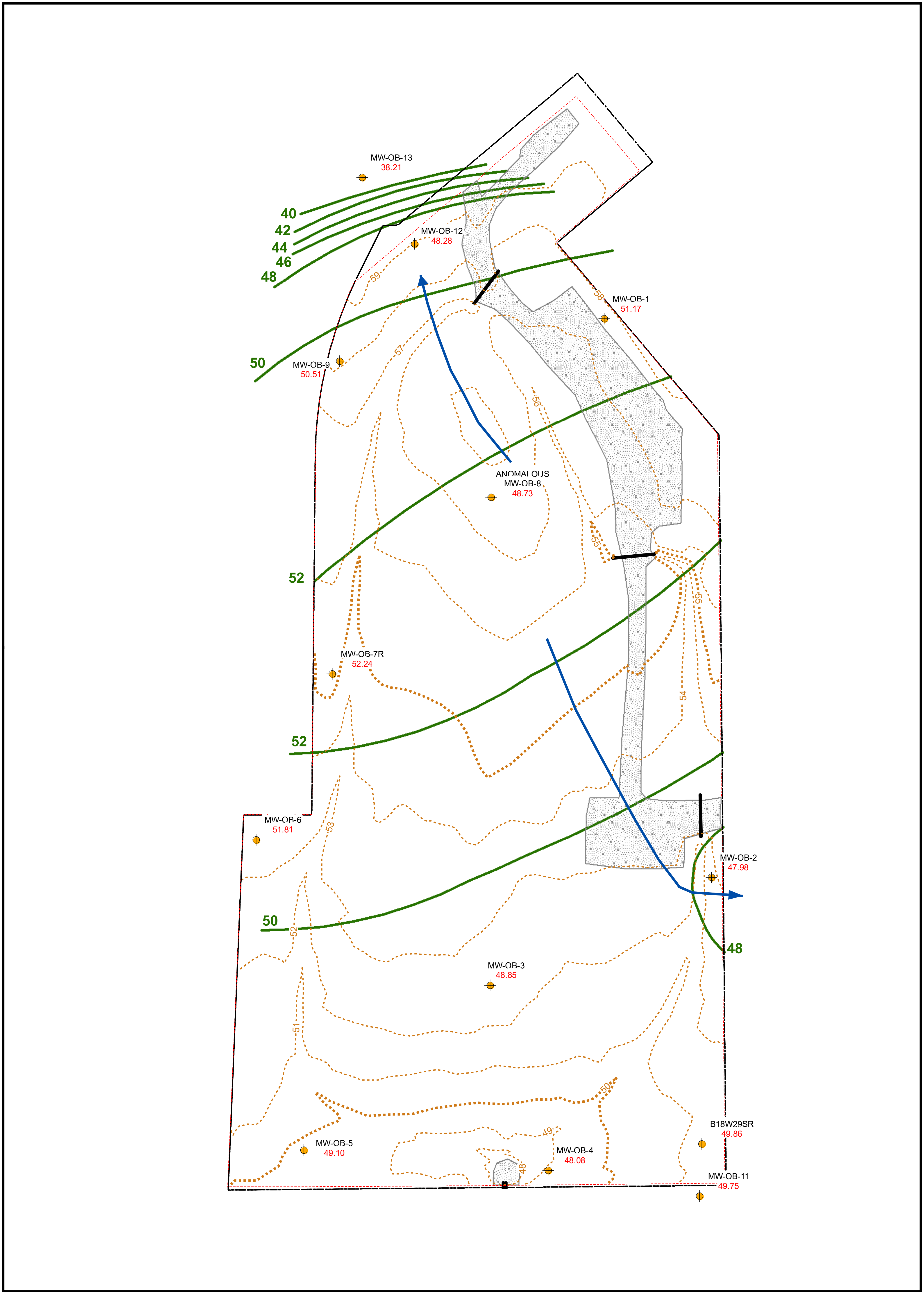
Middlesex Sampling Plant
Middlesex, New Jersey

Figure 1.9
Overburden Monitoring Well Sample Results from SE 15 and SE 16

Document Path: L:\Buffalo\Middlesex\2016\Maps\MXD\FS\2017_July\Figure_1-10_Potentiometric_Surface_Contours_for_Overburden_Wells.mxd



Legend

Fenceline

Property Line

Elevation Contours (feet AMSL)

Storm Drains

48.73 Overburden Monitoring Well with Groundwater Elevation

Potentiometric Surface Contours

Direction of Groundwater Flow

Gravel Areas

NOTE:
*Wells not used to determine groundwater flow direction.

Coordinate System:
North American Datum 1983 HARN
New Jersey State Plane FIPS 2600
Units: Feet

AMSL = above Mean Sea Level

N

Feet
0 25 50 100

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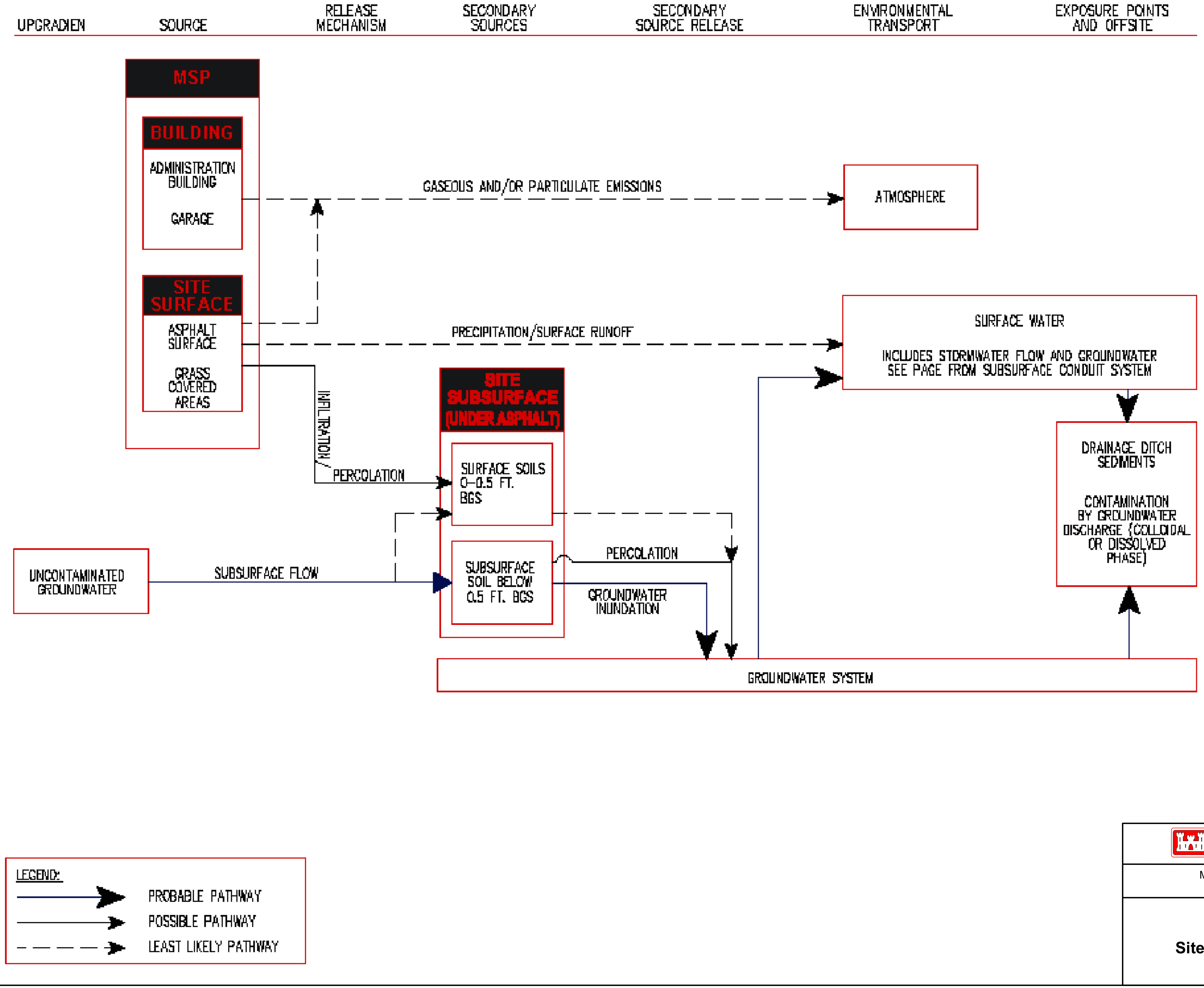
Middlesex Sampling Plant
Middlesex, New Jersey

Figure 1.10
December 2015 Potentiometric Surface Contours- Overburden Wells

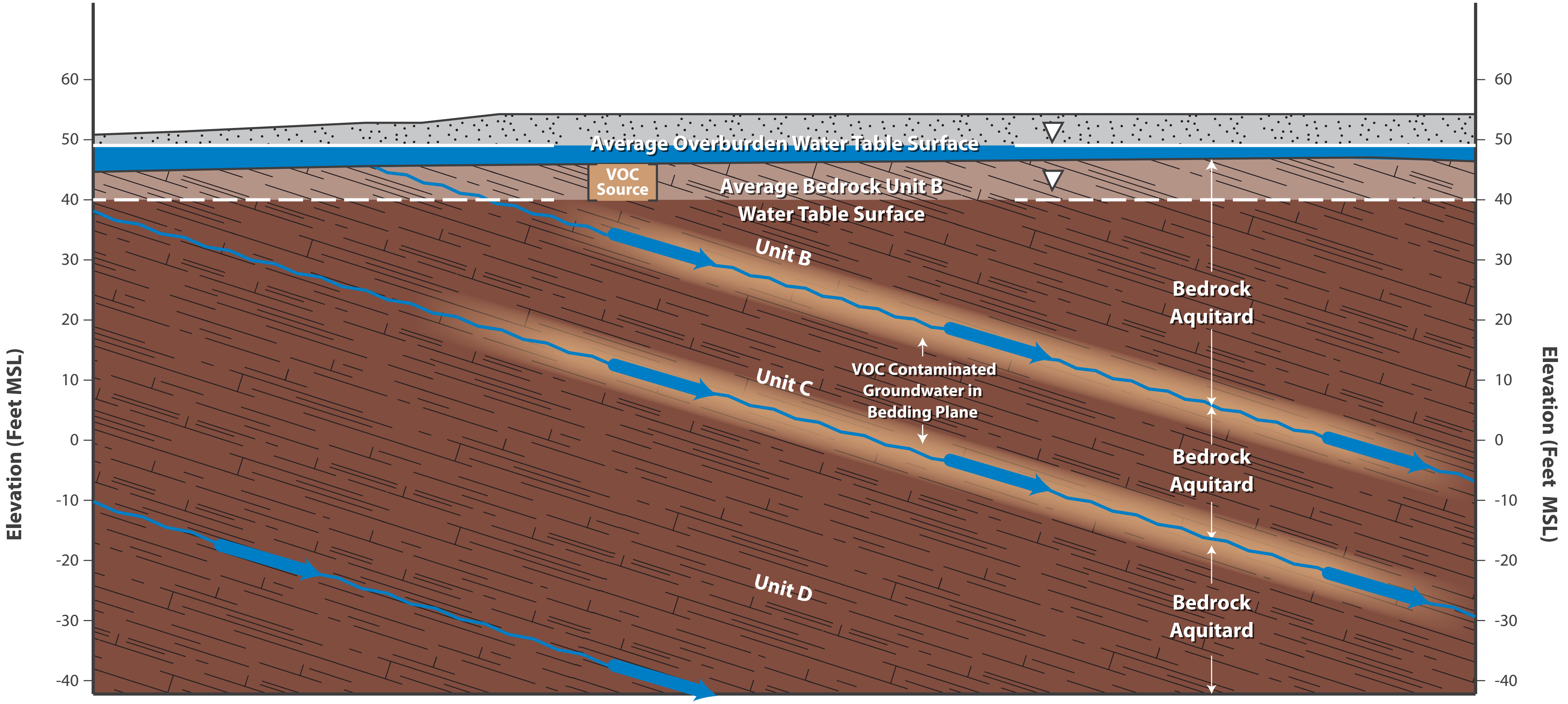


UNITED STATES ARMY
CORPS OF ENGINEERS

Middlesex Sampling Plant
Middlesex, New Jersey

Figure 1.11
Site Conceptual Model

1003239.0004.03\FS Report Figures\Figure 1.11 Cross Section_FS 2016.ai-8/15/16-GRA



LEGEND

▨ Overburden

🟦 Overburden Groundwater Unit

▨ Unsaturated Bedrock Zone

▨ Bedrock (Passaic Formation: Red Siltstone and Shale)

〰 Bedding Plane

➡ Bedrock Groundwater Flow Direction

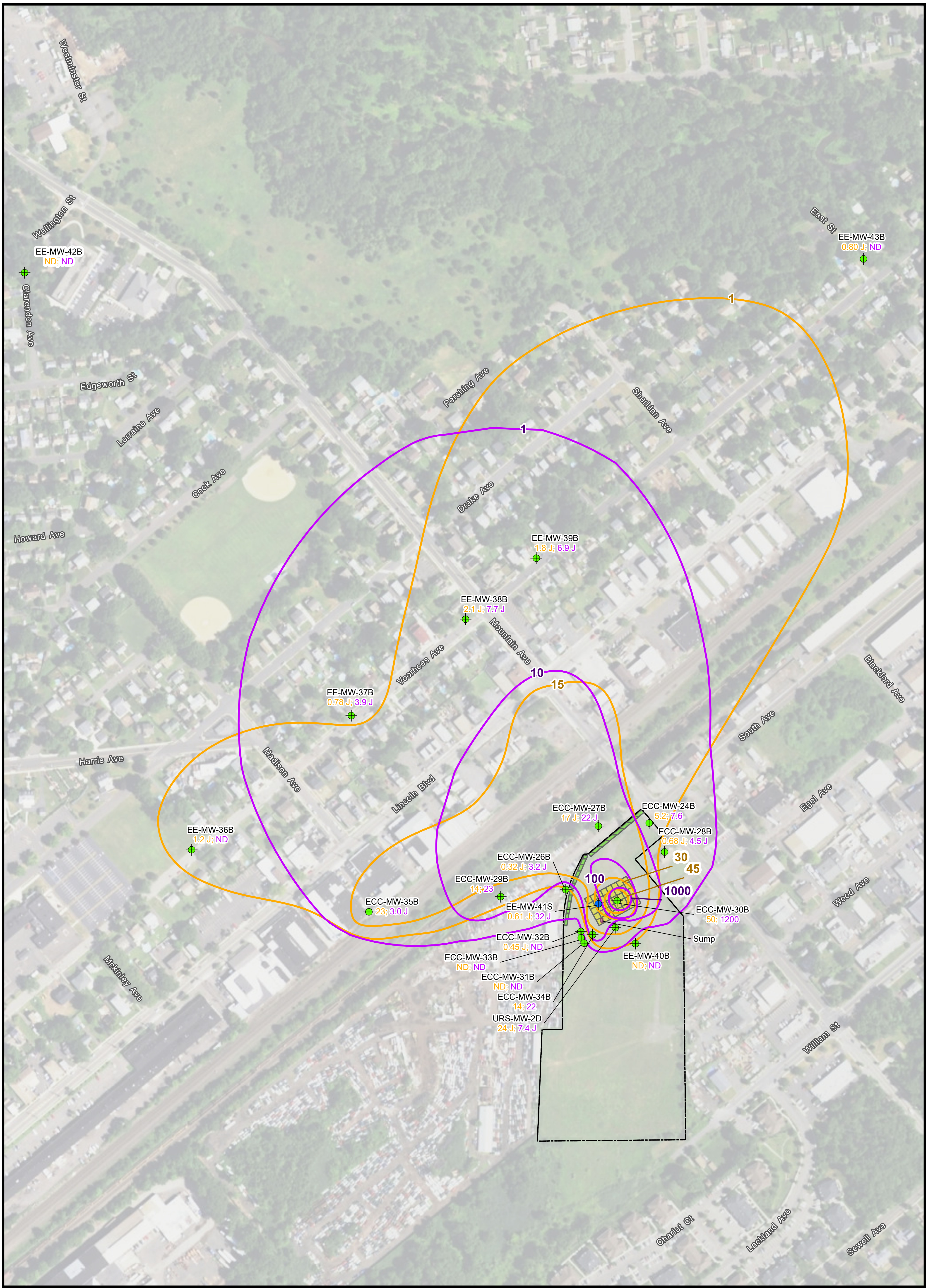
▨ VOC Contaminated Groundwater in Bedding Plane

Vertical Exaggeration=1.5X
Approximate Horizontal Scale=
1 inch Equals 45 Feet
MSL=Mean Sea Level

UNITED STATES ARMY CORPS OF ENGINEERS

Middlesex Sampling Plant
Middlesex, New Jersey

Figure 1.12
Indoor Air Pathway Conceptual Site Model



Legend

- Shallow Bedrock Monitoring Well
- Unit B Monitoring Well
- Carbon Tetrachloride Isocontour
- Trichloroethene Isocontour
- Property Line
- Sump
- Proposed Lines of Injection Points
- Proposed Injection Grid on 20-foot Centers

X; X - SE 16 Concentrations (µg/L) of
Trichloroethene (TCE); Carbon Tetrachloride (CT)

Notes:

Lines of injection consist of injection points at a 20-foot spacing. Total line length = 500 feet. Total number of points = 25.

6 x 9 injection grid is on 20-foot centers for a total of 54 points.

A total of 79 injection points will inject into the source area, on top of Unit B and into Unit B. Specific injection depths are identified in the text.

Coordinate System:
North American Datum 1983 HARN
New Jersey State Plane FIPS 2600
Units: Feet

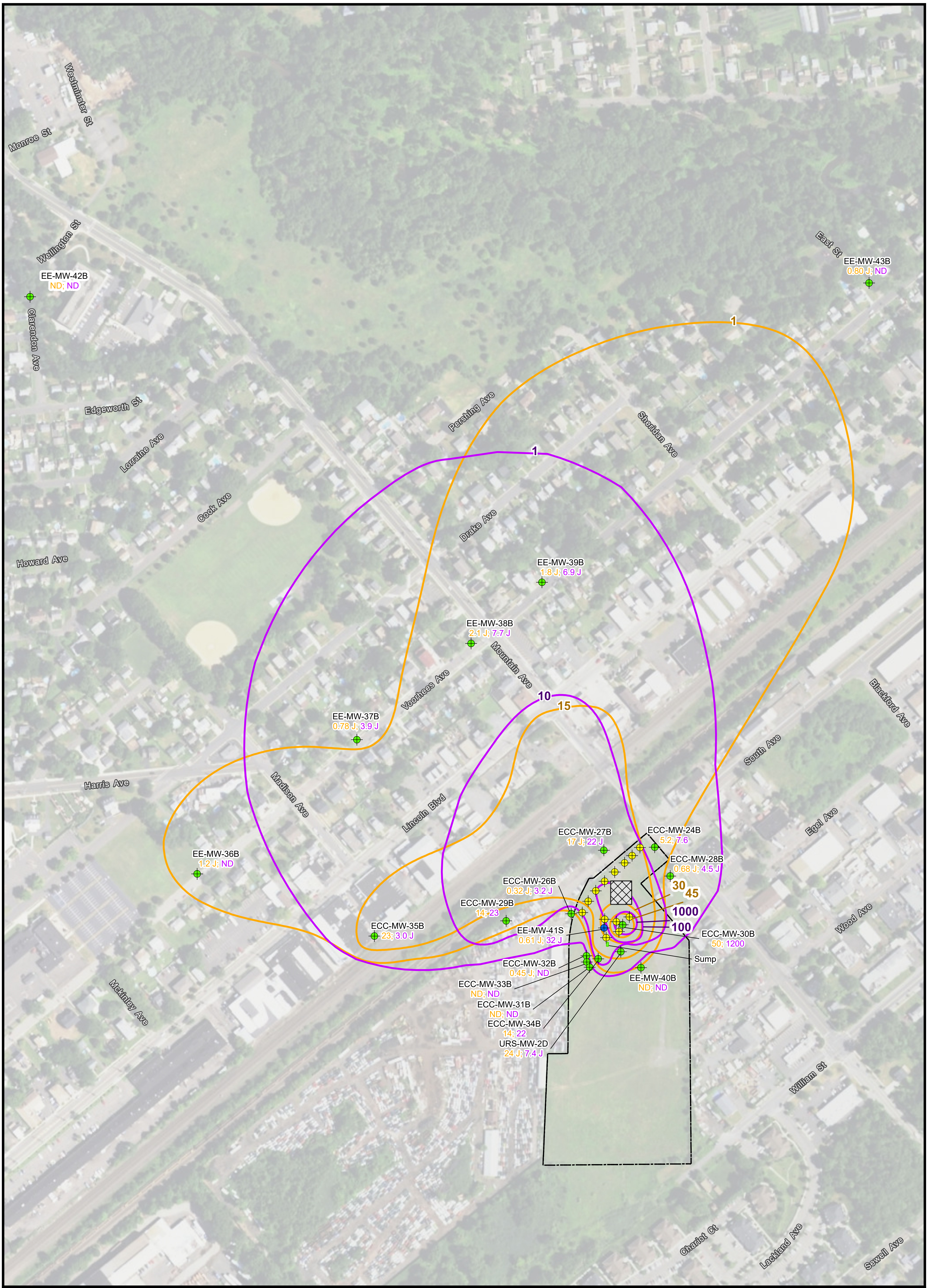
N

Feet
0 100 200 400

UNITED STATES ARMY
CORPS OF ENGINEERS

Middlesex Sampling Plant
Middlesex, New Jersey

Figure 3.1
Alternative 3: In-Situ Chemical Reduction Injection Points



Legend

- 🟢 Unit B Monitoring Well
- 🟡 Proposed Extraction Well
- 🔵 Shallow Bedrock Monitoring Well
- - - Property Line
- Carbon Tetrachloride Isocontour
- Trichloroethene Isocontour
- ▨ Proposed Treatment System Building
- 🟩 Sump
- X; X - SE 16 Concentrations (µg/L) of Trichloroethene (TCE); Carbon Tetrachloride (CT)

Notes:

Eight extraction wells will be placed along the downgradient boundary and five will be placed at the hot spot.

Coordinate System:
North American Datum 1983 HARN
New Jersey State Plane FIPS 2600
Units: Feet

N

Feet
0 100 200 400

UNITED STATES ARMY
CORPS OF ENGINEERS

Middlesex Sampling Plant
Middlesex, New Jersey

Figure 3.2
Alternative 4: Pump and Treat Extraction Well Locations

Appendix A
Site Historical Records

APPEDIX A - SITE HISTORICAL RECORDS

HISTORIC AMERICAN ENGINEERING RECORD

INDEX TO PHOTOGRAPHS

MIDDLESEX SAMPING PLANT,
ADMINISTRATION BUILDING
239 Mountain Avenue
Middlesex
Middlesex County
New Jersey

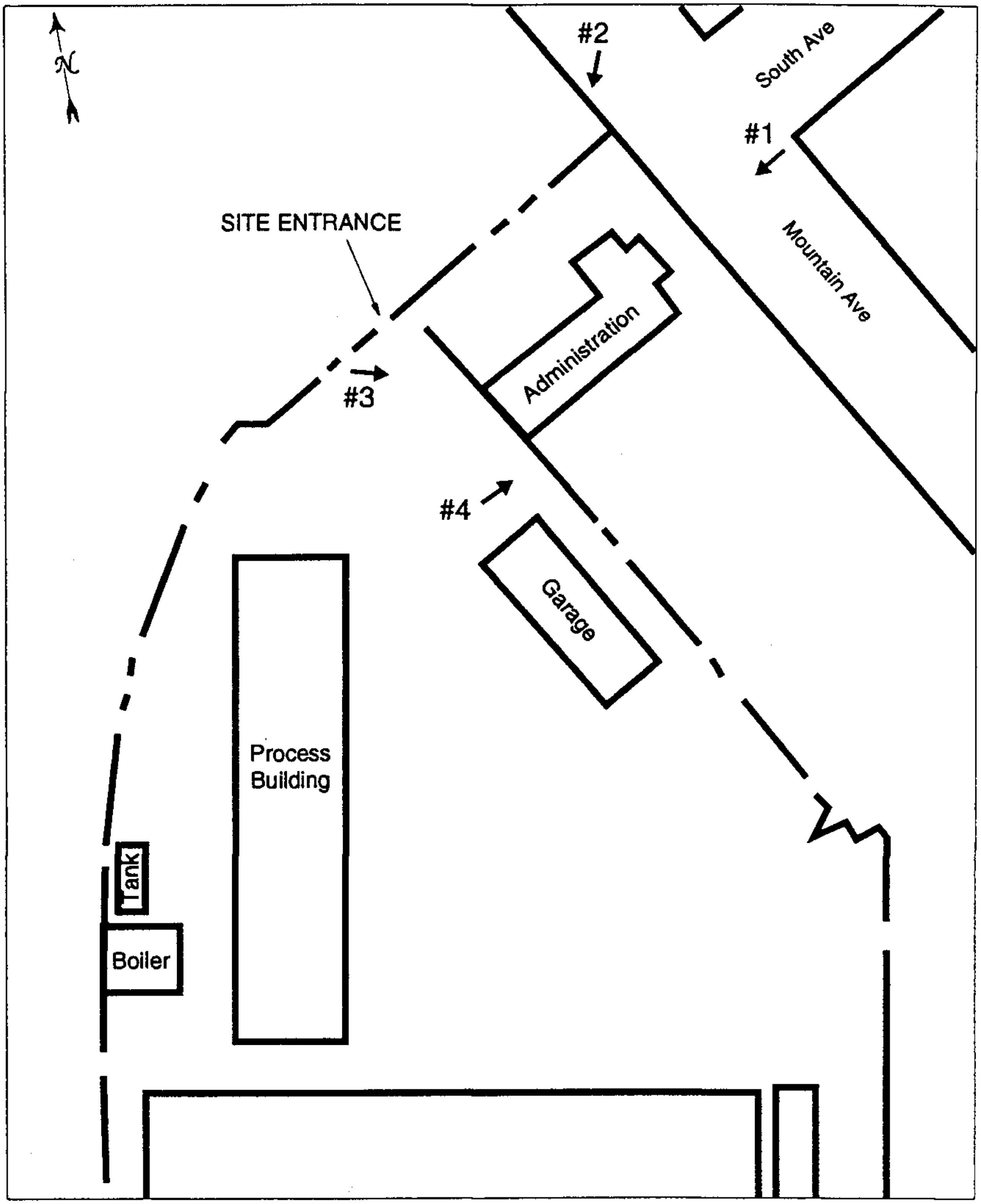
HAER NO. NJ-107-C

Dennis L. Hellawell, Photographer

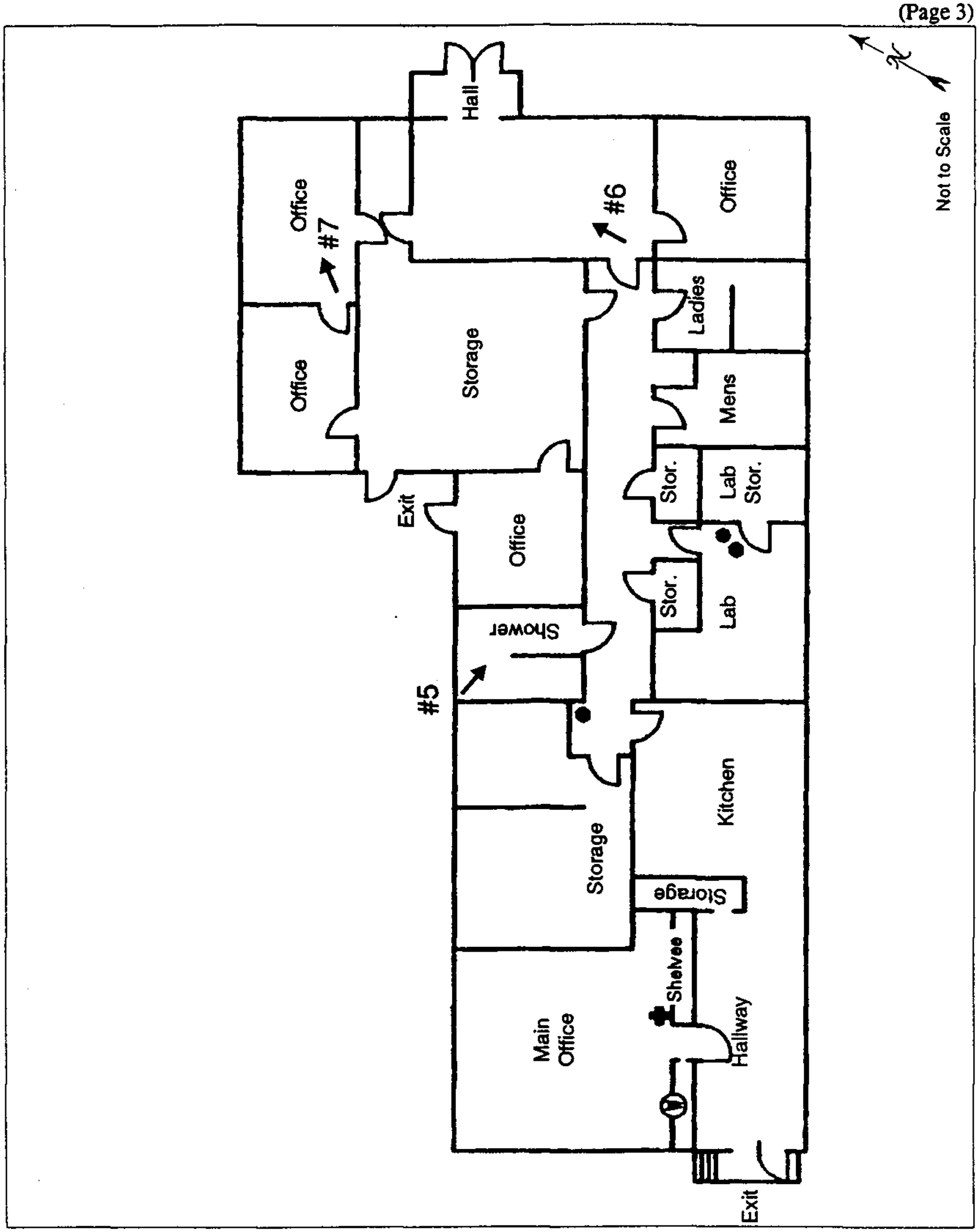
April 24 & 26, 1996

NJ-107-C-1	ADMINISTRATION BUILDING ELEVATION - TAKEN OFF THE COMPOUND, ACROSS THE STREET, THROUGH THE PERIMETER FENCE
NJ-107-C-2	ADMINISTRATION BUILDING NORTHEAST OBLIQUE FROM NORTHERN ACCESS ROAD
NJ-107-C-3	ADMINISTRATION BUILDING NORTHWEST OBLIQUE
NJ-107-C-4	ADMINISTRATION BUILDING SOUTHWEST OBLIQUE
NJ-107-C-5	ADMINISTRATION BUILDING, INTERIOR, SHOWER ROOM
NJ-107-C-6	ADMINISTRATION BUILDING, INTERIOR, FRONT ENTRANCE & FOYER
NJ-107-C-7	ADMINISTRATION BUILDING, INTERIOR, NORTHEAST CORNER OFFICE

KEY TO PHOTOGRAPHS
MIDDLESEX SAMPLING PLANT, ADMINISTRATION BUILDING
HAER NO. NJ-107-C



LAYOUT OF MIDDLESEX SAMPLING PLANT. 1996



ADMINISTRATION BUILDING FLOOR PLAN. 1996

MIDDLESEX SAMPLING PLANT,
ADMINISTRATION BUILDING
239 Mountain Avenue
Middlesex
Middlesex County
New Jersey

HAER No. NJ-107-C

HAER
NJ
12-MIDSX,
1C-

PHOTOGRAPHS

WRITTEN HISTORICAL AND DESCRIPTIVE DATA

HISTORIC AMERICAN ENGINEERING RECORD
National Park Service
Northeast Region
Philadelphia Support Office
U.S. Custom House
200 Chestnut Street
Philadelphia, P.A. 19106

HISTORIC AMERICAN ENGINEERING RECORD

MIDDLESEX SAMPLING PLANT, ADMINISTRATION BUILDING

HAER NO. NJ-107-C

Location:
239 Mountain Avenue
Middlesex, Middlesex County
New Jersey
UTM: Zone 0018, Easting 542994.49963, Northing 4491095.76065
Quad: Plainfield, New Jersey, 1:24,000

Date of Construction: 1949

Engineer/Architect: Unknown

Present Owner:
U.S. Department of Energy
Oak Ridge Operations Office
P.O. Box 2001
Oak Ridge, TN 37831-8723

Present Use: Bechtel office

Significance: The administration building was part of the Middlesex Sampling Plant used between 1943-67 for sampling uranium, beryllium, and thorium for the Manhattan Engineer District/Atomic Energy Commission for use in the development of atomic weapons. This work was part of a top-secret nationwide fabricating effort during World War II to develop an atom bomb, and post-war, to create atomic weapons as part of President Harry S. Truman's Cold War policy of military supremacy over the Soviet Union.

Project Information Statement: The Formerly Utilized Sites Remedial Action Program (FUSRAP) of the U.S. Department of Energy (DOE) will demolish the process building and the boiler house as part of site remediation and decontamination. A Memorandum of Agreement between the DOE-Former Sites Restoration Division (FSRD) and the New Jersey SHPO stipulated HAER documentation to mitigate this adverse effect. This documentation was undertaken to fulfill this stipulation.

Alexandra C. Cole
Formerly Utilized Sites Remedial Action Program
Contract No. DE-AC05-91OR21950
Science Applications International Corporation (SAIC)
816 State Street, Suite 500
Santa Barbara, CA 93101

NARRATIVE DESCRIPTION

The administration building, built in 1949 after the AEC bought the property from the American Marietta Company, replaced an existing frame administration building that was located in roughly the same area as the present building (see Sanborn Map 1927 revised in 1948). Constructed of concrete posts and beams with concrete block walls and a concrete bond beam above the windows, the building is a modest one-story L-shaped facility on a raised concrete foundation. The main block is rectangular, measuring 36 feet by 125 feet, with a wing measuring 22 feet by 51 feet extending to the north. The flat roof consists of concrete panels covered with composition roofing. The parapet walls are capped with a terra cotta coping.

The entrance bay, on the east side, has a double metal door with 9" square windows in the upper sections and two fixed sidelights of three panes each. A wide concrete landing with two steps leads to the doors. The rear entrance on the west side of the main block has a similar metal double door and is reached by a concrete porch with four steps. Two other entrances, located on the west side of the wing and the north side of the main block, have metal single doors with large glass upper panes bisected by single muntins. They are reached by three concrete steps and a concrete ramp.

Multi-paned fixed and transom industrial windows in metal sash are located on the north, south, and east sides, and on the west side of the wing. Paired recessed windows, each with three one-over-one light windows in aluminum sash, are located on the west side of the main block. A double window with two one-over-one light windows in aluminum sash are located on the north side of the main block, as well as two vertical three-pane windows that have been painted over.

The interior is divided into 16 rooms, including offices, a hallway, an entrance vestibule, storage closets, a large shower room, and two restrooms. The concrete block walls have been covered with plywood panelling, and the dropped ceilings have acoustical tile with fluorescent light fixtures inset. Floors are either concrete, with central drains, or covered with asphalt tiles 12" square. The bathrooms and shower room have glazed tile walls. The interior doors are metal, with either two recessed panels or a recessed bottom panel and a clear glass upper pane.

Minor alterations on the exterior include the concrete block infill of a door and window on the north side of the main block and aluminum sash windows at the north and west sides of the main block. On the interior the changes have been more extensive, and occurred probably when the Marine Reserve moved into the buildings in 1969. Such changes include the plywood panelling on the walls, the dropped ceilings, and the fluorescent lights.

DESCRIPTION OF USES IN THE ADMINISTRATION BUILDING

The administration building housed all the offices, health and safety facilities, lunchroom, locker rooms, shower, laundry, waste disposal unit, and restrooms for the sampling operation. The exact location of the rooms is unknown; a contemporary report indicated that the two locker rooms were on either side of the shower room (Cahalane 1958:39). These rooms may be the current storage and lab rooms, for they are large rooms with concrete floors. Mr. Porowski, a guard who worked there from 1946-51 indicated that the room where workers changed their work clothes and had their radiation exposure pens checked after working in the process building were at the rear of the building (E. Porowski, personal communication May 1996).

According to Porowski, workers came through the main gate onto the property, and entered the administration building's front door to have their passes and IDs checked. They then proceeded to the first locker room, where they changed into work clothes and shoes, before continuing on to the process building. When they finished work for the day, or when they returned to the administration building to eat lunch in the lunch room, they first removed their work clothes in a second locker room, placed them in the laundry room, showered, and changed into their street clothes in the first locker room. Porowski indicated that workers wore "pens" that were checked at the end of each shift. Workers whose radiation dose was too high did not work for several days (E. Porowski, personal communication, May 1996). A 1958 report indicated that workers wore a film badge that was developed weekly in New York City to monitor radiation exposure (Cahalane 1958:38).

Health and safety were of concern because of the radioactivity of the materials being sampled. In the early days at MSP, two factors combined to make the operations more hazardous than they would be later: the crude methods for handling the dust and the workers' lack of understanding of the hazards involved. Increased mechanization of dust collection and disposal, education of the workers, radiation monitoring, the provision of protective clothing and respirators by MSP, and air sampling all contributed to greater health standards over time. After 1951, when United Lead assumed control of the operations, a Health Physicist was on-site maintaining the AEC standards for working with radioactive materials, monitoring working areas and shipments for radiation, and collecting breath and urine samples at periodic intervals. Workers were given a yearly physical examination. The degree of radiation from alpha, beta, and gamma rays was checked daily by dosimeters in working areas (Cahalane 1958: 38-9; E. Porowski, personal communication May 1996).

The AEC left the site in 1967, and from 1969-79 the building was used as administrative offices by the U. S. Marine Corps, Sixth Motor Transport Battalion reserve training center. Currently, the building serves as offices for the Bechtel site supervisor.

Sources of Information:

Interviews

Edward Porowski, telephone interviews May 1996, Santa Barbara, California to Piscataway, New Jersey. Former guard at MSP from 1946-1951.

Gerry Blust, April 1996, Middlesex, New Jersey. Bechtel, Site Manager MSP.

Bibliography

Primary Sources

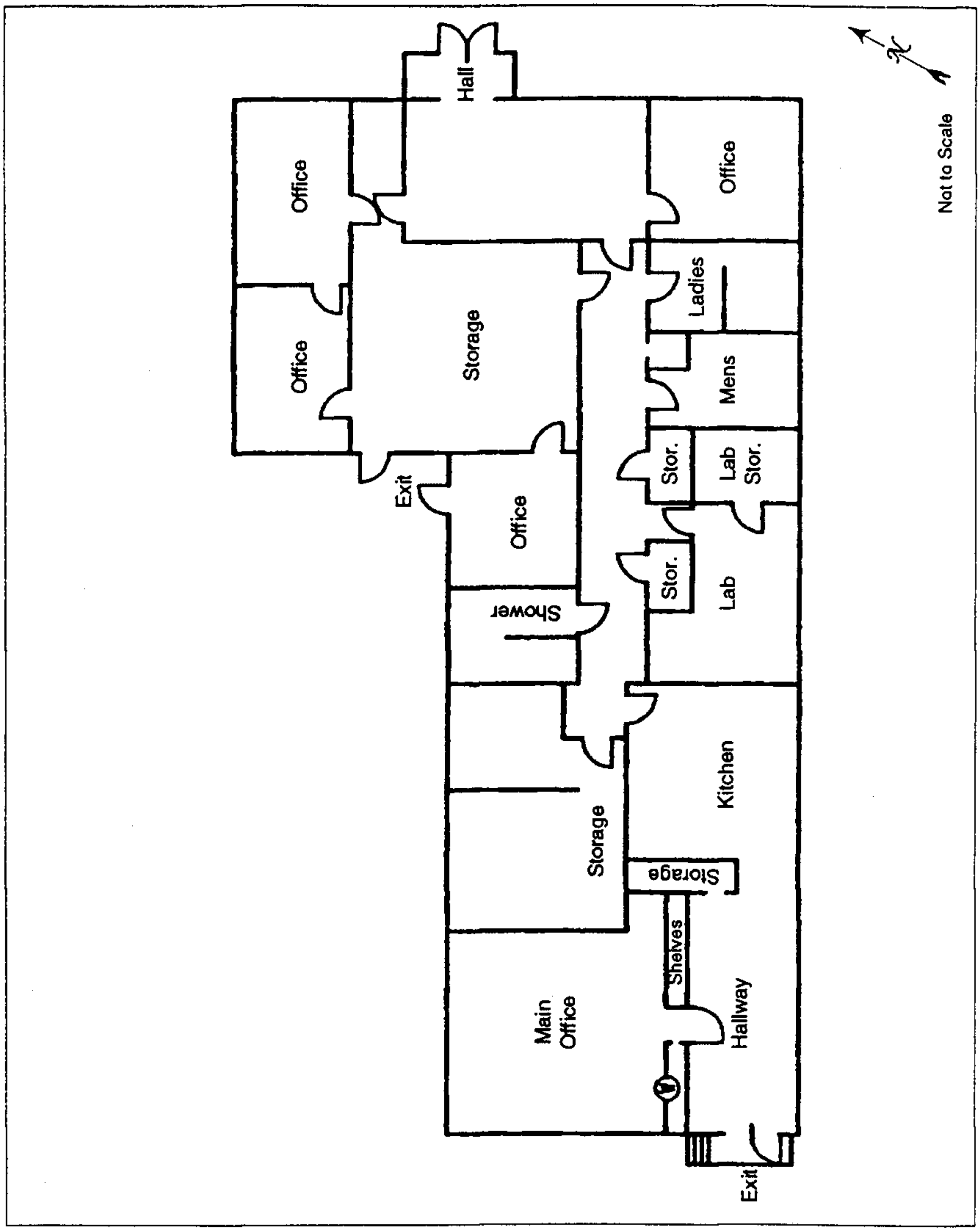
Borough of Middlesex Tax Assessors Records, Block 318, Lot 1A. Located at Middlesex Tax Assessor's Office.

Secondary Sources

Cahalane, R.W. *The History of the Middlesex Sampling Plant.* Cincinnati, Ohio: National Lead Company of Ohio, 1958. NLCO-733 Special. Contract Number AT (30-1)-1156.

Maps

1927 corrected to 1948. "Bound Brook, New Jersey, including South Bound Brook, Somerset County, and Middlesex, Middlesex County, New Jersey." The Sanborn Map Company, New York, New York.



ADMINISTRATION BUILDING FLOOR PLAN. 1996

HISTORIC AMERICAN ENGINEERING RECORD

INDEX TO PHOTOGRAPHS

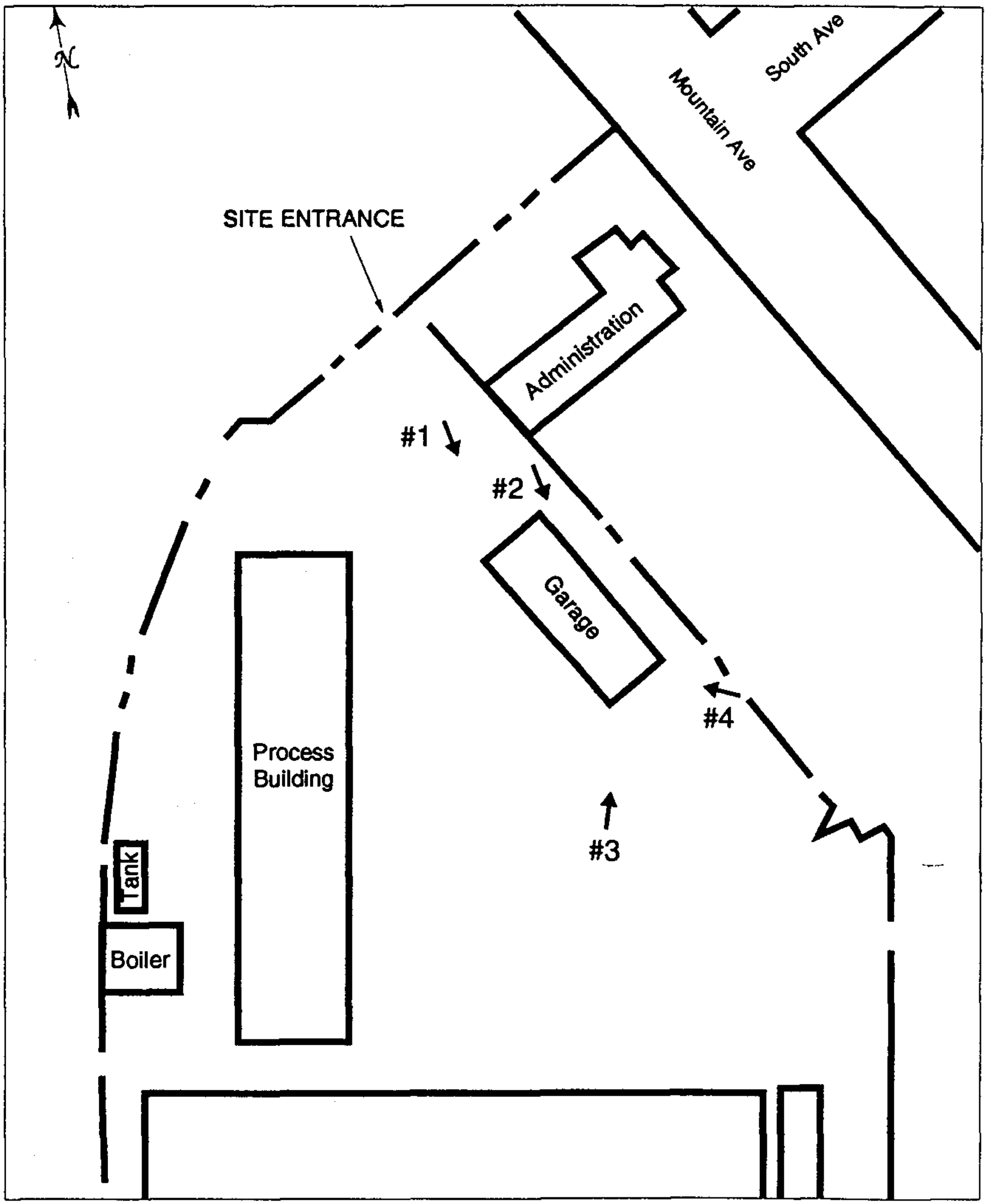
MIDDLESEX SAMPLING PLANT, GARAGE
239 Mountain Avenue
Middlesex
Middlesex County
New Jersey

HAER NO. NJ-107-D

Dennis L. Hellawell, Photographer

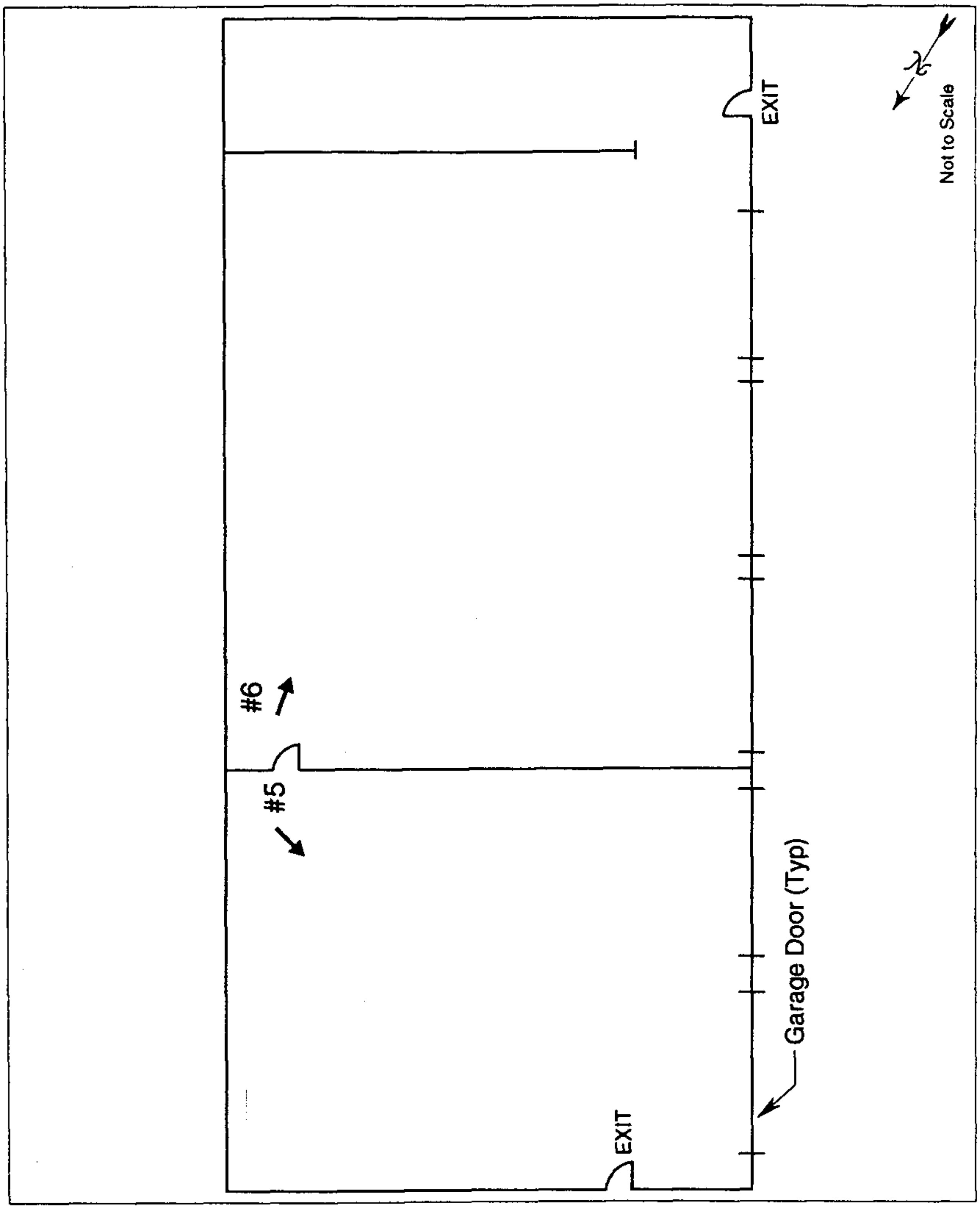
April 24 & 26, 1996

NJ-107-D-1	GARAGE, NORTH ELEVATION
NJ-107-D-2	GARAGE, NORTHEAST OBLIQUE
NJ-107-D-3	GARAGE, SOUTHWEST OBLIQUE
NJ-107-D-4	GARAGE, SOUTHEAST OBLIQUE
NJ-107-D-5	GARAGE INTERIOR, NORTH BAY
NJ-107-D-6	GARAGE INTERIOR, SOUTH BAY



LAYOUT OF MIDDLESEX SAMPLING PLANT. 1996

KEY TO PHOTOGRAPHS
MIDDLESEX SAMPLING PLANT, GARAGE
HAER NO. NJ-107-D
(Page 3)



GARAGE FLOOR PLAN. 1996

MIDDLESEX SAMPLING PLANT, GARAGE
239 Mountain Avenue
Middlesex
Middlesex County
New Jersey

HAER No. NJ-107-D

HAER
NJ
12-MIDSX,
1D-

PHOTOGRAPHS

WRITTEN HISTORICAL AND DESCRIPTIVE DATA

HISTORIC AMERICAN ENGINEERING RECORD
National Park Service
Northeast Region
Philadelphia Support Office
U.S. Custom House
200 Chestnut Street
Philadelphia, P.A. 19106

HISTORIC AMERICAN ENGINEERING RECORD

MIDDLESEX SAMPLING PLANT, GARAGE

HAER NO. NJ-107-D

HAER
NJ
12-MIDSX,
D-

Location:

239 Mountain Avenue
Middlesex, Middlesex County
New Jersey
UTM: Zone 0018, Easting 542994.49963, Northing 4491095.76065
Quad: Plainfield, New Jersey, 1:24,000

Dates of Construction: 1950, 1970s

Engineer/Architect: Unknown

Present Owner:

U.S. Department of Energy
Oak Ridge Operations Office
P.O. Box 2001
Oak Ridge, TN 37831-8723

Present Use: Storage

Significance: This six-car garage was part of the Middlesex Sampling Plant used between 1943-67 for sampling uranium, beryllium, and thorium for the Manhattan Engineer District/Atomic Energy Commission for use in the development of atomic weapons. This work was part of a top-secret nationwide fabricating effort during World War II to develop an atom bomb, and post-war, to create atomic weapons as part of President Harry S. Truman's Cold War policy of military supremacy over the Soviet Union.

Project Information Statement: The Formerly Utilized Sites Remedial Action Program (FUSRAP) of the U.S. Department of Energy (DOE) will demolish the process building and the boiler house as part of site remediation and decontamination. A Memorandum of Agreement between the DOE-Former Sites Restoration Division (FSRD) and the New Jersey SHPO stipulated HAER documentation to mitigate this adverse effect. This documentation was undertaken to fulfill this stipulation.

Alexandra C. Cole
Formerly Utilized Sites Remédial Action Program
Contract No. DE-AC05-91OR21950
Science Applications International Corporation (SAIC)
816 State Street, Suite 500
Santa Barbara, CA 93101

NARRATIVE DESCRIPTION

The six-car garage is a one-and-one-half story rectangular building of wood frame covered with stucco, measuring 36 feet by 96 feet. The flat roof is constructed of plywood covered with rolled asphalt roofing. The interior structural system consists of ten concrete piers topped by wood posts and trusses. On the west side are five roll-up wooden doors of paneled wood with top rows of windows. Four are identical in height and the fifth is lower. At the south corner of the west side is a single personnel door of wood. There are six-over-six pane double-hung wood sash windows on the first floor on the north, south, and east sides, and square fixed one-over-one pane windows at the mezzanine level on the west and south sides.

The interior is divided into three rooms, with spaces for two cars, three cars, and storage, respectively. An office space is located on the mezzanine at the south end of the building, reached by a flight of wooden stairs. The floors are concrete. The lighting is fluorescent.

There have been numerous alterations to this building. The original garage, constructed in 1950, was a shed-roof wood-frame building with corrugated metal siding. A 5-foot wide concrete apron extended along the front (west) of the building (Cahalane 1958:15). At some time, probably after 1969 when the Marine Sixth Motor Transport Battalion Reserves were stationed on the property, the roof was raised 8 feet to provide a mezzanine area, the front was extended 5 feet to encompass the original exterior apron, and stucco siding was added. The "ghost" of the original building outline is visible through cracks in the stucco siding.

The garage was used for parking cars during the MED period, and for trucks during the Marine period. It is currently used for parking trucks and as a workshop.

Sources of Information:

Interviews

Edward Porowski, telephone interviews May 1996, Santa Barbara, California to Piscataway, New Jersey. Former guard at MSP from 1946-1951.

Gerry Blust, April 1996, Middlesex, New Jersey. Bechtel, Site Manager MSP.

Bibliography

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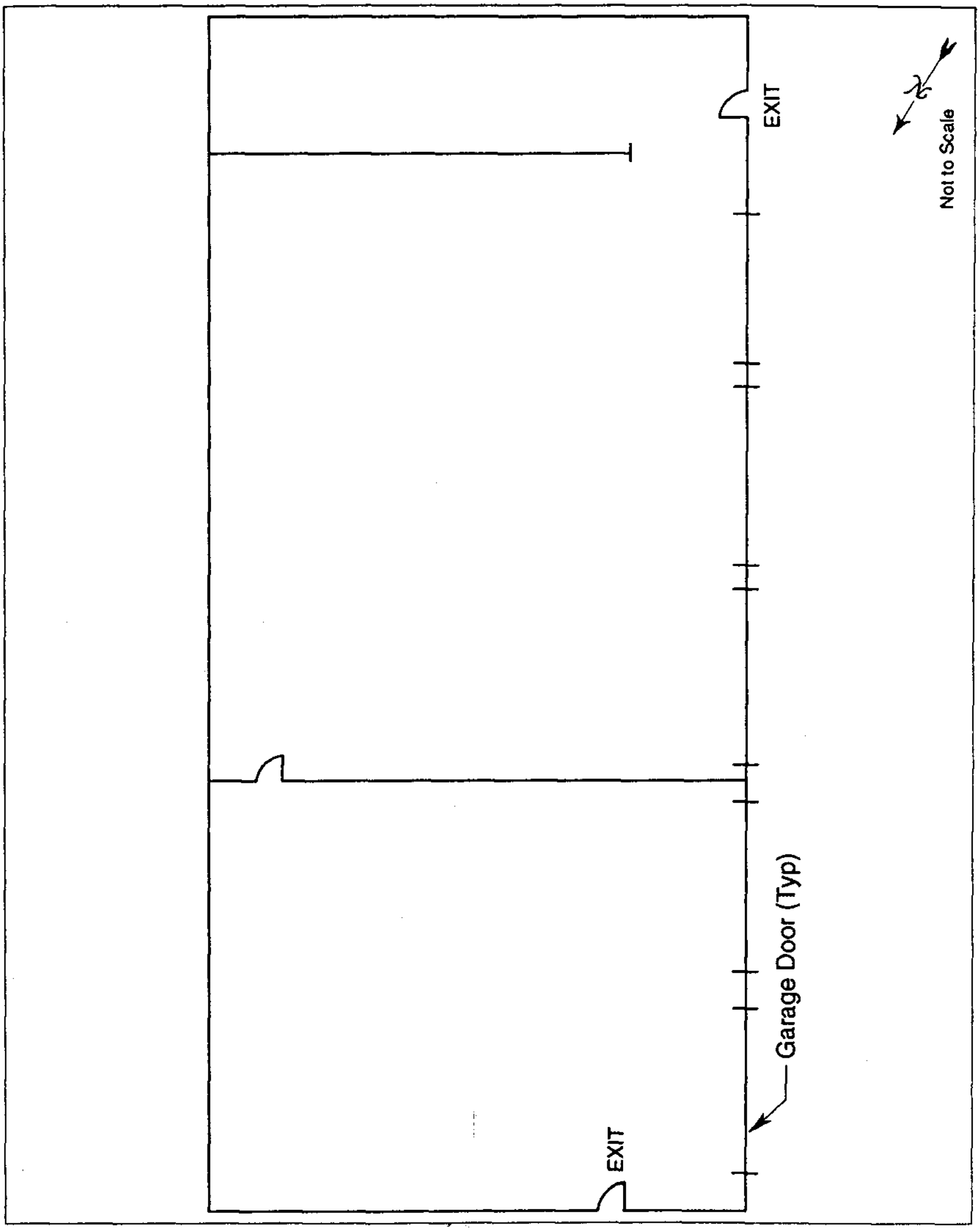

GARAGE FLOOR PLAN. 1996

HAER No. NJ-107-C-7

HAER No. NJ-107-C-1

HAER No. NJ-107-C-2

HAER No. NJ-107-C-3

HAER No. NJ-107-C-4

HAER No. NJ-107-C-5

HAER No. NJ-107-C-6

Appendix B
Off-Site Groundwater Delineation Investigation

URS **Draft**

Date: September 29, 2005
To: Helen Shannon – USEPA Region 2
Andy Crossland – USEPA Region 2
From: Britt Quinby – URS Buffalo
CC: Robin Wankum – USACE - NWK
Rich Johannes– URS Overland Park
Steve Krone – URS Cranford
Subject: Technical Memorandum Middlesex Sampling Plant Groundwater Delineation

1.0 INTRODUCTION

Data gaps were identified after completion of the Groundwater Operable Unit Remedial Investigation (RI) for the Middlesex Sampling Plant (MSP). The distribution of contaminants of concern in groundwater at MSP was not fully delineated within the RI. There were also uncertainties regarding the direction of the groundwater flow in the northern portion of the site. For these reasons the U.S. Army Corps of Engineers (USACE) requested that URS perform an additional investigation that addressed these issues. This technical memorandum presents a summary of the investigation and its results.

A three-phased approach to the investigation, described in the March 29, 2004, technical memorandum to USACE, was recommended. All work was conducted according to guidelines outlined in the approved Groundwater Operable Unit Work Plan dated December 2000. A summary of the phases follows. Details on the scope and on specific activities are presented in Sections 2.0 and 3.0, respectively. Results are presented in Section 4.0 and conclusions in Section 5.0. A summary is provided as Section 6.0. An overall description of the phases follows.

Phase I

The purpose of Phase I was to evaluate groundwater quality and any potential impacts from the site on offsite locations downgradient and sidegradient of MSP, and to better determine direction of groundwater flow in the northern portion of the site. Offsite groundwater quality was evaluated by collecting groundwater samples from the overburden zone via direct-push technology (DPT) at eight locations. The groundwater flow direction in the northern portion of the site was determined by installing nine piezometers, then obtaining water level measurements from these piezometers and from existing wells. The information obtained during Phase I was then used to determine the number and locations of additional bedrock/overburden monitoring well pairs to be installed during Phase II.

Phase II

Phase II consisted of the placement of four bedrock/overburden monitoring well pairs along the perimeter of the northern portion of the site. The primary function of these wells was to monitor groundwater quality and flow to/from the site (i.e., sentinel wells).

Phase III

Phase III included obtaining groundwater elevations from all existing site wells and piezometers and the sampling and analysis of groundwater from sentinel bedrock/overburden monitoring wells.

2.0 SCOPE OF WORK

The scope of work, described in the March 29, 2004, technical memorandum referenced above, is as follows:

Phase I

The DPT groundwater sampling locations included as part of Phase I (and presented in Figure 1) are based on review of overburden and bedrock groundwater analytical data compiled over the last nine sampling events. This included seven quarterly Environmental Surveillance and two groundwater RI sampling efforts. HydroPunch locations and placement rationales are described below. In all cases, results have been compared to the more stringent of Safe Drinking Water Act Maximum Contaminant Levels (MCLs) or New Jersey Class IIA Groundwater Quality Criteria. These are referred to generically here as the Comparison Criteria values.

1. HP-1 and HP-2 – Off site, north and northeast of B18W24S, across from the Absolute Auto Salvage Yard access road, and adjacent to the railway. The choice of these locations is based upon:
   a. Consistent exceedances of Comparison Criteria values for net alpha in groundwater collected from B18W24S, where concentrations ranged from 19.13 pCi/L to 68.80 pCi/L.
   b. Consistent exceedances of Comparison Criteria values for total uranium in groundwater collected from B18W24S, where concentrations ranged from 140 µg/L to 761 µg/L.
   c. The need to provide information on groundwater elevations and flow direction in the area downgradient of B18W24S.
2. HP-3, HP-4, HP-5, and HP-6 – Off site, east and southeast of URSMW2S/2D, and along Mountain Avenue. The choice of these locations is based on:
   a. Consistent exceedances of Comparison Criteria values for carbon tetrachloride in groundwater collected from URSMW2D, where concentrations ranged from 34.5 µg/L to 46.2 µg/L.
   b. Consistent exceedances of Comparison Criteria values for chloroform in groundwater collected from URSMW2D, where concentrations ranged from 19.4 µg/L to 22.4 µg/L.
   c. Consistent exceedances of Comparison Criteria values for trichloroethene in groundwater collected from URSMW2D, where concentrations ranged from 29.1 µg/L to 35.7 µg/L.
   d. The need to provide, if possible, offsite contaminant delineation downgradient and sidegradient of URSMW2S/2D (i.e., east of the site).
3. HP-7 and HP-8 – Off site, and northeast and southeast of B18W28SR. The choice of these locations is based on:
   a. Consistent exceedances of Comparison Criteria values for net alpha in groundwater collected from B18W28SR, where concentrations ranged from 15.2 pCi/L to 15.89 pCi/L.
   b. Consistent exceedances of Comparison Criteria values for total uranium in groundwater collected from B18W28SR, where concentrations ranged from 30.3 µg/L to 103 µg/L.
   c. The need to provide information on groundwater elevations and flow direction in the area downgradient of B18W28SR.

Grab samples of groundwater were collected from each location and analyzed for volatile organic compounds (VOCs) and radionuclides on a 14-day turnaround schedule.

Upon completion of DPT sampling, nine onsite piezometers (PZs) were installed at locations shown in Figure 1. The PZs were positioned to gain water table elevation data, which was intended to provide a better understanding of groundwater flow in the northern portion of the site. (Specifically, these PZs were installed in the area adjacent to the process building and the garage, where a suspected groundwater divide occurs). Additional PZs were placed in the northeast corner of the site and along the southern portion of the western boundary to provide water table elevation data between existing monitoring wells B18W25S and B18W27S.

Phase II

Upon review of the offsite DPT grab sample analytical results, permanent monitoring wells were installed at locations deemed suitable for sentinel wells. The permanent monitoring wells were installed as bedrock/overburden pairs. The locations, shown in Figure 2, include URSMW21S&D west of the process building foundation; URSMW22S&D along the northeast boundary of the site; URSMW23S&D along the northwest boundary of the site; and URSMW24S&D near the Administration Building along the northern boundary of the site. URSMW22S was created from URSPZ-5, and URSMW23S was created from URSPZ-3.

The abandonment of MSP-12 and replacement with URSMW22S was also included in Phase II due to the questionable nature of water table elevation data collected from MSP-12. MSP-12 was used for groundwater elevation data only, and anomalies noted during measuring activities of this well suggested that the well's integrity may have been compromised.

Phase III

The scope of Phase III covered the analysis of the groundwater samples collected. GPL Laboratories analyzed each sample for VOCs, semi-volatile organic compounds (SVOCs), and metals. Eberline Laboratories also analyzed the samples for radionuclides.

3.0 ACTIVITIES

Phase I

Phase I field activities began on July 6, 2004, and were completed on July 20, 2004. Table 1 presents details on when each DPT and piezometer was installed, to what depth, and when it was sampled. The DPT contractor who performed the work was Environmental Probing Investigations.

DPT was used in the installation of one-inch diameter temporary well screens by means of a Geoprobe® truck-mounted hydraulic sampler. DPT involves advancing a drive point by direct hydraulic pressure. Boreholes were to be advanced using a 2.5-3.0-inch diameter drive point attached to one or two-inch diameter drill rods, which were placed under hydraulic downward pressure. During the first attempts to advance DPT sampling tools, it became apparent that the density of overburden materials precluded the collection of groundwater samples from the required depths. Phase I sampling was subsequently conducted by temporarily placing 5-foot lengths of one-inch diameter PVC well screen inside boreholes drilled with a 6-inch outside diameter hollow-stem auger (HSA). The temporary wells, which contained stainless steel mesh PrePak® filter pack, were screened in the overburden aquifer.

HSA technology was used to install 2-inch diameter PVC piezometers. Boreholes were advanced using a 4¼-inch inner diameter hollow stem auger. Details of PZ installation are provided in the March 29, 2004, technical memorandum and in the approved Groundwater Operable Unit Work Plan**.**

Phase II

Upon confirmation of permanent groundwater delineation well locations (based on analytical results from Phase I), overburden and shallow bedrock paired well clusters were installed using a truck-mounted auger rig. With several exceptions, the groundwater delineation and onsite groundwater elevation wells were installed as described in the March 29, 2004, technical memorandum and the approved Groundwater Operable Unit Work Plan. The exceptions were as follows: (1) Split-spoon samples and rock cores were not collected, but determination of the thickness of overburden, depths to weathered bedrock, and depths to competent bedrock was made based on drill cuttings and feedback from the driller; (2) Because of its very low yield and slow recovery during development, URSMW24S was considered to be fully developed after the removal of three borehole volumes rather than the five volumes called for in the Work Plan.

Phase II activities began in October 7, 2004, and all but the abandonment of MSP-12 were completed by November 11, 2004. MSP-12 was abandoned on December 6, 2004, after the appropriate well permit information had been provided by USACE and approval had been obtained from the New Jersey Department of Environmental Protection (NJDEP).

Phase III

Phase III began on November 17, 2004, with well sampling and water level recording. This phase was completed by November 19, 2004. Table 2 presents a summary of the wells sampled, the date sampled, and the parameters analyzed.

4.0 RESULTS

Phase I

The locations of the offsite DPT samples and onsite piezometers are shown in Figure 1. The results of the piezometer and well water level measurements taken on August 23, 2004, are listed on Table 3. The groundwater contours constructed from these data are shown in Figure 3 for the overburden zone, and in Figure 4 for the bedrock zone.

Sample results for VOCs are listed on Table 4, and for radionuclides on Table 5. VOC results are also presented in Figure 5, and radionuclide results in Figure 6. Six VOCs exceed Comparison Criteria values. These are:

- Tetrachloroethene in HP-5 at 4.8 µg/L
- Trichloroethene in HP-5 and PZ-4 at 3.9 and 3.8 J µg/L respectively
- MTBE in PZ-8 at 280 µg/L
- Tert-butyl-alcohol in PZ-8 at 290 µg/L
- Carbon tetrachloride in PZ-4 at 89 J µg/L
- Chloroform in PZ-4 at 30 J µg/L

Only one radionuclide result was found to exceed Comparison Criteria values. This was total uranium in URSPZ-9, which was measured at 62.2 µg/L.

Phase II

Phase II covered only the installation of the new wells, whose locations are shown in Figure 2.

Phase III

The results of the piezometer and well water level measurements taken on November 16, 2004, are listed on Table 6, with the groundwater contours constructed from these data shown in Figure 7 for the overburden zone and Figure 8 for the bedrock zone.

VOC sample results are listed on Table 7, SVOC results on Table 8, metals results on Table 9, and radionuclide results on Table 10. VOC results are also presented in Figure 9 and radionuclides in Figure 10.

- Four VOCs were found to exceed Comparison Criteria values. All are in the bedrock wells. No exceedances were identified in the overburden wells. The exceedances were as follows:
    - Carbon tetrachloride in URSMW24D and URSMW2D at 430 µg/L and 19 µg/L, respectively.
    - MTBE in URSMW3D at 120 µg/L
    - Chloroform in URSMW24D at 41 J µg/L
    - Trichloroethene in URSMW22D, URSMW2D, and URSMW24D at 1.3 µg/L, 23 µg/L, and 24 µg/L, respectively.

- The only SVOC identified above the Comparison Criteria value was bis (2-ethylhexyl) phthalate in URSMW24D, URSMW2D, URSMW23D, and URSMW2S at 31 J µg/L, 6.7 µg/L, 13 µg/L, and 13 µg/L, respectively. However, this is a common laboratory contaminant.

- Levels of both iron and manganese were identified at levels above Comparison Criteria values, as follows:
    - Iron in bedrock wells URSMW21D, 22D, 23D, and 24D, measured at levels ranging from 1,160 to 4,330 µg/L. Exceedances of Comparison Criteria values for iron were identified in the overburden well URSMW21S at 8,890 µg/L.
    - Manganese was detected in two overburden wells URSMW21S and URSMW22S, and measured 1,060 µg/L and 418 µg/L, respectively.

- Arsenic was identified in URSMW2S at a level slightly above the criteria at 9.1 µg/L (criteria of 8 µg/L)

- Four samples were identified with slightly elevated net alpha levels. Collected from the overburden/bedrock pairs URSMW23S/23D and URSMW24S/24D, they exhibited concentrations ranging from 18.7 to 34.0 J pCi/L.

- Two samples were identified that exceeded the comparison criteria for total uranium. They were URSMW23S at 38.3 µg/L, and URSMW2S at 67.0 µg/L.

TABLES:

FIGURES:

Figure 1 – Hydropunch and Piezometer Installation Locations
Figure 2 – Phase II Well Installation Locations
Figure 3 – Monitoring Well Locations and Overburden Groundwater Contours – August 23, 2004
Figure 4 – Bedrock Monitoring Well Locations and Groundwater Contours – August 23, 2004
Figure 5 – Phase I Groundwater Delineation Hydropunch and Piezometer VOC Results
Figure 6 – Phase I Groundwater Delineation Hydropunch and Piezometer RAD Results
Figure 7 – Overburden Groundwater Contours With Flow Directions – November 16, 2004
Figure 8 – Bedrock Groundwater Contours With Flow Directions – November 16, 2004
Figure 9 – Phase III Groundwater Delineation VOC Results
Figure 10 – Phase III Groundwater Delineation RAD Results

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Table 1
Completion and Sampling Summary
Phase I Temporary Monitoring Wells and Piezometers
Middlesex Sampling Plant
Middlesex, New Jersey

Location	Date Installed	Date Sampled	Date of Results rec'd from GPL	Analysis (1)	Depth (Ft. BGS)	Depth to Water (Ft. BGS)
HP-1	7/13/2004	Not Sampled			15	- -
	7/16/2004				25	- -
HP-2	7/9/2004	7/13/2004	7/21/2004	VOCs & Radionuclides	20	7.9
HP-3	7/13/2004	7/15/2004	7/23/2004	VOCs & Radionuclides	15	13
HP-4	7/13/2004	7/14/2004	7/21/2004	VOCs & Radionuclides	15	Not Recorded
HP-5	7/19/2004	7/19/2004	7/27/2004	VOCs & Radionuclides	15	13
HP-6	7/7/2004	7/7/2004	7/15/2004	VOCs & Radionuclides	15	Not Measurable
HP-7	7/8/2004	7/8/2004	7/15/2004	VOCs & Radionuclides	25	22.0 *
HP-8	7/8/2004	7/8/2004	7/15/2004	VOCs & Radionuclides	25	18.0 *
PZ-1	7/12/2004	7/13/2004	7/21/2004	VOCs & Radionuclides	14.5	12.8
PZ-2	7/14/2004	7/14/2004	7/21/2004	VOCs & Radionuclides	15	8.0
PZ-3	7/14/2004	7/15/2004	7/23/2004	VOCs & Radionuclides	15	11
PZ-4	7/9/2004	7/13/2004	7/21/2004	VOCs & Radionuclides	14.5	6.9
PZ-5	7/14/2004	7/15/2004	7/23/2004	VOCs & Radionuclides	15	8.3
PZ-6	7/15/2004	7/15/2004	7/23/2004	VOCs & Radionuclides	15	10
PZ-7	7/15/2004	7/16/2004	7/27/2004	VOCs & Radionuclides	15	6.5
PZ-8	7/16/2004	7/16/2004	7/27/2004	VOCs & Radionuclides	15	8.6
PZ-9	7/12/2004	7/13/2004	7/21/2004	VOCs & Radionuclides	14.5	9.2

NOTES:

All HP locations use 10 feet of pre-packed 0.75-inch ID screens.
All PZ locations use 10 feet of 2-inch diameter, 10-slot PVC screens.
* Ground water level is not a stabilized reading.
\- - No measurable ground water since completion.
BGS = Below Ground Surface

(1) VOCs = Volatile organic Compounds including MTBE, TBA, and DIPE.
Radionuclides = Total Uranium, Isotopic Uranium, Isotopic Thorium, Radon 226/228, Gross α & β.

(2) Sampling for Radionuclides is pending additional groundwater accumulation in this HP location.

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Table 2
Summary of Monitoring Wells Sampled
Ground Water Delineation - Phase III
Middlesex Sampling Plant
Middlesex, New Jersey

Monitoring Well Identification	Date Sampled	Analysis Performed [1]
Overburden		
URSMW2S	26-Oct-04	VOCs, SVOCs, Metals, Radionuclides
URSMW21S	17-Nov-05	VOCs, SVOCs, Metals, Radionuclides
URSMW22S	18-Nov-04	VOCs, SVOCs, Metals, Radionuclides
URSMW23S	19-Nov-04	VOCs, SVOCs, Metals, Radionuclides
URSMW24S	19-Nov-04	VOCs, SVOCs, Metals, Radionuclides
Bedrock		
URSMW2D	27-Oct-04	VOCs, SVOCs, Metals, Radionuclides
URSMW3D	16-Nov-04	VOCs
URSMW9D	16-Nov-04	VOCs
URSMW11D	16-Nov-04	VOCs
URSMW21D	17-Nov-04	VOCs, SVOCs, Metals, Radionuclides
URSMW22D	18-Nov-04	VOCs, SVOCs, Metals, Radionuclides
URSMW23D	18-Nov-04	VOCs, SVOCs, Metals, Radionuclides
URSMW24D	18-Nov-04	VOCs, SVOCs, Metals, Radionuclides

Notes:

(1) Target Compound List (TCL) organics
VOC = Volatile Organic Compounds including TBA, MTBE, DIPE
SVOC = Semivolatile Organic Compounds
Target Analyte List (reduced) metals

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Table 3
Groundwater Elevation Data - August 23, 2004
Ground Water Delineation - Phase I Monitoring Wells and Piezometers
Middlesex Sampling Plant
Middlesex, New Jersey

Monitoring Well Identification	Northing NJ State Plane NAD 83	Easting NJ State Plane NAD 83	Top of Casing Elevation (FAMSL)	Depth to Water (FBTOR)	Ground Water Elevation (FAMSL)
Overburden					
PZ-1	633057.268	494434.069	61.97	12.22	49.75
PZ-2	632967.129	494310.370	61.21	11.48	49.73
PZ-3	632891.975	494222.455	61.84	10.65	51.19
PZ-4	632781.688	494374.349	59.41	8.34	51.07
PZ-5	632741.658	494574.840	60.18	5.77	54.41
PZ-6	632580.410	494230.187	57.79	5.21	52.58
PZ-7	632583.597	494484.383	58.13	4.25	53.88
PZ-8	632207.496	494112.368	53.87	3.20	50.67
PZ-9	632932.912	494411.234	61.02	10.91	50.11
URSMW1S	633015.064	494381.833	61.68	10.55	51.13
URSMW2S	632694.697	494354.241	59.63	5.56	54.07
URSMW4S	632475.989	494339.262	57.38	4.09	53.29
URSMW5S	632485.147	494568.157	57.42	7.84	49.58
URSMW6S	632252.358	494330.790	54.37	3.80	50.57
URSMW7SR	632263.490	494380.550	54.57	3.91	50.66
URSMW8S	632201.082	494478.811	54.52	6.70	47.82
URSMW10S	632200.125	494360.692	53.80	4.97	48.83
URSMW11S	632196.902	494569.932	55.09	9.08	46.01
URSMW12S	631961.315	494351.536	49.39	3.01	46.38
URSMW13S	631960.316	494449.661	51.48	5.90	45.58
URSMW14S	631907.241	494349.073	49.20	3.30	45.90
URSMW15S	631910.087	494448.324	51.11	5.51	45.60
URSMW16S	631844.430	494382.575	49.03	2.82	46.21
URSMW20S	Far Offsite		54.79		
B18W24S	632928.852	494285.085	60.48	8.91	51.57
B18W25S	632483.190	494196.619	56.86	4.55	52.31
B18W26S	632338.620	494378.026	54.67	4.05	50.62
B18W27SR	632031.997	494154.038	52.42	4.57	47.85
B18W28SR	632028.590	494390.401	51.86	6.75	45.11
B18W29SR	632031.850	494567.640	53.51	5.22	48.29
B18W30S	631838.721	494383.489	49.11	3.11	46.00
Bedrock					
URSMW1D	633019.486	494378.837	61.72	23.51	38.21
URSMW2D	632699.498	494354.546	59.91	19.31	40.60
URSMW3D	632479.074	494197.078	57.07	18.91	38.16
URSMW5D	632490.283	494568.247	57.59	19.28	38.31
URSMW9D	632039.945	494151.114	53.10	12.20	40.90
URSMW11D	632202.043	494570.252	55.13	17.96	37.17
URSMW20D	Far Offsite		55.46		

Notes:

FAMSL - Feet above mean sea level.

FBTOR - Feet below top of inner riser

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Table 4
Summary Analytical Results - VOCs
Groundwater Delineation - Phase I Temporary Monitoring Wells and Piezometers
Middlesex Sampling Plant
Middlesex, New Jersey

Location ID: Date Collected: Analysis Type: Matrix: Unit: Analyte	NJDEP CLASS IIA GW QUALITY STANDARDS µg/L	NJ STATE PRIMARY DRINKING WATER STANDARDS	USEPA NATIONAL PRIMARY DRINKING WATER REGS	URSPZ-1 7/13/04 REG Water µg/L	URSPZ-2 7/14/04 REG Water µg/L	URSPZ-3* 7/15/04 REG Water µg/L	URSPZ-4 7/13/04 REG Water µg/L	URSPZ-5* 7/13/04 REG Water µg/L	URSPZ-6 7/13/04 REG Water µg/L	URSPZ-7 7/13/04 REG Water µg/L	URSPZ-8 7/13/04 REG Water µg/L	URSPZ-9 7/13/04 REG Water µg/L	HP-2 7/13/04 REG Water µg/L	HP-3 7/15/04 REG Water µg/L	HP-4 7/14/04 REG Water µg/L	HP-5 7/19/04 REG Water µg/L	HP-6 7/7/04 REG Water µg/L	HP-7 7/8/04 REG Water µg/L	HP-8 7/8/04 REG Water µg/L
1,1-Dichloroethane	50	50	NE	1.0 UJ	1.0 UJ	1.0 U	1.0 UJ	1.0 U	1.0 U	1.0 U	1.0 U	1.0 UJ	1.0 UJ	1.0 U	1.0 UJ	1.2	1.0 U	1.0 U	1.0 U
1,1-Dichloroethene	2	2	7	1.0 UJ	1.0 UJ	1.0 U	1.0 UJ	1.0 U	1.0 U	1.0 U	1.0 U	1.0 UJ	1.0 UJ	1.0 U	1.0 UJ	1.5	1.0 U	1.0 U	1.0 U
1,4-Dichlorobenzene	75	75	75	1.0 UJ	1.0 UJ	1.0 U	1.3 J	1.0 U	1.0 U	1.0 U	1.0 U	1.0 UJ	1.0 UJ	1.0 U	1.0 UJ	1.0 U	2	1.0 U	1.0 U
Acetone	700	NE	NE	5.0 UJ	13 J	5.0 U	8.1 J	5.0 U	5.0 U	5.0 U	5.0 U	5.0 UJ	5.0 UJ	7.2	5.0 UJ	5.0 U	5.8	5.0 U	5.0 U
Benzene	1	1	5	1.0 UJ	1.0 UJ	1.0 U	0.5 J	1.0 U	1.0 U	1.0 U	1.0 U	1.0 UJ	1.0 UJ	1.0 U	1.0 UJ	0.40 J	0.39 J	0.77 J	1.0 U
Bromodichloromethane	1	NE	NE	1.0 UJ	1.0 UJ	1.0 U	1.0 UJ	1.0 U	1.0 U	1.0 U	1.0 U	1.0 UJ	1.0 UJ	1.0 U	1.0 UJ	1.0 U	1.0 U	1.0 U	1.0 U
Bromoform	4	NE	NE	1.0 UJ	1.0 UJ	1.0 U	1.0 UJ	1.0 U	1.0 U	1.0 U	1.0 U	1.0 UJ	1.0 UJ	1.0 U	1.0 UJ	1.0 U	1.0 U	1.0 U	1.0 U
Bromomethane	10	10	NE	1.0 UJ	1.0 UJ	1.0 U	1.0 UJ	1.0 U	1.0 U	1.0 U	1.0 U	1.0 UJ	1.0 UJ	1.0 U	1.0 UJ	1.0 U	1.0 U	1.0 U	1.0 U
Carbon Disulfide	800	NE	NE	3.1 UJ	1.0 UJ	1.2 U	3.4 UJ	1.0 U	1.3 U	1.0 U	1.3 U	4.1 UJ	1.6 UJ	1.5 U	1.0 UJ	1.0 U	1.0 U	1.0 U	1.0 U
Carbon Tetrachloride	2	2	5	1.0 UJ	1.0 UJ	1.0 U	**89 J**	1.0 U	1.0 U	1.0 U	1.0 U	1.0 UJ	1.0 UJ	1.0 U	1.0 UJ	1.0 U	1.0 U	1.0 U	1.0 U
Chloroform	6	6	NE	1.0 UJ	1.0 UJ	1.0 U	**30 J**	1.0 U	1.0 U	1.0 U	1.0 U	1.0 UJ	1.0 UJ	1.0 U	1.0 UJ	1.0 U	1.0 U	1.0 U	1.0 U
cis-1,2-Dichloroethene	10	70	70	1.0 UJ	1.0 UJ	1.0 U	1.8 J	0.43 J	1.0 U	1.0 U	1.0 U	1.0 UJ	1.0 UJ	1.0 U	1.0 UJ	6.5	1.0 U	1.0 U	1.0 U
Ethylbenzene	700	700	700	1.0 UJ	0.54 J	1.0 U	1.0 UJ	1.0 U	1.0 U	1.0 U	1.0 U	1.0 UJ	1.0 UJ	0.78 J	1.0 UJ	1.0 U	1.0 U	1.0 U	1.0 U
Isopropyl Ether	20,000	NE	NE	1.0 UJ	1.0 UJ	1.0U	1.0 UJ	1.0 U	1.0 U	1.0 U	1.2	1.0 UJ	1.0 UJ	1.0 U	1.0 UJ	1.0 U	1.0 U	1.0 U	1.0U
Methylene Chloride	2	3	5	2.2 UJ	1.0 UJ	1.0 U	5.7 UJ	1.0 U	1.0 U	1.0 U	1.0 U	4.7 UJ	1.0 UJ	1.0 U	1.0 UJ	1.0 U	1.9 U	4.5 U	5.2 U
Methyl tert-butyl ether	70	70	NE	1.0 UJ	1.0 UJ	1.0 U	0.68 J	8.3	1.6	6.7	**280**	1.0 UJ	1.0 UJ	1.0 U	2.9 J	1.0 U	1.0 U	5.8	1.3
Tert-butyl alcohol	100	NE	NE	20 UJ	20 UJ	20 U	20 UJ	20 U	20 U	20 U	**290**	20 UJ	20 UJ	20 U	20 UJ	20 U	20 U	20 U	20 U
Tetrachloroethene	1	1	5	1.0 UJ	1.0 UJ	1.0 U	1.0 UJ	0.63 J	1.0 U	1.0 U	1.0 U	1.0 UJ	1.0 UJ	1.0 U	1.0 UJ	**4.8**	1.0 U	1.0 U	1.0 U
Toluene	1000	1000	1000	1.0 UJ	1.8 J	1.0 U	1.0 UJ	1.0 U	0.62 J	1.0 U	1.0 U	1.0 UJ	1.0 UJ	2.6	1.0 UJ	1.0 U	1.0 U	0.34 J	1.0 U
Trichloroethene	1	1	5	1.0 UJ	1.0 UJ	1.0 U	**3.8 J**	1.0 U	1.0 U	1.0 U	1.0 U	1.0 UJ	1.0 UJ	1.0 U	1.0 UJ	**3.9**	1.0 U	1.0 U	1.0 U
m,p-Xylenes	1000	1000	10000	1.0 UJ	2.2 J	1.0 U	1.0 UJ	1.0 U	0.74 J	1.0 U	1.0 U	1.0 UJ	1.0 UJ	3.4	1.0 UJ	1.0 U	1.0 U	1.0 U	1.0 U
o-Xylene	1000	1000	10000	1.0 UJ	0.91 J	1.0 U	1.0 UJ	1.0 U	0.49 J	1.0 U	1.0 U	1.0 UJ	1.0 UJ	1.8	1.0 UJ	1.0 U	1.0 U	1.0 U	1.0 U

Notes:

Qualifiers

U - The compound was not detected above the laboratory method detection limit.

J - Result is regarded as estimated due to limitations identified during the data validation/quality assurance review.

R - Result regarded as unreliable. Analyte may or may not be present.

µg/L - micrograms per liter

NE - Not Established.

Boxed results - indicate an exceedance in applicable standards.

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Table 5
Summary Analytical Results - Radionuclides
Groundwater Delineation - Phase I Temporary Monitoring Wells and Piezometers
Middlesex Sampling Plant
Middlesex, New Jersey

Location ID: Date Collected: Analysis Type: Matrix: Unit:	New Jersey State Primary Drinking Water Standards MCL	USEPA Safe Drinking Water Act MCL	URSPZ-1 7/13/04 REG Water	URSPZ-2 7/14/04 REG Water	URSPZ-3** 7/14/04 REG Water	URSPZ-4 7/13/04 REG Water	URSPZ-5** 7/15/04 REG Water	URSPZ-6 7/15/04 DUP Water	URSPZ-7 7/16/04 REG Water	URSPZ-8 7/16/04 REG Water	URSPZ-9 7/13/04 REG Water	HP-2 7/13/04 REG Water	HP-3 7/15/04 REG Water	HP-4 7/14/04 REG Water	HP-5 7/19/04 REG Water	HP-6 7/7/04 REG Water	HP-7 7/8/04 REG Water	HP-8 7/8/04 REG Water
Actinium-228	NE	NE	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Bismuth-212	NE	NE	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Bismuth-214	NE	NE	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Gross Alpha	NE	NE	0.775 +/- 0.691 UJ	0.323 +/- 0.994 UJ	5.21 +/- 0.866	14.2 +/- 1.87J	0.769 +/- 0.402J	1.2 +/- 0.565	1.48 +/- 0.559	-1.81 +/- 1.01 UR	34.0 +/- 2.39 J	1.73 +/- 0.712 J	2.62 +/- 0.792 J	1.27 +/- 0.667 J	1.08 +/- 0.561	2.05 +/- 0.831 J	3.46 +/- 0.726	4.21 +/- 1.58 J
Gross Beta	NE	NE	6.65 +/- 0.620	6.93 +/- 0.676	10.1 +/- 0.943	10.6 +/- 0.919	2.09 +/- 0.344	4.99 +/- 0.811	4.33 +/- 0.539	6.24 +/- 0.679	27.3 +/- 1.09	1.91 +/- 0.442	5.34 +/- 1.04	3.92 +/- 0.413	5.02 +/- 0.828	9.63 +/- 0.734	8.12 +/- 0.922	11.7 +/- 1.31
Lead-212	NE	NE	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Lead-214	NE	NE	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Net Alpha	15	15	0.775 J	0.323 J	-3.2705 J	2.90 J	0.5498 J	0.69675 J	1.0355 J	NC	-8.20 J	-0.90 J	1.219 J	-1.1245 J	0.82255 J	0.88325 J	0.8665 J	2.393 J
Protactinium-234M	NE	NE	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Radium-226	NE	NE	0.395 +/- 0.247	0.205 +/- 0.201 UJ	0.00 +/- 0.170 UJ	0.949 +/- 0.325	0.167 +/- 0.224 UJ	0.315 +/- 0.207	0.237 +/- 0.237 UJ	0.320 +/- 0.260 UJ	1.04 +/- 0.393	0.361 +/- 0.192	0.594 +/- 0.436	0.332 +/- 0.237 UJ	0.246 +/- 0.180	0.0392 +/- 0.144 UJ	0.365 +/- 0.280 UJ	0.502 +/- 0.268
Radium-226+228	5	5	0.7325 J	0.299 J	0.094 J	1.454 J	0.223 J	0.7965 J	0.435 J	0.4595 J	1.486 J	4.651	0.795 J	0.268 J	1.246	0.9456 J	0.379 J	1.882 J
Radium-228	NE	NE	0.675 +/- 0.512 UJ	0.393 +/- 0.573 UJ	0.188 +/- 0.582 UJ	1.01 +/- 0.760 UJ	0.279 +/- 0.536 UJ	0.963 +/- 0.746 UJ	0.633 +/- 0.522 UJ	0.599 +/- 0.586 UJ	0.892 +/- 1.06 UJ	4.29 +/- 0.791	0.402 +/- 0.347UJ	0.204 +/- 0.549 UJ	1.00 +/- 0.491	0.926 +/- 0.485 J	0.393 +/- 0.602 UJ	1.38 +/- 0.531 J
Thallium-208	NE	NE	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Thorium-228	NE	NE	0.626 +/- 0.368	0.0961 +/- 0.274 UJ	0.163 +/- 0.279 UJ	-0.0977+/- 0.266 U	0.420 +/- 0.336 UJ	0.172 +/- 0.437 UJ	0.308 +/- 0.413 UJ	0.129 +/- 0.308 UJ	0.458 +/- 0.363 UJ	0.417 +/- 0.611 UJ	0.400 +/- 0.463 UJ	0.273 +/- 0.372 UJ	0.237 +/- 0.404 UJ	-0.0632 +/- 0.235 U	0.255 +/- 0.418 UJ	0.431 +/- 0.415 UJ
Thorium-230	NE	NE	0.695 +/- 0.446 R	1.83 +/- 0.551 R	1.00 +/- 0.459 R	1.32 +/- 0.471 R	1.06 +/- 0.431 J	1.46 +/- 0.528 R	1.31 +/- 0.458 R	2.01+/- 0.640 R	1.77 +/- 0.545 R	3.35 +/- 1.02 R	1.58 +/- 0.591 J	1.26 +/- 0.491 J	1.47 +/- 0.486 J	1.22 +/- 0.483 J	1.03 +/- 0.590 R	1.93 +/- 0.541 J
Thorium-232	NE	NE	0.235 +/- 0.217 UJ	0.154 +/- 0.150	0.109 +/- 0.189 UJ	0.336 +/- 0.208	0.00 +/- 0.141 UJ	0.189 +/- 0.196 UJ	0.179 +/- 0.211 UJ	0.326 +/- 0.302 UJ	0.271 +/- 0.251 UJ	0.463 +/- 0.428 UJ	0.326 +/- 0.252	-0.0463 +/- 0.272 U	0.218 +/- 0.202 UJ	0.356 +/- 0.257	0.384 +/- 0.337	0.237 +/- 0.245 UJ
Thorium-234	NE	NE	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Total Uranium*	30	30	0.710 +/- 0.848 UJ	1.75 +/- 1.32	12.1 +/- 3.58	17.0 +/- 4.39	0.804 +/- 1.08 UJ	0.443 +/- 1.07 UJ	0.655 +/- 0.816 UJ	1.12 +/- 0.982 UJ	***62.2 +/- 7.20***	4.07 +/- 1.99	0.659 +/- 0.807 UJ	1.87 +/- 1.64 UJ	0.186 +/- 0.694 UJ	3.05 +/- 1.83	3.89 +/- 2.04	1.47 +/- 1.15
Uranium-233/234	NE	NE	0.252 +/- 0.334 UJ	0.706 +/- 0.537 UJ	4.17 +/- 1.25	4.57 +/- 1.34	0.0534 +/- 0.330 UJ	0.487 +/- 0.513 UJ	0.385 +/- 0.427 UJ	0.189 +/- 0.302 UJ	20.1 +/- 2.38	1.15 +/- 0.625	1.14 +/- 0.672	1.90 +/- 0.935	0.242 +/- 0.472 UJ	0.267 +/- 0.521 UJ	1.22 +/- 0.689	1.12 +/- 0.608
Uranium-235/236	NE	NE	0.0632 +/- 0.168 UJ	0.0886 +/- 0.249 UJ	0.661 +/- 0.528 UJ	1.22 +/- 0.722	0.136 +/- 0.254 UJ	0.439 +/- 0.475 UJ	0.336 +/- 0.380 UJ	0.278 +/- 0.292 UJ	1.40 +/- 0.628	0.320 +/- 0.336 UJ	0.356 +/- 0.373 UJ	0.426 +/- 0.505 UJ	0.249 +/- 0.342 UJ	0.0265 +/- 0.251 UJ	0.187 +/- 0.259 UJ	0.239 +/- 0.271
Uranium-238	NE	NE	0.229 +/- 0.284 UJ	0.574 +/- 0.442	3.98 +/- 1.20	5.51 +/- 1.47	0.249 +/- 0.361 UJ	0.0805 +/- 0.352 UJ	0.168 +/- 0.268 UJ	0.334 +/- 0.327 UJ	20.7 +/- 2.42	1.32 +/- 0.668	0.166 +/- 0.265 UJ	0.563 +/- 0.547 UJ	0.0239 +/- 0.227 UJ	1.02 +/- 0.613	1.28 +/- 0.685	0.458 +/- 0.383

Notes:

* All results in pCi/L except for Total Uranium, which is reported in ug/L.

Qualifiers

U - The compound was not detected above the laboratory method detection limit

J - Result is regarded as estimated due to limitations identified during the data validation/quality assurance review.

R - Result regarded as unreliable. Analyte may or may not be present.

X - As defined by the analytical laboratory, result may be biased high due to tailing from the Th-229 region.

B - Indicates that the analyte was found in the associated blank as well as in the sample.

µg/L - micrograms per liter

pCi/L - Picocuries per liter

NA - Not Analyzed

NE - Not Established

NC - Not Calculated because Gross Alpha Value Not Reliable

Boxed results indicate an exceedance in standards.

** URSPZ-3 and URSPZ-5 were converted to wells URSMW23S and URSMW22S, respectively, during Phase II

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Table 6
Groundwater Elevation Data - November 16, 2004
Ground Water Delineation - Phase III Sampling
Middlesex Sampling Plant
Middlesex, New Jersey

Monitoring Well Identification	Northing NJ State Plane NAD 83	Easting NJ State Plane NAD 83	Top of Casing Elevation (FAMSL)	Depth to Water (FBTOR)	Ground Water Elevation (FAMSL)
Overburden					
PZ-1	633057.268	494434.069	61.67	12.35	49.32
PZ-2	632967.129	494310.370	61.21	11.87	49.34
PZ-3 (See URSMW23S)	632891.975	494222.455	61.84		61.84
PZ-4	632781.688	494374.349	59.41	8.18	51.23
PZ-5 (See URSMW22S)	632741.658	494574.840	60.18		60.18
PZ-6	632580.410	494230.187	57.79	5.23	52.56
PZ-7	632583.597	494484.383	58.13	8.12	50.01
PZ-8	632207.496	494112.368	53.87	3.32	50.55
PZ-9	632932.912	494411.234	61.02	10.10	50.92
URSMW1S	633015.064	494381.833	61.68	8.84	52.84
URSMW2S	632694.697	494354.241	59.63	5.55	54.08
URSMW4S	632475.989	494339.262	57.38	4.19	53.19
URSMW5S	632485.147	494568.157	57.42	8.18	49.24
URSMW6S	632252.358	494330.790	54.37	3.63	50.74
URSMW7SR	632263.490	494380.550	54.57	3.61	50.96
URSMW8S	632201.082	494478.811	54.52	6.69	47.83
URSMW10S	632200.125	494360.692	53.80	4.64	49.16
URSMW11S	632196.902	494569.932	55.09	8.97	46.12
URSMW12S	631961.315	494351.536	49.39	2.73	46.66
URSMW13S	631960.316	494449.661	51.48	4.34	47.14
URSMW14S	631907.241	494349.073	49.20	2.95	46.25
URSMW15S	631910.087	494448.324	51.11	4.80	46.31
URSMW16S	631844.430	494382.575	49.03	2.57	46.46
URSMW20S	Far Offsite		54.79		
URSMW21S	632755.33	494196.45	59.38	5.47	53.91
URSMW22S	632741.658	494574.840	60.18	5.60	54.58
URSMW23S	632891.975	494222.455	61.84	11.28	50.56
URSMW24S	633031.26	494492.71	58.74	12.47	46.27
B18W24S	632928.852	494285.085	60.48	8.07	52.41
B18W25S	632483.190	494196.619	56.86	4.51	54.13
B18W26S	632338.620	494378.026	54.67	3.48	51.19
B18W27SR	632031.997	494154.038	52.42	5.20	47.22
B18W28SR	632028.590	494390.401	51.86	4.54	47.32
B18W29SR	632031.850	494567.640	53.51	4.46	49.05
B18W30S	631838.721	494383.489	49.11	2.88	46.23
Bedrock					
URSMW1D	633019.486	494378.837	61.72	23.87	37.85
URSMW2D	632699.498	494354.546	59.91	19.19	40.72
URSMW3D	632479.074	494197.078	57.07	18.40	38.67
URSMW5D	632490.283	494568.247	57.59	18.73	38.86
URSMW9D	632039.945	494151.114	53.10	12.00	41.10
URSMW11D	632202.043	494570.252	55.13	17.57	37.56
URSMW20D	Far Offsite		55.46		
URSMW21D			59.55	21.60	37.95
URSMW22D	632751.39	494564.82	59.95	22.44	37.51
URSMW23D	632883.57	494226.57	61.54	23.88	37.66
URSMW24D	633024.60	494498.16	58.84	21.93	36.91

Notes:

FAMSL - Feet above mean sea level.
FBTOR - Feet below top of inner riser

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Table 7
Summary Analytical Results - VOCs - Detections Only
Groundwater Delineation - Phase III Monitoring Wells
Middlesex Sampling Plant
Middlesex, New Jersey

Location ID:	NJDEP CLASS IIA GW QUALITY STANDARDS µg/L	NJ STATE PRIMARY DRINKING WATER STANDARDS	USEPA NATIONAL PRIMARY DRINKING WATER REGS	URSMW2S	URSMW2D	URSMW3D	URSMW9D	URSMW11D	URSMW21S	URSMW21D	URSMW21D	URSMW22S*	URSMW22D	URSMW23S*	URSMW23D	URSMW24S	URSMW24D
Date Collected:				10/26/04	10/27/04	11/16/04	11/17/04	11/17/04	11/17/04	11/17/04	11/17/04	11/18/04	11/18/04	11/19/04	11/18/04	11/19/04	11/18/04
Analysis Type:				REG	REG	REG	REG	REG	REG	REG	DUP	REG	REG	REG	REG	REG	REG
Matrix:				Water	Water	Water	Water	Water	Water	Water	Water	Water	Water	Water	Water	Water	Water
Unit:				ug/l	ug/l	ug/l	ug/l	ug/l	ug/l	ug/l	ug/l	ug/l	ug/l	ug/l	ug/l	ug/l	ug/l
Analyte																	
1,1-DICHLOROETHANE	70	50	NE	1 U	0.3 J	0.69 J	1 U	1 U	1 UJ	1 U	1 U	1 U	1.3	1 U	1 U	1 U	1 UJ
1,1-DICHLOROETHENE	2	2	7	1 U	1 U	1 U	1 U	1 U	1 UJ	1 U	1 U	1 U	1.1	1 U	1 U	1 U	1 UJ
ACETONE	700	NE	NE	13 U	5 U	5 U	5 U	5.6	5 UJ	5 U	5 U	5 U	5 U	5 U	5.5	17	5 UJ
CARBON DISULFIDE	800	NE	NE	1.1 U	1 U	1 U	0.35 J	1 U	1.3 UJ	1 U	1 U	1 U	0.72 J	0.58 J	1 U	0.43 J	1 UJ
CARBON TETRACHLORIDE	2	2	5	1 U	**19**	1 U	1 U	1 U	1 UJ	1 U	1 U	1 U	1 U	1 U	1.6	1 U	**340**
CHLOROFORM	6	6	NE	1 U	2.8	1 U	1 U	1 U	1 UJ	1 U	1 U	1 U	1 U	1 U	0.32 J	1 U	**34 J**
CHLOROMETHANE	30	NE	NE	0.56 J	1 U	1 U	1 U	1 U	1 UJ	1 U	1 U	1 U	1 U	1 U	1 U	1 U	1 UJ
CIS-1,2-DICHLOROETHENE	10	70	70	1 U	0.45 J	1 U	1 U	1 U	1 UJ	1 U	1 U	1 U	1 U	1 U	1 U	1 U	0.66 J
ISOPROPYL ETHER	20,000	NE	NE	1 U	1 U	0.93 J	1 U	1 U	1 UJ	1 U	1 U	1 U	1 U	1 U	1 U	1 U	1 UJ
METHYLENE CHLORIDE	2	3	5	1 U	1 U	1.6 U	1.6 B	1.5 B	1 UJ	1 U	1 U	1.7 U	2 U	1.6 U	1 U	1.7 U	1 UJ
METHYL TERT-BUTYL ETHER	70	70	NE	1 U	1.6	**120**	17	1.9	1 UJ	1 U	1 U	2.5	5.1	1 U	1 U	1 U	1 UJ
TERT-BUTYL ALCOHOL	100	NE	NE	20 U	20 U	20 U	31	20 U	20 UJ	20 U	20 U	20 U	20 U	20 U	20 U	20 U	20 UJ
TETRACHLOROETHYLENE	1	1	5	1 U	1 U	1 U	1 U	1 U	1 UJ	1 U	1 U	0.42 J	0.28 J	0.24 J	1 U	1 U	1 UJ
TOLUENE	1000	1000	1000	1 U	1 U	1 U	1 U	1 U	1 UJ	1 U	1 U	1.2	1 U	1 U	1 U	1 U	1 UJ
TRICHLOROETHENE	1	1	5	1 U	**23**	1 U	1 U	1 U	1 UJ	1 U	1 U	1 U	**1.3**	1 U	1 U	1 U	**24 J**

Notes:

Qualifiers

U - The compound was not detected above the laboratory method detection limit.

J - Result is regarded as estimated due to limitations identified during the data validation/quality assurance review.

R - Result regarded as unreliable. Analyte may or may not be present.

µg/L - micrograms per liter

NE - Not Established.

Boxed results - indicate an exceedance in applicable standards.

*URSMW22S and URSMW23S were created from URSPZ-5 and URSPZ-3 during Phase II

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Table 8
Summary Analytical Results SVOCs - Detections Only
Groundwater Delineation - Phase III Monitoring Wells
Middlesex Sampling Plant
Middlesex, New Jersey

Location ID: Sample Date: Analysis Type Lab Sample ID: Matrix: Units: Analyte	NJDEP CLASS IIA GW QUALITY STANDARDS µg/L	NJ STATE PRIMARY DRINKING WATER STANDARDS	USEPA NATIONAL PRIMARY DRINKING WATER REGS	URSMW2S 10/26/04 REG Water	URSMW2D 10/27/04 REG Water	URSMW21S 11/17/04 REG Water	URSMW21D 11/17/04 REG Water	URSMW21D 11/17/04 DUP Water	URSMW22S* 11/18/04 REG Water	URSMW22D 11/18/04 REG Water	URSMW23S* 11/19/04 REG Water	URSMW23D 11/18/04 REG Water	URSMW24S 11/19/04 REG Water	URSMW24D 11/18/04 REG Water
BIS(2-ETHYLHEXYL) PHTHALATE	30	30	6	13 U	11 U	10 UJ	10 UJ	10 UJ	27 UJ	10 UJ	11 U	13 UJ	15 U	**31 J**
DI-N-BUTYL PHTHALATE	900	900	NE	12 U	11 U	10 UJ	10 UJ	10 UJ	11 UJ	10 UJ	11 U	11 UJ	15 U	10 UJ

Notes:

Qualifiers

U - The compound was not detected above the laboratory method detection limit.

J - Result is regarded as estimated due to limitations identified during the data validation/quality assurance review.

µg/L - micrograms per liter

NE - Not Established.

Boxed results - indicate an exceedance in applicable standards

*URSMW22S and URSMW23S were created from URSPZ-5 and URSPZ-3 during Phase II

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Table 9
Summary Analytical Results Metals - Detections Only
Groundwater Delineation - Phase III Monitoring Wells
Middlesex Sampling Plant
Middlesex, New Jersey

Location ID: Date Collected: Analysis Type: Matrix: Unit:	NJDEP CLASS IIA GW QUALITY STANDARDS µg/L	NJ STATE PRIMARY DRINKING WATER STANDARDS µg/L	USEPA NATIONAL PRIMARY DRINKING WATER REGS µg/L	URSMW2S 10/26/04 REG Water ug/l	URSMW2D 10/27/04 REG Water ug/l	URSMW21S 11/17/04 REG Water µg/L	URSMW21D 11/17/04 REG Water µg/L	URSMW21D 11/17/04 DUP Water µg/L	URSMW22S* 11/18/04 REG Water µg/L	URSMW22D 11/18/04 REG Water µg/L	URSMW23S* 11/19/04 REG Water µg/L	URSMW23D 11/18/04 REG Water µg/L	URSMW24S 11/19/04 REG Water µg/L	URSMW24D 11/18/04 REG Water µg/L
Analyte														
ARSENIC	8	5	10	**9.1**	4.8 U	7.9	4.8 U	4.8 U	4.8 U	4.8 U	4.8 U	4.8 U	4.8 U	4.8 U
IRON	300	NE	NE	87	**1540**	**8890**	**1160**	**1160**	186	**4330**	174	**1740**	32.4 U	**2250**
LEAD	10	15^+	15^+	2.2	2.1 U	2.1 U	2.1 U	2.1 U	2.1 U	2.1 U	2.1 U	2.1 U	2.1 U	2.1 U
MANGANESE	50	NE	NE	7.5	39.7	**1060**	10.6	10.6	**418**	21.8	37.1	13.7	29.1	18.5
NICKEL	100	NE	NE	6.1	1.1 U	1.1 U	1.1 U	1.1 U	4.7	1.1 U	1.1 U	1.1 U	1.1 U	1.1 U
SELENIUM	50	50	50	5	3 U	3 U	3 U	3 U	3 U	3 U	7.9	11.1	3 U	3 U

Notes:

Qualifiers

U - The compound was not detected above the laboratory method detection limit.

J - Result is regarded as estimated due to limitations identified during the data validation/quality assurance review.

R - Result regarded as unreliable. Analyte may or may not be present.

µg/L - micrograms per liter

NE - Not Established.

Boxed results - indicate an exceedance in applicable standards.

*URSMW22S and URSMW23S were created from URSPZ-5 and URSPZ-3 during Phase II

15^+ - Represents Action Limit, which is the trigger point at which remedial action is to take place.

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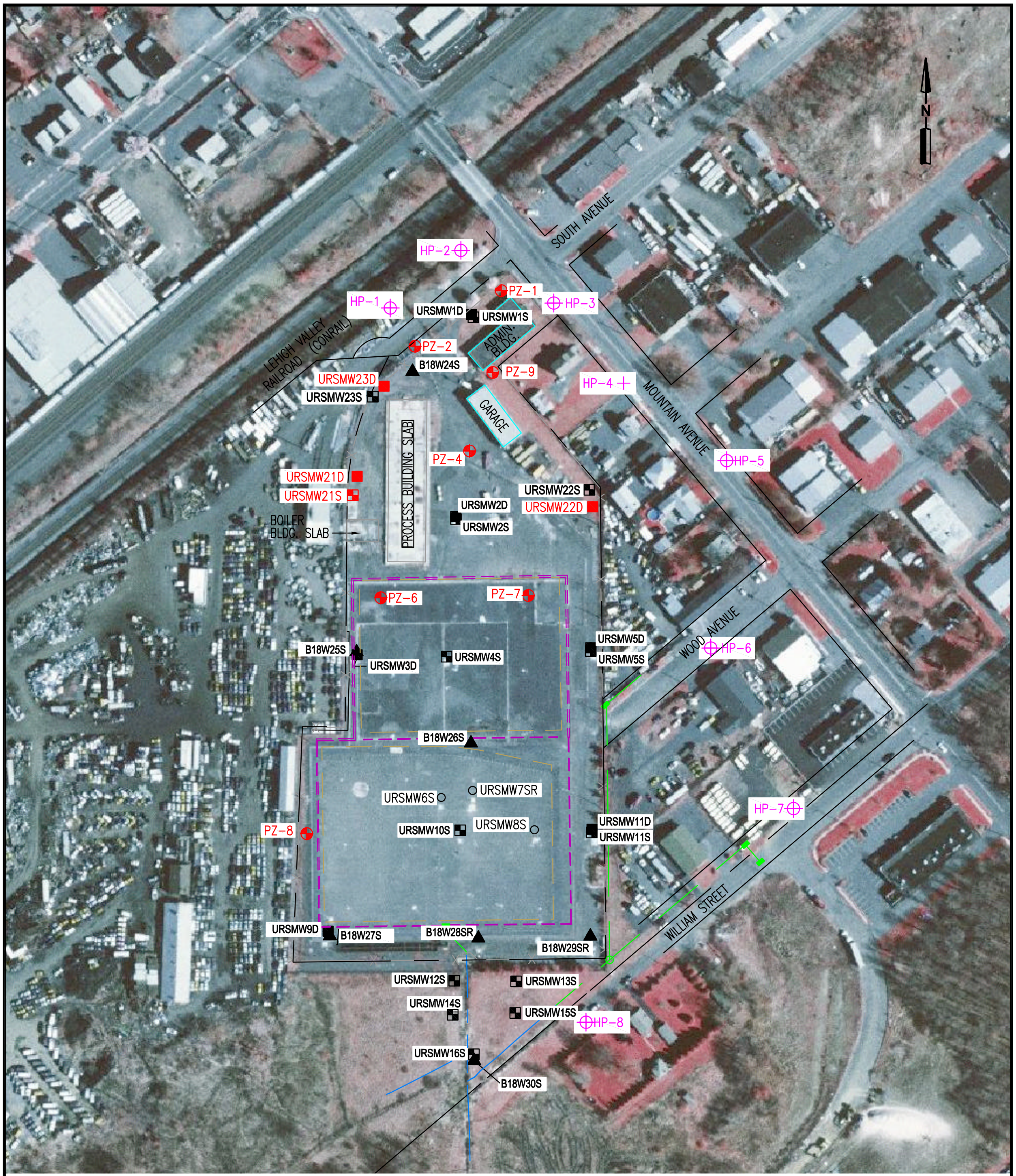
Table 10
Summary Analytical Results - Radionuclides
Groundwater Delineation Phase III - Monitoring Wells
Middlesex Sampling Plant
Middlesex, New Jersey

Location ID: Date Collected: Analysis Type: Matrix:	New Jersey State Primary Drinking Water Standards MCL	USEPA Safe Drinking Water Act MCL	URSMW2S 10/26/04 REG Water	URSMW2D 10/27/04 REG Water	URSMW21S 11/17/04 REG Water	URSMW21D 11/17/04 REG Water	URSMW21D 11/17/04 DUP Water	URSMW22S* 11/18/04 REG Water	URSMW22D 11/18/04 REG Water	URSMW23S* 11/19/04 REG Water	URSMW23D 11/18/04 DUP Water	URSMW24S 11/19/04 REG Water	URSMW24D 11/18/04 REG Water
Analyte													
Gross Alpha	NE	NE	51.39 +/- 4.78	2.78 +/- 1.05 J	2.24 +/- 1.38 J	6.19 +/- 1.59	3.76 +/- 1.50	12.9 +/- 1.58	18.9 +/- 2.31	46.5 +/- 4.06	25.8 +/- 2.84	39.3 +/- 4.20	27.8 +/- 2.89
Gross Beta	NE	NE	23.96 +/- 3.13	2.43 +/- 1.459 J	4.845 +/- 2.06 J	10.8 +/- 2.38	5.35 +/- 1.86	4.23 +/- 0.875	5.52 +/- 1.22	17.1 +/- 2.51	9.75 +/- 1.57	8.38 +/- 2.69	7.05 +/- 1.48
Radium-226	NE	NE	0.6247 +/- 0.185	0.182 +/- 0.144 UJ	0.122 +/- 0.145 UJ	0.0575 +/- 0.110 UJ	0.888 +/- 0.315	-0.0104 +/- 0.124 UJ	-0.0689 +/- 0.132 UJ	1.4 +/- 0.329	0.0476 +/- 0.118 UJ	0.25 +/- 0.296 UJ	1.31 +/- 0.226
Radium-226+228	5	5	3.5087	1.696 J	0.464 +/- 1 J	0.2957 J	1.582 J	0.875 J	0.9345 J	2.02 J	0.533 J	0.370 J	2.36 J
Radium-228	NE	NE	2.884 +/- 0.449 UJ	1.514 +/- 0.398 J	0.403 +/- 0.358 J	0.534 +/- 0.404 UJ	0.694 +/- 0.375 J	0.880 +/- 0.423 J	0.969 +/- 0.423 J	0.616 +/- 0.409 UJ	0.510 +/- 0.450 J	0.490 +/- 0.385 UJ	1.05 +/- 0.459 J
Thorium 228	NE	NE	0.08841 +/- 0.173 J	0.03676 +/- 0.119 UJ	-0.00571 +/- 0.0115 UJ	-0.0110 +/- 0.0156 UJ	0.0224 +/- 0.0698 U	0.102 +/- 0.184 UJ	0.0323 +/- 0.104 UJ	-0.0258 +/- 0.0262 UJ	0.171 +/- 0.179 UJ	0.169 +/- 0.217 UJ	0.123 +/- 0.173 UJ
Thorium-230	NE	NE	0.6966 +/- 0.367 J	0.653 +/- 0.312 J	0.291 +/- 0.204 J	0.374 +/- 0.228 J	0.626 +/- 0.308	0.560 +/- 0.366 J	0.227 +/- 0.173 J	0.587 +/- 0.314 J	0.363 +/- 0.250 J	0.409 +/- 0.273 J	0.746 +/- 0.358 J
Thorium-232	NE	NE	0.358 +/- 0.2517 J	0.111 +/- 0.130 UJ	0.126 +/- 0.134 UJ	0.126 +/- 0.128 UJ	0.166 +/- 0.151 J	0.0833 +/- 0.145 UJ	0.125 +/- 0.127 UJ	0.0245 +/- 0.0763 UJ	-0.02425 +/- 0.0786 UJ	0.110 +/- 0.147 UJ	0.0843 +/- 0.129 U
Total Uranium	30	30	**67.036 +/- 12.96**	1.606 +/- 0.817	0.350 +/- 0.357 UJ	0.899 +/- 0.563 J	1.24 +/-0.649	1.11 +/- 0.616	2.83 +/- 1.05	***38.3 +/- 7.46***	3.1 +/- 1.14	7.1 +/- 1.86	5.49 +/- 1.64
Uranium-233/234	NE	NE	23.35 +/- 4.533	1.922 +/- 0.591	0.257 +/- 0.179 J	2.46 +/- 0.649	2.134 +/- 0.574	0.558 +/- 0.259 J	3.84 +/- 0.872	13.6 +/- 2.63	3.12 +/- 0.771	2.59 +/- 0.670	7.15 +/- 1.43
Uranium-235/236	NE	NE	2.7072 +/- 1.159	0.4319 +/- 0.269 J	0.226 +/- 0.182 J	0.204 +/- 0.169 J	0.311 +/- 0.200 J	0.0873 +/- 0.108 R	0.479 +/- 0.257 R	1.12 +/- 0.563 J	0.352 +/- 0.226 R	0.348 +/- 0.228 UJ	0.150 =/- 0.151 R
Uranium-238	NE	NE	22.21 +/- 4.355	0.5009 +/- 0.273 J	0.101 +/- 0.118 UJ	0.285 +/- 0.188 J	0.401 +/- 0.218	0.369 +/- 0.207	0.932 +/- 0.354	12.7 +/- 2.51	1.01 +/- 0.381	2.35 +/- 0.625	1.83 +/- 0.0550
Net Alpha	15	15	3.128	-0.0748 J	1.706 J	3.241 J	0.914 J	11.973 J	14.13	***19.08 J***	***21.67***	***34.186 J***	***18.82***

Notes:
* All results in pCi/L except for Total Uranium which is reported in ug/L.
Qualifiers
U - The compound was not detected above the laboratory method detection limit.
J - Result is regarded as estimated due to limitations identified during the data validation/quality assurance review.
R - Result regarded as unreliable. Analyte may or may not be present.
B - Indicates that the analyte was found in the associated blank as well as in the sample.
µg/L - micrograms per liter
pCi/L - Pico Curies per liter
NA - Not Analyzed
NE - Not Established.
Boxed results indicate an exceedance in standards.
*URSMW22S and URSMW23S were created from URSPZ-5 and URSPZ-3 during Phase II



Legend

Monitoring Well Locations

- ▚ Overburden Well
- ■ Bedrock Well
- ○ Pipe Chase Well
- ▲ Existing E.S. Overburden Well
- ⊕ Piezometer Installation Locations
- ⌖ Off-Site Hydropunch Location
- 🟥 New Bedrock Monitoring Well Installation
- ▚ New Overburden Monitoring Well Location

(1) MSP-12 Was Abandoned and Replaced by PZ-5
PZ-5 Has been renamed URSMW22S
PZ-3 Has been renamed URSMW23S

MIDDLESEX SAMPLING PLANT

239 MOUNTAIN AVE.
MIDDLESEX, NEW JERSEY

HYDROPUNCH AND PIEZOMETER INSTALLATION LOCATIONS

US Army Corps of Engineers.
New York District

FUSRAP

DATE: NOVEMBER 2004
JOB: 19577-079-149

Figure 1

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Legend

Monitoring Well Locations

- ▩ Overburden Well
- ■ Bedrock Well
- ○ Pipe Chase Well
- ▲ Existing E.S. Overburden Well
- ⊕ Piezometer Installation Locations
- 🟥 New Bedrock Monitoring Well Installation
- ▩ New Overburden Monitoring Well Location
- (1) MSP-12 Was Abandoned and Replaced by PZ-5

PZ-5 Has been renamed URSMW22S
PZ-3 Has been renamed URSMW23S

MIDDLESEX SAMPLING PLANT

239 MOUNTAIN AVE.
MIDDLESEX, NEW JERSEY

PHASE II WELL INSTALLATION LOCATION

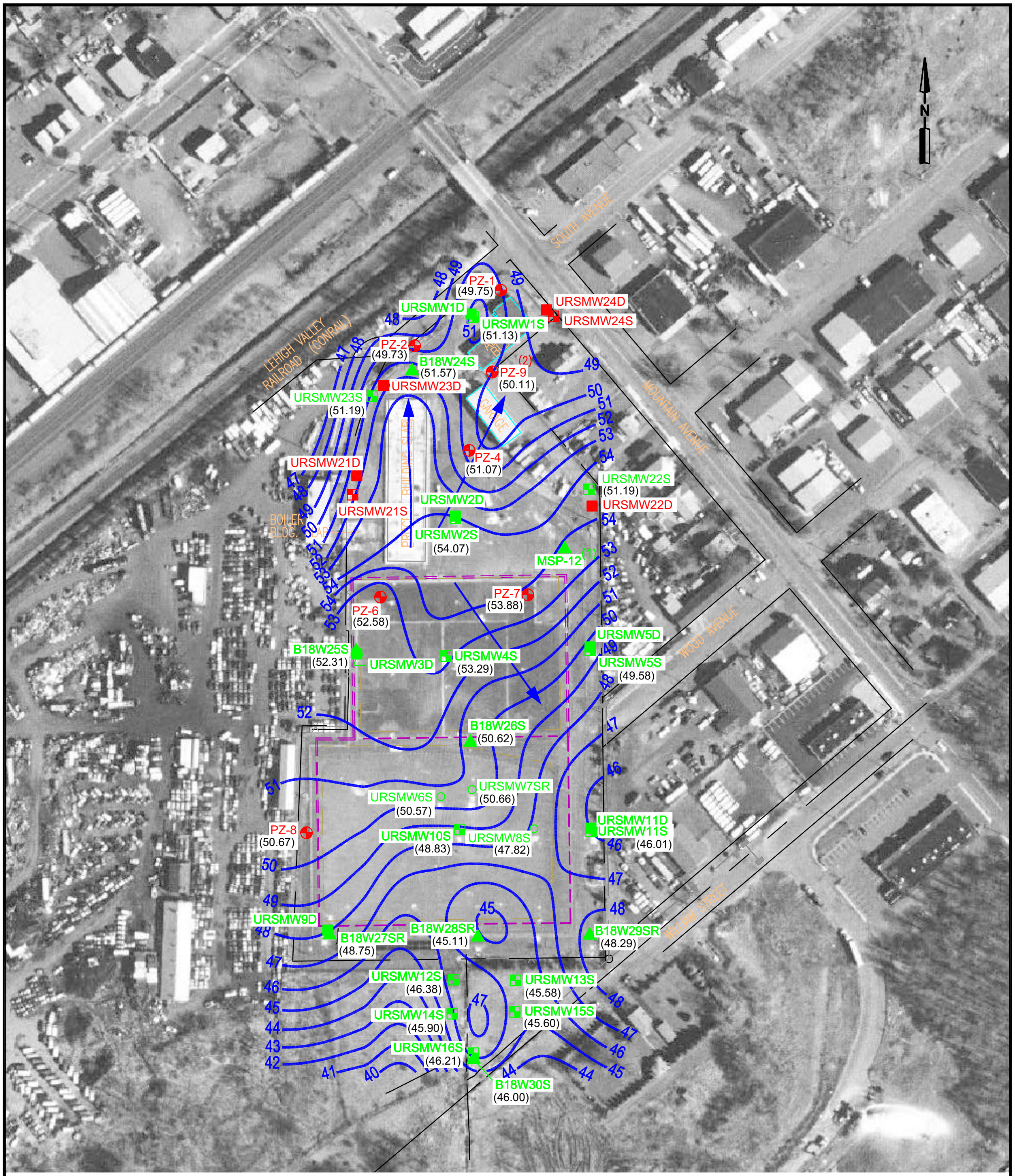
US Army Corps of Engineers
New York District

FUSRAP

DATE: NOVEMBER 2004
JOB: 19577-079-149

Figure 2

S:\19577\079\Year-2004\GWOU-RI Report\Plot\GWRI-002.dwg 3/16/2005 3:20:29 PM EST



Legend

Monitoring Well
Locations

- ▨ Overburden Well
- 🟩 Bedrock Well
- ○ Pipe Chase Well
- ▲ Existing E.S. Overburden Well
- ⊕ Piezometer Installation Locations
- 🟥 New Bedrock Monitoring Well Installation
- ▨ New Overburden Monitoring Well Location

(1) MSP-12 Was Abandoned on 12/12/04 and is Replaced by URSMW22S
PZ-5 Has been renamed URSMW22S
PZ-3 Has been renamed URSMW23S

40 Ground Water Contour Elevation in Feet msl
→ Ground Water Flow Direction
(53.07) Ground Water Elevation in Feet Above Mean Sea Level

GRAPHIC SCALE
160' 0 80' 160'

Image Source.
New Jersey 2002 High Resolution Orthophotography.
State of New Jersey Office of Information Technology,
Office of Geographic Information Systems. July 31, 2003.
Tiles H8B9 and H8B10.

DRAFT

MIDDLESEX SAMPLING PLANT

239 MOUNTAIN AVE.
MIDDLESEX, NEW JERSEY

MONITORING WELL LOCATIONS AND OVERBURDEN GROUND WATER CONTOURS - AUGUST 23, 2004

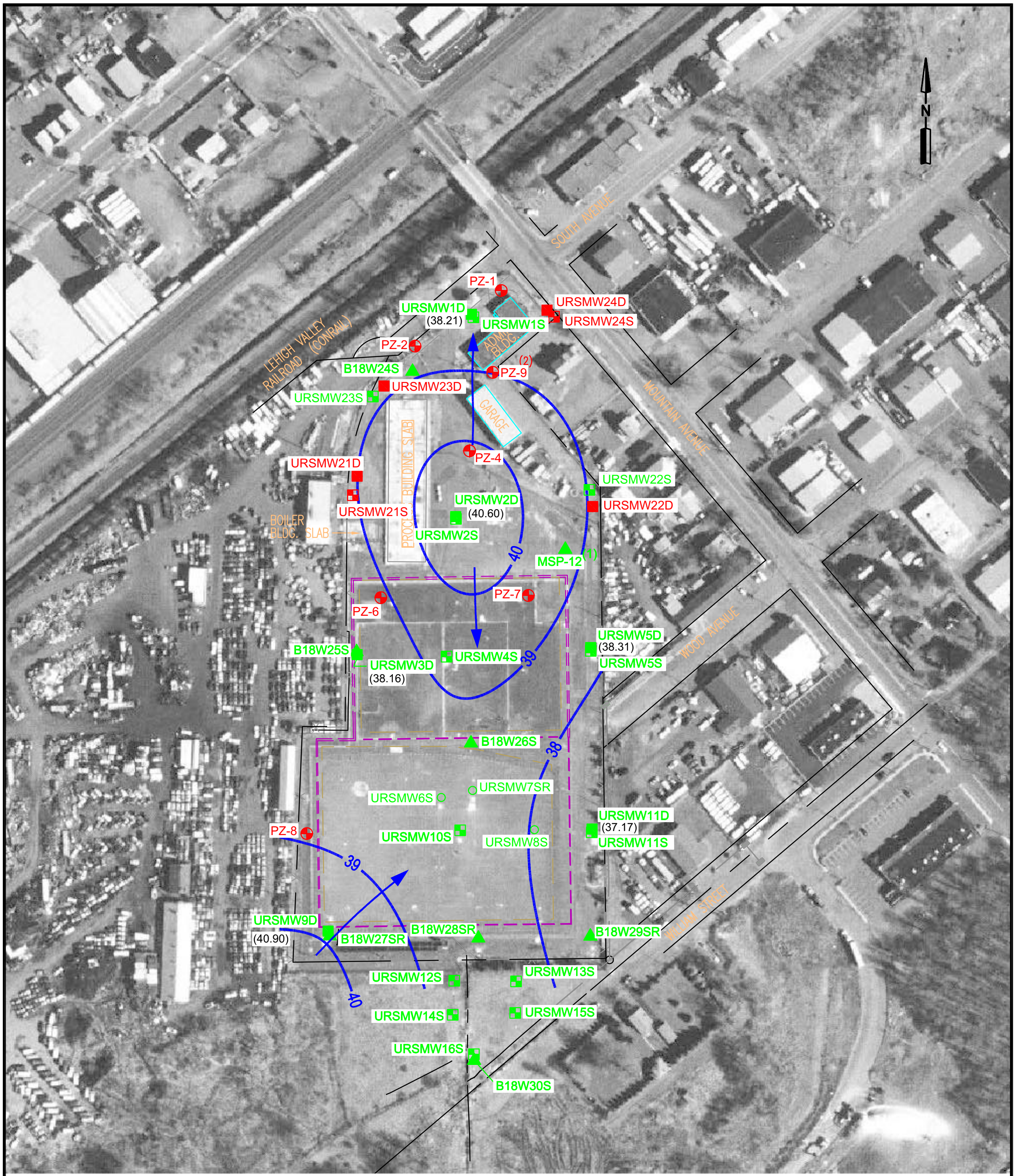
US Army Corps of Engineers
New York District

FUSRAP

DATE: NOVEMBER 2004
JOB: 19577-079-149

Figure 3

S:\19577\079\Year-2004\GWOU-RI Report\Plot\GWRI-003.dwg 3/11/2005 2:33:15 PM EST



S:\19577\079\Year-2004\GWOU-RI Report\Plot\GWRI-004.dwg 3/11/2005 2:25:43 PM EST

Legend

Monitoring Well Locations

- 🟩 Overburden Well
- 🟩 Bedrock Well
- ○ Pipe Chase Well
- ▲ Existing E.S. Overburden Well
- ● Piezometer Installation Locations
- 🟥 New Bedrock Monitoring Well Installation
- 🟥 New Overburden Monitoring Well Location

(1) MSP-12 Was Abandoned on 12/12/04 and is Replaced by URSMW22S
PZ-5 Has been renamed URSMW22S
PZ-3 Has been renamed URSMW23S

40 Ground Water Contour Elevation in Feet msl
→ Ground Water Flow Direction
(53.07) Ground Water Elevation in Feet Above Mean Sea Level

GRAPHIC SCALE
160' 0 80' 160'

Image Source.
New Jersey 2002 High Resolution Orthophotography.
State of New Jersey Office of Information Technology,
Office of Geographic Information Systems. July 31, 2003.
Tiles H8B9 and H8B10.

DRAFT

MIDDLESEX SAMPLING PLANT

239 MOUNTAIN AVE.
MIDDLESEX, NEW JERSEY

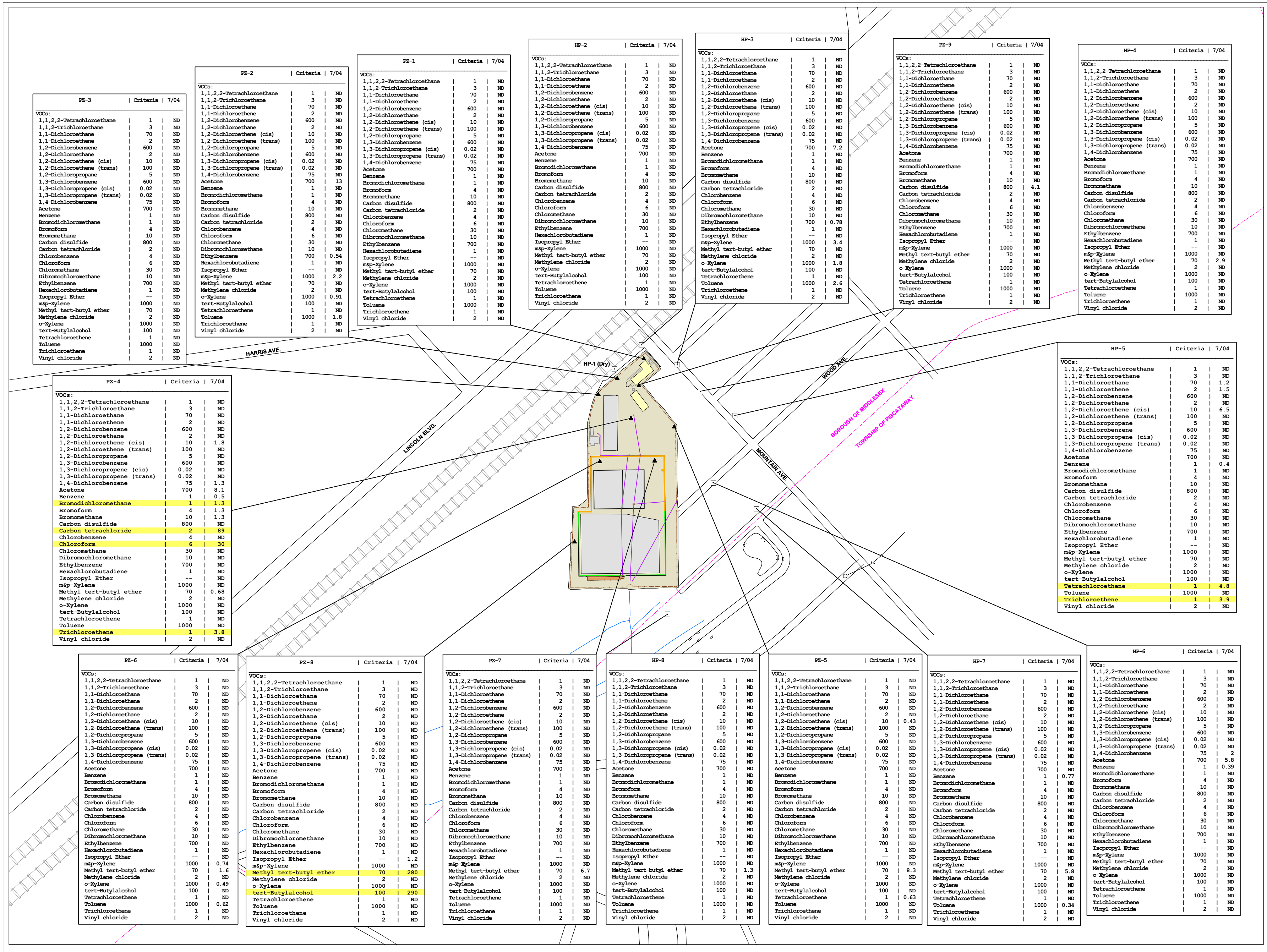
BEDROCK MONITORING WELL LOCATIONS AND GROUND WATER CONTOURS - AUGUST 23, 2004

US Army Corps of Engineers
New York District

FUSRAP

DATE: NOVEMBER 2004
JOB: 19577-079-149

Figure 4



PZ-3	Criteria	7/04
VOCs:		
1,1,2,2-Tetrachloroethane	1	ND
1,1,2-Trichloroethane	3	ND
1,1-Dichloroethane	70	ND
1,1-Dichloroethene	2	ND
1,2-Dichlorobenzene	600	ND
1,2-Dichloroethane	2	ND
1,2-Dichloroethene (cis)	10	ND
1,2-Dichloroethene (trans)	100	ND
1,2-Dichloropropane	5	ND
1,3-Dichlorobenzene	600	ND
1,3-Dichloropropene (cis)	0.02	ND
1,3-Dichloropropene (trans)	0.02	ND
1,4-Dichlorobenzene	75	ND
Acetone	700	ND
Benzene	1	ND
Bromodichloromethane	1	ND
Bromoform	4	ND
Bromomethane	10	ND
Carbon disulfide	800	ND
Carbon tetrachloride	2	ND
Chlorobenzene	4	ND
Chloroform	6	ND
Chloromethane	30	ND
Dibromochloromethane	10	ND
Ethylbenzene	700	ND
Hexachlorobutadiene	1	ND
Isopropyl Ether	--	ND
m&p-Xylene	1000	ND
Methyl tert-butyl ether	70	ND
Methylene chloride	2	ND
o-Xylene	1000	ND
tert-Butylalcohol	100	ND
Tetrachloroethene	1	ND
Toluene	1000	ND
Trichloroethene	1	ND
Vinyl chloride	2	ND

PZ-2	Criteria	7/04
VOCs:		
1,1,2,2-Tetrachloroethane	1	ND
1,1,2-Trichloroethane	3	ND
1,1-Dichloroethane	70	ND
1,1-Dichloroethene	2	ND
1,2-Dichlorobenzene	600	ND
1,2-Dichloroethane	2	ND
1,2-Dichloroethene (cis)	10	ND
1,2-Dichloroethene (trans)	100	ND
1,2-Dichloropropane	5	ND
1,3-Dichlorobenzene	600	ND
1,3-Dichloropropene (cis)	0.02	ND
1,3-Dichloropropene (trans)	0.02	ND
1,4-Dichlorobenzene	75	ND
Acetone	700	13
Benzene	1	ND
Bromodichloromethane	1	ND
Bromoform	4	ND
Bromomethane	10	ND
Carbon disulfide	800	ND
Carbon tetrachloride	2	ND
Chlorobenzene	4	ND
Chloroform	6	ND
Chloromethane	30	ND
Dibromochloromethane	10	ND
Ethylbenzene	700	0.54
Hexachlorobutadiene	1	ND
Isopropyl Ether	--	ND
m&p-Xylene	1000	2.2
Methyl tert-butyl ether	70	ND
Methylene chloride	2	ND
o-Xylene	1000	0.91
tert-Butylalcohol	100	ND
Tetrachloroethene	1	ND
Toluene	1000	1.8
Trichloroethene	1	ND
Vinyl chloride	2	ND

PZ-1	Criteria	7/04
VOCs:		
1,1,2,2-Tetrachloroethane	1	ND
1,1,2-Trichloroethane	3	ND
1,1-Dichloroethane	70	ND
1,1-Dichloroethene	2	ND
1,2-Dichlorobenzene	600	ND
1,2-Dichloroethane	2	ND
1,2-Dichloroethene (cis)	10	ND
1,2-Dichloroethene (trans)	100	ND
1,2-Dichloropropane	5	ND
1,3-Dichlorobenzene	600	ND
1,3-Dichloropropene (cis)	0.02	ND
1,3-Dichloropropene (trans)	0.02	ND
1,4-Dichlorobenzene	75	ND
Acetone	700	ND
Benzene	1	ND
Bromodichloromethane	1	ND
Bromoform	4	ND
Bromomethane	10	ND
Carbon disulfide	800	ND
Carbon tetrachloride	2	ND
Chlorobenzene	4	ND
Chloroform	6	ND
Chloromethane	30	ND
Dibromochloromethane	10	ND
Ethylbenzene	700	ND
Hexachlorobutadiene	1	ND
Isopropyl Ether	--	ND
m&p-Xylene	1000	ND
Methyl tert-butyl ether	70	ND
Methylene chloride	2	ND
o-Xylene	1000	ND
tert-Butylalcohol	100	ND
Tetrachloroethene	1	ND
Toluene	1000	ND
Trichloroethene	1	ND
Vinyl chloride	2	ND

HP-2	Criteria	7/04
VOCs:		
1,1,2,2-Tetrachloroethane	1	ND
1,1,2-Trichloroethane	3	ND
1,1-Dichloroethane	70	ND
1,1-Dichloroethene	2	ND
1,2-Dichlorobenzene	600	ND
1,2-Dichloroethane	2	ND
1,2-Dichloroethene (cis)	10	ND
1,2-Dichloroethene (trans)	100	ND
1,2-Dichloropropane	5	ND
1,3-Dichlorobenzene	600	ND
1,3-Dichloropropene (cis)	0.02	ND
1,3-Dichloropropene (trans)	0.02	ND
1,4-Dichlorobenzene	75	ND
Acetone	700	ND
Benzene	1	ND
Bromodichloromethane	1	ND
Bromoform	4	ND
Bromomethane	10	ND
Carbon disulfide	800	ND
Carbon tetrachloride	2	ND
Chlorobenzene	4	ND
Chloroform	6	ND
Chloromethane	30	ND
Dibromochloromethane	10	ND
Ethylbenzene	700	ND
Hexachlorobutadiene	1	ND
Isopropyl Ether	--	ND
m&p-Xylene	1000	ND
Methyl tert-butyl ether	70	ND
Methylene chloride	2	ND
o-Xylene	1000	ND
tert-Butylalcohol	100	ND
Tetrachloroethene	1	ND
Toluene	1000	ND
Trichloroethene	1	ND
Vinyl chloride	2	ND

HP-3	Criteria	7/04
VOCs:		
1,1,2,2-Tetrachloroethane	1	ND
1,1,2-Trichloroethane	3	ND
1,1-Dichloroethane	70	ND
1,1-Dichloroethene	2	ND
1,2-Dichlorobenzene	600	ND
1,2-Dichloroethane	2	ND
1,2-Dichloroethene (cis)	10	ND
1,2-Dichloroethene (trans)	100	ND
1,2-Dichloropropane	5	ND
1,3-Dichlorobenzene	600	ND
1,3-Dichloropropene (cis)	0.02	ND
1,3-Dichloropropene (trans)	0.02	ND
1,4-Dichlorobenzene	75	ND
Acetone	700	7.2
Benzene	1	ND
Bromodichloromethane	1	ND
Bromoform	4	ND
Bromomethane	10	ND
Carbon disulfide	800	ND
Carbon tetrachloride	2	ND
Chlorobenzene	4	ND
Chloroform	6	ND
Chloromethane	30	ND
Dibromochloromethane	10	ND
Ethylbenzene	700	0.78
Hexachlorobutadiene	1	ND
Isopropyl Ether	--	ND
m&p-Xylene	1000	3.4
Methyl tert-butyl ether	70	ND
Methylene chloride	2	ND
o-Xylene	1000	1.8
tert-Butylalcohol	100	ND
Tetrachloroethene	1	ND
Toluene	1000	2.6
Trichloroethene	1	ND
Vinyl chloride	2	ND

PZ-9	Criteria	7/04
VOCs:		
1,1,2,2-Tetrachloroethane	1	ND
1,1,2-Trichloroethane	3	ND
1,1-Dichloroethane	70	ND
1,1-Dichloroethene	2	ND
1,2-Dichlorobenzene	600	ND
1,2-Dichloroethane	2	ND
1,2-Dichloroethene (cis)	10	ND
1,2-Dichloroethene (trans)	100	ND
1,2-Dichloropropane	5	ND
1,3-Dichlorobenzene	600	ND
1,3-Dichloropropene (cis)	0.02	ND
1,3-Dichloropropene (trans)	0.02	ND
1,4-Dichlorobenzene	75	ND
Acetone	700	ND
Benzene	1	ND
Bromodichloromethane	1	ND
Bromoform	4	ND
Bromomethane	10	ND
Carbon disulfide	800	4.1
Carbon tetrachloride	2	ND
Chlorobenzene	4	ND
Chloroform	6	ND
Chloromethane	30	ND
Dibromochloromethane	10	ND
Ethylbenzene	700	ND
Hexachlorobutadiene	1	ND
Isopropyl Ether	--	ND
m&p-Xylene	1000	ND
Methyl tert-butyl ether	70	ND
Methylene chloride	2	ND
o-Xylene	1000	ND
tert-Butylalcohol	100	ND
Tetrachloroethene	1	ND
Toluene	1000	ND
Trichloroethene	1	ND
Vinyl chloride	2	ND

HP-4	Criteria	7/04
VOCs:		
1,1,2,2-Tetrachloroethane	1	ND
1,1,2-Trichloroethane	3	ND
1,1-Dichloroethane	70	ND
1,1-Dichloroethene	2	ND
1,2-Dichlorobenzene	600	ND
1,2-Dichloroethane	2	ND
1,2-Dichloroethene (cis)	10	ND
1,2-Dichloroethene (trans)	100	ND
1,2-Dichloropropane	5	ND
1,3-Dichlorobenzene	600	ND
1,3-Dichloropropene (cis)	0.02	ND
1,3-Dichloropropene (trans)	0.02	ND
1,4-Dichlorobenzene	75	ND
Acetone	700	ND
Benzene	1	ND
Bromodichloromethane	1	ND
Bromoform	4	ND
Bromomethane	10	ND
Carbon disulfide	800	ND
Carbon tetrachloride	2	ND
Chlorobenzene	4	ND
Chloroform	6	ND
Chloromethane	30	ND
Dibromochloromethane	10	ND
Ethylbenzene	700	ND
Hexachlorobutadiene	1	ND
Isopropyl Ether	--	ND
m&p-Xylene	1000	ND
Methyl tert-butyl ether	70	2.9
Methylene chloride	2	ND
o-Xylene	1000	ND
tert-Butylalcohol	100	ND
Tetrachloroethene	1	ND
Toluene	1000	ND
Trichloroethene	1	ND
Vinyl chloride	2	ND

PZ-4	Criteria	7/04
VOCs:		
1,1,2,2-Tetrachloroethane	1	ND
1,1,2-Trichloroethane	3	ND
1,1-Dichloroethane	70	ND
1,1-Dichloroethene	2	ND
1,2-Dichlorobenzene	600	ND
1,2-Dichloroethane	2	ND
1,2-Dichloroethene (cis)	10	1.8
1,2-Dichloroethene (trans)	100	ND
1,2-Dichloropropane	5	ND
1,3-Dichlorobenzene	600	ND
1,3-Dichloropropene (cis)	0.02	ND
1,3-Dichloropropene (trans)	0.02	ND
1,4-Dichlorobenzene	75	1.3
Acetone	700	8.1
Benzene	1	0.5
Bromodichloromethane	1	1.3
Bromoform	4	1.3
Bromomethane	10	1.3
Carbon disulfide	800	ND
Carbon tetrachloride	2	89
Chlorobenzene	4	ND
Chloroform	6	30
Chloromethane	30	ND
Dibromochloromethane	10	ND
Ethylbenzene	700	ND
Hexachlorobutadiene	1	ND
Isopropyl Ether	--	ND
m&p-Xylene	1000	ND
Methyl tert-butyl ether	70	0.68
Methylene chloride	2	ND
o-Xylene	1000	ND
tert-Butylalcohol	100	ND
Tetrachloroethene	1	ND
Toluene	1000	ND
Trichloroethene	1	3.8
Vinyl chloride	2	ND

HP-5	Criteria	7/04
VOCs:		
1,1,2,2-Tetrachloroethane	1	ND
1,1,2-Trichloroethane	3	ND
1,1-Dichloroethane	70	1.2
1,1-Dichloroethene	2	1.5
1,2-Dichlorobenzene	600	ND
1,2-Dichloroethane	2	ND
1,2-Dichloroethene (cis)	10	6.5
1,2-Dichloroethene (trans)	100	ND
1,2-Dichloropropane	5	ND
1,3-Dichlorobenzene	600	ND
1,3-Dichloropropene (cis)	0.02	ND
1,3-Dichloropropene (trans)	0.02	ND
1,4-Dichlorobenzene	75	ND
Acetone	700	ND
Benzene	1	0.4
Bromodichloromethane	1	ND
Bromoform	4	ND
Bromomethane	10	ND
Carbon disulfide	800	ND
Carbon tetrachloride	2	ND
Chlorobenzene	4	ND
Chloroform	6	ND
Chloromethane	30	ND
Dibromochloromethane	10	ND
Ethylbenzene	700	ND
Hexachlorobutadiene	1	ND
Isopropyl Ether	--	ND
m&p-Xylene	1000	ND
Methyl tert-butyl ether	70	ND
Methylene chloride	2	ND
o-Xylene	1000	ND
tert-Butylalcohol	100	ND
Tetrachloroethene	1	4.8
Toluene	1000	ND
Trichloroethene	1	3.9
Vinyl chloride	2	ND

PZ-6	Criteria	7/04
VOCs:		
1,1,2,2-Tetrachloroethane	1	ND
1,1,2-Trichloroethane	3	ND
1,1-Dichloroethane	70	ND
1,1-Dichloroethene	2	ND
1,2-Dichlorobenzene	600	ND
1,2-Dichloroethane	2	ND
1,2-Dichloroethene (cis)	10	ND
1,2-Dichloroethene (trans)	100	ND
1,2-Dichloropropane	5	ND
1,3-Dichlorobenzene	600	ND
1,3-Dichloropropene (cis)	0.02	ND
1,3-Dichloropropene (trans)	0.02	ND
1,4-Dichlorobenzene	75	ND
Acetone	700	ND
Benzene	1	ND
Bromodichloromethane	1	ND
Bromoform	4	ND
Bromomethane	10	ND
Carbon disulfide	800	ND
Carbon tetrachloride	2	ND
Chlorobenzene	4	ND
Chloroform	6	ND
Chloromethane	30	ND
Dibromochloromethane	10	ND
Ethylbenzene	700	ND
Hexachlorobutadiene	1	ND
Isopropyl Ether	--	ND
m&p-Xylene	1000	0.74
Methyl tert-butyl ether	70	1.6
Methylene chloride	2	ND
o-Xylene	1000	0.49
tert-Butylalcohol	100	ND
Tetrachloroethene	1	ND
Toluene	1000	0.62
Trichloroethene	1	ND
Vinyl chloride	2	ND

PZ-8	Criteria	7/04
VOCs:		
1,1,2,2-Tetrachloroethane	1	ND
1,1,2-Trichloroethane	3	ND
1,1-Dichloroethane	70	ND
1,1-Dichloroethene	2	ND
1,2-Dichlorobenzene	600	ND
1,2-Dichloroethane	2	ND
1,2-Dichloroethene (cis)	10	ND
1,2-Dichloroethene (trans)	100	ND
1,2-Dichloropropane	5	ND
1,3-Dichlorobenzene	600	ND
1,3-Dichloropropene (cis)	0.02	ND
1,3-Dichloropropene (trans)	0.02	ND
1,4-Dichlorobenzene	75	ND
Acetone	700	ND
Benzene	1	ND
Bromodichloromethane	1	ND
Bromoform	4	ND
Bromomethane	10	ND
Carbon disulfide	800	ND
Carbon tetrachloride	2	ND
Chlorobenzene	4	ND
Chloroform	6	ND
Chloromethane	30	ND
Dibromochloromethane	10	ND
Ethylbenzene	700	ND
Hexachlorobutadiene	1	ND
Isopropyl Ether	--	1.2
m&p-Xylene	1000	ND
Methyl tert-butyl ether	70	280
Methylene chloride	2	ND
o-Xylene	1000	ND
tert-Butylalcohol	100	290
Tetrachloroethene	1	ND
Toluene	1000	ND
Trichloroethene	1	ND
Vinyl chloride	2	ND

PZ-7	Criteria	7/04
VOCs:		
1,1,2,2-Tetrachloroethane	1	ND
1,1,2-Trichloroethane	3	ND
1,1-Dichloroethane	70	ND
1,1-Dichloroethene	2	ND
1,2-Dichlorobenzene	600	ND
1,2-Dichloroethane	2	ND
1,2-Dichloroethene (cis)	10	ND
1,2-Dichloroethene (trans)	100	ND
1,2-Dichloropropane	5	ND
1,3-Dichlorobenzene	600	ND
1,3-Dichloropropene (cis)	0.02	ND
1,3-Dichloropropene (trans)	0.02	ND
1,4-Dichlorobenzene	75	ND
Acetone	700	ND
Benzene	1	ND
Bromodichloromethane	1	ND
Bromoform	4	ND
Bromomethane	10	ND
Carbon disulfide	800	ND
Carbon tetrachloride	2	ND
Chlorobenzene	4	ND
Chloroform	6	ND
Chloromethane	30	ND
Dibromochloromethane	10	ND
Ethylbenzene	700	ND
Hexachlorobutadiene	1	ND
Isopropyl Ether	--	ND
m&p-Xylene	1000	ND
Methyl tert-butyl ether	70	6.7
Methylene chloride	2	ND
o-Xylene	1000	ND
tert-Butylalcohol	100	ND
Tetrachloroethene	1	ND
Toluene	1000	ND
Trichloroethene	1	ND
Vinyl chloride	2	ND

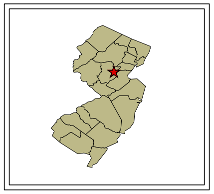
HP-8	Criteria	7/04
VOCs:		
1,1,2,2-Tetrachloroethane	1	ND
1,1,2-Trichloroethane	3	ND
1,1-Dichloroethane	70	ND
1,1-Dichloroethene	2	ND
1,2-Dichlorobenzene	600	ND
1,2-Dichloroethane	2	ND
1,2-Dichloroethene (cis)	10	ND
1,2-Dichloroethene (trans)	100	ND
1,2-Dichloropropane	5	ND
1,3-Dichlorobenzene	600	ND
1,3-Dichloropropene (cis)	0.02	ND
1,3-Dichloropropene (trans)	0.02	ND
1,4-Dichlorobenzene	75	ND
Acetone	700	ND
Benzene	1	ND
Bromodichloromethane	1	ND
Bromoform	4	ND
Bromomethane	10	ND
Carbon disulfide	800	ND
Carbon tetrachloride	2	ND
Chlorobenzene	4	ND
Chloroform	6	ND
Chloromethane	30	ND
Dibromochloromethane	10	ND
Ethylbenzene	700	ND
Hexachlorobutadiene	1	ND
Isopropyl Ether	--	ND
m&p-Xylene	1000	ND
Methyl tert-butyl ether	70	1.3
Methylene chloride	2	ND
o-Xylene	1000	ND
tert-Butylalcohol	100	ND
Tetrachloroethene	1	ND
Toluene	1000	ND
Trichloroethene	1	ND
Vinyl chloride	2	ND

PZ-5	Criteria	7/04
VOCs:		
1,1,2,2-Tetrachloroethane	1	ND
1,1,2-Trichloroethane	3	ND
1,1-Dichloroethane	70	ND
1,1-Dichloroethene	2	ND
1,2-Dichlorobenzene	600	ND
1,2-Dichloroethane	2	ND
1,2-Dichloroethene (cis)	10	0.43
1,2-Dichloroethene (trans)	100	ND
1,2-Dichloropropane	5	ND
1,3-Dichlorobenzene	600	ND
1,3-Dichloropropene (cis)	0.02	ND
1,3-Dichloropropene (trans)	0.02	ND
1,4-Dichlorobenzene	75	ND
Acetone	700	ND
Benzene	1	ND
Bromodichloromethane	1	ND
Bromoform	4	ND
Bromomethane	10	ND
Carbon disulfide	800	ND
Carbon tetrachloride	2	ND
Chlorobenzene	4	ND
Chloroform	6	ND
Chloromethane	30	ND
Dibromochloromethane	10	ND
Ethylbenzene	700	ND
Hexachlorobutadiene	1	ND
Isopropyl Ether	--	ND
m&p-Xylene	1000	ND
Methyl tert-butyl ether	70	8.3
Methylene chloride	2	ND
o-Xylene	1000	ND
tert-Butylalcohol	100	ND
Tetrachloroethene	1	0.63
Toluene	1000	ND
Trichloroethene	1	ND
Vinyl chloride	2	ND

HP-7	Criteria	7/04
VOCs:		
1,1,2,2-Tetrachloroethane	1	ND
1,1,2-Trichloroethane	3	ND
1,1-Dichloroethane	70	ND
1,1-Dichloroethene	2	ND
1,2-Dichlorobenzene	600	ND
1,2-Dichloroethane	2	ND
1,2-Dichloroethene (cis)	10	ND
1,2-Dichloroethene (trans)	100	ND
1,2-Dichloropropane	5	ND
1,3-Dichlorobenzene	600	ND
1,3-Dichloropropene (cis)	0.02	ND
1,3-Dichloropropene (trans)	0.02	ND
1,4-Dichlorobenzene	75	ND
Acetone	700	ND
Benzene	1	0.77
Bromodichloromethane	1	ND
Bromoform	4	ND
Bromomethane	10	ND
Carbon disulfide	800	ND
Carbon tetrachloride	2	ND
Chlorobenzene	4	ND
Chloroform	6	ND
Chloromethane	30	ND
Dibromochloromethane	10	ND
Ethylbenzene	700	ND
Hexachlorobutadiene	1	ND
Isopropyl Ether	--	ND
m&p-Xylene	1000	ND
Methyl tert-butyl ether	70	5.8
Methylene chloride	2	ND
o-Xylene	1000	ND
tert-Butylalcohol	100	ND
Tetrachloroethene	1	ND
Toluene	1000	0.34
Trichloroethene	1	ND
Vinyl chloride	2	ND

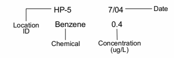
HP-6	Criteria	7/04
VOCs:		
1,1,2,2-Tetrachloroethane	1	ND
1,1,2-Trichloroethane	3	ND
1,1-Dichloroethane	70	ND
1,1-Dichloroethene	2	ND
1,2-Dichlorobenzene	600	ND
1,2-Dichloroethane	2	ND
1,2-Dichloroethene (cis)	10	ND
1,2-Dichloroethene (trans)	100	ND
1,2-Dichloropropane	5	ND
1,3-Dichlorobenzene	600	ND
1,3-Dichloropropene (cis)	0.02	ND
1,3-Dichloropropene (trans)	0.02	ND
1,4-Dichlorobenzene	75	2
Acetone	700	5.8
Benzene	1	0.39
Bromodichloromethane	1	ND
Bromoform	4	ND
Bromomethane	10	ND
Carbon disulfide	800	ND
Carbon tetrachloride	2	ND
Chlorobenzene	4	ND
Chloroform	6	ND
Chloromethane	30	ND
Dibromochloromethane	10	ND
Ethylbenzene	700	ND
Hexachlorobutadiene	1	ND
Isopropyl Ether	--	ND
m&p-Xylene	1000	ND
Methyl tert-butyl ether	70	ND
Methylene chloride	2	ND
o-Xylene	1000	ND
tert-Butylalcohol	100	ND
Tetrachloroethene	1	ND
Toluene	1000	ND
Trichloroethene	1	ND
Vinyl chloride	2	ND

Key Map



Legend

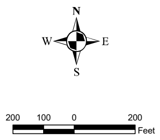
- ⊡ Hydropunch
- ▲ Piezometer
- Storm Drain
- Grate
- Pipe Chase
- Trench
- Water
- Boundary
- Road



Notes:

Criteria - Most Stringent of NJ GWQS, Federal MCLs or State MCLs
NA - Not Analyzed
ND - Not Detected
ug/L - micrograms per liter

Shaded Results - indicate an exceedance in applicable standards



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Middlesex Sampling Plant (MSP)
Middlesex, NJ

Figure 5
Phase I GW Delineation -
Hydropunch & Piezometer VOC Results

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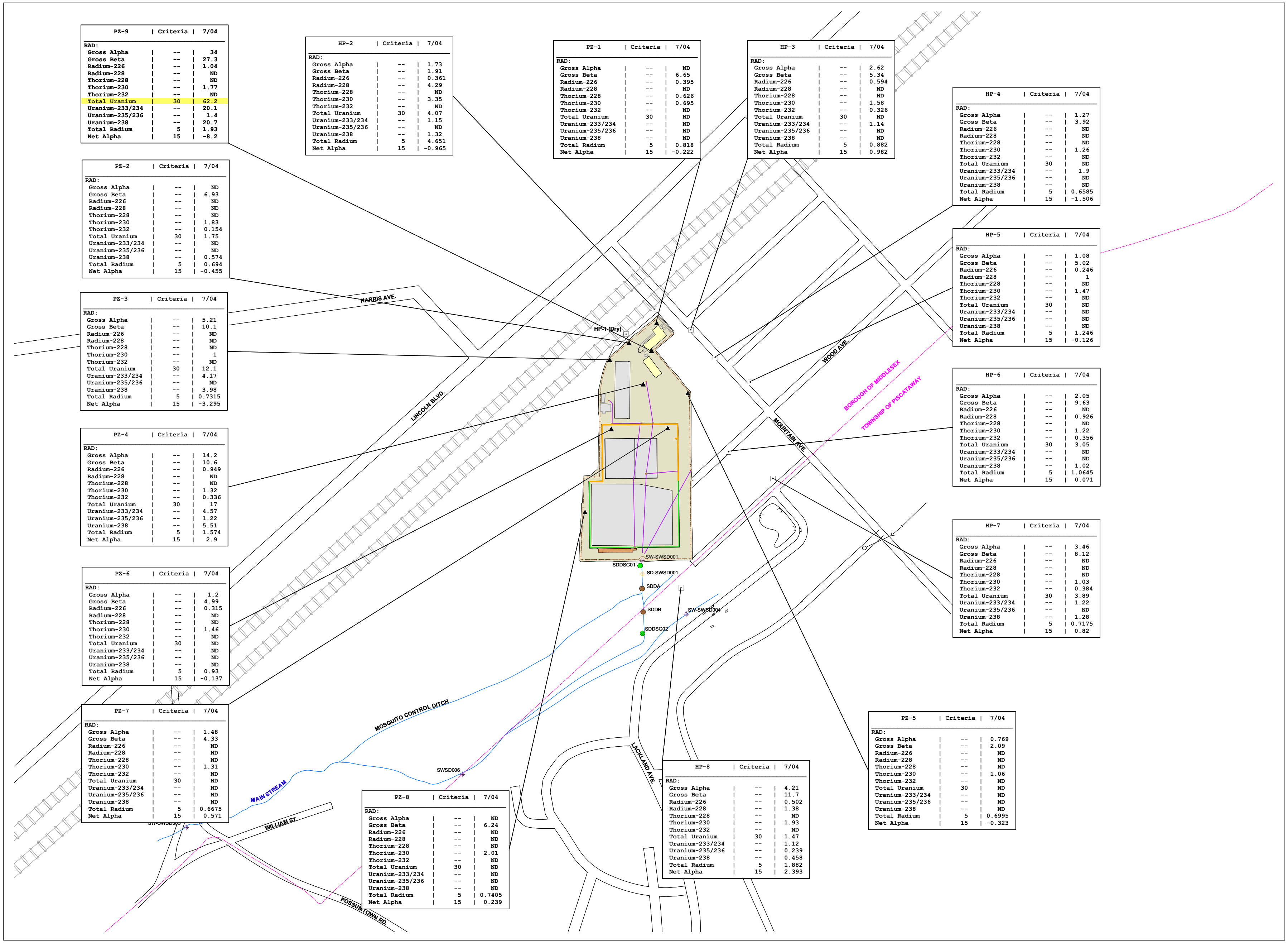


PZ-9	Criteria	7/04
RAD:		
Gross Alpha	--	34
Gross Beta	--	27.3
Radium-226	--	1.04
Radium-228	--	ND
Thorium-228	--	ND
Thorium-230	--	1.77
Thorium-232	--	ND
Total Uranium	30	62.2
Uranium-233/234	--	20.1
Uranium-235/236	--	1.4
Uranium-238	--	20.7
Total Radium	5	1.93
Net Alpha	15	-8.2

HP-2	Criteria	7/04
RAD:		
Gross Alpha	--	1.73
Gross Beta	--	1.91
Radium-226	--	0.361
Radium-228	--	4.29
Thorium-228	--	ND
Thorium-230	--	3.35
Thorium-232	--	ND
Total Uranium	30	4.07
Uranium-233/234	--	1.15
Uranium-235/236	--	ND
Uranium-238	--	1.32
Total Radium	5	4.651
Net Alpha	15	-0.965

PZ-1	Criteria	7/04
RAD:		
Gross Alpha	--	ND
Gross Beta	--	6.65
Radium-226	--	0.395
Radium-228	--	ND
Thorium-228	--	0.626
Thorium-230	--	0.695
Thorium-232	--	ND
Total Uranium	30	ND
Uranium-233/234	--	ND
Uranium-235/236	--	ND
Uranium-238	--	ND
Total Radium	5	0.818
Net Alpha	15	-0.222

HP-3	Criteria	7/04
RAD:		
Gross Alpha	--	2.62
Gross Beta	--	5.34
Radium-226	--	0.594
Radium-228	--	ND
Thorium-228	--	ND
Thorium-230	--	1.58
Thorium-232	--	0.326
Total Uranium	30	ND
Uranium-233/234	--	1.14
Uranium-235/236	--	ND
Uranium-238	--	ND
Total Radium	5	0.882
Net Alpha	15	0.982

HP-4	Criteria	7/04
RAD:		
Gross Alpha	--	1.27
Gross Beta	--	3.92
Radium-226	--	ND
Radium-228	--	ND
Thorium-228	--	ND
Thorium-230	--	1.26
Thorium-232	--	ND
Total Uranium	30	ND
Uranium-233/234	--	1.9
Uranium-235/236	--	ND
Uranium-238	--	ND
Total Radium	5	0.6585
Net Alpha	15	-1.506

PZ-2	Criteria	7/04
RAD:		
Gross Alpha	--	ND
Gross Beta	--	6.93
Radium-226	--	ND
Radium-228	--	ND
Thorium-228	--	ND
Thorium-230	--	1.83
Thorium-232	--	0.154
Total Uranium	30	1.75
Uranium-233/234	--	ND
Uranium-235/236	--	ND
Uranium-238	--	0.574
Total Radium	5	0.694
Net Alpha	15	-0.455

HP-5	Criteria	7/04
RAD:		
Gross Alpha	--	1.08
Gross Beta	--	5.02
Radium-226	--	0.246
Radium-228	--	1
Thorium-228	--	ND
Thorium-230	--	1.47
Thorium-232	--	ND
Total Uranium	30	ND
Uranium-233/234	--	ND
Uranium-235/236	--	ND
Uranium-238	--	ND
Total Radium	5	1.246
Net Alpha	15	-0.126

PZ-3	Criteria	7/04
RAD:		
Gross Alpha	--	5.21
Gross Beta	--	10.1
Radium-226	--	ND
Radium-228	--	ND
Thorium-228	--	ND
Thorium-230	--	1
Thorium-232	--	ND
Total Uranium	30	12.1
Uranium-233/234	--	4.17
Uranium-235/236	--	ND
Uranium-238	--	3.98
Total Radium	5	0.7315
Net Alpha	15	-3.295

HP-6	Criteria	7/04
RAD:		
Gross Alpha	--	2.05
Gross Beta	--	9.63
Radium-226	--	ND
Radium-228	--	0.926
Thorium-228	--	ND
Thorium-230	--	1.22
Thorium-232	--	0.356
Total Uranium	30	3.05
Uranium-233/234	--	ND
Uranium-235/236	--	ND
Uranium-238	--	1.02
Total Radium	5	1.0645
Net Alpha	15	0.071

PZ-4	Criteria	7/04
RAD:		
Gross Alpha	--	14.2
Gross Beta	--	10.6
Radium-226	--	0.949
Radium-228	--	ND
Thorium-228	--	ND
Thorium-230	--	1.32
Thorium-232	--	0.336
Total Uranium	30	17
Uranium-233/234	--	4.57
Uranium-235/236	--	1.22
Uranium-238	--	5.51
Total Radium	5	1.574
Net Alpha	15	2.9

PZ-6	Criteria	7/04
RAD:		
Gross Alpha	--	1.2
Gross Beta	--	4.99
Radium-226	--	0.315
Radium-228	--	ND
Thorium-228	--	ND
Thorium-230	--	1.46
Thorium-232	--	ND
Total Uranium	30	ND
Uranium-233/234	--	ND
Uranium-235/236	--	ND
Uranium-238	--	ND
Total Radium	5	0.93
Net Alpha	15	-0.137

HP-7	Criteria	7/04
RAD:		
Gross Alpha	--	3.46
Gross Beta	--	8.12
Radium-226	--	ND
Radium-228	--	ND
Thorium-228	--	ND
Thorium-230	--	1.03
Thorium-232	--	0.384
Total Uranium	30	3.89
Uranium-233/234	--	1.22
Uranium-235/236	--	ND
Uranium-238	--	1.28
Total Radium	5	0.7175
Net Alpha	15	0.82

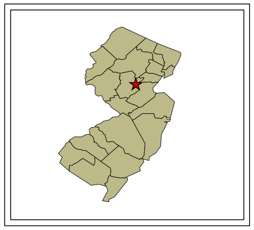
PZ-7	Criteria	7/04
RAD:		
Gross Alpha	--	1.48
Gross Beta	--	4.33
Radium-226	--	ND
Radium-228	--	ND
Thorium-228	--	ND
Thorium-230	--	1.31
Thorium-232	--	ND
Total Uranium	30	ND
Uranium-233/234	--	ND
Uranium-235/236	--	ND
Uranium-238	--	ND
Total Radium	5	0.6675
Net Alpha	15	0.571

PZ-5	Criteria	7/04
RAD:		
Gross Alpha	--	0.769
Gross Beta	--	2.09
Radium-226	--	ND
Radium-228	--	ND
Thorium-228	--	ND
Thorium-230	--	1.06
Thorium-232	--	ND
Total Uranium	30	ND
Uranium-233/234	--	ND
Uranium-235/236	--	ND
Uranium-238	--	ND
Total Radium	5	0.6995
Net Alpha	15	-0.323

HP-8	Criteria	7/04
RAD:		
Gross Alpha	--	4.21
Gross Beta	--	11.7
Radium-226	--	0.502
Radium-228	--	1.38
Thorium-228	--	ND
Thorium-230	--	1.93
Thorium-232	--	ND
Total Uranium	30	1.47
Uranium-233/234	--	1.12
Uranium-235/236	--	0.239
Uranium-238	--	0.458
Total Radium	5	1.882
Net Alpha	15	2.393

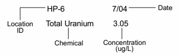
PZ-8	Criteria	7/04
RAD:		
Gross Alpha	--	ND
Gross Beta	--	6.24
Radium-226	--	ND
Radium-228	--	ND
Thorium-228	--	ND
Thorium-230	--	2.01
Thorium-232	--	ND
Total Uranium	30	ND
Uranium-233/234	--	ND
Uranium-235/236	--	ND
Uranium-238	--	ND
Total Radium	5	0.7405
Net Alpha	15	0.239

Key Map



Legend

- ▫ Hydropunch Location
- ▲ Piezometer Location
- Storm Drain
- Grate
- Pipe Chase
- Trench
- Water
- Boundary
- Road



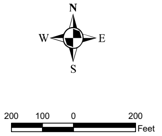
Notes:

-Total Uranium is measured in ug/L
-Net Alpha and Total Radium measured in pCi/L

-Net Alpha = Gross Alpha -
(Uranium238 + Uranium233/234 + Uranium235/236)
-Total Radium = Ra-226 + Ra-228

Criteria - Most Stringent of NJ GWQS, Federal MCLs or State MCLs
NA - Not Analyzed
ND - Not Detected
ug/L - micrograms per liter
pCi/L - Pico Curies per liter

Shaded Results - indicate an exceedance in applicable standards



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Middlesex Sampling Plant (MSP)
Middlesex, NJ

Figure 6
Phase I GW Delineation -
Hydropunch & Piezometer RAD Results

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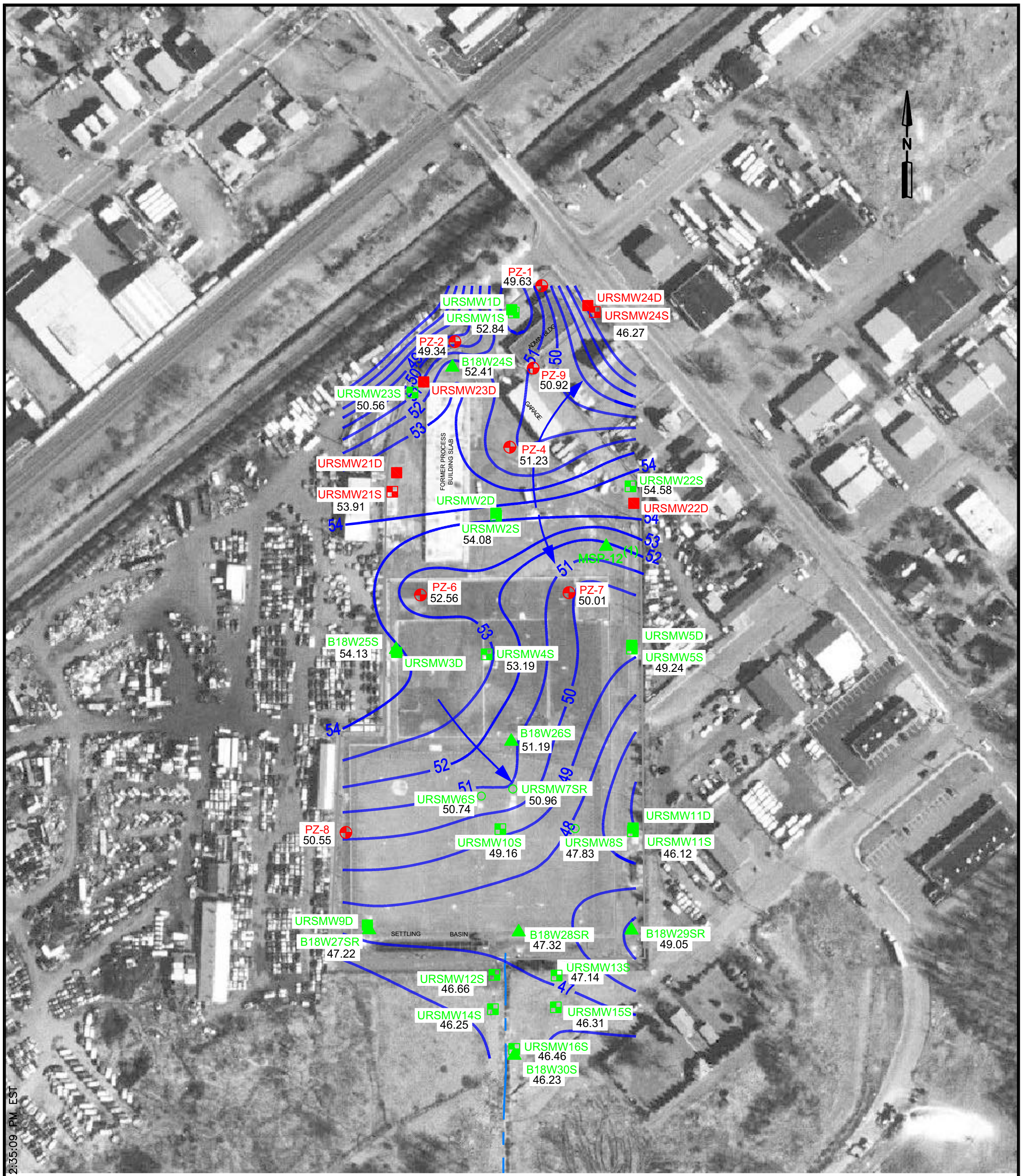


Legend

Monitoring Well Locations

- ▨ Overburden Well
- 🟩 Bedrock Well
- ○ Pipe Chase Well
- ▲ Existing E.S. Overburden Well
- ⊕ Piezometer Installation Locations
- 🟥 New Bedrock Monitoring Well Installation
- ▨ New Overburden Monitoring Well Location

(1) MSP-12 Was Abandoned on 12/12/04 and is Replaced by URSMW22S
PZ-5 Has been renamed URSMW22S
PZ-3 Has been renamed URSMW23S

40 ⌒ Ground Water Contour Elevation in Feet msl
→ Ground Water Flow Direction
(53.07) Ground Water Elevation in Feet Above Mean Sea Level

GRAPHIC SCALE
160' 0 80' 160'

Image Source.
New Jersey 2002 High Resolution Orthophotography.
State of New Jersey Office of Information Technology,
Office of Geographic Information Systems. July 31, 2003.
Tiles H8B9 and H8B10.

MIDDLESEX SAMPLING PLANT

239 MOUNTAIN AVE.
MIDDLESEX, NEW JERSEY

OVERBURDEN GROUNDWATER CONTOURS WITH FLOW DIRECTIONS
NOVEMBER 16, 2004

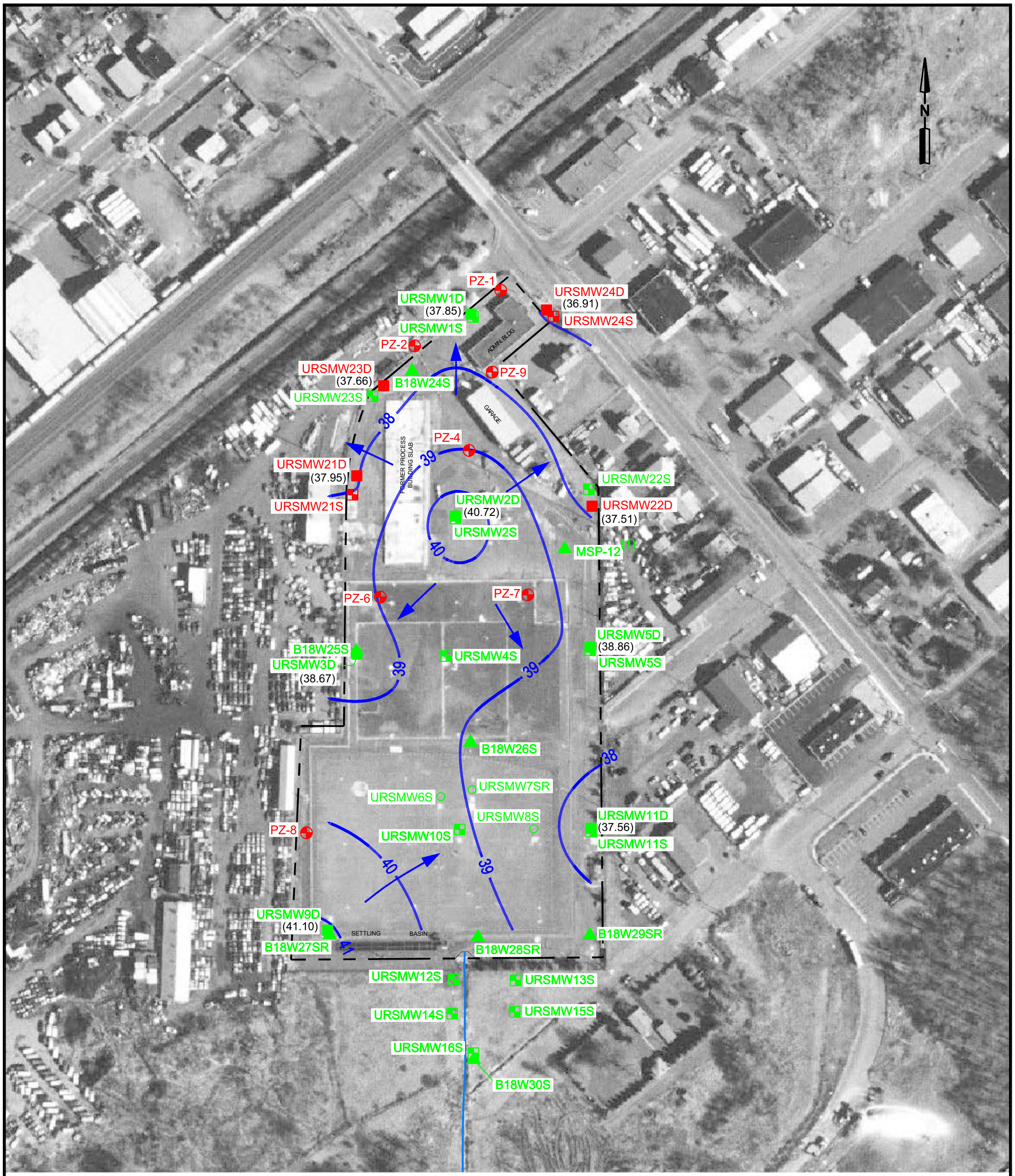
US Army Corps of Engineers
New York District

FUSRAP

DATE: NOVEMBER 2004
JOB: 19577-079-149

FIGURE 7

S:\19577\079\Year-2004\GWOU-RI Report\Plot\GWRI-007.dwg 3/11/2005 2:35:09 PM EST



Legend

Monitoring Well Locations

- 🟩 Overburden Well
- 🟩 Bedrock Well
- ○ Pipe Chase Well
- ▲ Existing E.S. Overburden Well
- ● Piezometer Installation Locations
- 🟥 New Bedrock Monitoring Well Installation
- 🟥 New Overburden Monitoring Well Location

(1) MSP-12 Was Abandoned on 12/12/04 and is Replaced by URSMW22S

PZ-5 Has been renamed URSMW22S

PZ-3 Has been renamed URSMW23S

40 Ground Water Contour Elevation in Feet msl

→ Ground Water Flow Direction

(53.07) Ground Water Elevation in Feet Above Mean Sea Level

Image Source.

New Jersey 2002 High Resolution Orthophotography.
State of New Jersey Office of Information Technology,
Office of Geographic Information Systems. July 31, 2003.
Tiles H8B9 and H8B10.

DRAFT

GRAPHIC SCALE

160' 0 80' 160'

MIDDLESEX SAMPLING PLANT

239 MOUNTAIN AVE.
MIDDLESEX, NEW JERSEY

BEDROCK GROUNDWATER CONTOURS WITH FLOW DIRECTIONS NOVEMBER 16, 2004

US Army Corps of Engineers
New York District

FUSRAP

DATE: NOVEMBER 2004

JOB: 19577-079-149

Figure 8

S:\19577\079\Year-2004\GWOU-RI Report\Plot\GWRI-008.dwg 3/11/2005 2:37:07 PM EST

URSMW23S	Criteria	11/04
VOCs:		
1,1,2,2-Tetrachloroethane	1	ND
1,1,2-Trichloroethane	3	ND
1,1-Dichloroethane	70	ND
1,1-Dichloroethene	2	ND
1,2-Dichlorobenzene	600	ND
1,2-Dichloroethane	2	ND
1,2-Dichloroethene (cis)	10	ND
1,2-Dichloroethene (trans)	100	ND
1,2-Dichloropropane	5	ND
1,3-Dichlorobenzene	600	ND
1,3-Dichloropropene (cis)	0.02	ND
1,3-Dichloropropene (trans)	0.02	ND
1,4-Dichlorobenzene	75	ND
2-Hexanone	100	ND
4-Methyl-2-pentanone	400	ND
Acetone	700	ND
Benzene	1	ND
Bromodichloromethane	1	ND
Bromoform	4	ND
Bromomethane	10	ND
Carbon disulfide	800	0.58
Carbon tetrachloride	2	ND
Chlorobenzene	4	ND
Chloroethane	100	ND
Chloroform	6	ND
Chloromethane	30	ND
Dibromochloromethane	10	ND
Ethylbenzene	700	ND
Hexachlorobutadiene	1	ND
Isopropyl Ether	--	ND
m&p-Xylene	1000	ND
Methyl ethyl ketone (2-Butanone)	300	ND
Methyl tert-butyl ether	70	ND
Methylene chloride	2	1.6
o-Xylene	1000	ND
Styrene	100	ND
tert-Butylalcohol	100	ND
Tetrachloroethene	1	0.24
Toluene	1000	ND
Trichloroethane	30	ND
Trichloroethene	1	ND
Vinyl chloride	2	ND

URSMW24S	Criteria	11/04
VOCs:		
1,1,2,2-Tetrachloroethane	1	ND
1,1,2-Trichloroethane	3	ND
1,1-Dichloroethane	70	ND
1,1-Dichloroethene	2	ND
1,2-Dichlorobenzene	600	ND
1,2-Dichloroethane	2	ND
1,2-Dichloroethene (cis)	10	ND
1,2-Dichloroethene (trans)	100	ND
1,2-Dichloropropane	5	ND
1,3-Dichlorobenzene	600	ND
1,3-Dichloropropene (cis)	0.02	ND
1,3-Dichloropropene (trans)	0.02	ND
1,4-Dichlorobenzene	75	ND
2-Hexanone	100	ND
4-Methyl-2-pentanone	400	ND
Acetone	700	17
Benzene	1	ND
Bromodichloromethane	1	ND
Bromoform	4	ND
Bromomethane	10	ND
Carbon disulfide	800	0.43
Carbon tetrachloride	2	ND
Chlorobenzene	4	ND
Chloroethane	100	ND
Chloroform	6	ND
Chloromethane	30	ND
Dibromochloromethane	10	ND
Ethylbenzene	700	ND
Hexachlorobutadiene	1	ND
Isopropyl Ether	--	ND
m&p-Xylene	1000	ND
Methyl ethyl ketone (2-Butanone)	300	ND
Methyl tert-butyl ether	70	ND
Methylene chloride	2	1.7
o-Xylene	1000	ND
Styrene	100	ND
tert-Butylalcohol	100	ND
Tetrachloroethene	1	ND
Toluene	1000	ND
Trichloroethane	30	ND
Trichloroethene	1	ND
Vinyl chloride	2	ND

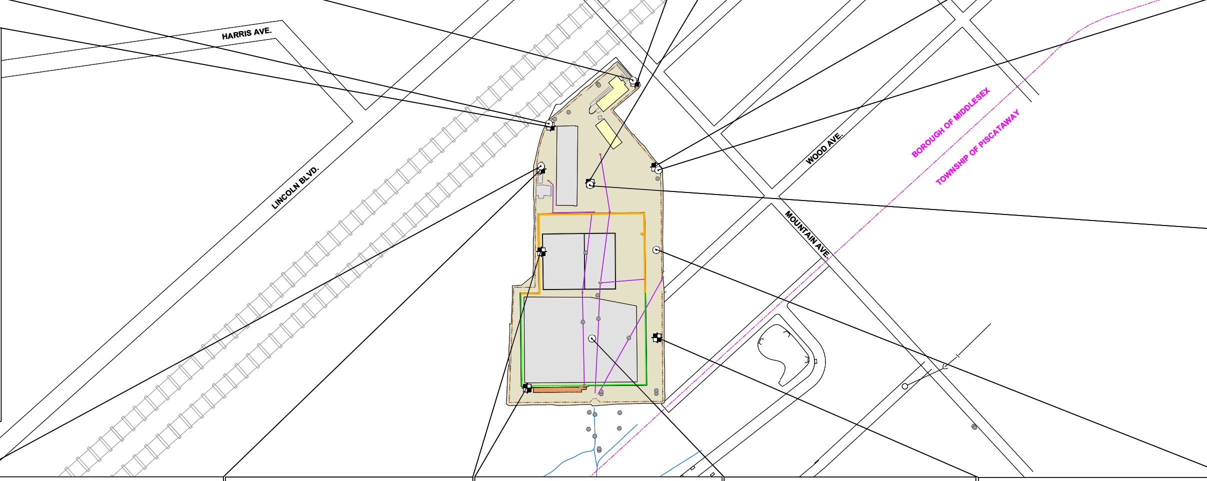
URSMW24D	Criteria	11/18/04	11/19/04
VOCs:			
1,1,2,2-Tetrachloroethane	1	ND	ND
1,1,2-Trichloroethane	3	ND	ND
1,1-Dichloroethane	70	ND	ND
1,1-Dichloroethene	2	ND	ND
1,2-Dichlorobenzene	600	ND	ND
1,2-Dichloroethane	2	ND	ND
1,2-Dichloroethene (cis)	10	0.66	ND
1,2-Dichloroethene (trans)	100	ND	ND
1,2-Dichloropropane	5	ND	ND
1,3-Dichlorobenzene	600	ND	ND
1,3-Dichloropropene (cis)	0.02	ND	ND
1,3-Dichloropropene (trans)	0.02	ND	ND
1,4-Dichlorobenzene	75	ND	ND
2-Hexanone	100	ND	ND
4-Methyl-2-pentanone	400	ND	ND
Acetone	700	ND	17
Benzene	1	ND	ND
Bromodichloromethane	1	ND	ND
Bromoform	4	ND	ND
Bromomethane	10	ND	ND
Carbon disulfide	800	9	0.43
Carbon tetrachloride	2	430	ND
Chlorobenzene	4	ND	ND
Chloroethane	100	ND	ND
Chloroform	6	41	ND
Chloromethane	30	ND	ND
Dibromochloromethane	10	ND	ND
Ethylbenzene	700	ND	ND
Hexachlorobutadiene	1	ND	ND
Isopropyl Ether	--	ND	ND
m&p-Xylene	1000	ND	ND
Methyl ethyl ketone (2-Butanone)	300	ND	ND
Methyl tert-butyl ether	70	ND	ND
Methylene chloride	2	49	1.7
o-Xylene	1000	ND	ND
Styrene	100	ND	ND
tert-Butylalcohol	100	ND	ND
Tetrachloroethene	1	ND	ND
Toluene	1000	ND	ND
Trichloroethane	30	ND	ND
Trichloroethene	1	24	ND
Vinyl chloride	2	ND	ND

URSMW2D	Criteria	10/04
VOCs:		
1,1,2,2-Tetrachloroethane	1	ND
1,1,2-Trichloroethane	3	ND
1,1-Dichloroethane	70	0.3
1,1-Dichloroethene	2	ND
1,2-Dichlorobenzene	600	ND
1,2-Dichloroethane	2	ND
1,2-Dichloroethene (cis)	10	0.45
1,2-Dichloroethene (trans)	100	ND
1,2-Dichloropropane	5	ND
1,3-Dichlorobenzene	600	ND
1,3-Dichloropropene (cis)	0.02	ND
1,3-Dichloropropene (trans)	0.02	ND
1,4-Dichlorobenzene	75	ND
2-Hexanone	100	ND
4-Methyl-2-pentanone	400	ND
Acetone	700	ND
Benzene	1	ND
Bromodichloromethane	1	ND
Bromoform	4	ND
Bromomethane	10	ND
Carbon disulfide	800	ND
Carbon tetrachloride	2	19
Chlorobenzene	4	ND
Chloroethane	100	ND
Chloroform	6	2.8
Chloromethane	30	ND
Dibromochloromethane	10	ND
Ethylbenzene	700	ND
Hexachlorobutadiene	1	ND
Isopropyl Ether	--	ND
m&p-Xylene	1000	ND
Methyl ethyl ketone (2-Butanone)	300	ND
Methyl tert-butyl ether	70	1.6
Methylene chloride	2	0.57
o-Xylene	1000	ND
Styrene	100	ND
tert-Butylalcohol	100	ND
Tetrachloroethene	1	ND
Toluene	1000	ND
Trichloroethane	30	ND
Trichloroethene	1	23
Vinyl chloride	2	ND

URSMW22D	Criteria	11/04
VOCs:		
1,1,2,2-Tetrachloroethane	1	ND
1,1,2-Trichloroethane	3	ND
1,1-Dichloroethane	70	1.3
1,1-Dichloroethene	2	1.1
1,2-Dichlorobenzene	600	ND
1,2-Dichloroethane	2	ND
1,2-Dichloroethene (cis)	10	ND
1,2-Dichloroethene (trans)	100	ND
1,2-Dichloropropane	5	ND
1,3-Dichlorobenzene	600	ND
1,3-Dichloropropene (cis)	0.02	ND
1,3-Dichloropropene (trans)	0.02	ND
1,4-Dichlorobenzene	75	ND
2-Hexanone	100	ND
4-Methyl-2-pentanone	400	ND
Acetone	700	ND
Benzene	1	ND
Bromodichloromethane	1	ND
Bromoform	4	ND
Bromomethane	10	ND
Carbon disulfide	800	0.72
Carbon tetrachloride	2	ND
Chlorobenzene	4	ND
Chloroethane	100	ND
Chloroform	6	ND
Chloromethane	30	ND
Dibromochloromethane	10	ND
Ethylbenzene	700	ND
Hexachlorobutadiene	1	ND
Isopropyl Ether	--	ND
m&p-Xylene	1000	ND
Methyl ethyl ketone (2-Butanone)	300	ND
Methyl tert-butyl ether	70	5.1
Methylene chloride	2	2
o-Xylene	1000	ND
Styrene	100	ND
tert-Butylalcohol	100	ND
Tetrachloroethene	1	0.28
Toluene	1000	ND
Trichloroethane	30	ND
Trichloroethene	1	1.3
Vinyl chloride	2	ND

URSMW22S	Criteria	11/04
VOCs:		
1,1,2,2-Tetrachloroethane	1	ND
1,1,2-Trichloroethane	3	ND
1,1-Dichloroethane	70	ND
1,1-Dichloroethene	2	ND
1,2-Dichlorobenzene	600	ND
1,2-Dichloroethane	2	ND
1,2-Dichloroethene (cis)	10	ND
1,2-Dichloroethene (trans)	100	ND
1,2-Dichloropropane	5	ND
1,3-Dichlorobenzene	600	ND
1,3-Dichloropropene (cis)	0.02	ND
1,3-Dichloropropene (trans)	0.02	ND
1,4-Dichlorobenzene	75	ND
2-Hexanone	100	ND
4-Methyl-2-pentanone	400	ND
Acetone	700	ND
Benzene	1	ND
Bromodichloromethane	1	ND
Bromoform	4	ND
Bromomethane	10	ND
Carbon disulfide	800	ND
Carbon tetrachloride	2	ND
Chlorobenzene	4	ND
Chloroethane	100	ND
Chloroform	6	ND
Chloromethane	30	ND
Dibromochloromethane	10	ND
Ethylbenzene	700	ND
Hexachlorobutadiene	1	ND
Isopropyl Ether	--	ND
m&p-Xylene	1000	ND
Methyl ethyl ketone (2-Butanone)	300	ND
Methyl tert-butyl ether	70	2.5
Methylene chloride	2	1.7
o-Xylene	1000	ND
Styrene	100	ND
tert-Butylalcohol	100	ND
Tetrachloroethene	1	0.42
Toluene	1000	1.2
Trichloroethane	30	ND
Trichloroethene	1	ND
Vinyl chloride	2	ND

URSMW23D	Criteria	11/04
VOCs:		
1,1,2,2-Tetrachloroethane	1	ND
1,1,2-Trichloroethane	3	ND
1,1-Dichloroethane	70	ND
1,1-Dichloroethene	2	ND
1,2-Dichlorobenzene	600	ND
1,2-Dichloroethane	2	ND
1,2-Dichloroethene (cis)	10	ND
1,2-Dichloroethene (trans)	100	ND
1,2-Dichloropropane	5	ND
1,3-Dichlorobenzene	600	ND
1,3-Dichloropropene (cis)	0.02	ND
1,3-Dichloropropene (trans)	0.02	ND
1,4-Dichlorobenzene	75	ND
2-Hexanone	100	ND
4-Methyl-2-pentanone	400	ND
Acetone	700	5.5
Benzene	1	ND
Bromodichloromethane	1	ND
Bromoform	4	ND
Bromomethane	10	ND
Carbon disulfide	800	ND
Carbon tetrachloride	2	1.6
Chlorobenzene	4	ND
Chloroethane	100	ND
Chloroform	6	0.32
Chloromethane	30	ND
Dibromochloromethane	10	ND
Ethylbenzene	700	ND
Hexachlorobutadiene	1	ND
Isopropyl Ether	--	ND
m&p-Xylene	1000	ND
Methyl ethyl ketone (2-Butanone)	300	ND
Methyl tert-butyl ether	70	ND
Methylene chloride	2	0.49
o-Xylene	1000	ND
Styrene	100	ND
tert-Butylalcohol	100	ND
Tetrachloroethene	1	ND
Toluene	1000	ND
Trichloroethane	30	ND
Trichloroethene	1	ND
Vinyl chloride	2	ND



URSMW2S	Criteria	10/04
VOCs:		
1,1,2,2-Tetrachloroethane	1	ND
1,1,2-Trichloroethane	3	ND
1,1-Dichloroethane	70	ND
1,1-Dichloroethene	2	ND
1,2-Dichlorobenzene	600	ND
1,2-Dichloroethane	2	ND
1,2-Dichloroethene (cis)	10	ND
1,2-Dichloroethene (trans)	100	ND
1,2-Dichloropropane	5	ND
1,3-Dichlorobenzene	600	ND
1,3-Dichloropropene (cis)	0.02	ND
1,3-Dichloropropene (trans)	0.02	ND
1,4-Dichlorobenzene	75	ND
2-Hexanone	100	ND
4-Methyl-2-pentanone	400	ND
Acetone	700	13
Benzene	1	ND
Bromodichloromethane	1	ND
Bromoform	4	ND
Bromomethane	10	ND
Carbon disulfide	800	1.1
Carbon tetrachloride	2	ND
Chlorobenzene	4	ND
Chloroethane	100	ND
Chloroform	6	ND
Chloromethane	30	0.56
Dibromochloromethane	10	ND
Ethylbenzene	700	ND
Hexachlorobutadiene	1	ND
Isopropyl Ether	--	ND
m&p-Xylene	1000	ND
Methyl ethyl ketone (2-Butanone)	300	ND
Methyl tert-butyl ether	70	ND
Methylene chloride	2	ND
o-Xylene	1000	ND
Styrene	100	ND
tert-Butylalcohol	100	ND
Tetrachloroethene	1	ND
Toluene	1000	ND
Trichloroethane	30	ND
Trichloroethene	1	ND
Vinyl chloride	2	ND

URSMW21S	Criteria	11/04
VOCs:		
1,1,2,2-Tetrachloroethane	1	ND
1,1,2-Trichloroethane	3	ND
1,1-Dichloroethane	70	ND
1,1-Dichloroethene	2	ND
1,2-Dichlorobenzene	600	ND
1,2-Dichloroethane	2	ND
1,2-Dichloroethene (cis)	10	ND
1,2-Dichloroethene (trans)	100	ND
1,2-Dichloropropane	5	ND
1,3-Dichlorobenzene	600	ND
1,3-Dichloropropene (cis)	0.02	ND
1,3-Dichloropropene (trans)	0.02	ND
1,4-Dichlorobenzene	75	ND
2-Hexanone	100	ND
4-Methyl-2-pentanone	400	ND
Acetone	700	3.5
Benzene	1	ND
Bromodichloromethane	1	ND
Bromoform	4	ND
Bromomethane	10	ND
Carbon disulfide	800	1.3
Carbon tetrachloride	2	ND
Chlorobenzene	4	ND
Chloroethane	100	ND
Chloroform	6	ND
Chloromethane	30	ND
Dibromochloromethane	10	ND
Ethylbenzene	700	ND
Hexachlorobutadiene	1	ND
Isopropyl Ether	--	ND
m&p-Xylene	1000	ND
Methyl ethyl ketone (2-Butanone)	300	ND
Methyl tert-butyl ether	70	ND
Methylene chloride	2	0.44
o-Xylene	1000	ND
Styrene	100	ND
tert-Butylalcohol	100	ND
Tetrachloroethene	1	ND
Toluene	1000	ND
Trichloroethane	30	ND
Trichloroethene	1	ND
Vinyl chloride	2	ND

URSMW21D	Criteria	11/04
VOCs:		
1,1,2,2-Tetrachloroethane	1	ND
1,1,2-Trichloroethane	3	ND
1,1-Dichloroethane	70	ND
1,1-Dichloroethene	2	ND
1,2-Dichlorobenzene	600	ND
1,2-Dichloroethane	2	ND
1,2-Dichloroethene (cis)	10	ND
1,2-Dichloroethene (trans)	100	ND
1,2-Dichloropropane	5	ND
1,3-Dichlorobenzene	600	ND
1,3-Dichloropropene (cis)	0.02	ND
1,3-Dichloropropene (trans)	0.02	ND
1,4-Dichlorobenzene	75	ND
2-Hexanone	100	ND
4-Methyl-2-pentanone	400	ND
Acetone	700	ND
Benzene	1	ND
Bromodichloromethane	1	ND
Bromoform	4	ND
Bromomethane	10	ND
Carbon disulfide	800	0.31
Carbon tetrachloride	2	ND
Chlorobenzene	4	ND
Chloroethane	100	ND
Chloroform	6	ND
Chloromethane	30	ND
Dibromochloromethane	10	ND
Ethylbenzene	700	ND
Hexachlorobutadiene	1	ND
Isopropyl Ether	--	ND
m&p-Xylene	1000	ND
Methyl ethyl ketone (2-Butanone)	300	ND
Methyl tert-butyl ether	70	ND
Methylene chloride	2	0.61
o-Xylene	1000	ND
Styrene	100	ND
tert-Butylalcohol	100	ND
Tetrachloroethene	1	ND
Toluene	1000	ND
Trichloroethane	30	ND
Trichloroethene	1	ND
Vinyl chloride	2	ND

URSMW3D	Criteria	11/04
VOCs:		
1,1,2,2-Tetrachloroethane	1	ND
1,1,2-Trichloroethane	3	ND
1,1-Dichloroethane	70	0.69
1,1-Dichloroethene	2	ND
1,2-Dichlorobenzene	600	ND
1,2-Dichloroethane	2	ND
1,2-Dichloroethene (cis)	10	ND
1,2-Dichloroethene (trans)	100	ND
1,2-Dichloropropane	5	ND
1,3-Dichlorobenzene	600	ND
1,3-Dichloropropene (cis)	0.02	ND
1,3-Dichloropropene (trans)	0.02	ND
1,4-Dichlorobenzene	75	ND
2-Hexanone	100	ND
4-Methyl-2-pentanone	400	ND
Acetone	700	ND
Benzene	1	ND
Bromodichloromethane	1	ND
Bromoform	4	ND
Bromomethane	10	ND
Carbon disulfide	800	1.7
Carbon tetrachloride	2	ND
Chlorobenzene	4	ND
Chloroethane	100	ND
Chloroform	6	ND
Chloromethane	30	ND
Dibromochloromethane	10	ND
Ethylbenzene	700	ND
Hexachlorobutadiene	1	ND
Isopropyl Ether	--	0.93
m&p-Xylene	1000	ND
Methyl ethyl ketone (2-Butanone)	300	ND
Methyl tert-butyl ether	70	120
Methylene chloride	2	1.6
o-Xylene	1000	ND
Styrene	100	ND
tert-Butylalcohol	100	ND
Tetrachloroethene	1	ND
Toluene	1000	ND
Trichloroethane	30	ND
Trichloroethene	1	ND
Vinyl chloride	2	ND

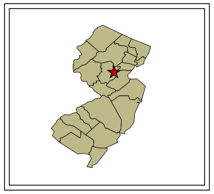
URSMW9D	Criteria	11/04
VOCs:		
1,1,2,2-Tetrachloroethane	1	ND
1,1,2-Trichloroethane	3	ND
1,1-Dichloroethane	70	ND
1,1-Dichloroethene	2	ND
1,2-Dichlorobenzene	600	ND
1,2-Dichloroethane	2	ND
1,2-Dichloroethene (cis)	10	ND
1,2-Dichloroethene (trans)	100	ND
1,2-Dichloropropane	5	ND
1,3-Dichlorobenzene	600	ND
1,3-Dichloropropene (cis)	0.02	ND
1,3-Dichloropropene (trans)	0.02	ND
1,4-Dichlorobenzene	75	ND
2-Hexanone	100	ND
4-Methyl-2-pentanone	400	ND
Acetone	700	ND
Benzene	1	ND
Bromodichloromethane	1	ND
Bromoform	4	ND
Bromomethane	10	ND
Carbon disulfide	800	0.35
Carbon tetrachloride	2	ND
Chlorobenzene	4	ND
Chloroethane	100	ND
Chloroform	6	ND
Chloromethane	30	ND
Dibromochloromethane	10	ND
Ethylbenzene	700	ND
Hexachlorobutadiene	1	ND
Isopropyl Ether	--	ND
m&p-Xylene	1000	ND
Methyl ethyl ketone (2-Butanone)	300	ND
Methyl tert-butyl ether	70	17
Methylene chloride	2	1.6
o-Xylene	1000	ND
Styrene	100	ND
tert-Butylalcohol	100	31
Tetrachloroethene	1	ND
Toluene	1000	ND
Trichloroethane	30	ND
Trichloroethene	1	ND
Vinyl chloride	2	ND

URSMW10S	Criteria	10/04
VOCs:		
1,1,2,2-Tetrachloroethane	1	ND
1,1,2-Trichloroethane	3	ND
1,1-Dichloroethane	70	ND
1,1-Dichloroethene	2	ND
1,2-Dichlorobenzene	600	ND
1,2-Dichloroethane	2	ND
1,2-Dichloroethene (cis)	10	ND
1,2-Dichloroethene (trans)	100	ND
1,2-Dichloropropane	5	ND
1,3-Dichlorobenzene	600	ND
1,3-Dichloropropene (cis)	0.02	ND
1,3-Dichloropropene (trans)	0.02	ND
1,4-Dichlorobenzene	75	ND
2-Hexanone	100	ND
4-Methyl-2-pentanone	400	ND
Acetone	700	ND
Benzene	1	ND
Bromodichloromethane	1	ND
Bromoform	4	ND
Bromomethane	10	ND
Carbon disulfide	800	0.37
Carbon tetrachloride	2	ND
Chlorobenzene	4	ND
Chloroethane	100	ND
Chloroform	6	ND
Chloromethane	30	ND
Dibromochloromethane	10	ND
Ethylbenzene	700	ND
Hexachlorobutadiene	1	ND
Isopropyl Ether	--	ND
m&p-Xylene	1000	ND
Methyl ethyl ketone (2-Butanone)	300	ND
Methyl tert-butyl ether	70	0.68
Methylene chloride	2	0.56
o-Xylene	1000	ND
Styrene	100	ND
tert-Butylalcohol	100	ND
Tetrachloroethene	1	ND
Toluene	1000	ND
Trichloroethane	30	ND
Trichloroethene	1	ND
Vinyl chloride	2	ND

URSMW11D	Criteria	11/04
VOCs:		
1,1,2,2-Tetrachloroethane	1	ND
1,1,2-Trichloroethane	3	ND
1,1-Dichloroethane	70	ND
1,1-Dichloroethene	2	ND
1,2-Dichlorobenzene	600	ND
1,2-Dichloroethane	2	ND
1,2-Dichloroethene (cis)	10	ND
1,2-Dichloroethene (trans)	100	ND
1,2-Dichloropropane	5	ND
1,3-Dichlorobenzene	600	ND
1,3-Dichloropropene (cis)	0.02	ND
1,3-Dichloropropene (trans)	0.02	ND
1,4-Dichlorobenzene	75	ND
2-Hexanone	100	ND
4-Methyl-2-pentanone	400	ND
Acetone	700	5.6
Benzene	1	ND
Bromodichloromethane	1	ND
Bromoform	4	ND
Bromomethane	10	ND
Carbon disulfide	800	ND
Carbon tetrachloride	2	ND
Chlorobenzene	4	ND
Chloroethane	100	ND
Chloroform	6	ND
Chloromethane	30	ND
Dibromochloromethane	10	ND
Ethylbenzene	700	ND
Hexachlorobutadiene	1	ND
Isopropyl Ether	--	ND
m&p-Xylene	1000	ND
Methyl ethyl ketone (2-Butanone)	300	ND
Methyl tert-butyl ether	70	1.9
Methylene chloride	2	1.5
o-Xylene	1000	ND
Styrene	100	ND
tert-Butylalcohol	100	ND
Tetrachloroethene	1	ND
Toluene	1000	ND
Trichloroethane	30	ND
Trichloroethene	1	ND
Vinyl chloride	2	ND

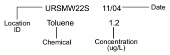
URSMW5S	Criteria	10/04
VOCs:		
1,1,2,2-Tetrachloroethane	1	ND
1,1,2-Trichloroethane	3	ND
1,1-Dichloroethane	70	ND
1,1-Dichloroethene	2	ND
1,2-Dichlorobenzene	600	ND
1,2-Dichloroethane	2	ND
1,2-Dichloroethene (cis)	10	ND
1,2-Dichloroethene (trans)	100	ND
1,2-Dichloropropane	5	ND
1,3-Dichlorobenzene	600	ND
1,3-Dichloropropene (cis)	0.02	ND
1,3-Dichloropropene (trans)	0.02	ND
1,4-Dichlorobenzene	75	ND
2-Hexanone	100	ND
4-Methyl-2-pentanone	400	ND
Acetone	700	ND
Benzene	1	ND
Bromodichloromethane	1	ND
Bromoform	4	ND
Bromomethane	10	ND
Carbon disulfide	800	2.9
Carbon tetrachloride	2	ND
Chlorobenzene	4	ND
Chloroethane	100	ND
Chloroform	6	ND
Chloromethane	30	ND
Dibromochloromethane	10	ND
Ethylbenzene	700	ND
Hexachlorobutadiene	1	ND
Isopropyl Ether	--	ND
m&p-Xylene	1000	ND
Methyl ethyl ketone (2-Butanone)	300	ND
Methyl tert-butyl ether	70	ND
Methylene chloride	2	0.78
o-Xylene	1000	ND
Styrene	100	ND
tert-Butylalcohol	100	ND
Tetrachloroethene	1	ND
Toluene	1000	ND
Trichloroethane	30	ND
Trichloroethene	1	ND
Vinyl chloride	2	ND

Key Map



Legend

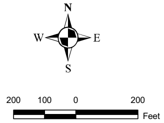
- ⊙ GWOU Monitoring Well - Overburden
- ▚ GWOU Monitoring Well - Bedrock
- Storm Drain
- Grate
- Pipe Chase
- Trench
- Water
- Boundary
- Road



Notes:

Criteria - Most Stringent of NJ GWQS, Federal MCLs or State MCLs
NA - Not Analyzed
ND - Not Detected
ug/L - micrograms per liter

Shaded Results - indicate an exceedance in applicable standards



Draft

Middlesex Sampling Plant (MSP)
Middlesex, NJ

Figure 9
Phase III GW Delineation
VOC Results

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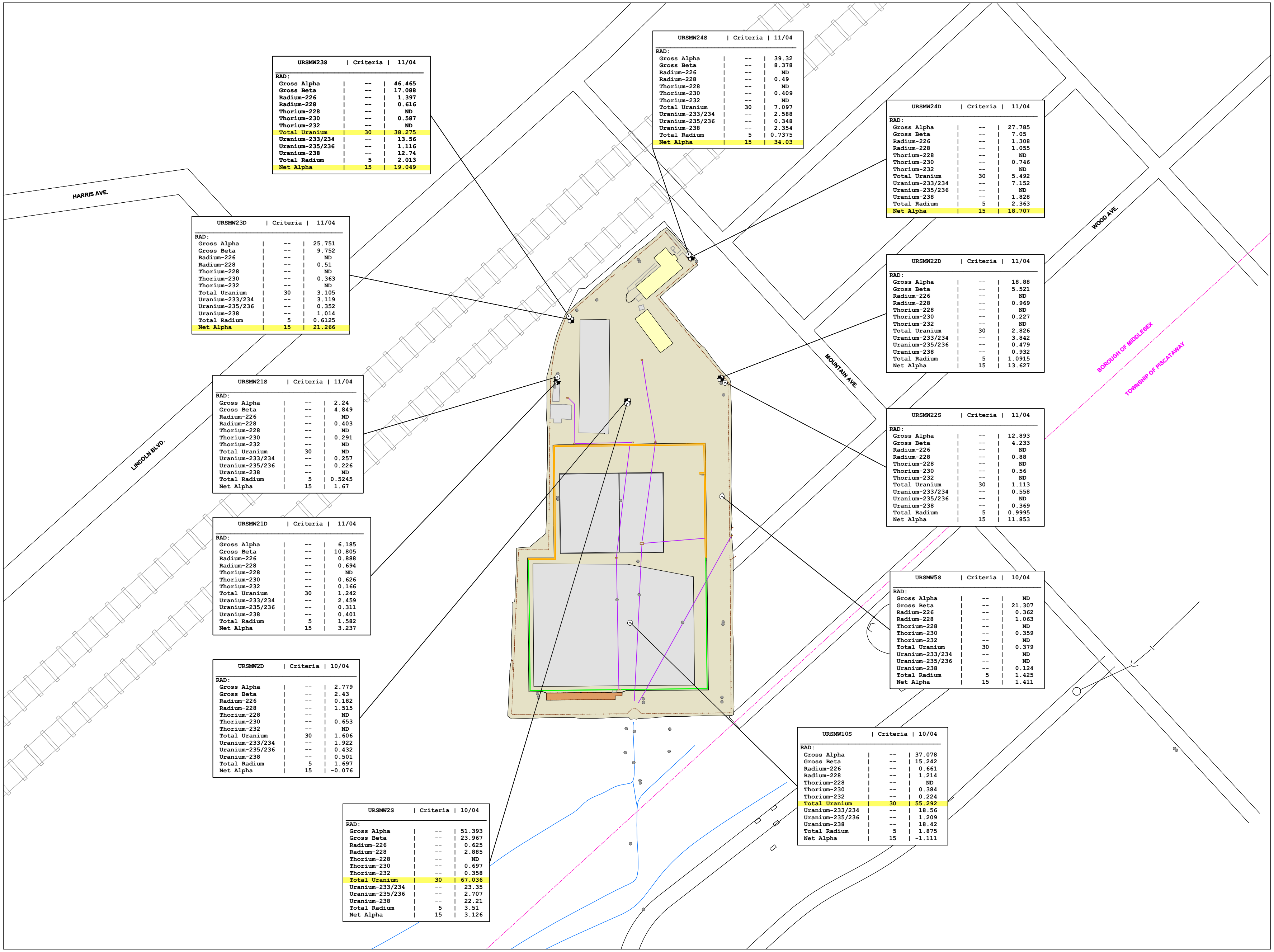


URSMW23S	Criteria	11/04
RAD:		
Gross Alpha	--	46.465
Gross Beta	--	17.088
Radium-226	--	1.397
Radium-228	--	0.616
Thorium-228	--	ND
Thorium-230	--	0.587
Thorium-232	--	ND
Total Uranium	30	38.275
Uranium-233/234	--	13.56
Uranium-235/236	--	1.116
Uranium-238	--	12.74
Total Radium	5	2.013
Net Alpha	15	19.049

URSMW24S	Criteria	11/04
RAD:		
Gross Alpha	--	39.32
Gross Beta	--	8.378
Radium-226	--	ND
Radium-228	--	0.49
Thorium-228	--	ND
Thorium-230	--	0.409
Thorium-232	--	ND
Total Uranium	30	7.097
Uranium-233/234	--	2.588
Uranium-235/236	--	0.348
Uranium-238	--	2.354
Total Radium	5	0.7375
Net Alpha	15	34.03

URSMW24D	Criteria	11/04
RAD:		
Gross Alpha	--	27.785
Gross Beta	--	7.05
Radium-226	--	1.308
Radium-228	--	1.055
Thorium-228	--	ND
Thorium-230	--	0.746
Thorium-232	--	ND
Total Uranium	30	5.492
Uranium-233/234	--	7.152
Uranium-235/236	--	ND
Uranium-238	--	1.828
Total Radium	5	2.363
Net Alpha	15	18.707

URSMW23D	Criteria	11/04
RAD:		
Gross Alpha	--	25.751
Gross Beta	--	9.752
Radium-226	--	ND
Radium-228	--	0.51
Thorium-228	--	ND
Thorium-230	--	0.363
Thorium-232	--	ND
Total Uranium	30	3.105
Uranium-233/234	--	3.119
Uranium-235/236	--	0.352
Uranium-238	--	1.014
Total Radium	5	0.6125
Net Alpha	15	21.266

URSMW22D	Criteria	11/04
RAD:		
Gross Alpha	--	18.88
Gross Beta	--	5.521
Radium-226	--	ND
Radium-228	--	0.969
Thorium-228	--	ND
Thorium-230	--	0.227
Thorium-232	--	ND
Total Uranium	30	2.826
Uranium-233/234	--	3.842
Uranium-235/236	--	0.479
Uranium-238	--	0.932
Total Radium	5	1.0915
Net Alpha	15	13.627

URSMW21S	Criteria	11/04
RAD:		
Gross Alpha	--	2.24
Gross Beta	--	4.849
Radium-226	--	ND
Radium-228	--	0.403
Thorium-228	--	ND
Thorium-230	--	0.291
Thorium-232	--	ND
Total Uranium	30	ND
Uranium-233/234	--	0.257
Uranium-235/236	--	0.226
Uranium-238	--	ND
Total Radium	5	0.5245
Net Alpha	15	1.67

URSMW22S	Criteria	11/04
RAD:		
Gross Alpha	--	12.893
Gross Beta	--	4.233
Radium-226	--	ND
Radium-228	--	0.88
Thorium-228	--	ND
Thorium-230	--	0.56
Thorium-232	--	ND
Total Uranium	30	1.113
Uranium-233/234	--	0.558
Uranium-235/236	--	ND
Uranium-238	--	0.369
Total Radium	5	0.9995
Net Alpha	15	11.853

URSMW21D	Criteria	11/04
RAD:		
Gross Alpha	--	6.185
Gross Beta	--	10.805
Radium-226	--	0.888
Radium-228	--	0.694
Thorium-228	--	ND
Thorium-230	--	0.626
Thorium-232	--	0.166
Total Uranium	30	1.242
Uranium-233/234	--	2.459
Uranium-235/236	--	0.311
Uranium-238	--	0.401
Total Radium	5	1.582
Net Alpha	15	3.237

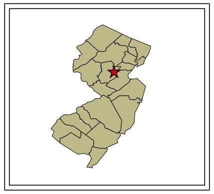
URSMW5S	Criteria	10/04
RAD:		
Gross Alpha	--	ND
Gross Beta	--	21.307
Radium-226	--	0.362
Radium-228	--	1.063
Thorium-228	--	ND
Thorium-230	--	0.359
Thorium-232	--	ND
Total Uranium	30	0.379
Uranium-233/234	--	ND
Uranium-235/236	--	ND
Uranium-238	--	0.124
Total Radium	5	1.425
Net Alpha	15	1.411

URSMW2D	Criteria	10/04
RAD:		
Gross Alpha	--	2.779
Gross Beta	--	2.43
Radium-226	--	0.182
Radium-228	--	1.515
Thorium-228	--	ND
Thorium-230	--	0.653
Thorium-232	--	ND
Total Uranium	30	1.606
Uranium-233/234	--	1.922
Uranium-235/236	--	0.432
Uranium-238	--	0.501
Total Radium	5	1.697
Net Alpha	15	-0.076

URSMW10S	Criteria	10/04
RAD:		
Gross Alpha	--	37.078
Gross Beta	--	15.242
Radium-226	--	0.661
Radium-228	--	1.214
Thorium-228	--	ND
Thorium-230	--	0.384
Thorium-232	--	0.224
Total Uranium	30	55.292
Uranium-233/234	--	18.56
Uranium-235/236	--	1.209
Uranium-238	--	18.42
Total Radium	5	1.875
Net Alpha	15	-1.111

URSMW2S	Criteria	10/04
RAD:		
Gross Alpha	--	51.393
Gross Beta	--	23.967
Radium-226	--	0.625
Radium-228	--	2.885
Thorium-228	--	ND
Thorium-230	--	0.697
Thorium-232	--	0.358
Total Uranium	30	67.036
Uranium-233/234	--	23.35
Uranium-235/236	--	2.707
Uranium-238	--	22.21
Total Radium	5	3.51
Net Alpha	15	3.126

Key Map



Legend

⊙ GWOU Monitoring Well - Overburden
◘ GWOU Monitoring Well - Bedrock
Storm Drain
Grate
Pipe Chase
Trench
Water
Boundary
Road

Notes:

-Total Uranium is measured in ug/L
-Net Alpha and Total Radium measured in pCi/L

-Net Alpha = Gross Alpha -
(Uranium238 + Uranium233/234 + Uranium235/236)
-Total Radium = Ra-226 + Ra-228

Criteria - Most Stringent of NJ GWQS, Federal MCLs or State MCLs
NA - Not Analyzed
ND - Not Detected
ug/L - micrograms per liter
pCi/L - Pico Curies per liter

Shaded Results - indicate an exceedance in applicable standards

Draft

Middlesex Sampling Plant (MSP)
Middlesex, NJ

Figure 10
Phase III Groundwater Delineation
RAD Results

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