FINAL
FEASIBILITY STUDY FOR
600 HILL WASTE PIT
(600 HILL GROUNDWATER PLUME [PICA-058]
AND INACTIVE MUNITIONS WASTE PIT
[PICA-013-R-01])

PICATINNY ARSENAL CLEANUP CONTRACT
PICATINNY ARSENAL, NEW JERSEY

May 2017

Prepared for:

Contract No.: W91ZLK-13-D-0014, Delivery Order 0007
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May 2017

Prepared for:

Prepared by:

Environmental Chemical Corporation
43 Broad Street, Suite A301
Hudson, Massachusetts 01749

Contract No.: W91ZLK-13-D-0014, Delivery Order 0007
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A.3  600 Area Groundwater Background Investigation Sampling Results (Dames and Moore, 1998-1999)

A.4  600 Area Groundwater Data Report/Feasibility Study Well Records, Boring Logs, and Construction Logs (Shaw Environmental, Inc., 2013)

A.5  600 Area Groundwater Data Report/Feasibility Study Human Health and Ecological Risk Assessment Report (Shaw Environmental, Inc., 2013)

Appendix B  Key Reference Documents (Provided on a DVD Attached To This Report).

B.1  Final Remedial Investigation Report, Military Munitions Response Program Remedial Investigation, Picatinny Arsenal, Morris County, New Jersey (Weston Solutions, Inc., September 2014)

B.2  Final 600 Area Groundwater Plume (PICA-058), Revision No. 3, Volume 1 - Report and Appendices A through P (Shaw Environmental, Inc., June 2013).

Appendix C  Detailed Remedial Alternative Cost Estimate

Appendix D  600 Hill Groundwater Plume Modeling Results

Appendix E  Munitions and Explosives of Concern Hazard Assessments for Remedial Alternatives
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<td>µg/L</td>
<td>microgram(s) per liter</td>
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<td>µg/m³</td>
<td>microgram(s) per cubic meter</td>
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<td>Argonne National Laboratory</td>
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<tr>
<td>AOC</td>
<td>Area of Concern</td>
</tr>
<tr>
<td>AOI</td>
<td>Area of Interest</td>
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<tr>
<td>ARAR</td>
<td>Applicable or Relevant and Appropriate Requirement</td>
</tr>
<tr>
<td>AWDF</td>
<td>Advanced Warhead Development Facility</td>
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<tr>
<td>BEM</td>
<td>BEM System, Inc.</td>
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<tr>
<td>bgs</td>
<td>below ground surface</td>
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<tr>
<td>BIP</td>
<td>blown-in place</td>
</tr>
<tr>
<td>CCOPC</td>
<td>criteria-based contaminant of potential concern</td>
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<tr>
<td>CEA</td>
<td>Classification Exemption Area</td>
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<tr>
<td>CERCLA</td>
<td>Comprehensive Environmental Response, Compensation, and Liability Act</td>
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<td>CFR</td>
<td>Code of Federal Regulations</td>
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<td>CN</td>
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<td>COC</td>
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<td>COPC</td>
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<td>DNT</td>
<td>Dinitrotoluene</td>
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<td>DO</td>
<td>dissolved oxygen</td>
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<td>DOT</td>
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<td>Explosives Site Plan</td>
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<td>EVO</td>
<td>emulsified vegetable oil</td>
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<td>EZ</td>
<td>Exclusion Zone</td>
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<tr>
<td>FS</td>
<td>Feasibility Study</td>
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<tr>
<td>ft</td>
<td>foot/feet</td>
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LIST OF ACRONYMS AND ABBREVIATIONS (continued)

546 GIS Geographic Information System
547 GRA General Response Action
550 GWSL Groundwater Screening Level
551 GWQS Groundwater Quality Standard
553 HA Hazard Assessment
554 HHICOPC Human health contaminant of potential concern
555 HHRA Human Health Risk Assessment
556 HMX 1,3,5,7-Tetranitro-1,3,5,7-tetrazacyclooctane
557 HQ Hazard Quotient
558 IC Institutional control
560 IRBC Industrial Risk-Based Criteria
561 IRP Installation Restoration Program
562 ISCO In Situ Chemical Oxidation
563 IT IT Corporation
565 LOC level of concern
566 LUC Land use control
568 MC munitions constituents
569 MCL maximum contaminant level
570 MCLG maximum contaminant level goal
571 MD munitions debris
572 MDAS materials documented as safe
573 MEC munitions and explosives of concern
574 mg/kg milligram(s) per kilogram
575 mg/L milligram(s) per liter
576 mm millimeter(s)
577 MMRP Military Munitions Response Program
578 MNA Monitored Natural Attenuation
579 MPPEH materials potentially presenting an explosives hazard
580 MRS Munitions Response Site
581 MTBE methyl tertiary-butyl ether
582 mV millivolt(s)
584 NA Not Available/Not Applicable
585 NCP National Oil and Hazardous Substances Pollution Contingency Plan
586 ND non-detect
587 N.J.A.C. New Jersey Administrative Code
588 NJDEP New Jersey Department of Environmental Protection
589 NJNR New Jersey Non-Residential Criteria
590 NJPDES New Jersey Pollutant Discharge Elimination System
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<thead>
<tr>
<th>Page</th>
<th>Acronym</th>
<th>Definition</th>
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<tr>
<td>591</td>
<td>NTCRA</td>
<td>Non-Time Critical Removal Action</td>
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<tr>
<td>594</td>
<td>NYSDEC</td>
<td>New York State Department of Environmental Conservation</td>
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<tr>
<td>597</td>
<td>O&amp;M</td>
<td>Operation and maintenance</td>
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<td>598</td>
<td>ORP</td>
<td>Oxidation reduction potential</td>
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<tr>
<td>599</td>
<td>PAH</td>
<td>polycyclic aromatic hydrocarbon</td>
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<td>600</td>
<td>PCE</td>
<td>tetrachloroethene</td>
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<td>601</td>
<td>PICA</td>
<td>Picatinny Arsenal</td>
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<td>602</td>
<td>PID</td>
<td>photoionization detector</td>
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<td>604</td>
<td>PPE</td>
<td>personal protective equipment</td>
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<td>605</td>
<td>ppm</td>
<td>part per million</td>
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<td>606</td>
<td>PQL</td>
<td>Practical quantification limit</td>
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<td>607</td>
<td>PRG</td>
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<td>RA</td>
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<td>610</td>
<td>RAO</td>
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<td>611</td>
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<td>Resource Conservation and Recovery Act</td>
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<td>612</td>
<td>RDX</td>
<td>Research Department Formula X (Cyclotrimethylenetritramine)</td>
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<td>613</td>
<td>RI</td>
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<td>614</td>
<td>RME</td>
<td>reasonable maximum exposure</td>
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<td>ROD</td>
<td>Record of Decision</td>
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<td>616</td>
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<td>Regional Screening Level</td>
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<td>618</td>
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<td>Superfund Amendments and Reauthorization Act</td>
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<td>SGL</td>
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<td>Shaw Environmental, Inc.</td>
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<tr>
<td>622</td>
<td>SI</td>
<td>Site Investigation</td>
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<td>623</td>
<td>SQB</td>
<td>sediment quality benchmark</td>
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<td>624</td>
<td>SRS</td>
<td>Soil Remediation Standard</td>
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<td>625</td>
<td>SUXOS</td>
<td>Senior Unexploded Ordnance Supervisor</td>
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<td>626</td>
<td>SVE</td>
<td>soil vapor extraction</td>
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<td>semivolatile organic compound</td>
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<td>631</td>
<td>TCE</td>
<td>trichloroethene</td>
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<td>632</td>
<td>TCR</td>
<td>Target Cancer Risk</td>
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<td>633</td>
<td>THQ</td>
<td>Target Hazard Quotient</td>
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<td>634</td>
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<td>635</td>
<td>TR</td>
<td>Test Trench</td>
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LIST OF ACRONYMS AND ABBREVIATIONS (continued)

636  TWRBC  Tap Water Risk-Based Concentration
639  UOM  Unit of measurement
640  USACE  U.S. Army Corps of Engineers
641  USACHPPM  U.S. Army Center for Health Promotion and Preventive Medicine
642  USAEC  U.S. Army Environmental Command
643  USATHAMA  U.S. Army Toxic and Hazardous Materials Agency
644  USEPA  U.S. Environmental Protection Agency
645  USGS  U.S. Geological Survey
646  UU/UE  unlimited use/unrestricted exposure
647  UXO  unexploded ordnance
648  UXOQCS  Unexploded Ordnance Quality Control Specialist
649  VI  Vapor Intrusion
650  VISL  Vapor Intrusion Screening Level
651  VOC  volatile organic compound
652  WESTON  Weston Solutions, Inc.
653  WRA  Well Restriction Area
654  yd  yard(s)
EXECUTIVE SUMMARY

The U.S. Army has contracted Environmental Chemical Corporation (ECC) to conduct a Feasibility Study (FS) for the 600 Hill Waste Pit, which is comprised of one Installation Restoration Program (IRP) site, 600 Hill Groundwater Plume (PICA-058), and one Military Munitions Response Program (MMRP) site, Inactive Munitions Waste Pit (PICA-013-R-01), at Picatinny Arsenal (PICA), New Jersey under the performance-based acquisition Contract No. W91ZLK-13-D-0014, Task Order 0007. These areas are combined as a group in this FS as the two sites are collocated and the Inactive Munitions Waste Pit has been determined to be the source area for the 600 Hill Groundwater Plume. The project stakeholders agreed to combine the IRP and MMRP sites into one FS during the 6 February 2014 Regulatory Meeting.

This FS provides a summary of the information presented in the Final 600 Area Data Report and Feasibility Study 600 Area Groundwater Plume (PICA-058), completed by Shaw Environmental, Inc. (Shaw) (Revision No. 3) (Shaw, 2013) and the Remedial Investigations (RIs) conducted for the Inactive Munitions Waste Pit Munitions Response Site (MRS) (PICA-013-R-01) under the MMRP, as presented in the Final Remedial Investigation Report, Military Munitions Response Program, Picatinny Arsenal, completed by Weston Solutions, Inc. (WESTON, 2014). The Inactive Munitions Waste Pit (PICA-013-R-01) (21 acres) is within the area of the 600 Hill Groundwater Plume and has been determined to be the source area for the trichloroethene (TCE) contamination of the 600 Hill Groundwater Plume (PICA-058). For this FS, these two areas are referred to as the 600 Hill Waste Pit. The information presented in the approved Final 600 Area Data Report/FS (Shaw, 2013) and the Final MMRP RI (WESTON, 2014) have been incorporated into this document and used in the development and evaluation of the Remedial Alternatives (RAs) presented herein.

In 1994, elevated concentrations of TCE were initially detected in groundwater at the newly installed well for the Advanced Warhead Development Facility (AWDF), and became the subject of a focused investigation. Subsequent testing of the AWDF and other 600 Area monitoring wells confirmed the presence of TCE, and detected elevated concentrations of Cyclotrimethylenetrinitramine (RDX) and methyl tertiary-butyl ether in groundwater. The groundwater investigation focused on determining the nature and extent of these contaminants, and providing sufficient background data for preparation of a follow-on 600 Area FS prepared by Shaw (Shaw, 2013). The results of the groundwater investigation indicated the potential for a thin layer of TCE-impacted soils, which could be a continuing source of groundwater contamination. This thin layer of soil was buried under rock debris blasted from the area of Building 660 during its construction. Following the removal of the majority of overlying rock debris, a source area investigation was performed in phases to determine the presence or absence of a continuing TCE source. The first phase of the source area investigation included passive soil gas testing across the newly uncovered area. The next phase involved intrusive investigation and sampling of test pits/trenches at the locations of elevated TCE concentrations in soil gas.

Based on available evidence, the location of the TCE source area coincided with the Munitions Waste Pit (PICA-013-R-01) MRS. The most recent sampling of the 600 Hill Groundwater Plume (January and February 2011) indicates that the approximate 26.1-acre TCE plume area is elongated, trending northeast-southwest, and extends into bedrock. The TCE concentrations...
range from 1.0 to 210 micrograms per liter (µg/L), which was reported in the downgradient well
13MW-2 (February 2011) located approximately 1,015 feet (ft) from the source area. The
highest concentrations of TCE have been reported in the bedrock wells located within the source
area (13MW-1 at 253 ft below ground surface [bgs]), and two wells downgradient of the source
area at the AWDF well (430 ft bgs) and well 13MW-2 (190 ft bgs). The TCE plume is wide, and
appears to be laterally dispersed by a local bedrock high and/or permeable fault (Picatinny Fault)
and prominent fold axis that traverse northeast-southwest coinciding with the plume orientation.
The overall width of the plume suggests some lateral TCE transport along the northern splay of
the Picatinny fault. The southwestern and southeastern edges of the plume terminate at the
wetland/stream areas within the 600 Area, which are the likely discharge points for the plume.

WESTON began the MMRP RI of the Munitions Waste Pit (WESTON, 2014) in 2012 to
determine the nature and extent of munitions and explosives of concern (MEC), munitions debris
(MD), and munitions constituents (MC) at the 21-acre MRS. RI activities included a
geophysical survey of the site, as well as MC sampling of the 2012 test pit/trenches to investigate
the TCE source area. The MMRP investigation confirmed the presence of a 0.24-acre Munitions
Waste Pit, containing MEC items. MEC were detected at a depth of 4.5 ft bgs; however, the
majority of the MEC, which were comingled with debris, were identified between 10 and 20 ft
bgs. No MEC items were identified during the investigation within the remaining 20.76-acre
MRS outside the Munitions Waste Pit. However, MD was identified and, based on the former
use as a testing area, there is potential for the presence of subsurface MEC at the MRS. A MEC
hazard assessment (HA) was conducted as part of the RI and the Inactive Munitions Waste Pit
MRS was assigned a hazard level of 3, which is a moderate potential explosive hazard condition.

The following Remedial Action Objectives (RAOs) were developed for 600 Hill Waste Pit
(which includes the TCE groundwater plume [PICA-058] along with the Inactive Munitions
Waste Pit MRS [PICA-013-R-01]) in this FS:

- Prevent residential exposure to TCE-contaminated groundwater (TCE greater than 1
  µg/L) via ingestion, dermal contact or inhalation, that would cause unacceptable risk
  (greater than 1E-4) over the duration of the response action.

- Prevent human exposure to contaminated groundwater that would cause unacceptable
  risk (greater than 1E-4) over the duration of the response action.

- Achieve the TCE New Jersey Groundwater Quality Standards (GWQS) to restore
  groundwater to meet the GWQS cleanup goal for TCE (1 µg/L) in a reasonable
timeframe (less than 50 years), thereby restoring groundwater to its beneficial use as a
drinking water source. This estimated reasonable clean-up timeframe is site-specific and
not applicable to other groundwater remediation projects.

- Prevent military personnel [PICA personnel (military and civilian), contractors, visitors,
  and recreational hunters from contact with MEC potentially present in the surface soil (0
to <6 inches bgs) and subsurface soil (> greater than 6 inches bgs).

In this FS, contaminants of concern (COCs) and site cleanup levels were developed for
groundwater and surface water within the 600 Area screening the RI data and evaluating
constituents identified as potential risks in human health risk assessments. TCE was identified as
the sole COC for groundwater. For the Inactive Munitions Waste Pit, the COCs are MEC only; there were no MC identified as COCs. Therefore, the response action is targeted to reduce explosive hazards associated with MEC from the site.

The RAs are designed to reduce overall unacceptable risks. The alternatives are described in Section 6 in terms of their objectives, anticipated implementation measures, and maintenance activities, consistent with the alternatives that were previously approved in the June 2013 Revision No. 3 FS (Shaw, 2013). The approved 600 Area Data Report and Feasibility Study, 600 Area Groundwater Plume (PICA-058) (Shaw, 2013) developed six RAs to address the TCE in groundwater as follows:

- Alternative GW-1 – No Action
- Alternative GW-2 – Monitored Natural Attenuation (MNA) with Institutional Controls (ICs)
- Alternative GW-3 – In Situ Chemical Oxidation (ISCO) and MNA Polishing with ICs
- Alternative GW-4 – In Situ Enhanced Anaerobic Bioremediation and MNA Polishing with ICs
- Alternative GW-5 – TCE Source Material Removal and MNA Polishing with ICs
- Alternative GW-6 – Total Munitions Waste Pit Removal and MNA Polishing with ICs.

These six original RAs (listed above) have been expanded upon (and renamed) to address the hazards associated with the Inactive Munitions Waste Pit MRS (PICA-013-R-01). However, the groundwater remediation components of the six original remedies remain unchanged. Additional RAs have been added to each of these original six alternatives to achieve the RAO for the potential MEC hazards associated with the MRS. This FS includes the evaluation of a total of seven RAs to address the TCE-impacted groundwater component and the MEC hazards associated with the MRS, which are listed below:

- Alternative 1 – No Action
- Alternative 2 – MNA and Land Use Controls (LUCs)
- Alternative 3 – ISCO, MNA Polishing, and LUCs
- Alternative 4 – In Situ Enhanced Anaerobic Bioremediation, MNA Polishing, and LUCs
- Alternative 5 – TCE Source Material Removal, MNA Polishing, and LUCs
- Alternative 6 – Total Munitions Waste Pit Removal, TCE Source Material Removal, MNA Polishing, and LUCs
- Alternative 7 – Total Munitions Waste Pit Removal, TCE Source Material Removal, MNA Polishing, LUCs, and MEC Clearance of Entire MRS.

A detailed analysis of each of the RAs was conducted using the following criteria specified in the Guidance for Conducting Remedial Investigations and Feasibility Studies under CERCLA (U.S. Environmental Protection Agency, 1998):

- Threshold Criteria
Overall Protection of Human Health and the Environment

Primary Balancing Criteria

- Long-Term Effectiveness and Permanence
- Reduction of Mobility, Toxicity, or Volume through Treatment
- Short-Term Effectiveness
- Implementability
- Cost

Modifying Criteria

- State Acceptance
- Community Acceptance

The modifying criteria, state acceptance and community acceptance, will be evaluated following comment on the RI/FS report and the Proposed Plan (PP). The modifying criteria will be addressed once a final decision is made and the Record of Decision (ROD) is prepared.

The threshold criteria must be met for an alternative to be further evaluated. All of the alternatives, with the exception of No Action, were shown to meet the threshold criteria. The primary balancing criteria were then applied, comparing the benefits and drawbacks of each alternative. The comparative analysis indicates the advantages and disadvantages of each alternative relative to the others so that the most appropriate alternative can be selected in the PP.

Alternative 7 offered the highest level of long-term effectiveness because groundwater would achieve RAOs within 8 years and no MEC hazards would remain at the MRS. Alternative 5 offers the same level of protection for groundwater; however, mitigation of risk from potential MEC in uncleared portions of the MRS would be addressed through LUCs. The MEC HA scores for the implementation of Alternatives 1, 2, 3, and 4 would result in no change to the baseline MEC HA hazard level of 3. The MEC HA for these alternatives would remain at 3, indicating a moderate potential explosive hazard condition. However, implementation of Alternatives 5 and 6 reduces the MEC HA to a hazard level of 4, which is considered a low potential explosive hazard condition. For Alternative 7, which includes the removal of all MEC from the MRS, the MEC HA hazard level is 4 due to the uncertainty associated with existing MEC removal technologies and the absence of any LUCs with achieving the unlimited use/unrestricted exposure (UU/UE) Criteria. Groundwater restoration timeframes associated with Alternatives 1, 2 and 3 are 35 years, whereas groundwater restoration for Alternative 4 is 14 years, providing a higher effectiveness than Alternative 3. Groundwater restoration timeframes associated with Alternatives 5, 6, and 7 is eight years, providing the highest long term effectiveness for groundwater.

Alternatives 2 and 3 offer the least reduction of contaminant concentrations, thereby reducing toxicity, mobility, or volume of contaminants in soil and groundwater through contaminant destruction. Alternative 3 offers slightly more reduction than Alternative 2.
because it provides some level of treatment of TCE in groundwater. Alternative 4 is more favorable than Alternatives 3, 5, 6 or 7 in reduction of toxicity, mobility and volume since it provides for source area treatment to the contaminated soil and the groundwater plume, whereas Alternative 3 provides limited source area soil treatment. Alternative 4 provides more volume reduction than Alternative 3 since the amendment will be applied uniformly over the entire source area as opposed to through injection points placed in selected locations to treat the groundwater plume. Alternatives 5, 6, and 7 reduce on-site TCE concentrations associated with contaminated soils; however, the contaminated soil will be disposed of at an off-site landfill and, therefore, the toxicity, mobility, or volume is not holistically reduced under these alternatives. However, Alternatives 5 and 6 reduce the volume of MEC present at the site through treatment. Alternative 7 provides the greatest reduction in the mobility and volume of MEC because all MEC would be removed and destroyed.

Alternatives 2 through 6 involve continuous implementation of ICs, in particular, restrictions on groundwater use and implementation of a long-term groundwater monitoring program for contaminated groundwater. The greatest short-term risks are posed by Alternative 7, followed by Alternatives 6 and 5. Alternative 7, followed by Alternatives 6 and 5, poses the greatest short-term risks. Alternative 7 has risk associated with its area of disturbance during the Munitions Waste Pit excavation and MRS clearance due to the potential for discovery of MEC. Alternative 6 has the second greatest short-term risk, followed by Alternative 5, as the risks are similar to Alternative 7 but the area of disturbance is smaller. However, the short-term risks associated with Alternatives 5, 6, and 7 are manageable through engineering controls. Safety zones will need to be established under Alternatives 5, 6 and 7 which to limit access to the areas surrounding the site during intrusive/intrusive activities at the munitions pit. Elevated short-term risks to the community and construction workers would be experienced under the implementation of Alternatives 3 and 4 in comparison to Alternative 2; however, these risks are considered manageable.

Risks to site workers and the community are associated with implementation of LUCs for Alternatives 2 through 6 related to the installation and maintenance of signs and/or fences. However, these risks are mitigation through the implementation of unexploded ordnance (UXO) safety procedures. Alternatives 5, 6, and 7 have similar risks associated with the excavation of TCE-impacted soils and associated dust generation, volatilization of TCE, and materials handling. The greatest short-term risks are posed by Alternative 7, followed by Alternatives 6 and 5. Alternative 7 has risk associated with its area of disturbance during the Munitions Waste Pit excavation and MRS clearance due to the potential for discovery of MEC. Elevated short-term risks to the community and construction workers will be experienced under the implementation of Alternative 3 from in situ injections of chemicals into the subsurface, in comparison to Alternative 2; however, risks are considered manageable with engineering controls and standard health and safety procedures. Alternative 4 does not pose a short-term risk to the community or construction workers do the organic nature of the carbon substrate amendment, and the minimally invasive approach. Risks to the environment are highest with Alternative 3, due to the potential for permanganate, or other oxidizer, to impact the environment if discharged to surface water, and potentially reacting with any organic material or acid.
compounds. However, this risk is minimal since the closest surface water is 825 ft from the site
and these risks can be controlled through the proper protocols for material handling and spill
control. Further, the chemical oxidants included in Alternative 3 may potentially come in
contact with MEC and present a health and safety hazard. Alternative 4 will not adversely
impact residual MEC items in the source area and is favorable for providing short-term
effectiveness since the carbon substrate treatment will be applied over the entire source area,
targeting both the vadose zone soils and the groundwater plume. Further, when carbon substrate
comes into contact with MEC, it provides a benefit of potentially mitigating any naturally
occurring oxidation of the metallic materials.

Alternatives 2 through 7 are implementable. Literature review has shown that Alternatives 3 and
4 have been demonstrated successfully on the field scale for treatment of TCE-contaminated
groundwater. However, large amounts of buried metal and potential MEC on-site provide an
additional challenge to implementing Alternative 3, requiring the injection points to be placed in
the non-optimal area outside of the boundaries of the munitions pit. The injection points for the
chemical amendment included in Alternative 3 must be installed outside the limits of the Munitions
Waste Pit, to avoid the potential interference with MEC, whereby reducing the effectiveness of
this alternative. Alternative 4 is more implementable than Alternative 3 due to the use of the
infiltration gallery technology for the application of the organic substrate amendment to treat the
source area and downgradient groundwater plume. Alternatives 5, 6, and 7 involve significant
logistical considerations coordinating construction activities with the active range operations, the
potential to encounter MEC, and handling of contaminated soil, and dust generation.
Implementability is more challenging for Alternative 7 due to the presence of stockpiled materials
and additional tree clearing (on potentially steep terrain) that will require removal to support the
larger excavation area and associated staging area.

Table ES-1 presents the costs associated with each alternative.
Feasibility Study for 600 Hill Waste Pit (600 Hill Groundwater Plume [PICA-058] and Inactive Munitions Waste Pit [PICA-013-R-01])
Picatinny Arsenal Cleanup Contract, Picatinny Arsenal, New Jersey
Contract No. W91ZLK-13-D-0014
Version: Final
May 2017
Page ES-7

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Table ES-1: Remedial Alternative Cost Estimates

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<th>Alternative</th>
<th>Description</th>
<th>Capital Cost</th>
<th>Discounted Operation and Maintenance</th>
<th>Total Present Worth</th>
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<td>In Situ Chemical Oxidation, Monitored Natural Attenuation Polishing, and Land Use Controls</td>
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<td>In Situ Enhanced Anaerobic Bioremediation, Monitored Natural Attenuation Polishing, and Land Use Controls</td>
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<td>Trichloroethene Source Removal, Monitored Natural Attenuation Polishing, and Land Use Controls</td>
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<td>Total Munitions Waste Pit Removal, Trichloroethene Source Material Removal, Monitored Natural Attenuation Polishing, and Land Use Controls</td>
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<td>7</td>
<td>Total Munitions Waste Pit Removal, Trichloroethene Source Material Removal, Monitored Natural Attenuation Polishing, Land Use Controls, and Munitions and Explosives of Concern Clearance of Entire Munitions Response Site (to achieve the Unlimited Use/Unrestricted Exposure Criteria)</td>
<td>$3,787,256</td>
<td>$332,124</td>
<td>$4,119,380</td>
</tr>
</tbody>
</table>
1. INTRODUCTION

The U.S. Army has contracted Environmental Chemical Corporation (ECC) to conduct a Feasibility Study (FS) for the 600 Hill Waste Pit area, which is comprised of one Installation Restoration Program (IRP) site, 600 Hill Groundwater Plume (PICA-058, which is IRP Site 12), and one Military Munition Response Program (MMRP) site, Inactive Munitions Waste Pit (PICA-013-R-01), at Picatinny Arsenal (PICA), New Jersey under the performance-based acquisition Contract No. W91ZLK-13-D-0014, Task Order 0007. The location of PICA is shown in Figure 1-1. In March 1990, PICA was included on the National Priorities List with a Hazard Ranking Score of 42.92. A Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) Section 120 Federal Facility Agreement was signed by the U.S. Environmental Protection Agency (USEPA) Region 2 and the U.S. Army in 1991 to integrate the U.S. Army’s CERCLA response and Resource Conservation and Recovery Act (RCRA) corrective action obligations into a comprehensive agreement. The Picatinny IRP is under the Federal-led CERCLA program. USEPA is the lead regulatory agency. To ensure selection of appropriate remedies, this FS has been conducted in accordance with CERCLA, as amended by the Superfund Amendments and Reauthorization Act of 1986 (SARA), and implemented by the National Oil and Hazardous Substances Pollution Contingency Plan (NCP) (40 Code of Federal Regulations [CFR] 300). USEPA guidance documents (USEPA, 1988a, 1988b) and New Jersey Department of Environmental Protection (NJDEP) guidance documents (NJDEP, 2012a) were also used in the preparation of this FS.

This FS provides a summary of the finalized 600 Area Groundwater Plume PICA-058 FS, Final 600 Area Data Report and Feasibility Study 600 Area Groundwater Plume (PICA-058), completed by Shaw Environmental, Inc. (Shaw) (Revision No. 3) (Shaw, 2013) and includes the Inactive Munitions Waste Pit Munitions Response Site (MRS) (PICA-013-R-01) that was investigated under the MMRP and presented in the Final Remedial Investigation Report, Military Munition Response Program, Picatinny Arsenal completed by Weston Solutions, Inc. (WESTON, 2014). MRS (PICA-013R-01) and 600 Hill Groundwater Plume (PICA-058) are located in the 600 Area as shown in Figure 1-2. These two areas are collocated whereas the MRS site (21 acres) is within the area of the 600 Hill Groundwater Plume. These areas are combined as a group in this FS since the Inactive Munitions Waste Pit MRS (PICA-013R-01) has been determined to be the source area for the trichloroethene (TCE)-impacted groundwater within the 600 Hill Groundwater Plume (PICA-058 [Site 12]). The combined site area that is the focus of this FS is referred to as the 600 Hill Waste Pit, and the site boundary is depicted in Figure 1-3.

The 600 Area has been investigated extensively under both the IRP and MMRP. As shown in Figure 1-2, the 600 Area overlaps into the northeastern portion of the Area of Interest (AOI) Code 300 Area, which is an area once used as a former artillery firing and fragmentation pattern testing area for munitions as large as 155-millimeter (mm) projectiles. This area is referenced in this FS.

The investigation information summarized and incorporated into this FS was initially reported in the 600 Area Data Report/Feasibility Study for 600 Area Groundwater Plume (Shaw, 2013) and
1.1 PURPOSE OF THE FEASIBILITY STUDY

The purpose of this FS is to develop and evaluate remedial options such that appropriate remedies may be selected for the 600 Hill Waste Pit, which is located in the 600 Area of the arsenal. As stated in Section 1, the 600 Hill Waste Pit is the combined area of the MRS (PICA-013R-01) and 600 Hill Groundwater Plume (PICA-058 [Site 12]). The project stakeholders agreed to combine the IRP and MMRP sites into one FS during the 6 February 2014 Regulatory Meeting. The remedies presented in this FS address both the groundwater plume and the munitions and explosives of concern (MEC) impacts associated with these two sites.

1.1.1 Site Area Description

Three IRP sites were originally identified in the 600 Area (Sites 11, 12, and 13) as they contained potential sources of groundwater contamination (U.S. Army Toxic and Hazardous Materials Agency [USATHAMA], 1991; Argonne National Laboratory [ANL], 1991).

The names of these three sites are listed below:

- Site 11 – Buildings 647, 649, and 650, Munitions Test Range
- Site 12 – Building 656, Munitions Waste Pit
- Site 13 – Building 640, Munitions/Pyrotechnics Test Area.

Site 12 (Building 656), Munitions Waste Pit, historically contained buildings used to store explosives and black powder (ANL, 1991). The site was operated for evaluating munitions from approximately 1955 until the mid-1980s. A layer of topsoil and sand was deposited on the waste pit after use of the site was discontinued in 1980. Subsequent to the buildings being removed, the area was used as a munitions test range and reportedly used for land-filling of items related to munitions testing, static testing, and testing of munitions using test stands and within a fragmentation cage. According to Picatinny personnel, from 1965 to the present, no munitions were disposed of at the site. In the late-1990s, a large amount of rock and fill dirt was placed on the site. The rock and fill dirt were removed from a nearby construction site. Reviews of aerial photographs indicate that the fill material extends up to 12 feet (ft) thick at the site. The contaminants of concern (COCs) associated with Site 12 are explosives, metals, MEC, and volatile organic compounds (VOCs) in soil and groundwater.

Site 12 includes the groundwater plume comprising PICA-058. In the early-1990s, a production well was installed to serve the Advanced Warhead Development Facility (AWDF), Building 660. Analysis of groundwater from this well indicated contamination with TCE and low levels of methyl tertiary-butyl ether (MTBE), freon, and toluene. Surface water and groundwater sampling of monitoring wells in the 600 Area identified levels of Research Department Formula X (cyclotrimethylenetrimine [RDX]) in surface water and groundwater. An additional investigation was performed to determine the source of the RDX contamination in the surface...
water and groundwater in the Building 650 area. The investigation delineated the contamination and the regulators concurred that no further investigation was needed for RDX associated with the 600 Hill Groundwater Plume (PICA-058). Site 12 (PICA-058) is the focus of this FS; the other two sites (Sites 11 and 13) are not included in this FS.

This FS was prepared to address the 600 Hill Waste Pit comprised of the following two sites:

- The 600 Hill Groundwater Plume (PICA-058), which covers the affected groundwater in the area (approximately 26 acres) of the AWDF, surface water, soils, or waste material that may have contributed to the groundwater contamination. Site 12 (Building 656), Munitions Waste Pit is the source of the groundwater contamination in this area. The COC at PICA-058 (Site 12) has been identified as TCE in the bedrock aquifer. Through the Remedial Investigation (RI) process, it has been determined that a response action is necessary for PICA-058. The response action for groundwater will restore the groundwater to the more stringent of the two cleanup levels, (i.e., either the Maximum Contaminant Levels (MCLs) or New Jersey Groundwater Quality Standards (GWQS), thereby restoring the groundwater to its beneficial use as a drinking water aquifer.

- The Inactive Munitions Waste Pit MRS (PICA-013-R-01), which includes the physical risk of MEC present at the MRS in the surface or subsurface to the top of bedrock encountered at 24.5 ft below ground surface (bgs) beneath the waste pit. Through the RI, the nature and extent of MEC and munitions constituents (MC) were determined and the hazards and potential risks posed to human health and the environment by MEC were identified for this MRS.

The total combined site area for the 600 Hill Waste Pit is approximately 47 acres. The remedial alternatives (RAs) developed, evaluated, and presented in this FS are inclusive of the TCE-impacted groundwater and the MEC associated with the MRS. The 600 Hill Waste Pit site boundary is depicted on Figure 1-3.

### 1.1.2 Remedial Action Objectives

The following Remedial Action Objectives (RAOs) were developed for 600 Hill Waste Pit:

- **Prevent residential exposure to TCE-contaminated groundwater** (TCE greater than 1 µg/L) via ingestion, dermal contact or inhalation, that would cause unacceptable risk (greater than 1E-4) over the duration of the response action. Prevent human exposure to contaminated groundwater that would cause unacceptable risk (greater than 1E-4) over the duration of the response action.

- **Achieve the TCE New Jersey Groundwater Quality Standards (GWQS) to restore groundwater to meet the GWQS cleanup goal for TCE (1 microgram per liter [µg/L]) in a reasonable timeframe (less than 50 years), thereby restoring groundwater to its beneficial use as a drinking water source. This estimated reasonable clean-up timeframe is site-specific and not applicable to other groundwater remediation projects.

- **Prevent PICA personnel (military and civilian), contractors, visitors, and recreational hunters from** contact with MEC.
potentially present in the surface soil (0 to 6 inches bgs) and subsurface soil (greater than 6 inches bgs).

This FS report addresses remediation of the 600 Hill Waste Pit through the completion of the following tasks whereby addressing both the TCE-impacted groundwater and the MEC within the MRS:

- RAOs that have been developed for the specific contaminants, affected media, and exposure pathways.
- Identification of chemical-specific applicable or relevant and appropriate requirements (ARARs) for each media at both sites.
- Remedial technologies that, alone or in combination, can treat media have been identified.
- The remedial technologies have been screened to eliminate those that cannot be technically implemented, either based on attainment of chemical-specific ARARs or the volume of media that must be treated.
- As required by CERCLA/SARA, the remedial technologies have been assembled into RAs that, to the maximum extent practicable, utilize permanent solutions and alternative technologies.
- A detailed analysis of the RAs using the nine evaluation criteria listed in the NCP has been performed.
- Comparative analysis of the RAs.

1.2 INSTALLATION HISTORY

PICA is located in Morris County, New Jersey and comprises approximately 5,900 acres (Figure 1-1). The Arsenal was a major source of munitions for World War I, World War II, the Korean War, and the Vietnam War. During these periods, PICA was involved in the production of explosives, rocket and munitions propellants, pyrotechnic signals and flares, fuses, and metal components, and included operational ranges for munitions testing and disposal of munitions.

Currently, PICA’s mission is research, development, and engineering of munitions and weapons. Note that any specific information regarding production, testing and research operations are prohibited because the FS is intended to be a publicly available document. Inclusion of such information is not compliant with existing Army security requirements.

PICA was added to the National Priorities List in March 1990, and assigned a Comprehensive Environmental Response, Compensation, and Liability Information System number. A CERCLA Section 120 Federal Facility Agreement was signed by USEPA Region 2 and the U.S. Army in 1991 to integrate the U.S. Army’s CERCLA response and RCRA corrective action obligations into a comprehensive agreement.

Subsequently, the U.S. Army prepared an RI/FS Concept Plan, which identified 156 potentially contaminated sites at PICA. The investigative approach suggested by the Concept Plan (ANL, 1991) was to consolidate the “Concept Sites” into “Areas” (i.e., Areas A-P). PICA Concept
Sites were additionally consolidated into “Groups” of sites as a result of agreements made at a series of meetings held in 2003 with USEPA Region 2, NJDEP, and U.S. Army Environmental Command (USAEC) program managers. The consolidation of Concept Sites into Groups was based on geographic attributes, similar schedules, and similar remedies. Figure 1-1 shows the Concept Areas throughout PICA. The 600 Hill Waste Pit is primarily located in Area N.

### 1.3 CURRENT AND PROJECTED LAND USE

Since 1977, most production of weapons and ammunition had ceased at Picatinny and the activities focused on research and development. PICA is known as the Joint Center of Excellence for Armaments and Munitions, providing products and services to all branches of the U.S. military and houses the headquarters for the Armament Research, Development, and Engineering Center under the U.S. Army Research, Development and Engineering Command giving it responsibility for developing small caliber weapons and munitions. In 1983, the U.S. Army disestablished the Armament Research and Development Command and Picatinny became the home of the Armament Research and Development Center. In 1986, the name again changed to the Armament Research, Development, and Engineering Center as further discussed in the Picatinny Arsenal Real Property Vision Plan (U.S. Army, 2015).

The facility houses government-operated munitions research and development facilities, operational ranges for munitions testing, residential housing, and recreational facilities that include a golf course and water park. PICA will continue to be used for military research and development, industrial, residential housing, and recreational activities (fishing, boating, hunting, and golfing) in the future.

The Action Memorandum, Interim Land Use Controls (LUCs), Picatinny Arsenal for 1926 Explosion Radius (PICA-003-R-01), Green Pond Site (PICA-005-R-01), Former Operational Areas (PICA-006-R-01), Lakes Sites (PICA-008-R-01), Shell Burial Grounds (PICA-010-R-01), and Inactive Munitions Waste Pit (PICA-013-R-01), MMRP (Action Memorandum) was finalized on March 2012 and signed by the Installation's Garrison Commander on 3 April 2012 (Picatinny Arsenal, 2012). The selected Non-Time Critical Removal Action (NTCRA) Interim LUC actions consist of a set of measures for achieving the removal action objective for the installation. The existing LUCs are described in Section 1.4, together with the supplemental LUC components needed for an effective NTCRA at PICA.

### 1.4 EXISTING LAND USE CONTROLS

An interim LUC program is already in place at PICA with existing LUCs that are installation-wide as well as specific to a particular CERCLA site. This section provides an overview of the installation-wide existing LUCs and the CERCLA site-specific existing LUCs, which are based on signed Records of Decision (RODs). The installation-wide LUCs are listed below and the CERCLA site-specific LUCs are summarized in Table 1-1. Further details regarding LUCs for the Installation are detailed in the Final Non-Time Critical Removal Action Interim Land Use Control Plan (U.S. Army, 2013).
Restrictions on digging are in place throughout the installation, and safety permits are required prior to excavation of any type as well as assurance that compliance with environmental regulations and guidance are followed through the internal Picatinny Environmental Management System. Additionally, unexploded ordnance (UXO) construction support is required for areas known, or with the potential, to have MEC. PICA has established the dig permit and an Activity Hazard Analysis program (U.S. Army, 2011a) for intrusive construction activities and uses the Picatinny UXO Hazard Map to determine which areas on the Installation require support for ground disturbing activities, the level of risk associated with each area, and the mitigation that should be used for UXO hazards. This determination is also assessed through the Picatinny PICA Environmental Management System database.

Safety and UXO training are required prior to initiating any intrusive operation. All contractors performing intrusive operations at PICA are required to attend a safety and UXO briefing prior to working on the Arsenal. A web-based UXO safety class is available to Arsenal personnel via the safety web page as an educational behavioral modification control. A video loop warning of UXO hazards plays at the Visitor’s Center, located at the Main Gate of the installation. All work entered into the PICA Environmental Management System is reviewed for UXO requirements. All hunters receive a hunter safety UXO briefing prior to annual issuance of their license. A chain link fence, with signage, surrounds the majority of PICA and access to the installation is restricted to two entrances: the Main Gate and Mount Hope. Further, the entire 600 Area lies entirely within the Robinson Enclosure, a secure part of PICA, which has restricted access, a security system, and fence with a locked entrance gate. All intrusive operations at PICA require the submittal of a site-specific health and safety plan and activity hazard analysis to the Installation Safety Office for review prior to work. A Classification Exception Area (CEA) and Well Restriction Area (WRA) are administrative restrictions on groundwater that were established in 2003 for the entire Arsenal to bring the arsenal groundwater into compliance with state requirements while the IRP is ongoing.

1.5 ORGANIZATION OF REPORT

The FS is organized into eight sections:

- **Section 1 – Introduction**—This section provides an introduction, the purpose of the FS along with installation history, current and projected land use, and existing LUCs. The report organization is presented in this section.
• **Section 2 – Background and Physical Setting**—This section provides the background of the 600 Area and an overview of the regional and local environmental setting. Previous investigations conducted in the 600 Area are presented and summarized in this section.

• **Section 3 – Nature and Extent of Contamination**—This section provides a summary of the nature and extent of the COCs for each media at the 600 Area Groundwater (PICA-058) and Inactive Munitions Waste Pit MRS (PICA-013-R-01), which are grouped together as the Inactive Munitions Waste Pit. The findings of the RIs completed at the site, including the source of TCE contamination in groundwater and the MEC source, are discussed in this section. A summary of the risk assessments completed is also included in this section.

• **Section 4 – Development of RAOs**—This section provides a statement of RAOs, identifies potential ARARs, To-Be-Considered (TBC) guidance, COCs, Areas of Attainment (AAs), and Site Cleanup Levels (SCLs).

• **Section 5 – Identification and Screening of Remedial Technologies**—This section identifies General Response Actions (GRAs) applicable to the RAOs presented in Section 3. The GRAs are broken down into technologies and process options screened according to implementability, effectiveness, and relative cost.

• **Section 6 – Development of RAs**—This section presents the development and screening of potential RAs. The retained technologies are assembled into functional alternatives that address site-specific factors. The resulting remedial action alternatives are further screened with respect to effectiveness, implementability, and cost.

• **Section 7 – Detailed Analysis of RAs**—This section presents the detailed analysis of remedial action alternatives. The detailed analysis includes a description of evaluation criteria and an individual and comparative analysis of alternatives into functional alternatives that address site-specific factors. The resulting remedial action alternatives are screened with respect to effectiveness, implementability, and cost.

• **Section 8 – References**—This section lists the reference materials utilized to develop this FS.

This FS includes the following appendices located after the above sections:

• **Appendix A** – Summary of RI Analytical Results and Historical Information
  — A.1 – MMRP RI, Results for the Inactive Munitions Waste Pit (PICA-013-R-01) (WESTON, 2014)
  — A.2 – 600 Area Groundwater Plume RI Results (Shaw, 2013)
  — A.3 – 600 Area Groundwater Background Investigation Sampling Results (Dames and Moore, 1998)
  — A.4 – 600 Area Groundwater Data Report/FS Well Records, Boring Logs, and Construction Logs (Shaw, 2013)

• **Appendix B** – Key Reference Documents (Provided on a DVD Attached To This Report).
B.1 Final Remedial Investigation Report, Military Munitions Response Program Remedial Investigation, Picatinny Arsenal, Morris County, New Jersey (WESTON Solutions, Inc., September 2014)

B.2 Final 600 Area Groundwater Plume (PICA-058), Revision No. 3, Volume 1 - Report and Appendices A through P (Shaw Environmental, Inc., June 2013).

- Appendix C – Detailed Remedial Alternative Cost Estimate
- Appendix D – 600 Hill Groundwater Plume Modeling Results
- Appendix E – Munitions and Explosives of Concern Hazard Assessments for Remedial Alternatives.
## Table 1-1: Summary of Land Use Control Components in Place at Picatinny Arsenal

<table>
<thead>
<tr>
<th>Land Use Control Component</th>
<th>Media Specific Restriction</th>
<th>Engineering Controls</th>
<th>Institutional Controls – Restriction</th>
<th>Institutional Controls – Mechanism</th>
<th>Institutional Controls – Awareness</th>
<th>Public Advisories</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Land Use Restrictions</strong></td>
<td>• Mitigation area(s) protection</td>
<td>• Guards</td>
<td>• Restrictions on land use change to residential</td>
<td>• Notations in Master Plan</td>
<td>• Educational programs</td>
<td>• Picatinny Arsenal Restoration Advisory Board</td>
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<tr>
<td></td>
<td>• No daycare, hospital, or school use</td>
<td>• Fences</td>
<td>• Restrictions on groundwater withdrawal</td>
<td>• Dig Permits</td>
<td>• Notices (in the grantor/grantee index, newspapers, etc.)</td>
<td></td>
</tr>
<tr>
<td></td>
<td>• No residential use</td>
<td>• Markers/Signs</td>
<td></td>
<td>• Construction Permits</td>
<td>• Picatinny Arsenal Environmental Management System (Picatinny Arsenal web-based environmental tracking system)</td>
<td></td>
</tr>
<tr>
<td>Media Specific Restriction</td>
<td>• Prohibit activities that would impact the landfill cap (or cover system) and drainage system</td>
<td></td>
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<tr>
<td></td>
<td>• Prohibit excavation on landfill cap or cover system</td>
<td></td>
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<td></td>
<td>• Prohibit installation of utility system lines through the site</td>
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<td></td>
<td>• Restrict access to the site</td>
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<td>Media-Specific Restriction</td>
<td>• Prohibit fishing except for recreational purposes (consumption warning Pennsylvania Regulation 215-1 and New Jersey Department of Fish Smart, Eat Smart Health Advisories)</td>
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<td></td>
<td>• Prohibit groundwater extraction that interferes with remedial action system</td>
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<td></td>
<td>• Prohibit use of groundwater for consumption or domestic purposes</td>
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<td></td>
<td>• Prohibit, or otherwise manage excavation</td>
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<td></td>
<td>• Prohibit, or otherwise manage excavation below a specified depth</td>
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<td></td>
<td>• Restrict drinking water well installation</td>
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<td></td>
<td>• Restrict withdrawal or use of groundwater for agricultural/irrigation purposes</td>
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<td></td>
<td>• Restrict withdrawal or use of groundwater without treatment</td>
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<td>Engineering Controls</td>
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<tr>
<td>Public Advisories</td>
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Placeholder for Figure 1-1
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2. BACKGROUND AND PHYSICAL SETTING

2.1 600 AREA BACKGROUND

The 600 Area is located on the northwest boundary of PICA, and comprises an area of approximately 450 acres. The current and projected land use in the 600 Area is controlled by the operation of active outdoor test ranges in Sites 11 (Building 650) and 13 (Building 640), the Building 647 Area, and the indoor range at the AWDF.

The 600 Area contains approximately 100 small structures associated with testing activities that take place in this portion of the facility. Many of these structures are less than 100 square ft in size and are used as shelters during testing operations. The structures typically have a sight glass or just a portion of the metal structure cut out to view testing. Other structures in the area include slightly larger buildings, which are currently locked. It is believed that these buildings are used for storing equipment and supplies involved with the testing in this area. At the western end of the 600 Area, an active testing area (Soft Recovery System Facility [SCat Gun]) utilizes Building 640. Buildings 640 and 660 are the only buildings used on a daily basis within the 600 Area.

The 600 Area boundary was established around the operational areas within Sites 11, 12, and 13 since these areas were suspected to contained potential sources of groundwater contamination (ANL, 1991). These three sites investigated under the IRP are within the Active Range Area. Of these three sites identified, Site 12 includes the 600 Hill Groundwater Plume (PICA-058) and is the focus of this FS. Sites 11 and 13 are not part of the 600 Hill Waste Pit, or discussed in this FS. It should be noted that while these areas were historically given IRP site designations, Sites 11 and 13 are no longer active sites within the IRP.

2.1.1 Advanced Warhead Development Facility

The AWDF (Building 660) is currently active and located near the top of Green Pond Mountain at an approximate elevation of 1,115 ft mean sea level within the 600 Area. As with all of the Building 600 Area, the AWDF is located in a remote portion of PICA amidst several test ranges that are currently used by the military for research and development (Figure 2-1). The AWDF was constructed in 1999, and became operational in 2000. The facility is utilized in support of Armament Research and Development and Engineering Center’s research and development mission. The AWDF includes a brick building containing a firing chamber shaped as a sphere having a 40-ft diameter, and a blast range tunnel with the dimensions of 16 ft high by 20 ft wide by 335 ft long. In addition to the sphere, the primary building contains an instrumentation room, control room, dark room, large target preparation room, restrooms, and small offices.

2.1.2 Advanced Warhead Development Facility Potable Well

In 1994, a potable well was drilled for the purpose of servicing the future AWDF (Figure 2-1). The well was drilled to a depth of 430 ft bgs and remained as a 6-inch diameter open hole until April 1999, when a well pump capable of discharging 5 gallons per minute was installed in the
well at 410 ft bgs along with the associated electrical wiring and plumbing. Northeastern Analytical Corporation first sampled the well in August 1994 for metals, polychlorinated biphenyls, VOCs, anions, and other water quality parameters. The sample results found TCE concentrations (1.3 μg/L) in exceedance of the New Jersey GWQS (1.0 μg/L). Exceedances were also detected for iron, manganese, radon, color, hardness, and pH. As a result, a water treatment system was installed as an interim action to remove the detected compounds from groundwater. The system consists of the following treatment processes: aeration system with reservoir, chemical feed, green sand filter, storage reservoir, a pneumatic tank, and a carbon filter. The treated well water was used for non-potable uses such as flushing toilets and fire suppression. Potable water was provided by bottled water. The AWDF has since been connected to the base water supply system so the treatment system is no longer used. The AWDF well is retained for use only as a monitoring well for groundwater sampling. In addition, a second interim action was taken with the implementation of a CEA in 2002.

Follow-on groundwater sampling from the spigot of the AWDF well found TCE exceedances in February 2001 (39 μg/L) and February 2003 (82 μg/L). Elevated concentrations of Freon-113 and MTBE were also detected in the February 2001 and February 2003 sampling rounds.

2.2 REGIONAL AND LOCAL FEATURES

2.2.1 Physiography and Topography

PICA is located within the New Jersey Highlands, a subdivision of the Appalachian Highland province. The highlands are characterized by a northeast-southwest trending system of folded and faulted Pre-Cambrian to Devonian Age Rocks that form a sequence of ridges and valleys. Thick glacial deposits are commonly encountered in valley and other lowland settings. PICA has developed significant relief by differential erosion of geologic units. Green Pond Mountain and Copperas Mountain consist of erosion resistant conglomerate and sandstone and are situated on the northwestern boundary of the facility.

The 600 Area lies on the southwestern upper slopes of Green Pond Mountain, and is bisected by Bear Swamp Road along its length. The topography in the Building 600 Area is characterized by long, northeast trending bedrock escarpments and intervening lowland areas. The northwest boundary of the 600 Area runs along the top of Green Pond Mountain, and reaches a maximum elevation of 1,260 ft mean sea level. The 600 Area slopes to the southeast, and is characterized by long northeast trending bedrock escarpments and intervening terraces and lowland areas. Bedrock outcrops consist of a massive bedded conglomerate, which is mapped by the U.S. Geological Survey as the Lower to Middle Silurian Age Green Pond Conglomerate. A thin layer of soil and glacial till overlies bedrock in low-lying areas.

The lowland areas are located to the northeast of Bear Swamp Road and contain most active range areas. These areas also feature two small wetlands and ponds in the 600 Area. Ground elevation ranges from 775 to 1,250 ft mean sea level within the 600 Area, with a total relief of 475 ft. Bear Swamp Road at 1,100 ft mean sea level and a steep escarpment that drops approximately 400 ft to Picatinny Lake bound the 600 Area to the southeast. Overland drainage
is toward the southwest, where surface runoff is captured by a string of northeast trending
wetlands, ponds, and drainages. These drainages ultimately discharge down a steep escarpment
and into Picatinny Lake. The topography of the 600 Area site is shown on Figure 2-2.

2.2.2 Hydrology

PICA lies within the Green Pond Brook Subwatershed, which flows into the Rockaway River. Green Pond Brook is the main surface water drainage pathway within the valley. Two manmade lakes (Lake Denmark and Picatinny Lake) are present, both drained by Green Pond Brook. Two tributaries to Green Pond Brook, Robinson Run, and Bear Swamp Brook flow from the ridges on the southeast and northwest sides of the valley, respectively. Wetlands and transition zones around the brooks are present throughout PICA.

The State of New Jersey use designation for Green Pond Brook upstream of and including Picatinny Lake is Fresh Water 2 – Trout Producing, Category 1 waters (FW-TP[C1]), reflecting the classification of the Green Pond Brook segment upstream from Picatinny Lake. The Green Pond Brook and Picatinny Lake are designated Category 1 (C1) because the “waterway or water body of interest flows through or is entirely located within State parks, forests, or fish and game lands, Federal wildlife refuges, or other special holdings.” Picatinny Lake is the receiving water for the 600 Area.

The drainage features and wetlands within the 600 Area are shown on Figure 2-3. Upland 600 Area drainage is toward the southwest, where a string of northeast-southwest trending wetlands, ponds, and drainages capture surface runoff. The drainage features include a small spring-fed pond located in the northeastern portion in the 600 Area boundary (north of Building 650), which regularly discharges to a culvert under the test range and into an unnamed stream. The unnamed stream flows southwest into a 0.46-acre wetland. The U.S. Army Corps of Engineers (USACE) Waterways Experiment Station mapped this small wetland area in 1994 (Waterways Experiment Station, USACE, 1995). This wetland also receives runoff from a portion of the AWDF Building 660 and seasonal spring(s) located to the northwest of the wetland. This perennial stream discharges to Picatinny Lake.

A second wetland area is mapped in the southwestern portion of the 600 Area (south of Building 641), and receives runoff via a culvert and drainage ditch from the western portion of the AWDF. This wetland is at least seasonally spring fed since the discharge stream flows during dry weather (Waterways Experiment Station data 1994). This wetland area totals 2.84 acres and is mapped as part man-made (1.51 acres) and red maple (1.33 acres). Discharge from the wetland is seasonal, although water is retained year round in a small wetland pond. The wetland stream discharges to a culvert under Bear Swamp Road, and into Picatinny Lake.
2.2.3 Geology

PICA resides within the Green Pond Valley bounded to the northwest by two mountains, which are Green Pond Mountain in the southern portion of the valley and Copperas Mountain in the northern part of the valley. The bedrock in the northwestern portion of the valley is composed of lower Paleozoic sedimentary rocks, which unconformably overlie the Middle Proterozoic basement rocks, and are faulted by a series of northeast trending faults (i.e., Tanners Brook-Green Pond Fault, Picatinny Fault, Berkshire Valley Fault, and the Gorge Fault, which splays off of the Tanners Brook-Green Pond Fault).

The 600 Area Bedrock Geology Map (Figure 2-4) shows that the Green Pond Conglomerate, a Silurian age conglomerate that makes up most of Green Pond Mountain, which underlies the AWDF. It is composed of medium- to coarse-grained quartz-pebble conglomerate, quartzitic arkose and orthoquartzite, and thin- to thick-bedded reddish-brown siltstone. It grades downward into less abundant gray, very dark red, or grayish-purple, medium- to coarse-grained, thin- to very thick-bedded pebble to cobble-conglomerate containing clasts of red shale, siltstone, sandstone, and chert; yellowish-gray sandstone and chert; dark-gray shale and chert; and white-gray and pink milky quartz. At Picatinny, the lower contact of the Green Pond Conglomerate has been cut out by the Tanners Brook-Green Pond Fault, which places the Green Pond conglomerate over the Leithsville.

Immediately south of the AWDF is the Picatinny Fault, which has a northeast trending strike and dips to the southeast at approximately 50 degrees. It has been characterized (Volkert, 2002) by a zone of brittle fabric a few hundred feet in width and terminates in a pair of splays in the western wall of the valley adjacent to the northern end of Picatinny Lake. The 600 Area lies between these two splays, immediately north of the southern splay. Figure 2-4 shows a mapped synform fold axis, located between the Picatinny Fault splays, both of which extend along the length of the 600 Area. Shaw (2013) conducted a fracture trace analysis as part of the 600 Area RI and identified three prominent lineations (fracture traces) within the 600 Area as shown on Figure 2-5. One of the lineations, trending north-northeast, extends northeast and southwest through the AWDF Building 660 Area terminating at the surface water bodies located beyond the 600 Area Boundary. A second lineation within the 600 Area extends northeast from the AWDF Building 660 and terminates in the vicinity of the Inactive Munitions Waste Pit MRS (Shaw, 2013).

2.2.4 Overburden and Bedrock Geology

The 600 Area occupies the southern slope of Green Pond Mountain, which largely consists of exposed bedrock outcrops (Green Pond Conglomerate) along its length. A thin veneer of overburden overlies bedrock along portions of the hillside, typically consisting of soil overlying dense sand, clay and pebble lodgment till and bedrock. The thickest deposits are found in isolated wetland and pond areas, where overburden measured 12 ft thick at well 13MW-2. The overburden is locally saturated in the wetland areas, but is not considered a viable overburden aquifer due to its limited thickness and extent.
Prominent bedrock outcrops in the 600 Area consist of a tan to grey, massive-bedded pebble conglomerate and sandstone, which are interbedded with a red, thinner-bedded siltstones and shales. These same lithologies were encountered during subsurface drilling and borehole geophysics in the study area. Bedding planes are massive and poorly defined, except in the thin siltstone and shale interbeds. Bedrock joints in the 600 Area are for the most part planar and well defined, mineralized, and steeply dipping. The spacing between joints varies between inches and tens of feet, with greater joint density seen in siltstone and shale bedrock. The outcrops are dominated by northwest trending cross-joints that dip steeply to the northeast and southwest. A subordinate set of joints was observed trending northeast and dip moderately to the northwest and southeast.

Evidence of bedrock faulting was seen along the escarpment north of well 13MW-11, including bedrock slickensides and mineralized breccias. Bedrock folds and mineralized fractures were observed in outcrops located adjacent both sides of the AWDF. The geologic field investigation findings are in close agreement with the published 600 Area geologic data and mapping (Volkert, 2002).

### 2.2.5 Hydrogeology

Based on previous hydrogeologic investigations conducted at the facility and geologic and hydraulic conductivity testing during the early Phase I RI (Dames and Moore, 1989) conducted at the installation and other previous investigations, four separate aquifers have been identified beneath Picatinny. The aquifers include an unconfined glacial aquifer, an upper semi-confined glacial aquifer, a lower semi-confined glacial aquifer, and a dolomitic bedrock aquifer (Dames and Moore, 1991 and 1998). The three valley-fill aquifers (unconfined, upper semi-confined, and lower semi-confined) are located within the Valley and the bedrock aquifer underlies the 600 Area. The characteristics of each of these aquifers are summarized below.

#### 2.2.5.1 Uppermost – Unconfined Glacial Aquifer

The uppermost aquifer is an unconfined aquifer that corresponds to the coarse-grained fluvial/deltaic upper sequence of glacial sediments that range from the ground surface to 45 to 62 ft bgs and consist of sand and gravel with variable amounts of silt, stratified drift on top of fine sand, and silt lake sediments. The unconfined aquifer (also referred to as the water table aquifer) has a thickness of approximately 20 to 35 ft and is continuous throughout the valley, with the exception of areas on the ridges where bedrock is exposed at the surface. Groundwater within this unit occurs from relatively near ground surface to about 30 ft bgs in upland areas.

Groundwater in the unconfined aquifer generally flows toward surface water discharge areas, such as Green Pond Brook, Bear Swamp Brook, and Lake Picatinny. Groundwater flow velocities vary greatly in the unconfined unit based on varying permeability and gradient, and are estimated to range from 50 ft per year to over 300 ft per year.
2.2.5.2 Upper and Lower Semi-Confined Glacial Aquifer

Based on sediment grain size and hydraulic conductivity testing conducted during the early RI at the installation, the upper and lower semi-confined glacial aquifers were recognized in the glacial sediments. The upper semi-confined glacial aquifer corresponds to the fine-grained lake-bottom/deltaic middle sequence, and consists of silt laminated with sand and clay. Encountered at depths ranging from 45 to 62 ft bgs, the thickness of the upper semi-confined glacial aquifer ranges from 21 to 150 ft. The upper semi-confined glacial aquifer is finer grained than the underlying lower semi-confined glacial and bedrock aquifers, and retards downward groundwater flow to these aquifers. The lower semi-confined glacial aquifer corresponds to the lowest glacial, sublacustrine, sequence that consists of poorly sorted till with variable amounts of clay, sand, gravel, and boulders. The thickness of the lower semi-confined glacial aquifer ranges from 11 to 91 ft and is encountered between 76 to 198 ft bgs.

The results of the slug tests performed during the Phase I RI indicate that hydraulic conductivity estimates for the lower semi-confined glacial aquifer (116 ft per day) are higher than those of the unconfined glacial aquifer. Hydraulic conductivity estimates for the unconfined glacial aquifer ranged from 0.8 to 195 ft per day, with an average of 32 ft per day (Dames and Moore, 1998). In general, trends in the hydraulic conductivity estimates in the unconfined glacial aquifer are higher in the upland areas that correspond to a coarser grain size of the sediments. Hydraulic conductivity estimates also generally increase with decreasing depth, corresponding to the coarsening upward nature of the unconfined glacial aquifer.

The upper semi-confined aquifer is generally encountered in the southern half of the valley. The lower semi-confined aquifer occurs beneath the upper only in the central valley portion of this area. The upper and lower semi-confined aquifers are the glacial till aquifers consisting primarily of sand and gravel and directly underlie the upper most aquifer. The primary water source for PICA is within the upper and lower semi-confined glacial till aquifer, known as the Upper Rockaway Aquifer, and is a designated sole source aquifer (Van De Venter, 2007; WESTON, 2014).

As the unconsolidated sediments become thinner on the sides of the valley, the lower aquifer pinches out against the bedrock. Groundwater flow direction in the semi confined aquifers is generally down valley to the southwest and toward surface water discharge areas. Vertical flow is typically upward toward discharge areas except where affected by groundwater withdrawal wells. Both the unconfined and semi-confined glacial aquifers for the most part discharge into Green Pond Brook. The groundwater flow direction within the 600 Area is shown in Figure 2-6, based on June 2007 water level gauging data.

These three valley-fill aquifers (unconfined, upper semi-confined, and lower semi-confined) have a maximum thickness of approximately 175 ft, and are impacted with various contaminants, including chlorinated and hydrocarbon compounds, and explosives identified at the following PICA sites: Area D Groundwater (PICA 076), Area B Groundwater (PICA-204), Area E Groundwater (PICA 077), 800 Area Buildings (PICA-079), the Mid-Valley Groundwater (PICA-205), and the Optics Lab (PICA-013) (Department of the Army, 2016).
2.2.5.3 Bedrock Aquifer

The fourth and deepest aquifer is a bedrock aquifer separated from the semi-confined glacial till aquifer by weathered bedrock with a maximum thickness of 60 ft (Dames and Moore, 1989 and 1991). The 600 Area is underlain by the Green Pond Conglomerate, a reddish-brown to olive-gray quartzitic conglomerate with little primary porosity in its matrix, and transmits groundwater via secondary interconnected fractures. The term fracture includes bedrock bedding planes, parting lineations, joints, and faults. The Green Pond Conglomerate is tight and massively bedded, except where interbedded with siltstone and shale units. The outcrops are crosscut by two well defined joint sets, which probably form the principal conduits for groundwater flow in the aquifer matrix (faulted/folded rock). The depth to bedrock within the 600 Area ranges from approximately 2 to 50 ft bgs. The depth to bedrock beneath the Inactive Munitions Waste Pit was encountered during trenching activities at 24.5 ft bgs.

The bedrock aquifer exhibits faults, fold axes, bedding planes, and foliation trends that affect contaminant transport. These complexities inherent to a bedrock aquifer plume, influence the contaminant transport pathways, introduce some uncertainty in the complete plume delineation, and introduce some uncertainty in prediction and modeling of the groundwater cleanup timeframes, as further discussed in Section 3.1.6. Groundwater flow in the bedrock is generally toward the central valley and surface water features; however, locally the foliation and fracturing can alter and control flow directions along fractures and fault planes. Impacts to the bedrock aquifer, including TCE and explosives, have been documented in the Mid-Valley Groundwater (PICA 204), 800 Building Area (PICA 079), Area K (PICA 50), Area J (PICA 008), and the 600 Hill Groundwater Plume (PICA-058) (Department of the Army, 2016; WESTON, 2014; Shaw, 2013).

The bedrock groundwater seepage velocity is calculated based on average gradient, pumping test well permeability value, and aquifer effective porosity. The seepage velocity was calculated pursuant to the following formula:

\[ V_s = \frac{K I}{n e} \]

where:

- \( V_s \) = Seepage Velocity, L/T.
- \( K \) = Hydraulic Conductivity, L/T.
- \( I \) = Hydraulic Gradient, L/L.
- \( n \) = Effective Porosity, L/L.

The applied hydraulic gradient is 0.046 ft/ft and effective porosity value of 0.05 for fractured bedrock. The applied effective porosity of 0.05 is the midpoint published value for the effective porosity of fractured crystalline rock (Driscoll, 1986). The applied aquifer test permeability is 2.52 ft per day. The calculated groundwater seepage velocity is 2.32 ft per day (Shaw, 2013).
A conceptual hydrogeologic model, developed during the RI (Shaw, 2013) using the above assumptions, and is shown on Figure 2-7. The groundwater model illustrates the predicted aquifer anisotropy and enhanced permeability along the faults and fold axis. The predicted aquifer anisotropy would have the probable effect of dispersing a plume (emanating from the Inactive Munitions Waste Pit) along conductive structures during contaminant migration.

According to the 600 Area Data Report and Feasibility Study for 600 Area Groundwater Plume (PICA-058 [Shaw, 2013]), the northeast and southwest of the AWDF are groundwater discharge points and include groundwater originating in the Inactive Munitions Waste Pit. Discharge from the northeastern wetland is perennial, with seasonal discharge from the southwestern wetland. The AWDF pumping well is a local groundwater discharge point, and pumped at an average of 850 gallons/day.

2.3 PREVIOUS INVESTIGATIONS 600 AREA

This section provides a brief summary of the key investigation conducted at the 600 Area in chronological order. The areas investigated previously investigated in the 600 Area include Sites 11, 12, and 13; the 600 Hill Groundwater Plume; and the Inactive Munitions Waste Pit MRS. Table 2-1 provides a summary of key previous investigations conducted at the 600 Area.

2.3.1 Remedial Investigation Concept Plan (USATHAMA 1991)

Between 1976 and 1989, PICA and USATHAMA identified 156 RI sites at PICA. Three sites were originally identified in the 600 Area (Sites 11, 12, and 13). These sites are located on Figure 2-1 and are as follows:

- Site 11 – Buildings 647, 649, and 650, Munitions Test Range
- Site 12 – Building 656, Munitions Waste Pit
- Site 13 – Building 640, Munitions/Pyrotechnics Test Area.

2.3.2 Site Investigation (Dames and Moore 1989)

Dames and Moore conducted a Site Investigation (SI) in 1989 for selected sites including Site 12 Munitions Waste Pit (Building 656). Site 12 was investigated to determine if explosive residue had accumulated in soils at the site. No pre-existing wells were found within the site area, and no new wells were installed. A total of four soil samples and two sediment samples were collected from the site, and were analyzed for anions, metals, and explosives. The 1989 sample locations are shown along with site features on Figure 2-8. The four surface soil samples were collected just to the north of the disposal area identified by USEPA’s Environmental Photographic Interpretation Center Installation Assessment of Picatinny Arsenal (USEPA, 1989).

However, the two sediment samples were collected adjacent to and immediately downhill from the disposal area in a wetland. The sample results indicated that localized contamination of surficial soils had occurred but that none of the soil contaminants had been transported to the wetland adjacent to the disposal area. 1,3-dinitrobenzene, 2,4-dinitrotoluene (DNT), nitroglycerine, RDX, and 2,4,6-trinitrotoluene were detected in at least one of the four surface
soil samples. The concentration of 2,4-DNT (11.7 milligrams per kilogram [mg/kg]) in sample SS12-2, which was collected near the metal cage, exceeded the level of concern (LOC) (4.2 mg/kg) for this explosive. No explosives were detected in the sediment samples. Several metals were detected in both surface soil samples and sediment samples. Copper in surface soil sample SS12-4 (1,400 mg/kg) exceeded the LOC of 600 mg/kg. Arsenic, copper, and lead in surface soil sample SS12-1 were reported greater than their respective reporting limits, which are all well below the sediment LOCs for these metals. Concentrations of cadmium (12.0 mg/kg), lead (120 mg/kg), and mercury (0.266 mg/kg) exceeded LOCs in sediment sample SD12-1 collected from the north side of the swampy area. The LOCs for these metals are 1.70, 38.8, and 0.249 mg/kg, respectively. Site 12 was the subject of the TCE source area investigation and MMRP RI (WESTON, 2014), which are summarized in Section 3.2. Site 12 is associated with the TCE-groundwater plume (PICA-058).

2.3.3 Phase I and II Human Health and Ecological Risk Assessment

The Phase I field study was initiated in 1998 (U.S. Army Center for Health Promotion and Preventive Medicine [USACHPPM], 1998) as a proactive environmental evaluation of currently active testing ranges. Phase I field sampling was conducted in March 1998. The study focused on residual metals and explosive compounds in surface soils, surface water, and sediment. In the Phase II investigation, soil, water, and sediment analytes were limited to those detected at each site in the first round of sampling. Phase II sampling was conducted in June 1999. The findings of the Phase I and II risk assessments are summarized in detail in the 600 Area Data Report and Feasibility Study (Shaw, 2013).

2.3.4 600 Area Groundwater Investigations

Three Areas of Concern (AOCs) were identified in the 600 Area Groundwater Remedial Investigation Work Plan (Shaw, 2004). These AOCs were identified during the 2004 investigation based upon review of existing reports and historical data, and personal interviews with individuals familiar with either former or current activities in the area. A fourth potential AOC (AOC 4) was identified after evaluation of sampling data from two newly installed wells. The four AOCs are identified as follows (Figure 2-2):

- AOC 1 – Munitions Waste Pit, Site 12
- AOC 2 – Metal containers in eastern portion of Site 11
- AOC 3 – Partially buried drums in western portion of Site 11
- AOC 4 – Fill and soil mounds near Building 647.

AOC 1 is the focused groundwater investigation that began in the 600 Area in April 2004 with sampling of the AWDF well, which resulted in confirmation of TCE contamination. The 600 Area RI was conducted using an iterative, step-wise approach in order to delineate the TCE plume. Six sequential investigation work plans were developed and implemented, followed by a test pitting and trenching investigation in the TCE source area.
A formal RI report was not completed for the 600 Area groundwater operable unit. However, data collected from the focused groundwater investigation and some of the other elements of an RI (i.e., risk assessments, fate and transport analysis) are presented in the Final Data Report/FS (Shaw, 2013). The scope of work, methodologies, and results of these various investigations within the 600 Hill Groundwater Plume are provided in detail in Sections 2 and 3 of the Final 600 Area Data Report and Feasibility Study 600 Area Groundwater Plume (PICA 058) (Shaw, 2014) and outlined in brief below. The monitoring well installation details and sampling for the wells installed at the 600 Area are provided in Appendix A.

2.3.4.1 600 Area Groundwater RI Work Plan (2004)

The 600 Area Groundwater investigations in 2004 (Shaw, 2004) included:

- Bedrock investigations and fracture trace analysis
- Monitoring well installation (Wells 13MW-1 through 4)
- Borehole geophysical and packer testing of the AWDF well and newly installed wells
- Passive soil gas survey
- Groundwater sampling for VOCs and water level monitoring at existing and newly installed wells.

2.3.4.2 600 Area Work Plan Addendum (2005)

In 2005, a Work Plan Addendum was prepared in order to further investigate the extent of TCE contamination found in newly installed wells (Shaw, 2005a). The Work Plan Addendum included the following elements:

- Monitoring well installation (Wells 13MW-5 through 9)
- Borehole geophysics and packer testing/sampling at newly installed wells
- Surface water/sediment sampling for VOCs
- Groundwater sampling for VOCs at existing and newly installed wells

2.3.4.3 600 Area Groundwater Investigation – Supplemental Work Plan (2006-2007)

In 2006, a Supplemental RI Work Plan was prepared to further investigate the side gradient extent of TCE contamination, and collect additional sampling and aquifer data for preparation of an RI/FS (Shaw, 2006a). The Supplemental RI Work Plan included the following elements:

- Installation of bedrock monitoring wells 13MW-10 and 11
- Borehole geophysics and packer testing of the new wells
- Aquifer pumping test
- Quarterly groundwater sampling for VOCs and baseline explosives at existing and newly installed wells (except wells 13MW-8 and 9)
Additional sampling of groundwater bioremediation parameters during second quarter
Quarterly surface water and sediment sampling at SW/SD-1 through 5 for VOCs and
baseline explosives
Collection of soil samples for VOCs
Preparation of the Human Health Risk Assessment (HHRA).

2.3.4.4 600 Area Groundwater Investigation – Pump Test Work Plan (2007)
In 2007, a Pump Test Work Plan was submitted by Shaw (Shaw, 2007a) and included the following elements:
Test and monitoring well selection
Water level monitoring
Step testing
A 48- to 72-hour constant rate test and recovery test
Groundwater treatment.

2.3.4.5 600 Area RDX Work Plan (2008)
The 600 Area RDX Work Plan was prepared in 2008, and included a supplemental round of VOC groundwater and surface water sampling with the RDX sampling event. The RDX Work Plan (Shaw, 2008b) and supplemental VOC sampling tasks included the following elements:
Installation of one well (13MW-12) near the Building 650 Pond
Baseline explosives sampling at select monitoring wells and surface water sampling points
VOC sampling at selected wells and surface water sampling points
Sediment sampling for baseline explosives at selected locations
Collection of 12 soil samples around the periphery of the Building 650 Pond.

Results of the RDX Work Plan were not reported in the subject report, but rather were included in a 600 Area RDX Data Report (Shaw, 2009). This report was submitted to the regulators on 3 April 2009 with a recommendation for no further action. The no further action recommendation was approved by NJDEP on 6 May 2009 with concurrence from USEPA. This included installation and sampling of well 13MW-12 and soil sampling around the Building 650 Pond. The excluded well and soil sample sites are located outside the 600 TCE plume study area.
2.3.4.6 600 Area Work Plan for Vapor Intrusion and Source Area Investigation (2010)

The Vapor Intrusion (VI) and Source Area Investigation Work Plan was submitted in December 2010, and approved by NJDEP in emails on 14 December 2010 and 7 January 2011. USEPA concurred with the Work Plan approval. Elements of the VI and Source Area Investigation Work Plan (Shaw, 2010) included:

- Passive soil gas survey at Site 12 in areas previously covered by rock fill placed in the late-1990s
- Soil sampling for VOCs from test pits and trenches based on the results of the passive soil gas survey
- Additional analyses of semivolatile organic compounds (SVOCs), explosives, and metals from a subset of the test pit and trench sampling locations
- Indoor air and soil gas sampling at Building 660 to investigate the potential for VI from the TCE groundwater plume.

The site-specific sampling approach developed in the approved Final 600 Area Work Plan for VI and Source Investigation was based on the site data obtained from the numerous investigations conducted at the site. According to the Work Plan, based on the location of existing buildings and comparison of groundwater analytical results to the NJDEP Groundwater Screening Level (GWSL), VI was determined to be a potential concern at Building 660 as it lies over the estimated extent of the 600 Area TCE plume, between source area well 13MW-1 and the AWDF well. Also the TCE concentrations in groundwater (maximum of 55 ug/L) in the AWDF well exceed the current USEPA Vapor Intrusion Screening Level (VISL) (https://www.epa.gov/vaporintrusion/vapor-intrusion-screening-levels-visls) of 7.4 ug/L, based on an industrial exposure. Under the current USEPA VI Guidance (USEPA, 2015) additional VI evaluation is required.

The VI sampling activities at the AWDF Building 660 included sub-slab soil gas sampling and indoor air sampling. The potential for VI to enter into buildings overlying the TCE plume was evaluated in accordance with the Department of Defense (DoD), NJDEP and USEPA protocols (DoD, 2009c; NJDEP, 2005a, and USEPA, 2002b). The investigation was conducted in the spring of 2011. The findings of this VI investigation were summarized in the Building 660 VI Investigation Report (Shaw, 2011) and are discussed below.

Three near-slab soil gas samples (13NSSG-1 through 13NSSG-3), four indoor air samples (13IA-1 through 13IA-4), and one ambient air sample (13IA-Amb) (Figure 2-9) were collected at Building 660 to investigate the potential for VI of chlorinated solvents (TCE and its daughter products) previously identified in the 600 Area groundwater.

Subslab - TCE was detected in soil gas in only one of three near-slab soil gas samples (13NSSG-2) at a concentration of 17 micrograms per cubic meter (μg/m³), below both the NJDEP Nonresidential Soil Gas Screening Level (SGSL) of 27 μg/m³ and USEPA commercial VISL.
During the intrusive investigation, MEC and MD were temporarily halted in order to notify the proper authorities. The results of the test pit/trenching and sampling investigation are shown on Figure 2-10. Discovery of a large amount of munitions debris (MD) and one MEC item changed the site status from a low probability of finding MEC to a high probability, therefore requiring the completion of an Explosives Safety Submission (ESS) that temporarily halted the TCE plume source area investigation activities.

During the intrusive investigation, MEC and MD were confirmed at the MRS. Only one MEC item was identified during the investigation (CDU-10 [T-1] B Canister with XM39E and XM44 Gravel Mines). The item was discovered at TP-2 at a depth of approximately 4.5 ft bgs during...
the June 2011 source area test pit/trenching investigation. (Figures 2-10, 2-11, and 2-12). No MD was discovered in test pit TP-1. A summary of the MEC and MD recovered during the 11 June test pit/trenching activities is listed in Table 2-4 (Shaw, 2013).

2.3.5.1 Source Area Test Pits and Trenching (2011)

From 20 through 24 June 2011, Shaw completed two test pits in order to investigate the source of TCE in the 600 Area groundwater. Key findings of the June 2011 source area test pits and trenching were as follows (Figure 2-11):

- Shaw completed the two test pits (TP-1 and TP-2) to a depth of 12 ft bgs (Figure 2-101).
- Shaw began excavation of the eastern end of the 45 ft trench (TR2). Excavation of TR2 reached a maximum depth of 5 ft bgs prior to the discovery of MEC, at which point the planned excavation was terminated.
- Nine soil samples were collected (three from each test pit and three from the trench TR2).
- Two soil samples were collected and named 13TR2-1(4.5-5). These two samples were collected at the same depth interval, within 2 to 3 ft, horizontally of each other, and were collected based on different sampling rationale. One sample, collected on 22 June 2011, was collected from beneath a crushed drum (potential TCE source) prior to the discovery of MEC. The rationale for the second sample, collected on 23 June, was the discovery of the gravel mine canister, and the continual collapsing of the gravel/soil sidewalls of the trench. The results indicated that VOCs were below LOCs in the soil samples. A total of six soil samples were analyzed for additional parameters (i.e., baseline explosives, SVOCs, and Target Analyte List metals). No explosive compounds were detected. With the exception of arsenic, detected below the soil background level for PICA (IT Corporation [IT], 2002) in all samples, only benzo(a)pyrene (0.601 mg/kg) was detected above its LOC (0.2 mg/kg).
- After completion of an ESS, the trenching investigation was restarted in May 2012.

2.3.5.2 Source Area Test Pits and Trenching (2012)

Between 22 and 24 May 2012, Shaw supported the continued trenching investigation in Inactive Munitions Waste Pit, suspected to contain the source of TCE contamination in the 600 Area groundwater. Trenching began at the southern extent of the intended 60-ft trench trending north-south (TR-1) through the suspected source area (based on the results of passive soil gas sampling completed in January 2011). Intended to be a 60-ft trench with a depth extending into clean native soil or top of bedrock, the loose gravel nature of the fill material resulted in the final excavation of a test pit with an approximate 40-ft diameter opening at the surface and a final depth of 24.5 ft bgs terminating at the bedrock interface. Locating the top of bedrock achieved one of the objectives of the source area investigation. Additionally, elevated photoionization detector (PID) readings from soil excavated from the bottom of the excavation indicated the possible presence of a TCE source area (Shaw, 2013). Figure 2-12 depicts cross sections of the test pit/trench excavations, including sample locations (with TCE results) and characterization of the materials encountered.
Key findings of the May 2012 source area trenching were as follows:

- Multiple drums and significant quantities of MD were excavated from the 10-ft to 20-ft bgs interval. All of the drums were crushed, exhibited no PID response, and contained no free phase liquid. A label on one of the excavated drums clearly identified its former contents as TCE. Soil in the 18-ft to 20-ft bgs interval exhibited apparent staining, in contrast to lighter colored soil both above and below. Sample TR1-1(19-20) was collected from the 19-ft to 20-ft bgs soil interval, which exhibited a PID response of 3.7 parts per million (ppm). TCE was detected at a concentration of 1.24 mg/kg, which is below the LOC but above default screening levels (0.007 mg/kg) established for the protection of groundwater.

- Liquid was observed dripping from one crushed and rusted drum containing a large quantity of MD. Soil from this interval exhibited no response on a PID. Sample TR1-1 (10.5-11) was collected from the 10.5-ft to 11-ft bgs soil interval directly below the crushed, rusted drum containing MD and analyzed for VOCs. A trace concentration of acetone was identified at a concentration significantly below LOCs.

- Soil in the 20-ft to 24.5-ft bgs interval exhibited PID responses from 700 to 1,000 ppm with the highest PID reading from soil collected directly on top of bedrock. Soil in this interval was found to contain little to no gravel or debris (the little debris that was included with the excavated soil from this depth was likely due to the collapsing sidewalls).

- A VOC sample TR1-1(24-ft to 24.5 ft bgs) was collected for laboratory analysis based on the PID screening results. TCE was identified at a concentration of 23.9 mg/kg in soil.

### 2.3.6 Remedial Investigation of the Inactive Munitions Waste Pit (PICA-013-R-01)

Between November 2011 and November 2012, WESTON performed an RI of nine MRSs under the MMRP (WESTON, 2014). The overall goal of the RI was to determine the nature and extent of MEC and MC and subsequently determine the potential hazards and risks posed to human health and the environment by MEC and MC. There were nine MRSs characterized as part of the RI, which included the Inactive Munitions Waste Pit MRS (PICA-013-R-01). The RI included geophysical surveys, intrusive investigations, and environmental sampling.

As part of the RI, WESTON performed a digital geophysical mapping (DGM) transect survey in January 2012 using a Geonics EM31-MK2 Ground Conductivity Meter as part of the MMRP RI of the PICA-013-R-01 MRS. The EM31-MK2 records ground conductivity (quad-phase) and magnetic susceptibility (in phase) measurements. The in-phase component is particularly useful for the detection of buried metal structure and waste material. Effective depth of exploration is approximately 18 ft (Shaw, 2013).

The EM31 MK2 transect survey was performed over the MRS to detect subsurface anomalies and determine if a munitions waste pit(s) was indicated in the subsurface. However, due to large equipment present at the site on the east side of the site at the time, several DGM transects...
planned were not completed until 20 August 2012 following the June 2012 TCE source area test pit/trenching investigation discussed in Section 2.3.5. WESTON completed the remaining DGM transects to the east of the confirmed buried waste to support determining the lateral extent of the waste pit.

The total length of geophysical transects completed across the site is 6,163 ft. Based on the DGM and intrusive investigation results, the lateral and vertical extent of a large waste pit was determined. The waste pit area has been estimated at 0.24 acres (10,498 square ft) and the depth to bedrock is 24.5 ft bgs beneath the waste pit. Assuming an even distribution of buried material, the approximate maximum volume of the waste pit has been estimated at 257,201 cubic ft or 9,526 cubic yards (yd) (Shaw, 2013). The activities and findings of the RI of the Inactive Munition Waste Pit are summarized in Section 3.2 (also see the Final MMRP RI Report [WESTON, 2014]).
Table 2-1: Previous Documents Relevant to Environmental Investigation at the 600 Area

<table>
<thead>
<tr>
<th>Title</th>
<th>Author</th>
<th>Approval Date</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Facility-Wide</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Site Investigation of Picatinny Arsenal, New Jersey Volume 1, Main Report and Appendices A through E.</td>
<td>Dames and Moore</td>
<td>1989</td>
</tr>
<tr>
<td>Site Investigation of Picatinny Arsenal, New Jersey, Volumes I and II.</td>
<td>Dames and Moore</td>
<td>1998</td>
</tr>
<tr>
<td>Picatinny Arsenal Facility-Wide Background Investigation. Prepared for the U.S. Army Corps of Engineers–Baltimore District, TERC Number DACA31-95-D-0083. May.</td>
<td>IT Corporation</td>
<td>2002</td>
</tr>
</tbody>
</table>

**600 Area Groundwater**

<table>
<thead>
<tr>
<th>Title</th>
<th>Author</th>
<th>Approval Date</th>
</tr>
</thead>
</table>
Table 2-1: Previous Documents Relevant to Environmental Investigation at the 600 Area (continued)

<table>
<thead>
<tr>
<th>Title</th>
<th>Author</th>
<th>Approval Date</th>
</tr>
</thead>
<tbody>
<tr>
<td>Picatinny Arsenal Task Order 17 600 Area RDX Investigation Data Report. April.</td>
<td>Shaw Environmental, Inc.</td>
<td>2009</td>
</tr>
<tr>
<td>Executive Order 11508 Picatinny Arsenal Survey Report, Picatinny Arsenal, Dover, New Jersey.</td>
<td>Department of Defense</td>
<td>1973</td>
</tr>
<tr>
<td>Final Site Inspection, Picatinny Arsenal, New Jersey. April.</td>
<td>Malcolm Pirnie, Inc.</td>
<td>2008</td>
</tr>
<tr>
<td>Picatinny Arsenal Task Order 17 600 Area RDX Investigation Data Report. April.</td>
<td>Shaw Environmental, Inc.</td>
<td>2009</td>
</tr>
</tbody>
</table>

Notes: Appendix A provides a compilation of the remedial investigation analytical result and historical information for 600 Area Groundwater and the Inactive Munitions Waste Pit (PICA-013-R-01). Appendix B provides Final Remedial Investigation Report, Military Munitions Response Program Remedial Investigation, Picatinny Arsenal, Morris County, New Jersey (WESTON, 2014) and Final 600 Area Groundwater Plume (PICA-058), Revision No. 3, Volume 1 – Report and Appendices A through P (Shaw, 2013) (provided on a DVD in this Feasibility Study).
Table 2-2: Near-Slab Soil Gas Sample Analytical Results

<table>
<thead>
<tr>
<th>Sample ID</th>
<th>USEPA VISL(^1) - Commercial</th>
<th>NJ Non-Residential Screening Level for Soil Gas(^1)</th>
<th>13NSSG-1</th>
<th>13NSSG-1DUP</th>
<th>13NSSG-2</th>
<th>13NSSG-3</th>
</tr>
</thead>
<tbody>
<tr>
<td>Units</td>
<td>ug/m(^3)</td>
<td>ug/m(^3)</td>
<td>ug/m(^3)</td>
<td>ug/m(^3)</td>
<td>ug/m(^3)</td>
<td>ug/m(^3)</td>
</tr>
<tr>
<td>VOLATILE ORGANIC COMPOUNDS</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Acetone</td>
<td>4,500,000</td>
<td>230,000</td>
<td>120</td>
<td>U</td>
<td>120</td>
<td>290</td>
</tr>
<tr>
<td>Cyclohexane</td>
<td>880,000</td>
<td>430,000</td>
<td>7</td>
<td>U</td>
<td>9</td>
<td>7</td>
</tr>
<tr>
<td>1,2-Dichloroethene (trans)</td>
<td>na</td>
<td>5,100</td>
<td>8</td>
<td>U</td>
<td>8</td>
<td>8</td>
</tr>
<tr>
<td>Tetrahydrofuran</td>
<td>290,000</td>
<td>na</td>
<td>150</td>
<td>U</td>
<td>150</td>
<td>150</td>
</tr>
<tr>
<td>Toluene</td>
<td>730,000</td>
<td>360,000</td>
<td>8</td>
<td>U</td>
<td>12</td>
<td>8</td>
</tr>
<tr>
<td>Trichloroethene</td>
<td>100</td>
<td>27</td>
<td>11</td>
<td>U</td>
<td>11</td>
<td>12</td>
</tr>
</tbody>
</table>

*1 NJDEP Generic Screening Levels for Soil Gas are as provided in the ‘Vapor Intrusion Guidance’ document issued by the NJDEP dated March 2007*

*2 USEPA VISL - https://www.epa.gov/vaporintrusion/vapor-intrusion-screening-levels-visls*

*Exceedences of Screening Levels are shaded.

*NA – Screening Levels not available for this compound*

*U – Compound analyzed but not detected at a concentration above the reporting limit*

*Q – Data Qualifier*

*D – Sample results are obtained from a dilution: the surrogate or matrix spike recoveries reported are calculated from diluted samples.*

*TCR – Target Cancer Risk*

*THQ – Target Hazard Quotient*

*na – not applicable*
Table 2-43: Indoor Air Sample Analytical Results

<table>
<thead>
<tr>
<th>Sample ID</th>
<th>Non-Residential Screening Levels for Indoor Air</th>
<th>USEPA Commercial VISL</th>
<th>13IA-1</th>
<th>13IA-1DUP</th>
<th>13IA-2</th>
<th>13IA-3</th>
<th>13IA-4</th>
<th>13IA-AMB</th>
</tr>
</thead>
<tbody>
<tr>
<td>Units</td>
<td>ug/m&lt;sup&gt;3&lt;/sup&gt;</td>
<td>ug/m&lt;sup&gt;3&lt;/sup&gt;</td>
<td>ug/m&lt;sup&gt;3&lt;/sup&gt;</td>
<td>Q</td>
<td>ug/m&lt;sup&gt;3&lt;/sup&gt;</td>
<td>Q</td>
<td>ug/m&lt;sup&gt;3&lt;/sup&gt;</td>
<td>Q</td>
</tr>
<tr>
<td>VOLATILE ORGANIC COMPOUNDS (GC/MS)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Acetone</td>
<td>4600</td>
<td>140000</td>
<td>14</td>
<td>U</td>
<td>U</td>
<td>24</td>
<td>12</td>
<td>12</td>
</tr>
<tr>
<td>Benzene</td>
<td>2</td>
<td>2</td>
<td>0.6</td>
<td>U</td>
<td>0.6</td>
<td>0.6</td>
<td>U</td>
<td>3</td>
</tr>
<tr>
<td>1,3-Butadiene</td>
<td>1</td>
<td>0.41</td>
<td>0.4</td>
<td>U</td>
<td>0.4</td>
<td>0.4</td>
<td>U</td>
<td>0.5</td>
</tr>
<tr>
<td>Chloromethane</td>
<td>130</td>
<td>390</td>
<td>2</td>
<td>1</td>
<td>1</td>
<td>2</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>Cyclohexane</td>
<td>8700</td>
<td>26000</td>
<td>0.9</td>
<td>4</td>
<td>1</td>
<td>2</td>
<td>1</td>
<td>0.7</td>
</tr>
<tr>
<td>Dichlorodifluoromethane</td>
<td>260</td>
<td>440</td>
<td>3</td>
<td>3</td>
<td>3</td>
<td>2</td>
<td>U</td>
<td>3</td>
</tr>
<tr>
<td>n-Heptane</td>
<td>NA</td>
<td>NA</td>
<td>0.8</td>
<td>U</td>
<td>1</td>
<td>0.8</td>
<td>U</td>
<td>2</td>
</tr>
<tr>
<td>n-Hexane</td>
<td>1000</td>
<td>3100</td>
<td>0.7</td>
<td>U</td>
<td>0.7</td>
<td>0.7</td>
<td>U</td>
<td>3</td>
</tr>
<tr>
<td>Methyl Ethyl Ketone</td>
<td>7200</td>
<td>22000</td>
<td>3</td>
<td>2</td>
<td>2</td>
<td>4</td>
<td>2</td>
<td>1</td>
</tr>
<tr>
<td>Toluene</td>
<td>7200</td>
<td>22000</td>
<td>3</td>
<td>5</td>
<td>4</td>
<td>21</td>
<td>3</td>
<td>1</td>
</tr>
<tr>
<td>Trichlorofluoromethane</td>
<td>1000</td>
<td>NA</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>Xylene (m,p)</td>
<td>NA</td>
<td>440</td>
<td>2</td>
<td>U</td>
<td>3</td>
<td>2</td>
<td>U</td>
<td>14</td>
</tr>
<tr>
<td>Xylene (o)</td>
<td>NA</td>
<td>440</td>
<td>0.9</td>
<td>U</td>
<td>0.9</td>
<td>0.9</td>
<td>U</td>
<td>5</td>
</tr>
<tr>
<td>Xylenes (total)</td>
<td>150</td>
<td>440</td>
<td>3.9</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

1 NJDEP Generic Screening Levels for Indoor Air are as provided in the 'Vapor Intrusion Guidance' document issued by the NJDEP dated March 2007
2 NJDEP Generic Screening Levels for Soil Gas are as provided in the 'Vapor Intrusion Guidance' document issued by the NJDEP dated March 2007
3 USEPA VISL Calculator - Version 3.5.1 (May 2016 RSLs)
4 Detections of VOCs are bolded.
5 Exceedances of NJDEP or USEPA Screening Levels shown are shaded.
6 NA - Screening Levels not available for this compound
7 U - Compound analyzed but not detected at a concentration above the reporting limit.
8 Q - Data Qualifier
Table 2-24: Summary of Munitions and Explosives of Concern and Munitions Debris Identified in June 2011 Test Pit/Trench Investigation

<table>
<thead>
<tr>
<th>Description</th>
<th>Quantity</th>
<th>Test Pit/Trench Location</th>
<th>Comments</th>
</tr>
</thead>
<tbody>
<tr>
<td>Munitions Debris</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Cartridge, Photoflash: practice, M121, Expended</td>
<td>1</td>
<td>TP-2, approximately 8 feet below ground surface</td>
<td></td>
</tr>
<tr>
<td>M72 Rocket Launcher for 66-millimeter Rocket (light anti-tank weapon), Empty – no sights</td>
<td>13</td>
<td>TP-2, approximately 10-12 feet below ground surface</td>
<td>3 sights were discovered, collected, and tested by Picatinny Radiation Protection Office – not radiologically contaminated</td>
</tr>
<tr>
<td>XM31 Anti-Tank Land Mine, Expended</td>
<td>1</td>
<td>TP-2</td>
<td>Item recovered from within garbage can removed from TP-2</td>
</tr>
<tr>
<td>155-Millimeter Fragment (ogive)</td>
<td>1</td>
<td>TP-2</td>
<td>Item recovered from within garbage can removed from TP-2</td>
</tr>
<tr>
<td>Aircraft Flare, MK45, Expended</td>
<td>1</td>
<td>TR2*</td>
<td>Photograph shows 2 pieces/components of fuze</td>
</tr>
<tr>
<td>PD Fuze, Expended</td>
<td>1</td>
<td>TR2*</td>
<td></td>
</tr>
<tr>
<td>BLU 3/B plate, CDU-10 canister cover</td>
<td>1</td>
<td>TR2*</td>
<td></td>
</tr>
<tr>
<td>BLU 39/B Skitters, CN/CS Tear Gas, Inert</td>
<td>3</td>
<td>TR2*</td>
<td></td>
</tr>
<tr>
<td>40-Millimeter Grenade Cartridge Cases, Expended</td>
<td>7</td>
<td>TR2*</td>
<td></td>
</tr>
<tr>
<td>Electric Blasting Cap, Expended</td>
<td>1</td>
<td>TR2*</td>
<td></td>
</tr>
<tr>
<td>Fuzes M48, M51, M81 Series, M557 Series, and M572</td>
<td>12</td>
<td>TR2</td>
<td>Several fuzes recovered folded into the side of a crushed drum</td>
</tr>
<tr>
<td>Munitions and Explosives of Concern</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>CDU-10 (T-1)/B Canister with XM39E and XM44</td>
<td>1</td>
<td>TR2, East End, approximately 4.5 feet below ground surface</td>
<td>Munitions and explosives of concern data sheet references approximately 680 XM40E5 and 48 XM44 mines per CDU-10/B</td>
</tr>
</tbody>
</table>

Notes: No munitions debris discovered in TP1.  
*TR2 trench offset 8 feet to the south due to concentration of munitions debris encountered at initial location. Locations noted with an asterisk (TR2*) refer to the location prior to the offset. Excavation of TR2 ceased upon encountering unexploded ordnance.  
CN = Chloracetophenone.  
CS = o-Chlorobenzylidenemalonitrile.  
TP = Test Pit.  
TR = Test Trench.
Feasibility Study for 600 Hill Waste Pit (600 Hill Groundwater Plume [PICA-058] and Inactive Munitions Waste Pit [PICA-013-R-01])
Picatinny Arsenal Cleanup Contract, Picatinny Arsenal, New Jersey
Contract No. W91ZLK-13-D-0014

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May 2017
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Feasibility Study for 600 Hill Waste Pit (600 Hill Groundwater Plume [PICA-058]) and Inactive Munitions Waste Pit [PICA-013-R-01])
Picatinny Arsenal Cleanup Contract, Picatinny Arsenal, New Jersey
Contract No. W912ZL-13-D-0014

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May 2017
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Feasibility Study for 600 Hill Waste Pit (600 Hill Groundwater Plume [PICA-058]) and Inactive Munitions Waste Pit [PICA-013-R-01])

Picatinny Arsenal Cleanup Contract, Picatinny Arsenal, New Jersey

Contract No. W912ZL-13-D-0014

Placeholders for Figure 2-5
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Feasibility Study for 600 Hill Waste Pit (600 Hill Groundwater Plume [PICA-058]) and Inactive Munitions Waste Pit [PICA-013-R-01])
Pohatcong Arsenic Cleanup Contract, Picatinny Arsenal, New Jersey
Contract No. W91ZLE-13-D-0014

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Placeholder for Figure 2-12
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3. NATURE AND EXTENT OF CONTAMINATION

3.1 600 HILL GROUNDWATER PLUME (PICA-058)

3.1.1 Origin of the Trichloroethene Plume

The source area of the 600 Area TCE Groundwater Plume (PICA-058 [i.e., Site 12]) has been identified as Inactive Munitions Waste Pit, historically referred to as AOC 1 (Figure 2-2). The waste pit is located in a former test area located north of Building 660. Based on historical aerial photographic analysis (USEPA, 1989), the site was constructed between 1957 and 1963 by clearing the native vegetation and leveling of the area. USEPA’s Environmental Photographic Interpretation Center Installation Assessment of Picatinny Arsenal (USEPA, 1989) reported disposal of debris along a fill face at the site in 1970. During a site reconnaissance in 1996, the face of the fill was visually observed to contain construction debris, drum debris, and the remnants of a buried military vehicle (truck). However, no rock fill had been placed at the site at that time. During a site reconnaissance conducted in 2007, the remnant of a steel structure was discovered at the location. The rock fill was present at the time of the 2007 site reconnaissance. The steel object was likely filled with sand or similar media and used as a target into which test munitions were fired. The partially bermed area was also present and would have served as a safety barrier that also utilized a natural depression in the ground surface. The feature was likely misidentified as a pit from the 1974 aerial photography and is, therefore, unrelated to the TCE plume. The 1986 to 1987 photographic analysis concluded that the area had likely been covered since 1974.

Large amounts of blasted rock from the Building 660 site were deposited in the Inactive Munitions Waste Pit area beginning in the late-1990s. Figure 3-1 shows the 2002 aerial extent of preexisting (1970) fill and later Building 660 fill (1990s), which was representative of site conditions prior to the removal of blasted rock in 2010/2011. The more recent fill material appears much lighter in contrast with the darker gray area immediately surrounding the burning cage and to the south and west where the drum and other debris are located. An inspection of the site in 2005 observed a partially buried drum and other canisters in the formerly (1970) filled areas, in addition to discarded light anti-tank weapon rocket tubes and 81-mm mortar shells. The maximum vertical extent of the blasted rock fill exceeded 20 ft when it was in place.

The probable source of TCE in groundwater is leaching of impacted soils/fill associated with the 1970s debris disposal activity in Inactive Munitions Waste Pit. This is supported by the presence of crushed drums seen in the fill material (at least one of which was labeled TCE), soil gas results, and the detection of TCE in monitoring well 13MW-1, immediately downgradient of the 1970s fill material. Initial sampling of the AWDF well, after its completion in 1994, resulted in the detection of TCE (1.3 μg/L). Increases in TCE concentrations at the AWDF well were observed in 2000 (39 μg/L), 2002 (82 μg/L), and 2003 (110 μg/L). The AWDF well began operation in 1999, and it is unclear whether the increasing TCE concentrations detected after that time reflect the migration of an incipient TCE plume or capture of existing side gradient plumes(s) via pumping. The wide lateral extent and depth of the current plume indicate that...
TCE is thoroughly dispersed within the bedrock aquifer, and suggest that the plume would have migrated within a broad front toward the AWDF well.

### 3.1.2 Contaminants the 600 Area Groundwater

As detailed in Section 4.0 of the Final 600 Area Data Report and Feasibility Study for the 600 Area Groundwater Plume (PICA-058) (Shaw, 2013), the following compounds have been found to exceed LOCs for groundwater in the 600 Area. These compounds were used to develop the contaminants of potential concern (COPCs) that were addressed in the 2013 Shaw FS. Table 3-1 provides a summary of the frequency and range of detection, location of maximum detection, and LOC source for the compounds detected in groundwater. Refer to the Final 600 Area Data Report and Feasibility Study 600 Area Groundwater Plume (PICA-058) (Shaw, 2013) for a summary of the RI analytical results (Appendix A).

The groundwater exceedances reported at the site between April 2004 and February 2011 are shown in Figure 3-2. A total of six VOCs and one explosive compound (RDX) have historically exceeded applicable LOCs. The compounds reported in groundwater at concentrations exceeding their respective LOCs are as follows:

- 1,2-Dichloroethane
- MTBE
- Methylene chloride
- Tetrachloroethene (PCE)
- RDX
- 1,1,2,2-Tetrachloroethane
- TCE.

### 3.1.2.1 Trichloroethene Groundwater Sampling Results

TCE groundwater isopleth maps (Figures 3-3a and 3-3b) were prepared from the June 2007 and January/February 2011 data, respectively. The June 2007 plume depictions indicate that the highest TCE concentration (130 μg/L) was detected at well 13MW-2 located southwest and downgradient of the former explosives detonation area (AOC 1). The next highest TCE concentration of 110 μg/L was detected at well 13MW-1, which is located in AOC 1 just south of the debris disposal activity that is the suspected source area. The plotted June 2007 TCE plume extends approximately 1,450 ft southwest from 13MW-1 to the 1.0 μg/L contour southwest of DM13-1. The axis of the plume runs south from well 13MW-1, and then southwest to well 13MW-2 and DM13-1. The southwest portion of the plume is bounded by well 13MW-10 (non-detect [ND]) and to the south by well DM13-3 (ND) and 13MW-7 (ND). The southeast edge of the plume extends an approximate 1,260 ft from well 13MW-1, and is bounded by monitoring wells 13MW-5 (ND) and 13MW-6 (ND); Figure 3-2 provides TCE concentrations detected in wells. The overall width of the plume suggests lateral TCE transport along the northern splay of the Picatinny fault and/or fractures is associated with the mapped fold axis (Figure 2-5). The southwestern and southeastern edges of the plume terminate in mapped...
wetland/stream areas, and likely discharge into these surface water bodies, where TCE is detected.

The comparison of the June 2007 and January/February 2011 isopleth maps (Figures 3-3a and 3-3b) show similar TCE concentrations in groundwater and illustrate the relatively little change in the plume extent and shape over this time period. The TCE data suggest that the plume is stable, where TCE mass (input) is in equilibrium with the rate of groundwater TCE attenuation and discharge to surface water. This is expected to change as source area concentrations decline resulting in lower overall groundwater plume and surface water TCE concentrations (Shaw, 2013).

The AWDF well has a VOC sampling history back to 1994 (Figure 3-4). The time versus concentration trend graphs for the AWDF well show increasing TCE concentrations from August 1994 (1.3 μg/L) to April 2004 (94 μg/L). The AWDF well began operation in 1999, and it is unclear whether the results show an incipient TCE plume or capture of an existing plume via pumping. AWDF well data for the period from April 2004 to January 2011 show fluctuating TCE concentrations over time, and do not show a discernable trend. TCE time-concentration plots were also prepared for wells 13MW-1, 13MW-2, 13MW-4, and DM13-1 to evaluate historical TCE concentration trends, and are shown on Figure 3-4. Source area well 13MW-1 shows fluctuating TCE concentrations during the sampling period from June 2005 to March 2007 (170 μg/L), with progressively lower TCE concentrations observed in June 2007 (130 μg/L), October 2007 (120 μg/L), June 2008 (110 μg/L), May 2010 (116 μg/L), and February 2011 (96 μg/L). This decrease in source area groundwater TCE concentrations may reflect the reduction of TCE mass due to leaching into the bedrock aquifer within the source area.

TCE data for downgradient plume monitoring well 13MW-2 show considerable fluctuation during the period July 2006 to June 2008, with no apparent concentration trend. Other plume monitoring wells 13MW-4, AWDF, and DM13-1 likewise show fluctuating TCE concentrations. A comparison of current and historical TCE well data and TCE isopleth maps (Figures 3-3a and 3-3b) shows little change in the plume shape and extent over time. These data suggest that the plume is stable at the downgradient edge of the plume, where TCE mass (input) is in equilibrium with the rate of groundwater TCE attenuation and discharge to surface water.

The vertical extent of TCE contamination is illustrated in Figure 3-5 using packer test data collected at the AWDF well and monitoring wells 13MW-1 and 13MW-2 and groundwater sampling data from 13MW-8, and DM13-3. Packer test data from the AWDF best illustrate the vertical distribution of TCE. As shown in the AWDF Production Well Schematic Packer Test Summary (Figure 3-6), the maximum TCE concentration at the AWDF well is at 140-160 ft bgs (71.0 μg/L), and declines with depth to 11.0 μg/L at 416 to 436 ft bgs.

Other VOCs have been reported in the 600 Area Plume. MTBE was historically reported at concentrations above the LOC (70 μg/L) in one monitoring well (13MW-5) during the July 2006 (130 μg/L) and November 2006 (140 μg/L) sampling rounds. However, the concentrations have since decreased in March 2007 (51 μg/L), June 2007 (35 μg/L), October 2007 (21 μg/L), April 2010 (7.26 μg/L), and February 2011 (2.3 μg/L) to below the LOC.
3.1.2.2 RDX Groundwater Sampling Results

RDX is characterized by moderate to high mobility in soil. Explosive compounds, such as RDX, are unlikely to adsorb strongly to soils (Agency for Toxic Substances and Disease Registry, 2012). RDX was detected in six samples during the October 2007 sampling round, with one sample exceeding the interim LOC of 0.50 μg/L. For RDX, there is no established MCL or promulgated New Jersey GWQS. The LOC for RDX (0.50 μg/L) used in this FS is based on the most current NJDEP Interim GWQS last amended on 30 November 2015. The Federal Health Advisory Level for RDX is 2.0 μg/L. Results of RDX groundwater sampling are shown in Table 3-1 and on Figure 3-2. As shown on Figure 3-2, an RDX exceedance of the Interim GWQS was detected at well 13MW-1 (0.67 μg/L). RDX was also detected at wells 13MW-2 (0.18 J), 13MW-3 (0.3 J), 13MW-7 (0.485 J), 13MW-8 (0.42 μg/L), and the AWDF well (0.2 J). RDX was reported in the groundwater at these wells (except for 13MW-8) in 2004 and 2005, and shows no apparent trends in concentration. Based on the locations of the wells exhibiting low levels of RDX along with the historical use of the 600 Area, it was suspected that the source of RDX contamination originated in AOC 1 and possibly from Site 11 (Shaw, 2009).

In order to determine the potential source of RDX within the 600 Area, an additional investigation for RDX was conducted where groundwater, soil, surface water, and sediment were sampled within Site 11 in 2008. The results of the RDX investigation were presented in the Picatinny Arsenal Task Order 17 600 Area RDX Investigation Data Report (Shaw, 2009), and no further action was recommended. NJDEP and USEPA approved the RDX Investigation Data Report and agreed to the no further action recommendation.

3.1.3 Contaminants Reported in Soil, Surface Water, and Sediment

Surface water, sediment, and soil were collected during the 1989 SI and subsequent investigations in the source area of the Munitions Waste Pit (PICA-013-R-01). The results are summarized in this section. For a summary of the RI analytical results, see the Final 600 Area Data Report and Feasibility Study 600 Area Groundwater Plume (PICA-058) (Shaw, 2013) (Appendix A) and refer to the 1989 Site Investigation of Picatinny Arsenal, New Jersey (Dames and Moore, 1989).

3.1.3.1 Surface Soil

Four surface soil samples were collected during the 1989 SI (Dames and Moore, 1989) at the Munitions Waste Pit (Building 656). The 1989 SI samples were analyzed for propellants, metals, and explosives. Surface soil samples SS12-1 and SS12-2 were collected from around the perimeter of a metal cage which was used for testing activities (Figure 2-10). Samples SS12-3 and SS12-4 were collected from locations where other evidence of testing was found that appeared to represent the greatest potential of contamination (Dames and Moore, 1989). The results of the 1989 SI soil sampling (shown in Figure 2-10) indicated that nitroglycerine and other explosives were detected in three of the four surface soil samples (SS12-2, SS12-3 and SS12-4) and no explosives were detected in SS12-1. Explosives -2,4-DNT and nitroglycerin
were detected in sample SS12-2 at levels slightly exceeding the NJDEP non-residential soil remediation standards (SRS). All other detections of explosives were below standards and therefore, explosives in surface soil were not determined to be widespread or significant. Metals were detected in all four surface soil samples and were attributed to past activities conducted outside the test cage, other testing activities, or the possible decay of metal debris present at the site (Dames and Moore, 1989). However, all metals concentrations were below the NJDEP non-residential SRS. The results of the sediment sampling indicated that explosives and propellants were not present in the sediment samples collected and the reported metals concentrations were below standards or similar to background concentrations.

During the 2011 to 2012 source area investigation (Shaw, 2013) four surface soil samples were collected for VOC analysis (13TP-1, 13TP-2, 13TR1-1 and 13TR2-1). Samples 13TP-1 and 13TR2-1 were also analyzed for metals, explosives and SVOCs. One sample, 13TR1-1 (1 to 1.5 ft) had detections of acetone and 2-butanol with concentrations well below NJDEP non-residential SRS and USEPA Regional Screening Levels (RSLS). VOCs were not detected in the other samples. Metals were detected in both samples at concentrations below the New Jersey non-residential SRS, USEPA RSLS and/or established background concentrations.

Polycyclic aromatic hydrocarbons (PAHs) were also detected in both samples. Sample 13TP-1 had benzo(a)pyrene concentration of 0.601 mg/kg which slightly exceeds the NJDEP non-residential SRS and USEPA Industrial RSL of 0.2 mg/kg and 0.21 mg/kg, respectively. However, multiple studies conducted support the presence of PAHs in surface soil due to various anthropogenic mechanisms (BEM System, Inc. [BEM], 2002; U.S. Geological Survey [USGS], 2003; USEPA, 2013; NJDEP, 1993). According to studies characterizing the ambient levels of selected metals and carcinogenic PAHs in New Jersey soils, benzo(a)pyrene was detected at a concentration that slightly exceeded the NJDEP Non-residential and Residential Direct Soil Contact Criteria (BEM, 2002). The reported detections of benzo(a)pyrene were collected from soil located in rural areas in the Highlands Province in New Jersey. The concentration reported in the background sample for the 2002 BEM study was 0.68 mg/kg and was determined to be attributed to unidentified anthropogenic sources. Therefore, these detection of benzo(a) pyrene at 0.601 mg/kg is likely attributable to anthropogenic sources and not mission related activities.

3.1.3.2 Subsurface Soil

As discussed in Section 2.3.5, nine subsurface soil samples were collected in June 2011 and May 2012 as part of the source area investigation for the 600 Area TCE groundwater plume (Shaw, 2013). All samples were analyzed for VOCs. Five samples were also analyzed for explosives, metals and SVOCs. The results of the source area investigation, within the munitions waste pit boundaries are shown in Figure 2-910. As shown in Figure 2-910 and discussed above, benzo(a)pyrene was reported in one surface soil sample during the June 2011 test pit investigation in the source area at test pit 13TP-1 between 1-5 to 1.5 ft bgs at a concentration of 0.601 mg/kg. TCE was reported in subsurface soil during the trenching investigation in the source area conducted in May 2012 at 13TR1-1 between 24 ft and 24.5 ft bgs at a concentration...
of 23.9 mg/kg, which is above their NJDEP non-residential SRS and USEPA Industrial Soil RSL (Figure 2-10). There were no explosives detected in subsurface soils, and detected metals were at concentrations below the NJDEP non-residential SRS, USEPA RSLs and/or established background.

3.1.3.3 Surface Water

Surface water VOC sampling started in June 2005, and expanded in October 2007 to include sample location 11SW-6. A summary of the VOC results for surface water sampling is shown in Table 3-2. One TCE LOC exceedance was detected at sample location 11SW-3 in June 2008 and April 2011. TCE LOC exceedances were identified in three surface water samples in January 2011 (11SW-3, 13SW-4, and 13SW-6). A summary of 600 Area surface water VOC detections, range of concentrations, and exceedances is presented in Table 3-2. The results of surface water sampling are shown on Figure 3-7 and provided in Appendix A.

TCE surface water exceedances have been consistently detected at sample location 11SW-3, including in June 2005 (7.6 μg/L), November 2006 (2.8 μg/L), March 2007 (4.4 μg/L), June 2007 (12.0 μg/L), October 2007 (14.0 μg/L), June 2008 (6.4 μg/L), and April 2010 (4.22 μg/L) sampling rounds. A TCE exceedance was detected at downgradient sample location 13SW-6 in January 2006 (2.2 μg/L). Low concentrations of TCE were more recently detected at 13SW-6 in October 2007 (0.88 J μg/L) and June 2008 (0.74 J). Historical TCE surface water exceedances were observed at sample location 13SW-4 in the June 2005 (9.6 μg/L) and November 2006 (5.0 μg/L) rounds. TCE was detected at low concentrations in March 2006 (0.82 J μg/L) and March 2007 (0.97 J μg/L), and not detected at this surface water location in June 2007, October 2007, and June 2008. As shown in Figures 3-3a and 3-3b, the TCE groundwater plume extends into the wetland areas adjacent to sample locations 11SW-3 and 13SW-4, and is the probable source of TCE in surface water.

3.1.3.4 Sediment

Two sediment samples were collected during the 1989 SI (Dames and Moore, 1989) at the Munitions Waste Pit (Building 656). Both of the 1989 SI sediment samples were analyzed for propellants, metals, and explosives. Co-located surface water samples were planned to be collected during the 1989 SI investigation at the two sediment sampling locations; however, during the time of sampling, no surface water was present in the swampy area located on the south side of the site where the sediment samples were collected. The locations of the two sediment samples (SD12-1 and SD-12-2) collected during the 1989 SI are shown in Figure 2-10. There were no reported exceedances in sample SD12-2, and mercury was reported in the sediment samples collected at SD12-1 at a concentration of 0.266 mg/kg, which is slightly above the NJDEP criteria (0.15 mg/kg) and slightly above the background value of 0.246 mg/kg for sediment (IT, 2002).

Sediment samples were also collected in 2004 and 2006, and corresponded with surface water sampling completed at the site. The results of this more recent sediment sampling data are shown on Figure 3-7. There were two historical toluene LOC exceedances at sample location 11SD-1.
in November 2004 (0.12 mg/kg) and January 2006 (0.071 mg/kg). The toluene LOC (sediment quality benchmark [SQB]) is 0.05 mg/kg. However, the toluene exceedances were below the NJDEP non-residential SRS of 6,300 mg/kg. Toluene was not detected in downstream sample location 11SD-2 in corresponding sampling rounds. No other VOCs were detected at concentrations exceeding LOCs, therefore, a risk assessment was not warranted for sediment. A summary of 600 Area sediment sampling detections, range of concentrations, and exceedances is presented in Table 3-3. Sediment sampling results are shown on Figure 3-7 and provided in Appendix A.

### 3.1.4 Monitored Natural Attenuation Assessment of Groundwater

This section provides a summary of the Monitored Natural Attenuation (MNA) assessment process and investigation results that were detailed in the Final 600 Area Data Report and Feasibility Study for the 600 Area Groundwater Plume (Shaw, 2013), which was initiated in 2008 to determine the potential efficacy of MNA for 600 Area Groundwater. Subsequent sections of this FS discuss the implementation of MNA polishing as a RA considered for the 600 Hill Waste Pit. MNA is defined as the reduction of contaminant concentrations in the environment through biological processes (aerobic and anaerobic biodegradation, plant and animal uptake), physical processes (advection, dispersion, dilution, diffusion, volatilization, sorption, and desorption), and chemical reactions (ion exchange, complexation, and abiotic transformation). MNA involves the reduction of contaminant concentrations to environmentally benign levels through the mechanisms of fate and transport. Consistent with USEPA guidance, MNA is most appropriate when used in conjunction with other remedial measures or as a follow-up to an active remedial action. MNA should not be considered a default remedy, and MNA is not appropriate for every site (USEPA, 1998). MNA may be appropriate as a sole groundwater remedy if no source is present and site conditions indicate that natural attenuation alone would meet the remediation objectives. It may also be used as a polishing step following treatment or concurrent with an “active” remedy.

The MNA assessment of the TCE Plume at the 600 Area Groundwater followed the guidance in Technical Protocol for Evaluating Natural Attenuation of Chlorinated Solvents in Groundwater (USEPA, 1998). To consider MNA as a remedial action, it must be demonstrated that attenuation of site contaminants is occurring at rates sufficient to be protective of human health and the environment. Three lines of evidence can be used to support MNA. At a minimum, the investigator must obtain either the first two lines of evidence or the first and third lines of evidence. The lines of evidence are:

1. Historical groundwater and/or soil chemistry data may be used to demonstrate that a clear and meaningful trend of decreasing contaminant mass and/or concentration has been observed over time at appropriate monitoring or sampling points.

2. Hydrogeologic and geochemical modeling data can be used to demonstrate indirectly the type(s) of MNA processes active at the site and the rate at which such processes will reduce contaminant concentrations to required levels.
3. Data from field or microcosm studies (conducted in or with actual contaminated site media) may be used to directly demonstrate the occurrence of a particular MNA process at the site and its ability to degrade the COCs.

As described in the 1998 USEPA protocol, the assessment of MNA typically consists of a two-step process: initial screening followed by a more detailed evaluation. Key steps for evaluating MNA include:

1. Review available site data and develop a preliminary conceptual model
2. Conduct a screening process if sufficient data with appropriate quality exist
3. Perform an additional site characterization if the preliminary screening results suggest that MNA may potentially occur
4. Refine the conceptual model based on the site characterization data
5. Perform analytical or numerical solute fate and transport models to estimate a site-specific MNA and biodegradation rate
6. Identify potential receptors and exposure points and conduct an exposure pathways analysis
7. Evaluate the need for supplemental source control measures; additional source control may allow MNA to be a viable remedial option or decrease the time needed for natural processes to attain the Remedial Action Objectives (RAOs).

### 3.1.4.1 Degradation Process of Trichloroethene

Biodegradation of TCE can occur under both anaerobic and aerobic conditions. Anaerobic biodegradation transforms TCE to lesser-chlorinated compounds by reductive dechlorination. Under anaerobic conditions, the pathway to transform TCE by reductive dechlorination to produce daughter products cis-1,2-DCE to vinyl chloride to ethane. Diverse microorganisms include methanogenic (iron [Fe-III] and sulfate reducing) bacteria have been shown to anaerobically biodegrade TCE through different pathways.

In aerobic conditions, TCE can be cometabolized and degraded by methanotrophic bacteria (aerobic bacteria that utilize methane, phenol, or toluene as a sole carbon source) and other bacteria in the presence of methane, propane, ethylene, toluene, or phenol (USEPA, 1998 and 2000a; Wiedemeier et al., 1999). During oxidation of the primary substrates, these aerobes oxidize or cometabolize the chlorinated substrate via enzymatic reactions. Potential degradation end products may vary depending on the specific enzyme, but would include carbon dioxide, oxalate, glyoxylate, formate, and trichloroethanol (Gao et al., 2010).

The groundwater results from samples collected between 2004 and 2011 in the 600 Area indicate low frequency of detections of daughter products cis-1,2-DCE, vinyl chloride, and ethane. The infrequent detection of cis-1,2-DCE and ethene in TCE-impacted wells indicates limited anaerobic degradation. The observed limited/incomplete degradation of TCE is consistent with the predicted slightly to moderately reducing redox conditions in the aquifer.
3.1.4.2 Trichloroethylene Concentration Trends and Accumulation of Daughter Products

The TCE sampling results were plotted for the AWDF well and 600 Area monitoring wells (13MW-1, 13MW-2, 13MW-4, and DM13-1) to evaluate parent TCE compound concentration trends (Figure 3-4). As discussed in Section 3.1.2.1, evaluation of the sampling data (from 2004 to present) from source area (13MW-1) and the downgradient plume monitoring wells does not show a definitive concentration trend other than TCE has decreased in the source area (13MW-1) and is increasing downgradient as exhibited predominantly at monitoring well 13 MW-2.

As summarized in Table 3-1, the groundwater data indicate low to trace concentrations of daughter products, such as cis-1,2-DCE (4.51 µg/L) and vinyl chloride (0.24 µg/L), both of which were detected at monitoring well 13MW-4 in April 2010 and June 2007, respectively. The limited detection of daughter products at the TCE-impacted wells indicates limited degradation. The observed incomplete degradation of TCE is consistent with the slightly reducing redox conditions exhibited at most wells in the aquifer.

3.1.4.3 Summary of Monitored Natural Attenuation Assessment

A total of nine wells were sampled in March 2007 for bioremediation MNA parameters. The MNA sampling results analytes and field parameters are listed in Table 3-4 and summarized below.

The MNA data indicate that seven of nine monitoring wells in the 600 Hill Groundwater Plume show dissolved oxygen (DO) readings in excess of 1.0 µg/L, which is consistent with aerobic groundwater conditions. Aerobic degradation of organic compounds is favorable in groundwater with DO concentrations greater than 1.0 µg/L but has been reported as low as 0.5 µg/L (USEPA, 1998).

After DO has been depleted in groundwater, nitrate can be used as the electron acceptor for anaerobic biodegradation. Evaluation of the nitrogen data shows utilization/depletion of nitrate in the wells sampled, along with the corresponding accumulation of reduced ammonia. These data, along with the findings of the oxidation-reduction potential (ORP) and DO data analysis, indicate slightly reduced conditions in the groundwater plume.

Manganese sampling results show utilization/depletion of Mn$^{4+}$ in all wells, and accumulation of dissolved phase Mn$^{2+}$. Under slightly reducing conditions, bacteria use manganese as electron acceptors. These results are consistent with the nitrogen speciation data indicating biodegradation is occurring. The ferric iron depletion exhibited in three of the wells sampled (13MW-4, 13MW-11, and DM13-3), along with the corresponding accumulation of ferrous iron, is also an indicator of the occurrence of MNA.

Once all of the ferric iron has been reduced, sulfate can serve as the terminal electron acceptor for anaerobic biodegradation. Sulfide was detected in well 13MW-4 (2.1 µg/L), and may indicate the utilization/reduction of sulfate to sulfide at that location. Once the sulfate is depleted, methane (carbon dioxide) can act as an electron acceptor during anaerobic
biodegradation, and is reduced to methane under strongly reducing (less than -240 millivolts [mV]) conditions.

Redox potentials were recorded during the March 2007 MNA sampling and ranged from -128.4 mV (13MW-4) to +216.1 mV (DM13-2). The majority of measured ORP values fall within the slightly reduced category (from greater than -100 mV to +250 mV), with well 13MW-4 categorized as under reduced conditions that is in agreement with the above summary of the electron acceptor data, indicating that the groundwater in the bedrock aquifer beneath the 600 Area is slightly reduced.

Redox potentials recorded during the March 2007 sampling round at the 600 Area Groundwater Plume wells ranged from -128.4 mV to +216.1 mV, with the lowest ORP value reported at well 13MW-4. The majority of measured ORP values fall within the slightly reduced category (from greater than -100 mV to +250 mV), with well 13MW-4 categorized as “reduced.” The ORP data are in agreement with the terminal electron acceptor data, exhibiting slightly reduced conditions in the aquifer.

Therefore, the groundwater sampling data and MNA assessment generally indicate that the TCE plume is relatively stable and has not expanded since the onset of regular sampling in 2005. The plotted extent and shape of the plume between 2007 and 2011 do not exhibit significant changes over this period of time (Figures 3-3a and 3-3b). The plume currently discharges into one wetland, where TCE has been detected in surface water samples. As was concluded in the Final Data Report/FS (Shaw, 2013), the stable characteristics of the plume along with the occurrence of MNA processes (and wetland TCE losses) are presumably in equilibrium with the input of TCE mass into the aquifer. The ORP data indicate evidence of limited intrinsic TCE degradation in the aquifer, which is consistent with the overall slightly reduced redox conditions found in 600 Area groundwater. The amount of TCE mass loss via groundwater discharge to wetlands is not known, but is considered significant based on the concentration in surface water as well as the fact that the plume has not extended beyond the surface water features. The most recent groundwater data collected from the plume in 2010 and 2011 also support these conclusions.

3.1.5 Summary of Risk Assessments

3.1.5.1 Groundwater and Surface Water Human Health Risk Assessment

An HHRA was prepared for 600 Area groundwater and surface water and is provided as Appendix M to the 600 Area Data Report and FS (Appendix A.5) (Shaw, 2013). Risks to anticipated current and future receptors (industrial research worker and construction excavation workers) were evaluated. A residential scenario was not evaluated because the 600 Area is located in a secure part of PICA and is restricted to on-site research workers and construction excavation workers. Future military housing is unlikely in the 600 Area due to the long-term projected range operations. The data evaluated in the risk assessment were the 600 Area groundwater sampling data from the delineated bedrock plume and the surface water data. No human health risk assessment was conducted for sediment because the results of sediment
The evaluated dermal exposure pathway and cancer risk is 2.2E-08 for the future construction excavation worker scenario is based entirely on the evaluated dermal exposure pathway and is below the USEPA target risk range.

A summary of estimated risks and hazards for the future exposure scenarios is shown in Table 3-6. The estimated reasonable maximum exposure (RME) risk for the future industrial research worker falls within USEPA’s cancer risk range of 1E-4 to 1E-6. The estimated total RME cancer risk is 2.2E-08 for the future construction excavation worker scenario is based entirely on the evaluated dermal exposure pathway and is below the USEPA target risk range.
The estimated total surface water RME non-cancer hazard of 0.000009 for the current/future industrial research worker scenario is also based solely on the dermal contact pathway. This estimated RME hazard for the industrial research worker receptor is below USEPA’s target non-cancer hazard index of 1 (Appendix M in Shaw, 2013). The risk assessment was performed prior to the VI investigation carried out at Building 660 in 2011. Therefore, the risk from VI to indoor air was modeled using the Johnson and Ettinger VI Model (J&E Model). The J&E Model was used to evaluate risks and hazards from the inhalation of organics that may migrate from in situ groundwater to indoor air.

A summary of estimated risks and hazards for the current and future inhalation of organics off-gassing from in situ groundwater to indoor air is shown in Table 3-7 (Appendix M in the J&E Model input and output files of Shaw, 2013). Table 3-7 results show that the estimated cancer risk from the off-gassing of organics from in situ groundwater to indoor air for the current and future industrial research worker is acceptable, as the risk (6.3E-06) falls within the USEPA’s target cancer risk range of from 1E-4 to 1E-6. The estimated non-cancer hazard of 0.002 is also acceptable, as it is below USEPA’s target hazard index of 1. Table 3-8 presents the cancer (1.1E-9) and non-cancer (Hazard Index less than ≈1) risk associated with exposure to surface water, all of which were acceptable.

The summation of risks and hazards from Tables 3-6, and 3-7 and 3-8 results in a total estimated industrial research worker cancer risk of 1.7E-5 and a total estimated hazard index of 0.007 (Table 3-89). The summed risks are within the USEPA’s target risk range and the summed hazards are below the target hazard index of 1. The risk and hazard driver in all cases is TCE.

3.1.5.2 Ecological Risk Assessment

Ecological concerns at 600 Area surface water were assessed using the surface water data collected at the site between November 2004 and January 2011 (Shaw, 2013) and comparing the data to the ecological LOCs that were initially derived in the Phase II Ecological Risk Assessment (IT, 2000) and in the Phase III Screening Level Ecological Risk Assessment (Shaw, 2005b). According the risk assessments, aquatic receptors (e.g., fish and macroinvertebrates) could potentially be exposed to surface water contaminants of potential ecological concern (COPECs) from groundwater feeding into 600 Area flowages via seeps or springs (Shaw, 2013). If concentrations are high enough, exposure to these high concentrations could lead to reduced survival and reproduction of aquatic organisms or alter the benthic macroinvertebrate community.

The chemicals that were reported in surface water samples collected between November 2004 and January 2011 at concentrations exceeding their respective LOCs included the following:

- MTBE
- RDX
- TCE.
According to the Final FS (Shaw, 2013), the concentrations of these chemicals reported in 600 Area surface water were not expected to pose any adverse effects on aquatic life at the 600 Area.
3.1.6 Conclusions of 600 Hill Groundwater Plume

The following conclusions for the 600 Hill Groundwater Plume are based on the results of the 2013 investigation results (Shaw, 2013):

- TCE sampling data show a steady state plume originating in Inactive Munitions Pit (AOC 1), which discharges to surface water at two locations, and impacted the (now off-line) AWDF non-potable well. The exact nature, volume, and size of the TCE source material were not known, but were presumed to be a thin layer of impacted soils buried under blasted rock debris from the Building 600 site.

- Further investigation of the potential source soils has been considered impracticable due to the 10-ft to 30-ft-thick overlying rock debris, and potentially buried MEC in the former munitions testing area. However, additional investigations were conducted that included passive soil gas testing in the newly uncovered source area, followed by excavation and sampling of test pits and/or trenches based on the passive soil sampling results, and two additional rounds of groundwater and surface water sampling.

- The trenching investigation in Inactive Munitions Waste Pit conducted in May 2012 to investigate the TCE contamination in the 600 Area Groundwater Soil indicated elevated soil headspace PID responses (700 to 1,000 ppm) within the 20-ft to 24.5-ft bgs interval directly on top of bedrock. VOCs soil analysis of sample TR1-1 (24 to 24.5 ft) collected from this interval indicated TCE at a concentration of 23.9 mg/kg. This sample was collected approximately 120 ft northeast of 13MW-1. The results indicate that the active source of the 600 Area TCE groundwater plume is an approximately 5-ft thick layer of TCE-impacted soil located just above bedrock centered between 13MW-1 and the burning cage located on-site.

- Two conceptual source models were developed (Shaw, 2013) to predict plume characteristics and time to cleanup.
  - The Inactive Source Model assumed an inactive or rapidly declining TCE source to the bedrock aquifer, and predicted time to cleanup based upon observed TCE concentration decreases at source area well 13MW-1 using sampling data from the well over a 6-year period. A cleanup time of 53 years was calculated from well 13MW-1 data using the USEPA time-dependent degradation rate method. However, the model should be applied with caution due to the relatively small data set from 13MW-1.

  - The Soil Leaching Model assumes an ongoing, but declining source of TCE to the bedrock aquifer over time, and estimates time to cleanup using predicted soil leaching rates. Using the model VLEACH to simulate leaching of source area soils, the model results predicted that TCE-impacted soils would decrease to NJDEP Impact to Groundwater Standards for TCE in 35 years. The soil leaching model should be considered a more reliable estimate of groundwater restoration timeframes.

- Based on the Shaw 2013 RI, it has been determined that a response action is necessary for PICA-058 to restore the groundwater to its beneficial use as a drinking water aquifer.
3.2 INACTIVE MUNITIONS WASTE PIT (PICA-013-R-01)

3.2.1 Site Location

The Inactive Munitions Waste Pit MRS consists of 21 acres and is located northwest of the northernmost end of Picatinny Lake, near the installation boundary. The MRS area mainly contains bare ground associated waste pit and the filled areas that are surrounded by deciduous forest. The MRS boundary was defined by the 1,250-ft surface danger zone for a former testing area within the MRS. Figure 1-2 presents the location of the Inactive Munitions Waste Pit (PICA-013-R-01) within the 600 Area. The Inactive Munitions Waste Pit consisted of an open field with a burn cage, a gun turret, and a building (Building 656). It is unknown whether all these structures were present throughout the site’s operation. The 2012 trenching operations conducted at this MRS, under the IRP to locate the source of the TCE plume, have also indicated potential disposal activities.

As shown on Figure 1-2, Inactive Munitions Waste Pit MRS (PICA-013-R-01) is bordered by the installation boundary to the northwest. There are no distinct boundaries to the south and east; the closest boundaries are Site 13 and Site 11, respectively. The Inactive Munitions Waste Pit MRS (PICA-013-R-01) lies between two Operational Ranges that give the area its irregular shape. PICA-013-R-01 is south of the Inactive Munition Waste Pit – Off-Post MRS, which is tracked separately in the Army Environmental Database – Restoration (AEDB-R) System as the Inactive Munitions Waste Pit – Off-Post MRS, (PICA-014-R-01) and is not included in this FS.

A small portion of the AOI Code 300 Area (depicted on Figure 1-2) overlaps the Inactive Munitions Waste Pit MRS. The AOI Code 300 Area consists of approximately 975 acres. According to the Picatinny Arsenal Survey Report (DoD, 1973), PICA had 2,036 acres located throughout the portion of the PICA defined as the Former Operational Areas MRS (Malcolm Pirnie, Inc., 2008) that were used for research and development and testing. Code 300 Area was used as a former artillery firing and fragmentation pattern testing area for munitions as large as 155-mm projectiles (WESTON, 2012). However, only a small portion of the AOI Code 300 Area overlaps the 600 Area, and 155-mm projectiles from testing were not identified within the 600 Area. The Department of Defense Explosives Safety Board (DDESB) has previously identified the 6-inch Mk 20 Mod 0-4 as the most probable munition at the 600 Area. The locations of these areas are depicted on Figure 1-2. Currently, the Inactive Munitions Waste Pit MRS is a non-operational area that acts as a buffer between active ranges. The former testing area at the center of the MRS is currently being used as a storage space for vehicles and fill/gravel and other rubble piles. There are no planned land use changes for the Inactive Munitions Waste Pit MRS (WESTON, 2014).

3.2.2 Site History

The Inactive Munitions Waste Pit MRS testing area was reportedly used from 1955 to the mid-1980s for testing and storage of munitions and explosives. Based on information contained in the RI Concept Plan (ANL, 1991), it appears the Inactive Munitions Waste Pit consisted of an
open field with a burn cage, a gun turret, and a building (Building 656). It is unknown whether all these structures were present throughout the site’s operation. Although the site name suggests that materials may have been buried in pits, no site features or other evidence have been identified indicating that burial of munitions took place. In the 1980s, the site was covered with topsoil and sand and, in the late-1990s, the majority of the site was covered with fill and rock. A review of recent aerial photographs confirms that fill material up to 12 ft in thickness is present at the site. Based on the available historical information, MEC and MD have been released in the Inactive Munitions Waste Pit MRS from former testing activities and munitions disposal. According to the 2006 Installation Action Plan Report after 1963, all material generated from munitions testing was removed and transported to the Picatinny Burning Ground. Limited historical information is available for Inactive Munitions Waste Pit MRS; however, two key reports (a 2006 Installation Action Plan [Malcolm Pirnie, Inc., 2006] and 1989 SI [Dames and Moore, 1989]) provide the basis for the Inactive Munitions Waste Pit MRS description and site history. The 2006 Installation Action Plan Report states that the area was used for evaluating munitions, whereas the 1989 SI Report states that the area was used for static testing of explosives and propellants (Malcolm Pirnie, Inc., 2006).

Historical records and aerial photography also indicate that the potential testing area in the center of the Inactive Munitions Waste Pit MRS was filled with up to 12 ft of sand, gravel, and rock during the 1980s and 1990s (Malcolm Pirnie, Inc., 2006). The fill work has most likely obscured any surface signs of former use as a disposal or burial area. It was also reported that metal objects have been found partially buried at the Inactive Munitions Waste Pit MRS, but none of the objects identified constituted MEC or MD (Malcolm Pirnie, Inc., 2006). Based on the aerial photographs included in the Inactive Munitions Waste Pit MRS White Paper in Appendix B (included in Appendix D of the WESTON 2014 MMRP RI Report), it appears that initial clearing (disturbance) and construction of the former testing area were performed between 1957 and 1963. The 1963 aerial photograph shows that native vegetation was removed and the area was leveled with fill. A burn cage is shown in the center of the cleared area. In a 1970 aerial photograph, the burn cage is shown relocated approximately 125 ft to the east and additional land to the south is disturbed. A 1979 aerial photograph indicates the presence of berms that might be demolition pits or burial locations, and the first appearance of Building 656. Building 656 was not evident in the 2002 aerial photograph, and large amounts of fill material are evident at the former testing area. Large stockpiles of soil and debris are also currently present at the site. The primary source of hazard identified for the Inactive Munitions Waste Pit MRS is exposure to suspect MEC at ground surface or in subsurface soil with a subsequent hazard identified as a release of MC to environmental media from a MEC source.

Currently, the Inactive Munitions Waste Pit MRS is a restricted access area (fully fenced) within PICA that abuts operational ranges to the east and south, with the installation boundary forming the northwestern extent of the MRS. The Inactive Munitions Waste Pit MRS is only accessible to authorized personnel. The current access restrictions are not anticipated to change in the future, and the Inactive Munitions Waste Pit MRS is not currently included in any future overall redevelopment plans for PICA because of its proximity to operational ranges.
3.2.3 Previous Investigations

3.2.3.1 Site Inspection MRS (AEDB-R ID: PICA-013-R-01)

In 2008, the Inactive Munitions Waste Pit MRS was included in the 2008 SI Report conducted under the MMRP (Malcom Pirnie, Inc., 2008) that addresses a total of 10 MMRP eligible sites at PICA. The SI at PICA included both MEC and MC field activities, which were conducted from 16 July through 18 July 2007. For on-post sites included in the SI, field screening/sampling included the collection of sufficient information to determine if MEC or MC were present at the MMRP sites. Fieldwork involved locating surface evidence of MEC through instrument assisted visual surveys and, at one site, collecting soil samples for MC of concern (copper, iron, lead, zinc, and explosives). The information obtained during the SI was used to make the recommendation of whether to proceed to an RI/FS, conduct an immediate response, or further action. The Inactive Munitions Waste Pit (PICA-013-R-01) was separated into on-post and off-post portions (PICA-014-R-01) for the SI Report.

No field activities were conducted in the Inactive Munitions Waste Pit MRS during the MMRP SI as the Historical Records Review (Malcolm Pirnie, Inc., 2006) provided justification for a recommendation to proceed to RI/FS for MEC and MC without further investigation. The presence of 12 ft of fill at the on-post portion of the MRS limited the value of a magnetometer-assisted visual survey conducted as part of the SI; however, the findings of the visual inspection of the Munitions Waste Pit – Off-Post MRS were applied to the on-post MRS where no MEC items or MD were observed during the survey.

The findings and recommendations of the SI at the Inactive Munition Pit (PICA-013-R-01) were that, although no MEC or MD were observed at this site during the SI fieldwork, evidence of historical range activity was observed; structures observed included a burn cage and gun turret. Four surface soil samples and two sediment samples were collected from this site. Both explosives and metals were detected in the samples; some of the parameters exceeded the comparison criteria. As RI/FS was recommended to be conducted at the MRS for MEC and MC, Section 3.2.4.1 provides details regarding the types of MD identified at the site during the RI.

3.2.3.2 Remedial Investigation Munitions Response Site (AEDB-R ID: PICA-013-R-01)

In accordance with the Final MMRP RI Work Plan (WESTON, 2012), WESTON conducted an RI at nine MRSs located at PICA in support of the MMRP. The overall goal of the MMRP RI was to determine the nature and extent of MEC and MC and subsequently determine the potential hazards and risks posed to human health and the environment by MEC and MC. PICA-013-R-01 was included in the MMRP RI (WESTON, 2014). The findings and conclusions of the RI activities conducted at the Inactive Munitions Waste Pit MRS to characterize the MEC and MC are summarized in the following sections.
3.2.4 Munitions and Explosives of Concern Characterization

The MMRP RI approach included performing EM31-MK2 transect surveys to detect burial features in the MRS where potential testing and burial activities would have occurred. If MEC burial sites were detected by DGM transect surveys, then the extent of the burial feature would be delineated. A second MMRP RI field objective was to conduct analog transect surveys to detect potential MEC releases. Density transects were to be conducted in the portion of the MRS that overlapped with the AOI Code 300 Area to detect high density areas that would be indicative of a MEC release. As noted in Section 3.2.1, only a small portion of the AOI Code 300 Area overlaps the Inactive Munitions Waste Pit MRS (Figure 1-3). The AOI Code 300 Area consists of approximately 975 acres. The AOI Code 300 Area was used as a former artillery firing and fragmentation pattern testing area for munitions as large as 155-mm projectiles.

On 30 January 2012, DGM transect surveys were performed for the MMRP RI with the EM31-MK2 over the central portion of the Inactive Munitions Waste Pit MRS to detect subsurface anomalies and determine whether a munitions waste pit(s) was indicated in the subsurface. The results of the Inactive Munitions Waste Pit MRS soil sampling and DGM are shown in Figure 3-89. In the 600 Area, a total of 6,163 linear ft of EM31-MK2 transects were surveyed within the Inactive Munitions Waste Pit MRS. The waste pit area is estimated to extend laterally over 0.24 acres (10,498 square ft) from ground surface down to bedrock, approximately 24.5 ft bgs. Assuming an even distribution of buried material, the approximate maximum volume of the waste pit is 257,201 cubic ft (9,526 cubic yd) (WESTON, 2014).

No intrusive investigations for MEC were performed based on the DGM described above to define the lateral extent of buried debris, as the presence of MEC and MD was confirmed based on the available historical information. However, limited intrusive investigation within the Inactive Munitions Waste Pit MRS was performed during the IRP trench excavation including visual inspection and characterization sampling for MC (WESTON, 2014).

No anomalies were detected that warranted intrusive investigation during the 830 linear ft of analog transects performed within the Inactive Munitions Waste Pit MRS, around the periphery of the burial site identified via DGM and not overlapping with the AOI Code 300 Area (WESTON, 2014).

A total of 3,020 linear ft of density transects were conducted in the area of the Inactive Munitions Waste Pit MRS overlapping with the AOI Code 300 Area. After the density transects were completed, an analog grid Code 300-12 (50 ft by 50 ft) was placed to characterize a potential high density area. A total of 14 anomalies were identified within the grid; only one item was identified as MD, an M42 submunition body (as detailed in Section 3.2.3.1), which was recovered from 3 inches bgs. The remaining 13 items were classified as cultural debris. The items were recovered between 0 and 3 inches bgs.
3.2.4.1 Munitions and Explosives of Concern Source

During the intrusive investigation, MEC and MD were confirmed at the MRS. One MEC item identified during the investigation (CDU-10 [T-1]/B Canister with XM39E and XM44 [Gravel Mines]) was recovered at 4.5 ft bgs at the eastern end of trench TR2 during the June 2011 pitting and trenching investigation (Shaw, 2013). Numerous MD were recovered during the test pit and trenching activities at the former testing area (source area) of the Inactive Munitions Waste Pit MRS consisting of an expended M72 Rocket Launcher for 66-mm (light anti-tank weapon) rockets, chloracetophenone/o-chlorobenzylidenemalononitrile (CN/CS) tear gas canisters (inert), expended 40-mm grenade cartridge cases, an exploded XM31 antitank landmine, 155-mm fragments (found within the waste pit from disposal activities), expended MK45 aircraft flare, and expended PD fuzes (Shaw, 2013). Outside the former testing area in the remainder of the MRS, one MD item was identified, in the AOI Code 300, as an M42 submunitions body. Figure 2-10 shows the location of the MEC and MD discovered in Inactive Munitions Waste Pit MRS. The MEC and MD discovered in the source area are listed in Table 2-2.

According to the MMRP RI, numerous MD and discarded military munitions, which is the one MEC item discovered (CDU-10 [T-1]/B Canister with XM39E and XM44 [Gravel Mines]), were discovered in the center of the waste pit commingled with other debris and 55-gallon drums. The debris layer was observed below the unconsolidated fill material and extended to 20 ft bgs (4.5 ft above where bedrock was encountered at 24.5 ft bgs) within the excavated trenching area (TR2). The MD items were discovered in TP-2 completed in the source area. Based on the DGM and intrusive investigation results, the lateral and vertical extent of a large waste pit has been determined. The waste pit area is estimated at 0.24 acres (10,498 square ft) and the depth to bedrock is 24.5 ft bgs. Assuming an even distribution of buried material, the approximate maximum volume of the waste pit is 257,201 cubic ft (9,526 cubic yd).

Based on the weight of evidence obtained during the RI, the MEC density in the former testing area/burial pit is considered high compared to the surrounding portions of the Inactive Munitions Waste Pit MRS where no MEC were identified. There is evidence that MEC remain at the former testing area/burial pit at the center of the Inactive Munitions Waste Pit MRS commingled with debris in subsurface soil, and MD at ground surface in the portion that overlaps with the AOI Code 300 Area. Based on RI observations, the bulk of buried debris containing potential MEC is located from 10 to 20 ft bgs, although activities document one MEC discovery in the Inactive Munitions Waste Pit MRS at 4.5 ft bgs.

3.2.4.2 Fate and Transport – Munitions and Explosives of Concern

Based on RI characterization activities at the Inactive Munitions Waste Pit MRS, the bulk source for MEC and MD is buried approximately 10 to 20 ft bgs. However, several MD items and one MEC item were discovered at approximately 4.5 ft bgs in the Inactive Munitions Waste Pit MRS. The anticipated MEC and MD at the MRS are too deep for natural erosion to affect, especially since the MRS has a relatively flat topography that would make a large-scale erosional event such as a landslide unlikely. Soils contained within the MRS are typically not susceptible
to frost heave; additionally, the anticipated MEC and MD are present below the frost line (3 ft). Therefore, surface interactions such as wet/dry erosion and frost heave are not likely to impact source material. Biota that may nest or burrow are also not anticipated to impact residual MEC and MD due to the depth of buried debris observed during the RI. The maximum depth of biological activity is anticipated to be less than 4 ft bgs, which is shallower than the depth of MEC and MD. Impact/displacement through human activities (e.g., intrusive activities) is the only potential factor that could impact the fate of residual MEC and transport it to another location within the Inactive Munitions Waste Pit MRS (WESTON, 2014). Based on the RI field data, the conceptual site model for MEC was revised and is depicted on Figure 3-10 for the MRS as a flow chart summarizing the pathway and exposure mechanisms.

3.2.4.3 Munitions and Explosives of Concern Hazard Assessment

In October 2008, the Technical Working Group for Hazard Assessment (HA), which included representatives from the DoD, Department of the Interior, USEPA, and other officials, made available the technical reference document, Interim MEC HA Methodology (USEPA, 2008). This reference document is designed to be used as the CERCLA HA methodology for MRSs where there is an explosive hazard from the known or suspected presence of MEC. As part of this FS, each of the RAs developed and evaluated have been assessed using the USEPA 2008 MEC HA method. The purpose of the MEC HA is twofold:

1. Support the hazard management decision-making process by analyzing site-specific information to assess existing explosives hazards, evaluate hazard reductions associated with removal and RAs, and evaluate hazard reductions associated with land use activity decisions;

2. Support hazard communication between the project team and project stakeholders (USEPA, 2008).

The MEC HA fits into MMRP activities and the regulatory structure of CERCLA by addressing the NCP Code of Federal Regulations (CFR): 300.430(d)(4) requirement to conduct site-specific risk assessments for threats to human health and the environment; however, the MEC HA does not directly address environmental or ecological concerns that may be associated with MEC (USEPA, 2008).

The MEC HA scoring is based on input factor categories, which describe the site-specific conditions. The input factors may change as different land use activities are assessed, but generally include the following:

- **Energetic Material Type**—The type of energetic material is the primary determinant of the severity of the explosive hazard.

- **Location of Additional Human Receptors**—It is possible that additional human receptors beyond the individual, who causes an item to detonate, may be exposed to overpressure and/or fragmentation hazards from the detonation of MEC.

- **Site Accessibility**—The ease with which people can access an MRS.
• Potential Contact Hours — The effect of human receptors intentionally performing activities at an MRS when they might come into contact with MEC.

• Amount of MEC — The relative quantity of MEC that may remain from past munitions related activities.

The MEC HA includes evaluation of three components of a potential explosive hazard incident:

• Severity — The potential consequences (e.g., death, severe injury, property damage) of MEC detonating.

• Accessibility — The likelihood that a receptor will be able to come in contact with MEC.

• Sensitivity — The likelihood that a receptor will be able to interact with MEC so that it will detonate.

Each of these components is assessed in the MEC HA by determining input factor scores for an MRS. The sum of the input factor scores falls within one of four defined ranges, called hazard levels. Each of the four levels reflects site attributes that describe groups of sites and site conditions ranging from the highest to the lowest hazards. The MEC HA hazard levels include the following:

• Hazard Level 1 — Sites with the highest hazard potential. There may be instances where an imminent threat to human health exists from MEC.

• Hazard Level 2 — Sites with a high hazard potential. A site with surface MEC or one undergoing intrusive activities so that MEC would be encountered in the subsurface. The site would also have moderate or greater accessibility by the public.

• Hazard Level 3 — Sites with a moderate hazard potential. A site that would be considered safe for the current land use without further munitions response, although not necessarily suitable for reasonable, anticipated future use. Level 3 areas generally would have restricted access, a low number of contact hours, and typically MEC only in the subsurface.

• Hazard Level 4 — Sites with a low hazard potential. A site compatible with current and reasonably anticipated future use. Level 4 sites typically have had a MEC cleanup performed.

The MEC HA guidance document (USEPA, 2008) includes an automated workbook that develops site scoring through standardized input and formulas. The MEC HA results for each of the RAs presented in this FS are summarized and further discussed in Sections 6 and 7. The MEC HA methodology was used for assessing potential explosive hazards, including human health and safety concerns associated with potential exposure to MEC by human receptors at the MRS. The MEC HA considers the current and reasonably anticipated future conditions, and the various RAs, land use activities, and LUC alternatives presented in this FS. Risks from MEC explosive hazards are evaluated as being either present or not present. If the potential for an encounter with MEC exists, the potential that the encounter may result in death or injury also exists. Consequently, if MEC are known or suspected to be present, a munitions response typically will be required. The munitions response may include further investigation, cleanup of
The Final MMRP RI Work Plan (WESTON, 2012) stated that, to the extent possible, MC sampling within the Inactive Munitions Waste Pit MRS would be conducted concurrently with IRP trenching investigations already underway within the MRS. Both random sampling and biased sampling approaches were detailed for the MRS. Random sampling would only be collected from native soil, not fill material. However, the random sampling approach was not employed as a result of both safety concerns and field observations, as the trench consisted of fill material, and native soil was not encountered until near bedrock. Except for the sample collected near bedrock, sampling was conducted in a biased manner in conjunction with IRP sampling activities, and the MMRP RI samples were co-located with the IRP samples.

The MC sampling in the Inactive Munitions Waste Pit MRS was completed between 22 and 24 May 2012. Three soil samples and one field duplicate were collected and analyzed for explosives MC and perchlorate. The soil samples were collected in accordance with the Final RI Work Plan (WESTON, 2012). The MC samples were collected at various depths from soil associated with buried debris, as well as from soil below the observed burial area. Note that no surface soil samples were collected during the MMRP RI because there were no identified MEC in surface soil. The MC soil sample locations and sampling depths are shown on Figure 3-8.

Sample PTA-2012-IMWP-002 was collected at 10- to 11 ft bgs at sample location IMWP-2002 from soil directly below a drum that was observed to contain MD in the form of various fuzes and leaking fluids, and represented the most impacted soil that was assessed based on field observations (i.e., worst-case scenario).

The May 2012 RI sampling results indicate that only one explosive compound (2,4-DNT) in one sample was detected at a concentration (8.3 mg/kg) above the project screening level selected to assess human health (1.6 mg/kg). Aluminum was detected in all samples at a concentration of 11,000 mg/kg, which was slightly above the project screening level of 7,700 mg/kg selected to assess a target hazard quotient (HQ) of 0.1, but below the Picatinny subsurface soil background level of 20,500 mg/kg. Cadmium was detected in one sample (PTA-2012-IMWP-002) at a concentration of 29 mg/kg that slightly exceeded the project screening level of 7 mg/kg, which was also selected to assess a target HQ of 0.1. Zinc was the only other metal analyte detected at a notable concentration, which was 190 mg/kg in one sample (PTA-2012-IMWP-002) and above the Picatinny-specific background value of 56.12 mg/kg, but well below the project screening level of 2,300 mg/kg (WESTON, 2014). These results are consistent with the soil sample results from the IRP sampling program, which were previously discussed in Section 3.1.3 Only subsurface soil samples were collected, which were associated with the buried debris.
3.2.5 Fate and Transport – Munitions Constituents

Fate and transport dynamics specific to MC are not applicable to the Inactive Munitions Waste Pit MRS because no evidence of a MC hazard source was identified during the RI to provide the basis for a detailed discussion. Analytical sampling and risk evaluation did not warrant selection of any COPCs or COPECs for quantitative risk assessment.

3.2.6 Summary of Human Health Risk Assessment for Munitions Constituents

A HHRA was conducted for MC at the site, as described in Section 9.2 of the MMRP RI (Appendix B1, Weston 2014). As discussed in Section 3.2.4, geophysical investigations were conducted over representative portions of the 21-acre MRS. During the geophysical investigation, soil samples were collected if there were visual observations or geophysical results indicating the presence of MEC or disposal activities. During these investigations, there was no surface MEC identified, and no historical surface disposal activities were identified. Therefore, no surface soil samples were collected, and surface soil is not considered a complete exposure pathway. However, subsurface soil samples were collected during the IRP test pit/trench investigations due to the presence of subsurface MEC and buried debris indicative of a disposal area. As previously discussed, the buried debris was identified at the depth of 10-2 ft bgs.

The 2014 RI analytical results and results of the collocated IRP investigation indicate that risks to human health are not present from MC in subsurface soil associated with the buried debris at the Inactive Munitions Waste Pit MRS. Metals were identified at concentrations exceeding human health screening criteria. However, results were below Picatinny-specific background values and/or below alternative screening levels (adjusted upwards to assess a target HQ of 1.0). Therefore, no metals were selected as COPCs, given that the two analytes observed in excess of initially selected screening levels were found to be below Picatinny-specific background values and/or below alternative screening levels (adjusted upwards to assess a target HQ of 1.0).

All explosives compounds analyzed in the biased soil samples, except for one, were found to be below project screening levels. The one exceedance was an estimated detection of 2,4-DNT in soil collected from 124 ft bgs at the bottom of the test trench and below the observed debris. However, 2,4-DNT was not detected in the collocated IRP sample, or any other of the biased samples collected from soil in contact with buried debris. Because the 2,4-DNT detection, and has negligible potential for exposure due to depth (14 ft bgs) and no confirmed groundwater impacts, it was not selected as a COPC and no risks were identified. Because there were no COPCs identified in subsurface soil, and surface soil is not a media of concern, no quantitative risk assessment was performed.

Further, the RI risk assessment concluded that all considered pathways in the exposure analysis for MC at the Inactive Munitions Waste Pit MRS were determined to be incomplete. Based on the location of observed debris with MEC in subsurface soil, primary or secondary release to sediment/surface water and air is not anticipated to be exposure pathways of concern, as there is no source impacting the media. Similarly, no source for exposure to potential ecological receptors is probable based on the depth of buried debris. The revised conceptual site model for
MC is depicted on Figure 3-11 for the Inactive Munitions Waste Pit MRS as a flow chart summarizing the pathway and exposure mechanisms.

3.2.7 Conclusions for Inactive Munitions Waste Pit Munitions Response Site

The following conclusions were provided based on the results of the 2014 RI field activities (WESTON, 2014):

- A burial pit feature was confirmed to be present based on DGM performed at ground surface extending over 0.24 acres laterally within the MRS boundary.
- Previous SIs and intrusive investigations performed during the RI confirm that MD and MEC are present, comingled with other debris containing constituents being addressed under the IRP.
- MEC identified during the RI intrusive investigation were limited to discarded military munitions, which is the one MEC item discovered (the CDU-10 [T-1]/B Canister with XM39E and XM44 [Gravel Mines]) identified in subsurface soil at 4.5 ft bgs; however, the majority of the debris was between 10 and 20 ft bgs.
- MD was recovered at ground surface from the portion of the MRS that overlaps with the AOI Code 300 Area only.
- An estimated volume of 257,201 cubic ft (9,526 cubic yd) of fill material with debris containing one MEC item (the CDU-10 [T-1]/B Canister with XM39E and XM44 [Gravel Mines]), which is a type of discarded military munitions and MD remains within the MRS boundary.
- An explosive safety hazard may exist at the Inactive Munitions Waste Pit MRS based on the discovery of MEC. A MEC HA was conducted as part of the RI and the Inactive Munitions Waste Pit MRS was assigned a hazard level of 3, which is a moderate potential explosive hazard condition.
- The extent of buried debris containing discarded military munitions and MD present as a result of past munitions testing/burial within the Inactive Munitions Waste Pit MRS has been adequately defined and the nature of the buried debris has been determined to the extent that intrusive investigation was practical.
- The extent of MD present because of artillery firing and fragmentation pattern testing within the AOI Code 300 Area has been adequately defined.
- MEC pathways to potential receptors with subsurface exposure potential at the MRS have been determined to be complete.
- MEC pathways to potential receptors with surface exposure only at the Inactive Munitions Waste Pit MRS have been determined to be incomplete for lack of a confirmed source for MEC at ground surface or within the subsurface at depths that are likely to be susceptible to transport to the surface.
- All MC pathways to potential receptors at the MRS have been determined to be incomplete for lack of a confirmed release/source.
Although access is restricted within the Inactive Munitions Waste Pit MRS, future risk management was recommended as a result of the discovery of one MEC item (discarded military munitions) and numerous MD identified during IRP intrusive activities.
### Table 3-1: Summary of Groundwater Analytical Results, 600 Area (April 2004 through February 2011)

<table>
<thead>
<tr>
<th>Compound</th>
<th>Frequency of Detection</th>
<th>Range of Detected Concentrations</th>
<th>Location of Maximum Concentration</th>
<th>LOC</th>
<th>LOC Source</th>
<th>UOM</th>
<th>Exceed LOC?</th>
<th>Number of Hits Exceeding LOC</th>
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<tbody>
<tr>
<td>Acetone</td>
<td>11 / 124</td>
<td>1.4 / 19.7</td>
<td>13MW-13 04/20/2010</td>
<td>6000</td>
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<td>µg/L</td>
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<td>--</td>
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<td>2 / 91</td>
<td>2.5 / 55</td>
<td>13MW-7 03/06/2007</td>
<td>120</td>
<td>TWRBC</td>
<td>µg/L</td>
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<td>--</td>
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<td>Benzene</td>
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<td>--</td>
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<td></td>
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<td>--</td>
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<td>New Jersey MCL and Quality Criteria</td>
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<td>Chloroethane</td>
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<td>2 / 124</td>
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<td>2.22 / 2.8</td>
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<td>1,1-Dichloroethane</td>
<td>0 / 124</td>
<td>--</td>
<td>50</td>
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<td>µg/L</td>
<td>No</td>
<td>--</td>
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<tr>
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<td>1 / 124</td>
<td>20 / 20</td>
<td>13MW-1 10/24/2007</td>
<td>2</td>
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<td>µg/L</td>
<td>Yes</td>
<td>1</td>
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<tr>
<td>1,1-Dichloroethene</td>
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<td>--</td>
<td>1</td>
<td>Quality Criteria, New Jersey PQL</td>
<td>µg/L</td>
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<td>cis-1,2-Dichloroethene</td>
<td>15 / 124</td>
<td>0.23 / 4.51</td>
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<td>70</td>
<td>MCL, Quality Criteria, MCLG</td>
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<td>trans-1,2-Dichloroethene</td>
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<td>0.38 / 0.59</td>
<td>13MW-2 02/08/2011</td>
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<td>MCL, Quality Criteria, MCLG</td>
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<td>1,2-Dichloropropane</td>
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<td>New Jersey PQL</td>
<td>µg/L</td>
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<td>cis-1,3-Dichloropropene</td>
<td>0 / 124</td>
<td>--</td>
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<td>New Jersey PQL</td>
<td>µg/L</td>
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<td>0 / 124</td>
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<td>µg/L</td>
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<td>700</td>
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<td>Range of Detected Concentrations</td>
<td>Location of Maximum Concentration</td>
<td>LOC</td>
<td>LOC Source</td>
<td>UOM</td>
<td>Exceed LOC?</td>
<td>Number of Hits Exceeding LOC</td>
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<tr>
<td>--------------------------------</td>
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<td>------------</td>
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<tr>
<td>2-Hexanone</td>
<td>3 / 124</td>
<td>0.58 / 0.62</td>
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<td>0.504 / 15</td>
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<td>1,1,2,2-Tetrachloroethane</td>
<td>1 / 124</td>
<td>5.1 / 5.1</td>
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<td>Toluene</td>
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<td>0.17 / 8</td>
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<td>600</td>
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<td>30</td>
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<td>--</td>
<td>--</td>
<td>3</td>
<td>New Jersey MCL, Quality Criteria, MCLG</td>
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<td>74 / 124</td>
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<td>0.275 / .278</td>
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<td>2000</td>
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<td>0.31 / 2750</td>
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<td>New Jersey Interim Standard GWQS</td>
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<tr>
<td>Vinyl chloride</td>
<td>1 / 124</td>
<td>0.24 / 0.24</td>
<td>13MW-4 07/24/2006</td>
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<td>New Jersey PQL</td>
<td>µg/L</td>
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<td>--</td>
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<tr>
<td>Total Xylenes</td>
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<td>--</td>
<td>--</td>
<td>1000</td>
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<td>µg/L</td>
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<tr>
<td>1,3-Dinitrobenzene</td>
<td>3 / 68</td>
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<td>HA</td>
<td>µg/L</td>
<td>No</td>
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</tr>
<tr>
<td>2,4-Dinitrotoluene</td>
<td>2 / 68</td>
<td>0.15 / 0.88</td>
<td>13MW-4 10/22/2007</td>
<td>10</td>
<td>New Jersey PQL</td>
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<tr>
<td>2,6-Dinitrotoluene</td>
<td>1 / 68</td>
<td>0.2 / 0.2</td>
<td>13MW-4 10/22/2007</td>
<td>10</td>
<td>New Jersey PQL</td>
<td>µg/L</td>
<td>No</td>
<td>--</td>
</tr>
<tr>
<td>2-amino-4,6-Dinitrotoluene</td>
<td>2 / 68</td>
<td>0.066 / 0.15</td>
<td>13MW-8 06/20/2007</td>
<td>73</td>
<td>TWRBC</td>
<td>µg/L</td>
<td>No</td>
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</tbody>
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Table 3-1: Summary of Groundwater Analytical Results, 600 Area (April 2004 through February 2011) (continued)

<table>
<thead>
<tr>
<th>Compound</th>
<th>Frequency of Detection</th>
<th>Range of Detected Concentrations</th>
<th>Location of Maximum Concentration</th>
<th>LOC</th>
<th>LOC Source</th>
<th>UOM</th>
<th>Exceed LOC?</th>
<th>Number of Hits Exceeding LOC</th>
</tr>
</thead>
<tbody>
<tr>
<td>4-aminodinitrotoluene</td>
<td>3 / 68</td>
<td>0.091 / 0.16</td>
<td>13MW-8 10/24/2007</td>
<td>73</td>
<td>TWRBC</td>
<td>µg/L</td>
<td>No</td>
<td>--</td>
</tr>
<tr>
<td>HMX</td>
<td>18 / 68</td>
<td>0.073 / 0.33</td>
<td>13MW-5 07/26/2006</td>
<td>400</td>
<td>HA</td>
<td>µg/L</td>
<td>No</td>
<td>--</td>
</tr>
<tr>
<td>Nitrobenzene</td>
<td>17 / 68</td>
<td>1.1 / 1.1</td>
<td>13MW-8 10/24/2007</td>
<td>6</td>
<td>New Jersey PQL</td>
<td>µg/L</td>
<td>No</td>
<td>--</td>
</tr>
<tr>
<td>2-Nitrotoluene</td>
<td>17 / 68</td>
<td>0.68 / 0.68</td>
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<td>61</td>
<td>TWRBC</td>
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<td>No</td>
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</tr>
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<td>3-Nitrotoluene</td>
<td>17 / 68</td>
<td>0.16 / 0.16</td>
<td>13MW-7 10/31/2006</td>
<td>61</td>
<td>TWRBC</td>
<td>µg/L</td>
<td>No</td>
<td>--</td>
</tr>
<tr>
<td>4-Nitrotoluene</td>
<td>17 / 68</td>
<td>0.88 / 0.88</td>
<td>13MW-4 10/22/2007</td>
<td>61</td>
<td>TWRBC</td>
<td>µg/L</td>
<td>No</td>
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</tr>
<tr>
<td>RDX</td>
<td>28 / 68</td>
<td>0.11 / 1.1</td>
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<td>New Jersey Interim GWQS</td>
<td>µg/L</td>
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<td>5</td>
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<tr>
<td>Tetryl</td>
<td>17 / 68</td>
<td>0.42 / 0.42</td>
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<td>150</td>
<td>TWRBC</td>
<td>µg/L</td>
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<td>--</td>
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<tr>
<td>1,3,5-Trinitrobenzene</td>
<td>17 / 68</td>
<td>0.061 / 0.061</td>
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<td>1100</td>
<td>TWRBC</td>
<td>µg/L</td>
<td>No</td>
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<tr>
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<td>27 / 68</td>
<td>0.11 / 0.3</td>
<td>13MW-1 11/01/2006</td>
<td>1.2</td>
<td>Quality Criteria</td>
<td>µg/L</td>
<td>No</td>
<td>--</td>
</tr>
</tbody>
</table>

Notes:
Bolded values indicate a detection. D = Result was obtained from the analysis of a dilution.
Bolded and shaded values indicate the detected result is above the LOC.

µg/L = Microgram per liter.
GWQS = Groundwater Quality Standards.
HA = Federal Drinking Water Health Advisories.
HMX = 1,3,5,7-tetranitro-1,3,5,7-tetrazacyclooctane.
J = Detect, value is an estimate.
LOC = Level of concern.
MCL = Maximum contaminant level.
MCLG = Maximum contaminant level goal.
N = The matrix spikes are outside of precision and/or accuracy criteria.
NA = No value available.
NJDEP = New Jersey Department of Environmental Protection.
PQL = Practical Quantification Limit.
RDX = Research Department Formula X (Cyclotrimethylenetetranitramine).
TWRBC = USEPA Region 3 Tap Water Risk-Based Concentration.
U = Non-detect, value is the detection limit.
UOM = Unit of measurement.
Table 3-2: Summary of Surface Water Analytical Results, 600 Area (June 2005 through January 2011)

<table>
<thead>
<tr>
<th>Compound</th>
<th>Frequency of Detection</th>
<th>Range of Detected Concentrations</th>
<th>Location of Maximum Concentration</th>
<th>LOC</th>
<th>LOC Source</th>
<th>UOM</th>
<th>Exceed LOC?</th>
<th>Number of Hits Exceeding LOC</th>
</tr>
</thead>
<tbody>
<tr>
<td>Acetone</td>
<td>11 / 51</td>
<td>1.2 / 11.1</td>
<td>11SW-10.04/19/2010</td>
<td>5500</td>
<td>TWRBC</td>
<td>µg/L</td>
<td>No</td>
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</tr>
<tr>
<td>Acetonitrile</td>
<td>0 / 37</td>
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<td>--</td>
<td>120</td>
<td>TWRBC</td>
<td>µg/L</td>
<td>No</td>
<td></td>
</tr>
<tr>
<td>Benzene</td>
<td>0 / 51</td>
<td>--</td>
<td>--</td>
<td>0.15</td>
<td>SWQC</td>
<td>µg/L</td>
<td>No</td>
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<tr>
<td>Bromodichloromethane</td>
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<td>--</td>
<td>0.266</td>
<td>SWQC</td>
<td>µg/L</td>
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<tr>
<td>Bromoform</td>
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<td>4.3Water &amp; Organisms</td>
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<td>Water &amp; Organisms</td>
<td>µg/L</td>
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<td>Bromomethane</td>
<td>0 / 51</td>
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<td>47Water &amp; Organisms</td>
<td>47</td>
<td>Water &amp; Organisms</td>
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<tr>
<td>2-Butanone</td>
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<td>13SW-4.03/30/2007</td>
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<td>1000</td>
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<td>Carbon tetrachloride</td>
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<tr>
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<td>LOC assigned</td>
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</tr>
<tr>
<td>Methyl Tertiary-Butyl Ether</td>
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<td>2.6</td>
<td>TWRBC</td>
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<tr>
<td>4-Methyl-2-pentanone</td>
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<td>6300</td>
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### Table 3-2: Summary of Surface Water Analytical Results, 600 Area (June 2005 through January 2011) (continued)

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<th>Compound</th>
<th>Frequency of Detection</th>
<th>Range of Detected Concentrations</th>
<th>Location of Maximum Concentration</th>
<th>LOC</th>
<th>LOC Source</th>
<th>UOM</th>
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<th>Number of Hits Exceeding LOC</th>
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<td>0.049 / 10</td>
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<td>New Jersey Interim GWQS</td>
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<td>--</td>
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Table 3-2: Summary of Surface Water Analytical Results, 600 Area (June 2005 through January 2011) (continued)

<table>
<thead>
<tr>
<th>Notes:</th>
</tr>
</thead>
</table>
| µg/L | Microgram per liter.  
| GWQS | Groundwater Quality Standards.  
| LOC | Level of concern.  
| MCL | Maximum Contaminant Level.  
| NJDEP | New Jersey Department of Environmental Protection.  
| PQL | Practical Quantitation Limit.  
| RDX | Research Department Formula X (Cyclotrimethylenetrinitramine).  
| SWQC | Surface Water Quality Criteria.  
| TWRBC | U.S. Environmental Protection Agency Region 3 Tap Water Risk-Based Concentration.  
| U | Non-detect, value is the detection limit.  
| UOM | Unit of measurement.  

Feasibility Study for 600 Hill Waste Pit (600 Hill Groundwater Plume [PICA-058]) and Inactive Munitions Waste Pit [PICA-013-R-01])
Picatinny Arsenal Cleanup Contract, Picatinny Arsenal, New Jersey
Contract No. W91ZLK-13-D-0014

Version: Final
May 2017

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Table 3-3: Summary of Sediment Analytical Results, 600 Area (November 2004 through June 2008)

<table>
<thead>
<tr>
<th>Compound</th>
<th>Frequency of Detections</th>
<th>Range of Detected Concentrations</th>
<th>Location of Maximum Concentration</th>
<th>LOC</th>
<th>LOC Source</th>
<th>UOM</th>
<th>Exceed LOC?</th>
<th>Number of Hits Exceeding LOC</th>
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<tr>
<td>Acetone</td>
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<td>--</td>
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<td>Acetonitrile</td>
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<td>46</td>
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<td>1000</td>
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<td>No</td>
<td>--</td>
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<tr>
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<td>mg/kg</td>
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<td>4.2</td>
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<td>IRBC</td>
<td>mg/kg</td>
<td>No</td>
<td>--</td>
</tr>
<tr>
<td>4-Nitrotoluene</td>
<td>0 / 6</td>
<td>--</td>
<td>--</td>
<td>10000</td>
<td>IRBC</td>
<td>mg/kg</td>
<td>No</td>
<td>--</td>
</tr>
<tr>
<td>RDX</td>
<td>0 / 6</td>
<td>--</td>
<td>--</td>
<td>26</td>
<td>NJNR, IRBC</td>
<td>mg/kg</td>
<td>No</td>
<td>--</td>
</tr>
<tr>
<td>Tetryl</td>
<td>0 / 6</td>
<td>--</td>
<td>--</td>
<td>4100</td>
<td>IRBC</td>
<td>mg/kg</td>
<td>No</td>
<td>--</td>
</tr>
<tr>
<td>1,3,5-Trinitrobenzene</td>
<td>0 / 6</td>
<td>--</td>
<td>--</td>
<td>310000</td>
<td>IRBC</td>
<td>mg/kg</td>
<td>No</td>
<td>--</td>
</tr>
<tr>
<td>2,4,6-Trinitrotoluene</td>
<td>0 / 6</td>
<td>--</td>
<td>--</td>
<td>95</td>
<td>NJNR, IRBC</td>
<td>mg/kg</td>
<td>No</td>
<td>--</td>
</tr>
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### Table 3-3 Summary of Sediment Analytical Results, 600 Area (November 2004 through June 2008) (continued)

<table>
<thead>
<tr>
<th>Notes:</th>
<th>IRBC</th>
<th>GWQS</th>
<th>LOC</th>
<th>MCL</th>
<th>mg/kg</th>
<th>SQB</th>
<th>TWRBC</th>
<th>UOM</th>
</tr>
</thead>
<tbody>
<tr>
<td>IRBC</td>
<td>Industrial Risk-Based Criteria</td>
<td>Groundwater Quality Standards.</td>
<td>Level of concern</td>
<td>Maximum contaminant level.</td>
<td>Milligram per kilogram</td>
<td>Sediment quality benchmark</td>
<td>U.S. Environmental Protection Agency Region 3 Tap Water Risk-Based Concentration</td>
<td>Unit of measurement</td>
</tr>
<tr>
<td>GWQS</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>LOC</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>MCL</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>mg/kg</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>SQB</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>TWRBC</td>
<td>U.S. Environmental Protection Agency Region 3 Tap Water Risk-Based Concentration</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>UOM</td>
<td>Non-detect, value is the detection limit</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>UOM</td>
<td>Unit of measurement</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
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</tr>
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</table>
Table 3-4: Results of Monitored Natural Attenuation Sampling, March 2007, 600 Area Groundwater

<table>
<thead>
<tr>
<th>Well</th>
<th>Dissolved Oxygen (mg/L)</th>
<th>Dissolved Oxygen (Winkler method, mg/L)</th>
<th>Oxidation-Reduction Potential</th>
<th>Ammonia (mg/L)</th>
<th>Nitrate, in mg/L</th>
<th>Sulfate, in mg/L</th>
<th>Sulfide, in mg/L</th>
<th>Iron (total), in mg/L</th>
<th>Iron (filtered), in mg/L</th>
<th>Total Ferric Iron (calculated)</th>
<th>Manganese (total), in mg/L</th>
<th>Manganese (filtered), in mg/L</th>
<th>Total Mn⁴⁺ (calculated)</th>
<th>Ethane, in μg/L</th>
<th>Ethene, in μg/L</th>
<th>Methane, in μg/L</th>
</tr>
</thead>
<tbody>
<tr>
<td>13MW-1</td>
<td>4.4</td>
<td>9.4</td>
<td>149.8</td>
<td>0.15</td>
<td>U</td>
<td>9</td>
<td>U</td>
<td>0.045</td>
<td>0.045</td>
<td>0.01J</td>
<td>0.007J</td>
<td>0.003</td>
<td>U</td>
<td>U</td>
<td>U</td>
<td></td>
</tr>
<tr>
<td>13MW-4</td>
<td>0.21</td>
<td>0.6</td>
<td>(-)128.4</td>
<td>0.16</td>
<td>U</td>
<td>17.7</td>
<td>2.1</td>
<td>2.2</td>
<td>1.83</td>
<td>0.37</td>
<td>0.175</td>
<td>0.171</td>
<td>0.004</td>
<td>U</td>
<td>4.1</td>
<td>2</td>
</tr>
<tr>
<td>13MW-7</td>
<td>2.88</td>
<td>3.1</td>
<td>152.2</td>
<td>0.11</td>
<td>0.2</td>
<td>2.7</td>
<td>U</td>
<td>0.096</td>
<td>NA</td>
<td>0.08</td>
<td>0.083</td>
<td>NA</td>
<td>U</td>
<td>U</td>
<td>U</td>
<td></td>
</tr>
<tr>
<td>13MW-8</td>
<td>0.5</td>
<td>(-)</td>
<td>48.1</td>
<td>0.11J</td>
<td>0.21J</td>
<td>229</td>
<td>U</td>
<td>0.069 J</td>
<td>0.145</td>
<td>NA</td>
<td>0.0002</td>
<td>0.0024</td>
<td>NA</td>
<td>U</td>
<td>U</td>
<td>U</td>
</tr>
<tr>
<td>13MW-9</td>
<td>8.22</td>
<td>7.9</td>
<td>170.3</td>
<td>0.11J</td>
<td>0.068J</td>
<td>12.2</td>
<td>U</td>
<td>0.051 J</td>
<td>0.145</td>
<td>NA</td>
<td>0.083</td>
<td>0.083</td>
<td>NA</td>
<td>U</td>
<td>U</td>
<td>U</td>
</tr>
<tr>
<td>13MW-10</td>
<td>7.12</td>
<td>7.8</td>
<td>(-)186.6</td>
<td>0.13</td>
<td>0.33J</td>
<td>70.3</td>
<td>U</td>
<td>0.065 J</td>
<td>none</td>
<td>0.00033</td>
<td>0.00073</td>
<td>NA</td>
<td>U</td>
<td>U</td>
<td>U</td>
<td></td>
</tr>
<tr>
<td>13MW-11</td>
<td>10.25</td>
<td>10</td>
<td>197.5</td>
<td>0.073J</td>
<td>U</td>
<td>10.4</td>
<td>U</td>
<td>0.159</td>
<td>U</td>
<td>0.159</td>
<td>0.1</td>
<td>0.1</td>
<td>U</td>
<td>U</td>
<td>U</td>
<td></td>
</tr>
<tr>
<td>DM13-2</td>
<td>10.59</td>
<td>10.5</td>
<td>216.1</td>
<td>U</td>
<td>9</td>
<td>U</td>
<td>0.11</td>
<td>U</td>
<td>0.11</td>
<td>0.078</td>
<td>0.079</td>
<td>NA</td>
<td>U</td>
<td>U</td>
<td>U</td>
<td></td>
</tr>
<tr>
<td>DM13-3</td>
<td>2.91</td>
<td>2.6</td>
<td>68.9</td>
<td>0.19J</td>
<td>0.13</td>
<td>9.2</td>
<td>U</td>
<td>2.83</td>
<td>0.587</td>
<td>2.24</td>
<td>0.068</td>
<td>0.07</td>
<td>NA</td>
<td>U</td>
<td>U</td>
<td>0.14</td>
</tr>
</tbody>
</table>

Notes:
- µg/L = Microgram per liter.
- J = Detect, value is an estimate of the concentration.
- mg/L = Milligram per liter.
- NA = Not analyzed
- (U) = Non-detect, chemical was detected in blank.
- U = Non-detect, value is the detection limit.
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### Table 3-5: Summary of 600 Area Groundwater and Surface Water Human Health Contaminants of Potential Concern

<table>
<thead>
<tr>
<th>Contaminants of Potential Concern by Media</th>
<th>Groundwater (maximum detected concentration in μg/L)</th>
<th>Groundwater Level of Concern (μg/L)</th>
<th>Surface Water (maximum detected concentration in μg/L)</th>
<th>Surface Water Level of Concern (μg/L)</th>
</tr>
</thead>
<tbody>
<tr>
<td>2,4,6-Trinitrotoluene</td>
<td>0.30</td>
<td>1.2</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>2,4-Dinitrotoluene</td>
<td>0.15</td>
<td>10</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>cis-1,2-Dichloroethene</td>
<td>2</td>
<td>70</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Acetonitrile</td>
<td>55</td>
<td>120</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Methyl Tertiary-Butyl Ether</td>
<td>140</td>
<td>70</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Vinyl Chloride</td>
<td>0.24</td>
<td>1</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Research Department Formula X (Cyclotrimethylenetritramine)</td>
<td>1.1</td>
<td>0.5 (interim)</td>
<td>10</td>
<td>0.5 (interim)</td>
</tr>
<tr>
<td>Tetrachloroethene</td>
<td>2.2</td>
<td>1</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Trichloroethene</td>
<td>170</td>
<td>1</td>
<td>14</td>
<td>1.09</td>
</tr>
</tbody>
</table>

Notes:
1. The determination of human health contaminants of potential concern for trichloroethene in surface water was based upon 1.09 μg/L; however, the current New Jersey Department of Environmental Protection Surface Water Quality Standards for trichloroethene is 1.0 μg/L (New Jersey Department of Environmental Protection Surface Water Quality Standards, last amended 4 April 2011).
- = Not applicable.
μg/L = Microgram per liter.
### Table 3-6: Summary of 600 Area Groundwater Estimated Future Risk and Hazards

<table>
<thead>
<tr>
<th>Receptor (Future)</th>
<th>Estimated Total Cancer Risk</th>
<th>Cancer Risk Drivers</th>
<th>Pathway Contributing Most to Cancer Risk</th>
</tr>
</thead>
<tbody>
<tr>
<td>Industrial Research Worker</td>
<td>1.1E-5</td>
<td>Trichloroethene, Tetrachloroethene</td>
<td>Ingestion</td>
</tr>
<tr>
<td>Construction Excavation Worker</td>
<td>2.2E-8</td>
<td>None (Cancer Risk &lt; 1E-6)</td>
<td>Not applicable</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Receptor (Future)</th>
<th>Estimated Total Non-Cancer Risk</th>
<th>Non-Cancer Risk Drivers</th>
<th>Groundwater Pathway Contributing Most to Non-Cancer Risk</th>
</tr>
</thead>
<tbody>
<tr>
<td>Industrial Research Worker</td>
<td>1.1E-5</td>
<td>None (Hazard Index &lt; 1)</td>
<td>Ingestion</td>
</tr>
<tr>
<td>Construction Excavation Worker</td>
<td>0.0001</td>
<td>None (Hazard Index &lt; 1)</td>
<td>Not applicable</td>
</tr>
</tbody>
</table>
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Table 3-7: Summary of 600 Area Groundwater Estimated Current and Future Risks and Hazards from Vapor Intrusion of Volatile Organic Compounds from In Situ Groundwater

<table>
<thead>
<tr>
<th>Receptor (Future)</th>
<th>Estimated Total Cancer Risk</th>
<th>Cancer Risk Drivers</th>
</tr>
</thead>
<tbody>
<tr>
<td>Industrial Research Worker</td>
<td>6.3E-6</td>
<td>Trichloroethene</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Receptor (Future)</th>
<th>Estimated Total Non-Cancer Risk</th>
<th>Non-Cancer Risk Drivers</th>
</tr>
</thead>
<tbody>
<tr>
<td>Industrial Research Worker</td>
<td>0.002</td>
<td>None (Hazard Index &lt;1)</td>
</tr>
</tbody>
</table>
### Table 3-8: Summary of 600 Area Surface Water Estimated Current and Future Risks and Hazards

<table>
<thead>
<tr>
<th>Receptor (Future)</th>
<th>Estimated Total Cancer Risk</th>
<th>Cancer Risk Drivers</th>
<th>Non-Cancer Risk Drivers</th>
</tr>
</thead>
<tbody>
<tr>
<td>Industrial Research Worker</td>
<td>1.1E-9</td>
<td>None</td>
<td></td>
</tr>
<tr>
<td>Receptor (Future)</td>
<td>Estimated Total Non-Cancer Risk</td>
<td>Non-Cancer Risk Drivers</td>
<td></td>
</tr>
<tr>
<td>Industrial Research Worker</td>
<td>000009</td>
<td>None (Hazard Index &lt;1)</td>
<td></td>
</tr>
</tbody>
</table>
Table 3-89: Summary of 600 Area Estimated Current and Future Risks and Hazards

<table>
<thead>
<tr>
<th>Receptor (Future)</th>
<th>Estimated Total Cancer Risk</th>
<th>Cancer Risk Drivers</th>
<th>Pathway Contributing Most to Cancer Risk</th>
</tr>
</thead>
<tbody>
<tr>
<td>Industrial Research Worker</td>
<td>1.7E-5</td>
<td>Trichloroethylene</td>
<td>Ingestion and inhalation</td>
</tr>
<tr>
<td>Receptor (Future)</td>
<td>Estimated Total Non-Cancer Risk</td>
<td>Non-Cancer Risk Drivers</td>
<td>Groundwater Pathway Contributing Most to Non-Cancer Risk</td>
</tr>
<tr>
<td>Industrial Research Worker</td>
<td>0.007</td>
<td>None (Hazard Index &lt;1)</td>
<td>Not applicable</td>
</tr>
</tbody>
</table>
Feasibility Study for 600 Hill Waste Pit (600 Hill Groundwater Plume [PICA-058]
and Inactive Munitions Waste Pit [PICA-013-R-01])
Picatinny Arsenal Cleanup Contract, Picatinny Arsenal, New Jersey
Contract No. W912ZL-13-D-0014

Placeholder for Figure 3-1
Feasibility Study for 600 Hill Waste Pit (600 Hill Groundwater Plume [PICA-058]) and Inactive Munitions Waste Pit [PICA-013-R-01])
Picatinny Arsenal Cleanup Contract, Picatinny Arsenal, New Jersey
Contract No. W91ZLK-13-D-0014

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Placeholder for Figure 3-2
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Placeholders for Figure 3-3a
Feasibility Study for 600 Hill Waste Pit (600 Hill Groundwater Plume [PICA-058]) and Inactive Munitions Waste Pit [PICA-013-R-01])
Picatinny Arsenal Cleanup Contract, Picatinny Arsenal, New Jersey
Contract No. W912IZ-13-D-0014

Placeholder for Figure 3-4
Feasibility Study for 600 Hill Waste Pit, (600 Hill Groundwater Plume [PICA-058]
and Inactive Munitions Waste Pit [PICA-013-R-01])
Picatinny Arsenal Cleanup Contract, Picatinny Arsenal, New Jersey
Contract No. W912ZK-13-D-0014

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Feasibility Study for 600 Hill Waste Pit, 600 Hill Groundwater Plume [PICA-058] and Inactive Munitions Waste Pit [PICA-013-R-01]

Picatinny Arsenal Cleanup Contract, Picatinny Arsenal, New Jersey
Contract No. W91ZKR-13-D-0014

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Feasibility Study for 600 Hill Waste Pit (600 Hill Groundwater Plume [PICA-058]) and Inactive Munitions Waste Pit [PICA-013-R-01]) Picatinny Arsenal Cleanup Contract, Picatinny Arsenal, New Jersey

Contract No. W912ZL-13-D-0014

Placeholder for Figure 3-8
Feasibility Study for 600 Hill Waste Pit, (600 Hill Groundwater Plume [PICA-058]) and Inactive Munitions Waste Pit [PICA-013-R-01])
Picatinny Arsenal Cleanup Contract, Picatinny Arsenal, New Jersey
Contract No. W912Y8-13-D-0014

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Feasibility Study for 600 Hill Waste Pit, (600 Hill Groundwater Plume [PICA-058] and Inactive Munitions Waste Pit [PICA-013-R-01])
Picatinny Arsenal Cleanup Contract, Picatinny Arsenal, New Jersey
Contract No. W912PK-13-D-0014

Placeholder for Figure 3-10
4. DEVELOPMENT OF REMEDIAL ACTION OBJECTIVES

This section develops and presents the RAOS for the 600 Hill Waste Pit area (i.e., the 600 Hill Groundwater Plume [PICA-058] and the Inactive Munitions Waste Pit [PICA-013-R-01]). The development of the RAOS includes the evaluation of ARARs, identification of contaminants and media of concern, and determination of PRGs.

4.1 APPLICABLE OR RELEVANT AND APPROPRIATE REQUIREMENTS

In July 2009, a resolution was reached between USEPA and the U.S. Army regarding differing approaches to addressing contaminated groundwater and surface water. This resolution is referred to as the “Mid-Valley” dispute agreement. The resolution involved the recognition of USEPA policy of returning groundwater to its beneficial use. The U.S. Army agreed to recognize promulgated groundwater criteria as ARARs even when sites have excess risk levels less than 1E-4 for exposure to groundwater. Surface water was a secondary issue for which the U.S. Army agreed to monitor surface water but not recognize surface water criteria as ARARs without an unacceptable risk from surface water. Based on this resolution, a response action is necessary for 600 Area groundwater because concentrations of TCE in groundwater are greater than the promulgated USEPA MCL standard. The agreed upon approach developed as part of the Mid-Valley resolution has been used in this FS.

Based on the decision to take a response action for groundwater, an ARARs analysis was conducted in accordance with 40 CFR 300.400(g). ARARs that address the 600 Hill Waste Pit area are identified in this section. Identification of ARARs is an integral part of the remediation process mandated under Section 121 (d) of CERCLA, as amended by SARA. ARARs are used to develop remedial action cleanup levels, determine the appropriate extent of site cleanup, and govern implementation and operation of the selected remedial action. The preamble of CERCLA states the purpose of the law is “to provide for liability, compensation, cleanup, and emergency response for hazardous substances released into the environment and the cleanup of inactive hazardous waste disposal sites.” Remedial actions that “clean up” hazardous substances at CERCLA sites must comply with state and federal standards and criteria that are legally applicable to the substance, pollutant, or contaminant; or that are relevant and appropriate under the circumstances (42 U.S. Code 9621(d)(2)(A)). Furthermore, the more stringent ARAR identified may be applicable (40 CFR 300.5). “More stringent” also includes those State laws or programs that have no Federal counterpart as “they add to the Federal law requirements that are specific to the environmental conditions in the State” (USEPA, 1989). State requirements, however, must be adopted by formal means (i.e., promulgated) and applied universally throughout the state (i.e., not just to Superfund sites, but to all circumstances addressed in the requirement) (42 U.S. Code 9621(d)(2)(C)(iii)(I)).

4.1.1 Applicable or Relevant and Appropriate Requirement Classification Requirements

In order to be classified as an ARAR, the NCP states that Federal and/or State laws must meet one of the following two requirements: (1) applicability or (2) relevance and appropriateness. “Applicable” requirements are “those cleanup standards, standards of control, and other
substantive requirements, criteria, or limitations promulgated under Federal environmental, 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” (40 CFR 300.5). “Relevant and appropriate” requirements are “those cleanup standards, standards of control, and other substantive requirements, criteria, or limitations promulgated under Federal environmental, 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.” Only those State standards that are identified in a timely manner and are more stringent than Federal requirements may be relevant and appropriate (40 CFR 300.5).

Once a Federal or State law has been classified as applicable or relevant and appropriate, its requirements must be distinguished between substantive and administrative. “Substantive” requirements are “those requirements that pertain directly to actions or conditions in the environment” (CERCLA Compliance with Other Laws Manual: Interim Final §1.2.2.1). “Administrative” requirements are “those mechanisms that facilitate the implementation of the substantive requirements of a statute or regulation.” Administrative requirements do not in and of themselves define a level or standard of control (53 Federal Register 51443). Administrative requirements include the approval of, or consultation with, administrative bodies, issuance of permits, documentation, and reporting and recordkeeping. Response actions under CERCLA are required to comply with ARARs, which are defined not to include administrative requirements.

Thus, compliance with administrative requirements is not mandated for on-site actions (USEPA, 1988a). For example, CERCLA specifically exempts on-site actions from Federal, State, and local permitting requirements (42 U.S. Code 9621(e)(1)).

In addition, the NCP identifies a third category, termed “information TBCs.” TBCs are guidelines or advisories that are issued by the Federal or State government, but which are neither legally binding nor promulgated (USEPA, 1988a). However, these guidelines may be used when they are necessary to ensure protection of public health and the environment (USEPA, 1988a). If ARARs do not address a particular circumstance at a CERCLA site, then TBCs can be used to establish remedial guidelines or targets. Even when TBCs are used, the requirements imposed on the remedy, including cost-effectiveness, still apply (55 Federal Register 8745, 8 March 1990).

### 4.1.2 Types of Applicable or Relevant and Appropriate Requirements

Based on USEPA guidance (USEPA, 1988a), ARARs are categorized as chemical-specific, action specific, or location-specific:

- Chemical-specific ARARs are based on health- or risk-based concentration limits or discharge limitations in environmental media (i.e., air, soil, or water) for specific hazardous chemicals. The requirements may be used to set cleanup levels for the COCs in the designated media, or to set a safe level of discharge (e.g., air emission or wastewater discharge) where a discharge occurs as a part of the remedial action.
• Action-specific ARARs generally set performance, design, or other similar operational controls or restrictions on particular activities related to management of hazardous substances or pollutants. These requirements address specific activities that are used to accomplish a remedy. Action-specific requirements do not in themselves determine the remedial action; rather, they indicate how a selected remedial action alternative must be designed, operated, or managed.

• Location-specific ARARs are restrictions on the types of activities that may occur in particular locations. The location of a site may be an important characteristic in determining its impact on human health and the environment. Location-specific ARARs include federal requirements for wetlands protection and floodplain restrictions on management of hazardous waste.

Potential chemical-specific, chemical-specific (by COC), and action-specific, and location-specific ARARs and TBCs for 600 Hill Waste Pit are presented in Tables 4-1, 4-2, and 4-3, respectively. There were no location-specific ARARS identified.

4.2 CONTAMINANTS OF CONCERN AND MEDIA OF CONCERN

The determination of COCs for groundwater within the 600 Hill Groundwater Plume was previously identified in the Final Data Report and Feasibility Study (Shaw, 2013). The only groundwater COC is TCE, as presented below in Table 4-45. There were no unacceptable human health or ecological risks identified for exposure to 600 Area surface water or soil. The most stringent of the Federal MCL and the NJDEP GWQS ARAR concentration of 1.0 µg/L for TCE will be used as the SCLs within the defined groundwater AA that is the area throughout which the cleanup goal will be attained (which is further discussed in Section 6). The proposed remedy will address the plume until such time that it is demonstrated using an exit strategy that the RAOs have been met. The point of compliance for the groundwater SCL will be groundwater extracted from monitoring wells located within the AA. A groundwater SCL was identified only for contaminants that are considered as COCs, which was determined to only be TCE, with an SCL of 1.0 µg/L.

MEC are likely present in the subsurface within the Munitions Waste Pit itself, but are unlikely present in the remaining portions of the MRS. However, this cannot be stated with 100 percent confidence due to limitations in technology and investigation methods for MEC detection. Despite the overlap of the 600 Area within the AI Code 300 Area, based on the MD found- and historical records, the most probable munitions present at the 600 Area is a 6-inch Mk 20 Mod 0-4, as approved by the DDES B for previous investigation work at the site.

Most MD items found were relatively shallow (approximately 6 inches from the surface) and no MEC were found on the surface. However, one MEC item was found at a depth of 4 ft, within the Munitions Waste Pit and MD was found at depths up to 20 ft within the Munitions Waste Pit. Therefore, an incomplete exposure pathway exists for surface soil; however, a complete exposure pathway exists for subsurface soil. The MEC HA identified a hazard level of 3, which indicates a moderate potential explosive hazard condition. The proposed remedy will address
the potential subsurface MEC hazard by preventing exposure of future receptors to MEC.

Potential receptors are military personnel (military and civilian), contractors, visitors, and recreational hunters.

4.2.1 Groundwater Contaminants of Concern

The starting point for the development of the list of groundwater COCs is the entire list of contaminants that were detected in samples collected from the 600 Hill Area. These contaminants are listed in Appendix A.2 - Tables 4-2 and 4-4. In these tables, the entire list of detected chemicals is presented along with a summary of detected concentrations and comparison with the appropriate LOC for the PICA Restoration Program. These lists of compounds were also screened using the results of the HHRA and, where available, chemical-specific ARARs. The constituents identified as a human health risk or those that exceed chemical-specific TBCs, are presented in Table 4-2.

If the maximum concentration of the COPC exceeds the ARAR level, the COPC is evaluated further. The next step is to determine whether contaminant distribution is indicative of a contaminant plume. Contaminants that were sporadically detected and not confirmed in adjacent or subsequent samples were also eliminated via this criterion. The final step is to screen the remaining compounds versus those that were identified as risk drivers as a result of the HHRA. All COPCs passing this screening step are considered as COCs.

Table 4-5 details the implementation of this refinement process that identifies TCE as the principle groundwater COC. It should also be noted that while RDX was screened out as a COC in this document, additional data and analysis of RDX in the 600 Hill Area was conducted in a separate investigation which further supports this decision. In order to determine the potential for a source of RDX into the 600 Area, all groundwater, surface water and sediment data was analyzed, and additional soil sampling was performed within Site 11 along with surface water/sediment data. The results of this investigation along with a recommendation for no further action were presented in the Picatinny Arsenal Task Order 17 600 Area RDX Investigation Data Report (Shaw, 2009). The NJDEP and USEPA approved the data report and agreed with this recommendation, as previously discussed in Section 3.1.2.2.

4.3 REMEDIAL ACTION OBJECTIVES

Through the RI process, it has been determined that a response action is necessary for the 600 Hill Waste Pit (600 Hill Groundwater Plume [PICA-058] and the Inactive Munitions Waste Pit MRS [PICA-013-R-01]). Actions are required to address the groundwater TCE contamination and to address potential explosive hazards. A subsequent evaluation of ARARs identified the lowest of the USEPA Safe Drinking Water Act MCLs, and the New Jersey GWQS, New Jersey Groundwater Remediation Standards, and the New Jersey Safe Drinking Water Act MCLs as appropriate chemical-specific criteria. As such, the response actions for groundwater will restore the groundwater to the more stringent of the two cleanup levels.
RAOs for MEC are defined differently than for chemical compounds, as there are no established risk-based “values” to use for MEC. Therefore, PRGs are used as the basis for the development of RAOs. USEPA provides the following definition for MEC PRGs (USEPA, 2005):

- PRGs for a munitions response are the preliminary goals pertaining to the depth of that response action and are used for planning purposes. PRGs are directly related to the specific media that are identified in the conceptual site model as potential pathways for MEC exposure. The PRGs for response depths for munitions are a function of the goal of the investigation and the reasonable anticipated land use on the range.

USACE defines PRGs as follows:

- A PRG for MEC would be a description of a method likely to be protective of the particular exposure pathway(s) identified at the site (e.g., levels of cleanup such as surface removal, removal to depth, or the implementation of LUCs).

PRGs are a function of the reasonably anticipated future land use. No MEC were found in the surface and only one MEC item has been found at the MRS during the previous investigations. It was concluded in the RI that the likelihood of MEC being present in the subsurface at the MRS is low, except within the Munitions Waste Pit itself. However, technologies used to locate MEC in the subsurface have limitations in their ability to locate small MEC at depth. The MRS is under DoD control, and the anticipated future land use will be consistent with the current use as military/industrial with occasional recreational users (hunters). Because the MRS is under DoD control and will continue to be under DoD control, the following PRGs were developed:

- Prevent direct contact with MEC in the subsurface
- Comply with location and action-specific and location-specific ARARs identified in Tables 4-3 and 4-4, respectively.

The RAOs were developed based on criteria outlined in Section 300.430(e)(2)(i) of the NCP. RAOs specify the item/COCs, media of concern, exposure routes and receptors, and an acceptable contaminant level or range of levels for each exposure route.

The following RAOs were developed for the 600 Hill Waste Pit:

- Prevent residential human exposure to TCE-contaminated groundwater (TCE greater than 1 µg/L) via ingestion, dermal contact or inhalation, that would cause unacceptable risk (greater than 1E-4) over the duration of the response action.
- Achieve the TCE New Jersey GWQS to restore groundwater to meet the GWQS cleanup goal for TCE (1 µg/L) in a reasonable timeframe (less than 50 years), thereby restoring groundwater to its beneficial use as a drinking water source. This estimated reasonable clean-up timeframe is site-specific and not applicable to other groundwater remediation projects.
- Prevent PICA personnel (military and civilian), contractors, visitors, and recreational hunters from military personnel, contractor, and recreational hunter contact with
MEC potentially present in the surface soil (0-6 inches bgs) and subsurface soil (> 6 inches bgs).
Table 4-1: Chemical-Specific Groundwater Criteria

<table>
<thead>
<tr>
<th>Chemical</th>
<th>Laws/Regulations</th>
<th>Requirement(s)</th>
<th>ARAR or TBC</th>
</tr>
</thead>
<tbody>
<tr>
<td>See Table 4-2 for specific chemicals</td>
<td>Safe Drinking Water Act Maximum Contaminant Levels, 40 CFR 141.61 through 141.62</td>
<td>Maximum Contaminant Levels have been promulgated and regulate contaminants in public drinking water.</td>
<td>ARAR</td>
</tr>
<tr>
<td>New Jersey Safe Drinking Water Act State Maximum Contaminant Levels, N.J.A.C. 7:10-5.2 through 5.4</td>
<td>Maximum Contaminant Levels have been promulgated by the state and regulate contaminants in public drinking water.</td>
<td>ARAR</td>
<td></td>
</tr>
<tr>
<td>New Jersey Groundwater Quality Standards, N.J.A.C. 7:9C-1.7 and Table 1</td>
<td>Groundwater quality standards have been promulgated and regulate contaminants in groundwater.</td>
<td>ARAR</td>
<td></td>
</tr>
<tr>
<td>New Jersey Interim Specific Groundwater Quality Criteria. N.J.A.C. 7:9C-1.7 Table II</td>
<td>Groundwater quality standards have been promulgated and regulate contaminants in groundwater.</td>
<td>ARAR</td>
<td></td>
</tr>
<tr>
<td>New Jersey Remediation Standards, N.J.A.C. 7:26D-4.1; 7:26D-4.4; 7:26D-4.5</td>
<td>Soil Remediation Standards have been promulgated and regulate contaminants in soil</td>
<td>ARAR</td>
<td></td>
</tr>
<tr>
<td>Safe Drinking Water Act Maximum Contaminant Level Goals, 40 CFR 141.50 through 141.51</td>
<td>Promulgated health-based goals for drinking water sources.</td>
<td>TBC</td>
<td></td>
</tr>
<tr>
<td>U.S. Environmental Protection Agency Office of Drinking Water Health Advisories</td>
<td>Non-promulgated advisories that estimate risk due to consumption of contaminated drinking water/groundwater.</td>
<td>TBC</td>
<td></td>
</tr>
<tr>
<td>U.S. Environmental Protection Agency Regional Screening Levels (November 2015)</td>
<td>Non-promulgated concentrations that estimate risk due to standard lifetime exposure scenarios.</td>
<td>TBC</td>
<td></td>
</tr>
<tr>
<td>New Jersey Department of Environmental Protection, Site Remediation Program, Fill Material Guidance for SRP Sites (April 2015 Version 3.0)</td>
<td>Guidance on the use of fill materials strictly at Site Remediation Program (SRP) sites, and specifically at an area of concern as defined in Technical Requirements for Site Remediation (technical rules), N.J.A.C. 7:26E-18.</td>
<td>TBC</td>
<td></td>
</tr>
</tbody>
</table>
ARAR = Applicable or relevant and appropriate requirements.
N.J.A.C. = New Jersey Administrative Code.
TBC = To Be Considered.
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### Table 4-2: Applicable or Relevant and Appropriate Requirements and Other Guidance To Be Considered for 600 Area Groundwater

<table>
<thead>
<tr>
<th>Chemical(a)</th>
<th>Promulgated Standards (µg/L)</th>
<th>Non-Promulgated Standards (µg/L)</th>
<th>Federal Drinking Water Standards(b)</th>
<th>New Jersey Drinking Water</th>
<th>New Jersey Groundwater(c)</th>
<th>Federal Drinking Water Health Advisories(b)</th>
<th>USEPA Regional Screening Level -Tap Water(d)</th>
<th>C/N</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>MCL</td>
<td>MCLG</td>
<td>New Jersey MCL</td>
<td>Quality Criteria</td>
<td>HA</td>
<td>Regional Screening Level</td>
<td>C/N</td>
<td></td>
</tr>
<tr>
<td>Acetonitrile (HHCOPC)</td>
<td>---</td>
<td>---</td>
<td>---</td>
<td>100 (interim)</td>
<td>---</td>
<td>130</td>
<td>N</td>
<td></td>
</tr>
<tr>
<td>cis-1,2-Dichloroethene(e) (HHCOPC)</td>
<td>70</td>
<td>70</td>
<td>---</td>
<td>70</td>
<td>70</td>
<td>36</td>
<td>N</td>
<td></td>
</tr>
<tr>
<td>Methyl Tertiary-Butyl Ether (CCOPC and HHCOPC)</td>
<td>---</td>
<td>---</td>
<td>70</td>
<td>---</td>
<td>14</td>
<td>C</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Methylene Chloride (CCOPC)</td>
<td>5</td>
<td>0</td>
<td>3</td>
<td>3</td>
<td>---</td>
<td>11</td>
<td>C</td>
<td></td>
</tr>
<tr>
<td>Tetrachloroethylene (CCOPC and HHCOPC)</td>
<td>5</td>
<td>0</td>
<td>1</td>
<td>1</td>
<td>10</td>
<td>11</td>
<td>C</td>
<td></td>
</tr>
<tr>
<td>Trichloroethylene (CCOPC and HHCOPC)</td>
<td>5</td>
<td>0</td>
<td>1</td>
<td>1</td>
<td>---</td>
<td>0.49</td>
<td>C</td>
<td></td>
</tr>
<tr>
<td>Vinyl chloride (HHCOPC)</td>
<td>2</td>
<td>0</td>
<td>---</td>
<td>1</td>
<td>---</td>
<td>0.019</td>
<td>C</td>
<td></td>
</tr>
<tr>
<td>2,4-Dinitrotoluene(f) (HHCOPC)</td>
<td>---</td>
<td>---</td>
<td>---</td>
<td>10</td>
<td>---</td>
<td>0.24</td>
<td>C</td>
<td></td>
</tr>
<tr>
<td>RDX(g) (CCOPC and HHCOPC)</td>
<td>---</td>
<td>---</td>
<td>---</td>
<td>0.5 (interim)</td>
<td>2</td>
<td>0.7</td>
<td>C</td>
<td></td>
</tr>
<tr>
<td>2,4,6-Trinitrotoluene (HHCOPC)</td>
<td>---</td>
<td>---</td>
<td>---</td>
<td>1 (interim)</td>
<td>2</td>
<td>2.5</td>
<td>C</td>
<td></td>
</tr>
</tbody>
</table>
Table 4-2: Applicable or Relevant and Appropriate Requirements and Other Guidance To Be Considered for 600 Area Groundwater (continued)

<table>
<thead>
<tr>
<th>Notes:</th>
</tr>
</thead>
<tbody>
<tr>
<td>a. Criteria-Based Contaminants of Potential Concern (CCOPCs)</td>
</tr>
<tr>
<td>and Human Health Contaminants of Potential Concern (HHCOPCs).</td>
</tr>
<tr>
<td>b. USEPA Drinking Water Standards and Health Advisories Publication</td>
</tr>
<tr>
<td>USEPA 822-R-04-005 (USEPA, 2012).</td>
</tr>
<tr>
<td>c. NJDEP (2005).</td>
</tr>
<tr>
<td>d. USEPA (2016). Residential exposure based on ingestion of tap water</td>
</tr>
<tr>
<td>and inhalation while showering for 350 days. A hazard index of 1 was</td>
</tr>
<tr>
<td>used for non-carcinogenic Regional Screening Levels.</td>
</tr>
<tr>
<td>e. The Regional Screening Level value for 1,2-dichloroethene (total)</td>
</tr>
<tr>
<td>was used.</td>
</tr>
<tr>
<td>f. The value for 2,4-dinitrotoluene and 2,6-dinitrotoluene mixture</td>
</tr>
<tr>
<td>was used for the quality control values.</td>
</tr>
<tr>
<td>g. The New Jersey Groundwater Quality Criteria values are Interim</td>
</tr>
<tr>
<td>Specific Criterion.</td>
</tr>
<tr>
<td>--- = Not available.</td>
</tr>
<tr>
<td>C/N = Carcinogenic or non-carcinogenic according to USEPA (2015).</td>
</tr>
<tr>
<td>GWQS = Groundwater Quality Standards.</td>
</tr>
<tr>
<td>HA = Federal Drinking Water Health Advisories.</td>
</tr>
<tr>
<td>MCL = Maximum contaminant level.</td>
</tr>
<tr>
<td>MCLG = Maximum contaminant level goal.</td>
</tr>
<tr>
<td>NJDEP = New Jersey Department of Environmental Protection.</td>
</tr>
<tr>
<td>R = Rejected result, value should not be used for any purpose.</td>
</tr>
<tr>
<td>RDX = Research Department Formula X (Cyclotrimethyleneimine).</td>
</tr>
<tr>
<td>U = Non-detect, value is the detection limit.</td>
</tr>
<tr>
<td>USEPA = U.S. Environmental Protection Agency.</td>
</tr>
</tbody>
</table>

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<table>
<thead>
<tr>
<th></th>
<th>3779</th>
<th>3780</th>
<th>3781</th>
<th>3782</th>
<th>3783</th>
<th>3784</th>
<th>3785</th>
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<th>3793</th>
<th>3794</th>
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<th>3796</th>
<th>3797</th>
<th>3798</th>
<th>3799</th>
<th>3800</th>
</tr>
</thead>
</table>
**Table 4-3: Action-Specific Applicable or Relevant and Appropriate Requirements and To Be Considered**

<table>
<thead>
<tr>
<th>Action</th>
<th>Law/Regulation</th>
<th>Requirement of Law/Regulation</th>
<th>ARAR or TBC Status</th>
</tr>
</thead>
</table>
| General Remediation and Institutional Controls | Technical Requirements for Site Remediation N.J.A.C. 7:26E-5.1(d)(3) | Specifies that remediation must not cause an uncontrolled discharge or transfer of contaminants to another media.  
Requirement is substantive because it specified a standard of control for onsite remedial action. | TBC – Relevant and appropriate for onsite remedial activities. Relevant and appropriate for all remedial actions except No Action. |
|        | N.J.A.C. 7:26E-5.1(e) | Requires that remediation must remove free product and residual product to the extent practicable, or contain free product and residual product when treatment or removal is not practicable. Prohibits monitored natural attenuation of residual product.  
Requirement is substantive because it provides a standard of control related to protectiveness of the onsite action. | ARAR – Although no free product or residual product has been identified at the site, this requirement is applicable in the event free product or residual product is identified during the response action. |
|        | Technical Requirements for Site Remediation N.J.A.C. 7:26E 5.1(h) | Excavated soil or drill cuttings may be returned to the original location provided neither free product nor residual product is present.  
Requirement is substantive because it provides a standard of control related to protectiveness of the onsite action. | TBC – Applicable to drilling of monitoring wells and injection/recovery wells. Although no free product or residual product has been identified at the site, this requirement is applicable in the event free product or residual product is identified during the response action. |
|        | Technical Requirements for Site Remediation N.J.A.C. 7:26E 5.2 (b) through (f) | Specifies the requirements for using alternative fill from an onsite or offsite source for backfilling excavations. Specifies the requirements for utilizing clean fill for backfilling excavations.  
Requirement is substantive because it dictates levels for soil allowable to be utilized as backfill. | TBC – Applicable to the excavation alternative that will utilize backfill. |
<table>
<thead>
<tr>
<th>Action</th>
<th>Law/Regulation</th>
<th>Requirement of Law/Regulation</th>
<th>ARAR or TBC Status</th>
</tr>
</thead>
<tbody>
<tr>
<td>Technical Requirements for Site Remediation N.J.A.C. 7:26E:7.2 (b) 1.9</td>
<td>Provides guidance on public participation requirements for discharge to groundwater proposals.</td>
<td>ARAR – Applicable for injection to groundwater proposals associated with injections.</td>
<td></td>
</tr>
<tr>
<td>Well Construction and Maintenance; Sealing of Abandoned Wells N.J.A.C. 7:7D-2.3</td>
<td>Technical requirements for the installation and abandonment of monitoring wells.</td>
<td>TBC – Applicable for the installation and abandonment of wells.</td>
<td></td>
</tr>
<tr>
<td>Monitored Natural Attenuation Technical Guidance, NJ Site Remediation Program</td>
<td>Provides on guidance implementing and evaluating MNA remedies</td>
<td>TBC – Applicable to MNA components of alternatives.</td>
<td></td>
</tr>
<tr>
<td>Groundwater Technical Guidance; SDRPRA Performance Monitoring NJ Site Remediation Program</td>
<td>Provides on guidance on groundwater remedial action performance monitoring</td>
<td>TBC – Applicable to monitoring of remedial action performance for groundwater remedies.</td>
<td></td>
</tr>
<tr>
<td>NJPDES Discharge to Groundwater Technical Manual (June 2007).</td>
<td>Provides on guidance on soil remedial action verification sampling.</td>
<td>TBC – Applicable to verification sampling associated with remedial actions for soil.</td>
<td></td>
</tr>
</tbody>
</table>
Table 4-3: Action-Specific Applicable or Relevant and Appropriate Requirements and To Be Considered (continued)

<table>
<thead>
<tr>
<th>Action</th>
<th>Law/Regulation</th>
<th>Requirement of Law/Regulation</th>
<th>ARAR or TBC Status</th>
</tr>
</thead>
<tbody>
<tr>
<td>MEC Removal</td>
<td>RCRA, Subpart M (Military Munitions Rule). 40 CFR 266.203- through 206</td>
<td>Relevant portions relate to the management of MEC that is recovered, including characterization as hazardous waste and requirements for treatment, storage, and transportation. The Rule provides for the storage and transportation of recovered military munitions in accordance with Department of Defense Explosives Safety Board standards. New Jersey has adapted the Federal Military Munitions Rule. Therefore, munitions handling and disposal are addressed under the Federal Military Munitions Rule.</td>
<td>ARAR – Applicable to the management of MEC recovered during remedial action</td>
</tr>
<tr>
<td>Open Burning/Open Detonation (Treatment) of Waste Explosives</td>
<td>40 CFR 265.370 and 265.382, Subpart P, Subpart X – Miscellaneous units: 40 CFR 264.601 Environmental Performance Standards</td>
<td>Requirements for treatment of explosives through burning.</td>
<td>TBC – Applies to the treatment of explosives through burning or detonation. Open burning/open detonation is considered “treatment in miscellaneous units.” This is a procedural requirement, and does not provide site-specific criteria.</td>
</tr>
<tr>
<td>Explosives Storage</td>
<td>40 CFR 264 Subpart EE</td>
<td>Provides standards for the storage of explosive materials.</td>
<td>ARAR – Provides specific requirements for storing explosive materials that may be pertinent to MEC response actions. This is a procedural requirement, and does not provide site-specific criteria.</td>
</tr>
<tr>
<td>Action</td>
<td>Law/Regulation</td>
<td>Requirement of Law/Regulation</td>
<td>ARAR/TBC Status</td>
</tr>
<tr>
<td>--------------------------------------------</td>
<td>--------------------------------------------------------------------------------</td>
<td>---------------------------------------------------------------------------------------------</td>
<td>--------------------------------------------------------------------------------</td>
</tr>
<tr>
<td>Discharge of Aqueous Waste to Surface Water or groundwater</td>
<td>Clean Water Act Effluent Guidelines 40 CFR 401, 13, 15, 16, 17 40 CFR 122 and 125</td>
<td>Provides requirements for point source discharges of pollutants. Requirement is substantive because it specifies the level or standard of control for potential discharge of stormwater resulting from remedial activities.</td>
<td>ARAR – Applicable for discharge of stormwater that may result from on-site in situ and/or clearing activities and the discharge of treated wash water to the drainage ditch or wetlands. Provisions have been delegated to the State of New Jersey, which has been authorized to administer and enforce the requirements (or more stringent requirements).</td>
</tr>
<tr>
<td></td>
<td>New Jersey Water Pollution Control Act – New Jersey Pollutant Discharge Elimination System (NJPDES) (N.J.A.C. 7:14A–, 12).</td>
<td>Discharge of pollutants to surface water and groundwater from remediation sites is regulated via New Jersey Pollutant Discharge Elimination System requirements. Substantive requirements include effluent limitations, water quality based limitations, monitoring, and monitoring techniques.</td>
<td>ARAR – Applicable to the substantive requirements of the program for stormwater and purge water discharges to surface water features.</td>
</tr>
<tr>
<td>Groundwater Injection</td>
<td>New Jersey Water Pollution Control Act – New Jersey Pollutant Discharge Elimination System (N.J.A.C. 7:14A–87.5b) New Jersey Technical Requirements for Site Remediation, N.J.A.C. 7:26E-5.6b (1-8)</td>
<td>Provides requirements for the discharge of wastes or other fluids (i.e., treated groundwater, treatment media) to groundwater as either a point or nonpoint discharge to groundwater to protect underground sources of groundwater/drinking water.</td>
<td>ARAR – Applicable if a treatment fluid is injected into groundwater. Requires a groundwater protection and monitoring program including engineering design, groundwater modeling, and long-term monitoring.</td>
</tr>
<tr>
<td>Packaging, Labeling and Storage</td>
<td>RCRA Hazardous Waste Generation 40 CFR 262, Subpart C.</td>
<td>Specifies requirements for hazardous waste Pre-Transport Requirements (packaging, labeling, marking).</td>
<td>ARAR – Potentially applicable to on-site requirements related to the off-site transportation of hazardous waste (off-site requirements are legally applicable but are not ARAR as they apply outside of the CERCLA process). Potentially applicable to in situ treatment alternatives that may generate hazardous waste.</td>
</tr>
</tbody>
</table>
### Table 4-3: Action-Specific Applicable or Relevant and Appropriate Requirements and To Be Considered (continued)

**Notes:**
- **ARAR** = Applicable or relevant and appropriate requirement.
- **CERCLA** = Comprehensive Environmental Response, Compensation, and Liability Act.
- **CFR** = Code of Federal Regulations.
- **MEC** = Munitions and explosives of concern.
- **MNA** = Monitored Natural Attenuation.
- **N.J.A.C.** = New Jersey Administrative Code.
- **NJDEP** = New Jersey Department of Environmental Protection.
- **TBC** = To Be Considered.
### Table 4-4: Location-Specific Applicable or Relevant and Appropriate Requirements and To Be Considered

<table>
<thead>
<tr>
<th>Location</th>
<th>Law/Regulation</th>
<th>Requirement of Law/Regulation</th>
<th>ARAR or TBC Status</th>
</tr>
</thead>
<tbody>
<tr>
<td>Wetlands</td>
<td>Clean Water Act Section 402 40 CFR 320.4 and pertinent substantive provisions of N.J.A.C. 7:7A (the Freshwater Wetlands Protection Act, Public Law 1987)</td>
<td>To the extent possible, action must be taken to avoid degradation or destruction of wetlands. Discharges for which there are practicable alternatives with less adverse impacts or those that would cause or contribute to significant degradation are prohibited. If adverse impacts are unavoidable, action must be taken to enhance, restore, or create alternative wetlands.</td>
<td>ARAR — Applicable to the substantive requirements if clearing or drilling activities encroach on wetlands or wetland transition zones. As shown on Figure 3-3, there are multiple wetland areas within the groundwater plume boundary.</td>
</tr>
</tbody>
</table>

Notes:

- ARAR = Applicable or relevant and appropriate requirement.
- TBC = To Be Considered.
### Table 4-45: Contaminants of Concern Groundwater Screening

<table>
<thead>
<tr>
<th>Chemical (a)</th>
<th>Historical Maximum Observed Concentration (µg/L)</th>
<th>ARAR (µg/L)</th>
<th>Frequency of ARAR Exceedances</th>
<th>COC Screening Criteria (b)</th>
<th>COC</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>600 Area</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Volatiles</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Acetonitrile (HHCOPC)</td>
<td>55</td>
<td>100</td>
<td>0 / 91</td>
<td>No</td>
<td>No</td>
</tr>
<tr>
<td>cis-1,2-Dichloroethene (HHCOPC)</td>
<td>2.2</td>
<td>70</td>
<td>0 / 124</td>
<td>No</td>
<td>No</td>
</tr>
<tr>
<td>Methyl tert-Butyl ether (CCOPC and HHCOPC)</td>
<td>140</td>
<td>70</td>
<td>2 / 115</td>
<td>Yes</td>
<td>No</td>
</tr>
<tr>
<td>Methylene chloride (CCOPC)</td>
<td>15</td>
<td>3</td>
<td>1 / 124</td>
<td>Yes</td>
<td>No</td>
</tr>
<tr>
<td>Tetrachloroethene (CCOPC and HHCOPC)</td>
<td>2.2</td>
<td>1</td>
<td>1 / 124</td>
<td>Yes</td>
<td>No</td>
</tr>
<tr>
<td>Trichloroethene (CCOPC and HHCOPC)</td>
<td>210</td>
<td>1</td>
<td>67 / 124</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>Vinyl chloride (HHCOPC)</td>
<td>0.245</td>
<td>1</td>
<td>0 / 124</td>
<td>No</td>
<td>No</td>
</tr>
<tr>
<td><strong>Explosives</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2,4-Dinitrotoluene (HHCOPC)</td>
<td>0.15</td>
<td>10</td>
<td>0 / 68</td>
<td>No</td>
<td>No</td>
</tr>
<tr>
<td>RDX (CCOPC and HHCOPC)</td>
<td>1.1</td>
<td>0.5</td>
<td>4 / 68</td>
<td>Yes</td>
<td>No</td>
</tr>
<tr>
<td>2,4,6-Trinitrotoluene (HHCOPC)</td>
<td>0.3</td>
<td>1.0</td>
<td>0 / 68</td>
<td>No</td>
<td>No</td>
</tr>
</tbody>
</table>

**Notes:**

a. Criteria-Based Contaminants of Potential Concern (CCOPCs) and Human Health Contaminants of Potential Concern (HHCOPCs).

b. “No” indicates elimination as a COC, only a “yes” will be evaluated by next criterion. The Risk-Based Concentration value for 1,2-dichloroethene (total) was used.

c. The value for 2,4-dinitrotoluene and 2,6-dinitrotoluene mixture was used for the quality control and the Practical Quantitation Limit values.

**Abbreviations:**

- µg/L = Microgram per liter.
- ARAR = Applicable or relevant and appropriate requirement.
- COC = Contaminant of concern.
- RDX = Research Department Formula X (cyclotrimethylenetrinitramine).
5. IDENTIFICATION AND SCREENING OF REMEDIAL TECHNOLOGIES

This section identifies and screens remedial technologies and process options that are potentially suitable for addressing human exposure at the 600 Hill Waste Pit.

To identify applicable remedial technologies, it was assumed that any field proven technology or remedial process option that had successfully mitigated similar COCs in groundwater and MEC in subsurface soil may also be suitable for remediating the contaminated media and subsurface MEC in the 600 Area. In addition to potentially applicable technologies, this section discusses technologies that are mandated for FS inclusion in the NCP, such as no action, technologies that were requested for inclusion via regulatory comments, and MNA mandated by U.S. Army policy.

Discussions for each matrix include identification of GRA and technologies associated with the GRAs; a brief description of each technology; and an initial screening of technologies based on effectiveness, implementability, and cost. GRAs are broad classes of responses or remedial actions that can potentially achieve the RAOs. GRAs may encompass many remedial technologies and remedial technology process options. For example, in situ active restoration is a GRA, in situ biological treatment is a remedial technology, and methane sparging is a remedial technology process option. Technologies that pass the preliminary screening process are then used in the development of RAs in Section 6.

In this FS, all RAs for the 600 Area will be implemented in conjunction with LUCs until SCLs are achieved.

5.1 IDENTIFICATION AND SCREENING OF GENERAL RESPONSE ACTIONS AND PRELIMINARY SCREENING OF REMEDIAL ACTION TECHNOLOGIES

This section presents the GRAs as well as the identification and preliminary screening of remedial action technologies. TCE is the only COC identified for groundwater, and MEC are the only COCs in subsurface soil. There are no surface soil COCs. Surface water contamination is derived from TCE-contaminated groundwater. Both active and passive technologies are evaluated in the following sections.

5.1.1 General Response Actions

GRAs that will be potentially applicable for groundwater and MEC in the subsurface for the 600 Area are described below.

5.1.1.1 No Action

The NCP and CERCLA require the evaluation of a No Action alternative as a baseline for comparison with other RAs (40CFR 300.430(e)(6)). The No Action alternative does not involve remedial action; therefore, environmental media at the site, or emanating from the site, remain
contaminated, and potential MEC remain in-place. For this reason, CERCLA, as amended, requires a review of site conditions every five years.

### 5.1.1.2 Land Use Restrictions (Land Use Controls)

Land use restrictions will prevent or limit the use of, and access to, the contamination at the site. These LUCs could include property access restrictions, groundwater use restrictions, limitations on future construction activities, and/or deed restrictions. These restrictions can limit property usage or specify special considerations, such as required UXO construction support or personal protective equipment (PPE) during future site clearing or construction activities. Land use restrictions and development controls can also be an effective means of protecting public health by decreasing risk of exposure to contamination or MEC at a site. LUCs can also include educational controls (i.e., site-specific training).

Access restrictions may also include installing and maintaining fencing around controlled areas; posting warning signs prohibiting entry; or implementing zoning, planning, or deed restrictions. As part of this response, administrative controls and deed restrictions will be implemented that could include stipulation that property could be used only for surface activities or recreational uses (i.e., hunting) as appropriate. Zoning/planning could be implemented to control the designated land use (residential, agricultural, etc.). Deed restrictions could also include stipulation that UXO Technician support will be required for grading or other intrusive construction activities. Educational programs will be tailored to community needs and could include public meetings, distribution of fact sheets, exhibits, videos, and educational signage at the MRS.

The final component of LUCs is long-term monitoring of chemical and biological parameters in groundwater to ensure site conditions do not change or adversely affect human or ecological receptors and to monitor the long-term effectiveness of the LUCs.

An institutional analysis was prepared to identify parties with jurisdiction over the 600 Hill Munition Waste Pit and assess their ability and interest in supporting LUCs (Table 5-1). Because the 600 Hill area is entirely contained within the boundaries of PICA, PICA and the U.S. Army were the only institutions identified as having geographical jurisdiction. Both parties are capable and willing to implement the LUCs and have the financial capability. Existing LUCs, as previously discussed in Section 1.4, have already been successfully implemented at PICA as a non-time critical removal action.

### 5.1.1.3 Monitored Natural Attenuation

MNA technologies do not reduce the toxicity, mobility, or volume of contamination by engineered action. Limited Action-MNA technologies consist of LUCs, long-term monitoring, and site modeling that reduce the potential for exposure of populations to contaminated media. MNA manages the naturally occurring volatilization, adsorption to soil matrix, dispersion, abiotic transformation, and/or biodegradation of contaminants without engineering steps to enhance the process. It differs from the No Action alternative in that it requires comprehensive...
5.1.1.4 Ex Situ Active Restoration

Ex situ active restoration consists of groundwater extraction, treatment, and discharge technologies. The main advantage of ex situ treatment is that the treatment process is controlled and the effectiveness can be verified through monitoring of pre- and post-treatment samples. Groundwater extraction can also be an effective means to control contaminant migration through hydraulic control of the plume. Ex situ active restoration is most effective for high contaminant concentrations in groundwater or when separate-phase contaminants can be recovered. However, ex situ treatment requires potentially cost-intensive material-handling activities and the effectiveness can be limited by the desorption rates of contaminants adhering to aquifer soils.

5.1.1.5 In Situ Active Restoration

In situ active restoration consists of technologies that remove or destroy contaminant mass without being brought to the surface, which usually results in significant cost savings. In situ active restoration tends to be limited by the ability to distribute amendments uniformly across the plume. In situ treatment generally requires longer time periods to accomplish RAOs and has primarily been used to treat lower contaminant concentrations. Recent research focuses on in situ technologies that have led to the development of more rapid treatments capable of treating higher contaminant concentrations.

5.1.1.6 Containment

Barrier and capping technologies can reduce contaminant mobility and potential for exposure, but they do not reduce contaminant volume or toxicity. In situ containment technologies include capping for soils and grout injection and slurry walls for groundwater. Capping involves covering the area with a low-permeability material to reduce the infiltration of surface water through contaminated media to the groundwater. Containment technologies for groundwater prevent natural movement of the groundwater, by controlling the groundwater migration from the site through the installation of vertical and/or horizontal barriers.

5.1.1.7 Source Removal

Source removal involves the excavation of TCE-impacted soil/fill in Inactive Munitions Waste Pit, thereby eliminating the source of TCE to groundwater. Excavation is defined as the physical removal of solid material from the ground by mechanical means, and can be accomplished by digging up impacted material with a backhoe, excavator, or other suitable equipment.
5.1.1.8 Surface Munitions and Explosives of Concern Clearance

A surface removal is the removal of any MEC/materials potentially presenting an explosives hazard (MPPEH) visible in part or whole on the surface. No subsurface removal of MEC/MPPEH will be completed under this action. The surface removal will be conducted by qualified UXO Technicians using handheld analog metal detectors. Qualified UXO Technicians will conduct the surface removal using handheld analog metal detectors. If MEC or MPPEH are discovered, it will be disposed of using explosive demolition procedures. The general components for a surface removal include:

- Vegetation removal (to expose the ground surface only as necessary; no clear cutting)
- Physical surface removal of MEC/MPPEH in designated areas or across the entire site
- Demolition and disposal operations.

Based on the RI investigation, no surface MEC were identified and, therefore, surface clearance will not be required to achieve the RAOs and is not retained for further evaluation.

5.1.1.9 Subsurface Munitions and Explosives of Concern Clearance

Subsurface anomalies may be identified using handheld analog magnetometer or DGM instruments (e.g., EM-61 or similar). Subsurface removal consists of employing geophysical instruments (analog or DGM) to identify subsurface anomalies followed by an intrusive investigation (hand dig and inspect). Surface anomalies are also identified, investigated, and removed as necessary during a subsurface removal. The components of a subsurface removal include:

- Vegetation removal (to expose the ground surface)
- Surface removal of MEC/MPPEH in designated areas or across the entire site
- DGM
- Subsurface investigations
- Demolition and disposal operations.

Investigation and removal techniques include hand digging and mechanical digging with conventional earth moving equipment.

5.1.2 Identification of Volumes and Areas of Media

During the development of the alternatives an initial determination is made of areas or volumes of media to which GRA might be applied. The initial determinations are presented below by media:

1. Soil Contamination: Approximately 1,334 cy of TCE contaminated soil are anticipated within the source area which are leaching to groundwater.
1. The contaminated soil is a 120' x 6' x 5' area located approximately 20'-
25 ft bgs (1,334 cy). Excavation of the source area requires removal of the clean
overburden material (120' x 60' x 20' = 5,334 cy) plus a slope of 2:1 for
excavation cutback (11,539 cy), which requires UXO construction support or
screening.

2. MEC in surface soil: 21 acres of land are present which have a potential to contain
explosive hazards, primarily in the surface soils

3. MEC in subsurface soil: There are approximately 9,526 cy of soil and buried debris
present in the Munitions Waste Pit which potentially contain explosive hazards. This
volume was based geophysical investigation and test pit activities, which identified a
0.24-acre (10,454 square feet) waste pit extending to 24.5 ft bgs. Excavation of the entire
waste pit requires a 2:1 side slope (14,200 cy). There is also stockpiled debris and gravel
present within the excavation footprint that will require removal and inspection for MEC,
which is estimated at 2,000 cy.

4. Groundwater contamination: An approximate 26-acre groundwater plume exceeds the
New Jersey GWQS of 1 µg/L, to depths up to approximately 430 feet bgs within the
bedrock aquifer, as demonstrated by sampling of the AWDF well sampling results.

5.1.3 Identification and Screening of Remedial Action Technologies

The identification and screening process is performed in accordance with the CERCLA FS
guidance document (USEPA, 1988a), as specified by the NCP (40 CFR Part 300). Identification
of potentially applicable technologies is based primarily on technical feasibility using the
following criteria:

- Compatibility with constituent characteristics
- Compatibility with Picatinny/600 Area characteristics
- Ability to achieve RAO – either alone or as a component of a treatment train
- Development status – a technology must be developed to the point of field-scale
demonstration so that information is available on performance, reliability, and cost.

Based on these criteria, some groundwater remedial action technologies were eliminated from
further consideration. Table 5-2 provides the list of MEC and groundwater remedial action
technologies considered in the preliminary screening process for each GRA, along with brief
descriptions of each technology. Information for this section was obtained from the Federal
Remediation Technologies Roundtable website (http://www.frtr.gov), the Naval Facility
Engineering Service Environmental Restoration website (http://enviro.nfesc.navy.mil/erb/restoration), the Defense Environmental Network and
5.2 EVALUATION AND SCREENING OF PROCESS OPTIONS

5.2.1 Evaluation of Process Options

Process options within potential remedial technology types are evaluated based on three criteria: implementability, effectiveness, and cost.

5.2.1.1 Implementability

The evaluation of implementability focuses on: (1) technical feasibility, (2) availability, and (3) administrative feasibility. Technical feasibility refers to the ability to build and reliably operate/maintain a technology, while administrative feasibility refers to the ability to gain approval from regulators and other agencies and to obtain the necessary materials and skilled labor.

The NCP instructs that alternatives “that are technically or administratively infeasible or that will require equipment, specialists, or facilities that are not available within a reasonable period of time may be eliminated from further consideration” (40CFR300.430(e)(7)(ii)).

5.2.1.2 Effectiveness

The effectiveness criterion focused on the ability of a technology to:

- Reduce toxicity, mobility, or volume through treatment
- Minimize residual risks
- Afford long-term protection
- Comply with ARARs
- Minimize short-term impacts
- Achieve protection within a reasonable timeframe.

The NCP instructs that “alternatives providing significantly less effectiveness than other, more promising alternatives may be eliminated. Alternatives that do not provide adequate protection of human health and the environment shall be eliminated from further consideration” (40CFR300.430(e)(7)(i)).

5.2.1.3 Cost

The evaluation of cost addresses direct and indirect capital costs and annual operation and maintenance (O&M) costs. When the information is available, the cost range is presented quantitatively. Otherwise, qualitative descriptions of low, moderate, and high are used. The cost ranges are based on a review of the literature, vendor quotations, and data prepared for other studies.
The NCP instructs that "costs that are grossly excessive compared to the overall effectiveness of alternatives may be considered as one of several factors used to eliminate alternatives. Alternatives providing effectiveness and implementability similar to that of another alternative by employing a similar method of treatment or engineering control, but at greater cost, may be eliminated" (40CFR300.430(e)(7)(iii)).

5.2.2 Preliminary Screening of Process Options

Table 5-3 describes the preliminary screening process for the process options for the 600 Area, including those process options previously considered in the 2014 FS (Shaw, 2103). Based on this screening, the following process options were either retained or eliminated from further consideration.

Retained Technologies or Process Options

- No Action
- Institutional Restrictions
- Access/Land Use Restrictions
- Public Education
- Emergency Provisions
- Long-Term Monitoring of Groundwater and Surface Water
- MNA
- Chemical Oxidation
- Zero Valent Iron Injection
- Accelerated Anaerobic Bioremediation
- Source Removal/Excavation
- Long-Term Monitoring
- MNA
- Analog Magnetometers
- Analog Electromagnetic Induction, All Metals Detectors
- Manual Excavation
- Mechanical Excavation and Sifting
- Blown-in-Place (BIP)
- Consolidated Shots.

Eliminated Technologies or Process Options

- Capping and other Impermeable Covers
- Pumping – Mass Removal
- Air Stripping
• Carbon Absorption
• Ultraviolet Oxidation
• Bioreactor
• Discharge to Surface Water
• Aquifer Reinjection
• Cometabolism
• Soil Vapor Extraction
• DGM using Electromagnetic Induction
• Magnetics (Sub Audio Magnetics)
• Airborne Laser and Infrared Sensors.
Table 5-1: Institutional Analysis

<table>
<thead>
<tr>
<th>Name of Agency</th>
<th>Picatinny Arsenal</th>
<th>U.S. Army Environmental Center</th>
<th>U.S. Army Corps of Engineers</th>
</tr>
</thead>
<tbody>
<tr>
<td>Origin of Institution</td>
<td>PICA is owned and operated by the U.S. Army. The facility was a major source of munitions for World War I, World War II, and the Korean conflict. During those periods, PICA was involved in the production of explosives, rocket and munitions propellants, pyrotechnic signals and flares, fuses, and metal components. Currently, the primary mission of PICA is research, development, and engineering of munitions and weapons.</td>
<td>USAEC was originally established in 1972 to oversee demilitarization of chemical weapons stockpiles. It has since evolved to provide program management on U.S. Army DERP projects for active installations and non-Base Realignment and Closure excess properties. USAEC has provided the funding source for the MMRP projects at Picatinny.</td>
<td>USACE was established in 1775 to provide the U.S. Army with military construction and engineering support. In the 1880s, Congress also provided USACE authority over dumping and dredging in harbors and waterways. With the formation of DERP in 1983, USACE adopted a role of providing the DoD with technical and project management support on environmental and MMRP projects.</td>
</tr>
<tr>
<td>Basis of Authority</td>
<td>PICA manages environmental and MMRP sites within the installation through DERP (10 U.S. Code Section 2701 et seq.), Executive Order 12580. The National Defense Authorization Action of Fiscal Year 2002 modified DERP to establish the MMRP.</td>
<td>USAEC is authorized to fund projects under DERP (10 U.S. Code Section 2701 et seq.), Executive Order 12580. The National Defense Authorization Action of Fiscal Year 2002 modified DERP to establish the MMRP.</td>
<td>USACE conducts munitions response actions under the provisions of CERCLA, as amended by the Superfund Amendments and Reauthorization Act, Executive Orders 12580 and 13016, and the safety requirements of the DoD Explosives Safety Board. USACE has project-specific management and technical oversight authority on U.S. Army MMRP projects as contracted through USAEC. The USACE–Baltimore District is one of four USACE districts that have a Military Munitions Design Center and provide MMRP project oversight for Picatinny Arsenal.</td>
</tr>
<tr>
<td>Sunset Provision</td>
<td>None</td>
<td>None</td>
<td>None</td>
</tr>
<tr>
<td>Geographical Jurisdiction</td>
<td>PICA has jurisdiction over the DoD–owned property within the installation boundary</td>
<td>USAEC has funding and program authority for U.S. Army environmental and MMRP projects associated with active installations and non-Base Realignment and Closure excess properties under the Installation Management Command.</td>
<td>USACE has nine regional divisions that include all of the United States, the Pacific, Europe, the Middle East, and Afghanistan. USACE has provided MMRP project oversight for Picatinny Arsenal through the Baltimore District.</td>
</tr>
</tbody>
</table>
Table 5-1: Institutional Analysis (continued)

<table>
<thead>
<tr>
<th>Name of Agency</th>
<th>Picatinny Arsenal</th>
<th>U.S. Army Environmental Center</th>
<th>U.S. Army Corps of Engineers</th>
</tr>
</thead>
<tbody>
<tr>
<td>Public Safety Function</td>
<td>PICA maintains its own fire and emergency services and law enforcement, and also has cooperative agreements with local first responders.</td>
<td>USAEC provides funding for MMRP projects with the objective of protecting human health and the environment. USAEC has provided funding for moving the site through the CERCLA process.</td>
<td>USACE is a major U.S. Army command that provides engineering, design, and construction management services. One of its critical missions is public safety in munitions response, which is captured in the mission statement for the Directorate of Ordnance and Explosives: “To safely eliminate or reduce risks from ordnance, explosives and recovered chemical warfare materiel at current or formerly used defense sites.”</td>
</tr>
<tr>
<td>Land Use Control</td>
<td>PICA primary function for LUCs will be to provide continued implementation of existing LUCs, including the Well Head Protection Program, Base access restrictions, unexploded ordnance clearance procedures, PICA safety program, Site Clearance and Soil Management Procedures, Master Plan Regulations, Geographic Information System database, and the Military Construction Program</td>
<td>USAEC can program funds for the implementation of LUCs.</td>
<td>As technical advisor to the U.S. Army, USACE influences the selection of LUCs, as well as establishing them in the Decision Document. In addition, they can perform real estate services for the military and civil works activities of the U.S. Army, and for other federal agencies, as requested.</td>
</tr>
<tr>
<td>Financial Capability</td>
<td>Defense Environmental Restoration Account for environmental restoration activities.</td>
<td>Funding is provided through DERP.</td>
<td>USACE could administer a LUC maintenance/oversight contract if programmed and funded by USAEC.</td>
</tr>
<tr>
<td>Desire to Participate</td>
<td>Yes.</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>Constraint to Institutional Effectiveness</td>
<td>None. LUCs as currently implemented are effective</td>
<td>Other than programing funds for LUCs, USAEC will have limited influence on the implementation or maintenance of LUCs on county property.</td>
<td>USACE will have control and authority to maintain or implement LUCs on DoD property if programmed and funded through the USAEC.</td>
</tr>
</tbody>
</table>
Table 5-1: Institutional Analysis (continued)

<table>
<thead>
<tr>
<th>Notes:</th>
</tr>
</thead>
<tbody>
<tr>
<td>CERCLA = Comprehensive Environmental Response, Compensation and Liability Act</td>
</tr>
<tr>
<td>DERP = Defense Environmental Restoration Program.</td>
</tr>
<tr>
<td>DoD = Department of Defense.</td>
</tr>
<tr>
<td>LUC = Land use control.</td>
</tr>
<tr>
<td>MMRP = Military Munitions Response Program.</td>
</tr>
<tr>
<td>PICA = Picatinny Arsenal.</td>
</tr>
<tr>
<td>USACE = U.S. Army Corps of Engineers.</td>
</tr>
<tr>
<td>USAEC = U.S. Army Environmental Command.</td>
</tr>
</tbody>
</table>
### Table 5-2: General Response Actions, Identification, and Screening of Remedial Action Technologies

<table>
<thead>
<tr>
<th>General Response Action</th>
<th>Technology</th>
<th>Process Option</th>
<th>Description</th>
<th>Screening Results</th>
</tr>
</thead>
<tbody>
<tr>
<td>No Action</td>
<td>Not applicable</td>
<td>Not applicable</td>
<td>&quot;No Action&quot; is not a category of technologies but provides a risk baseline to which all other alternatives may be compared. The NCP requires that “No Action” be included among the general response actions evaluated (40 CFR 300.43(e)(6)).</td>
<td>Retain</td>
</tr>
<tr>
<td>Land Use Controls</td>
<td>Institutional Controls</td>
<td>Institutional Restrictions</td>
<td>Institutional restrictions involve controlling access to contaminated areas by implementing administrative policies. Administrative policies of interest include restricting future property uses within contaminated areas and restricting the installation of new drinking water wells. One such institutional restriction is the Classification Exemption Area. The Classification Exemption Area is a state of New Jersey administrated designation of areas that are not potable due to contamination. The State exercises its authority by utilizing a statute that requires permits prior to the construction of any groundwater well. Thus, the drinking water well exposure pathway is administratively controlled by the State for those areas classified as a Classification Exemption Area.</td>
<td>Retain</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Restrictions on Land Use</td>
<td>To prevent potential receptors from encountering MEC, future development-particularly for residential areas, daycare facilities, hospitals, or schools, be stringently managed and require proper approvals and that excavation is prohibited or otherwise managed.</td>
<td>Retain</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Notations in Master Plan</td>
<td>This LUC component provides the mechanism through which the selected land use restrictions are incorporated into the PICA Master Plan. To identify where on the MRS munitions-related items were discovered, notations will be made in the PICA Master Plan.</td>
<td>Retain</td>
</tr>
</tbody>
</table>
### Table 5-2: General Response Actions, Identification, and Screening of Remedial Action Technologies (continued)

<table>
<thead>
<tr>
<th>General Response Action</th>
<th>Technology</th>
<th>Process Option</th>
<th>Description</th>
<th>Screening Results</th>
</tr>
</thead>
<tbody>
<tr>
<td>Land Use Controls (continued)</td>
<td>Administrative Controls</td>
<td>Access Restrictions/</td>
<td>Access restrictions involve controlling access to contaminated areas by installing physical boundaries and/or signs.</td>
<td>Retain</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Engineering Controls</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Dig Permits</td>
<td>PICA issues dig permits whenever ground is broken. The Installation Safety Office reviews and issues all dig permits and requires UXO construction support for areas where there is suspected MEC.</td>
<td>Retain</td>
</tr>
<tr>
<td></td>
<td></td>
<td>UXO Construction Support</td>
<td>Direct supervision of intrusive activity by contracted UXO Technicians.</td>
<td>Retain</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Worker Education</td>
<td>Safety and UXO training requirements for site workers.</td>
<td>Retain</td>
</tr>
<tr>
<td></td>
<td>Public Education/Public Advisories</td>
<td></td>
<td>An increased public awareness of the hazards present at the site will be achieved through public meetings, presentations at local schools, press releases, and posting of signs. Recreational users of the site (hunters) will be required to have safety training prior to annual issuance of their license.</td>
<td>Retain</td>
</tr>
<tr>
<td></td>
<td>Emergency Provisions</td>
<td></td>
<td>In the event of an unexpected deterioration of site conditions resulting in an increased threat to public health and the environment, emergency measures are outlined to allow prompt attention to the problem. Existing emergency provisions, if any, should be identified and updated.</td>
<td>Retain</td>
</tr>
<tr>
<td>Long-Term Monitoring</td>
<td>Groundwater Monitoring and</td>
<td>The primary objectives of long term monitoring include: (1) evaluation of long-term behavior of the plume, (2) verify that exposure to contaminants and their breakdown products do not pose additional risks, and (3) assess when it is necessary to implement a contingent remedy.</td>
<td>Retain</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Surface Water monitoring</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Monitored Natural Attenuation</td>
<td>Monitored Natural Attenuation</td>
<td>Natural Attenuition</td>
<td>Natural attenuation includes a variety of natural processes which work together to reduce the concentration of contaminants and their impact on the environment. Natural attenuation includes intrinsic bioremediation of contaminants, and reduction of contaminant concentrations through sorption/dispersion in the aquifer. Monitored Natural Attenuation or “MNA” is a formal and systemic approach of monitoring and measuring the rate at which the natural attenuation of contaminants occurs, so as to demonstrate that RAOs are achieved.</td>
<td>Retain</td>
</tr>
</tbody>
</table>
Table 5-2: General Response Actions, Identification, and Screening of Remedial Action Technologies (continued)

<table>
<thead>
<tr>
<th>General Response Action</th>
<th>Technology</th>
<th>Process Option</th>
<th>Description</th>
<th>Screening Results</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Barrier/Containment</strong></td>
<td>Impermeable/Low Permeability Barriers</td>
<td>Vertical Impermeable Barriers – Sheet piling, slurry wall and liner</td>
<td>Installation of vertical sheet piling, slurry walls or impermeable liners in the aquifer to prevent further migration of groundwater contaminants. Installation of sheet pile or a slurry wall is not practical in the overburden due to the potential for encountering MEC and boulders, and will not limit migration from the overburden soil to the bedrock aquifer. Installation of vertical barriers is not possible in the fractured granitic gneiss aquifer.</td>
<td>Do not retain</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Capping and other impermeable covers</td>
<td>Installation of an impermeable or low permeability cap (e.g., clay and/or concrete) or cover (liner) to prevent infiltration of rain and leaching of contaminated soils.</td>
<td>Retain</td>
</tr>
<tr>
<td>Permeable Barriers</td>
<td>Drains, Interceptor Trenches</td>
<td>Drains and interceptor trenches are installed across the flow path of a contaminated plume to intercept shallow groundwater and prevent further migration. Water is then treated via an ex situ technology. Drains and interceptor trenches could not be drilled within or directly downgradient of the source area because MEC avoidance could not be conducted. Drains or interceptor trenches installed downgradient of the source area will be of limited effectiveness because source area soil sits on top of bedrock and may be releasing TCE to the bedrock aquifer through fractures directly below the TCE-contaminated soil.</td>
<td>Do not retain</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Permeable Reactive Barrier</td>
<td>A permeable reactive barrier composed of zero valent iron filings or other material is installed across the flow path of a contaminated plume, allowing the water portion of the plume to passively move through while reacting precipitating with chlorinated solvents and other contaminants. Installation of a permeable reactive barrier is not possible in the fractured granitic gneiss aquifer, where the TCE plume is located.</td>
<td>Do not retain</td>
<td></td>
</tr>
<tr>
<td>Ex Situ Active Restoration</td>
<td>Extraction</td>
<td>Pumping/Extraction Wells for Mass Removal</td>
<td>Mass removal extraction wells consist of a series of pumping wells installed into highly contaminated areas of the plume to remove contaminated groundwater. Specifically, the well field configuration is optimized to remove groundwater from the highest contaminant concentration areas of the plume. The technology is most useful in formations with high transmissivity.</td>
<td>Retain</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Air Stripping</td>
<td>Air stripping is a full-scale technology in which volatile organics are separated from groundwater by increasing the surface area of the contaminated water that is exposed to air. Types of aeration methods include packed towers, diffused aeration, tray aeration, and spray aeration. Air stripping involves the mass transfer of volatile contaminants from water to air. For groundwater remediation, this process is typically conducted in a packed tower or an aeration tank.</td>
<td>Retain</td>
</tr>
</tbody>
</table>
### Table 5-2: General Response Actions, Identification, and Screening of Remedial Action Technologies (continued)

<table>
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<tr>
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</tr>
</thead>
<tbody>
<tr>
<td>Ex Situ Active Restoration (continued)</td>
<td>Physical/Chemical Treatment (continued)</td>
<td>Carbon Adsorption</td>
<td>Liquid phase carbon adsorption is a full-scale technology in which groundwater is pumped through a vessel or series of vessels containing granular activated carbon to which dissolved contaminants adsorb. When the concentration of contaminants in the effluent from the bed exceeds a certain level, the carbon can be regenerated in place, removed and regenerated at an off-site facility, or discarded and replaced. Adsorption by activated carbon has a long history of use in treating municipal, industrial, and hazardous waste. Carbon adsorption is most efficient for removing organic compounds with a high boiling point, high molecular weight, and low solubility in water.</td>
<td>Retain</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Ultraviolet Oxidation</td>
<td>Ultraviolet oxidation is a destruction process that oxidizes organic, inorganics, and explosive constituents present in water by the addition of strong oxidizers and irradiation with ultraviolet light. The oxidation reaction is achieved through the synergistic action of ultraviolet light, in combination with ozone and or hydrogen peroxide. If complete mineralization is achieved, the final products of oxidation are carbon dioxide, water, and salts. The main advantage of ultraviolet oxidation is that it is a destruction process, as opposed to air stripping or carbon adsorption, for which contaminants are extracted and concentrated in a separate phase. Ultraviolet oxidation processes can be configured in batch or continuous flow modes, depending on the throughput under consideration.</td>
<td>Retain</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Zero Valent Iron</td>
<td>This technology has been demonstrated to be capable of treating a wide range of contaminants, including halogenated organics and heavy metals.</td>
<td>Retain</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Biological Treatment</td>
<td>Bioreactor</td>
<td>Retain</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Extracted groundwater is amended with nutrients, microbial cultures, and pH adjustment to facilitate biodegradation of contaminants. Granular activated carbon is typically added as a microbial growth substrate. Granular activated carbon provides a secondary benefit of adsorbing contaminants, limiting aqueous concentrations and potential toxicity to the microbes, and desorbing as aqueous concentrations are reduced though degradation.</td>
<td>Retain</td>
</tr>
</tbody>
</table>
Table 5-2: General Response Actions, Identification, and Screening of Remedial Action Technologies (continued)

<table>
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<tr>
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</tr>
</thead>
<tbody>
<tr>
<td>Ex Situ Active Restoration (continued)</td>
<td>Discharge</td>
<td>Surface Water</td>
<td>Treated groundwater is discharged into an on-site surface water channel.</td>
<td>Retain</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Rejection</td>
<td>Treated groundwater is reinjected back to the aquifer through a series of reinjection wells.</td>
<td>Retain</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Publicly Owned Treatment Works</td>
<td>Discharge of treated or untreated water to a publicly owned treatment works facility. Pretreatment may be required if the untreated water has high content of heavy metals that could be toxic to the microorganisms used in the treatment system.</td>
<td>Retain</td>
</tr>
<tr>
<td>In Situ Active Restoration</td>
<td>Physical and Chemical</td>
<td>Air Sparging and SVE</td>
<td>Air sparging is the process of injecting air into the saturated subsurface to remove contaminants. Air travels through the soil column and creates an in situ stripping mechanism in which the volatile contaminants partition from the solution phase into the vapor phase. The contaminated vapors travel upwards to the unsaturated zone where they can be extracted via SVE wells. Treatment of the contaminated vapors is then required. The water table depth (&gt;50 feet below ground surface) and tight fractured bedrock aquifer is not favorable for air sparging, due to the lack of aquifer/vadose zone permeability. Fracture communication between the saturated bedrock aquifer and bedrock/overburden vadose zone is expected to be variable, and poor where present. SVE will be limited to overburden glacial deposits and fill, which limits the area and depth of SVE treatment. Installation of either vertical or horizontal SVE wells in the source area is problematic due to buried MEC and large boulders/debris in the overburden fill. The primary biological degradation pathway is anaerobic. The aquifer is already oxygenated inhibiting the primary pathway. Increasing the level of oxygen will not improve the biological degradation pathway.</td>
<td>Do not retain</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Injection of Zero Valon Iron</td>
<td>This technology has been demonstrated to be capable of treating a wide range of contaminants, including halogenated organics and heavy metals. Zero valent iron may be dispersed into one or more aquifers as a nanoscale liquid suspension or through pneumatic fracturing followed by liquid atomized injection.</td>
<td>Retain</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Chemical Oxidation</td>
<td>In situ chemical oxidation involves the addition of oxidizing agents, such as hydrogen peroxide, permanganate, ozone, or Fenton’s reagent in order to facilitate direct oxidation of contaminants. Chemical oxidants are injected into the subsurface through injection wells.</td>
<td>Retain</td>
</tr>
</tbody>
</table>
### Table 5-2: General Response Actions, Identification, and Screening of Remedial Action Technologies (continued)

<table>
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</tr>
</thead>
<tbody>
<tr>
<td>In Situ Active Restoration (continued)</td>
<td>Physical and Chemical (continued)</td>
<td>Steam Injection with Dual Phase Recovery</td>
<td>This alternative involves the injection of steam into the subsurface. This technology serves to remove contaminated groundwater via three mechanisms. First, steam displaces groundwater and causes a cold water flush. Second, steam that has condensed to warm water is also displaced by continued steam injection causing a warm water flush. Third, adsorbed or physically isolated volatile organic compounds are volatilized through heat imparted by the steam. Each flush of groundwater will have to be extracted and treated via a conventional pump and treat system. As the TCE source area is in unsaturated soil above the water table, the flushing mechanisms of steam treatment will be ineffective. Drilling steam injection/recovery wells within or immediately adjacent to the source area will be infeasible (while practicing MEC avoidance) because of the amount of metal and potential MEC.</td>
<td>Do not retain</td>
</tr>
<tr>
<td>Biological</td>
<td>Cometabolism</td>
<td></td>
<td>Cometabolism is when microorganisms degrade contaminants without getting any benefits. This occurs by the activity of non-specific enzymes that are generated during the degradation of another compound. Cometabolic processes can occur under a variety of electron accepting conditions, including aerobic and anaerobic. PCE and TCE can undergo cometabolic degradation under aerobic conditions in the presence of a co-substrate such as methane or propane. This technology was tested at Area D with limited success.</td>
<td>Retain</td>
</tr>
<tr>
<td>Accelerated Anaerobic Bioremediation</td>
<td></td>
<td></td>
<td>This alternative stimulates the growth of microbial populations to consume available dissolved oxygen to generate anaerobic conditions, through the addition of an organic substrate (electron donor). Under anaerobic conditions, microbes utilize terminal electron accepting reactants that yield the greatest free energy. The depletion of electron receptors results in increasingly reducing conditions favorable to enhanced degradation of PCE and TCE.</td>
<td>Retain</td>
</tr>
</tbody>
</table>
### Table 5-2: General Response Actions, Identification, and Screening of Remedial Action Technologies (continued)

<table>
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<tr>
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<th>Process Option</th>
<th>Description</th>
<th>Screening Results</th>
</tr>
</thead>
<tbody>
<tr>
<td>Source Removal</td>
<td>Physical</td>
<td>Excavation</td>
<td>This alternative involves the physical removal TCE-impacted soils/fill from the ground, performed mechanically with standard earthmoving equipment.</td>
<td>Retain</td>
</tr>
<tr>
<td></td>
<td></td>
<td>SVE</td>
<td>SVE without air sparging is potentially applicable to the removal of the TCE source identified in the overburden soil. However, installation of traditional vertical SVE wells is impractical due to the vast amount of metallic debris and the potential to encounter MEC during drilling. An alternative will be to install horizontal SVE wells below the Munitions Waste Pit.</td>
<td>Retain</td>
</tr>
<tr>
<td>Subsurface MEC Clearance</td>
<td>MEC Detection</td>
<td>Analog Magnetometers</td>
<td>Locate buried military munitions by detecting irregularities in the earth’s magnetic field caused by materials in munitions. This is a passive system that emits no electromagnetic radiation. Detects only ferrous metals. Usually used in mag and dig operations.</td>
<td>Retained</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Analog Electromagnetic Induction All Metals Detectors</td>
<td>Electromagnetic Induction sensors detect both ferrous and non-ferrous metallic objects. Usually used in mag and dig operations.</td>
<td>Retained</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Digital Geophysical Mapping using Electromagnetic Induction</td>
<td>Electromagnetic Induction induces a pulsed magnetic field beneath the Earth’s surface with a transmitter coil, which in turn causes a secondary magnetic field to emanate from nearby objects that have conductive properties. Technology is well developed and was used during the RI. Capable of detecting the MEC items expected to be present at the site.</td>
<td>Retained</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Sub Audio Magnetics</td>
<td>Sub Audio Magnetics is a patented methodology by which a total field magnetic sensor is used to simultaneously acquire both magnetic and electromagnetic response of subsurface conductive items.</td>
<td>Retained</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Airborne Laser and Infrared Sensors</td>
<td>Airborne laser and infrared technologies can be used to identify objects by measuring their thermal energy signatures. UXO or discarded military munitions on or near the soil surface may possess different heat capacities or heat transfer properties than the surrounding soil, and this temperature difference theoretically can be detected and used to identify MEC.</td>
<td>Retained</td>
</tr>
</tbody>
</table>
### Table 5-2: General Response Actions, Identification, and Screening of Remedial Action Technologies (continued)

<table>
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<tr>
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<th>Process Option</th>
<th>Description</th>
<th>Screening Results</th>
</tr>
</thead>
<tbody>
<tr>
<td>Subsurface MEC Clearance (continued)</td>
<td>MEC Removal</td>
<td>Manual Excavation</td>
<td>Excavation of individual anomalies with hand tools (shovels).</td>
<td>Retained</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Mechanical Excavation</td>
<td>Excavation of individual or groups of anomalies with assisted with mechanized equipment.</td>
<td>Retained</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Area Mechanical Excavation and Sifting</td>
<td>Mechanical excavation of a specified area to a specified depth. Removes all items larger than the specified screen size. For this MRS, a 1/8-inch screen will likely remove all anomalies (smallest items are nails).</td>
<td>Retained</td>
</tr>
<tr>
<td>MEC Disposal</td>
<td>Blown-in-Place</td>
<td></td>
<td>Destruction of MEC by detonation with an explosive charge.</td>
<td>Retained</td>
</tr>
<tr>
<td></td>
<td>Consolidated Shots</td>
<td></td>
<td>Movement of MEC may be considered acceptable. MEC are destroyed by demolition at a location beyond the vicinity of detection.</td>
<td>Retained</td>
</tr>
</tbody>
</table>

Notes:

- LUC = Land use control.
- MEC = Munitions and explosives of concern.
- MNA = Monitored natural attenuation.
- MRS = Munitions Response Site.
- NCP = National Contingency Plan.
- PCE = Tetrachloroethylene.
- PICA = Picatinny Arsenal.
- RAO = Remedial action objective.
- SVE = Soil vapor extraction.
- TCE = Trichloroethene.
- UXO = Unexploded ordnance.
Table 5-3: Screening of Process Options

<table>
<thead>
<tr>
<th>General Response Action/Technology</th>
<th>Effectiveness</th>
<th>Implementability</th>
<th>Relative Cost</th>
<th>Screening Result</th>
<th>Comments</th>
</tr>
</thead>
<tbody>
<tr>
<td>A. NO ACTION</td>
<td>Does not achieve remedial action objectives.</td>
<td>Straightforward</td>
<td>None</td>
<td>Retained</td>
<td>The no action alternative must be fully evaluated according to 40 CFR 300.43(e)(6).</td>
</tr>
<tr>
<td>B. LAND USE CONTROLS</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Institutional Restrictions</td>
<td>High institutional restrictions will help to reduce the potential for future exposure to MEC and groundwater, does not protect waters of the state.</td>
<td>Straightforward</td>
<td>Low capital, Low O&amp;M</td>
<td>Retained</td>
<td>Institutional controls have been implemented, and proven effective, at PICA and other Department of Defense sites where risks and hazards have been identified as low and/or manageable. Institutional controls are retained for further evaluation.</td>
</tr>
<tr>
<td>Land Use Restriction</td>
<td>If properly enforced, land-use restrictions are an effective means of preventing exposure to contaminated media. Because the site is a controlled military base, access is already restricted to authorized personnel only.</td>
<td>Straightforward</td>
<td>Low capital, Low O&amp;M</td>
<td>Retained</td>
<td></td>
</tr>
<tr>
<td>Notations in Master Plan</td>
<td>Land use restrictions will be memorialized in the PICA Master Plan, effectively controlling future site uses.</td>
<td>Straightforward</td>
<td>Low capital, Low O&amp;M</td>
<td>Retained</td>
<td></td>
</tr>
<tr>
<td>Access Restrictions</td>
<td>Fencing, gates around the munitions disposal prevents worker access. Fencing and security at PICA prevent public assess.</td>
<td>Straightforward</td>
<td>Low capital, Low O&amp;M</td>
<td>Retained</td>
<td></td>
</tr>
<tr>
<td>Public Education/Public Advisories</td>
<td>Public education will facilitate site remediation by keeping potentially affected individuals aware of site contamination and pending remedial actions. Hunters receive training prior to issuance of hunting permits.</td>
<td>Straightforward</td>
<td>Low capital, Low O&amp;M</td>
<td>Retained</td>
<td></td>
</tr>
</tbody>
</table>
### General Response Action/Technology

<table>
<thead>
<tr>
<th>General Response Action/Technology</th>
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<th>Implementability</th>
<th>Relative Cost</th>
<th>Screening Result</th>
<th>Comments</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dig Permits</td>
<td>Dig permits identify the need for UXO support during intrusive activities.</td>
<td>Straightforward</td>
<td>Low Capital/Low O&amp;M</td>
<td>Retained</td>
<td></td>
</tr>
</tbody>
</table>
Table 5-3: Screening of Process Options (continued)

<table>
<thead>
<tr>
<th>General Response Action/Technology</th>
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<th>Relative Cost</th>
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</tr>
</thead>
<tbody>
<tr>
<td>UXO Construction Support</td>
<td>Provides a high level of UXO safety by having UXO Technicians onsite during intrusive activity</td>
<td>Straightforward</td>
<td>High</td>
<td>Retained</td>
<td></td>
</tr>
<tr>
<td>Worker Training</td>
<td>Provide written or digital information describing the potential explosive hazards at the MRS and anomaly avoidance and encounter protocols</td>
<td>Straightforward</td>
<td>Low Capital/Low O&amp;M</td>
<td>Retained</td>
<td></td>
</tr>
<tr>
<td>Emergency Provisions</td>
<td>Outlining emergency measures allows for a prompt and organized response to threats to public health and the environment</td>
<td>Straightforward</td>
<td>Low capital, Low O&amp;M</td>
<td>Retained</td>
<td></td>
</tr>
<tr>
<td>Long-Term Groundwater and surface water monitoring (long-term monitoring)</td>
<td>Useful for documenting long-term groundwater/surface water conditions and compliance; alone does not reduce risk</td>
<td>Straightforward</td>
<td>Low capital, Low O&amp;M</td>
<td>Retained</td>
<td></td>
</tr>
<tr>
<td>C. MONITORED NATURAL ATTENUATION</td>
<td>Effective for predicting, monitoring and measuring natural attenuation in groundwater and related reduction in risk. MNA cleanup timeframes can be lengthy</td>
<td>Straightforward</td>
<td>Low capital, Low O&amp;M</td>
<td>Retained</td>
<td></td>
</tr>
<tr>
<td>D. CONTAINMENT</td>
<td>Capping and other impermeable covers can prevent leaching of contaminated soil through infiltration of precipitation if soil is effectively isolated</td>
<td>Straightforward</td>
<td>Low capital, Low O&amp;M</td>
<td>Not Retained</td>
<td>The contaminated soil is located on top of bedrock. Capping even the entire land fill could not provide assurance that perched groundwater flowing on top of the bedrock surface will not continue to slowly mobilized TCE for an extended period of time.</td>
</tr>
</tbody>
</table>
### Table 5-3: Screening of Process Options (continued)

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<tr>
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<th>Implementability</th>
<th>Relative Cost</th>
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<th>Comments</th>
</tr>
</thead>
<tbody>
<tr>
<td>E. EX SITU ACTIVE RESTORATION</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Pumping – Mass Removal, Hydraulic Barrier, and Pulse Pumping</strong></td>
<td>Groundwater extraction can be used to pump contaminated groundwater from multiple aquifers directly to on-site treatment facilities.</td>
<td>Straightforward. Services and equipment available.</td>
<td>Medium capital, Medium O&amp;M</td>
<td>Not Retained</td>
<td>Groundwater extraction is not considered a cost effective technology due to the large number of extraction/monitoring wells required to control/monitor the fractured bedrock contaminant of concern plume, low detected contaminant of concern concentrations, and relatively high O&amp;M costs. Groundwater extraction without source removal will not be effective since the source area is above the water table and will continue releasing TCE to the aquifer.</td>
</tr>
<tr>
<td><strong>Air Stripping</strong></td>
<td>Air stripping is a well demonstrated technology for the removal of VOCs in groundwater.</td>
<td>Straightforward for most organic compounds</td>
<td>Low to medium capital, Medium O&amp;M</td>
<td>Not Retained</td>
<td>Requires groundwater extraction</td>
</tr>
<tr>
<td><strong>Carbon Adsorption</strong></td>
<td>Effective for removal of most VOCs and other organic compounds.</td>
<td>Straightforward</td>
<td>Medium capital, Medium O&amp;M</td>
<td>Not Retained</td>
<td>Requires groundwater extraction</td>
</tr>
<tr>
<td><strong>Ultraviolet Oxidation</strong></td>
<td>Demonstrated effective for the removal of most VOCs and other organic compounds. However, ultraviolet oxidation is considerably more complex and expensive in comparison to carbon adsorption and air stripping.</td>
<td>Straightforward</td>
<td>High capital, High O&amp;M</td>
<td>Not Retained</td>
<td>Given the low contaminant concentrations in site groundwater ultraviolet oxidation is not a cost effective alternative.</td>
</tr>
<tr>
<td><strong>Bioreactor</strong></td>
<td>Effective for treatment of a wide range of organic contaminants including chlorinated solvents.</td>
<td>Straightforward</td>
<td>High capital, Low to medium O&amp;M costs</td>
<td>Not Retained</td>
<td>Requires groundwater extraction</td>
</tr>
<tr>
<td><strong>Zero Valent Iron</strong></td>
<td>Effective for treating of organic contaminants.</td>
<td>Straightforward</td>
<td>High capital, High O&amp;M</td>
<td>Not Retained</td>
<td>Requires groundwater extraction</td>
</tr>
</tbody>
</table>
### Table 5-3: Screening of Process Options (continued)

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<tr>
<th>General Response Action/Technology</th>
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<th>Implementability</th>
<th>Relative Cost</th>
<th>Screening Result</th>
<th>Comments</th>
</tr>
</thead>
<tbody>
<tr>
<td>Discharge to Surface Water</td>
<td>Discharge to a surface water body (Green Pond Brook) is currently ongoing at PICA. A National Pollutant Discharge Elimination System permit equivalent will be required.</td>
<td>Implementable when combined with appropriate treatment operations, strict surface water discharge standards.</td>
<td>Low capital, Low O&amp;M</td>
<td>Not Retained</td>
<td>Requires groundwater extraction</td>
</tr>
<tr>
<td>Publicly Owned Treatment Works</td>
<td>Discharge of treated or untreated water to a publicly owned treatment works facility is an effective treatment technique.</td>
<td>Implementable, but may require pre-treatment prior to discharge</td>
<td>High capital if pre-treatment is required, high fees associated with discharge</td>
<td>Not Retained</td>
<td>Would be used in tandem with groundwater extraction</td>
</tr>
<tr>
<td>Reinjection</td>
<td>Treated groundwater will be injected into the subsurface. A National Pollutant Discharge Elimination System permit equivalent will be required.</td>
<td>Implementable when combined with appropriate treatment operations. Groundwater metals removal may be required to avoid injection well biofouling and clogging.</td>
<td>Medium capital and medium to high O&amp;M due to potential well and formation plugging.</td>
<td>Not Retained</td>
<td>Requires groundwater extraction</td>
</tr>
</tbody>
</table>

### F. IN SITU ACTIVE RESTORATION

<table>
<thead>
<tr>
<th>General Response Action/Technology</th>
<th>Effectiveness</th>
<th>Implementability</th>
<th>Relative Cost</th>
<th>Screening Result</th>
<th>Comments</th>
</tr>
</thead>
<tbody>
<tr>
<td>Chemical Oxidation</td>
<td>Chemical oxidation is an effective treatment and has been demonstrated to be effective for the rapid destruction of chlorinated solvents in groundwater. Services and equipment available.</td>
<td>Straightforward. Services and equipment available.</td>
<td>Medium to high capital, Low O&amp;M</td>
<td>Retained</td>
<td>Remedial alternative to be implemented in conjunction with MNA as a polishing step.</td>
</tr>
<tr>
<td>Zero Valant Iron Injection-Mass Removal</td>
<td>Effective treatment for removal of chlorinated solvents and degradation products in groundwater. Can be injected into aquifers as a liquid suspension or slurry.</td>
<td>Moderately complex to complex, requires batch testing and pilot study. Services and equipment available.</td>
<td>High capital, Low to medium O&amp;M costs</td>
<td>Not Retained</td>
<td>Complex and higher costs than technologies with easier implementation, lower costs and similar effectiveness.</td>
</tr>
</tbody>
</table>
Table 5-3: Screening of Process Options (continued)

<table>
<thead>
<tr>
<th>General Response Action/Technology</th>
<th>Effectiveness</th>
<th>Implementability</th>
<th>Relative Cost</th>
<th>Screening Result</th>
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</tr>
</thead>
<tbody>
<tr>
<td>Cometabolism</td>
<td>Cometabolic processes can occur under a variety of electron accepting conditions, including aerobic and anaerobic. PCE and TCE can undergo cometabolic degradation under aerobic conditions in the presence of a co-substrate such as methane or propane. This technology was tested at Area D with limited success.</td>
<td>Straightforward to moderately complex. May require pilot study to demonstrate effectiveness. Services and equipment available.</td>
<td>High capital, Low to medium O&amp;M costs</td>
<td>Not Retained</td>
<td>Aerobic cometabolism does not produce consistent results when compared to other in situ technologies, and may require a pilot test to demonstrate effectiveness in the field. Higher cost than other comparable in situ technologies.</td>
</tr>
<tr>
<td>Accelerated Anaerobic Bioremediation</td>
<td>Enhanced anaerobic bioremediation is an effective treatment and has resulted in the mineralization of chlorinated solvents in groundwater.</td>
<td>Straightforward. Services and equipment available.</td>
<td>Medium to high capital, Low O&amp;M</td>
<td>Retained</td>
<td>Remedial alternative to be implemented in conjunction with MNA as a polishing step.</td>
</tr>
<tr>
<td>Excavation</td>
<td>Physical removal of TCE-impacted soils/fill will eliminate the source of groundwater contamination. Intrusive activity of this magnitude may be prohibitively expensive due to required UXO support and avoidance procedures.</td>
<td>Straightforward. Services and equipment available</td>
<td>High capital, Low O&amp;M costs</td>
<td>Retained</td>
<td>Remedial alternative to be implemented in conjunction with MNA as a polishing step.</td>
</tr>
</tbody>
</table>
Table 5-3: Screening of Process Options (continued)

<table>
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<tr>
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<th>Comments</th>
</tr>
</thead>
<tbody>
<tr>
<td>Soil Vapor Extraction</td>
<td>Removal of the TCE source in soil through SVE will eliminate the source of groundwater contamination. Horizontal SVE wells feasible with available services and equipment; however, likely time and labor intensive due to logistics (thin 5-foot interval of native soil identified in TR1 not characterized throughout the site).</td>
<td>Complex. Traditional vertical SVE wells not feasible due to potential MEC.</td>
<td>High capital, Medium O&amp;M costs</td>
<td>Not Retained</td>
<td>Installation of either vertical or horizontal SVE wells in the source area is problematic due to buried MEC and large boulders/debris in the overburden fill. Specifically, installation of vertical SVE wells will be infeasible (while practicing MEC avoidance) because of the amount of metal and potential MEC in and immediately adjacent to the source area. Horizontal well installation will likely require “trial and error” approach, with several wells attempted for each one completed. Lack of characterization of the native overburden soil is likely to greatly increase costs.</td>
</tr>
</tbody>
</table>

H. SUBSURFACE MEC DETECTION, REMOVAL AND DISPOSAL

<table>
<thead>
<tr>
<th>General Response Action/Technology</th>
<th>Effectiveness</th>
<th>Implementability</th>
<th>Relative Cost</th>
<th>Screening Result</th>
<th>Comments</th>
</tr>
</thead>
<tbody>
<tr>
<td>Analog Magnetometers</td>
<td>Has a 90 percent probability of detection of items to a depth of 14 inches (Institute for Defense Analysis, 2007). However, some MD items at the MRS have been encountered up to 42 inches deep. <strong>Potential interference from background debris, “hot rocks”, range-related debris and cultural items.</strong></td>
<td>Straightforward Light and compact. Can be used in any traversable terrain. Widely available from a variety of sources. Minimal to no impacts to cultural or natural resources.</td>
<td>Low capital /Low O&amp;M</td>
<td>Retained</td>
<td>Can be used successfully in conjunction with source removal, excavation of soil in lifts.</td>
</tr>
</tbody>
</table>
### Table 5-3: Screening of Process Options (continued)

<table>
<thead>
<tr>
<th>General Response Action/Technology</th>
<th>Effectiveness</th>
<th>Implementability</th>
<th>Relative Cost</th>
<th>Screening Result</th>
<th>Comments</th>
</tr>
</thead>
<tbody>
<tr>
<td>Analog Electromagnetic Induction All Metals Detectors</td>
<td>Effective at detecting surface and shallow bury items (less than 18 inches). Less effective at detecting smaller items at deeper depths. The MD items were generally small (&lt;60-millimeter diameter). Some MD items at the MRS have been encountered deeper than 42 inches and up to 20 feet deep. By detecting both ferrous and nonferrous metals, the number of anomalies increases. Most MD were ferrous.</td>
<td>Straightforward Hand-held detectors are generally light and compact. Can be used in any traversable terrain. Widely available from a variety of sources. Minimal to no impacts to cultural or natural resources.</td>
<td>Low capital /Low O&amp;M Analog Electromagnetic Induction detectors have a low cost for purchase/rental and operation compared to other detection systems</td>
<td>Retained</td>
<td>MD and MEC were primarily ferrous and, therefore, provide no additional advantages over magnetometers.</td>
</tr>
<tr>
<td>Digital Geophysical Mapping using Electromagnetic Induction</td>
<td>Digital geophysical mapping is an industry standard for MEC detection. Detects both ferrous and nonferrous metallic objects. Provides for anomaly discrimination based on signal type and intensity. Detection of 60-millimeter diameter items may not be reliable below a depth of about 26 inches.</td>
<td>Straightforward Can be used in most traversable terrain, however, it is a challenge on steep terrain. Requires specialized knowledge and training to collect and interpret data. Requires clearing of forested areas for equipment access.</td>
<td>Moderate capital costs Has a moderate purchase cost compared to other technologies. Lower costs can be realized when using arrays of multiple detector sensors.</td>
<td>Not Retained</td>
<td>Is effective; however, it will require more extensive clearing than a magnetometer and will be difficult to implement due to the steep terrain at the MRS areas outside the munition disposal pit.</td>
</tr>
</tbody>
</table>
### Table 5-3: Screening of Process Options (continued)

<table>
<thead>
<tr>
<th>General Response Action/Technology</th>
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</tr>
</thead>
<tbody>
<tr>
<td>Sub Audio Magnetics</td>
<td>Detects both ferrous and non-ferrous metallic objects. Capable tool for detection of deep MEC. Complex High data processing requirements. Available from a few sources. High power requirements. Has longer than average setup times. Low industry familiarization and limited availability. Requires clearing of forested areas (more than 50 percent of the MRS). Minor impacts to cultural or natural resources based on clearing of areas for high quality data collection.</td>
<td>High</td>
<td>Has a high operating cost and low availability.</td>
<td>Not Retained</td>
<td>High costs, low industry familiarization and limited availability do not offset the added effectiveness of detecting deep MEC.</td>
</tr>
<tr>
<td>Airborne Laser and Infrared Sensors</td>
<td>Detects both ferrous and non-ferrous objects. Low industry familiarity. Effectiveness increases when used for wide area assessment in conjunction with other airborne technologies. Complex Requires aircraft and an experienced pilot. Substantial data processing and management requirements. Available from few sources. Minimal to no impacts to cultural or natural resources.</td>
<td>High</td>
<td>Requires aircraft and an experienced pilot. Substantial data processing and management requirements. Available from few sources. Minimal to no impacts to cultural or natural resources.</td>
<td>Not Retained</td>
<td>Not cost effective and difficult to implement.</td>
</tr>
</tbody>
</table>
Table 5-3: Screening of Process Options (continued)

<table>
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<tr>
<th>General Response Action/Technology</th>
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<th>Comments</th>
</tr>
</thead>
<tbody>
<tr>
<td>Manual Excavation</td>
<td>Effective at exposing shallow, low density small item anomalies in loose soils. At the MRS, outside of the munitions disposal pit the anomaly density is low. Nearly all (&gt;90 percent) of the anomalies and MD were found in shallow soils. Anomalies in the munition pit were found at depths ranging from 48 inches to 20 feet.</td>
<td>Straightforward Readily implementable over much of the MRS. Would be more difficult in the forested land due to tree roots. More labor intensive for items deeper than 24 inches. Does not require heavy equipment and is less disruptive to natural resources.</td>
<td>Moderate Manpower intensive, but does not require use of heavy equipment.</td>
<td>Retained</td>
<td>Is effective, implementable and cost effective for removal of the relatively shallow MEC expected at the MRS. May need to be combined with mechanical excavation for deeper items.</td>
</tr>
<tr>
<td>Mechanical Excavitation</td>
<td>Effective at exposing and removing potential MEC anticipated at the MRS.</td>
<td>Straightforward Equipment is readily available and requires less manpower than manual excavation. For very low density shallow items (&lt;24 inches) mobilization and set up of equipment may require more effort than manual excavation. Movement of heavy equipment through wooded areas may require some clearing to provide access.</td>
<td>Moderate Has lower labor requirements and equipment is relatively lower cost.</td>
<td>Retained</td>
<td>Effective, implementable, and cost effective for deeper buried items. May need to be combined with manual excavation if shallow items are also present.</td>
</tr>
</tbody>
</table>
### Table 5-3: Screening of Process Options (continued)

<table>
<thead>
<tr>
<th>General Response Action/Technology</th>
<th>Effectiveness</th>
<th>Implementability</th>
<th>Relative Cost</th>
<th>Screening Result</th>
<th>Comments</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Area Mechanical Excavation and Sifting</strong></td>
<td>Source area soils are well graded fill/gravel and MD will not be readily separated from gravel materials by sifting. The most effective method of removing all anomalies and it does not rely on prior detection for anomaly removal. However, it will be an inefficient process and large effort for the low density of MD present in the majority of the MRS. This could be efficient during the removal of materials from the waste pit.</td>
<td>Low Equipment is readily available. However, to clear the MRS by this method will require excavating all soils. The process option is very destructive and will require clearing all vegetation and existing infrastructure. Extensive restoration will be needed following the action.</td>
<td>Very High Large area of excavation and extensive post action restoration.</td>
<td>Screened</td>
<td>Effective but inefficient method given the low density of anomalies in the majority of the MRS. Very destructive of existing natural resources and infrastructure. Mechanical excavation and sifting viable for use for sifting material removed from the waste pit.</td>
</tr>
<tr>
<td><strong>BIP</strong></td>
<td>Each item is individually destroyed and verified by qualified personnel. BIP can release MC and MD, which can be restricted by engineering controls.</td>
<td>Straightforward Field proven techniques.</td>
<td>Moderate Significant costs may result in engineering controls to protect the prison facility as evacuation of inmates is not feasible.</td>
<td>Retained</td>
<td>Retained for items that cannot be safely moved.</td>
</tr>
</tbody>
</table>
## Table 5-3: Screening of Process Options (continued)

<table>
<thead>
<tr>
<th>General Response Action/Technology</th>
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<th>Implementability</th>
<th>Relative Cost</th>
<th>Screening Result</th>
<th>Comments</th>
</tr>
</thead>
<tbody>
<tr>
<td>Consolidated Shots</td>
<td>Moderate to High</td>
<td>Straightforward</td>
<td>Moderate</td>
<td>Retained</td>
<td>Retained because the shot can be completed in locations far from populated or sensitive structures.</td>
</tr>
<tr>
<td></td>
<td>Limited to use for MEC deemed safe to move by UXO-qualified personnel.</td>
<td>Same techniques as BIP but may require larger area and greater controls. However, items may be moved to area where no buildings, persons, etc. are located within blast Exclusion Zone, so may increase short-term protectiveness and, therefore, implementability.</td>
<td>Labor intensive, requires materials for larger scale operation.</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

### Notes:

- **BIP** = Blown-in-place.
- **CFR** = Code of Federal Regulations.
- **MC** = Munitions constituents.
- **MD** = Munitions debris.
- **MEC** = Munitions and explosives of concern.
- **MNA** = Monitored natural attenuation.
- **MRS** = Munitions Response Site.
- **O&M** = Operation and maintenance.
- **PICA** = Picatinny Arsenal.
- **SVE** = Soil Vapor Extraction.
- **TCE** = Trichloroethene.
- **UXO** = Unexploded ordnance.
- **VOC** = Volatile organic compound.
6. DEVELOPMENT OF REMEDIAL ALTERNATIVES

The approved Final 600 Area Data Report and Feasibility Study, 600 Area Groundwater Plume (PICA-058) (Shaw, 2013) developed six RAs to address the TCE in groundwater that were titled as follows:

- Alternative GW-1 – No Action
- Alternative GW-2 – MNA with Institutional Controls (ICs)
- Alternative GW-3 – In Situ Chemical Oxidation (ISCO) and MNA Polishing with ICs
- Alternative GW-4 – In Situ Enhanced Anaerobic Bioremediation and MNA Polishing with ICs
- Alternative GW-5 – TCE Source Material Removal and MNA Polishing with ICs
- Alternative GW-6 – Total Munitions Waste Pit Removal and MNA Polishing with ICs.

These six alternatives listed above (Shaw, 2013) have been expanded upon and re-named in order to address the hazards associated with the Inactive Munitions Waste Pit MRS (PICA-013-R-01). Although the groundwater remediation components of the original six RAs remain unchanged, remedial technologies have been added to each of these original six RAs in order to achieve the RAO for the potential MEC hazards associated with the MRS included within the site boundary in this FS. One additional RA was added for removal of the entire waste pit and MEC clearance within the entire MRS. All seven alternatives were determined to meet the screening evaluation for effectiveness, implementability and cost and were all, therefore, included for detailed analysis. The seven RAs evaluated in this FS are as follows:

- Alternative 1 – No Action
- Alternative 2 – MNA, and LUCs
  - and Construction Support
- Alternative 3 – ISCO, MNA Polishing, LUCs
  - and Construction Support
- Alternative 4 – In Situ Enhanced Anaerobic Bioremediation, MNA Polishing, LUCs
  - and Construction Support
- Alternative 5 – TCE Source Material Removal, MNA Polishing, LUCs,
  - and Construction Support
- Alternative 6 – Total Munitions Waste Pit Removal, TCE Source Material Removal, MNA Polishing, LUCs, and Construction Support
- Alternative 7 – Total Munitions Waste Pit Removal, TCE Source Material Removal, MNA Polishing, LUCs, and MEC Clearance of Entire MRS.

6.1 REMEDIAL ALTERNATIVES FOR 600 HILL WASTE PIT

The RAs for the 600 Hill Waste Pit are designed to reduce the overall unacceptable risks. The general assumptions for each of the seven RAs listed above are outlined in this section. The
assumptions related to cost estimates are included in Appendix C (also see USEPA, 200b).

References to the Final FS (Shaw, 2013) are included for modeling results, and groundwater restoration timeframes associated with each alternative, where appropriate. For each of the RAs evaluated, the MEC HA scores (USEPA, 2008) were determined and are presented in the sections below and the assessment results are provided in Appendix E.

6.1.1 Alternative 1 – No Action

No additional actions will be undertaken at the site as part of this RA. In addition, the LUCs implemented at the MRS as part of the NTCRA Land Use Control Plan (U.S Army, 2013) will be allowed to expire. According to the NCP, the level of treatment achieved must be compared to the required expenditures of time and materials as an integral portion of the remedy selection process. The No Action alternative is intended to serve as a baseline by which to compare the risk reduction effectiveness of other potential alternatives. In this alternative, no remedial actions will be performed. No efforts will be undertaken to contain, remove, monitor, or treat the TCE-contaminated groundwater or removal of MEC contained within the Inactive Munitions Waste Pit or potential MEC hazards from the remaining portions of the MRS. The site will essentially be left as is with no additional actions taken.

Under Alternative 1, no action is taken and the MEC HA score of 560 remains the same, indicating a moderate explosive hazard at the site with a hazard level of 3 (Appendix E).

6.1.2 Alternative 2 – Monitored Natural Attenuation and Land Use Controls, and Construction Support

Alternative 2 includes the following components:

- Monitored Natural Attenuation (MNA), including groundwater and surface water sampling and an assessment of contaminant trends.
- LUCs, including access control, groundwater and land use restrictions, fencing and signage, safety program, and annual inspections and assessment for VI potential during future building construction.
- Construction support is a specific type of LUC which requires UXO support for all intrusive activities included in this alternative.

Alternative 2 will involve MNA for the contaminated groundwater within the AA and LUCs to prevent exposure to groundwater and MEC hazards. There are no provisions in this alternative to provide a cap for the Munitions Waste Pit. The AA for the TCE-impacted groundwater plume is shown in Figure 6-1. MNA will continue until the TCE ARAR is achieved in groundwater. A 50-year monitoring period has been assumed based upon the hypothetical leaching rate of TCE from source soils, as was determined in the Final 600 Area Groundwater FS (Shaw, 2013), which is included in Appendix D. The continuous leaching of the TCE source material significantly extends the time to achieve RAOs, as the soils will continue to leach in-place, and upon depletion of the source, the groundwater still requires additional time to attenuate to below...
cleanup levels. In contrast, removal of TCE source soils will result in an MNA period of only 8-10 years.

MNA sampling will be conducted at selected wells and surface water sampling locations on a semiannual basis to year 10, annually to year 20, and once every 5 years to year 50. MNA will continue until the cleanup goal for TCE (NJDEP GWQS 1 µg/L) is achieved in groundwater. The MNA program will be used to determine whether subsequent actions will be required and determine if MNA is progressing as anticipated. Results of the first and subsequent CERCLA Five-Year Review will include a revised MNA timeframe for the remainder of the dissolved TCE plume.

For Alternative 2, if MNA and LUCs and Construction Support are implemented and maintained, the MEC HA score will remain at 560, indicating a moderate hazard potential with a hazard level of 3 (Appendix E).

Alternative 2 involves continuous implementation of LUCs, in particular, restrictions on groundwater use and intrusive activities, access restrictions, fencing and signage requirements, safety programs, and annual inspections. Warning signs are required to prohibit entrance to unauthorized personnel, warn of potential MEC hazards, and provide a telephone number to contact if potential MEC are observed. Existing signage and fencing (both the Garrison fencing and Roberton Enclosure) are considered adequate to prevent unauthorized access.

Inspections will need to be performed once per year to ensure that LUCs remain in effect and are being properly implemented. Inspections are needed to ensure that the fencing or signage is uncompromised and erosion has not exposed MEC causing potential migration of MEC within the MRS. Breaks in the fence will need to be repaired quickly to prevent unauthorized entry. Following annual inspections and maintenance, one annual report will be completed describing the inspection results, needed maintenance or repairs, evaluation of erosion and potential migration of MEC, and assessment of the effectiveness of the administrative LUCs to prevent exposure and trespassing.

An integral element of this alternative is a combination of MNA and LUCs, which includes institutional and access restrictions, public education, emergency provisions, and MNA. No active treatment will be implemented to remove contaminants from the AA. Rather, monitoring of groundwater and surface water will provide data on the rate at which TCE is attenuating.

Currently, the U.S. Army enforces strict LUCs throughout the installation, as detailed in Section 1.4, and includes the following:

- **Site Clearance/Soil Management Procedures**—Prior to all soil movement, the PICA Environmental Affairs Office must be notified and give approval.

- **UXO Clearance Procedures**—Intrusive activities will require a permit from the Picatinny Safety Office and will be subject to PICA UXO Safety requirement and review. Construction support will be required for any planned excavations. Identified UXO will be handled in accordance with PICA UXO safety requirements.
• **Master Plan Regulations** (Army Regulation 210-20)—Land use restrictions will be memorialized in the PICA Master Plan.

• **Geographic Information System (GIS) Database**—The GIS will record site location, size, and chemical analytical data (and screening criteria for site COCs). Furthermore, the GIS will be used by the Environmental Affairs Office to administer the Site Clearance/Soil Management Procedures.

• **Base Access Restrictions (Security)**—The Base is enclosed in a fence and entrances are guarded 24 hours per day. The site is enclosed within a restricted access (Robertson Enclosure) within PICA.

• **Safety Program**—All contractors are required to attend safety training conducted by the PICA Safety Office.

NJDEP approved a CEA for all of PICA in 2002. The corresponding WRA covers all of PICA and, therefore, all of the 600 Area. Via the CEA, the State limits access to contaminated groundwater, thus adding an additional level of IC. The elements of LUCs detailed above and the existing CEA are existing and constant. Therefore, the combination of these controls does not necessitate a rapid restoration timeframe.

Because the remedial action will result in hazardous substances, pollutants, or contaminants remaining at the site above levels that allow limited use and unrestricted exposure, CERCLA Five-Year Reviews will be conducted no less than every five years after initiation of the remedial action. Five-Year Reviews will be conducted to evaluate the implementation and performance in order to determine if the remedy continues to be protective of human health and the environment.

The selected area will remain in government ownership. As a result, other process options such as deed restriction, zoning, and planning will not apply to this RA. Also, education support will be provided to inform and educate the public about the risk and control measures implemented at the 600 Hill Waste Pit to minimize risk to human receptors.

### 6.1.2.1 Description of Alternative

Alternative 2 will involve implementation of an MNA monitoring program and continuous implementation of LUCs, in particular restrictions on groundwater use throughout the AA and access and dig restrictions within the entire Inactive Munitions Waste Pit MRS.

### Land Use Controls

The only objective for the implementation of LUCs will be to safeguard human health. LUCs will achieve this objective by restricting exposure to MEC hazards and to TCE in groundwater, surface water, and subsurface soil that result in an unacceptable risk to human health. LUCs will be implemented by ensuring the continued enforcement of existing LUCs, as discussed in

**Section 1.4.** As long as Picatinny is under military control, LUCs will be in place. To ensure
the implementation of these controls, Picatinny has developed a series of interlocking protective measures to safeguard human health and the environment.

- Restrictions on digging are in place throughout the installation, and safety permits are required prior to excavation of any type as well as assurance that compliance with environmental regulations and guidance are followed through the internal Picatinny Environmental Management System. Additionally, UXO construction support is required for areas known, or with the potential, to have MEC. PICA has established the dig permit and an Activity Hazard Analysis program (U.S. Army, 2011a) for intrusive construction activities and uses the Picatinny UXO Hazard Map to determine which areas on the installation require support for ground disturbing activities, the level of risk associated with each area, and the mitigation that should be used for UXO hazards. This determination is also assessed through the Picatinny Environmental Management System database.

- Safety and UXO training is required prior to initiating any intrusive operation.

- All contractors performing intrusive operations at PICA are required to attend a safety and UXO briefing prior to working on the Arsenal.

- A web-based UXO safety class is available to Arsenal personnel via the safety web page as an educational behavioral modification control.

- A video loop warning of UXO hazards plays at the Visitor’s Center, located at the Main Gate of the installation.

- Work entered into the PICA Environmental Management System is reviewed for UXO requirements.

- All hunters receive a hunter safety UXO briefing prior to annual issuance of their license.

- A chain link fence, with signage, surrounds the majority of PICA and access to the installation is restricted to four entrances: the Main Gate, Mount Hope Gate, Escape Gate, and the Navy Gate. Further, the entire 600 Area lies entirely within the Robinson Enclosure, a secure part of PICA, which has restricted access, a security system, and fence with a locked entrance gate.

- All intrusive operations at PICA require the submittal of a site-specific health and safety plan and activity hazard analysis to the Installation Safety Office for review prior to work.

- A CEA and WRA are administrative restrictions on groundwater that were established in 2003 for the entire Arsenal to bring the Arsenal groundwater into compliance with state requirements while the IRP is ongoing.

- All future construction of buildings at the 600 Area will be assessed for potential VI.

Inspections will need to be performed once per year to ensure that the fencing or signage is uncompromised and erosion has not exposed MEC causing potential migration of MEC. The inspection and maintenance will be documented in an annual report.
Figure 6-2 presents the areas that require LUCs and Construction Support to minimize hazards associated with potential MEC exposure. Figure 6-3 presents the groundwater AA that will be subject to groundwater related LUCs, including the Picatinny WRA. The LUC areas are different for MEC and groundwater exposure because the MRS boundary and Groundwater AA are geographically different.

Construction Support

UXO Technicians will be required for construction support for any subsurface activities such as digging or intrusive construction within the entire 21-acre Inactive Munitions Waste Pit MRS, as depicted on Figure 6-2. The minimum UXO Technician construction support team is assumed for subsurface construction. The support team will consist of one UXO Technician III and one UXO Technician II in accordance with USACE Engineering Pamphlet 75-1-2 requirements for construction sites with known or suspected MEC (USACE, 2004).

Design

Once an RA has been selected and the Proposed Plan (PP) and ROD have been completed, a remedial design will be prepared. This will include, at a minimum, a site-specific work plan describing the remedial activities, quality assurance/quality control procedures, technical specifications, and a site health and safety plan. The design documents will be submitted for review and approval by the appropriate agencies prior to initiation of remedial activities. The initial phase of the work will consist of the preparation of a site-specific health and safety plan. Because the remedial action will be conducted under CERCLA, the substantive requirements of the permits, and permitting agencies, will be followed in lieu of obtaining formal permits for required activities. The health and safety plan will outline the physical and chemical hazards associated with the work to be performed at the site and will serve as the instrument of control for ensuring the health and safety of personnel at the site.

Contractor and Material Procurement

Contractor and material procurement will include preparation of bid packages for the remedial activities, solicitation of bids, bid review, and contractor selection. Materials and equipment required to complete the remedial activities will be limited to the installation or maintenance of signage or fencing, and the collection of MNA samples.

Groundwater Use Restrictions

Groundwater use restrictions will involve prohibitions of well installation/operation without well head protection and groundwater consumption or other beneficial uses, such as agricultural irrigation by extraction through wells or by other means. For groundwater, the base-wide CEA is already in place in which the 600 Area groundwater is included. The CEA, which includes both unconsolidated and consolidated aquifers to a depth of 380 ft bgs, was approved by NJDEP in November 2002. The CEA identifies contaminant concentrations within the CEA boundary (the property boundary of Picatinny) above Primary Drinking Water Standards; therefore, the CEA also serves as a WRA. The WRA functions as the LUCs by which potable use restriction can be affected.
Monitored Natural Attention

The primary objectives of the MNA program under Alternative 2 are to:

- Ensure that contaminant concentrations decrease as predicted.
- Assess when it is necessary to implement a contingent remedy.

Implementation of the MNA program under Alternative 2 will involve submittals of plans, field sampling activities, and reporting requirements. The submittal of plans will include the health and safety plan, project work plan, and a Uniform Federal Policy-Quality Assurance Project Plan that will detail elements, such as sampling locations, parameters, and frequency, as well as the exit strategy and the general evaluation criteria to evaluate the necessity of a contingent remedy. The reporting requirements will involve, at a minimum, submittal of the monitoring results and CERCLA Five-Year Review reports.

The project work plan will address all aspects of the program and direct the work to be performed. The field sampling plan will direct the technical requirements of the sampling program, including field sampling techniques, sampling locations, sampling frequency, proposed data use, sampling analytical programs, and use of site screening equipment. The Uniform Federal Policy-Quality Assurance Project Plan will detail the requirements of the chemical analytical program (i.e., analytical methods), data quality objectives, data quality, and standard operating procedures.

To address groundwater contamination, a total of eight monitoring wells (13MW-1, 13MW-2, 13MW-4, 13MW-6, 13MW-7, 13MW-8, 13MW-11, and DM13-3) will be included in the MNA sampling program, with an option for four additional monitoring wells. Eight-Twelve monitoring wells have been assumed for costing purposes based on an analysis of the data. However, the final number of wells will be established in the MNA plan. All groundwater samples will be analyzed for select VOCs including TCE and their associated daughter products, and field parameters, such as DO, temperature, ORP, and pH. The wells selected for the MNA sampling program are shown on Figure 6-3. In addition, surface water samples will be collected contemporaneously with each groundwater sampling event from two locations in the two marshlands into which groundwater apparently discharges and from two drainageways downgradient of the respective marshlands. One additional surface water sample from the drainageway is also assumed for costing. Surface water samples will be analyzed for selected VOCs.

When the concentrations of TCE are below the RAO of 1 µg/L, groundwater and surface water monitoring will be continued for an additional one to three years to ensure that the new reduced concentrations are not the result of seasonal fluctuation. Under this alternative, each groundwater monitoring well will be maintained over the entire 30-year period and replaced as necessary to provide continuous service. Note that the length of time required for the groundwater and surface water monitoring stated herein is estimated for costing purposes and may be modified once the RA is implemented on the basis of the analytical results, in collaboration with the regulators.
6.1.3 Alternative 3 – In Situ Chemical Oxidation, Monitored Natural Attenuation
Polishing, and Land Use Controls, and Construction Support

Alternative 3 includes the following components:

- In situ treatment using chemical oxidants to reduce TCE concentrations in groundwater;
- MNA, including groundwater and surface water sampling, and an assessment of contaminant trends;
- LUCs, including access control, groundwater and land use restrictions, fencing and signage, safety training, and annual inspections;
- Construction Support is a specific type of LUC that requires UXO support for all intrusive activities is included in this alternative.

Alternative 3 will involve up to three annual injections of a chemical oxidizer in six wells (three upgradient of the source area of the plume and three downgradient) (Figure 6-4) for the in situ treatment of TCE concentrations in groundwater thereby decreasing contaminant discharge into downgradient well and wetland receptors. Due to the potential for encountering MEC during this remedial action, MEC construction support and MEC avoidance will be performed during the implementation of the RA. The upgradient wells will be completed in the overburden on top of the bedrock surface. Overburden injections will allow the oxidant to advectively migrate over the top of the bedrock surface through the source area. The three downgradient wells will be installed in the saturated zone of shallow bedrock just downgradient of the source. Sodium permanganate will rapidly oxidize TCE in groundwater at an approximate minimum concentration of 300 milligram(s) per liter (mg/L) (permanganate), yielding carbon dioxide and water. Successful treatment will result in surface water receptor TCE concentrations dropping below ARARs in an approximate eight-year period (Shaw, 2013). Performance monitoring will be conducted at source injection wells and upgradient monitoring wells to evaluate the effectiveness of the remedy. Monitoring will be performed monthly for the first six months and quarterly thereafter until the last treatment. During this period, downgradient wells and surface water will be monitored on a semiannual basis.

Active treatment in the form of ISCO will be conducted over a three-year period, followed by MNA polishing for the remainder of the TCE-contaminated groundwater within the AA. Groundwater TCE concentrations are likely to rebound after active treatment in the source area, and later impact the downgradient receptors. TCE source soil concentrations are expected to leach and lose mass with time, with a consequent decrease in groundwater TCE concentrations. A 50-year monitoring period has been assumed based upon the hypothetical leaching rate of TCE from source soils, as was determined in the Final 600 Area Groundwater FS (Shaw, 2013) and is included in Appendix D. After completion of ISCO performance monitoring, monitoring wells and surface water will continue to be monitored on a semiannual basis to year 10. Wells will subsequently then be sampled annually to year 20, and once every 5 years to year 35. Results of the CERCLA Five-Year Review will include a revised MNA timeframe for the remainder of the dissolved TCE plume. Note that the length of time required for the groundwater
and surface water monitoring stated herein is estimated for costing purposes and may be modified once the RA is implemented on the basis of the analytical results, in collaboration with the regulators.

In addition, Alternative 3 will include implementation of LUCs and MNA sampling, as previously discussed in Section 6.1.2.

For Alternative 3, if In Situ Chemical Oxidation (ISCO), Monitored Natural Attenuation (MNA) Polishing, Land Use Controls (LUCs), and Construction Support are implemented and maintained, the MEC HA score will be 560, indicating a moderate hazard potential with a hazard level of 3 (Appendix E).

### 6.1.3.1 Description of Alternative

Alternative 3 will involve: (1) installation of six injection/monitoring wells, and (2) injection of approximately 6,700 pounds of sodium permanganate (applied in a five percent solution) to reduce COC concentrations in situ. Sodium (or potassium) permanganate is generally the preferred oxidizer for treatment of TCE. Figure 6-4 shows the approximate treatment zone and proposed injection grid in which Alternative 3 will be applied. This treatment zone covers an area of approximately 48,000 square ft and corresponds to the region that is the source area of the TCE plume. The permanganate solution will be pumped or gravity fed directly into each injection well. Up to three annual treatments are assumed, based on the likelihood of TCE rebound, to reduce concentrations to levels that will prevent TCE discharge into downgradient well and surface water receptors above applicable standards.

The first stage of this treatment will include a pilot test conducted upgradient of monitoring well 13MW-1, immediately downgradient near the source area of the plume. The purpose of the pilot test is to collect site-specific geochemical and laboratory data during a small-scale ISCO application to optimize the specific quantity and types of injectants to be used during full-scale treatment. Due to the location of the TCE source within a “Munitions Waste Pit,” in which MEC were discovered during the source investigation, injection/monitoring wells will need to be installed outside of the boundaries of the Munitions Waste Pit as depicted on Figure 6-4. The pilot study will utilize the six injection/monitoring wells installed for the pilot test, which will be used for the full-scale treatment as injection points. Selection of one well to use as the pilot injection well will be made based on observations made during installation, well yield, and number and distribution of producing fractures determined from borehole geophysics.

### Design

Once an RA has been selected and the PP and ROD have been completed, a remedial design will be prepared. This will include, at a minimum, a site-specific work plan describing the remedial activities, quality assurance/quality control procedures, technical specifications, and a site health and safety plan. The design documents will be submitted for review and approval by the appropriate agencies prior to initiation of remedial activities.
The initial phase of the work will consist of the preparation of a site-specific health and safety plan. Because the remedial action will be conducted under CERCLA, the substantive requirements of the permits and permitting agencies will be followed in lieu of obtaining formal permits for required activities. The health and safety plan will outline the physical and chemical hazards associated with the work to be performed at the site and will serve as the instrument of control for ensuring the health and safety of personnel at the site.

**Contractor and Material Procurement**

Contractor and material procurement will include preparation of bid packages for the remedial activities, solicitation of bids, bid review, and contractor selection. Materials and equipment required to complete the remedial activities will be selected and procured.

**Mobilization and Demobilization**

The first phase of this alternative will include mobilization of the required personnel, equipment, and facilities. It is anticipated that locations for injection wells can be selected from currently accessible areas or with limited site preparation. Following installation of the injection wells and initial round of substrate injections, all personnel, equipment, and materials will be demobilized, as subsequent treatment will be performed using the existing injection wells minimizing additional mobilization/demobilization.

6.1.4 Alternative 4 – In Situ Enhanced Anaerobic Bioremediation, Monitored Natural Attenuation Polishing, and Land Use Controls, and Construction Support

Alternative 4 includes the following components:

- In situ treatment using carbon substrate to reduce TCE concentrations in groundwater
- **Monitored Natural Attenuation (MNA)**, including groundwater and surface water sampling and an assessment of contaminant trends
- LUCs, including access control, groundwater and land use restrictions, fencing and signage, safety training, and annual inspections.
- Construction Support is a specific type of LUC, which requires UXO support for all intrusive activities is included in this alternative.

Alternative 4 will involve up to two periodic injection applications of an organic carbon substrate (emulsified vegetable oil [EVO]) into the soil above the source area of the plume for the in situ treatment of TCE contaminated soil, which is the source of the groundwater contamination. Sufficient quantity of EVO will be injected to saturate the vadose zone soils and fractured bedrock down to the water table. Under this Alternative, the organic carbon solution will be introduced into the source area via a specific method through an infiltration gallery (120 feet by 60 feet), which is the same size as the source area (Figure 6-5). A second application of the carbon substrate is included in the remedy as a contingency, depending on the results of the performance groundwater monitoring.
Alternative 4 includes the installation of an upgradient extraction well to provide continual source water to trickle over the infiltration gallery and further distribute the amendment through the vadose and saturated zones after the initial amendment application in the source area. In the event that the water source well cannot provide adequate yield, water will be obtained from the Picatinny Arsenal potable water system and transported to an onsite winterized water storage tank to be used to supplement the supply of water to the remediation area. The treatment scenario for Alternative 4 was simulated using the model Biochlor®, which found that treatment will result in the reduction of TCE concentrations in a well 100 ft downgradient to the 1 µg/L standard in approximately six years. The model simulation also predicts that remediation of the TCE plume extending 1,100 ft downgradient from the source area would occur approximately 14 years after treatment is initiated in surface water receptor TCE concentrations dropping below the promulgated surface water standard in an approximate 4-year period (Appendix D).

Performance monitoring will be conducted at source area wells and select downgradient injection wells to evaluate the effectiveness of the remedy. The installation of an additional source area bedrock monitoring well is included in this Alternative to provide performance data on the groundwater in the source area after treatment. Due to the potential for encountering MEC during this remedial action, MEC construction support and MEC avoidance will be performed during the implementation of the RA. For costing purposes, it is assumed that performance monitoring will be conducted monthly for the first six months in the source area wells, and quarterly thereafter until the last application of the amendment has been completed. During this period, downgradient monitoring wells and surface water will be monitored on a semi-annual basis.

After active treatment is complete, will be conducted over a 3-year period, followed by MNA polishing for the remainder of the TCE-contaminated groundwater will be performed within the AA. Groundwater TCE concentrations are likely to rebound after active treatment in the source area, and later impact the downgradient receptors. TCE source soil concentrations are expected to leach and lose mass with time, with a consequent decrease in groundwater TCE concentrations. A 5014-year monitoring period has been assumed based upon the Alternative design and groundwater modeling, hypothetical leaching rate of TCE from source soils, as was determined in the Final 600 Area Groundwater FS (Shaw, 2013) and is included in which are included in Appendix D. After completion of performance monitoring, monitoring wells and surface water will continue to be monitored on a semiannual basis to year 10. Wells will then be sampled annually to year 20, and once every 5 years to year 50 after treatment is initiated. Note that the length of time required for the groundwater and surface water monitoring stated herein is estimated for costing purposes and may be modified once the RA is implemented on the basis of the analytical results, in collaboration with the regulators. Results of the first Five-Year Review will include a revised MNA timeframe, if needed, for the remainder of the dissolved TCE plume.

In addition, Alternative 4 will involve continuous implementation of LUCs, in particular, restrictions on groundwater use. The long-term groundwater monitoring program for this area will be used to determine whether subsequent actions are required and demonstrates continued
decreasing contaminant trends. The MNA, LUC, Construction Support, and CERCLA Five-Year Review components of this alternative are presented under Alternative 2.

For Alternative 4, if In Situ Enhanced Anaerobic Bioremediation, Monitored Natural Attenuation, MNA Polishing, and Land Use Controls, LUCs, and Construction Support are implemented and maintained, the MEC HA score will be 560, indicating a moderate hazard potential with a hazard level of 3 (Appendix E).

6.1.4.1 Description of Alternative

Alternative 4 will involve:

- One round of sampling from existing monitoring wells will be collected during the Proposed Plan phase for use in remedy selection and for pre-design purposes. The groundwater and surface water samples will be analyzed for MNA parameters and VOCs. Selective groundwater samples will also be analyzed for microbial bacteria to determine the appropriate solution for the carbon substrate, and whether or not additional bioaugmentation culture will be required for source area treatment should the data indicate limited microbial populations.

- Installation of a source area bedrock well (or nested wells) to monitor performance after treatment. The well will be advanced in the location of the former test trench.

- Installation of an upgradient extraction well to provide a water source, which will provide a slow water application, following amendment applications. The specific location of the extraction well will be determined during the remedial design, and will be placed such that it does not hydraulically influence the groundwater plume.

- Construction of an infiltration gallery (120 ft by 60 ft) to be the same size as the source area, constructed of perforated PVC piping, set in gravel.

- Dilution and application of carbon substrate and bio-augmentation (if needed)

- Low-flow water application to keep vadose zone moisture content elevated, and to promote a slow downward migration of the amendment.

For the purpose of the cost estimate, it was assumed the substrate will be EVO solution. Approximately 7,300 gallons of 19,000 pounds of sodium lactate, carbon substrate, diluted with water to make a 172,300-gallon solution, (applied in a 15 percent solution) is estimated to be required to reduce source area TCE concentrations in situ. The amendment requirement volume is based on the required quantity of EVO required to treat the mass of the existing TCE, which is estimated at 23.9 mg/kg within the source area, and enough in addition to the mass-volume of solution to saturate one effective pore volume, achieve a concentration of 500 mg/L within the targeted region. This concentration of sodium lactate amendment will stimulate microbial growth that will deplete naturally occurring electron receptors and drive the target area into increased reducing conditions (lower ORP) favorable to the sequential reductive dechlorination of TCE and its daughter products. As discussed above, Alternative 4 includes the addition of bioaugmentation should the pre-design sampling results indicate additional microbial species are required in the source area for optimal treatment of the TCE. Figure 6-4 shows the approximate
treatment zone and proposed infiltration gallery injection grid in which Alternative 4 will be applied. This treatment zone covers an area of approximately 48,720,000 square ft and corresponds to the source area of the TCE plume. Appendix D includes design criteria and the results of the groundwater modeling for this alternative.

Due to the location of the TCE source within a “Munitions Waste Pit,” in which MEC were discovered during the source area investigation, injection/monitoring wells will need to be installed outside of the boundaries of the waste pit. The sodium lactate solution will be pumped or gravity fed directly into each injection well. A total of three annual treatments will be performed to reduce TCE groundwater concentrations in the source area and later to downgradient receptors.

The first stage of this treatment will include bench scale and pilot tests to ensure the efficacy of the RA and select the most effective carbon substrates. Bench scale studies will incorporate the evaluation of multiple carbon substrates. A pilot test will then be conducted in the source area of the plume. The purpose of the pilot test is to collect site-specific geochemical and laboratory data during a small scale bioamendment application to optimize the specific quantity and types of injectants to be used during full scale treatment. The pilot study will utilize the six injection/monitoring wells installed for the pilot test, which will be used for the full-scale treatment as injection points. Selection of one well to use as the pilot injection well will be made based on observations made during installation, well yield, and number and distribution of producing fractures determined from borehole geophysics.

Design

Once an RA has been selected and the PP and ROD have been completed, a remedial design will be prepared. Prior to preparing the Proposed Plan, one round of groundwater and surface water samples will be collected from the existing site wells and wetland areas at the site for use in the remedy selection and for re-design purposes. The samples will be analyzed for VOC’s, MNA and the groundwater from select wells will also be analyzed to determine the existing microbial populations in the groundwater. The remedial design work plans will include, at a minimum, a site-specific work plan describing the remedial activities, quality assurance/quality control procedures, technical specifications, and a site health and safety plan. The design documents will be submitted for review and approval by the appropriate agencies prior to initiation of remedial activities.

The initial phase of the work will consist of the preparation of a site-specific health and safety plan. Because the remedial action will be conducted under CERCLA, the substantive requirements of the permits and permitting agencies will be followed in lieu of obtaining formal permits for required activities. The health and safety plan will outline the physical and chemical hazards associated with the work to be performed at the site and will serve as the instrument of control for ensuring the health and safety of personnel at the site.

Contractor and Material Procurement

This will include preparation of bid packages for the remedial activities, solicitation of bids, bid review, and contractor selection. Materials and equipment required to complete the remedial activities will be selected and procured.
Mobilization and Demobilization

The first phase of this alternative will include mobilization of the required personnel, equipment, and facilities to install the new source area monitoring well and upgradient source water well. After installation of the wells, the driller will be demobilized and the installation of the infiltration gallery can commence. It is anticipated that the location of the injection wells can be selected. Infiltration gallery and wells will be from currently accessible areas or and with limited site preparation requirements. Following installation of the injection wells, infiltration gallery over the source area, installation of the upgradient source water well, the source area performance monitoring well and initial and the application of the carbon round of substrate injections, all personnel, equipment, and materials will be demobilized as Subsequent treatment will be performed using the existing infiltration gallery, injection wells minimizing additional mobilization/demobilization.

6.1.5 Alternative 5 – Trichloroethene Source Material Removal, Monitored Natural Attenuation Polishing, and Land Use Controls, and Construction Support

Alternative 5 includes the following components:

- Excavation and off-site disposal of TCE-contaminated soil, carbon substrate application and removal of MEC located within the limits of the excavation
- Monitored Natural Attenuation MNA, including groundwater and surface water sampling and an assessment of contaminant trends
- LUCs, including access control, groundwater, and land use restrictions, fencing and signage, safety training, and annual inspections.
- Construction Support is a specific type of LUC that requires UXO support for all intrusive activities is included in this alternative.

This alternative entails excavation of MEC/MD and refuse that is collocated with the suspected TCE-contaminated source soils. This alternative also includes confirmatory soil sampling of the limits of excavation. MNA will be used as a polishing step upon completion of the proposed source material removal, and continue until the TCE cleanup goal (NJDEP GWQS 1 µg/L) is achieved in groundwater. Figures 6-68 and 6-67 show the approximate location of the source area to be excavated and the extent of the required sidewall cutback. During intrusive activities, UXO personnel will be on-site to assess the site for MEC/MD within the TCE-contaminated source area. All MEC/MD will be removed within the limits of excavation. However, areas outside of the excavation will still have the potential for MEC and will require construction support during intrusive activities and the implementation of LUCs, including construction support to prevent exposure to MEC as discussed in Alternative 2.

Following the excavation of collocated MEC/MD and TCE-contaminated source soil, a carbon substrate amendment (3,500 gallons) will be added to the excavation to enhance degradation of any residual contamination in the source area and the excavation will then be backfilled with clean fill to restore existing site contours. The quantity of EVO is conservatively based on 50...
percent of the quantity estimated for Alternative 4 because there is approximately 50 percent less effective pore volume under Alternative 5, as compared to Alternative 4, requiring treatment.

A 10-year monitoring period is assumed based upon the results of USEPA Bioscreen® simulations, which indicate MNA will result in TCE groundwater concentrations below the RAO in approximately 8-eight years, following TCE source removal. For the Bioscreen® simulations, TCE was treated as a conservative solute without any degradation or transformation. The simulation was run, first, using the maximum observed source area groundwater concentration (in 13MW-1) and, second, using the calculated groundwater leachate concentration calculated from the maximum detected TCE soil concentration from the source area investigation using VLEACH®. Both computations yielded an 8-eight-year timeframe to reach the TCE cleanup goal, which is the NJDEP GWQS of 1 µg/L (Shaw, 2013). Following the proposed excavation, downgradient wells and surface water will be monitored on a semi-annual basis to year five. Wells will then be sampled annually to year 10. Note that the length of time required for the groundwater and surface water monitoring stated herein is estimated for costing purposes and may be modified once the RA is implemented on the basis of the analytical results, in collaboration with the regulators. Results of the first and subsequent five-year study will include a revised MNA timeframe for the remainder of the dissolved TCE plume.

An integral element of this alternative is a combination of MNA and LUCs, which includes institutional and access restrictions, construction support public education, emergency provisions, as well as MNA of the groundwater and surface water. No active treatment will be implemented to remove contaminants from the impacted groundwater. Rather, monitoring of groundwater and surface water will verify that contaminants are being attenuated. Therefore, groundwater use restrictions must be implemented until the RAO for TCE (1 µg/L) is met to minimize risk to potential receptors.

In addition, Alternative 5 will involve continuous implementation of LUCs, in particular, restrictions on groundwater use and intrusive activities. The long-term groundwater monitoring program for this area will be used to determine whether subsequent actions were required and determine if MNA is progressing as anticipated following completion of the source remediation, if it is required. Discussions of the MNA, LUCs, construction support, and CERCLA Five-Year Review components of this alternative are presented under Alternative 2.

For Alternative 5, if Trichloroethene-TCE Source Removal, Monitored Natural Attenuation MNA Polishing, and Land Use Controls LUCs, and Construction Support are implemented and maintained, the MEC HA score will be 365, indicating a low hazard potential with a hazard level of 4 (Appendix E). This alternative has the lowest MEC HA score and achieves the lowest MEC hazard potential due to the partial removal of surface and subsurface MEC at the source area, combined with LUCs.

6.1.5.1 Description of Alternative
Alternative 5 will involve the excavation, transport, and disposal of approximately 1,334 cubic yd of TCE-contaminated soil and subsurface MEC/MD. In addition, an estimated 5,334 cubic yd of clean overburden and 11,539 cubic yd of sidewall cutback soils will need to be excavated and staged near the site in order to facilitate excavation of TCE-contaminated soil and subsurface MEC/MD. The clean overburden volume is based on the same area estimate of 120 ft by 60 ft, with a 20-ft thickness. The sidewall cutback volume was calculated based on a total excavation depth of 25 ft (which is the assumed depth to bedrock), and a sidewall slope of 1:2 (a worst-case scenario applicable to the fill material encountered at the site). The total disturbed area would be approximately 32,000 square ft² with an additional two acres needed for stockpiling, staging, and UXO sorting areas. Once the excavation is complete, carbon substrate amendment will be applied to the excavation to enhance degradation of any residual TCE in the source area. During excavation, all soil will be assessed for MEC/MD. Based on the munitions pit investigation, it is assumed that the majority of MEC/MD items will be located within a 20-to 25-ft bgs depth interval, and therefore the implementation of this alternative presents a safety hazard and risk of encountering MEC/UXO during excavation of the source area material. Assuming MEC/MD and other MD items will account for approximately 30 percent of the material from 20 to 25 ft bgs, in both the TCE-impacted soil (1,334 cubic yd) and the cutback soil (914 cubic yd), approximately 675 cubic yd of MEC/MD and other MD are anticipated at the site. The timeframe for completion of the excavation is approximately 16 weeks.

The major elements are discussed in further detail below.

**Design**

Once an RA has been selected and the PP and ROD have been completed, a remedial design will be prepared. This will include, at a minimum, a site-specific work plan describing the remedial activities, quality assurance/quality control procedures, technical specifications, a soil erosion and sedimentation control plan, and a site health and safety plan. During the design phase, NJDEP Soil Standard Guidance will be used to determine the Impact to Ground Water Soil Remediation Standard to be used during soil excavation. The design documents will be submitted for review and approval by the appropriate agencies prior to initiation of remedial activities.

The initial phase of the work will consist of the preparation of a site-specific health and safety plan. Because the remedial action will be conducted under CERCLA, the substantive requirements of the permits, and permitting agencies, will be followed in lieu of obtaining formal permits for required activities. The health and safety plan and Explosives Safety Submission (ESS) will outline the physical and chemical hazards associated with the work to be performed at the site and will serve as the instrument of control for ensuring the health and safety of personnel at the site. The health and safety plan will also outline the air monitoring program that will be implemented during the excavation activities to ensure that a safe working environment is maintained. The health and safety plan will provide the action levels that will dictate the need for implementation of dust controls at the site.
Critical design elements and considerations will include work plan preparation, ESS, development of waste excavation and handling procedures, development of MEC/MD handling procedures, and design of erosion and sedimentation controls. Because this action will be performed under CERCLA, Picatinny is only required to file State and local permit equivalents. Permit equivalents will be filed for a stormwater permit. Preparation of a Soil Erosion and Sedimentation Control Plan will also be required.

**Contractor and Material Procurement**

This will include preparation of bid packages for the remedial activities, solicitation of bids, bid review, and contractor selection. Materials and equipment required to complete the remedial activities will also be selected and procured.

**Mobilization and Site Preparation**

The first phase of this alternative will include mobilization of the required personnel, equipment, and facilities. Following mobilization, site preparation will occur. During the site preparation task, a small equipment decontamination area will be constructed to allow for the decontamination of equipment used on-site during construction activities. Liquids generated during decontamination activities will be collected, sampled, analyzed, and disposed of at an appropriate permitted facility. Material and waste staging areas will also be constructed during the site preparation phase to provide an area for storage of soils, MEC, MD, materials, and miscellaneous equipment used during site activities. A “clean” access road may also be required to allow trucks hauling clean backfill and waste materials to enter and exit without requiring decontamination.

Prior to the commencement of site clearing activities, the soil and sediment and erosion controls that are required to meet applicable local, State, and Federal guidelines will be installed. These soil and sediment controls will be properly maintained during contaminated soil and sediment excavation, and will be removed once the disturbed areas have been restabilized. As required, the controls will consist of installation of silt fence, straw bale barriers, and diversion berms, as well as construction of a stabilized entrance through which vehicles will enter and exit the site. Erosion and sedimentation controls will be detailed in the site-specific Soil Erosion and Sedimentation Control Plan.

**Contaminated Soil Excavation, Disposal, and Confirmatory Sampling**

Contaminated soil will be excavated using an armored excavator with a minimum reach of 40 ft. All excavated soil to be transported to off-site landfills (RCRA Subtitle C or D) will be screened by a separate team of UXO Technicians and certified as safe prior to being loaded into dump trucks and transported off-site. Multiple landfills permitted to accept contaminated soils are located within a reasonable distance from the site (less than 60 miles). Additional details on MEC support are provided in the section below. Waste characterization samples will be collected and analyzed to ensure proper disposal of the excavated source area material. Standard dust control techniques will be used during the excavation activities to mitigate the potential for release of contaminated dust. Visual observations and confirmatory sampling will be used to determine the limits of the excavation. For cost purposes, confirmatory samples will be collected.
for every 30 ft of each excavation sidewall and 900 square ft of each excavation bottom, which
would be considered representative of post-excitation conditions. However, bedrock will likely
be encountered at the base of the excavation in some areas, which will reduce the number of
collection samples collected from the bottom of excavation. Sample locations will be biased
toward locations and depths of the highest expected contamination, utilizing an organic vapor
analyzer as a field indicator.— Samples will be analyzed for VOCs. Details regarding the
confirmation sampling would be included in the Remedial Action Work Plan. Confirmation
samples will be collected for every 30 ft of each excavation sidewall and 900 square ft of each
evacuation bottom. Sample locations will be biased toward locations and depths of the highest
expected contamination, utilizing an organic vapor analyzer and field indicators. Samples will
be analyzed for VOCs. The excavation of contaminated soil will comply with the NJDEP
Technical Requirements for Site Remediation set forth in New Jersey Administrative Code
40:42A.

Munitions and Explosives of Concern Support

Based on the findings of the source area investigation and past site use, MEC support will be
required for intrusive activities. The purpose of MEC support is to reduce the potential for
exposure to MEC and eliminate the potential for MEC to be transported off-site. All MEC
support activities will be conducted in accordance with Engineer Manual 385-1-97 and DoD
6055.09-M Volume 7. The type of MEC support required at the site will be dependent on the
likelihood of encountering MEC/MD.

In areas where the MEC/MD are not likely (i.e., clean overburden), construction support
activities will be required. This will consist of having two UXO Technicians visually observe
the excavation. Armoring and shielding will take place prior to excavation. Additional details
on the armoring and shielding requirements will be provided in the ESS. Excavation will
proceed in six-inch lifts such that debris will be observed if present. A UXO team will perform
the construction support activities. Prior to non-intrusive activities (i.e., clearing, grubbing, and
sampling), the UXO team will perform a visual survey of the site and identify any MEC/
MPPEH items. One UXO team member will be located to the rear and upwind of the excavation
equipment and visually observe excavation. If debris is observed or once the excavation
approaches within 2 ft of where the debris is anticipated, the construction support process will be
terminated and soil screening will commence. Soil screening will require a team consisting of
UXO Technicians. Soil screening will continue for the areas saturated with debris (i.e., vehicles,
drums, MEC, MPPEH, etc.).

During the soil removal, a spread and scan method will be used to screen and sort any MEC in
the soil and excavated debris. 1) A surface clearance would be done prior to any removal. 2) An
armored excavator would remove a six-inch lift of soil, which would then be spread out for
examination. The thickness of the layer would be smaller than the most probable MEC item. 3)
The UXO Team will then manually inspect, remove, and clear the soil for any MEC/debris. 4)
The cleared soil would then be removed by a loader and stockpiled for disposal. 5) The
process would repeat every six inches in depth until soil is excavated and cleared. All details of
operations have begun. Essential personnel and the UXO team will be allowed within the EZ once the demolition site.

During demolition activities, the SUXOS/UXO Tech will schedule the demolition to allow sufficient time to complete all notifications, approvals, and evacuations as required. If an item is safe to move, the item may be relocated for disposal due to safety concerns or to consolidate sh

Demolition will be conducted through BIP operations or consolidated shots. If an item is to be removed in 6-inch lifts. These soils will be visually inspected and all MEC/MPEH will be removed. The debris will be separated into bins based on the type of debris. MPPEH will be placed in a lockable container for further certification. MEC will be placed in a container (i.e., wooden box) with packing material or sand to prevent movement, pending transport to the consolidation area for future disposal or into the MEC storage areas. MEC determined unsafe to handle will be BIP in accordance with the approved Explosives Staging Plan (ESP) and/or ESS. Non-munitions related scrap metal will be segregated into hazardous and non-hazardous waste bins for appropriate off-site disposal. During disposal operations, a UXO Safety Officer will be present to ensure compliance with operations as outlined in Engineer Manual 385-1-97.

Exclusion zones (EZs) will be established, implemented, and enforced during intrusive activities. The size of the EZ will be determined by the size and type of MEC expected at the site. EZ distances could potentially encompass on-post facilities, including roads and buildings, which could result in the restriction of some activities and workspace at PICA during implementation of this RA. Additional details on the EZ required for intrusive activities will be presented in the site-specific ESS.

Munitions and Explosives of Concern/Munitions Debris Identification and Handling

UXO Technicians will make every effort to identify MEC through visual examination of items for markings and other identifying features such as shape, size, and external fittings. All MEC and MD identified at the site will be carefully cataloged and the location accurately recorded. Items will not be moved during the inspection/identification until the nature and condition of the item can be ascertained.

The Senior UXO Supervisor/Specialist (SUXOS) or UXO Technician II and the UXO Quality Control Specialist (UXOQCS) will agree on the positive identification and disposition of the item prior to implementing any disposal operations. All MEC disposal activities will be performed in accordance with Engineer Manual-385-1-97 (USACE, 2008) in addition to Federal, State, and local regulations. All MEC will be subjected to demolition procedures. Demolition will be conducted through BIP operations or consolidated shots. If an item is to be moved, the item may be relocated for disposal due to safety concerns or to consolidate shots. Prior to any detonation, a pre-established notification procedure will be initiated. As soon as it is determined that a detonation will be required, the SUXOS will initiate this procedure. The SUXOS/UXO Technician III will schedule the demolition to allow sufficient time to complete all notifications, approvals, and evacuations as required.

During demolition activities, the SUXOS/UXO Technician III will maintain overall control of the site. An EZ will be established around the demolition area according to the ESS. Only essential personnel and the UXO team will be allowed within the EZ once the demolition operations have begun. The SUXOS will ensure safe work practices are observed, and the UXO
Team Leader will perform the necessary steps to safely dispose of the MEC item. Additional details on MEC demolition procedures will be provided in the site-specific work plan and ESS.

**Investigation-Derived Waste Disposal**

All recovered material (i.e., MD or other debris) will be considered MPPEH and removed from the site. The contractor will ensure that all recovered MPPEH is free of explosive hazards and certified as materials documented as safe (MDAS) through inspection by qualified UXO Technicians in accordance with procedures in Engineer Manual 385-1-97 and DoD 6055.9M, Volume 7 Enclosure 6. Because the MPPEH recovered and certified as MDAS will ultimately be treated as solid waste and disposed off-site, it is imperative that procedures be established to preclude live ordnance from becoming intermingled with the certified MDAS. The MPPEH inspection process will be designed to ensure that all such material is 100 percent inspected by a UXO Technician II and verified by a UXO Technician III and then 100 percent independently re-inspected by a UXO Technician III with the process validated by inspection by a UXO Safety Officer or UXOQCS as part of the certification and verification process. Additional details on MPPEH management will be provided in the site-specific work plan.

**Backfill and Restoration**

The excavated areas will be backfilled as soon as practicable with clean fill from an approved off-post source and clean overburden and sidewall cutback soil. The excavated areas will be restored to the original contours. Run-off collection and retention will be considered during the design phase to comply with all location- and action-specific ARARs.

**Site Cleanup and Demobilization**

The final phase of the work will involve site cleanup and demobilization of all personnel, facilities, and equipment.

### 6.1.6 Alternative 6 – Total Munitions Waste Pit Removal, Trichloroethene Source Material Removal, Monitored Natural Attenuation Polishing, and Land Use Controls, and Construction Support

Alternative 6 includes the following components:

- Excavation and off-site disposal of TCE-contaminated soil, and MEC removal -within the entire Munitions Waste Pit
- **Monitored Natural Attenuation (MNA)**, including groundwater and surface water sampling and an assessment of contaminant trends
- LUCs, including access control, groundwater, and land use restrictions, fencing and signage, safety training, and annual inspections.
- Construction Support, a specific type of LUC, which requires UXO support for all intrusive activities, is included in this alternative.
This alternative entails excavation of the entire 0.24-acre Inactive Munitions Waste Pit, including the suspected TCE-contaminated source soils, with confirmatory soil sampling of the limits of excavation. MNA will be used as a polishing step upon completion of the proposed source material removal, and continue until the TCE cleanup goal (NJDEP GWQS 1 µg/L) is achieved in groundwater. Figures 6-78 and 6-810 show the approximate location of the source area to be excavated and the extent of the required sidewall cutback. UXO personnel will be on-site to assess the site for MEC/MD during excavation activities. All MEC/MD will be removed within the limits of excavation. However, MEC/MD is still potentially present in the remaining uncleared areas of the MRS (20.76 acres) and the implementation of LUCs, including construction support is necessary to prevent exposure to MEC as discussed in Alternative 2.

Following the excavation of waste pit and the collocated TCE-contaminated source soil, the excavation will be backfilled with clean fill to restore existing site contours.

A 10-year monitoring period is assumed based upon the results of USEPA Bioscreen simulations, which indicate that MNA will result in TCE groundwater concentrations below the RAO in approximately eight years, following TCE source removal. For the Bioscreen simulations, TCE was treated as a conservative solute without any degradation or transformation. The simulation was run, first, using the maximum observed source area groundwater concentration (in 13MW-1) and, second, using the calculated groundwater leachate concentration calculated from the maximum detected TCE soil concentration from the source area investigation using VLEACH®. Both computations yielded an eight-year timeframe to reach the TCE cleanup goal, which is the NJDEP GWQS of 1 µg/L (Appendix D). Following the proposed excavation, downgradient wells and surface water will be monitored on a semi-annual basis to year five. Wells will then be sampled annually to year 10. Note that the length of time required for the groundwater and surface water monitoring stated herein is estimated for costing purposes and may be modified once the RA is implemented on the basis of the analytical results, in collaboration with the regulators. Results of the first and subsequent five-year study will include a revised MNA timeframe for the remainder of the dissolved TCE plume.

An integral element of this alternative is a combination of MNA and LUCs, which includes institutional and access restrictions, construction support public education, emergency provisions, as well as MNA of the groundwater and surface water. No active treatment will be implemented to remove contaminants from the impacted groundwater. Rather, monitoring of groundwater and surface water will verify that contaminants are being attenuated. Therefore, groundwater use restrictions must be implemented until the RAO for TCE (1 µg/L) is met to minimize risk to potential receptors.

In addition, Alternative 6 will involve continuous implementation of LUCs and construction support, in particular restrictions on groundwater use and intrusive activities. The long-term groundwater monitoring program for this area will be used to determine whether subsequent actions were required and determine if MNA is progressing as anticipated following completion of the source remediation, if it is required. Discussions of the MNA, LUCs, construction support and CERCLA Five-Year Review components of this alternative are presented under Alternative 2.
For Alternative 6, if Total Munitions Waste Pit Removal, Trichloroethene (TCE) Source Material Removal, Monitored Natural Attenuation (MNA) Polishing, and Land Use Controls (LUCs), and Construction Support are implemented and maintained, the MEC HA score will be 365, indicating a low hazard potential with a hazard level of 4 (Appendix E). This alternative has the lowest score and achieves the lowest hazard potential.

6.1.6.1 Description of Alternative

Alternative 6 will involve the excavation of the entire Inactive Munitions Waste Pit (0.24 acres) (approximately 9,526 cubic yd), including transport and disposal of approximately 1,334 cubic yd of TCE-contaminated soil. In addition, an estimated 16,200 cubic yd of clean overburden and sidewall cutback soils and stockpiled gravel and debris will need to be excavated and staged near the site in order to facilitate excavation of TCE-contaminated soil. The total disturbed area would be approximately 42,000 square ft with an additional two acres needed for stockpiling, staging and UXO sorting areas. During excavation, all soil will be assessed for MEC/MD. It is assumed that the majority of MEC/MD items will be located within the waste pit itself at a depth of 20- to 25 ft and not in the cutback material. Assuming MEC/MD/other debris items will account for approximately 30 percent of the Munitions Waste Pit volume, approximately 2,857 cubic yd of MEC/MD/other debris are anticipated at the site. The timeframe for completion of the excavation is approximately 18 weeks.

The major elements are discussed in further detail below.

Design

Once an RA has been selected and the PP and ROD have been completed, a remedial design will be prepared. This will include, at a minimum, a site-specific work plan describing the remedial activities, quality assurance/quality control procedures, technical specifications, a soil erosion and sedimentation control plan, and a site health and safety plan. During the design phase, NJDEP Soil Standard Guidance will be used to determine the Impact to Groundwater Soil Remediation Standard to be used during soil excavation. The design documents will be submitted for review and approval by the appropriate agencies prior to initiation of remedial activities.

The initial phase of the work will consist of the preparation of a site-specific health and safety plan. Because the remedial action will be conducted under CERCLA, the substantive requirements of the permits, and permitting agencies, will be followed in lieu of obtaining formal permits for required activities. The health and safety plan and ES will outline the physical and chemical hazards associated with the work to be performed at the site and will serve as the instrument of control for ensuring the health and safety of personnel at the site. The health and safety plan will also outline the air monitoring program that will be implemented during the excavation activities to ensure that a safe working environment is maintained. The health and safety plan will provide the action levels that will dictate the need for implementation of dust controls at the site.
Critical design elements and considerations will include work plan preparation, ESS, development of waste excavation and handling procedures, development of MEC/MD handling procedures, and design of erosion and sedimentation controls. Because this action will be performed under CERCLA, PICA is only required to file state and local permit equivalents. Permit equivalents will be filed for a stormwater permit. Preparation of a Soil Erosion and Sedimentation Control Plan will also be required.

**Contractor and Material Procurement**

This will include preparation of bid packages for the remedial activities, solicitation of bids, bid review, and contractor selection. Materials and equipment required to complete the remedial activities will also be selected and procured.

**Mobilization and Site Preparation**

The first phase of this alternative will include mobilization of the required personnel, equipment, and facilities. Following mobilization, site preparation will occur. During the site preparation task, a small equipment decontamination area will be constructed to allow for the decontamination of equipment used on-site during construction activities. Liquids generated during decontamination activities will be collected, sampled, analyzed, and disposed of at an appropriate permitted facility. Material and waste staging areas will also be constructed during the site preparation phase to provide an area for storage of soils, MEC, MD, materials, and miscellaneous equipment used during site activities. A “clean” access road may also be required to allow trucks hauling clean backfill and waste materials to enter and exit without requiring decontamination.

Prior to the commencement of site clearing activities, the soil and sediment and erosion controls that are required to meet applicable local, state, and federal guidelines will be installed. These soil and sediment controls will be properly maintained during contaminated soil and sediment excavation, and will be removed once the disturbed areas have been restabilized. As required, the controls will consist of installation of silt fence, straw bale barriers, and diversion berms, as well as construction of a stabilized entrance through which vehicles will enter and exit the site. Erosion and sedimentation controls will be detailed in the site-specific Soil Erosion and Sedimentation Control Plan.

**Contaminated Soil Excavation, Disposal and Confirmatory Sampling**

Contaminated soil will be excavated using an armored excavator with a minimum reach of 40 ft. All excavated soil to be transported to off-site landfills (RCRA Subtitle C or D) will be screened by a separate team of UXO Technicians and certified as safe prior to being loaded into dump trucks and transported off-site. Multiple landfills permitted to accept contaminated soils are located within a reasonable distance from the site (less than 60 miles). Additional details on MEC support are provided in the section below. Waste characterization samples will be collected and analyzed to ensure proper disposal. Standard dust control techniques will be used during the excavation activities to mitigate the potential for release of contaminated dust. Visual observations and confirmatory sampling will be used to determine the limits of the excavation.
For cost purposes, confirmatory samples will be collected for every 30 ft of each excavation sidewall and every 900 square ft of each excavation bottom, which would be considered representative of post-excavation conditions. However, bedrock will likely be encountered at the base of the excavation in some areas, which will reduce the number of confirmation samples collected from the bottom of excavation. Sample locations will be biased toward locations and depths of the highest expected contamination, utilizing an organic vapor analyzer as a field indicator. Samples will be analyzed for VOCs. Details regarding the confirmatory sampling would be included in the Remedial Action Work Plan.

Confirmatory samples will be collected for every 30 ft of each excavation sidewall and 900 square ft of each excavation bottom. Sample locations will be biased toward locations and depths of the highest expected contamination, utilizing an organic vapor analyzer and field indicators. Samples will be analyzed for VOCs. The excavation of contaminated soil will comply with the NJDEP Technical Requirements for Site Remediation set forth in New Jersey Administrative Code 7:26E.

Munitions and Explosives of Concern Support

Based on the findings of the source area investigation and past site use, MEC support will be required for intrusive activities. The purpose of MEC support is to reduce the potential for exposure to MEC and eliminate the potential for MEC to be transported off-site. All MEC support activities will be conducted in accordance with Engineer Manual 385-1-97 and DoD 6055.09-M Volume 7. The type of MEC support required at the site will be dependent on the likelihood of encountering MEC/MD.

In areas where the MEC/MD are not likely (i.e., clean overburden), construction support activities will be required. This will consist of having two UXO Technicians visually observe the excavation. Armoring and shielding will take place prior to excavation. Additional details on the armoring and shielding requirements will be provided in the ESS. Excavation will proceed in six-inch lifts such that debris will be observed if present. A UXO team will perform the construction support activities. Prior to non-intrusive activities (i.e., clearing, grubbing, and sampling), the UXO team will perform a visual survey of the site and identify any MEC/MPPEH items. One UXO team member will be located to the rear and upwind of the excavation equipment and will visually observe excavation.

If debris is observed or once the excavation approaches 2 ft of where the debris is anticipated, the construction support process will be terminated and soil screening will commence. Soil screening will require a team consisting of UXO Technicians. Soil screening will continue for the areas saturated with debris (i.e., vehicles, drums, MEC, MPPEH, etc.).

During the soil removal phase, a spread and scan method will be used to screen and sort any MEC in the soil and excavated debris. 1) A surface clearance would be done prior to any removal. 2) An armored excavator would remove a six-inch lift of soil, which would then be spread out for examination. The thickness of the layer would be smaller than the most probable MEC item. 3) The UXO Team will then manually inspects, remove and clear the soil for any MEC/debris. 4) The cleared soil will then be removed by a loader and stockpiled for
disposal. 5) The process would repeat every six inches in depth until soil is excavated and cleared. All details of the spread and scan method will be detailed in the Remedial Action WP and in the ESS amendment.

All material will be removed in 6-inch lifts. These soils will be visually inspected and all MEC/MPPEH will be removed. The debris will be separated into bins based on the type of debris. MPPEH will be placed in a lockable container for further certification. MEC will be placed in a container (i.e., wooden box) with packing material or sand to prevent movement, pending transport to the consolidation area for future disposal or into the MEC storage areas. MEC determined unsafe to handle will be BIP in accordance with the approved Explosive Safety Plan ESP and/or ESS. Non-munitions related scrap metal will be segregated into hazardous and non-hazardous waste bins for appropriate off-site disposal. During disposal operations a UXO Safety Officer will be present to ensure compliance with operations as outlined in Engineer Manual 385-1-97. EZs will be established, implemented, and enforced during intrusive activities. The size of the EZ will be determined by the size and type of MEC expected at the site. EZ distances could potentially encompass on-post facilities, including roads and buildings, which could result in the restriction of some activities and workspace at PICA during implementation of this RA. Additional details on the EZ required for intrusive activities will be presented in the site-specific ESS.

Munitions and Explosives of Concern/Munitions Debris Identification and Handling

UXO Technicians will make every effort to identify MEC through visual examination of items for markings and other identifying features such as shape, size, and external fittings. All MEC and MD identified at the site will be carefully cataloged and the location accurately recorded. Items will not be moved during the inspection/identification until the nature and condition of the item can be ascertained.

The SUXOS or UXO Technician III and the UXOQCS will agree on the positive identification and disposition of the item prior to implementing any disposal operations. All MEC disposal activities will be performed in accordance with Engineer Manual-385-1-97 (USACE, 2008) in addition to Federal, State, and local regulations. All MEC will be subjected to demolition procedures. Demolition will be conducted through BIP operations or consolidated shots. If an item is safe to move, the item may be relocated for disposal due to safety concerns or to consolidate shots. Prior to any detonation, a pre-established notification procedure will be initiated. As soon as it is determined that a detonation will be required, the SUXOS will initiate this procedure. The SUXOS/UXO Technician III will schedule the demolition to allow sufficient time to complete all notifications, approvals, and evacuations as required.

During demolition operations, the SUXOS/UXO Technician III will maintain overall control of the site. An EZ will be established around the demolition area according to the ESS. Only essential personnel and the UXO team will be allowed within the EZ once the demolition operations have begun. The SUXOS will ensure safe work practices are observed, and the UXO...
Team Leader will perform the necessary steps to safely dispose of the MEC item. Additional details on MEC demolition procedures will be provided in the site-specific work plan and ESS.

**Investigation-Derived Waste Disposal**

All recovered material (i.e., MD or other debris) will be considered MPPEH and removed from the site. The contractor will ensure that all recovered MPPEH is free of explosive hazards and certified as MDAS through inspection by qualified UXO Technicians in accordance with procedures in Engineer Manual 385-1-97 and DoD 6055.9M, Volume 7 Enclosure 6. Because the MPPEH recovered and certified as MDAS will ultimately be treated as solid waste and disposed off-site, it is imperative that procedures be established to preclude live ordnance from becoming intermingled with the certified MDAS. The MPPEH inspection process will be designed to ensure that all such material is 100 percent inspected by a UXO Technician II and verified by a UXO Technician III and then 100 percent independently re-inspected by a UXO Technician III with the process validated by inspection by a UXO Safety Officer or UXOQCS as part of the certification and verification process. Additional details on MPPEH management will be provided in the site-specific work plan.

**Backfill and Restoration**

The excavated areas will be backfilled as soon as practicable with clean fill from an approved off-post source and clean overburden and sidewall cutback soil. The excavated areas will be restored to the original contours. Run-off collection and retention will be considered during the design phase to comply with all location- and action-specific ARARs.

**Site Cleanup and Demobilization**

The final phase of the work will involve site cleanup and demobilization of all personnel, facilities, and equipment.

### 6.1.7 Alternative 7 – Total Munitions Waste Pit Removal, Trichloroethene Source Material Removal, Monitored Natural Attenuation Polishing, Land Use Controls, and Munitions and Explosives of Concern Clearance of Entire Munitions Response Site

Alternative 7 includes the following components:

- Excavation and off-site disposal of TCE-contaminated soil, and MEC removal within the entire Munitions Waste Pit.
- MEC removal from the entire Munitions Response Site MRS.
- Monitored Natural Attenuation MNA, including groundwater and surface water sampling and an assessment of contaminant trends.
- LUCs, including access control, groundwater, and land use restrictions, fencing and signage, safety training, and annual inspections.
- Excavation of the entire 0.24-acre Inactive Munitions Waste Pit, including suspected TCE-contaminated source soils, and confirmatory sampling of the limits of excavation is proposed in
this alternative. This alternative also includes MEC clearance of the remaining 20.76-acre MRS.

The extent of the entire waste pit has been based on the final delineation of the “Munitions Waste Pit,” by WESTON in the MMRP RI. MNA polishing and groundwater monitoring will be implemented upon completion of the proposed Munitions Waste Pit removal, and continue until the TCE cleanup goal (NJDEP GWQS 1 µg/L) is achieved in groundwater. Figure 6-8-2 shows the approximate location of the total area to be excavated, as well as the extent of the required sidewall cutback. During intrusive activities, UXO personnel will be on-site to assess the site for MEC/MD. Following excavation of the waste pit, the excavation will be backfilled with clean fill to restore existing site contours.

A 10-year monitoring period is assumed based upon the results of USEPA Bioscreen® simulations that indicate MNA will result in TCE groundwater concentrations below the RAO in approximately eight years, following TCE source removal. For the Bioscreen® simulations, TCE was treated as a conservative solute without any degradation or transformation. The simulation was run, first, using the maximum observed source area groundwater concentration (in 13MW-1) and, second, using the calculated groundwater leachate concentration calculated from the maximum detected TCE soil concentration, from the source area investigation, using VLEACH. Both computations yielded an eight-year timeframe to reach the TCE cleanup goal (NJDEP GWQS 1 µg/L) (Shaw, 2013). Following the proposed excavation, downgradient wells and surface water will be monitored on a semi-annual basis to year five. Wells will then be sampled annually to year 10. Note that the length of time required for the groundwater and surface water monitoring stated herein is estimated for costing purposes and may be modified once the RA is implemented on the basis of the analytical results, in collaboration with the regulators. Results of the first and subsequent five-year study will include a revised MNA timeframe for the remainder of the dissolved TCE plume.

An integral element of this alternative is a combination of MNA and LUCs, which includes institutional and access restrictions, public education, emergency provisions, as well as MNA of the groundwater and surface water. No active treatment will be implemented to remove contaminants from the impacted groundwater. Rather, monitoring of groundwater and surface water will verify that contaminants are being attenuated. Therefore, LUCs must be implemented until the TCE cleanup goal (NJDEP GWQS 1 µg/L) is met to minimize risk to potential receptors.

In addition, Alternative 7 will involve continuous implementation of LUCs, in particular, restrictions on groundwater use. The long-term groundwater monitoring program for this area will be used to determine whether subsequent actions were required and determine if MNA is progressing as anticipated following completion of the source remediation, if it is required. The MNA, LUCs, and CERCLA Five-Year Review components of this alternative are presented under Alternative 2. Because the entire MRS will be cleared of MEC to a level where the risk of encountering MEC is negligible; MEC-related LUCs are included for ten years and five-year reviews are proposed for two review periods to document that the remedy remains protective in regards to explosive hazards. After the two - five-year periods, the need for new construction support or LUCs associated with limiting exposure to MEC hazards would no longer be required, are required after remedial actions are completed. Implementation of Alternative 7 will achieve
the unlimited use/unrestricted exposure (UU/UE) after TCE concentrations in groundwater are below cleanup goals.

For Alternative 7, if Total Munitions Waste Pit Removal, **Trichloroethene TCE Source Material Removal, Monitored Natural Attenuation MNA Polishing, Land Use Controls LUCs**, and **Munitions and Explosives of Concern MEC Clearance of Entire Munitions Response Site MRS** are implemented, the MEC HA score will be 430, indicating a low hazard potential with a hazard level of 4 (*Appendix E*). This alternative achieves the lowest hazard potential.

### 6.1.7.1 Description of Alternative

Alternative 7 will involve the excavation of the entire Inactive Munitions Waste Pit (0.24 acres) (approximately 9,526 cubic yd), including transport and disposal of approximately 1,334 cubic yd of TCE-contaminated soil. In addition, an estimated 16,200 cubic yd of clean overburden and sidewall cutback soils will need to be excavated and staged near the site in order to facilitate excavation of TCE-contaminated soil. **This volume includes a large quantity of stockpiled soils and debris present at the site above the proposed excavation and cutback area.** The total disturbed area would be approximately 42,000 square ft with an additional two acres needed for stockpiling, staging, and UXO sorting areas. During excavation, all soil will be assessed for MEC/MD. It is assumed that the majority of MEC/MD items will be located within the waste pit at a depth of 20- to 25 ft. Assuming MEC/MD/other debris items will account for approximately 30 percent of the Munitions Waste Pit volume, approximately 2,857 cubic yd of MEC/MD/other debris is anticipated at the site. The timeframe for completion of the excavation is approximately 38 weeks.

Clearance of the remaining 20.76 acres will be accomplished through an instrument assisted surface clearance, followed by vegetation removal, and intrusive investigation of all anomalies (mag and dig).

The major elements are discussed in further detail below.

### Design

Once an RA has been selected and the PP and ROD have been completed, a remedial design will be prepared. This will include, at a minimum, a site-specific work plan describing the remedial activities, quality assurance/quality control procedures, technical specifications, a soil erosion and sedimentation control plan, and a site health and safety plan. During the design phase, **NJDEP Soil Standard Guidance will be used to determine the Impact to Ground Water Soil Remediation Standard to be used during soil excavation.** The design documents will be submitted for review and approval by the appropriate agencies prior to initiation of remedial activities. The initial phase of the work will consist of preparation of a site-specific health and safety plan. Because the remedial action will be conducted under CERCLA, the substantive requirements of the permits and permitting agencies will be followed in lieu of obtaining formal permits for required activities. The health and safety plan and ESS will outline the physical and chemical hazards associated with the work to be performed at the site and will serve as the
instrument of control for ensuring the health and safety of personnel at the site. The health and safety plan will also outline the air monitoring program that will be implemented during the excavation activities to ensure that a safe working environment is maintained. The health and safety plan will provide the action levels that will dictate the need for implementation of dust controls at the site.

Critical design elements and considerations will include work plan preparation, ESS, development of waste excavation and handling procedures, development of MEC/MD handling procedures, and design of erosion and sedimentation controls. Because this action will be performed under CERCLA, PICA is only required to file State and local permit equivalents. Permit equivalents will be filed for a stormwater permit. Preparation of a Soil Erosion and Sedimentation Control Plan will also be required.

Contractor and Material Procurement

This will include preparation of bid packages for the remedial activities, solicitation of bids, bid review, and contractor selection. Materials and equipment required to complete the remedial activities will also be selected and procured.

Mobilization and Site Preparation

The first phase of this alternative will include mobilization of the required personnel, equipment, and facilities. Following mobilization, site preparation will occur. During the site preparation task, a small equipment decontamination area will be constructed to allow for the decontamination of equipment used on-site during construction activities. Liquids generated during decontamination activities will be collected, sampled, analyzed, and disposed of at an appropriate permitted facility. Material and waste staging areas will also be constructed during the site preparation phase to provide an area for storage of soils, MEC, MD, materials, and miscellaneous equipment used during site activities. A “clean” access road may also be required to allow trucks hauling clean backfill and waste materials to enter and exit without requiring decontamination.

Prior to the commencement of site clearing activities, the soil and sediment and erosion controls that are required to meet applicable local, State, and Federal guidelines will be installed. These soil and sediment controls will be properly maintained during contaminated soil and sediment excavation, and will be removed once the disturbed areas have been restabilized. As required, the controls will consist of installation of silt fence, straw bale barriers, and diversion berms, as well as construction of a stabilized entrance through which vehicles will enter and exit the site. Erosion and sedimentation controls will be detailed in the site-specific Soil Erosion and Sedimentation Control Plan.

Contaminated Soil Excavation, Disposal, and Confirmatory Sampling

Contaminated soil will be excavated using an armored excavator with a minimum reach of 40 ft bgs. All excavated soil to be transported to off-site landfills (RCRA Subtitle C or D) will be screened by a separate team of UXO Technicians and certified as safe prior to being loaded into dump trucks and transported off-site. Multiple landfills permitted to accept contaminated soils.
are located within a reasonable distance from the site (less than 60 miles). Additional details on MEC support are provided in the section below. Waste characterization samples will be collected and analyzed to ensure proper disposal. Standard dust control techniques will be used during the excavation activities to mitigate the potential for release of contaminated dust. Visual observations and confirmatory sampling will be used to determine the limits of the excavation.

For cost purposes, confirmatory samples will be collected for every 30 ft of each excavation sidewall and 900 square ft of each excavation bottom, which would be considered representative of post-extraction conditions. However, bedrock will likely be encountered at the base of the excavation in some areas, which will reduce the number of confirmatory samples collected from the bottom of excavation. Sample locations will be biased toward locations and depths of the highest expected contamination, utilizing an organic vapor analyzer as a field indicator. If the field screening indicates that contaminated soils exceeding action limits are present, then additional soils would be removed until field screening results are below action levels. Samples will be analyzed for VOCs. Details regarding the confirmatory sampling would be included in the Remedial Action Work Plan. Confirmatory samples will be collected for every 30 ft of each excavation sidewall and 900 square ft of each excavation bottom. Sample locations will be biased toward locations and depths of the highest expected contamination, utilizing an organic vapor analyzer and field indicators. Samples will be analyzed for VOCs. The excavation of contaminated soil will comply with NJDEP Technical Requirements for Site Remediation set forth in New Jersey Administrative Code 7:26E.

Munitions and Explosives of Concern Support

Based on the findings of the source area investigation and past site use, MEC support will be required for intrusive activities. The purpose of MEC support is to reduce the potential for exposure to MEC and eliminate the potential for MEC to be transported off-site. All MEC support activities will be conducted in accordance with Engineering Pamphlet 75-1-2 (USACE, 2004) and DoD 6055.09-M. The type of MEC support required at the site will be dependent on the likelihood of encountering MEC/MD.

Prior to non-intrusive activities (i.e., clearing and grubbing), the UXO team will perform a visual survey of the site and identify and remove any MEC/MD items. For activities where the MEC/MD are not likely (i.e., clean overburden and cutback area), construction support activities will be required. This will consist of having two UXO Technicians visually observe the excavation.

One UXO team member will be located to the rear and upwind of the excavation equipment and will visually observe excavation. Excavation will proceed in six-inch lifts such that debris will be observed if present. A UXO team, consisting of UXO-qualified personnel, will perform the construction support activities. If debris is observed or once the excavation approaches within 2 ft of where the debris is anticipated, the construction support process will be terminated and soil screening will commence. Armoring and shielding will take place prior to further excavation. Additional details on the armoring and shielding requirements will be provided in the ESS.
This will continue for the activities in areas saturated with debris (i.e., vehicles, drums, MEC, MD, etc.).

In areas where the MEC/MD are not likely (i.e., clean overburden and cutback area), construction support activities will be required. This will consist of having two UXO Technicians visually observe the excavation. Armoring and shielding will take place prior to excavation.

Additional details on the armoring and shielding requirements will be provided in the ESS. Excavation will proceed in 6-inch lifts such that debris will be observed if present. A UXO team, consisting of UXO-qualified personnel, will perform the construction support activities. All material will be removed in 6-inch lifts. These soils will be visually inspected and all MEC/MD will be removed.

During the soil removal phase, a spread and scan method will be used to screen and sort any MEC in the soil and excavated debris. 1) A surface clearance would be done prior to any removal. 2) An armored excavator would remove a six-inch lift of soil which would then be spread out for examination. The thickness of the layer would be smaller than the most probable MEC item. 3) The UXO Team will then manually inspect, remove and clear the soil for any MEC/debris. 4) The cleared soil would then be removed by a loader and stockpiled for disposal. 5) The process would repeat every six inches in depth until soil is excavated and cleared. All details of the spread and scan method will be detailed in the Remedial Action WP and in the ESS amendment.

The debris will be separated into bins based on the type of debris. MD will be placed in a lockable container for further certification. MEC will be placed in a bin pending transport to the consolidation area for future disposal. Non-MD will be segregated into hazardous and non-hazardous waste bins for appropriate off-site disposal.

An EZ will be established, implemented, and enforced during intrusive activities. The size of the EZ will be determined by the size and type of MEC expected at the site. EZ distances could potentially encompass on-post facilities, including roads and buildings, which could result in the restriction of some activities and workspace at PICA during implementation of this RA.

Additional details on the EZ required for intrusive activities will be presented in the site-specific ESS.

Munitions and Explosives of Concern Clearance of Entire Munitions Response Site (20.76 acres)

Previous geophysical investigations conducted in a small portion of the remaining MRS, outside of the Munitions Waste Pit, did not identify any MEC on the surface. However, MD was identified on the surface (0 to 3 inches bgs). To achieve an unlimited use for the MRS, the remaining portions of the MRS outside of the Munitions Waste Pit need to be 100 percent surveyed and cleared of potential MEC to depth of potential MEC/MPPEH. An instrument assisted surface clearance will be employed for 100 percent of the remaining 20.76-acre MRS. All identified anomalies will be investigated and removed, following the same procedures employed for excavation of the Munitions Waste Pit, as described above. Following surface
clearance, the vegetation will be removed; however, large trees (greater than 4\,four\ inches in
diameter) will remain. Following vegetation removal, subsurface clearance will be
accomplished using mag and flag techniques until all anomalies have been identified and
removed. For cost purposes, it is anticipated that the subsurface clearance will extend to an
average depth of 2\,ft\ bgs, however, anomalies will be removed to depth and may extend deeper
than 2\,ft\ bgs in some areas. Both mechanical and hand digging techniques are anticipated
depending on the depth of the identified anomalies.

The establishment of EZs and segregation of MD/MEC and debris will be the same as associated
with the excavation of the Munitions Waste Pit as described above.

Munitions and Explosives of Concern/Munitions Debris Identification and Handling

UXO Technicians will make every effort to identify MEC through visual examination of items
for markings and other identifying features such as shape, size, and external fittings. All MEC
and MD identified at the site will be carefully cataloged and the location accurately recorded.
Items will not be moved during the inspection/identification until the nature and condition of the
item can be ascertained. The SUXOS and the UXOQCS will agree on the positive identification
and disposition of the item prior to implementing any disposal operations. All MEC disposal
activities will be performed in accordance with Engineer Manual 385-1-97 (USACE, 2008) and
Technical Manual 60A-1-1-31 (Department of the Army, 2000) in addition to Federal, State,
and local regulations.

All MEC and MPPEH will be subjected to demolition procedures. Demolition will be conducted
through BIP operations or consolidated shots. If an item is safe to move, the item may be
relocated for disposal due to safety concerns or to consolidate shots. Prior to any detonation, a
pre-established notification procedure will be initiated. As soon as it is determined that a
detonation will be required, the SUXOS will initiate this procedure. The SUXOS will schedule
the demolition to allow sufficient time to complete all notifications, approvals, and evacuations
as required.

During demolition activities, the SUXOS will maintain overall control of the site. An EZ will be
established around the demolition area according to the ESS. Only essential personnel and the
UXO team will be allowed within the EZ once the demolition operations have begun. The
SUXOS will ensure safe work practices are observed, and the UXO Team Leader will perform
the necessary steps to safely dispose of the MEC item. Additional details on MEC demolition
procedures will be provided in the site-specific work plan and ESS.

Investigation-Derived Waste Disposal

All recovered scrap metal (i.e., MD or other debris) will be removed from the site. The
contractor will ensure that all recovered scrap metal is free of MEC through expert inspection by
UXO Technicians. Because the MD recovered will ultimately be treated as solid waste and
disposed off-site, it is imperative that procedures be established to preclude live ordnance from
becoming intermingled with MD. MD inspection will be designed to ensure that all such
material is 100 percent independently inspected and then 100 percent re-inspected as part of the
certification and verification process. Additional details on MD management will be provided in the site-specific work plan.

**Backfill and Restoration**

The excavated areas will be backfilled as soon as practicable with clean fill from an approved off-post source and clean overburden and sidewall cutback soil. The excavated areas will be restored to the original contours. Run-off collection and retention will be considered during the design phase to comply with all location- and action-specific ARARs.

**Site Cleanup and Demobilization**

The final phase of the work will involve site cleanup and demobilization of all personnel, facilities, and equipment.
Feasibility Study for 600 Hill Waste Pit and 600 Hill Groundwater Plume (PICA-058) and Inactive Munitions Waste Pit (PICA-013-R-01))
Picatinny Arsenal Cleanup Contract, Picatinny Arsenal, New Jersey
Contract No. W912ZH-13-D-0014

Placeholder for Figure 6-1
Feasibility Study for 600 Hill Waste Pit, 600 Hill Groundwater Plume [PICA-058] and Inactive Munitions Waste Pit [PICA-013-R-01]
Picatinny Arsenal Cleanup Contract, Picatinny Arsenal, New Jersey
Contract No. W91ZEK-13-D-0014

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Feasibility Study for 600 Hill Waste Pit (600 Hill Groundwater Plume [PICA-058] and Inactive Munitions Waste Pit [PICA-013-R-01])
Picatinny Arsenal Cleanup Contract, Picatinny Arsenal, New Jersey
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Feasibility Study for 600 Hill Waste Pit and 600 Hill Groundwater Plume (PICA-058) and Inactive Munitions Waste Pit (PICA-013-R-01))
Picatinny Arsenal Cleanup Contract, Picatinny Arsenal, New Jersey
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Feasibility Study for 600 Hill Waste Pit and Inactive Munitions Waste Pit
Picatinny Arsenal Cleanup Contract, Picatinny Arsenal, New Jersey
Contract No. W91ZLK-13-D-0014

Version: Draft
August 2016

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Placeholder for Figure 6-4
Feasibility Study for 600 Hill Waste Pit and Inactive Munitions Waste Pit (PICA-013-R-01)
Picatinny Arsenal Cleanup Contract, Picatinny Arsenal, New Jersey
Contract No. W912ZL-13-D-0014

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Placeholder for Figure 6-5
Feasibility Study for 600 Hill Waste Pit and Inactive Munitions Waste Pit (PICA-058 and PICA-013-R-01))

Picatinny Arsenal Cleanup Contract, Picatinny Arsenal, New Jersey

Contract No. W91ZLK-13-D-0014

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Placeholder for Figure 6-6
Feasibility Study for 600 Hill Waste Pit, 600 Hill Groundwater Plume [PICA-058] and Inactive Munitions Waste Pit [PICA-013-R-01]
PICA-058

Picatinny Arsenal Cleanup Contract, Picatinny Arsenal, New Jersey
Contract No. W912ZL-13-D-0014

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Placeholder for Figure 6.7
Feasibility Study for 600 Hill Waste Pit, 600 Hill Groundwater Plume (PICA-058) and Inactive Munitions Waste Pit (PICA-013-R-01))
Picatinny Arsenal Cleanup Contract, Picatinny Arsenal, New Jersey
Contract No. W91ZLK-13-D-0014

Placeholder for Figure 6-8
Feasibility Study for 600 Hill Waste Pit and 600 Hill Groundwater Plume (PICA-058) and Inactive Munitions Waste Pit (PICA-013-R-01)

Picatinny Arsenal Cleanup Contract, Picatinny Arsenal, New Jersey

Contract No. W912IZ-13-D-0014

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7. DETAILED ANALYSIS OF REMEDIAL ALTERNATIVES

7.1 DESCRIPTION OF EVALUATION CRITERIA

Section 300.430(e) of the NCP lists nine criteria against which each RA must be assessed. The acceptability or performance of each alternative against the criteria is evaluated individually so that relative strengths and weaknesses may be identified. The detailed criteria are as follows:

1. Protection of human health and the environment
2. Compliance with ARARs
3. Long-term effectiveness and permanence
4. Reduction of toxicity, mobility, or volume through treatment
5. Short-term effectiveness
6. Implementability
7. Cost
8. State acceptance
9. Community acceptance.

The NCP (Section 300.430(f)(1)(i)(A)) states that the first two criteria, protection of human health and the environment and compliance with ARARs, are “threshold criteria” that must be met by the selected remedial action. In certain identified circumstances, a waiver can be granted for specific ARARs under Section 121(d)(4) of CERCLA. Criteria three through seven are “primary balancing criteria,” and the trade-offs within this group must be balanced. The preferred alternative will be the alternative that is protective of human health and the environment, is ARAR-compliant, and provides the best combination of primary balancing attributes. The final two criteria, state and community acceptance, are “modifying criteria,” which are evaluated following the comment period on the FS report and the PP. The NCP criteria are described in further detail in the following sections.

Only the first seven criteria are evaluated in this report. State and community acceptance will be evaluated in the ROD following the public comment period.

7.1.1 Overall Protection of Human Health and the Environment

This criterion involves an assessment based on a composite of factors addressed under other evaluation criteria, including long-term effectiveness, short-term effectiveness, and compliance with ARARs. This criterion provides an evaluation of how the RA, as a whole, achieves RAOs and maintains protection of human health and the environment from unacceptable risk posed by TCE contamination in groundwater and by MEC at the site in both the short- and long-term. A qualitative evaluation of whether the alternative will reduce the MEC hazard is also provided. A determination and declaration that this criterion will be met by the proposed remedial action must be made in the ROD; therefore, this is a threshold criterion, which must be met by the selected remedy. This criterion will be met if the risks associated with exposure of human and ecological receptors to contaminated media are eliminated, reduced, or controlled through
treatment, engineering, or land use monitoring, and if the remedial action is protective of human health and the environment. Additionally, the MEC HA, as discussed in Section 3.2.4.3, provides the input to the threshold criteria or protection of human health and the environment. These tools are used qualitatively to evaluate the relative protection allowed by the RAs.

7.1.2 Compliance with Applicable or Relevant and Appropriate Requirements

This criterion assesses the compliance of an alternative with all contaminant-specific, action-specific, and location-specific ARARs. In the absence of ARARs, TBCs may also be taken into consideration as well as any other appropriate State or Federal criteria, advisories, and guidance as they apply.

7.1.3 Long-Term Effectiveness and Permanence

This criterion addresses the long-term effectiveness of each alternative and assesses the results of the remedial action in terms of the risks remaining after the RAOs have been met. In particular, this criterion assesses the effectiveness of controls that are applied to manage the risks posed by potential MEC remaining at the site.

7.1.4 Reduction of Toxicity, Mobility, or Volume through Treatment

This criterion examines the effectiveness of the remedial actions in reducing the toxicity, mobility, or volume of contaminants through treatment. Each alternative is assessed against the statutory preference that treatment be used to reduce the principal threats of contaminants and MEC, to provide irreversible reduction of contaminants and MEC, or to reduce the total volume of impacted media. Under CERCLA, a principal threat refers to source materials considered to be highly toxic or highly mobile that generally cannot be reliably contained, or would present a significant risk to human health or the environment should exposure occur (USEPA, 1991). For the 600 Area the principal threats are identified as TCE in source soils and MEC.

Factors of this criterion that are evaluated include the following:

- Treatment process to be employed
- Amount of MEC or hazardous materials that will be destroyed or treated
- Degree of expected reduction in mobility or volume
- Degree to which treatment will be irreversible
- Types and quantities of treatment residuals that will remain following treatment.

7.1.5 Short-Term Effectiveness

This criterion addresses the period of time needed to achieve protection and any adverse impacts of the RA during the construction and implementation phase. Factors evaluated include:

- Protection of workers, including risks associated with the presence of MEC and TCE-contaminated soil and debris
Protection of the community during the remedial action, including effects of dust from excavation and transportation of contaminated materials

Environmental impacts resulting from implementation of the remedial action

Time needed to implement the proposed alternative.

7.1.6 Implementability

This criterion evaluates the technical and administrative feasibility of implementing each RA and the availability of required services and materials during implementation. Factors of technical feasibility include the following:

- Construction and operational difficulties
- Reliability of the technology
- Ease of undertaking additional removal actions
- Ability to monitor the effectiveness of the remedy.

Administrative feasibility includes the ability to obtain required permits as well as the availability of necessary services, materials, specialists, and equipment.

7.1.7 Cost

This criterion assesses the costs of the remedial action alternative based on present worth. To estimate the present value of the alternative cost, a discount rate of 3.5 percent has been used, which is the most recent rate published by the Office of Management and Budget (http://www.whitehouse.gov/omb/circulars_a094_a04_appx-c/). The discount rate, which is similar to an interest rate, is used to account for the time value of money over 30 years. A dollar is worth more today than in the future because, if invested in an alternative use today, the dollar could earn a return (that is, interest).

The cost of a remedial action alternative includes capital costs and O&M costs over the period of time deemed appropriate and practicable for the selected RA. Capital costs include expenditures for project administration, planning, labor, equipment, and materials to conduct the remedial action. O&M costs include labor and associated maintenance costs expended over time. The level of detail employed in developing these estimates is considered appropriate for making choices between alternatives; however, the estimates are not intended for use in detailed budgetary planning.

7.2 DETAILED ANALYSIS OF ALTERNATIVES

This section presents a description of the evaluation criteria and an analysis and evaluation of the RAs developed for the different response action areas of the 600 Hill Waste Pit.
7.2.1 Alternative 1 – No Action

This alternative does not meet this threshold criterion. No additional actions will be undertaken at the site as part of this RA. According to the NCP (Section 300.430 (e)(6)), the level of treatment achieved must be compared to the required expenditures of time and materials as an integral portion of the remedy selection process. The No Action alternative is intended to serve as a baseline by which to compare the risk reduction effectiveness of other potential alternatives. In this alternative, no remedial actions will be performed. No efforts will be undertaken to contain, remove, monitor, or treat the TCE-contaminated groundwater at the site or to contain, remove, or monitor potential explosive hazards at the site. The site will be left without any additional actions.

Overall Protection of Human Health and the Environment

This alternative does not meet this threshold criterion. Alternative 1 provides no control of exposure to the contaminated media and no reduction in risk to human health or the environment for the site.

Compliance with Applicable or Relevant and Appropriate Requirements

Since no remedial activities are associated with this alternative, chemical-specific ARARs for the groundwater will not be met. Action-specific and location-specific ARARs are not applicable since no remedial activities will be implemented.

Long-Term Effectiveness and Permanence

The No Action alternative does not provide any controls for reduction of exposure or long-term management measures. All current and potential future risks will remain the same under this alternative.

Reduction of Toxicity, Mobility, or Volume through Treatment

This alternative does not employ any treatment that will reduce the toxicity, mobility, or volume of TCE or MEC; therefore, it does not reduce the principal threats at the site or provide any treatment.

Short-Term Effectiveness

Implementation of this alternative does not pose any additional risks to the community, the workers, or the environment since there are no remedial activities associated with it.

Implementation

There are no implementability concerns posed by this alternative.

Cost

The total present worth cost and capital cost of Alternative 1 are estimated to be $0.00 since there will be no remedial action taken at the site.
7.2.2 Alternative 2 – Monitored Natural Attenuation and Land Use Controls, and

Overall Protection of Human Health and the Environment

This alternative meets this threshold criterion. Alternative 2 provides an adequate protection of the human health and the environment through the implementation of LUCs and groundwater controls, primarily through groundwater use restrictions. Therefore, this alternative meets this criterion. MNA is expected to reduce TCE contaminant concentrations in groundwater to the cleanup goal (NJDEP GWQS 1 µg/L) within 350 years. Concentrations in surface water are likewise expected to be reduced below Federal and State promulgated standards with MNA of TCE in groundwater. The entirety of PICA is within a WRA as specified in a CEA established by NJDEP in 2002. The CEA is updated biennially by the Army with a biennial certification sent to NJDEP. As part of the biennial certification, the Army reviews site use to ensure the remedy (including groundwater restrictions) is operating successfully.

Enforcement of existing LUC procedures identified in Section 6.1.2 will prevent unauthorized site access or activities that could pose unacceptable risk to human health due to TCE in subsurface soil. Residual risk posed to human health by the potential presence of MEC will be reduced because the existing LUCs will be enforced. This approach deters contact between the source (MEC potentially present in the MRS, primarily in the Munitions Waste Pit) and human receptors, assuming the controls identified in Section 6.1.2 are properly implemented and enforced.

Compliance with Applicable or Relevant and Appropriate Requirements

This alternative meets this threshold criterion. Chemical-specific ARARs for groundwater contaminants will be met at the end of the remedial action, when contaminants levels fall below the NJ Groundwater Quality Standards, NJDEP GWQS, the most stringent groundwater ARAR. Compliance with ARARs for groundwater will be met at the end of the remedial action. The only location-specific ARARs is include the wetland regulations within the Clean Water Act (Section 402 40 CFR 320.4) and pertinent substantive provisions of NJAC 7:7A (the Freshwater Wetlands Protection Act, Public Law 1987). These regulations will be complied with during well drilling and abandonment activities, by following best management practices to minimize any disturbance or impacts to wetlands. The only action-specific ARARs associated with groundwater sampling and analysis is the NJPDES regulations, restricting discharges of purge water into surface water features. This ARAR will be complied with by disposing all contaminated purge water off-site, will be complied with during the remedial action.

Multiple action-specific ARARs are applicable for well installation and abandonment activities. TBC guidance for well drilling and abandonment procedures can be easily complied with using industry standard practices. NJDEP regulation (N.J.A.C 7:26E-1.5h) also dictates that drill cuttings can be returned to the site provided they do not contain free product or residual product. These regulations can be complied with through testing and proper disposal of cuttings should
they contain free or residual product. Construction support, which is required for subsurface excavation within the MRS, will comply with all RCRA regulations for the treatment, storage, and transportation of MEC, which includes RCRA Subparts M, X and E. The ESS amendment will address procedures required for compliance with these regulations.

**Long-Term Effectiveness and Permanence**

TCE concentrations will decrease over time through MNA. Long-term effectiveness will be dictated by the success of LUCs implemented under the RA. Land use restrictions include construction support, dig restrictions, CEA with corresponding WRA, and groundwater use restrictions evaluated during the CERCLA Five-Year Review. These LUCs are adequate to ensure that any exposure to receptors is within protective levels. Although the alternative provides some long-term effectiveness, potential risk will remain within the MRS due to the potential presence of MEC. This alternative will meet the MEC RAO by minimizing unacceptable risks posed by exposure to MEC and supporting future limited recreational land use (military training and hunting). LUCs are an adequate and reliable control method to reduce long-term risk associated with potential exposure to MEC. Existing interim LUCs already implemented at PICA have demonstrated that they are capable of adequately addressing the long-term risk.

Funding for LUCs will be programmed by the U.S. Army for the duration of the remedial action ensuring continuous implementation of LUCs. Additionally, because the TCE and MEC will remain at the site above UU/UE levels, five-year reviews will be conducted no less than every five years after initiation of the remedial action.

**Reduction of Toxicity, Mobility, or Volume through Treatment**

This alternative does not satisfy the statutory requirement for treatment of the principal threat. This alternative does not employ any treatment that will reduce the toxicity, mobility, or volume of COCs in groundwater or MEC at the site. However, the toxicity and volume of the TCE plume will be reduced over the anticipated 350-year time frame, during which LUCs will effectively mitigate potential exposure. This alternative includes no treatment actions that will reduce the mobility or volume of MEC in the MRS. However, MEC migration at the MRS is unlikely because the detection depth of the munitions is below that expected from frost heaves or erosion. This alternative does not reduce the explosive hazard associated with any MEC items present at the site, should they be encountered, nor does it treat TCE in groundwater.

**Short-Term Effectiveness**

*Based on the MNA modeling, the estimated time to achieve the RAOs is 35 years.* The implementation of this alternative does not pose any additional risks to the community, the workers, or the environment that cannot be mitigated through LUCs or construction support. Increased risk to the community may be present if MEC are encountered during the installation of signage or fencing. However, adherence to Picatinny UXO safety requirements will minimize these risks associated with potential handling of MEC items. Potential risk to workers collecting samples in support of the RA will be mitigated through the use of proper sampling techniques, PPE, and construction support. There are also potential risks to workers installing or repairing...
fencing and signs, and providing construction support. However, the possibility of contact between humans and MEC will be minimized by maintaining the access controls for the MRS, requiring construction support during any intrusive actions (i.e., installing signage) and following the Picatinny UXO Safety procedures.

Implementability

There are no implementability concerns posed by this remedy. Fencing and signage already exist in portions of the MRS and the material and labor for the installation of additional signage or fencing are readily available. Picatinny has the administrative and financial capability to implement, monitor, and maintain LUCs, many of which are currently in place. The greatest obstacle to the implementation of Alternative 2 is acceptance by regulatory agencies.

Cost

The total estimated cost for Alternative 2 is $674,505,703, including $71,600 in capital costs and $602,905,432,381 in O&M costs. Detailed costs for Alternative 2 are provided in Appendix C.

7.2.3 Alternative 3 – In Situ Chemical Oxidation, Monitored Natural Attenuation Polishing, and Land Use Controls, and Construction Support

Overall Protection of Human Health and the Environment

This alternative meets this threshold criterion for the protection of human health and the environment. The treatment proposed under Alternative 3 should rapidly reduce TCE groundwater concentrations in the source area, and later reduce TCE concentrations in downgradient plume and receptor areas. However, TCE concentrations may rebound. Following the source zone treatment of the groundwater plume, MNA is expected to treat the remaining groundwater contamination to the TCE cleanup goal (NJDEP GWQS 1 µg/L) within a 5035-year timeframe. Thus, the risk to human health and the environment from TCE in groundwater will be minimized with this alternative and eventually eliminated, once the RAO is achieved. The protection of human health from the groundwater contamination in the bedrock aquifer will be further afforded through the implementation of LUCs, particularly the groundwater use restrictions. The entirety of PICA is within a WRA as specified in a CEA established by NJDEP. The CEA is updated biennially by the Army with a biennial certification sent to NJDEP. As part of the biennial certification, the Army reviews site use to ensure the remedy (including groundwater restrictions) is operating successfully. Concentrations in surface water are expected to be reduced to below Federal and State promulgated standards at the end of the 5035-year period. Protection of field personnel using engineering controls and PPE is effective and reliable as this remedial technology has well established protocols.

Enforcement of LUCs identified in Section 6.1.2 will prevent unauthorized site access or activities that could pose unacceptable risk to human health due to TCE in subsurface soil. Although it will not reduce the residual risk posed to human health by the potential presence of MEC, the existing LUCs will be enforced. This approach deters contact between the source (MEC potentially present in the MRS, primarily in the Munitions Waste Pit) and human
Receptors, assuming the controls identified in Section 6.1.2 are properly implemented and enforced.

Compliance with Applicable or Relevant and Appropriate Requirements

This alternative meets this threshold criterion. ISCO is a proven technology for the treatment of TCE-contaminated groundwater. Chemical-specific ARARs for groundwater contaminants will be met at the end of the remedial action, when contaminants levels fall below the NJ Groundwater Quality Standards (GWQS), the most stringent groundwater ARAR. Alternative 3 will comply with all location- and action-specific ARARs. The only location-specific ARAR is the wetland regulations within the Clean Water Act (Section 402 40 CFR 320.4) and pertinent substantive provisions of NJAC 7:7A (the Freshwater Wetlands Protection Act, Public Law 1987), Location-specific ARARs include wetland regulations within the Clean Water Act. Compliance with these regulations will be complied with during well drilling, ISCO injection, and abandonment activities. These regulations will be complied with during ISCO injections, well drilling and abandonment activities, by following best management practices to minimize any disturbance or impacts to wetlands. The only action-specific ARAR associated with injections and groundwater sampling is the NIPDES regulations (N.J.A.C. 7:14A-8 and 12), restricting discharges of purge water into surface water features and injections into the groundwater. This ARAR will be complied with by disposing all contaminated purge water off-site. Due to the distance from the injection location, to the surface water (greater than 700 ft), daylighting of injectant into the wetlands is not expected. Discharge to groundwater permit by rule regulations requires that the remedial action not contravene NJDEP groundwater quality standards, GWQS. These regulations can be complied with through thorough planning, dosage calculations, and post-injection monitoring. Compliance with action-specific ARARs for activities related to the injection of permanganate can easily be met.

Multiple action-specific ARARs are applicable for well installation and abandonment activities. TBC guidance for well drilling and abandonment procedures can be easily complied with using industry standard practices. Discharge to groundwater permit by rule regulations requires that the remedial action not contravene NJDEP groundwater quality standard. These regulations can be complied with through thorough planning, dosage calculations, and post-injection monitoring. NJDEP regulation (N.J.A.C 7:26E-1.5b) also dictates that drill cuttings can be returned to the site provided they do not contain free product or residual product. These regulations can be complied with through testing and proper disposal of cutting should they contain free or residual product. Construction support, which is required for subsurface excavation within the MRS, will comply with all RCRA regulations for the treatment, storage, and transportation of MEC, which includes RCRA Subparts M, X and E. The ESS amendment will address procedures required for compliance with these regulations.

Long-Term Effectiveness and Permanence

Upon completion of the ISCO treatment, the groundwater will exhibit rapid decreases in TCE concentrations within the treatment area. The long-term effectiveness of ISCO in the treatment zone is limited; however, an active source area will remain on-site with an expected rebound of TCE concentrations in groundwater. The effectiveness of this alternative to remediate the
groundwater is limited because the large amount of buried metal, debris, and MEC at the site does not allow the injection points to be optimally located. In order to be more effective, permanganate must be in contact with the contaminated soil within the source area. The contaminated soil is comingled with or below MEC, MD, crushed drums and other debris. Therefore, injection wells will have to be placed upgradient of the source area, minimizing the required contact with the contaminated soil in the source area. However, long-term TCE groundwater concentrations are expected to decrease to ARARs in 50-55 years; therefore, the groundwater will eventually achieve the RAOs.

However, the LUC aspects of this alternative will provide long-term effectiveness, reducing the potential risk to explosive hazards within the MRS, and minimizing the exposure to contaminated groundwater. This alternative will meet the RAOs by minimizing unacceptable risks posed by exposure to MEC and groundwater, and supporting future military/industrial land use limited recreational land use (hunting). Additionally, because the TCE and MEC will remain at the site above UU/UE levels, five-year reviews will be conducted no less than every 5-5.5 years after initiation of the remedial action.

Reduction of Toxicity, Mobility, or Volume through Treatment

This alternative is expected to provide effective reduction of toxicity, mobility, or volume of contamination. Implementation of Alternative 3 should result in the rapid destruction of groundwater TCE within the treatment zone reducing both toxicity and volume of TCE at the site, satisfying the statutory preference for treatment as a principal element of the remedy. However, because the ISCO treatment targets the areas upgradient and downgradient of the source only, there is not a significant amount of reduction in the volume of TCE, because the majority of the source will remain untreated. It is estimated that the reduction in TCE contamination. However, the injections will not reduce the toxicity, mobility, or volume of MEC. As a result, discharge of contaminated groundwater to downgradient receptors will be subsequently reduced by ISCO for a three-or-more-year period after start of treatment. Without additional treatment, the volume of the TCE plume will likely rebound to a similar shape and extent with respect to current conditions. However, continued leaching of TCE from soil will reduce TCE concentrations in soil and corresponding migration to groundwater. Mobility will be reduced through the periodic treatments, as TCE will be attenuated by advection and dispersion through the treatment zone, with gradual reduction of residual TCE concentration to ARARs by MNA over a 3-5 year period. This alternative includes no treatment actions that will reduce the mobility, toxicity, or volume of MEC in the MRS. However, MEC migration is unlikely because the detection depth of the munitions is below that expected from frost heaves or erosion.

Short-Term Effectiveness

The short-term effectiveness of this alternative is good. Based on the modeling, the estimated time to achieve the RAO is estimated to be 5-5.5 years. There is a risk that site workers may be exposed to contaminated groundwater during the injections of permanganate. In addition, permanganate is a strong oxidizer; however, procurement and use of sodium permanganate solution (commercially available as a 40 percent solution) will reduce the hazards associated with the handling of permanganate (use of potassium permanganate in crystalline powder form...
can lead to potentially serious inhalation hazard). The risk to the community from the transportation of permanganate is minimal, as the materials will be transported in accordance with Department of Transportation (DOT) regulations, which are protective of public health. In addition, there is no risk to the community during the injection of the permanganate due to its limited volatility and the distance to any community receptors. Hazards to site workers will be minimized through the use of proper personal protection and field techniques. Use of PPE and engineering controls has been shown to be effective and reliable because this technology has well established protocols. There is also the potential that permanganate, or other oxidizer, could impact the environment if discharged to surface water, and could react with any organic material or acid compounds. However, this risk is minimal since the closest surface water is 825 ft from the site. This risk will also be mitigated through the use of proper protocols for material handling and spill control, if necessary. However, the oxidizer is expected to rapidly react with TCE in groundwater, resulting in the destruction of both compounds. Based on available site data, groundwater in the vicinity of the TCE source soil will take several years to reach, and discharge into the downgradient wetlands, yielding little possibility of discharging permanganate. The oxidant will be injected a depth that is below the depth where MEC are located. Therefore, there will be no contact between the MEC and oxidant, and no risks due to potential reactions between the permanganate and MEC.

The possibility of contact between humans and MEC will be minimized by maintaining the access controls for the MRS while installing signage. During installation and maintenance of fencing and signage, protectiveness of workers will be implemented by construction support.

**Implementability**

This remedy is easily implemented. Although considered innovative, ISCO has been implemented widely for groundwater remediation in recent years and is readily accepted by regulators. Technology implementation is contingent upon a successful pilot scale study. A potential issue could be obtaining the regulatory approval for ISCO, although a formal permit from the NJDEP is not required for a CERCLA action. However, this technology is generally acceptable in the state of New Jersey. ISCO is both technically and administratively feasible, however, its implementability at the munitions waste pit is compromised by the use of a chemical oxidant into the source area environment where there is a potential for MEC/UXO, which presents a potential safety hazard and risk issue, although complicated by the site conditions and the presence of MEC. Materials and equipment to implement the ISCO aspects of this remedy are readily available.

In addition, there are no implementation concerns posed by the LUC aspects of this remedy. Fencing and signage already exist in portions of the MRS and the material and labor for the installation of additional signage or fencing are readily available. Picatinny has the administrative and financial capability to implement, monitor, and maintain LUCs, many of which are currently in place.
Cost

The total estimated cost for Alternative 3 is $1,367,829. This includes $451,412 in capital costs and $916,417,018,902 in O&M costs. Detailed costs for Alternative 3 are provided in Appendix C.

7.2.4 Alternative 4 – In Situ Enhanced Anaerobic Bioremediation, Monitored Natural Attenuation Polishing, and Land Use Controls, and Construction Support

Overall Protection of Human Health and the Environment

This alternative meets this threshold criterion for the protection of human health and the environment. The treatment proposed under Alternative 4 will rapidly reduce contaminant concentrations within the treatment area, and later reduce downgradient TCE concentrations at the downgradient well and wetland receptors. A Biochlor® MNA simulation (USEPA, 2000) was used to re-evaluate MNA of the downgradient plume. Similar to MNA modeling conducted previously for this site (Shaw, 2013), the simulation indicated that the TCE concentration would drop to 1 µg/L in well 13MW-2 approximately 14 years after remediation commences. Following source zone treatment of the groundwater plume, MNA is expected to treat the remaining groundwater contamination to the TCE cleanup goal (NJDEP GWQS 1 µg/L) within a 50-year period. MNA attenuation rates will be evaluated during the first and subsequent five-year reviews. Thus, the risk to human health and the environment from TCE in groundwater will be minimized with this alternative and eventually eliminated once the cleanup goal is achieved. The protection of human health from the groundwater contamination in the bedrock aquifer will be further afforded through the implementation of LUCs, particularly the groundwater use restrictions. The entirety of PICA is within a WRA as specified in a CEA established by NJDEP. The CEA is updated biennially by the Army with a biennial certification sent to NJDEP. As part of the biennial certification, the Army reviews site use to ensure the remedy (including groundwater restrictions) is operating successfully. Concentrations in surface water are expected to be reduced to below federal and state promulgated standards within approximately a 50-14 years period after the treatment is following remedy implemented.

Enforcement of LUCs identified in Section 6.1.2 will prevent unauthorized site access or activities that could pose unacceptable risk to human health due to TCE in subsurface soil. Although it will not reduce the residual risk posed to human health by the potential presence of MEC, the existing LUCs will be implemented and enforced. This approach minimizes potential contact between the source (MEC potentially present in the MRS, primarily in the Munitions Waste Pit) and human receptors, assuming the controls identified in Section 6.1.2 are properly implemented and enforced. Further, the use of EVO–MNA polishing and the use of continued saturation in the source area to distribute the carbon substrate through the vadose and saturated zone will not pose an increased safety hazard or risk should any residual MEC remain in the source area.
Compliance with Applicable or Relevant and Appropriate Requirements

This alternative meets this threshold criterion. Enhanced anaerobic bioremediation is a proven technology for the treatment of TCE-contaminated groundwater. Chemical-specific ARARs for groundwater contaminants will be met at the end of the remedial action, when contaminants levels fall below the NJDEP GWQS, the most stringent groundwater ARAR Chemical-specific ARARs will be met at the end of the remedial action. Alternative 4 will comply with all location- and action-specific ARARs. The only location-specific ARAR is the wetland regulations within the Clean Water Act (Section 402 40 CFR 320.4) and pertinent substantive provisions of NJAC 7:7A (the Freshwater Wetlands Protection Act, Public Law 1987). Location-specific ARARs include wetland regulations within the Clean Water Act. These regulations will be complied with during carbon substrate injection application, well drilling, installation, and abandonment activities, by following best management practices to minimize any disturbance or impacts to wetlands. The only action-specific ARARs associated with injections and groundwater sampling is the NJPDES regulations (N.J.A.C. 7:14A-8 and 12), restricting discharges of purge water into surface water features and injections into the groundwater. This ARAR will be complied with by disposing all contaminated purge water off-site. Due to the distance from the injection location, to the surface water (greater than 700 ft), daylighting of injectant into the wetlands is not expected. NJPDES Discharge to groundwater permit by rule regulations also requires that the remedial action not contravene NJDEP groundwater quality standards GWQS. These regulations can be complied with through thorough planning, dosage calculations, and post-injection monitoring. Compliance with these regulations will be complied with during well drilling, injection of electron donor, and abandonment activities. Compliance with action-specific ARARs for activities related to the injection of electron donor can easily be met.

Multiple action-specific ARARs are applicable for well installation and abandonment activities. TBC guidance for well drilling and abandonment procedures can be easily complied with using industry standard practices. Discharge to groundwater permit by rule regulations requires that the remedial action not contravene NJDEP groundwater quality standards. These regulations can be complied with through thorough planning, dosage calculations, and post-injection monitoring. NJDEP regulation (N.J.A.C 7:26E-15b) also dictates that drill cuttings can be returned to the site provided they do not contain free product or residual product. These regulations can be complied with through testing and proper disposal of cutting should they contain free or residual product. Construction support, which is required for subsurface excavation within the MRS, will comply with all RCRA regulations for the treatment, storage, and transportation of MEC, which includes RCRA Subparts M, X and E. The ESS amendment will address procedures required for compliance with these regulations.

Long-Term Effectiveness and Permanence

Upon completion of the application of the organic substrate (EVO) via the infiltration gallery, the groundwater is expected to show rapid TCE concentration decreases within the treatment area. The long-term effectiveness of organic substrate injection in the treatment zone is limited, however, by an active source area and expected rebound of the TCE concentrations in groundwater. Based on the groundwater modeling simulations, the long-term TCE groundwater
concentrations extending approximately 1,100 ft downgradient are expected to decrease concentrations down to the TCE ARARs of 1 ug/L, within 14 years after treatment is initiated, and in 50 years, therefore, the groundwater will eventually achieve the RAO. The effectiveness of this alternative on the remediation of the groundwater is limited because the large amount of buried metal, debris, and MEC at the site does not allow the injection points to be optimally located. In order to be more effective, the electron donor must be in contact with the contaminated soil within the source area. The contaminated soil is contained with or below MEC, MD, crushed drums, and other debris. Therefore, injection wells will have to be placed upgradient of the source area, minimizing required contact.

Although the LUC monitoring aspects of this alternative will provide some long-term effectiveness, potential risk to explosive hazards will remain within the MRS. This alternative will meet the RAOs by minimizing unacceptable risks posed by exposure to MEC and supporting future limited recreational land use (military training and hunting). Additionally, because the TCE and MEC will remain at the site above UU/UE levels, five-year reviews will be conducted no less than every five years after initiation of the remedial action.

Reduction of Toxicity, Mobility, or Volume through Treatment

This alternative is expected to provide effective reduction of toxicity, mobility, or volume of contamination within the treatment zone by reduction of groundwater TCE concentrations and, therefore, satisfies the statutory requirement for treatment of the principal threat. Concentrations of TCE in source area groundwater is expected to reduce from 240 pg/L up to 1 pg/L, as a result of this treatment in the first six years, representing a 99% percent reduction in source area groundwater contamination. However, there is potential for a temporary contaminant rebound in groundwater due to mobilization of contaminants during the treatment process. Therefore, a second application of carbon substrate into the source area is planned as a contingency measure. As a result of treatment, discharge of contaminated groundwater to downgradient receptors will be subsequently reduced for a 3- or more-year period after treatments, with gradual reduction of residual TCE concentration by MNA over a 50-year period. This alternative includes no treatment actions that will reduce the mobility or volume of MEC in the MRS. However, MEC migration at the MRS is unlikely because the detection depth of the munitions is below that expected from frost heaves or erosion.

Short-Term Effectiveness

The short-term effectiveness of this alternative is good. Based on the groundwater modeling predictions, remediation of the downgradient TCE plume extending 1,100 ft downgradient would occur approximately 14 years after treatment is initiated. There is a risk that site workers may be exposed to contaminated groundwater during the injections of the application of the substrate or monitoring well installation in the source area. However, those hazards will be minimized through the use of proper personal protection and field techniques. There are no special procedures or precautions for substrate application, either from integrity and effectiveness or a health and safety standpoint. In the short-term, implementation of Alternative 4 could result in the increase of potentially hazardous TCE daughter products. However, these compounds will be subsequently degraded within the treatment zone, although bioaugmentation
may be required (is costed) for mineralization of vinyl chloride during the TCE degradation process. Bioaugmentation has been demonstrated effectively where the indigenous microbial population is incapable of vinyl chloride degradation. Bioaugmentation cultures are commercially available. There is also the potential that carbon substrate could impact the environment if discharged to surface water. However, this risk is minimal since the closest surface water is 825 ft from the site. This risk will also be mitigated through the use of proper protocols for material handling and spill control, if necessary.

The possibility of contact between humans and MEC will be minimized by maintaining the access controls for the MRS, while installing signage. During installation and maintenance of fencing and signage, protectiveness of workers will be accomplished by construction support. Increased risk to the community may be present if MEC are encountered during the installation of signage or fencing. However, adherence to Picatinny UXO safety requirements will minimize these risks associated with potential handling of MEC items.

**Implementability**

This remedy is easily implemented. Enhanced aerobic biodegradation has been implemented widely for groundwater remediation in recent years and is readily accepted by regulators. Technology implementation is contingent upon a successful pilot scale study. A potential issue could be obtaining the regulatory approval for injections, although a formal permit from the NJDEP is not required for a CERCLA action. However, the use of carbon substrates emulsified vegetable oil (EVO) this technology is generally acceptable in the state of New Jersey and by the USEPA. Enhance bioremediation is both technically and administratively feasible and materials and equipment to implement the remedy, including drilling services, and excavation equipment are readily available. For implementation of this remedy, an upgradient water source well would be installed to supply a low flow (approximately 5 gpm) of water over the source area to keep the vadose zone saturated following the addition of the carbon substrate amendment. In the event that the water source well cannot provide adequate yield, water will be obtained from the Picatinny Arsenal potable water system and transported to an onsite winterized water storage tank to be used to supplement the supply of water to the remediation area.

In addition, there are no implementation concerns posed by the LUC aspects of this remedy. Fencing and signage already exist in portions of the MRS and the material and labor for the installation of additional signage fencing are readily available. Picatinny has the administrative and financial capability to implement, monitor, and maintain LUCs, many of which are currently in place.

**Cost**

The total estimated cost for Alternative 4 is $1,608,008, including $465,117,622,326 in capital costs and $1,139,915,985,682 in O&M costs. Detailed costs for Alternative 4 are provided in Appendix C.
7.2.5 Alternative 5 – Trichloroethene Source Material Removal, Monitored Natural Attenuation Polishing, and Land Use Controls, and Construction Support

Overall Protection of Human Health and the Environment

This alternative meets this threshold criterion for the protection of human health and the environment. Alternative 5 provides an adequate protection of the human health through removal of MEC/MD and TCE-contaminated soil in source zone excavation as well as the implementation of groundwater LUCs and LUCs primarily through groundwater use restrictions and construction support. Therefore, this alternative meets this criterion. Following source zone excavation, MNA is expected to treat the remaining groundwater contamination to the TCE cleanup goal (NJDEP GWQS 1 µg/L) within a 10-year period. The 10-year time period is based on the results of USEPA Bioscreen® simulations that indicate MNA will result in TCE groundwater concentrations below the RAO in approximately eight years, following TCE source removal. Concentrations in surface water are expected to be reduced below Federal and State promulgated standards with MNA of TCE in groundwater, providing protection of the environment. MNA attenuation rates will be evaluated during the first and subsequent five-year reviews. Thus, the risk to human health and the environment will be minimized with this alternative and eventually eliminated. The protection of human health from the groundwater contamination in the bedrock aquifer will be further afforded through the implementation of LUCs, particularly the groundwater use restrictions. The entirety of PIC is within a WRA as specified in a CEA established by NJDEP. The CEA is updated biennially by the Army with a biennial certification sent to NJDEP. As part of the biennial certification, the Army reviews site use to ensure the remedy (including groundwater restrictions) is operating successfully. Concentrations in surface water are expected to be reduced to below federal and state promulgated standards within a 10-year period following remedy implementation.

Enforcement of LUCs identified in Section 6.1.2 will prevent unauthorized site access or activities that could pose unacceptable risk to human health due to potential MEC remaining in the Munitions Waste Pit and in the remaining portion of the MRS not addressed by Alternative 5. Construction support by UXO Technicians will be provided for any excavation in the area as an additional measure to prevent human exposure to MEC potentially present in the subsurface soil.

Compliance with Applicable or Relevant and Appropriate Requirements

This remedy meets this threshold criterion. Chemical-specific ARARs for groundwater contaminants will be met at the end of the remedial action, when contaminants levels fall below the NJDEP GWQS, the most stringent groundwater ARAR. Excavation and disposal is a proven technology for the treatment of TCE-contaminated soil and chemical-specific ARARs will be met at the end of the remedial action. Alternative 5 will comply with all location- and action-specific ARARs. The only location-specific ARAR is the wetland regulations within the Clean Water Act (Section 402 40 CFR 320.4) and pertinent substantive provisions of NJAC 7:7A (the Freshwater Wetlands Protection Act, Public Law 1987). Location-specific ARARs include wetland regulations within the Clean Water Act—These regulations will be complied with during well drilling and abandonment activities by following best management practices to minimize any disturbance or impacts to wetlands. Compliance with these regulations will be complied with
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and Inactive Munitions Waste Pit (PICA-013-R-01))
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Termination of Effectiveness and Permanence

Upon completion of the excavation, the groundwater is expected to show a gradual TCE concentration decrease within the AA. The source material excavation will permanently remove TCE contamination from the site soil likely resulting in a significantly reduced MNA time period.
Reduction of Toxicity, Mobility, or Volume through Treatment

This alternative satisfies the statutory requirement for treatment of a principal threat. This alternative is expected to effectively reduce the volume of MEC/MD within the excavated soils through treatment; thereby, reducing the MEC hazard at the site. All encountered MEC are treated. In addition, this alternative is expected to remove the entire volume of the TCE source soil. Toxicity and mobility of TCE in groundwater will be reduced through removal of the TCE source. However, the toxicity and volume of soil removed from the site will be transferred to the disposal facility rather than eliminated. Although, carbon substrate amendment will be added to the excavation prior to backfilling to enhance degradation of residual contamination in the source area. This alternative does not employ any treatment that will directly reduce the toxicity, mobility, or volume of TCE in groundwater. However, as a result of excavation, a gradual reduction of residual TCE concentrations in groundwater by MNA is anticipated over a 10-year period. This alternative includes treatment actions that will reduce the mobility or volume of MEC in the Munitions Waste Pit, but will not address potential MEC in other portions of the MRS. It is estimated that the reduction in MEC from implementing Alternative 5 will be 50 percent. Short-Term Effectiveness

The short-term effectiveness of this alternative is adequate. Based on the modeling results, the estimated time to achieve the RAO is eight years.

Excavation activities will result in significant material handling and some dust generation and potential volatilization of TCE, posing a risk that site workers may be exposed to contaminated soil. Additional short-term risks include those posed by the short-term presence of an open excavation, increased vehicle and equipment traffic, and backfilling of the excavation. Increased
vehicle traffic includes on-site activities as well as off-site traffic due to the delivery of required equipment and materials, including clean backfill soil. However, the potential for exposure and/or physical injury will be minimized through the use of proper personal protection, good construction practices, and standard dust suppression techniques. In addition, there is the potential to encounter MEC during the excavation, posing additional risks to site workers and the community. All site workers will be properly trained in MEC safety procedures, thereby reducing their risk, and safety EZs will be established, reducing any risk to the community.

During the excavation, and potential transportation of MEC to consolidated shot locations, appropriate MEC controls, such as evacuation of non-essential personnel, engineering controls during demolitions activities, etc., will be implemented. These controls will mitigate risk to the community and site workers. Construction and MEC safety protocols have been shown to be effective and reliable at mitigating the identified risks when properly implemented. There are no significant environmental impacts associated with this RA. TCE-contaminated soil and debris that have been in contact with contaminated soils will be assessed for contaminant levels and transported off-site for disposal in accordance with the appropriate RCRA and DOT regulations. Implementation of RCRA and DOT regulations provide protection to the community during transportation of these materials.

The possibility of contact between humans and MEC will be minimized by maintaining the access controls for the MRS, while installing signage or fencing. During installation and maintenance of fencing and signage, protectiveness of workers will be implemented by construction support in accordance with Picatinny MEC safety procedures.

Due to the site’s location adjacent to active range area, access restrictions and work delays are anticipated during munitions testing at the nearby ranges. However, all site activities included in this alternative can be completed despite these restrictions through the use of prior planning, continuous communication, and alternative work schedules.

**Implementability**

Alternative 5 is readily implementable. Soil removal, subsurface clearance, and MEC removal can be accomplished through specialized equipment and trained personnel (UXO Technicians) will need to be mobilized. Due to the site’s location adjacent to an active range area, access restrictions and work delays are anticipated during munitions testing at the nearby ranges. Construction practices, materials, and equipment are standard and readily available. Armoring of the excavator requires relatively simple modifications. Several services/facilities are capable of transporting and disposing of the TCE-contaminated soil.

Fencing and signage already exist in portions of the MRS and the material and labor for the installation of additional signage or fencing are readily available. Picatinny has the administrative and financial capability to implement, monitor, and maintain LUCs, many of which are currently in place.
Cost

The total estimated cost for Alternative 5 is $2,090,921 including $1,488,792 in capital costs and $602,129 in O&M costs. Detailed costs for Alternative 5 are provided in Appendix C.

7.2.6 Alternative 6 – Total Munitions Waste Pit Removal, Trichloroethene Source

Material Removal, Monitored Natural Attenuation Polishing, and Land Use Controls, and Construction Support

Overall Protection of Human Health and the Environment

This alternative meets this threshold criterion for the protection of human health and the environment. Alternative 6 provides an adequate protection of human health through removal of MEC/MD and TCE-contaminated soil in Munitions Waste Pit excavation as well as the implementation of groundwater LUCs primarily through groundwater use restrictions and construction support; therefore, this alternative meets this criterion. Following Munitions Waste Pit excavation, MNA is expected to treat the remaining groundwater contamination to the TCE cleanup goal (NJDEP GWQS 1 µg/L) within a 10-year period. The 10-year time period is based on the results of USEPA Bioscreen simulations that indicate MNA will result in TCE groundwater concentrations below the RAO in approximately eight years, following TCE source removal. Concentrations in surface water are likewise expected to be reduced below Federal and State promulgated standards with MNA of TCE in groundwater. MNA rates will be evaluated during the first and subsequent five-year reviews. Thus, the risk to human health and the environment will be minimized with this alternative and eventually eliminated. The protection of human health from the groundwater contamination in the bedrock aquifer will be further afforded through the implementation of LUCs, particularly the groundwater use restrictions. The entirety of PICA is within a WRA as specified in a CEA established by NJDEP. The CEA is updated biennially by the Army with a biennial certification sent to NJDEP. As part of the biennial certification, the Army reviews site use to ensure the remedy (including groundwater restrictions) is operating successfully. Concentrations in surface water are expected to be reduced to below federal and state promulgated standards within a 10-year period following remedy implementation.

Enforcement of LUCs identified in Section 6.1.2 will prevent unauthorized site access or activities that could pose unacceptable risk to human health due to potential MEC remaining in the Munitions Waste Pit and in the remaining portion of the MRS not addressed by Alternative 6. Construction support by UXO Technicians will be provided for any excavation in the area as an additional measure to prevent human exposure to MEC potentially present in the subsurface soil.

Compliance with Applicable or Relevant and Appropriate Requirements

This remedy meets this threshold criterion. Chemical-specific ARARs for groundwater contaminants will be met at the end of the remedial action, when contaminant levels fall below the NJDEP GWQS, the most stringent groundwater ARAR. Excavation and disposal are a proven technology for the treatment of TCE-contaminated soil and chemical-specific ARARs will be met at the end of the remedial action. Alternative 6 will comply with all location-
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action-specific ARARs. The only location-specific ARAR is the wetland regulations within the Clean Water Act (Section 402 40 CFR 320.4) and pertinent substantive provisions of NJAC 7.7A (the Freshwater Wetlands Protection Act, Public Law 1987). Location-specific ARARs include wetland regulations within the Clean Water Act. These regulations will be complied with during well drilling and abandonment activities, by following best management practices to minimize any disturbance or impacts to wetlands. The only action-specific ARARs associated with groundwater sampling and analysis is the NJPDES regulations, restricting discharges of purge water into surface water features. This ARAR will be complied with by disposing all contaminated purge water off-site. Compliance with action-specific ARARs for activities related to the RA can easily be met.

Multiple action-specific ARARs are applicable for well installation and abandonment activities and soil excavation. TBC guidance for well drilling and abandonment procedures can be easily complied with using industry standard practices. NJDEP regulation dictates that remediation must remove free or residual product to the extent practicable. In the event that free or residual product be identified, this will be complied with through testing of the waste streams and post-excavation sampling. NJDEP regulation (N.J.A.C 7:26E-1.5h) also dictates that drill cuttings and excavation spoils can be returned to the site provided they do not contain free product or residual product. These regulations can be complied with through testing and proper disposal of soil should it contain free or residual product. In the case of this RA, all soil contaminated with TCE will be disposed of off-site. RCRA regulations related to the categorization, packing, labeling, shipping, and disposal of waste will be followed through testing and examination of the waste streams.

NJDEP regulations [N.J.A.C 7:26E 5.2 (b) through (f)] dictate allowable levels in soil for alternative backfill from onsite or offsite sources. This regulation will be complied with through testing of fill prior to use. NJPDES regulations (N.J.A.C. 7:14A-12 and 40 CFR 401) require stormwater management for sites disturbing more than 1/acre. This ARAR will be complied with by establishing best management practices to control stormwater runoff. Additionally, NJDEP Fill Material Guidance for Site Remediation Program Sites, provides guidance and requirements for the use of fill materials for backfill (NJDEP, 2015) and is a TBC.

RCRA military munitions regulations that determine whether military munitions are solid or hazardous waste and the required storage and transportation provisions (40 CFR 266.203-206) will be complied with through examination and testing of the military munitions items and procedures established in the ESS amendment Treatment of MEC or MPPEH by BIP or consolidated shot will comply with RCRA subpart P and X, as identified in Table 4-3, by establishing the required procedures in the ESS amendment.

RCRA military munitions regulations that determine whether military munitions are solid or hazardous waste will be complied with thorough examination and testing of the military munitions items. NJDEP regulations dictate allowable levels in soil for alternative backfill from onsite or offsite sources. This regulation will be complied with through testing of fill prior to use. State and federal regulations regarding stormwater control will be complied with through testing in the event a waste stream is generated. Construction support, which is required for
subsurface excavation within the MRS will comply with all RCRA regulations for the treatment, storage, and transportation of MEC.

**Long-Term Effectiveness and Permanence**

Upon completion of the excavation, the groundwater is expected to show a gradual TCE concentration decrease within the AA. The source material excavation will permanently remove TCE contamination from the site soil likely resulting in a significantly reduced MNA time period to clean up. MEC will also be permanently removed from within the limits of excavation. Long-term TCE groundwater concentrations are expected to decrease to the RAO in eight years.

Long-term effectiveness will also be dictated by the success of LUCs implemented under the RA until the TCE groundwater RAO is achieved. These LUCs are adequate to ensure that any exposure to receptors is within protective levels. LUCs include UXO construction support for subsurface excavations, the base-wide CEA with corresponding WRA, and groundwater use restrictions evaluated during the CERCLA Five-Year Review. Although the LUC aspects of this alternative provide some long-term effectiveness, potential risk to explosive hazards will remain within the MRS. This alternative will meet the RAOs by minimizing unacceptable risks posed by exposure to MEC and supporting future military and limited recreational land use (military training and hunting). LUCs are an adequate and reliable control method to reduce long-term risk associated with potential exposure to MEC. Existing interim LUCs already implemented at Picatinny have demonstrated that they are capable of adequately addressing the long-term risk.

Funding for the LUCs will be programmed by the U.S. Army for the duration of the remedial action ensuring continuous implementation of LUCs. Additionally, because the TCE and MEC will remain at the site above UU/UE levels, five-year reviews will be conducted no less than every five years after initiation of the remedial action.

**Reduction of Toxicity, Mobility, or Volume through Treatment**

This alternative satisfies the statutory requirement for treatment of a principal threat. This alternative is expected to effectively reduce the volume of MEC/MD within the excavated soils through treatment, thereby reducing the MEC hazard at the site. All encountered MEC are treated. In addition, this alternative is expected to remove up to 95 percent of the entire volume of the TCE source soil. Toxicity and mobility of TCE in groundwater will be reduced through removal of the TCE source. However, the toxicity and volume of soil removed from the site will be transferred to the disposal facility rather than eliminated. This alternative does not employ any treatment that will directly reduce the toxicity, mobility, or volume of TCE in groundwater. However, as a result of excavation, a gradual reduction of residual TCE concentrations in groundwater by MNA is anticipated over a 10-year period. This alternative includes treatment actions that will reduce the mobility or volume of MEC in the Munitions Waste Pit, but will not address potential MEC in other portions of the MRS.

**Short-Term Effectiveness**

The short-term effectiveness of this alternative is adequate. Based on the modeling results, the estimated time to achieve the RAOs is eight years.
Excavation activities will result in significant material handling and some dust generation and potential volatilization of TCE, posing a risk that site workers may be exposed to contaminated soil. Additional short-term risks include those posed by the short-term presence of an open excavation, increased vehicle and equipment traffic, and backfilling of the excavation. Increased vehicle traffic includes on-site activities as well as off-site traffic due to the delivery of required equipment and materials, including clean backfill soil. However, the potential for exposure and/or physical injury will be minimized through the use of proper personal protection, good construction practices, and standard dust suppression techniques. In addition, there is the potential to encounter MEC during the excavation, posing additional risks to site workers and the community. All site workers will be properly trained in MEC safety procedures, thereby reducing their risk, and safety EZs will be established, reducing any risk to the community.

During the excavation, and potential transportation of MEC to consolidated shot locations, appropriate MEC controls, such as evacuation of non-essential personnel, engineering controls during demolitions activities, etc., will be implemented. These controls will mitigate risk to the community and site workers. Construction and MEC safety protocols have been shown to be effective and reliable at mitigating the identified risks when properly implemented. There are no significant environmental impacts associated with this RA. TCE-contaminated soil and debris that have been in contact with contaminated soils will be assessed for contaminant levels and transported off-site for disposal in accordance with the appropriate RCRA and DOT regulations. Implementation of RCRA and DOT regulations provides protection to the community during transportation of these materials.

The possibility of contact between humans and MEC will be minimized by maintaining the access controls for the MRS, while installing signage or fencing. During installation and maintenance of fencing and signage, protectiveness of workers will be implemented by construction support in accordance with Picatinny MEC safety procedures.

Due to the site’s location adjacent to an active range area, access restrictions and work delays are anticipated during munitions testing at the nearby ranges. However, all site activities included in this alternative can be completed despite these restrictions through the use of prior planning, continuous communication, and alternative work schedules.

**Implementability**

Alternative 6 is readily implementable. Soil removal, subsurface clearance, and MEC removal can be accomplished through specialized equipment and trained personnel (UXO Technicians) will need to be mobilized. Due to the site’s location adjacent to an active range area, access restrictions and work delays are anticipated during munitions testing at the nearby ranges.

Construction practices, materials, and equipment are standard and readily available. Armoring of the excavator requires relatively simple modifications. Several services/facilities are capable of transporting and disposing of the TCE-contaminated soil.

Fencing and signage already exist in portions of the MRS and the material and labor for the installation of additional signage or fencing are readily available. Picatinny has the
administrative and financial capability to implement, monitor, and maintain LUCs, many of which are currently in place.

The total estimated cost for Alternative 6 is $3,274,041 including $2,671,913 in capital costs and $602,128 in O&M costs. Detailed costs for Alternative 5 are provided in Appendix C.

7.2.7 Alternative 7 – Total Munitions Waste Pit Removal, Trichloroethene Source Material Removal, Monitored Natural Attenuation Polishing, Land Use Controls, and Munitions and Explosives of Concern Clearance of Entire Munitions Response Site

Overall Protection of Human Health and the Environment

This alternative meets this threshold criterion for the protection of human health and the environment. Alternative 7 removes all potential MEC within the 21 acres of the Inactive Munitions Waste Pit MRS, such that the potential residual explosive hazard is negligible. Alternative 7 provides an adequate protection of human health through removal of the Munitions Waste Pit that contains MEC/MD/other debris and TCE-contaminated soil, as well as the implementation of groundwater LUCs, primarily through groundwater use restrictions. Therefore, this alternative meets this criterion. Following source zone excavation, MNA is expected to treat the remaining groundwater contamination to the TCE cleanup goal (NJDEP GWQS 1 µg/L) within a 10-year period. The 10-year time period is based on the results of USEPA Bioscreen® simulations that indicate MNA will result in TCE groundwater concentrations below SCLs in approximately eight years, following TCE source removal. Concentrations in surface water are likewise expected to be reduced below federal and state promulgated standards with MNA of TCE in groundwater. MNA attenuation rates will be evaluated during the first and subsequent five-year reviews. Thus, the risk to human health and the environment will be minimized with this alternative and eventually eliminated. The protection of human health from the groundwater contamination in the bedrock aquifer will be further afforded through the implementation of LUCs, particularly the groundwater use restrictions. Concentrations in surface water are expected to be reduced to below federal and state promulgated standards within a 10-year period following remedy implementation.

Compliance with Applicable or Relevant and Appropriate Requirements

This alternative meets this threshold criterion. Chemical-specific ARARs for groundwater contaminants will be met at the end of the remedial action, when contaminants levels fall below the NJDEP GWQS, the most stringent groundwater ARAR. Chemical-specific ARARs will be met at the end of the remedial action. Alternative 7 will comply with all location- and action-specific ARARs. The only location-specific ARAR is the wetland regulations within the Clean Water Act (Section 402 40 CFR 320.4) and pertinent substantive provisions of NJAC 7:7A (the Freshwater Wetlands Protection Act, Public Law 1987). Location-specific ARARs include wetland regulations within the Clean Water Act. These regulations will be complied with during well drilling and abandonment activities, by following best management practices to minimize any disturbance or impacts to wetlands. Compliance with these regulations will be complied with

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NJDEP regulations, restricting discharges of purge water into surface water features. This ARAR will be complied with by disposing all contaminated purge water off-site.

Compliance with action-specific ARARs for activities related to the RA can easily be met.

Multiple action-specific ARARs are applicable for well installation and abandonment activities and soil excavation. TBC guidance for well drilling and abandonment procedures can be easily complied with using industry standard practices. NJDEP regulation (N.J.A.C 7:26E-5.1e) dictates that remediation must remove free or residual product to the extent practicable. In the event that free or residual product be identified, this will be complied with through testing of the waste streams and post-extraction sampling. NJDEP regulation (N.J.A.C 7:26E-5.1h) also dictates that drill cuttings and excavation spoils can be returned to the site provided they do not contain free product or residual product. These regulations can be complied with through testing and proper disposal of soil should it contain free or residual product. In the case of this RA, all soil contaminated with TCE will be disposed of off-site. RCRA regulations (40 CFR 262, subparts subpart C) related to the categorization, packing, labeling, shipping, and disposal of waste will be followed through testing and examination of the waste streams.

NJDEP regulations (N.J.A.C. 7:26E 5.2 (b) through (f)) dictate allowable levels in soil for alternative backfill from onsite or offsite sources. This regulation will be complied with through testing of fill prior to use. Additionally, NJDEP Fill Material Guidance for Site Remediation Program Sites, provides guidance and requirements for the use of fill materials for backfill (NJDEP, 2015) and is a TBC. NJDEP regulations (N.J.A.C. 7:14A:12 and 40 CFR 401) require stormwater management for sites disturbing more than one acre. This ARAR will be complied with by establishing best management practices to control stormwater runoff.

RCRA military munitions regulations that determine whether military munitions are solid or hazardous waste and the required storage and transportation provisions (40 CFR 266, 203-206) will be complied with through examination and testing of the military munitions items and procedures established in the ESS amendment. Treatment of MEC and MarPP by BIP or consolidated shot will comply with RCRA subpart P and X, as identified in Table 4-3, by establishing the required procedures in the ESS amendment.

NJDEP regulations dictate allowable levels in soil for alternative backfill from onsite or offsite sources. This regulation will be complied with through testing of fill prior to use. State and federal regulations regarding stormwater control will be complied with through testing in the event a waste stream is generated.

Long-Term Effectiveness and Permanence

Upon completion of the excavation, the groundwater is expected to show a gradual TCE concentration decrease within the AA. The source material excavation will permanently remove contaminants from the site likely resulting in a significantly reduced MNA time period to clean up. MEC will also be permanently removed. Long-term TCE groundwater concentrations are expected to decrease to the RAO in eight years. Long-term effectiveness will also be dictated
by the success of LUCs implemented under the RA until the TCE groundwater RAO is achieved.

- LUCs include the base-wide CEA with corresponding WRA and groundwater use restrictions evaluated during the CERCLA Five-Year Review.

Alternative 7 will provide long-term effectiveness and permanence related to MEC hazards because all potential MEC in the Inactive Waste Pit MRS will be removed. Given the limitations of MEC detection technologies, MEC survey and detections are not 100 percent effective. However, the risk of human exposure to potential residual explosives hazards would be negligible.

Funding for the LUCs will be programmed by the U.S. Army for the duration of the remedial action ensuring continuous implementation of LUCs. Implementation of Alternative 7 will achieve UU/UE, after TCE concentrations in groundwater are below cleanup goals. However, because it will take approximately eight years for the groundwater to achieve the cleanup goals, five-year reviews will be conducted no less than every five years after initiation of the remedial action, until the groundwater cleanup goals are achieved.

Reduction of Toxicity, Mobility, or Volume through Treatment

This alternative satisfies the statutory requirement for treatment of a principal threat. This alternative is expected to effectively reduce the volume of MEC/MD within the entire MRS; thereby eliminating the MEC hazard at the site. It is estimated that the reduction in MEC will be 99 percent. Any encountered MEC are treated. In addition, this alternative is expected to remove up to 95 percent of the volume of the TCE source soil. In addition, environmental media within the potential source material will be removed. However, the toxicity and volume of TCE removed from the site will be transferred to the disposal facility rather than be eliminated.

This alternative does not employ any treatment that will reduce the toxicity, mobility, or volume of COCs in groundwater. However, as a result of excavation, a gradual reduction of residual TCE concentrations in groundwater by MNA is anticipated over a 10-year period.

Short-Term Effectiveness

The short-term effectiveness of this alternative is adequate. Based on the modeling results, the estimated time to achieve the RAOs by implementing Alternative 7 is eight years.

Excavation activities will result in significant material handling and some dust generation and potential volatilization of TCE, posing a risk that site workers may be exposed to contaminated soil. Additional short-term risks include those posed by the short-term presence of an open excavation, increased vehicle and equipment traffic, and backfilling of the excavation. Increased vehicle traffic includes on-site activities as well as off-site traffic due the delivery of required equipment and materials, including clean backfill soil. However, the potential for exposure and/or physical injury will be minimized through the use of proper personal protection, good construction practices, and standard dust suppression techniques. In addition, there is the potential to encounter MEC during the excavation posing additional risks to site workers and the community. All site workers will be properly trained in MEC safety procedures, thereby reducing their risk, and safety EZs will be established, reducing any risk to the community.
During the excavation, and potential transportation of MEC to consolidated shot locations, appropriate MEC controls, such as evacuation of non-essential personnel, engineering controls during demolitions activities, etc., will be implemented. These controls will mitigate risk to the community. Construction and MEC safety protocols have been shown to be effective and reliable at mitigating the identified risks when properly implemented. There are no significant environmental impacts associated with this RA. Due to the site’s location adjacent to an active range area, access restrictions and work delays are anticipated during munitions testing at the nearby ranges. However, all site activities included in this alternative can be completed despite these restrictions through the use of prior planning, continuous communication and alternative work schedules.

TCE-contaminated soil and debris that have been in contact with contaminated soils will be assessed for contaminant levels and analyzed for characterization and transported off-site for disposal in accordance with the appropriate RCRA and DOT regulations. Implementation of RCRA and DOT regulations provide protection to the community during transportation of these materials.

**Implementability**

Alternative 7 is readily implementable. Soil removal, surface and subsurface MEC clearance, and MEC removal can be accomplished although specialized equipment and trained personnel (UXO Technicians) will need to be mobilized. Implementability is more challenging for Alternative 7 due to the presence of stockpiled materials and additional tree clearing (on potentially steep terrain) that will require removal to support the larger excavation area and associated staging area. Due to the site’s location adjacent to an active range area, access restrictions and work delays are anticipated during munitions testing at the nearby ranges. Construction practices, materials, and equipment are standard and readily available. Armoring of the excavator requires relatively simple modifications. Several services/facilities are capable of transporting and disposing of the TCE-contaminated soil.

Picatinny has the administrative and financial capability to implement, monitor, and maintain LUCs, many of which are currently in place.

**Cost**

The total estimated cost for Alternative 7 is $4,114,389,366 including $3,787,256 in capital costs and $344,628,877 in O&M costs. Detailed costs for Alternative 7 are provided in Appendix C.

**7.3 COMPARATIVE ANALYSIS OF ALTERNATIVES**

This section provides a comparative analysis of the RAs against one another for the threshold and balancing criteria that are applicable to the 600 Hill Area. The comparative analysis indicates the advantages and disadvantages of each of the seven remedial alternatives RAs relative to the others so that the most appropriate alternative can be selected.
7.3.1 Overall Protection of Human Health and the Environment

Alternative 1 – No Action will be the least protective of human health and the environment and does not meet the threshold criterion for the protection of human health and the environment. Alternatives 2 through 7 meet this threshold criterion because they provide protection to human health and the environment through a combination of treatment or removal and LUCs.

7.3.2 Compliance with Applicable or Relevant and Appropriate Requirements

All alternatives comply with the action- and location-specific ARARs. Chemical-specific ARARs for the groundwater will not be met by the No Action alternative, but will be achieved by Alternatives 2 through 7.

7.3.3 Long-Term Effectiveness and Permanence

Alternative 1 does not provide long-term effectiveness or permanence because no remedial actions will be performed and receptors will potentially be exposed to contaminated groundwater and subsurface MEC hazards. Alternatives 5, 6, and 7 provide the greatest long-term effectiveness through removal of the MEC and TCE-contaminated soil. Compared to other alternatives, Alternative 7 offers the greatest long-term effectiveness and permanence because only groundwater LUCs will be required for a period of 10 years and MEC hazards will be removed such that the risk of exposure will be negligible. A minimum of two five-year review cycles for MEC-related LUCs will be implemented to verify protective effectiveness for explosive hazards, all MEC hazards are removed, providing a permanent remedy for MEC. Alternatives 5 and 6 offer the same level of effectiveness for groundwater, with a groundwater restoration timeframe of eight years but only partially mitigate the risk of MEC as the entire Inactive Munitions Waste Pit MRS will not be addressed and LUCs will be implemented to reduce the long-term risks associated with potential exposure to MEC.

Alternatives 3 and 4 provide greater long-term effectiveness than Alternatives 2 and 3 through treatment of the groundwater Munitions Waste Pit source area resulting in the reduction of groundwater concentrations. However, the long-term effectiveness and permanence of these active groundwater treatment alternatives is compromised by an active source in the Munitions Waste Pit and LUCs are required to prevent exposure to MEC. Therefore, the groundwater restoration timeframe for both Alternative 2 and Alternative 3 is 35 years. TCE concentrations may rebound after treatment, and extend the follow-on monitoring period. Because Alternative 4 targets the TCE-source area, the groundwater restoration timeframe is 14 years, significantly less than Alternatives 2 and 3. Whereas, Alternatives 5, 6 and 7 all achieve the groundwater RAO within eight years. Under Alternative 2, the residual risks in groundwater will remain unchanged. The adequacy and reliability of Alternatives 2, 3, and 4 exceed that of Alternative 1 due to the groundwater and surface water monitoring program and monitoring and enforcement of LUCs to prevent exposure to contaminated groundwater and MEC. Additionally, because the TCE and MEC will remain at the site above UU/UE levels, five-year reviews will be conducted no less than every five years.
after initiation of the remedial action, even after TCE cleanup goals are achieved. However, five-year reviews for Alternative 7 will be discontinued after achieving the TCE cleanup goal in groundwater and after a minimum of two five-year review cycles for MEC-related LUCs, because MEC will no longer be present.

Implementation of Alternatives 1, 2, 3, or 4 will result in no change to the baseline MEC HA hazard level for the MRS. These four RAs have a MEC hazard level of 3, which indicates a moderate potential explosive hazard condition exists. Implementation of Alternatives 5 and 6 reduces the MEC hazard level to a 4 and achieves the lowest potential explosive hazard condition. For Alternative 7, which includes the removal of all MEC from the MRS, the MEC HA score is slightly higher than in Alternatives 5 and 6 due to the uncertainty associated with existing MEC removal technologies and the absence of any LUCs with achieving the UI/UE Criteria. However, this alternative still achieves the lowest potential hazard level of 4 similar to Alternatives 5 and 6 as summarized in Table 7.1.

### 7.3.4 Reduction of Toxicity, Mobility, or Volume through Treatment

Alternatives 1 and 2 offer no treatment and, therefore, do not provide any reduction in the toxicity, mobility, or volume of TCE contamination or MEC. Alternatives 3 and 4 reduce TCE contaminant concentrations by treatment, thereby reducing toxicity, mobility, or volume in the soil and groundwater through contaminant destruction, thereby satisfying the statutory requirement for treatment of the principal threat. Alternative 4 is more favorable than Alternatives 3, 5 and 6 for the reduction of toxicity, mobility and volume of TCE contaminated soil since it provides for source area treatment of the contaminated soil and to the groundwater plume. whereas Alternative 3 provides limited source area soil treatment, and.

Alternatives 5, 6, and 7 reduce on-site TCE concentrations associated with contaminated soils; however, the contaminated soil will be disposed of at an off-site landfill and, therefore, the toxicity, mobility, or volume is not holistically reduced under these alternatives. Alternatives 2, 3 and 4 -These alternatives, however, do not reduce the mobility or volume of MEC on-site. It should be noted, however, that MEC migration at the MRS is unlikely because the detection depth of the munitions is below that expected from frost heaves or erosion. Alternatives 5, 6, and 7 reduce on-site TCE concentrations associated with contaminated soils; however, the contaminated soil will be disposed of at an off-site landfill and, therefore, the toxicity, mobility, or volume is not holistically reduced under these alternatives. Alternatives 5, 6, and 7 also reduce the volume of MEC at the site, through removal and destruction. Alternative 6 offers a greater reduction of MEC volume than Alternative 5 because the entire Munitions Waste Pit will be removed, as opposed to only that portion collocated with TCE-impacted soil. Alternative 7 provides the greatest reduction in the mobility and volume of MEC because all MEC will be removed and destroyed.

### 7.3.5 Short-Term Effectiveness

Alternative 1 offers unchanged risk to the community; thus, the RAOs will not be achieved. Alternatives 2 through 6 involve continuous implementation of LUCs, in particular, restrictions on groundwater use and implementation of a long-term groundwater monitoring program for...
contaminated groundwater and construction support for intrusive activities. Risks to site workers and the community are associated with implementation of LUCs for Alternatives 2 through 6 related to the installation and maintenance of signs and/or fences. However, these risks are mitigation through the implementation of UXO safety procedures. Alternatives 5, 6, and 7 have similar risks associated with the excavation of TCE-impacted soils and associated dust generation, volatilization of TCE, and materials handling. The greatest short-term risks are posed by Alternative 7, followed by Alternatives 6 and 5, due to MEC handling. Alternative 7 has risk associated with its area of disturbance during the Munitions Waste Pit excavation and MRS clearance due to the potential for discovery of MEC. Alternatives 6 and 5 have the second greatest short-term risk, as the risks are similar to Alternative 7 but the area of disturbance is smaller. However, the short-term risk associated with Alternatives 5, 6, and 7 are manageable through engineering controls and UXO safety procedures. Note that Alternatives 5, 6 and 7 will involve the setup of safety EZs which will limit access to nearby areas around the site during intrusive operations in the munitions pit. Elevated short-term risks to the community and construction workers will be experienced under the implementation of Alternatives 3 and 4, from in situ injections of chemicals into the subsurface, in comparison to Alternative 2; however, risks are considered manageable with engineering controls and standard health and safety procedures.

Alternative 4 does not pose a short-term risk to the community or construction workers due to the organic nature of the carbon substrate amendment. Risk exists from Alternative 3 and 4 if there is a spill or release of amendments to the surface water from daylighting or spills. Risk to the environment are higher with Alternative 3, that Alternative 4, due to the potential for permanganate, or other oxidizer, to impact the environment if discharged to surface water, and potentially reacting with any organic material or acid compounds. However, this risk is minimal since the closest surface water is 825 ft from the site and these risks can be controlled through the proper protocols for material handling and spill control. Further, the chemical oxidants included in Alternative 3 may potentially come in contact with MEC and present a health and safety hazard. Alternative 4 will not adversely impact residual MEC items in the source area and is favorable for providing short-term effectiveness since the treatment will be over the entire source area targeting both the vadose zone soils and the groundwater plume, and when the carbon substrate comes in contact with MEC, it will have the benefit of potentially mitigating any naturally occurring oxidation of the metallic materials.

7.3.6 Implementability

Alternatives 2 through 7 are implementable, with labor and materials readily available to implement these remedies. Picatinny has the administrative and financial capability to implement, monitor, and maintain LUCs, many of which are currently in place.

Approvals from agencies will be the most difficult for Alternative 2, as indicated from previous negotiations with NJDEP and USEPA. The implementability of Alternatives 3 and 4 will be slightly more involved as these technologies are considered innovative and are contingent upon a successful bench study and/or pilot studies. In-situ treatments using oxidants or carbon substrate materials are generally acceptable to regulators and have been successfully demonstrated to treat the chemical contaminants. Alternatives 3 and 4 have been demonstrated
Successfully on the field scale for treatment of TCE contaminated groundwater, when treatment is conducted within the source area. However, large amounts of buried metal and potential MEC on-site provide an additional challenge to implementing Alternatives 3. The injection points for the chemical amendment included in Alternative 3 must be installed outside the limits of the Munitions Waste Pit to avoid the potential interference with MEC, thereby reducing the effectiveness of this alternative. Alternative 4 is more implementable due to the use of the infiltration gallery technology for the application of the organic substrate amendment to treat the source area and downgradient groundwater plume. Alternatives 5, 6, and 7 involve significant logistical considerations coordinating construction activities with the active range operations, the potential to encounter MEC, and handling of contaminated soil, and dust generation. Implementability is more challenging for Alternative 7 due to the presence of stockpiled materials and additional tree clearing (on potentially steep terrain) that will require removal to support the larger excavation area and associated staging area.

7.3.7 Cost

Alternative 1 is the least costly option, followed by Alternative 2. Alternative 3 is slightly less expensive than Alternative 4. Alternative 4 is less expensive than Alternatives 5, 6 and 7. Alternative 7 involves the highest cost including the greatest initial capital costs, followed by Alternatives 5 and 6. The costs associated with the removal of the entire munitions waste pit under Alternatives 6 and 7 are much higher than those for Alternative 5 due to the presence of stockpiled soil and debris above the larger excavation footprint and staging area. The estimated costs for each alternative detailing the estimated capital costs, discounted O&M, and total present worth costs are summarized in Table 7-2 and are provided in detail in Appendix C.

7.3.8 Summary of Comparative Analysis of Alternatives

Table 7-3 summarizes the detailed analysis of alternatives developed in this FS for the 600 Hill Waste Pit by presenting the results of performance of each alternative to the NCP Section 300.430(e) nine evaluation criteria as presented in this section.
### Table 7-1. Summary of Munitions and Explosives of Concern Hazard Assessment Results for 600 Hill Waste Pit Remedial Alternatives

<table>
<thead>
<tr>
<th>Alternative</th>
<th>Description</th>
<th>Munitions and Explosives of Concern Hazard Level</th>
<th>Munitions and Explosives of Concern Hazard Assessment Score</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>No Action</td>
<td>3</td>
<td>560</td>
</tr>
<tr>
<td>2</td>
<td>Monitored Natural Attenuation and Land Use Controls, and Construction Support</td>
<td>3</td>
<td>560</td>
</tr>
<tr>
<td>3</td>
<td>In Situ Chemical Oxidation, Monitored Natural Attenuation Polishing, and Land Use Controls, and Construction Support</td>
<td>3</td>
<td>560</td>
</tr>
<tr>
<td>4</td>
<td>In Situ Enhanced Anaerobic Bioremediation, Monitored Natural Attenuation Polishing, and Land Use Controls, and Construction Support</td>
<td>3</td>
<td>560</td>
</tr>
<tr>
<td>5</td>
<td>Trichloroethene Source Removal, Monitored Natural Attenuation Polishing, and Land Use Controls, and Construction Support</td>
<td>4</td>
<td>365</td>
</tr>
<tr>
<td>6</td>
<td>Total Munitions Waste Pit Removal, Trichloroethene Source Material Removal, Monitored Natural Attenuation Polishing, and Land Use Controls, and Construction Support</td>
<td>4</td>
<td>365</td>
</tr>
<tr>
<td>7</td>
<td>Total Munitions Waste Pit Removal, Trichloroethene Source Material Removal, Monitored Natural Attenuation Polishing, Land Use Controls, and Munitions and Explosives of Concern Clearance of Entire Munitions Response Site (to achieve the Unlimited Use/Unrestricted Exposure Criteria)</td>
<td>4</td>
<td>430</td>
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## Table 7-2: 600 Area Comparative Analysis – Cost Estimates

<table>
<thead>
<tr>
<th>Alternative</th>
<th>Description</th>
<th>Capital Cost</th>
<th>Discounted Operation and Maintenance</th>
<th>Total Present Worth</th>
</tr>
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<tr>
<td>1</td>
<td>No Action</td>
<td>$0</td>
<td>$0</td>
<td>$0</td>
</tr>
<tr>
<td>2</td>
<td>Monitored Natural Attenuation and Land Use Controls and Construction Support</td>
<td>$71,600</td>
<td>$602,905</td>
<td>$674,505</td>
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<tr>
<td>3</td>
<td>In Situ Chemical Oxidation, Monitored Natural Attenuation Polishing, and Land Use Controls, and Construction Support</td>
<td>$451,412</td>
<td>$1,018,902</td>
<td>$1,470,313</td>
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<tr>
<td>4</td>
<td>In Situ Enhanced Anaerobic Bioremediation, Monitored Natural Attenuation Polishing, and Land Use Controls, and Construction Support</td>
<td>$622,326</td>
<td>$985,682</td>
<td>$1,608,008</td>
</tr>
<tr>
<td>5</td>
<td>Trichloroethene Source Removal, Monitored Natural Attenuation Polishing, and Land Use Controls, and Construction Support</td>
<td>$1,525,182</td>
<td>$602,129</td>
<td>$2,127,311</td>
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<td>6</td>
<td>Total Munitions Waste Pit Removal, Trichloroethene Source Material Removal, Monitored Natural Attenuation Polishing, and Land Use Controls, and Construction Support</td>
<td>$2,671,913</td>
<td>$602,128</td>
<td>$3,274,041</td>
</tr>
<tr>
<td>7</td>
<td>Total Munitions Waste Pit Removal, Trichloroethene Source Material Removal, Monitored Natural Attenuation Polishing, Land Use Controls, and Munitions and Explosives of Concern Clearance of Entire Munitions Response Site (to achieve the Unlimited Use/Unrestricted Exposure Criteria)</td>
<td>$3,787,256</td>
<td>$332,124</td>
<td>$4,119,380</td>
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### Table 7-3: Summary of Detailed Analysis of Remedial Alternatives

<table>
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<tr>
<th></th>
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<tr>
<td>Protection of human health and the environment</td>
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<td>✓</td>
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<td>Compliance with ARARs</td>
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<td>✓</td>
<td>✓</td>
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<tr>
<td>Long-term effectiveness and permanence</td>
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<td>✓</td>
<td>✓</td>
<td>✓</td>
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<td>✓</td>
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<tr>
<td>Reduction of toxicity, mobility, or volume through treatment</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
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<td>Short-term effectiveness</td>
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<td>✓</td>
<td>✓</td>
<td>✓</td>
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<td>Implementability</td>
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<td>✓</td>
<td>✓</td>
<td>✓</td>
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<td>✓</td>
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<td>Costs(^{(a)})</td>
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<td>$1,608,008</td>
<td>$2,127,311</td>
<td>$3,274,041</td>
<td>$4,119,380</td>
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<tr>
<td>State Acceptance</td>
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<tr>
<td>Community Acceptance</td>
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<td>TBD</td>
<td>TBD</td>
<td>TBD</td>
<td>TBD</td>
<td>TBD</td>
<td>TBD</td>
</tr>
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</table>

\(^{(a)}\) Costs include all costs associated with each alternative.

\(^{(b)}\) State and Community Acceptance data is TBD (To Be Determined) for all alternatives.
### Table 7-3: Summary of Detailed Analysis of Remedial Alternatives (continued)

- **Notes:**
  - FAVORABLE (YES for threshold criteria).
  - MODERATELY FAVORABLE.
  - NOT FAVORABLE (NO for threshold criteria).

- **ARAR** = Applicable or relevant and appropriate requirement.
- **LUC** = Land use control.
- **MEC** = Munitions and explosives of concern.
- **MNA** = Monitored natural attenuation.
- **MRS** = Munitions response site.
- **TBD** = To Be Determined.
- **TCE** = Trichloroethene.

- **Costs** (shown in this table as the total present worth costs) are detailed in *Appendix C*.
- **The Modifying criteria of regulator and community acceptance are To Be Determined following review and input from these parties.**

**ARAR** = Applicable or relevant and appropriate requirement.

**LUC** = Land use control.

**MEC** = Munitions and explosives of concern.

**MNA** = Monitored natural attenuation.

**MRS** = Munitions response site.

**TBD** = To Be Determined.

**TCE** = Trichloroethene.
8. REFERENCES


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