Per the Federal Facility Agreement for Iowa Army Ammunition Plant, Article X.B.1, the attached document is the final version of the submitted document.
Treatability Study Test Plan for In Situ Biodegradation of RDX in Off-Site Groundwater

for

Iowa Army Ammunition Plant
Middletown, Iowa

NOVEMBER 2004

Prepared for:
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DRAFT FINAL

TREATABILITY STUDY TEST PLAN FOR IN SITU BIODEGRADATION OF RDX IN OFF-SITE GROUNDWATER for IOWA ARMY AMMUNITION PLANT, MIDDLETOWN, IA

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NOVEMBER 2004
IAAAP
Final Treatability Study Test Plan for In Situ Biodegradation of RDX in Off-Site Groundwater

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**ACRONYMS**

<table>
<thead>
<tr>
<th>Abbreviation</th>
<th>Description</th>
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<tr>
<td>AO</td>
<td>American Ordnance</td>
</tr>
<tr>
<td>Army</td>
<td>U.S. Army</td>
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<tr>
<td>bgs</td>
<td>below ground surface</td>
</tr>
<tr>
<td>CERCLA</td>
<td>Comprehensive Environmental Response, Compensation, and Liability Act</td>
</tr>
<tr>
<td>DNX</td>
<td>di-nitroso breakdown product of RDX</td>
</tr>
<tr>
<td>DO</td>
<td>dissolved oxygen</td>
</tr>
<tr>
<td>DPT</td>
<td>Direct-Push Technology</td>
</tr>
<tr>
<td>FFA</td>
<td>Federal Facility Agreement</td>
</tr>
<tr>
<td>FS</td>
<td>Feasibility Study</td>
</tr>
<tr>
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<td>feet per foot</td>
</tr>
<tr>
<td>IAAAP</td>
<td>Iowa Army Ammunition Plant</td>
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<tr>
<td>µg/L</td>
<td>micrograms per liter</td>
</tr>
<tr>
<td>MNX</td>
<td>mono-nitroso breakdown product of RDX</td>
</tr>
<tr>
<td>MW</td>
<td>Monitoring Well</td>
</tr>
<tr>
<td>NPL</td>
<td>National Priorities List</td>
</tr>
<tr>
<td>REDOX</td>
<td>oxidation-reduction potential</td>
</tr>
<tr>
<td>OU</td>
<td>operable unit</td>
</tr>
<tr>
<td>ppb</td>
<td>parts per billion</td>
</tr>
<tr>
<td>PQL</td>
<td>practical quantitation limit</td>
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<tr>
<td>psi</td>
<td>pounds per square inch</td>
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<tr>
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<td>polyvinyl chloride</td>
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<tr>
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<td>Resource Conservation and Recovery Act</td>
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<td>TNX</td>
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<tr>
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<td>U.S. Environmental Protection Agency</td>
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<tr>
<td>VOA</td>
<td>volatile organic analysis</td>
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1.0 INTRODUCTION

Tetra Tech, Inc. (Tetra Tech) proposes to conduct a field-scale treatability study to address the Royal Demolition Explosive (RDX) contaminated groundwater at the Off-Site Groundwater Plume near the Iowa Army Ammunition Plant (IAAAP) (Figure 1-1). The treatability study is being conducted pursuant to the recommendations of the feasibility study (FS) (URS, 2004a) and proposed plan (URS, 2004b). The treatability study will evaluate the potential for remediation of RDX in groundwater by enhanced in situ bioremediation. This document presents a summary of the planned activities and schedules for the treatability study. Activities will be conducted in accordance with the Installation-Wide SAP/QAPP (URS, 2002).

The origins and extent of the Off-Site Groundwater Plume have been documented in detail elsewhere (URS, 2003; URS, 2004c). Briefly, shallow groundwater downgradient of the IAAAP, near the confluence of Brush Creek and the Skunk River (Figure 1-2), exhibits elevated concentrations of RDX. The upgradient edge of the RDX plume is defined by groundwater wells adjacent to Highway 61 (Figure 1-2). Off-site, upgradient wells closer to the IAAAP site have been sampled and have RDX levels that are below the reporting limit [2 micrograms per liter (µg/L) for RDX] (Figure 1-2). It is apparent that the source of RDX is historical releases from IAAAP manufacturing activities to Brush Creek with surface water transport off site. Hydraulic interactions between Brush Creek and the shallow aquifer resulted in groundwater contamination beginning near Highway 61.

The treatability study will comprise injection of a dilute, quick-acting, biodegradable carbon source to stimulate anaerobic bioremediation of RDX. The initial carbon source will be a 12% solution of dextrose. Groundwater monitoring for REDOX potential, biodegradation breakdown products, and reduced explosives concentrations will be collected to determine the effectiveness of dextrose. If it is deemed that dextrose is not an effective carbon source, an alternative source will be selected. Groundwater monitoring wells (MW) at the site will be sampled before, during, and after the treatability study for explosives, RDX/HMX characteristic degradation products, and parameters characteristic of anaerobic groundwater environments. The study will be conducted according to the detailed schedule presented in Appendix A. The treatability study will focus on the area of consistently highest RDX concentration within the 50 µg/L isoconcentration contour (Figure 1-2).

The field-scale treatability study will include the following field activities:

- Installing direct-push technology (DPT) injection points and small diameter monitoring wells around existing monitoring well MW-117, with injection and monitoring zones similar to the screened interval of MW-117 containing RDX.
- Initial injection activities in DPT points. Injection with moderate pressure will enhance aquifer permeability, and thus, the spread of the carbon source material.
- Additional injection(s) of a bioavailable carbon source in dilute solution, as needed.
- Groundwater sampling prior to, during, and after injections.
The results of the treatability study will be used to evaluate in situ bioremediation of dissolved RDX:

- Comparing RDX contaminant (and degradation product) concentrations in pre- and post-treatability study groundwater samples.
- Comparing the pre- and post-treatability study oxidation-reduction states of the aquifer.
- Evaluating the cost and implementability of enhanced in situ bioremediation for the Off-Post Groundwater Plume.

The proposed pilot test/field treatability study has been designed to produce the required supplemental data needed for designing a full-scale remedy for the Off-Post Groundwater plume. Modifications have been made to the design of the treatability study based on comments received from the U.S. Army (Army) and USEPA. USEPA comments and Army responses to the draft plan are included as Appendix B. Results of the study will indicate:

- How the aquifer system and target contaminants respond to the electron donor dosage, frequency, and cycles;
- The effective bioremediation treatment radius;
- The appropriateness of injection pressure and injectate volumes along with determination of needed injection point spacing;
- The preferable injection method – expendable vs. reusable injection points; and
- The effectiveness of the prescribed electron donor.
2.0 SITE BACKGROUND

2.1 HISTORY

IAAAP is a government-owned, contractor-operated facility under the command of the U.S. Army Operations Support Command, Rock Island, Illinois. The current operating contractor is American Ordnance (AO). Production of munitions began in 1941, and the facility remains in operation. Production activities at IAAAP currently include loading, assembling, and packaging of munitions, including projectiles, mortar rounds, warheads, demolition charges, anti-tank mines, and anti-personnel mines. The loading, assembling, and packaging operations use explosive materials and lead-based initiating compounds.

IAAAP occupies approximately 19,000 acres adjacent to the town of Middletown in Des Moines County, Iowa (Figure 2-1). IAAAP is bordered by U.S. Highway 34 to the north, upland agricultural farms to the east and west, and the Skunk River Valley to the south. Surface topography is characterized by flat-to-gently rolling uplands dissected by entrenched streams and rivers. Approximately one third of the IAAAP property is occupied by active or formerly active production or storage facilities. Sites include surface impoundments, production lines, landfills, disposal areas, burn areas, demolition areas, and a fire training area. The remaining land at IAAAP is either woodlands or leased for agricultural usage. The facility map (Figure 2-1) shows site locations, creeks, and other features of interest.

Wastewater generated at various plant facilities and effluent from wastewater treatment plants is discharged to surface streams under the provisions of a National Pollutant Discharge Elimination System permit. The munitions production at IAAAP has resulted in contamination of soil and groundwater and discharge of wastewater containing explosives and explosives by-products to surface water. The majority of contamination resulted from discharging explosives directly on soil and into surface water. Explosives contaminants migrated through the soil into the groundwater, and also over land into surface water (e.g., Brush Creek). Volatile organic compound (VOC) contamination in soil and groundwater has also been identified at a small number of sites at the facility.

2.1.1 Previous Investigations and Reports

Pursuant to the Resource Conservation and Recovery Act (RCRA) Hazardous and Solid Waste Amendments of 1984, the U.S. Environmental Protection Agency (USEPA) completed an assessment of the facility in 1987 (USEPA, 1988) and reported that releases had occurred. The IAAAP was subsequently proposed for the National Priorities List (NPL) and, in August 1990, the facility was placed on the NPL with a Hazard Ranking Score of 29.73.

A Federal Facility Agreement (FFA) between Department of Defense and USEPA Region 7 was signed on September 20, 1990. Under the agreement, IAAAP
investigations and remediation activities will be completed under the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA). The agreement allows RCRA and CERCLA activities at the site to be coordinated. In response to the FFA, JAYCOR (1992) completed a facility-wide Preliminary Assessment/Site Investigation for the 44 sites listed in the FFA. Subsequently, JAYCOR (1996) completed a facility-wide Remedial Investigation (RI)/Risk Assessment for approximately 35 of the sites. Two of the sites (IAAAP-16 and 44) had ongoing RIs and were not addressed; one site (IAAAP-42) was eliminated because a removal action was undertaken at the site; and six sites (IAAAP-13, 14, 15, 18, 19, 22) were recommended for no further action. The IAAAP facility has been divided into three operable units (OUs) to facilitate project management. These include:

- Soils OU#1: Established to address contamination in soil.
- Soil Removal OU#2: Originally established for soil removal actions, but subsequently merged into OU#1.
- Groundwater OU#3: Established to address contamination of groundwater within the IAAAP boundaries and off site.
- OU#4: Established to address closure of the Corrective Action Management Unit, institutional controls, previously unaddressed areas of soil contamination, VOC-contaminated media, ecological impacts, groundwater monitoring requirements, and any other concerns which may be identified and not addressed in either OU#1 or OU#3.

### 2.1.2 Off-Site Groundwater Area Description and History

The off-site area is located southeast of the IAAAP facility and approximately 3 miles south of Burlington, Iowa, on Highway 61 (Figure 2-2). The off-site area occupies the Brush Creek watershed south of the facility and portions of the Skunk River floodplain.

Explosives used during production, assembly, burning, or demolition at IAAAP are potential sources for chemical release. Explosives compounds may have inadvertently been transferred to surface water and sediment via spills, leaking containers, incomplete combustion or detonation, and stormwater runoff. Permitted discharge points for process water and the wastewater treatment plant were, and may still be, significant sources of RDX-contaminated water entering into Brush Creek. Indirect product discharges to Brush Creek have resulted in the contamination of the surface water. Contaminated surface water infiltrates and percolates through the soil/sediment to groundwater in the off-site area.

In 1993, the presence of explosives in off-site groundwater was confirmed after an initial round of private drinking water well sampling was completed. IAAAP contracted to connect private residences in the contaminated area to the public water supply. This interim remedial action, completed in the Fall of 1994, was designed to eliminate the future exposure to contaminated drinking water. In 2001, IAAAP provided connection to the public water supply for several homeowners who declined in 1994.
2.1.3 Previous Off-Site Investigations and Reports

Previous off-site groundwater investigations included four phases of field activities. Phase I was completed between June 22 and July 12, 1999, and presented in a January 2000 Technical Memorandum (Harza, 2000a). Phase II was completed between September 27 and October 12, 1999, and presented in a January 2000 Technical Memorandum (Harza, 2000a). Phase III was completed between May 15 and May 24, 2000, and presented in a July 2000 Technical Memorandum (Harza, 2000b). Phase IV was completed between March 12 and April 3, 2001, and presented in a May 2001 Technical Memorandum (Harza, 2001).

Following the completion of numerous groundwater sampling events in the off-site area, URS conducted an RI in 2003 (URS, 2003) utilizing data collected in 2002. The RI defined the extent of RDX contaminated groundwater and assessed the potential risks to human exposure to the RDX under a variety of exposure scenarios. RDX concentrations detected in groundwater above 50 µg/L indicated a potential for adverse human health effects and/or cancer risks to an age-adjusted resident. The estimated total lifetime excess cancer risk for the age-adjusted resident \(2.1 \times 10^{-4}\) exceeded the USEPA target risk range of \(1 \times 10^{-6}\) to \(1 \times 10^{-4}\). The hazard index (3.9) was greater than 1.

The exceedance of the target risk range and hazard index by off-site RDX groundwater concentrations triggered the development and evaluation of remedial alternatives in an FS. URS completed a FS in March 2004 (URS, 2004a). The results of the FS indicated that monitored natural attenuation/enhanced degradation barriers (also referred to as in situ biodegradation) was the preferred remedial alternative. The FS also concluded that a field-scale treatability study should be conducted to determine the most effective biodegradation substrate and to evaluate the overall effectiveness of bioremediation at reducing RDX concentrations.

As required by CERCLA, a proposed plan was prepared for the off-site area to document the selected remedial alternative and present relevant background information for regulatory and public review, including conclusions of the RI/FS. The draft-final proposed plan was issued in July 2004 and is being review by the public as of the issue date of this document.

2.2 GEOLOGY/HYDROGEOLOGY

This section describes the physical site characteristics of the off-site area, including topography and surface features, geology, hydrogeology, and surface water/groundwater relationships. The information presented within this section is based chiefly on that provided in the FS (URS, 2004a) and proposed plan (URS, 2004b).
2.2.1 **TOPOGRAPHY AND SURFACE FEATURES**

The study area of the off-site groundwater is located southeast of the IAAAP property near the intersection of Brush Creek and Highway 61 (Figure 2-2). The study area occupies portions of the Skunk River/Mississippi River floodplain, which is bounded to the north by a topographic bluff or upland forming the limit of the floodplain. A few small tributaries and two major creeks (Brush and Spring Creeks) dissect the upland area and empty onto the Skunk River floodplain. The downstream reach of Brush Creek has been channeled and rerouted from its original course, which flowed to the east toward the Mississippi River. Brush Creek currently flows directly south into the Skunk River. To the east, the floodplain is occupied by wetlands, ponds, and sloughs. To the west, the floodplain extends to the Highway 61 bridge. The Skunk River floodplain is primarily agricultural/rural residential land, with some minor commercial activity. To the south, the Skunk River/Mississippi River floodplain is relatively broad, continuing south of the Skunk River and extending to the Mississippi River, which is 4 miles to the south.

2.2.2 **GEOLOGY**

The study area includes three different geologic profiles: an upland profile, a transition zone profile, and a lowland profile. A detailed discussion of each profile is provided in the section following. The general areal distribution of these three profiles in the off-site study area near Brush Creek is shown on Figure 2-3. Geologic cross-section A-A’ (Figure 2-4) illustrates the relationships between the various geologic units underlying the study area. The actual lithologies between borings may vary from the interpretation shown on the cross-section. The locations of the cross-section line and the existing direct-push and monitoring well soil boring locations are shown on Figure 2-3.

2.2.2.1 **Upland Geologic Profile**

The upland area can be described as a dissected glacial till plain that consists of unconsolidated Pleistocene glacial deposits overlying sedimentary bedrock units (IGS 1980). Groundwater flow in this glacial till profile is expected to be minimal. Brush Creek dissects this area and is interpreted to be a gaining stream within the glacial till upland plain area.

The typical subsurface geologic profile in the upland part of the study area, as determined from direct-push soil borings DP-400, DP-406, and DP-500 (Figure 2-3), generally consisted of:

- Silty clay glacial till from the ground surface to about 82 feet below ground surface (bgs),
- Sand and gravel glacial outwash from about 82 to 88 feet bgs, and
- Deep glacial till or bedrock units below about 88 feet bgs.
Shallow and Intermediate Glacial Till

A very stiff-to-hard, reddish-brown and gray mottled, medium-to-high plastic, silty clay with thin sand seams was encountered at the surface in most borings. The thickness of the upper silty clay averaged about 32 feet. Underlying the upper silty clay was a very stiff-to-hard, dark gray, high-plastic clay with traces of fine sand. The thickness of the lower dark gray clay averaged about 50 feet.

Glacial Outwash

Underlying the clay-rich glacial till was a glacial outwash unit. The glacial outwash consisted of a dark gray, poorly graded, fine-grained, sandy gravel with a trace of coarse gravel and occasional 1- to 2-inch thick, gray, high-plastic clay seams. Groundwater was encountered within this unit.

Weathered Bedrock

It is anticipated that weathered limestone and shale bedrock underlies the glacial till and glacial outwash sand units in the upland area. The borings drilled in the upland area for the RI did not encounter bedrock. It should be noted that weathered limestone and shale is present at the ground surface at the southern edge of IAAAP near Brush Creek.

2.2.2.2 Transition Zone Geologic Profile

The surface expression of the transition zone from the upland profile to the lowland profile consists of a bluff which bounds the upland and Brush Creek floodplain to the north, and a slightly lower and gently sloping bench located mostly north of Highway 61 (Figure 2-3).

The subsurface geologic profile in this area is shown on cross-section A-A’ (Figure 2-4). Loess and silty clay with sand (colluvium) were encountered at the surface near MW-502 and MW-502S, underlain by a high-plastic alluvial clay unit. This alluvial clay unit, interpreted as an older deposit, pinched out laterally against the brown alluvial sands of the lowland profile. Gray alluvial sand and gravel units were encountered underlying this alluvial clay unit in both borings.

The gray sand and gravel units also pinched out laterally against the brown alluvial sands of the lowland profile. A hard, gray, clay-rich glacial till was encountered underlying the sandy gravel unit and was found to be laterally extensive in the transition zone area and the lowland area also (Figure 2-4). The glacial till was underlain by glacial outwash sands in the transition zone and lowland areas. It is anticipated that bedrock is present below the outwash sand. The typical subsurface geologic profile in the transition zone of the study area varied from north to south. The northern edge of the transition zone profile generally consists of:
• Silty clay loess with sand colluvium from the surface to about 15 to 20 feet bgs,
• Silty clay alluvium from about 20 to 40 feet bgs, and
• Fine-grained, gray alluvial sand from about 40 to 60 feet bgs.

The southern edge generally consisted of:

• Silty clay topsoil from the surface to about 4 feet bgs, and
• Medium-grained, brown to reddish-brown alluvial sand from about 4 to 60 feet bgs.

Below the 60-foot depth, across the entire transition zone, the geologic profile consisted of:

• Fine-grained, gray alluvial sandy gravel from about 60 to 65 feet bgs,
• Silty clay glacial till encountered about 65 to 80 feet bgs,
• Dark gray, poorly-graded glacial outwash sands, and
• Weathered limestone and shale bedrock.

Shallow Silty Clay Topsoil and Loess

A very stiff, dark brown to black, low-plastic, silty clay topsoil layer was encountered at the surface in most borings. The thickness of the topsoil averages about 2 to 4 feet where present. Underlying the topsoil was a silty clay loess. The loess consists of a stiff-to-very stiff, brown and gray mottled, low-plastic, silty clay with iron stains and blocky soil structure. The thickness of the loess averaged about 20 feet near MW-502, and was present to the north, but not present near DP-504 (Figure 2-3) and south of Highway 61.

Shallow Silty Clay Colluvium

Underlying the topsoil and loess was a silty clay with sand colluvium. The colluvium consisted of a soft-to-medium stiff, reddish-brown, low-plastic, silty clay with fine sand. The thickness of this unit was about 20 feet at MW-502, and was not present near DP-504 and south of Highway 61. This unit was interpreted to have been deposited by slope wash from the upland profile.

Shallow Terrace Silty Clay Alluvium

Underlying the shallow, silty clay colluvium was a dark gray, silty clay alluvium. This alluvial clay unit consists of a stiff-to-very stiff, dark gray, high-plastic, silty clay and is approximately 20 feet thick. The alluvial clay deposit pinched out just north of DP-504 and was not present (i.e., eroded away) south of Highway 61. This unit is interpreted to be part of an older alluvial terrace depositional sequence.

Intermediate Terrace Alluvial Sands

Underlying the dark gray clay alluvium was a gray, fine-grained sand unit. The gray, fine-grained sand unit consisted of an unoxidized, dense, gray, fine-grained, poorly sorted
sand with trace silts and clays. The thickness of this unit was approximately 20 feet near MW-502 and DP-504, but pinched out laterally against the brown, oxidized sands of the lowland profile at MW-309, and was not present near Highway 61. This unit is interpreted to be part of an older alluvial terrace depositional sequence.

**Intermediate Terrace Sandy Gravel Alluvium**

Underlying the gray fine-grained terrace sand was a fine-grained, alluvial, sandy gravel. The gravel unit consisted of a fine-grained, gray and olive gray, poorly sorted, sandy gravel with some silts and clays. The thickness of this unit was approximately 2 to 5 feet. This unit is interpreted to be part of an older alluvial terrace depositional sequence.

**Intermediate Glacial Till**

Underlying the sandy terrace gravel was a dark gray, glacial till unit. The glacial till consisted of a hard, dark gray, medium-to-high plastic, silty clay with trace fine sand. The glacial till unit was typically encountered at about 60 to 70 feet bgs throughout the transition zone and the lowland areas. With about 25 feet of measured thickness at MW-117D, the unoxidized glacial till in the transition zone area was typically thinner than the till found in the upland area (greater than 50 feet), but slightly thicker than that found in the lowland area (5 to 15 feet).

**Deep Glacial Outwash**

Underlying the clay-rich glacial till was a glacial outwash unit. The glacial outwash consisted of a dark gray, poorly graded, fine-grained sand with trace gravel and occasional gray, high-plastic clay seams. The thickness of this unit was greater than 14 feet in MW-117D boring. Groundwater was encountered within this unit.

**Weathered Bedrock**

Although none of the borings in the transition zone were drilled to bedrock, it is anticipated that the bedrock underlying the glacial outwash in the transition zone would be weathered limestone and shale. Bedrock has been encountered at about 160 feet bgs in the lowland area.

2.2.2.3 **Lowland Geologic Profile**

Geology in the lowland profile area consisted of alluvial sand and silt floodplain deposits of the Skunk River, and older alluvial sand deposits from the Mississippi River overlying a laterally extensive, unoxidized glacial till unit. Deep glacial outwash sands were encountered between the base of the glacial till and the underlying limestone bedrock. The lowland profile was interpreted to be present from near old Highway 61, extending to the south side of the Skunk River (Figure 2-3).
As illustrated on cross-section A-A’ (Figure 2-4), the top of the glacial till generally slopes downward from the upland area to the south towards the Skunk River and the Mississippi River alluvial floodplains.

There is a localized remnant ridge in the glacial till surface, creating a topographic low spot near the MW-117 cluster, which is the current plume hotspot location and the focus of the treatability study.

The typical subsurface geologic profile in the lowland part of the study area (floodplain south of Highway 61), as determined from direct-push borings and monitoring well borings, generally consisted of:

- Silty clay topsoil, silty clay loess, and clayey silt alluvium from the surface to about 15 feet bgs;
- Medium-grained, brown to reddish-brown, alluvial sand from about 15 to 60 feet bgs grading laterally into fine-grained, gray, alluvial sand near the Skunk River;
- Fine-grained, alluvial, sandy gravel from about 60 to 65 feet bgs;
- Clay-rich glacial till encountered at about 65 to 75 or 85 feet bgs;
- Dark gray, poorly graded, glacial outwash sands from 75 or 85 feet to about 160 feet bgs; and
- Weathered limestone and shale bedrock underlying the glacial outwash sands.

**Shallow Silty Clay Topsoil, Silty Clay Loess, and Clayey Silt with Sand Alluvium**

A very stiff, dark brown to black, low-plastic, silty clay topsoil layer was encountered at the surface in most borings. The thickness of the topsoil averages 2 to 5 feet in the floodplain. Underlying the topsoil is a silty clay loess or a silty clay with sand alluvium. The loess consists of a stiff to very stiff, brown and gray mottled, low-plastic, silty clay with iron stains and blocky soil structure. The thickness of the loess averages about 5 feet south of the Skunk River. The silty clay alluvium consists of a medium stiff to stiff, dark and reddish-brown, low-plastic, silty clay with fine sand. The thickness of this unit averages about 5 feet on the north side of the Skunk River. These shallow units are interpreted to be more recent sediments related to the Skunk River.

**Intermediate Brown Sand Alluvium**

North of the Skunk River, a medium- to coarse-grained brown, alluvial sand underlies the shallow alluvial sediments. This intermediate alluvial sand unit consists of a medium-to coarse-grained, brown to reddish-brown, poorly sorted sand that has been highly oxidized. This unit is approximately 25 to 50 feet thick, and it is interpreted to be an older unit deposited in a higher energy, braided stream alluvial environment.

**Intermediate Gray Sand Alluvium**

South of the Skunk River, a gray, fine-grained alluvial sand underlies the topsoil and loess. The gray, fine-grained sand unit consists of an unoxidized, dense, gray,
fine-grained, poorly sorted sand with trace silts and clays. This unit is approximately 20 to 50 feet thick and is interpreted to be a younger meandering stream deposit, possibly associated with the Mississippi or Skunk Rivers.

**Intermediate Sandy Gravel Alluvium**

Underlying the gray and brown alluvial sands is a fine-grained, alluvial, sandy gravel. The gravel unit consists of a fine-grained, gray and olive gray, poorly sorted, sandy gravel with some silt and clay rip-up clasts (from the underlying till unit). The thickness of this unit is approximately 2 to 5 feet.

**Intermediate Glacial Till**

Underlying the sandy gravel alluvium is a dark gray, unoxidized, glacial till unit. The glacial till consists of a hard, dark gray, medium-to-high plastic, silty clay with fine sand. The majority of borings drilled in the lowland profile area encountered the glacial till unit, usually at depths of about 60 to 70 feet bgs. Near MW-117D, the glacial till was over 25 feet thick. As shown on Figure 2-4, the top of the glacial till unit drops off slightly to the south from Highway 61 towards the Skunk River alluvial plain. The till unit thins (to less than 10 feet) and was absent in a localized area around MW-509D (near a Skunk River oxbow lake) (Figure 2-3). This glacial till unit is the base of the upper aquifer unit and is interpreted to be an aquitard, preventing the vertical movement of contaminants across much of the lowland profile area.

**Deep Glacial Outwash**

Underlying the clay-rich glacial till in the lowland area was a glacial outwash unit. The glacial outwash consisted of a dark gray, poorly graded, fine-grained sand with trace gravel and occasional gray, high-plastic clay seams.

**Weathered Bedrock**

A weathered limestone bedrock was encountered at about 160 feet bgs in MW-509D, near the Skunk River (Figure 2-3). Verbal reports of well records in the area further east of Brush Creek in the lowland profile area indicate bedrock had also been encountered at depths in excess of 150 feet (Harza, 2001).

**2.3 HYDROGEOLOGY**

Twenty-eight monitoring wells have been installed in the off-site study area; 23 wells were installed as part of the 2002/2003 RI (URS, 2003), and five were installed as part of a previous study (Harza, 2001). The monitoring wells were typically installed in water-bearing units of interest in and around the off-site RDX plume. Water levels, shallow potentiometric surface contours, and groundwater flow directions are illustrated on Figures 2-5A and B for the shallow alluvial aquifer in June and November 2002.
The unconsolidated sediments resting on Pennsylvanian bedrock or clay-rich glacial till comprise the principal aquifer of the study area. The principal aquifer occurs mainly in two of the three unique hydrogeologic profiles recognized in the off-site study area, the transition zone and the lowland areas, which directly correlate to the previously described geologic profiles. The RDX plume only occurs in the principal aquifer in the same areas, therefore, there are no wells installed in the upland hydrogeologic profile. The general hydrogeologic conceptual model for groundwater occurrences in the off-site study area is as follows:

- In the transition zone and lowland hydrogeologic profiles, a shallow sandy aquifer unit exists perched atop a laterally extensive, unoxidized glacial till aquitard (confining unit). A second, deeper aquifer unit is found in the underlying deep glacial outwash sands. The bedrock appears to be the lower confining unit for the entire sequence.
- In the upland hydrogeologic profile, the transmission of groundwater is generally limited by the low permeability of the glacial till units, which typically continuously extend from the near surface to the underlying bedrock.

Groundwater occurrences are generally limited to localized sand seams found within the till. The bedrock appears to be the lower confining unit for the glacial till sequence.

Current direct-push and monitoring well groundwater sampling results indicated that the unoxidized glacial till units have restricted the vertical and horizontal movement of contaminants. These results also suggest that glacial till units restrict the movement of groundwater also, essentially acting as aquitard units.

### 2.3.1 Transition Zone Hydrogeologic Characteristics

Monitoring wells screened within transition zone water-bearing units included: MW-502S (screened in shallow colluvium), and MW-121, MW-502, and MW-505 (screened in the intermediate terrace sand alluvium). The principal aquifer unit within the transition zone hydrogeologic profile is the intermediate terrace sand alluvium.

#### 2.3.1.1 Transition Zone Water Levels, Hydraulic Gradients, and Flow Directions

In June 2002, depth to groundwater ranged from about 18 to 28 feet bgs in the intermediate terrace sand alluvium wells, but was encountered at only 6 feet bgs in the shallow colluvium well (MW-502S).

The groundwater flow directions in the intermediate terrace sand unit generally had a strong southerly component (i.e., toward the lowland alluvial plain) (Figure 2-5A). The potentiometric surface of the intermediate terrace sand unit was also influenced by surface water infiltrating from Brush Creek, which was typically at a higher elevation than the surrounding aquifer in this area (i.e., acting as a losing stream).
Groundwater encountered in the shallow colluvium unit (e.g., MW-502S) was interpreted to be perched atop a shallow, low permeability, alluvial clay aquitard. The water level in MW-502S (screened in the shallow colluvium) was about 18 feet higher than the water level measured in MW-502 (screened in the underlying intermediate terrace sand unit).

Horizontal hydraulic gradients estimated from Figure 2-5A for the intermediate terrace sand unit ranged from 0.0011 to 0.00035 feet per foot (ft/ft). Hydraulic gradients were interpreted to increase closer to Brush Creek reflecting the influence of the addition of surface water from Brush Creek to the aquifer.

The horizontal hydraulic gradient near MW-502S was estimated to be about 0.01 ft/ft based on the water level in the well compared to the shallowest water-table levels (in the intermediate sand units) about 1,000 feet downgradient where the shallow unit was absent.

2.3.1.2 Transition Zone Estimated Hydraulic Conductivities and Groundwater Flow Velocities

Aquifer slug test results indicate the hydraulic conductivities in the intermediate terrace sand unit range from 5.5 to 151 feet per day. The shallow colluvium well had a hydraulic conductivity of 0.06 feet per day. Using Darcy’s law and the aquifer-specific parameter values, average linear groundwater flow velocity values were estimated for each well and the unit in which they were screened. The average linear groundwater velocity estimates were as follows:

- The shallow colluvium had an estimated groundwater flow velocity of 0.63 feet per year, and
- The intermediate terrace sand unit had estimated groundwater flow velocities ranging from 7.4 to 68 feet per year.

2.3.2 Lowland Hydrogeologic Characteristics

The principal aquifer unit within the lowland hydrogeologic profile is the intermediate brown and gray sand units. Of lesser importance is the deeper aquifer comprised of the deep glacial outwash sands. The two aquifers are separated by a laterally extensive, low permeability, glacial till aquitard unit.

Both Brush Creek and Skunk River are interpreted to be in contact with groundwater and exert considerable influence on the potentiometric surface of the principal aquifer unit (i.e., shallow aquifer) in the lowland area.

2.3.2.1 Lowland Water Levels, Flow Directions, and Hydraulic Gradients

In June 2002, depth to groundwater ranged from about 3 to 25 feet bgs in all wells in the lowland area. Groundwater was generally encountered deeper (e.g., 16 to 25 feet bgs) in
the wells located near Highway 61 (higher ground elevation) and shallower (e.g., 3 to 6 feet bgs) in the wells located near the Skunk River (lower ground elevation). There was no significant difference in water levels measured in wells screened in the upper part of the shallow aquifer (e.g., MW-117S and MW-304S) versus wells screened at the base of the shallow aquifer (e.g., MW-117 and MW-304). This indicated complete hydraulic connection of the shallow aquifer.

Water levels (i.e., potentiometric surface elevations) measured in the deep aquifer wells were generally similar to the overlying clustered shallow aquifer unit wells, but were slightly lower (e.g., 0.62 feet and 0.09 feet lower at MW-117D and MW-509D, respectively). The groundwater flow directions in the intermediate sand units generally had strong southerly components (e.g., towards the Skunk and Mississippi rivers) (Figure 2-5A and 2-5B). The potentiometric surface of the shallow aquifer mimicked site topography, especially near the Skunk River.

The potentiometric surface of the shallow aquifer is also significantly influenced by interactions with surface water in Brush Creek. In the reach between Old Highway 61 and MW-409, Brush Creek is at a higher elevation than the surrounding aquifer area (i.e., losing stream), creating a significant groundwater mound (up to 2 feet) in the aquifer around the creek. In the reach between MW-136 and the Skunk River, Brush Creek changes back to a gaining stream (similar to the upland profile) with water levels that are similar to, or lower than, the surrounding aquifer.

Horizontal hydraulic gradients estimated from Figure 2-5A for the intermediate alluvial sand units (including both the brown and gray sand units) ranged from 0.00028 to 0.002 ft/ft. Hydraulic gradients generally increased in proximity to Brush Creek and/or to the Skunk River. The 0.62-foot difference in potentiometric surface elevations measured at intermediate/deep well cluster MW-117/MW-117D indicated a downward vertical hydraulic gradient of 0.015 ft/ft existed between the shallow aquifer and deep aquifer in June 2002. There was only a small difference (0.09 feet) in the potentiometric surface elevations measured at intermediate/deep well cluster MW-509/MW-509D, which indicated a slight downward vertical gradient of 0.00147 ft/ft existed between the shallow aquifer and deep aquifer in June 2002.

2.3.2.2 Lowland Estimated Hydraulic Conductivities and Groundwater Flow Velocities

Aquifer slug test results indicated the hydraulic conductivities of the intermediate alluvial sand units (i.e., the shallow aquifer) ranged from 190 to 390 feet per day. The intermediate brown sands had a slightly higher average hydraulic conductivity (geometric mean of 260 feet per day) than the intermediate gray sands (geometric mean of 190 feet per day). The wells screened in the deep glacial outwash had estimated hydraulic conductivities of 18 and 80 feet per day (mean of 38 feet per day), which were significantly lower than the shallow aquifer unit. Using Darcy’s law and the aquifer-specific parameter values, average linear groundwater flow velocity values were
estimated for each well, and the unit in which they were screened. Some of the more significant groundwater flow velocity trends were as follows:

- The intermediate alluvial sand unit closer to Brush Creek near Highway 61 (including wells MW-123, MW-125, MW-409) had estimated groundwater flow velocities of 210 to 470 feet per year. The high groundwater flow velocities in this area were created by the higher hydraulic gradients created by the influx of water from Brush Creek.
- The intermediate alluvial sand unit near the current RDX hotspot area (including wells MW-117, MW-307, MW-309, MW-501) had estimated groundwater flow velocities ranging from 80 to 130 feet per year. The combination of lower hydraulic conductivities and lower hydraulic gradients resulted in flow velocities that were significantly lower than all other areas in which the RDX plume was found in the intermediate alluvial sand units.
- The intermediate alluvial sand unit between Brush Creek and the Skunk River (including wells MW-303, MW-304, MW-407, MW-510, and MW-511) had estimated groundwater flow velocities ranging from 230 to 500 feet per year. These flow velocities were, on average, the highest measured in the off-site area.
- The intermediate alluvial sand unit south of the Skunk River (including wells MW-513, MW-514, MW-515, MW-516, and excluding well MW-517) had estimated groundwater flow velocities ranging from 110 to 250 feet per year. These flow velocities were lower than those on the north side of the Skunk River.
- The deep glacial outwash sand unit (including wells MW-117D and MW-509D) had estimated groundwater flow velocities of 7.6 and 40 feet per year. These flow velocities were significantly lower than the shallow aquifer.

2.4 SURFACE WATER/GROUNDWATER RELATIONSHIPS

2.4.1 Brush Creek Influence on Groundwater

The surface water and groundwater level data collected in May and June 2002 generally indicated that Brush Creek was in hydraulic contact with the surrounding aquifer, especially in the lowland alluvial profile area just south of Highway 61. A comparison of the staff gauge data with groundwater levels in monitoring wells located near Brush Creek indicated that Brush Creek was a gaining stream in the upland reaches from the IAAAP facility boundary to just north of Highway 61, and then changed to a losing stream in the transition zone and upper part of the lowland area. The interpreted June 2002 water-table surface (Figure 2-5A) indicated a groundwater mound was present surrounding Brush Creek from just north of new Highway 61 (and MW-123) to near MW-409. Staff gauge SG503 indicated the creek level was about 1 foot higher than the surrounding aquifer near MW-123, indicating the creek was a losing stream (i.e., discharging to the shallow aquifer) in that reach. The mound appears to dissipate as Brush Creek changes from a losing stream to a gaining stream once again near MW-136. Staff gauge SG504 indicated the creek level was slightly lower than the surrounding aquifer near MW-136. The final reach from MW-136 to the Skunk River appears to
remain a gaining stream (i.e., draining the shallow aquifer in that area) until the creek discharges into the river. Staff gauge SG505 indicated the creek level was about 2 feet lower than the surrounding aquifer near MW-511 and MW-408.

The geologic and hydrogeologic relationships suggest that surface water in Brush Creek (in the reach near Highway 61) discharges into the subsurface due to the increased hydraulic head pressure in Brush Creek. Additionally, where Brush Creek exits the upland till area, a large area of contamination was found in the groundwater surrounding the creek and deeper in the aquifer. Based on the hydrologic monitoring data collected during this investigation, it is interpreted that dissolved contaminants were transported in Brush Creek from the IAAAP facility through the upland area to just south of Highway 61 into the lowland area where Brush Creek became a losing stream discharging surface water (and contaminants) into the surrounding alluvial sand aquifer. Also, the direct-push and monitoring well groundwater samples collected from the upland glacial outwash and alluvial sand units north of the current plume locations were all nondetect for explosives. Therefore, it was interpreted that contaminants were not transported from the north (i.e., from the facility) by groundwater in the subsurface, but from surface water discharging from Brush Creek.

2.4.2 Skunk River and Mississippi River Influences on Groundwater

The groundwater level data collected in May and June 2002 generally indicated that Skunk River was in hydraulic contact with the surrounding aquifer. The interpreted June 2002 water-table surface contours (Figure 2-5A) mimicked the river channel.

Also important to note is that groundwater levels were generally higher on the north side of the Skunk River than the south side. This was potentially an effect of the Mississippi River regional flow system. The Mississippi River, which is located about 4 miles due south of the site, flows from northeast to southwest at that location, which may be the cause of the southerly component of groundwater flow seen on the south side of Skunk River.
3.0 ENHANCED IN SITU BIOREMEDIATION OF RDX

3.1 CHARACTERISTICS OF RDX

The cyclic nitramine explosive hexahydro-1,3,5-trinitro-1,3,5-triazine (RDX) is a powerful energetic compound that is commonly used in conventional munitions and various military applications. Activities associated with manufacturing, training, waste disposal, and closures of bases have resulted in soil and groundwater contamination with RDX, which is toxic.

RDX is of particular environmental concern because it is generally resistant to microbial transformation in aerobic soils (McCormick, Cornell, and Kaplan 1981) and is readily leachable (Singh et al. 1998, Sheremata et al. 2001). The fate and transport of RDX in the environment can be influenced by many factors including photolysis by sunlight, hydrolysis, and biologically mediated degradation. Photodegradation of RDX occurs rapidly under normal environmental conditions, but this is not a viable pathway for groundwater remediation. Likewise, although hydrolysis of RDX has been shown to occur, it is not a likely pathway under normal environmental conditions.

Biodegradation studies of RDX can be traced back to the 1970s. McCormick, Cornell, and Kaplan (1981) reported RDX biodegradation with municipal anaerobic sludge and proposed a degradation pathway based on the sequential reduction of RDX to nitroso daughter products (Figure 3-1) and, ultimately, ring cleavage.

3.2 MECHANISMS FOR IN SITU BIOREMEDIATION AND ENHANCEMENT

Numerous researchers have reported that the results from anaerobic studies suggest that degradation of RDX was a cometabolic process, and a source of organic carbon must be present to achieve RDX degradation (McCormick, Cornell, and Kaplan, 1981; Hawari, 2000; Kaplan, 1998; Card and Autenrieth, 1998; Price et al., 1998). The observation that RDX degradation occurred only in the presence of sugars implies that a large amount of reducing power is required. Freedman and Sutherland (1998) studied RDX degradation under nitrate-reducing conditions and found that RDX was biotransformed only after nitrate is completely consumed.

The bacteria-catalyzed reduction of RDX is similar to bidenitrification. In that process, oxygen ions are successively stripped from the nitrate, leaving the tri-nitroso compound TNX (subject to ring cleavage and further degradation). The same electron donors that can be used for chlorinated solvent reduction can be used for RDX reduction. Degradation of RDX has been observed under anaerobic conditions over a pH range of 5 to 8 (Price, et al. 1998).
The understanding of the fate and toxicity of intermediary RDX breakdown products such as MNX, DNX, and TNX is not well known and is under further development. However, mineralization of RDX and HMX has been demonstrated along with the generation of innocuous end products such as methane, ammonia, carbon dioxide, and water (McCormick, Cornell, and Kaplan, 1981; Hawari, 2000) (Figure 3-1). RDX and HMX are expected to be cometabolized in the subsurface based on previous laboratory and field studies performed. HMX, being more recalcitrant than RDX, is anticipated to degrade more slowly (Brannon and Pennington, 2002). HMX and RDX final degradation products are the same, although analysis of intermediaries by conventional laboratory methods is only possible for RDX (Hawari, 2000). Metals inhibition is not anticipated in the off-site plume area and has not been shown to be a significant issue in other bioremediation applications and studies.

Much of the research into explosives bioremediation has focused on bench-scale studies of soil or groundwater and field-scale remediation of soils and sludges. Only limited field scale studies have been conducted on in situ bioremediation of explosives in groundwater. Further research and field-scale implementation are on-going at Army ammunition plants, landfills, and Army bases across the United States.

Bioremediation of RDX and HMX in groundwater has been successfully demonstrated at bench and field scale in varying hydrogeochemical environments. Two noteworthy RDX and HMX bioremediation field treatability studies have been completed for groundwater plumes at Milan Army Ammunition Plant in Tennessee by ARCADIS and Camp Bonneville in Washington by Tetra Tech. Results of both studies are available in Army files but have not been published. Both projects utilized the addition of a fast release carbon source such as dextrose or molasses to stimulate anaerobic biodegradation, an identical approach to that proposed at IAAAP. The Milan Army Ammunition Plant and Camp Bonneville projects have shown significant RDX and HMX concentration reductions (greater than 80%) in less than 9 months. Concomitant with carbon source/carbohydrate injection, REDOX potentials declined several fold and became negative, nitrate was reduced, and RDX degradation products (MNX, DNX, and TNX) were produced.
4.0 PROPOSED PILOT TEST PLAN

4.1 INTRODUCTION

The treatability study will be conducted in a test area selected based on a review of the available groundwater monitoring data from five rounds of off-site groundwater sampling from 2002 to 2004. The initial available data set contained groundwater monitoring results through 2002 and was the data set that provided the basis for the FS, PP, and ROD for off-site groundwater (URS, 2002a, b, c). Since the issuance of the FS, PP, and draft ROD, additional groundwater monitoring data was collected in 2003 and 2004 (Hydrogeologic, 2004; Hydrogeologic, preliminary data). Based on a review and comparison of the 2003 and 2004 data with respect to the 2002 data (5 rounds of data total), the treatability study test area was selected to be performed in the vicinity of MW-117 (Figure 4-1). This area was selected to optimize treatment in the portion of the off-site groundwater plume containing consistently elevated RDX concentrations greater than the health advisory level (Table 4-1). The portion of the plume in the vicinity of MW-309 provides a secondary candidate for the treatability study, but is substantially more difficult to implement from a logistics perspective. It is on the shoulder of U.S. Highway 61 (a very busy highway) and flanked to the north by a fairly steep embankment. To the south the area is covered by multiple lanes of busy U.S. Highway 61. Access to areas surrounding MW-309 would be problematic and potentially cause injection and monitoring points to be spaced farther apart than optimal (due to width of U.S. Highway 61) to observe meaningful RDX and HMX results during the projected treatability study timeframe (approximately 9 months).

A multi-phase injection and monitoring approach will be utilized to gather the required data to design and implement a remedial action for RDX in the off-site groundwater plume. The phases are identified below and a schedule of activities detailed in Appendix A.

Phase 1

Step 1A – Install and develop supplemental monitoring network around MW-117 for groundwater treatability study performance monitoring.

Step 1B – Purge and sample monitoring network in treatability study area, including existing and newly installed wells to establish baseline (pre-injection) aquifer conditions.

Step 1C – Inject soluble quick-release carbon source into target zone of aquifer around MW-117 to stimulate anaerobic biodegradation of RDX and HMX.

Step 1D – Monitor REDOX potentials semiweekly in monitoring points and injection points to determine aquifer REDOX values and effects of carbon source injection.
Step 1E – Decision Point: If REDOX potentials are greater than -50mV after 4 weeks of monitoring, inject the same carbon source as in Step 1C. Vary the injection scheme (number of injection points, distance from monitoring well, injectate concentration) as needed based on REDOX monitoring results to lower REDOX over as much of the treatability area as possible. Continue to monitor REDOX on a semweekly basis for 4 weeks. If after two rounds of dextrose injection, REDOX values are not less than -50 mV, collect groundwater samples to confirm that RDX is not being biodegraded into DNX, MNX, and TNX.

If REDOX potentials are less than -50mV, collect groundwater analytical samples and MNA parameters to determine degradation byproducts and reduction in RDX and HMX concentrations.

Phase 2

Phase 2A – Decision Point: If groundwater analytical results from Step 1E do not demonstrate a 25% or greater reduction in RDX concentrations as compared with pre-injection results, evaluate whether reinjection of the same carbon source augmented with slower release carbon source would be beneficial. Also consider reinjection of just the fast release carbon source as initially used (perhaps with closer injection spacing or higher injectate concentration), particularly if REDOX is near -50 mV and RDX concentration reduction is near, but less than, 25%. If groundwater analytical data from Step 1E demonstrates greater than 25% reduction in RDX concentrations, evaluate reinjection based on trends in REDOX. If REDOX appears to have stabilized, reinject same carbon source as used in Step 1E to drive aquifer to more reducing state. Vary number of injection points, distance from monitoring well, and injectate concentration, as needed, based on REDOX monitoring results. If REDOX appears to be steadily declining, continue to monitor its progress and resample for explosives, degradation byproducts, and biodegradation indicators when REDOX is at its lowest.

Phase 2B – Repeat Steps 1C, 1D, and 1E, as necessary, until the 9-month test period has ended or RDX is below 2 µg/L (health advisory level).

4.2 TEST LOCATION AND WELL INSTALLATION

The pilot test will evaluate treatment of RDX in groundwater immediately downgradient of the proposed injection zone, specifically, near monitoring well MW-117 (Figure 4-1). The RDX hot spot containing concentrations greater than 50 µg/L in 2002 to 2004 will be targeted, as RDX reduction within the hot spot is a primary remedial goal for off-site groundwater. Three injection points (IP-1 through IP-3) will be installed at varying distances as part of the initial treatability test (Figure 4-2). The points will be installed downgradient of MW-117, based on the winter and summer groundwater flow directions (Figure 4-2). Additional injection points may be installed, depending on the groundwater monitoring results obtained after the first injection event and as dictated by the steps outlined in Section 4.1. Post-injection sampling will include explosives, RDX breakdown
products, and biodegradation indicator parameters, and is discussed further in Section 5.0.

Injection points will be installed using hydraulic push technology (e.g., Geoprobe™) and will be used for one-time injections only. Injection will be accomplished in the basal 15-foot interval of the alluvial sands on top of the Intermediate Glacial Till, and at the approximate same elevation as the screen interval of monitoring well MW-117 to target the base of the shallow alluvial sand aquifer containing RDX contamination (Figure 4-3). Prior to injection point installation, the proposed locations will be marked with paint on the ground, and a Tetra Tech field technician will coordinate clearance of the proposed locations of any utilities with One-Call and Des Moines County. Injection points will be installed in accordance with SOP No. 13 provided as an addendum to the Installation-Wide Work Plan (URS, 2002) and in Appendix C.

4.3 INJECTION/OBSERVATION WELL NETWORK

The number, location, spacing, and construction of the proposed injection points are based on a review of the hydrogeologic and analytical information available for the site. Prior to injecting, a permit will be obtained, if necessary, from the Iowa Department of Natural Resources to install and inject within the proposed electron donor injection points. Based on the permeability anticipated in the injection zone, injection point construction will be sufficient to maintain slightly elevated injection pressures during electron donor application. Injection with elevated pressures will generate small fractures in the soil and improve aquifer permeability while increasing the dispersion of the electron donor.

Based on the calculated seepage velocity (80 to 130 feet per year) in the proposed injection zone, injection points will be installed at a spacing of 10 to 30 feet upgradient of monitoring points (Figure 4-1). This spacing will permit data collection (particularly RDX and its degradation products) over the 9-month life of the treatability study, and will permit the calculation of an effective radius of influence and degradation rate based on RDX degradation. Injection points will be at sufficient depths to target the highest concentration area of the plume within the sandy gravel alluvium and the lower portion of the alluvial sand unit (Figure 4-3). Injection points will be created by injecting over the target zone using a direct-push borehole. Approximately 200 to 400 gallons of dextrose solution will be injected into each boring at a pressure of 20 to 100 pounds per square inch. This pressure is sufficient to inject substrate fluids without damaging the well screen (e.g., MW-117). The location of injection points is detailed in Figure 4-2. Table 4-1 details injection program information.

The expendable boreholes will be available for a one-time use for each injection event. Expendable boreholes will be used for up to 3 injection events. This option will provide for a more flexible injection scheme that can be easily modified to accommodate changes dictated by the ongoing collection of injection/monitoring results. Should the required number of injection events exceed 3, it may be necessary to install temporary injection
wells to provide a more cost-effective longer term carbon delivery system. Injection wells will be installed according to SOP No, 13 (Appendix C).

In addition to monitoring existing well MW-117, five small diameter monitoring wells will be installed at variable distances downgradient of the injection points as shown in Figure 4-2. The number of monitoring piezometers will be sufficient to capture information on the radius of influence and monitor the concentrations of RDX, HMX, degradation products, and biodegradation indicator parameters. The spacing of both injection and monitoring points is based on observed seasonal groundwater flow directions and calculations of groundwater velocity in the immediate vicinity of the test. Injection locations have been selected to be upgradient of monitoring points at a distance (10 to 30 feet) to allow results to be effectively monitored within the proposed sampling frequency. If it is determined during the test that additional monitoring locations are needed to effectively evaluate test results, they will be added at the optimum location and spacing based on best available data and information.

Monitoring piezometer installation and construction will consist of 1-inch (nominal inside diameter) schedule 40 PVC, 0.020 slot screen, filter sand, and flush-mounted completion (Appendix A). A mini-vault with bolt-on cover will be used to house the piezometer. The piezometer cap will be lockable to prevent tampering. Depending on the results of the treatability study, the piezometer may be retained for use during future remedial actions or abandoned.

Newly-installed injection points and monitoring piezometers will be surveyed for horizontal coordinates and vertical elevations with a precision of 0.01 feet in the vertical direction and 0.1 feet in the horizontal direction and in accordance with the Installation-Wide Work Plan (URS, 2002).

4.4 ELECTRON DONOR INJECTION

Following issuance of an injection permit by the IDNR (if necessary), injection point and monitoring piezometer installation, and baseline monitoring, the electron donor solution will be injected.

4.4.1 Solution Composition

A dextrose solution will be used as the initial injectate. Dextrose has been selected based on past experience by Tetra Tech, industry practitioners, and the research community. A simple carbon source (sugar solution) has been used successfully as an in situ bioremediation supplement for years where anaerobic biodegradation is required. Dextrose provides an effective short-term electron donor/carbon source to drive oxidation-reduction potentials to moderately to strongly reducing conditions (-50 to -150 mV) in the aquifer. The raw dextrose product (corn syrup) is provided by the manufacturer as a liquid concentrate consisting of 71% solids (95% dextrose mixed with lesser amounts of maltose and saccharides). This mixture will be diluted at a ratio of five
parts tap water to one part raw dextrose corn syrup. This will produce a mixture consisting of approximately 12% dextrose corn syrup solids. This process facilitates the biodegradation of RDX, HMX, and TNT. In the case of RDX, analytical measurable intermediate byproducts such as MNX, DNX, TNX, and ultimately innocuous mineralization end products (e.g., water, nitrous oxide, and methane) are produced (Figure 3-1). Intermediate byproducts for HMX are not measurable by conventional laboratory methods, although end products are the same as for RDX.

The solution will be injected into the injection points. The injection will be a one-time event in each injection point. Following collection, analysis, and evaluation of groundwater monitoring results an additional round of electron donor injection may be conducted.

Sodium bicarbonate (NaHCO₃) will be added to the electron donor solution to moderate any pH changes initiated by generation of organic acids produced by the increased biological activity. Evaluation of the need for additional buffer capacity will depend on the results of alkalinity measurements during pre-test baseline monitoring. Alkalinity additions are used to ensure aquifer pH remains in a range favorable for biological activity (typically in the pH range of 4 to 8). Historical groundwater analytical data, incorporating pH and alkalinity measurements have been used to guide the initial decision about the addition of sodium bicarbonate. An initial amount of sodium bicarbonate will be added to the injectate at a concentration that will maintain the current alkalinity (150 milligrams per liter) of the aquifer. For 200 gallons of injectate, 97 grams of sodium bicarbonate will be added. For 400 gallons of injectate, 194 grams will be added. Subsequent field measurements of pH will be evaluated in combination with evidence for biological activity (e.g., generation of intermediates) to determine whether subsequent injections will include sodium bicarbonate.

The composition and concentration of the electron donor solution may be adjusted during subsequent pilot test injections, depending on interpretation of field measurements and analytical results obtained during performance monitoring and in accordance with the steps and decision logic presented in Section 4.1. Each electron donor solution composition and injected volumes will be documented in the field logbook.

The treatability study will be conducted in phases. The first phase is to utilize a rapid consumable carbon source (dextrose), as described within this plan. Given the relatively low concentrations present (10s of ppb rather than 100s to 1,000s of ppb) in the off-post plume, the rapid consumable carbon source will likely reduce concentrations substantially within the treatment area after only one to two applications.

The effectiveness of dextrose will be monitored initially by the REDOX potential in the aquifer. REDOX potentials of -50mV or lower will signify that anaerobic biodegradation is occurring and that groundwater sampling and analysis is warranted for the detection of explosives and explosives breakdown products. If after two rounds of dextrose injection, a REDOX potential of lower than -50 mV is not measured, groundwater analytical
samples will be collected as confirmation that RDX and HMX degradation has not occurred to a substantial degree (>25% concentration reduction).

If the approximately 25% reduction is not observed, a longer lasting carbon source such as EOS® or HRC® will be utilized in a subsequent test phase. EOS® and HRC® are patented combinations of quick and slow consumable carbon sources observed to remain available in the aquifer for up to 3 years. Both products have been proven on the anaerobic bioremediation of RDX and TNT. Due to their long lasting capabilities and the limited duration of the pilot test (less than 1 year), the full benefits of the slow release component of EOS® and HRC® are beyond the scope of the treatability study.

4.4.2 Loading and Frequency

Following the initial sugar solution injection, an appropriate solution feed rate will be established and maintained to ensure that the available electron acceptors are fully metabolized and that the resultant biogeochemical conditions are sufficiently reducing. At the same time, the feed rate needs to be controlled so as to minimize the amount of material that has to be injected into the subsurface. Injection will take place under relatively low pressure conditions [20 to 100 pounds per square inch (psi)]. The solution feed rate will be determined by field conditions and will be a balance between safe injection pressure limits of the equipment and the ability of the aquifer to accept the feed solution. Injection will take place in accordance with the SOP No. 13 provided as an addendum to the Installation-Wide Work Plan (URS, 2002) and as Appendix C.

The proposed solution feed rate has been calculated based on achieving a carbohydrate concentration of at least 50 grams per liter in the groundwater that passes through each injection point zone. The electron donor solution feed loading and frequency will be adjusted to create and maintain an anaerobic biogeochemical environment (minimally iron-reducing to sulfate-reducing). The target total consumable carbohydrate concentration of available carbon in the feed solution is based on a range of published short-term studies under controlled conditions using multiple types of carbohydrate (e.g., acetate at 6 mg C/L by Pombo, et al., 2002; acetate at 56 mg C/L by Kleikemper et al., 2002; lactic acid at 40 mg C/L in a case study summarized by USEPA, 2000) and a conservative engineering factor (x 1000).

Approximately 200 to 400 gallons of sugar electron donor solution will initially be introduced into each injection point. The anticipated range of 200 to 400 gallons per injection point is based on other tests in similar hydrogeologic environments. The actual injection volume will be a balance among: 1) injecting the maximum amount of carbohydrate in the aquifer; 2) maximizing the area of influence from the injection point; and 3) minimizing the time required to complete the injection. Additional electron donor feed solution injections will be conducted based on the steps and decision logic presented in Section 4.1.
4.4.3 **Procedure**

Electron donor solution preparation and injection will be directed by experienced personnel. Prior to each injection, the electron donor solution will be prepared with the use of a trailer-based mobile injection system. This unit includes a tank, mixer, pump, and power source required for reagent mixing and injection. The electron donor solution will be prepared by thoroughly mixing the dextrose corn syrup with potable water, and sodium bicarbonate (as necessary). The resulting solution (five parts tap water to one part dextrose corn syrup, and sodium bicarbonate as needed) will be pressure-fed into the appropriate injection point from the mobile injection unit. A field log will be maintained to record the electron donor solution composition, the volume of solution introduced into each injection well, the length of time required for injection, and the injection pressure.

The actual injection pressure used during the test will be determined in the field based on field conditions, specifically the resistance of the formation to accept low viscosity aqueous fluids. Since Tetra Tech will be injecting approximately 40 feet below the water table, sufficient pressure will have to be applied to overcome the hydrostatic pressure exerted by the overlying column of groundwater. This pressure will be less than 20 psi. In practicality, the needed injection pressure will be influenced more by the lithology, sorting, hydraulic conductivity, and other physical properties of the geologic formation. As such, we anticipate injecting at approximately 100 psi. The actual injection pressure may vary from this predicted value based on field conditions encountered at the time of the injection.

The radius of influence of injected material will be indirectly measured by the reduction in RDX and HMX concentrations in downgradient and cross-gradient directions. Influence will also be gauged by measurements of TOC which will indicate the incursion of additional carbon (dextrose injectate) into the vicinity of the monitoring location. As previously indicated in the plan, monitoring wells have been positioned at varying distances and vectors from planned injection points to evaluate the maximum effective biodegradation radius. This information will be used in the future to determine the optimal spacing of injection points for full scale remedy implementation.
5.0 PILOT TEST MONITORING PLAN

Performance monitoring will be conducted to gather the data critical to evaluating the effectiveness of the pilot test. Trained personnel will conduct field monitoring and groundwater sample collection in accordance with the Installation-Wide Work Plan and SOPs (Appendix C). Data collected during performance monitoring will be analyzed to adjust the electron donor solution strength, volume, and/or frequency of injections. In addition, the data will be evaluated to determine whether the objectives of the pilot test have been achieved. The general objectives of the treatability study are to identify an effective electron donor, dosage rate, and frequency of application; define the effective radius of influence; identify suitable injection pressures; and ascertain the most effective injection approach ( expendable versus reusable injection points).

Monitoring well MW-117 and five additional monitoring wells will be sampled. These wells will be sampled during the test duration as specified in the following sections and Section 4.1.

Standard operating procedures (SOP) have been developed for injection point and monitoring well installation using a DPT rig and are contained in Appendix C. The SOP will also be included as an addendum to the Installation-Wide Work Plan (URS, 2002).

5.1 DURATION OF TEST

Based on the estimated groundwater seepage velocities, the low-pressure injection of the electron donor solution and the proposed well locations, the pilot test duration is anticipated to be up to 9 months. A lesser duration of the pilot test would be achieved if the performance objectives of the treatability study are met. Specifically, if a RDX concentration reduction is greater than 25%, the treatability study would be deemed successful. Additional injection and monitoring events may be performed once a 25% reduction is achieved if best professional judgment indicates additional degradation could be induced within the 9-month treatability study timeframe.

The actual test duration is planned to allow adequate time to demonstrate the effectiveness of the technology and provide engineering data for potential subsequent applications. It is possible that the test will successfully create anaerobic conditions in the groundwater with demonstrable RDX degradation (up to or greater than 25% degradation) but the RDX concentration will remain above the target concentration of 2 µg/L at the end of the test period.

5.2 MONITORING FREQUENCY

Prior to adding electron donor solution to the groundwater, a groundwater sampling event will be conducted for existing monitoring wells, and new monitoring wells, to establish
baseline aquifer conditions (Table 5-2). Monitoring well MW-117 has a history of sampling events and the variability of RDX concentrations are reasonably established (Table 4-1). Field parameters, RDX and other explosive compounds, anticipated degradation products, and biogeochemical analytes will be measured and/or analyzed (Table 5-2). Total organic carbon (TOC) will be sampled from the observation wells approximately 1 month after the first electron donor injection. Data from this sampling event will be used to evaluate possible changes in the electron donor solution composition, volume, and/or the extent of the reactive zone. TOC monitoring will continue in the observation wells/piezometers every 2 months (or as needed). The first performance monitoring event will be triggered by the decision logic in Section 4.1. Additional performance monitoring events will also be conducted according to Section 4.1. The final monitoring event will be conducted for all observation wells/piezometers and will be conducted approximately 1 month after the last electron donor injection.

Field parameters and water levels will be measured in all wells prior to each electron donor injection. These results will be used to modify the reagent injection volume/concentration/frequency.

5.3 DATA COLLECTION

The proposed data to be collected will be critical to any future remedial action design efforts where in situ biodegradation is used for groundwater remediation. The frequency of data collection has been designed to facilitate the timely completing of future remedial actions.

5.3.1 Baseline

During the baseline sampling event, groundwater samples from the observation wells/piezometers will be analyzed for selected field and laboratory parameters to determine pre-injection biogeochemical conditions. Sample collection methods will conform to those in the Installation-Wide Work Plan (URS, 2002).

Field Parameters. Field parameters will be measured at each well in the treatability monitoring network (Figure 4-2). Field parameters include dissolved oxygen (DO), oxidation-reduction potential (REDOX), pH, temperature, and specific conductance. These parameters will be measured using an in-line multi-parameter meter during low-flow groundwater purging (prior to sample collection). Field measurements of alkalinity, ferrous iron, and sulfide will be measured using Hach or Chemetrics test kits (Table 5-1). These data will be used to assess conditions in the groundwater system supporting anaerobic biodegradation of RDX. Water-level measurements will be collected at each treatability study area, monitoring location, as well as surrounding wells MW-309, MW-307, MW-303, MW-501, MW-123, and MW-502.
**RDX.** Analyses for RDX and its degradation products in the baseline and subsequent sampling rounds provide information directly demonstrating the effectiveness of the pilot test. RDX and the degradation products (MNX, DNX, and TNX) will be determined by SW-846 Method 8330. Practical quantitation limits (PQL) for this method are 0.5 ppb.

**Biogeochemical Analytes.** Analyses for electron acceptors and reduction products provide data regarding the relative levels of natural inorganic compounds, which act as electron acceptors for various specific terminal electron accepting processes. Electron acceptors and reduced products measured in the pilot test will include nitrate, nitrite, total iron, total manganese, sulfate, carbon dioxide, and methane. Evaluation of electron acceptor and reduction product concentrations in site groundwater before and after electron donor injection can facilitate a determination regarding which metabolic processes are active or dominant. The dominant metabolic processes in turn control the potential degradative processes that the RDX can undergo.

**TOC.** TOC is sampled as a quantitative measure of the amount of organic carbon being introduced to the groundwater through electron donor injections. If TOC concentrations are low, there will not be sufficient electron donor to grow a viable microbial population to degrade RDX and its daughter products. If TOC concentrations are high, biological activity can result in accumulation of organic acids and a pH change that adversely impacts the microbial population.

### 5.3.2 Performance Monitoring

Following the initiation of the electron donor injections, groundwater samples will be collected to assess the performance of the pilot test and assess the biogeochemical conditions of the reactive zones. Groundwater samples will be collected from the injection well and monitoring well network according to the decision points in Section 4.1. Planned sampling events include performance sampling events and a final sampling event (Table 5-3). Data collected during performance monitoring will be interpreted to determine any adjustments that may be required to optimize reagent volume, strength, or injection frequency.

### 5.3.3 Groundwater Sampling Procedures

The preferred method of groundwater sampling for the treatability test is low-flow purging and sampling using pneumatic bladder pumps. This method of sampling will provide the highest quality groundwater sample with minimal investigation derived waste. Water level measurements will be collected at each location where groundwater sampling activities occur and at other pertinent nearby monitoring wells. Please refer to the list of wells to be gauged in Section 5.3.1.

### 5.3.4 Sample Analyses

Groundwater samples will be analyzed according to the program specified in Tables 5-2 and 5-3. Analytical methods and PQLs for each analyte are presented in Table 5-4. Bottle
requirements, preservatives, and holding times for analytical parameters are also summarized in Table 5-4.

5.3.5 **Quality Control/Quality Assurance Samples**

Quality assurance/quality control (QA/QC) samples collected in the field will consist of temperature blanks, field duplicates, and sampling equipment rinsate blanks. These samples will be collected at the frequency summarized in Table 5-5 and in accordance with the *Installation-Wide Work Plan* (URS, 2002).

Laboratory QA/QC samples will be collected and will include batch specific matrix spike/matrix spike duplicate samples, laboratory control samples, surrogate spikes, blank samples, laboratory duplicates, and extraction blanks. These samples will be collected at the frequency summarized in Table 5-5 and in accordance with the *Installation-Wide Work Plan* (URS, 2002).
6.0 DATA EVALUATION AND REPORTING

Performance data collected during the pilot test will be compared to baseline data and periodically evaluated to ensure treatability test performance. The results will be evaluated to determine the treatability test effectiveness. Multiple lines of evidence will be evaluated to determine if biodegradation has been enhanced. These include, but are not limited to:

- Were biogeochemical conditions created such that enhanced biodegradation should be expected?
- Did RDX concentrations decline?
- Were RDX degradation products consistent with enhanced degradation observed?

An initial increase in dissolved-phase contaminant concentrations may be observed after treatment begins due to enhanced soil desorption of RDX. These concentrations then decline to below baseline concentrations once enhanced biodegradation begins. Following the pilot test, if the pilot scale reactive zone is not maintained, concentration increases can be expected as additional upgradient constituent mass is transported to the well by groundwater flow and/or chemical dispersion. A full-scale system would not be subject to such a rebound effect if the hot spot (> 50 ppb RDX) area were effectively treated.

The treatability test, although limited in size, will provide an estimate of the design parameters that will be required in a scale-up application of the technology. Injection point construction, the monitoring network, and reagent dosing will all be aided by treatability test results.

Following completion of the treatability test, a report will be prepared to document baseline and performance monitoring results, present an evaluation of the success of the treatability test, and provide a general recommendation regarding possible future applications of this technology at the site. Lessons learned applicable to other sites with energetics groundwater contamination will also be discussed.
REFERENCES


TABLES
Table 4-1. Comparison of MW-117 and MW-309 Historical RDX Concentrations in the Off-Site Groundwater Treatability Study Area

<table>
<thead>
<tr>
<th>Well</th>
<th>MW-117 (RDX in µg/L)</th>
<th>MW-309 (RDX in µg/L)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Spring 2002</td>
<td>120</td>
<td>89</td>
</tr>
<tr>
<td>Fall 2002</td>
<td>20</td>
<td>160</td>
</tr>
<tr>
<td>Spring 2003</td>
<td>76</td>
<td>41</td>
</tr>
<tr>
<td>Fall 2003</td>
<td>32</td>
<td>100</td>
</tr>
<tr>
<td>Spring 2004</td>
<td>70</td>
<td>66</td>
</tr>
</tbody>
</table>

Note that the maximum detected value is shown.
### Table 5-1. Injection Program Details

<table>
<thead>
<tr>
<th>Approximate Injection Depth</th>
<th>Estimated Injection Pressures</th>
<th>Volume of Injectate</th>
<th>Preferred Injectate/dilution</th>
<th>Alternative Injectates</th>
<th>Type of Injection Point</th>
<th>Location of Injection Points</th>
</tr>
</thead>
<tbody>
<tr>
<td>~40 to 55 feet bgs (see Figure 4-3)</td>
<td>20 to 100 psi</td>
<td>~200 to 400 gallons per point</td>
<td>Dextrose/5 parts water: 1 part dextrose (sodium bicarbonate as needed for pH adjustment)</td>
<td>EOS® and HRC®</td>
<td>Expendable</td>
<td>See Figure 4-2</td>
</tr>
</tbody>
</table>

### Table 5-2. Baseline Sampling Event

<table>
<thead>
<tr>
<th>WELL</th>
<th>Sample Event</th>
<th>Analytes/Parameters</th>
<th>Aquifer¹</th>
<th>Field²</th>
<th>RDX³</th>
<th>Biogeochemical⁴</th>
<th>TOC⁵</th>
</tr>
</thead>
<tbody>
<tr>
<td>MW-117</td>
<td>Baseline</td>
<td>WELL</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td>Performance Monitoring Wells</td>
<td>Baseline</td>
<td>WELL</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
</tr>
</tbody>
</table>

---

¹ DO, REDOX, pH, temperature, specific conductance measured for stabilization during well purging.
² Field analyses with test kits: DO, ferrous iron, sulfide, and alkalinity.
³ RDX, explosives, and RDX degradation products (MNX, DNX, TNX) by SW-846 Method 8330.
⁴ Sulfate and nitrate/nitrite by *Methods for the Chemical Analysis of Water and Waste*, 19th edition, Method 300.0 or SW-846 9056; Total iron and total manganese by SW-846 Method 6010B, methane by RSK175, carbon dioxide by SM4500.
⁵ TOC by Method 415.1.
Table 5-3. Performance Sampling Events

<table>
<thead>
<tr>
<th>Well</th>
<th>Event Frequency</th>
<th>Analytes/Parameters</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Aquifer&lt;sup&gt;1&lt;/sup&gt;</td>
</tr>
<tr>
<td>MW-117</td>
<td>B</td>
<td>X</td>
</tr>
<tr>
<td>Performance Monitoring</td>
<td>B</td>
<td>X</td>
</tr>
<tr>
<td>Wells</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Sample frequency B – first sample approximately 3 months after first electron donor injection. Additional performance sampling events approximately every month thereafter depending on REDOX and as specified in the decision logic presented in Section 4.1.

<sup>1</sup> DO, REDOX, pH, temperature, turbidity, and specific conductance measured for stabilization during well purging.

<sup>2</sup> Field analyses with test kits: ferrous iron, sulfide, and alkalinity.

<sup>3</sup> RDX and degradation products (MNX, DNX, TNX) by SW-846 Method 8330.

<sup>4</sup> Sulfate and nitrate/nitrite by Method 300.0 or SW-846 9056; total iron and total manganese by SW-846 Method 6010B; methane by RSK 175; carbon dioxide by SM 4500.

<sup>5</sup> TOC by Method 415.1.
## Table 5-4. Summary of Analytical Methods, Practical Quantitation Limits (PQLs) and Packaging Requirements for Laboratory Analyzed Parameters

<table>
<thead>
<tr>
<th>Analyte Suite</th>
<th>Matrix</th>
<th>Analytical Method</th>
<th>PQL (µg/L)</th>
<th>Container</th>
<th>Preservation</th>
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</thead>
<tbody>
<tr>
<td>RDX and Metabolites</td>
<td></td>
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<td></td>
<td></td>
</tr>
<tr>
<td>RDX</td>
<td>Water</td>
<td>SW-846 8330</td>
<td>0.5</td>
<td>1-L Amber glass</td>
<td>4° C</td>
</tr>
<tr>
<td>MNX</td>
<td>Water</td>
<td>SW-846 8330</td>
<td>0.5</td>
<td>1-L Amber glass</td>
<td>4° C</td>
</tr>
<tr>
<td>DNX</td>
<td>Water</td>
<td>SW-846 8330</td>
<td>0.5</td>
<td>1-L Amber glass</td>
<td>4° C</td>
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<tr>
<td>TNX</td>
<td>Water</td>
<td>SW-846 8330</td>
<td>0.5</td>
<td>1-L Amber glass</td>
<td>4° C</td>
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<tr>
<td>Biogeochemistry</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total iron</td>
<td>Water</td>
<td>SW-846 6010B</td>
<td>50</td>
<td>1-L Plastic</td>
<td>HNO₃</td>
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<tr>
<td>Total manganese</td>
<td>Water</td>
<td>SW-846 6010B</td>
<td>15</td>
<td>1-L Plastic</td>
<td>HNO₃</td>
</tr>
<tr>
<td>Sulfate</td>
<td>Water</td>
<td>9056</td>
<td>100</td>
<td>1-L Plastic</td>
<td>4° C</td>
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<tr>
<td>Nitrate</td>
<td>Water</td>
<td>9056</td>
<td>100</td>
<td>1-L Plastic</td>
<td>4° C</td>
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<tr>
<td>Nitrite</td>
<td>Water</td>
<td>9056</td>
<td>100</td>
<td>1-L Plastic</td>
<td>4° C</td>
</tr>
<tr>
<td>Carbon Dioxide</td>
<td>Water</td>
<td>SM 4500</td>
<td>5000</td>
<td>1-L Plastic</td>
<td>4° C</td>
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<tr>
<td>Methane</td>
<td>Water</td>
<td>RSK 175</td>
<td>26</td>
<td>2-40 mL VOA vial</td>
<td>4° C</td>
</tr>
<tr>
<td>TOC</td>
<td>Water</td>
<td>SW-846 9060</td>
<td>1000</td>
<td>1-L Plastic</td>
<td>4° C</td>
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## Table 5-5. Quality Control Sample Collection Summary

<table>
<thead>
<tr>
<th>Sample Type</th>
<th>Frequency</th>
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<tbody>
<tr>
<td>Temperature blanks</td>
<td>1 per cooler</td>
</tr>
<tr>
<td>Field duplicates</td>
<td>10 percent</td>
</tr>
<tr>
<td>Matrix spike</td>
<td>5 percent</td>
</tr>
<tr>
<td>Matrix spike duplicates</td>
<td>5 percent (organics only)</td>
</tr>
<tr>
<td>Laboratory duplicates</td>
<td>5 percent (inorganics only)</td>
</tr>
</tbody>
</table>
FIGURES
Final Treatability Study Test Plan for In Situ Biodegradation of RDX in Off-Site Groundwater

Figure 1-1 Facility Location Map
Final Treatability Study Test Plan for In Situ Biodegradation of RDX in Off-Site Groundwater

Figure 1-2 Horizontal Extent of RDX Exceeding PRGs in Groundwater

[Map showing the horizontal extent of RDX exceeding PRGs in groundwater]
IAAAP
Final Treatability Study Test Plan for In Situ Biodegradation of RDX in Off-Site Groundwater

Figure 2-3 Off-Site Geologic Profiles
Figure 3-1  Denitration (path a) and nitroso (path b) routes for anaerobic biodegradation of RDX (McCormick, Cornell and Kaplan, 1981).
APPENDIX A

SCHEDULE
<table>
<thead>
<tr>
<th>ID</th>
<th>WBS</th>
<th>Task Name</th>
<th>Work Days</th>
<th>Start</th>
<th>Finish</th>
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</thead>
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<td>1</td>
<td>Work Plan</td>
<td>30 days</td>
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<td>Fri 10/29/04</td>
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<td>1.1</td>
<td>Draft-Final Work Plan</td>
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<td>1.1.1</td>
<td>Milestone Completion and Response</td>
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<td>Fri 10/29/04</td>
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<td>4</td>
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<td>Pilot Test Field Work</td>
<td>252 days</td>
<td>Tue 9/28/04</td>
<td>Fri 9/23/05</td>
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<td>2.1</td>
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<td>34 days</td>
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<td>2.1.1</td>
<td>Subcontractor Procurement</td>
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<td>Mon 11/8/04</td>
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<td>2.1.2</td>
<td>Permitting and Access Agreements</td>
<td>25 days</td>
<td>Mon 10/11/04</td>
<td>Fri 11/12/04</td>
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<td>2.1.3</td>
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<td>Mon 11/15/04</td>
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<td>2.2.1</td>
<td>Subcontractor and Tt Mob</td>
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<td>Mon 11/15/04</td>
<td>Mon 11/15/04</td>
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<td>MW Installation</td>
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<td>Install and Develop New MWs</td>
<td>4 days</td>
<td>Tue 11/16/04</td>
<td>Fri 11/19/04</td>
</tr>
<tr>
<td>13</td>
<td>2.4</td>
<td>Groundwater Sampling and Analysis</td>
<td>215 days</td>
<td>Thu 11/18/04</td>
<td>Fri 9/23/05</td>
</tr>
<tr>
<td>14</td>
<td>2.4.1</td>
<td>Pre-Injection Sampling</td>
<td>2 days</td>
<td>Thu 11/18/04</td>
<td>Fri 11/19/04</td>
</tr>
<tr>
<td>15</td>
<td>2.4.2</td>
<td>Pre-Injection Analysis</td>
<td>20 days</td>
<td>Mon 11/22/04</td>
<td>Tue 12/21/04</td>
</tr>
<tr>
<td>16</td>
<td>2.4.3</td>
<td>REDOX Monitoring</td>
<td>210 days</td>
<td>Mon 11/29/04</td>
<td>Fri 9/23/05</td>
</tr>
<tr>
<td>17</td>
<td>2.4.4</td>
<td>Performance Sampling-Round 1</td>
<td>2 days</td>
<td>Wed 12/29/04</td>
<td>Thu 12/30/04</td>
</tr>
<tr>
<td>18</td>
<td>2.4.5</td>
<td>Performance Analysis-Round 1</td>
<td>20 days</td>
<td>Mon 1/3/05</td>
<td>Fri 1/28/05</td>
</tr>
<tr>
<td>19</td>
<td>2.4.6</td>
<td>Performance Sampling-Round 2</td>
<td>2 days</td>
<td>Thu 3/3/05</td>
<td>Fri 3/4/05</td>
</tr>
<tr>
<td>20</td>
<td>2.4.7</td>
<td>Performance Analysis-Round 2</td>
<td>20 days</td>
<td>Mon 3/7/05</td>
<td>Fri 4/1/05</td>
</tr>
<tr>
<td>21</td>
<td>2.4.8</td>
<td>Performance Sampling-Round 3</td>
<td>2 days</td>
<td>Fri 7/1/05</td>
<td>Tue 7/5/05</td>
</tr>
<tr>
<td>22</td>
<td>2.4.9</td>
<td>Performance Analysis-Round 3</td>
<td>20 days</td>
<td>Wed 7/6/05</td>
<td>Tue 8/2/05</td>
</tr>
<tr>
<td>23</td>
<td>2.5</td>
<td>Injection</td>
<td>93 days</td>
<td>Mon 11/22/04</td>
<td>Wed 4/6/05</td>
</tr>
<tr>
<td>24</td>
<td>2.5.1</td>
<td>Round 1</td>
<td>3 days</td>
<td>Mon 11/22/04</td>
<td>Wed 11/24/04</td>
</tr>
<tr>
<td>25</td>
<td>2.5.2</td>
<td>Round 2</td>
<td>3 days</td>
<td>Mon 1/31/05</td>
<td>Wed 2/2/05</td>
</tr>
<tr>
<td>26</td>
<td>2.5.3</td>
<td>Round 3</td>
<td>3 days</td>
<td>Mon 4/4/05</td>
<td>Wed 4/6/05</td>
</tr>
<tr>
<td>27</td>
<td>2.6</td>
<td>Demobilization</td>
<td>2 days</td>
<td>Wed 7/6/05</td>
<td>Thu 7/7/05</td>
</tr>
<tr>
<td>28</td>
<td>2.6.1</td>
<td>Site Cleanup and Demob</td>
<td>2 days</td>
<td>Wed 7/6/05</td>
<td>Thu 7/7/05</td>
</tr>
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</table>
APPENDIX B

USEPA COMMENT/U.S. ARMY RESPONSE MATRIX
### General Comments

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| 1          |                | The Plan should identify the data that will be needed to design the remedial action, consistent with the Off-Post Groundwater Feasibility Study (FS), Proposed Plan, and upcoming Record of Decision. Further, the Plan should insure that this data is collected to the maximum extent possible as part of this Study so that the Remedial Design and ultimately the Remedial Action can be completed in a timely manner. | Data needed for designing a full-scale remedy for the Off-Post Groundwater plume that has not already been collected consists of:  
- Electron Donor Dosage, Frequency, and Cycles (how much, how frequently, and how many times must an electron donor be injected to achieve the objectives outlined in the PP and ROD?)  
- Effective Bioremediation Treatment Radius, Injection Pressure and Injectate Volume – this will determine the minimum spacing of injection points  
- Injection Method – Expendable vs. Reusable points  
- Selection of an Effective Electron Donor – Balance Short Term vs. Long Term Aquifer Needs  
All of these data needs will be fulfilled through data collection as part of the pilot test/field treatability study. |
| 2          |                | The Plan contains little detail and is lacking sufficient decision/evaluation criteria for EPA to determine with much certainty how the Pilot Test will be conducted. Without this information, we are uncertain whether a crew will be able to reliably implement the Plan in the field. Details, including Standard Operating Practices (SOPs), should be incorporated or referenced to insure that the work is performed as intended. In general, rationale supporting the proposed activities is lacking in many instances, as outlined in the Specific Comments.  
The following brief outline could be used in revising the Plan to describe how you intend to conduct the study, and to address a number of EPA’s comments: | Additional detail will be added to the plan to define the specific steps, thought process, evaluation methods, decision points, and performance criteria by which the treatability study will be measured. A step by step approach similar to the one outlined in the comment will be used to facilitate field implementation.  
Additional questions concerning the selection of a treatment area, number of injection points, injection methodology, monitoring network, monitoring scheme, and decision points are summarized below and discussed in more detail in the revised Treatability Study Test Plan |

**Treatability Study Test Area**
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<td></td>
<td></td>
<td>• Step 1 - Establish test area. Update plume extent based on most recent data sets.</td>
<td>• The test area was chosen based on a review of the available groundwater monitoring data from the off-post area. The available data set contained groundwater monitoring results through 2002 and provided the basis for the FS, PP, and ROD for this area. Since the issuance of the draft treatability study plan, groundwater monitoring data from 2003 and 2004 has become available. Based on a review and comparison of the 2003 and 2004 data with respect to the 2002 data, the choice for a treatability study test area remains unchanged. The treatability study will be conducted in the vicinity of MW-117. This area was selected to optimize treatment in the portion of the off-post plume containing consistently elevated RDX concentrations. The area around MW-309 provides a secondary candidate for the treatability study, but is substantially more difficult to implement from a logistic perspective. It is on the shoulder of US Highway 61 (a very busy highway) and flanked to the north by a fairly steep embankment. Access to areas surrounding MW-309 would be problematic and potentially cause Tetra Tech to space injection and monitoring points too far apart to observe meaningful RDX and HMX results during the projected treatability study timeframe.</td>
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<td></td>
<td></td>
<td>• Step 2 - Install monitoring points; How? What depth? Are you planning to install “injection points”, or use a geoprobe?</td>
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<td>• Step 3 - Inject substrate: Why use sugar in the concentration prescribed? What about “amendments”? What locations? What depth? How much? Injection rate/pressure?</td>
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<td>• Step 4 - Monitor; For what? When? How? Why (How will the data be used)?</td>
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<td>• Step 5 - Decision Point; Inject more substrate? Why? Where? When?</td>
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<td></td>
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<td>• Step 6 - Reinject substrate; What? Where? When? How?</td>
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<td>• Step 7 - Back to Step 4</td>
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**Injection and Monitoring Points**

- Injection and monitoring points will be installed using DPT with a Geoprobe D66 rig. Monitoring wells will be constructed of 1” PVC screen and riser installed inside of 3.25 nominal ID DPT rods. DPT rods will be pulled as the well is constructed. Sand
pack will be flowed/pumped into place to an elevation of at least 2 feet higher than the top of the screen. The remainder of the borehole will be filled with a bentonite slurry mixture and a flush mount well completion constructed. An SOP for the installation of this type of monitoring point is being issued as an addendum to the Installation-Wide QAPP to facilitate its future use on other parts of the IAAAP environmental restoration project.

- Expendable injection points will initially be used. Expendable points are being used to increase flexibility associated with the location of subsequent injection events. Data from each monitoring event will be reviewed by the lead Tetra Tech hydrogeologist/explosives bioremediation specialist to determine the optimal location for subsequent injections as well as the need to modify the composition of the injectate. Please see additional information pertaining to injection point construction under the Injectate response below. Should the number of injection rounds necessary to reduce RDX concentrations to the treatability study goals exceed three, expendable injection points will be replaced with injection wells. Injection wells will be constructed identically to the DPT monitoring wells.

**Injectate**

- A dextrose solution was selected as the initial injectate based on past experience by Tetra Tech, industry practitioners, and researchers. Dextrose provides an effective short-term electron donor to drive oxidation-reduction potentials to moderately to
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<td>The raw dextrose product (corn syrup) is provided by the manufacturer as a liquid consisting of 71% solids (95% dextrose mixed with lesser amounts of maltose and saccharides). This mixture will be diluted at a ratio of 5 parts tap water to 1 part raw dextrose syrup. This will produce a mixture consisting of approximately 12% corn syrup solids. This process facilitates the biodegradation of RDX, HMX, and TNT. In the case of RDX, intermediate byproducts such as MNX, DNX, TNX, and ultimately innocuous mineralization endproducts (e.g., water and nitrous oxide) are produced. Please see the transformation pathway diagram presented as Figure 3-1 in the test plan.</td>
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<td>Industry experience indicates that micronutrient amendments are not typically required to facilitate biodegradation of RDX, HMX, and TNT.</td>
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<td>Injections will be performed using expendable DPT points and injection into existing hot spot monitoring well MW-117. For expendable DPT injection points, a D66 Geoprobe rig will advance the injection rods to the target total depth (depth interval equivalent to plume thickness observed around MW-117-approximately 490 to 505 ft msl). The number of planned injection and monitoring points is described in Section 4.0 and illustrated on Figure 4-1. Injection points will also be illustrated on the cross section shown on Figure 4-2.</td>
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<td>The composition of the injectate may be modified during the treatability study based on performance monitoring data.</td>
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</table>
### Comment Response Matrix

**Draft Treatability Study for In Situ Biodegradation of RDX in Off-Site Groundwater  August 2004**

**Commenter:** EPA Region VII  
**Comments dated:** September 22, 2004

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<tr>
<td>• If REDOX potentials measured in the injection and monitoring points in the field 4 weeks after the initial injection event are not at least -50 mV, an additional injection of dextrose will be performed without collecting chemical analytical data.</td>
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<tr>
<td><strong>Monitoring Scheme</strong></td>
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<tr>
<td>• The test plan will be clarified to more clearly indicate that groundwater monitoring will be performed for nitroaromatic explosives, RDX degradation products (MNX, DNX, and TNX) by Method 8330, nitrate/nitrite by Method 300.0, water quality field parameters (ORP, DO, pH, temperature, conductivity, turbidity). Monitoring will be performed at the following points within the treatability study:</td>
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<td>o After the new monitoring wells are installed and prior to the injection of dextrose (baseline conditions).</td>
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<td>o After dextrose injection and REDOX potentials are measure in the aquifer at -50 mV or lower to monitor the progress of biodegradation.</td>
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<tr>
<td>o After an additional injection of dextrose or modified carbon source once the REDOX potential is less than -50 mV. After the additional rounds of progress samples are collected and analyzed, a decision will be made to continue with injectate or modify its composition.</td>
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<td>conducted should be specified and referenced where appropriate.</td>
<td>Study will be conducted will be added to the plan.</td>
</tr>
<tr>
<td>4</td>
<td></td>
<td>The Treatability Study needs to include specific quantitative criteria that will be used to judge its success or failure. These criteria could include the amount of contaminant mass treated, the rate of treatment, the radius of treatment, the mass of nutrient required, verification of full-breakdown to innocuous end products, and any other specific criteria that will be used to demonstrate the viability of the remedy.</td>
<td>See response to General Comment 2.</td>
</tr>
<tr>
<td>5</td>
<td></td>
<td>The Treatability Study relies on 2002 groundwater monitoring data for selecting the area to inject a bioavailable carbon source solution. More recent data should be evaluated/presented to assist in determining the test area. It would be beneficial to conduct at least one round of groundwater monitoring to evaluate RDX plume migration. This will ensure that the Treatability Study focuses on the area with the highest RDX contamination.</td>
<td>Data from 5 recent sampling events (Spring 2002 through Spring 2004) have been further evaluated to confirm the appropriateness of the proposed test location. Given the seasonal fluctuations in the two most impacted wells, it is unlikely that an additional sampling event will be needed to locate the highest concentration area of the RDX plume.</td>
</tr>
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</table>
### Comment Response Matrix

**Draft Treatability Study for In Situ Biodegradation of RDX in Off-Site Groundwater  August 2004**

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**Comment**
**Response**

6
Sections 2.2 and 2.3 contain a great deal of information regarding various aquifer-related properties (such as flow velocities, hydraulic conductivity, hydraulic gradient, etc...). The references from which this information has been obtained should be cited to insure that the data was adequately evaluated/reviewed. Otherwise, please provide all information required to verify that the aquifer information presented is accurate. Further, the significance of the aquifer information relative to the ultimate design of the remedy should be discussed. Temporal variations should also be evaluated since they may be significant and could impact the design of the remedy.

Additional references to historical documents will be added to the test plan.

### Specific Comments

1
Section 1.0, page 1-1.

a. The second paragraph in this section states that off-site, upgradient wells have been sampled and are “clean”. Please revise the Treatability Study to reference concentration ranges in lieu of subjective terminology.

b. The third paragraph refers to “biodegradable carbon sources and other amendments”. Since a primary objective of the treatability study is to determine the most appropriate/effective biodegradation substrate, the details of any amendments or other carbon sources should be described in the Plan.

c. Important considerations for the remedy that this Study addresses, as discussed in the FS and Proposed Plan, should be summarized.

a. Changed sentence to “Off-site, upgradient wells closer to the IAAAP site have been sampled and have RDX levels that are below the reporting limits.”

b. The initial carbon source injected in the aquifer will be a 12% solution of dextrose (see response to comment 12a). The effectiveness of this carbon source will be monitored initially by the REDOX potential in the aquifer. REDOX potentials of -50mV or lower will signify that anaerobic biodegradation is occurring and that groundwater sampling and analysis is warranted for the detection of explosives and explosives breakdown products. If after two rounds of dextrose injection, a REDOX potential of lower than -50 mV is not measured, groundwater analytical samples will be collected as confirmation that RDX and HMX degradation has not occurred to a substantial degree (>25% concentration.
**Comment Response Matrix**

**Draft Treatability Study for In Situ Biodegradation of RDX in Off-Site Groundwater August 2004**

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<tr>
<td>2</td>
<td>Section 2.1.1, page 2-2.</td>
<td>In the 4th bullet, please revise to describe “OU4” as the “Miscellaneous Sites” operable unit.</td>
<td>The suggested change has been made.</td>
</tr>
</tbody>
</table>
| 3 | Section 2.1.3, page 2-3. | a. Paragraph 3 indicates that the FS concluded that a field-scale treatability study should be conducted to determine the most effective bioremediation substrate (and to evaluate the effectiveness of bioremediation). The Study calls for the evaluation of only a single substrate, thus it is unclear how the most effective substrate will be identified. Please discuss.  
b. The text should identify that the performance standard/remediation goal for RDX in groundwater, as outlined in the FS and Proposed Plan, is 2 ug/L. References to appropriate figures illustrating site reduction). If an RDX/HMX concentration reduction greater than 25% is measured, dextrose injections and monitoring will continue and the dextrose will be deemed a successful and viable carbon source for further applications. If an RDX/HMX concentration reduction greater than 25% is NOT measured, an alternative carbon source will be selected which possesses short and long lasting carbon sources such as EOS® or HRC®. EOS® and HRC® are patented combinations of quick and slow consumable carbon sources observed to remain available in the aquifer for up to 3 years. Both products have been proven on the anaerobic bioremediation of RDX and TNT. Due to their long lasting capabilities and the limited duration of the pilot test (less than 1 year), the full benefits of the slow release component of EOS® and HRC® are beyond the scope of the treatability study.  
c. The suggested changes have been made. | a. The treatability study will be conducted in phases. The first phase is described in the treatability test plan and utilizes a rapid consumable carbon source (dextrose). Given the relatively low concentrations present (10s of ppb rather than 100s to 1,000s of ppb) in the off-plume, the rapid consumable carbon source will likely reduce concentrations substantially within the treatment area after only one to two applications. As described in response to specific comment 1 above, Phase 2 will be implemented if Phase 1 fails. Phase 2 will consist of injection of combined slow and fast consumable carbon sources. Phase 1 (sugar solution) and 2 |
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<td>4</td>
<td>Section 2.2.2.2, page 2-7.</td>
<td>This section contains numerous subsections that describe the subsurface geologic profile. However, the geologic descriptions presented in this section do not match the descriptions presented in Figure 2-4. For example, subsection titles of “Intermediate Terrace Alluvial Sands,” “Intermediate Terrace Sandy Gravel Alluvium,” and “Intermediate Glacial Till” are included in Section 2.2.2.2, however, “intermediate” is not used in any geologic descriptions shown on Figure 2-4. Revise either Section 2.2.2.2 or Figure 2-4 so that correct and consistent geologic descriptions are used throughout the Treatability Study.</td>
<td>The legend in Figure 2-4 was changed to reflect the terminology used in the text. The figure and text are now consistent.</td>
</tr>
<tr>
<td>5</td>
<td>Section 2.2.2.2, page 2-7.</td>
<td>The subsection titled “Weathered Bedrock” refers to bedrock that was encountered at approximately 160 feet below ground surface (bgs) in MW509D. However, MW509D is not shown on Figure 2-4. Please revise the text to refer to the correct well or add MW509D to Figure 2-4.</td>
<td>Reference to MW-509D was removed from the text in most places. Where references to MW-509D were relevant, another figure was cited to indicate its location.</td>
</tr>
</tbody>
</table>
| 6           | Section 3.2, page 3-1. | a. Citations of other applications or successes for in-situ (enhanced) bioremediation of RDX in groundwater should be provided. Details of successful applications, including the nature of successful substrates should be discussed.  
b. Please present the complete pathway for the metabolism/destruction of RDX to innocuous end products. | a. Additional references of RDX bioremediation successes are provided.  
b. Additional biotransformation pathway information will be provided in the revised treatability test plan. The fate and toxicity of intermediary breakdown products such as MNX, DNX, and TNX are not known. However, mineralization of RDX and HMX has been demonstrated along with the... |
## Comment Response Matrix

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<td>7</td>
<td>Section 4.1, page 4-1.</td>
<td>Products. Discuss the fate and toxicity of the various RDX breakdown products. c. While metals and HMX are not considered contaminants of concern in the off-post area, the potential impacts of these constituents should be considered in the Pilot Study. Some metals may inhibit microbial growth if present at sufficient levels. Further, HMX will act as a food source for microbial populations and could impact the degradation rate of RDX. HMX degradation products should be evaluated and their toxicity discussed.</td>
<td>generation of innocuous end products such as methane, ammonia, carbon dioxide, and water. Additional references and discussion will be added. c. RDX and HMX will be cometabolized in the subsurface based on previous laboratory and field studies performed. HMX is more recalcitrant than RDX, so HMX is anticipated to degrade more slowly than RDX. HMX and RDX degradation products are the same. Metals inhibition is not anticipated in the off-site plume area and has not been shown to be a significant issue in other bioremediation applications and studies.</td>
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<tr>
<td>8</td>
<td>Section 4.2, page 4-1.</td>
<td>Permits are not required for “on-site” CERCLA response actions. Since the “site” is generally defined as any area where contaminants have come to be located, the off-post area would be considered on-site for purposes of the CERCLA permit exclusion. We do suggest that you coordinate with the State immediately to identify any issues or concerns they may have regarding the underground injection activities associated with this Study. Any necessary clearances or permits will be obtained in advance of injection activities. County and State DOT departments as well as the One-Call utilities clearance organization will be contacted for appropriate right-of-way agreements and utilities clearance. The Iowa DNR will be contacted to determine state underground injection control requirements. Local residents will be contacted to inform the public of impending activities.</td>
<td>Three upgradient points and one cross-gradient point will be installed surrounding MW-117. The spacing of injection points will take advantage of groundwater flow under summer and winter conditions to disperse the injection fluid. The criteria for choosing these locations is discussed in Section 4.3. This section states that as many as four injection points will be installed at varying distances apart, and that additional injection points may be installed, depending on the groundwater monitoring results obtained after the first injection event. However, the text does not describe the criteria to be evaluated in determining injection point spacing and the need for additional injection points. Please expand the text to discuss the criteria to be evaluated in determining injection point spacing.</td>
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| 9           | Section 4.3, page 4-2. | a. Details of the injection program should be provided. For example, the location of the injection points, the depth at which injection will occur, the injection pressure, the amount of substrate to be injected, etc... should all be described in the Plan.  

b. It is not obvious why injection points should be installed 20 - 50 feet upgradient of monitoring points. Please discuss.  

c. The second paragraph of this section states that injection points will be created using an “expendable borehole.” Please describe the term “expendable borehole.” | a. See Figure 4-2 for locations. The depth, injection pressure and amount of substrate is detailed in the text for Section 4.3. A table will be added to facilitate review and field implementation. Nomenclature and construction details associated with injection and monitoring wells/expendable points will be tabulated.  

b. The spacing and location of the points was based on a rate of seepage 80-130 feet per year, which is discussed in Section 4.3.  

c. Expendable denotes the one-time use of injection points as compared with injection wells which provide a means to inject multiple times at the same location. As described in response to general comment 2 above, expendable injection points will be used for up to 3 injection events. This will provide a more flexible injection scheme that can be easily modified to accommodate changes dictated by injection/monitoring results. Should the required number of injection events exceed 3, it may be necessary to install injection wells as described above to provide a more cost-effective longer term carbon delivery system. |
<p>| 10          | Section 4.3, pages 4-1 and 4-2. | a. The first full paragraph on this page states that a series of up to five monitoring piezometers will be installed. However, the text does not describe the criteria that will be used to determine the exact number of monitoring piezometers to be installed. Please expand the text to discuss the criteria to be evaluated to determine the exact number of monitoring piezometers to be installed. | a. The term “up to” was used to qualify the number of monitoring points, to cover potential logistical constraints (access agreements, utilities clearance, and topographic limitations) unknown to Tetra Tech at the time of the test plan issuance. The paragraph will be revised to state that 5 monitoring wells will be installed for bioremediation performance monitoring purposes. Their approximate... |</p>
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<td>b. The Study refers to “holes in pavement”. Based on the figures included, it appears that you may be proposing to inject thru/beneath Highway 61. Suggest that you coordinate with the appropriate State or Federal agencies prior to undertaking operations that may cause damage to the highway.</td>
<td>locations are shown on Figure 4-1 and may require modification based on site logistics such as access agreements, utilities clearance, and topographic limitations. The five new monitoring wells are being installed at variable distances and vectors from injection points to determine the effective radius and directionality of biodegradation and production of biotransformation byproducts. Predominant groundwater flow directions change from the summer to winter in this area, as reported by URS (URS, 2004) and shown on Figure 4-1 of the treatability test plan.</td>
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<tr>
<td>11</td>
<td>Section 4.4, page 4-2.</td>
<td>You appear to describe a step in the Study called “injection point (and monitoring piezometer) installation”. We are unclear what would comprise the “injection point installation”. Please describe.</td>
<td>An SOP will be constructed for injection point and monitoring well installation using a DPT rig. An SOP will be submitted for EPA review and concurrence prior to the onset of injection and monitoring well installation. The SOP will be submitted as an addendum to the installation-wide QAPP/SAP.</td>
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<td>12</td>
<td>Section 4.4.1, page 4-2.</td>
<td>a. The first paragraph of this section states that the injection solution will consist of sugar mixed with potable water using a 1:2 mixture (i.e., four liters of</td>
<td>a. The text will be modified to reflect the following. A dextrose solution was selected as the injectate based on past experience by Tetra Tech, industry practitioners, and</td>
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Middletown, Iowa 12 August 2004
### Comment Response Matrix

**Draft Treatability Study for In Situ Biodegradation of RDX in Off-Site Groundwater  August 2004**

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<td></td>
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<td>sugar for every eight liters of water) prior to injection. Please describe how you have selected this substrate and concentration.</td>
<td>researchers. A simple carbon source (sugar solution) has been used successfully as an in situ bioremediation supplement for years where anaerobic biodegradation is required. Dextrose provides an effective short-term electron donor/carbon source to drive oxidation-reduction potentials to moderately to strongly reducing conditions (-50 to -150 mV) in the aquifer. The raw dextrose product (corn syrup) is provided by the manufacturer as a liquid concentrate consisting of 71% solids (95% dextrose mixed with lesser amounts of maltose and saccharides). This mixture will be diluted at a ratio of 5 parts tap water to 1 part raw dextrose corn syrup. This will produce a mixture consisting of approximately 12% corn syrup solids. This process facilitates the biodegradation of RDX, HMX, and TNT. In the case of RDX and HMX, intermediate byproducts such as MNX, DNX, TNX, and ultimately innocuous mineralization endproducts (e.g., water, nitrous oxide, and methane) are produced. Please see the transformation pathway diagram presented as Figure 3-1 in the test plan.</td>
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<td>b. Information in Section 4.4.2 states that the injection solution will consist of a 1:20 mixture (i.e., four liters of water for every 80 liters of potable water) rather than a 1:2 mix as discussed in this section. Please revise/clarify appropriately.</td>
<td>b. The typo will be fixed. Please see the response to comment 12a above.</td>
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<td>c. It is unclear whether the substrate chosen in this evaluation will provide a carbon source that is sufficiently persistent to promote microbial activity over the time period needed to treat RDX to the levels required. Please discuss.</td>
<td>c. Please see responses to specific comments 1 and 3 above.</td>
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<td>d. It is unclear what information will be used to determine whether sodium bicarbonate will be added to the donor solution, and in what quantities. Please clarify.</td>
<td>d. Alkalinity additions through use of sodium bicarbonate are used to ensure aquifer pH remains in a range favorable for biological activity (typically in the pH range of 4 to 8). However, ambient microbiota have often adapted to environmental conditions (such as low pH). Therefore, historical groundwater analytical data, incorporating pH and alkalinity measurements will be used to guide the initial</td>
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<td>e. The Plan states that the composition of the substrate may be adjusted during subsequent pilot test injections. The basis for such additional injections and adjustments to the substrate composition should be discussed.</td>
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</table>
### Comment Response Matrix

**Draft Treatability Study for In Situ Biodegradation of RDX in Off-Site Groundwater  August 2004**

**Commenter:** EPA Region VII  
**Comments dated:** September 22, 2004

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| 13 | Section 4.4.2, page 4-3. | a. Please describe how the “appropriate solution feed rate” will be determined.  
b. How has it been established that a carbohydrate concentration of 60 mg/L is desirable? How will you measure this?  
c. Describe how you have determined that 200 gallons sugar water/injection point is appropriate. | a. The goal is to inject the feed solution under relatively low pressure. The solution feed rate will be determined by field conditions and are a balance among the safe injection pressure limits of the equipment and the rate of aquifer acceptance of feed solution.  
b. The concentration of available carbon in the feed solution (60 mg dextrose $[\text{C}_6\text{H}_{12}\text{O}_6]$ per liter or 22.5 mg C/L) is based on a range of published studies using multiple types of carbohydrate (e.g., acetate at 6 mg C/L by Pombo, et al., 2002; acetate at 56 mg C/L by Kleikemper et al., 2002; lactic acid at 40 mg C/L in a case study summarized by EPA, 2000).  
c. A range of 200 to 400 gallons per injection point have been used in other environments. The proposed injection volume is a balance among: 1) minimizing the amount of injection fluid to inject; 2) getting the maximum amount of carbohydrate in the aquifer; 3) maximizing the area of influence from the injection; and 4) minimizing the time required to complete the injection. |
| 14 | Section 4.4.3, page 4-3. | a. Please describe how you will determine the injection pressure (or solution feed rate, as above).  
b. How will you measure the radius of influence of each injection point? | a. The injection pressure will be determined in the field based on the resistance of the formation to accept low viscosity aqueous fluids. Since Tetra Tech will be injecting approximately 40 feet below the static potentiometric... |
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<tr>
<td>15</td>
<td>Section 5.0, page 5-1.</td>
<td>a. The text states that trained personnel will conduct field monitoring and sample collection. Please specify the methods that will be employed to conduct the monitoring and sample collection. b. The text also indicates that the data will be evaluated to determine whether the objectives of the Pilot Test are met.</td>
<td>a. Standard operating procedures (SOP) have been added as appendices to the test plan to clarify field procedures related to groundwater sampling, monitoring well installation, injection point installation, equipment decontamination, and other pertinent field activities. b. The objectives of the treatability study will be more clearly defined.</td>
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</table>

The text states that trained personnel will conduct field monitoring and sample collection. Please specify the methods that will be employed to conduct the monitoring and sample collection. The data will be evaluated to determine whether the objectives of the Pilot Test are met.

The actual injection pressure may vary from this based on field conditions encountered at the time of the injection. However, the goal remains the same which is to introduce the maximum amount of injectate per injection point/interval in a reasonable amount of time.

The radius of influence of each injection will be indirectly measured by the reduction in RDX and HMX concentrations in downgradient and cross-gradient monitoring wells. It will also be measured directly through TOC analyses which will indicate the incursion of additional carbon (dextrose injectate) into the well. As indicated in the test plan, monitoring wells have been positioned at varying distances and vectors from the injection points to evaluate the maximum effective biodegradation radius, primarily to determine the optimal future spacing of injection points for full scale remedy implementation.
### Comment Response Matrix

**Draft Treatability Study for In Situ Biodegradation of RDX in Off-Site Groundwater**

**Commenter:** EPA Region VII  
**Comments dated:** September 22, 2004

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| 16 | Section 5.1, page 5-1. | a. The Plan states that the test will last up to 9 months. Please indicate the minimum duration of the test.  
b. The Plan states that the period of performance will allow adequate time to demonstrate the effectiveness of the technology and provide engineering data for potential subsequent applications. Please identify the specific criteria that will be used to evaluate the effectiveness of the technology, and the engineering data that will be required/colllected from the test.  
c. In the last sentence of this section, you indicate that the test may achieve anaerobic conditions, but not degrade RDX to meet cleanup criteria at the conclusion of the test. This highlights the need to establish specific evaluation criteria for the test. | a. The minimum duration of the pilot test is linked to achieving the performance objectives of the treatability study. Specifically, if the objectives listed in response to general comment 1 are achieved after 1 treatment and monitoring cycle (approximately 6 weeks duration), the treatability study would cease, the results documented, and a remedial design initiated. A more pragmatic minimum duration is anticipated to be 2 injection cycles (approximately 12 weeks).  
b. Please see response to general comment 1 and specific comments 3 and 9 above.  
c. Noted. Please see response to specific comment 1 above where the percent degradation (25%) is defined as a goal of the treatability study. |
| 17 | Section 5.2, page 5-1. | The details of the monitoring program are unclear. | As stated in response to general comment 2 above, additional details will be added to the injection, monitoring, and decision logic portions of this plan. |
| 18 | Table 5-1, page 5-2. | a. The adequacy of “test kits” for measuring various parameters (iron, sulfide, alkalinity) is unclear. Please clarify if the use of test kits is consistent with the SAP/QAPP, and will satisfy the Data Quality Objectives.  
b. Since HMX is present in the aquifer, we suggest that you report the entire suite of explosives which are evaluated in SW-846, method 8330. HMX degradation products should be identified and assessed analytically. | a. Verified field procedures are consistent with Installation-wide SAP/QAPP that we are using as a foundation for this and future work.  
b. The entire suite of nitroaromatic explosives will be reported, including the RDX and HMX degradation products MNX, DNX, and TNX. Based on published literature the formation of breakdown products and the degradation pathways are essentially the same for cyclic nitramine compounds such as RDX and HMX (Hawari, 2000). These...
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| 19          | Section 5.3.1, page 5-3. | a. In general, all methods referenced here should be described in the SAP/QAPP. Please verify that this is the case.  
  b. Under “RDX” you indicate that analysis will be conducted by SW-846, method 8330, or approved modification. Please clarify your reference to “approved modification”. Are such modifications described in the QAPP? How do you intend to seek “approval” for such modifications? | a. Verified with Installation-wide URS SAP/QAPP that Tetra Tech is using methods and procedures outlined in the Installation-Wide SAP/QAPP as a basis. SOPs related to DPT injection and DPT well installation will be submitted as addenda to the Installation-Wide plan and referenced in the treatability study test plan.  
  b. All nitroaromatic explosives analyses will be performed using SW846, Method 8330. Additionally, the RDX/HMX degradation products MNX, DNX, and TNX will be analyzed using Method 8330. |
| 20          | Section 5.3.3, page 5-4. | a. The text in this section states that alternate approaches to sampling, such as the use of bailers, may be used when total organic carbon is required to guide system operations. However, the text does not state why the use of bailers may be necessary. Please revise the text to explain why bailers may be used as an alternate method. | a. The text will be revised to add clarification. Bailers will be used if progress parameters not affected by purge volume (e.g. total organic carbon) are needed during the treatability study. They will essentially be used to collect grab samples, if necessary to access injectate progress. |
|             |                 | c. The methods listed under Footnote 4 are unclear. Are these methods specified in the QAPP?  
  d. It is unclear whether you are intending to monitor water levels as part of the Plan. Water level measurements are important to interpreting the test results and should be collected on a frequent basis. | c. Methods referenced under Footnote 1 for sulfate, chloride, nitrate/nitrite, total iron and total manganese are in agreement with those presented in the QAPP. The methods under Footnote 4 for methane and carbon dioxide are methods which are currently used throughout the industry and commonly employed by analytical laboratories.  
  d. Water level measurements will be taken during each monitoring event as conditions allow. |
Comment Response Matrix
Draft Treatability Study for In Situ Biodegradation of RDX in Off-Site Groundwater  August 2004

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<td>for groundwater sampling.</td>
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<td>b. Appropriate procedures from the SAP/QAPP should be referenced.</td>
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<td>b. Procedures and SOPs from the installation-wide SAP/QAPP and revisions thereto will be referenced throughout the document.</td>
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APPENDIX C

STANDARD OPERATING PROCEDURES
Standard Operating Procedure No.1
Surface Soil Sampling
1.1 PURPOSE AND SCOPE

The purpose of this document is to define the Standard Operating Procedure (SOP) for collecting surface soil samples at Iowa Army Ammunition Plant (IAAAP). These procedures give descriptions of equipment, field procedures, documentation procedures, and Quality Assurance/Quality Control (QA/QC) procedures implemented for the collection of surface soil samples. These procedures described are sufficiently detailed to allow field personnel to properly collect surface samples. Field procedures for surface soil sampling were developed in accordance with USAGE EM 1110 (USACE 1998) and USAGE Omaha District Geology Scope of Services, and are detailed in this SOP. Specific sample locations and frequency of collection will be presented in future Field Sampling and Analysis Plan (FSAP) addenda.

These procedures are intended to be used together with FSAP and other appropriate SOPs. Health and safety procedures and equipment for the investigation are detailed in the IAAAP Health and Safety Plan (HSP). Applicable SOPs are listed below:

- SOP No. 7 - Sample Identification, Handling, and Documentation
- SOP No. 8 - Headspace Analysis
- SOP No. 10 - Equipment and Personnel Decontamination
- SOP No. 11 - Boring Abandonment
- SOP No. 12 - Permits and Clearances

Reference Standards


1.2 PROCEDURES FOR SOIL SAMPLING

Surface soil samples will be collected using stainless-steel hand utensils or, for drilling rig borings, a stainless-steel split-spoon sampler. Surface soil samples will be collected from 0 to 0.5 feet below ground surface (bgs). If surface debris, such as rocks, will not allow sample collection at the target depth, surface soil samples may be collected by expanding the sampling area, without increasing depth.

1.2.1 Equipment List

The following list of equipment will be needed to collect surface soil samples at IAAAP:
SOP NO. 1
Surface Soil Sampling

Equipment for Surface Soil Sampling

- Stainless-steel spoon or trowel, hand auger equipment, or drill rig with appropriate drilling and sampling tools (stainless-steel split spoons)
- Weighted tape measure with 0.1-foot increments
- Surveyor’s stakes and flags
- Ruler marked in 0.1-foot increments
- Field books/field sheets
- Stainless-steel knife, bowl, and spoon
- Sample bottles provided by the laboratory
- Sample bottle labels
- Label tape (clear)
- Paper towels
- Aluminum foil
- Camera and film
- Waterproof and permanent marking pens
- Plastic bags
- Plastic sheeting
- Appropriate health and safety equipment, as specified in the HSP
- Appropriate decontamination supplies, as specified in SOP No. 10
- Ice chest with ice

1.2.2 Decontamination

Before drilling or sampling begins, the drilling and sampling equipment will be decontaminated according to the procedures contained in SOP No. 10. Drilling and sampling equipment will be decontaminated between boring and sampling locations. Sampling equipment will also be decontaminated between collection of samples from different depths at the same location.

1.2.3 Surface Soil Sampling Procedures

The procedures for collecting surface soil samples are provided in the following sections.

1.2.3.1 Surface Soil Sampling Using Hand Utensils

This method of soil sample collection is to be used at IAAAP in situations where conditions will not permit the use of hand auger or drilling methods. Soil samples will be collected at the specific depth using a stainless-steel spoon and stainless-steel bowl. Before the sampling begins, clear and remove any vegetation or surface debris such as rocks, as necessary. The hand utensils and bowl will be decontaminated once the sample depth has been reached to avoid possible cross-contamination. When collecting surface soil samples, if additional soil is necessary to fill sample jars, the sample area is to be expanded without increasing the depth. The step-by-step procedure for collecting surface soil samples using hand utensils is described in Section 1.2.3.4.
1.2.3.2 Surface Soil Sampling Using Hand Auger

This method of soil sample collection is to be used at IAAAP in situations where conditions will not permit the use of hand utensils or drilling methods. Hand auger samples will be collected at the specified depth using a stainless-steel hand auger with a minimum 3-inch outside diameter (OD) bucket. Before the augering activities, clear and remove vegetation and any surface debris such as rocks, as necessary. The hand auger will be advanced in 6-inch intervals to the top of the specified sampling depth. The auger bucket will be decontaminated once the target depth has been reached to avoid possible cross-contamination. When collecting surface soil samples, if additional soil is necessary to fill sample jars, an additional borehole will be done adjacent to the initial borehole, without increasing depth. Hand auger borings will be completed in accordance with ASTM D 1452. The step-by-step procedure for collecting surface soil samples using a hand auger is described in Section 1.2.3.4.

1.2.3.3 Surface Soil Sampling Using a Split Spoon

This method of soil sample collection is to be used at IAAAP in situations where the site conditions are appropriate for the use of heavy drilling equipment or where a subsurface soil boring is to be completed. Clear and remove vegetation and any surface debris such as rocks, as necessary. The stainless-steel split spoon soil sampler will be driven or pushed by the drill rig prior to drilling activities. The soil cuttings will be treated as IDW according to Section 7, IDW Transportation and Disposal Plan.

Soil samples will be obtained according to specifications in future FSAP addenda and the resistance to soil penetration will be measured using a split spoon sampler in accordance with ASTM D 1586. Penetration resistance (blow counts) for each sampling depth will be recorded on the field boring log (Figure 2). The coupling head for the split-spoon sampler will be provided with a ball check valve and will have open vents. Where necessary for sample recovery, the sampler will also be equipped with a spring-type sample retainer or an equivalent retainer. The step-by-step procedure for collecting surface soil samples using a split spoon sampler is described in Section 1.2.3.4.

1.2.3.4 Surface Soil Sample Collection

The following step-by-step procedure should be used to collect surface soil samples:

- Record the sample location on a site map and in the field logbook.
- Decontaminate the sampling and drilling equipment according to SOP No. 10.
- Obtain PID background (BG) readings at the sampling location in the breathing zone.
- Before handling any samples, don a clean pair of gloves.
- Collect the soil samples at the depths specified in future FSAP addenda.
For hand auger and split-spoon samples, measure the recovery, and scrape off any soil smear zone from the recovered sample with a stainless-steel knife. If the soil is not cohesive or if the smear zone cannot be easily removed, an attempt will be made to remove soil from the portion of the sample that has not come in contact with the sampler.

Determine and identify the use of the recovered sample. This will always be for soil classification and stratigraphic logging and may be for chemical or headspace analysis.

The sample must be handled quickly, especially if it is loose or crumbling, to avoid losing volatile contaminants.

Collect any required volatile organic carbon (VOC) samples immediately in appropriate sample containers.

A portion of selected surface soil samples will be collected in the appropriate glass container for headspace analysis according to SOP No. 8.

Composite the remaining soil by thoroughly mixing the soil from the sampler in a clean stainless-steel bowl with a stainless-steel spoon. The bottles will then be filled with the composited soil for the specified samples. Collect any required SVOC samples immediately after compositing the soil, then collect any remaining parameters, using the appropriate containers. The required analyses and appropriate volume of containers of soil will be stated in future FSAP addenda.

Complete the description of materials for the recovered sample according to the Unified Soil Classification System.

Identify, handle, and document the samples (depending on the use of the sample) according to SOP No. 7.

If no other samples will be collected, the boring will be abandoned according to SOP No. 11.

Identify the location for future reference using surveying stakes and flags.

1.2.4 Field Quality Assurance/Quality Control Procedures and Samples

Field QA/QC samples are designed to help identify potential sources of external sample contamination and to evaluate potential error introduced by sample collection and handling. All QA/QC samples are labeled with QA/QC identification numbers and sent to the laboratory with the other samples for analyses.

1.2.4.1 Field Blanks

No field blanks or QA split samples will be collected for soil sampling activities.

1.2.4.2 Duplicate Samples

Duplicate samples are samples collected to assess precision of sampling and analysis. For the soil sampling, a duplicate sample will be collected at the same time as the initial sample. The initial sample bottles for a particular parameter or set of parameters will be filled first, then the duplicate sample bottles for the same parameter(s), and so on until all necessary sample bottles for both the initial sample and the duplicate sample have been filled. The duplicate soil sample will be handled in the same manner as the primary sample. The duplicate sample will be assigned a QA/QC identification number, stored in an iced cooler, and shipped to the laboratory.
1.2.4.3 Matrix Spikes and Matrix Spike Duplicates

Matrix spikes (MS) and matrix spike duplicates (MSD) are used to assess the potential for matrix effects. Samples will be designated for MS/MSD analysis on the chain-of-custody form and on the bottles. It may be necessary to increase the sample volume for samples where this designation is to be made.

1.2.5 Sample Identification, Handling, and Documentation

Samples will be identified, handled and recorded as described in this SOP and SOP No. 7. The parameters for analysis and preservation will be specified in future FSAP addenda.

1.2.6 Documentation

Each field activity must be properly documented to facilitate a timely and accurate reconstruction of events in the field (see SOP No. 7). Sample Collection Field Sheets will be completed for all soil samples submitted for chemical analysis (Figure 1).

1.2.6.1 Sample Collection Field Sheet

A sample collection field sheet for surface soil samples (Figure 1) will be completed at each sampling location. The data sheet will be completely filled in. If items on the sheet do not apply to a specific location, the item will be labeled as not applicable (NA). The information on the data sheet includes the following:

- Sample location number
- Date and time of sampling
- Person performing sampling
- Type of sample
- Description of the soil sample
- Number of samples taken
- Sample identification number
- Preservation of samples
- Headspace analysis
- Record of any QC samples from site
- Any irregularities or problems which may have a bearing on sampling quality

1.2.6.2 Field Logbook

The most important aspect of documentation is thorough, organized, and accurate record
keeping. All information pertinent to the investigation and not documented on the boring log will be recorded in a bound logbook with consecutively numbered pages. All entries in logbooks will be made in waterproof ink and corrections will consist of line-out deletions that are initialed and dated. Entries in the logbook will include the following, as applicable:

- Project name and number
- Sampler’s name
- Date and time of sample collection
- Sample number, location, and depth
- Sampling method
- Observations at the sampling site
- Unusual conditions
- Information concerning drilling decisions
- Decontamination observations
- Weather conditions
- Names and addresses of field contacts
- Names and responsibilities of field crew members
- Names and titles of any site visitors
- Location, description, and log of photographs (if taken)
- References for all maps and photographs
- Information concerning sampling changes, scheduling modifications, and change orders
- Summary of daily tasks (including costs) and documentation on any cost or scope of work changes required by field conditions
- Signature and date by personnel responsible for observations

Field investigation situations vary widely. No general rules can include each type of information that must be entered in a logbook for a particular site. A site-specific logging procedure will be developed to include sufficient information so that the sampling activity can be reconstructed without relying on the memory of field personnel. The logbooks will be kept in the field team member’s possession or in a secure place during the investigation. Following the investigation, the logbooks will become a part of the final project file.
Figure 1

SOIL SAMPLE COLLECTION FIELD SHEET

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<thead>
<tr>
<th>SITE NAME</th>
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<td>PERSONNEL</td>
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<td>SAMPLE SPLITS (Circle 1):</td>
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<td>FIELD DUPLICATE (Circle 1):</td>
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### HTRW DRILLING LOG

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ENG FORM 5056-R, AUG 94
Standard Operating Procedure No.2
Subsurface Drilling, Soil Sampling, and Logging
2.1 PURPOSE AND SCOPE

The purpose of this document is to define the Standard Operating Procedure (SOP) for subsurface drilling and collection of soil samples at Iowa Army Ammunition Plant (IAAAP). These procedures give descriptions of equipment, field procedures, documentation procedures, and Quality Assurance/Quality Control (QA/QC) procedures implemented for the collection of subsurface soil samples. These procedures described here are sufficiently detailed to allow field personnel to properly collect subsurface soil samples and maintain descriptive logs on the HTRW drilling log form (Figure 1). These procedure were developed in accordance with IAC 567 Chapter 49 (IDNR 1998), USACE EM 1110 (USACE1998) and USACE Omaha District Geology Scope of Services, and are detailed in this SOP. Specific sample locations and frequency of collection will be presented in future Field Sampling and Analysis Plan (FSAP) addenda.

These procedures are intended to be used together with FSAP and other appropriate SOPs. Health and safety procedures and equipment for the investigation are detailed in the IAAAP Health and Safety Plan (HSP). Applicable SOPs are listed below:

- SOP No. 7 - Sample Identification, Handling, and Documentation
- SOP No. 8 - Headspace Analysis
- SOP No. 10 - Equipment and Personnel Decontamination
- SOP No. 11 - Boring Abandonment
- SOP No. 12 - Permits and Clearances

Reference Standards

2.2 PROCEDURES FOR SOIL SAMPLING

The characterization of the soils at IAAAP will be done by logging and sampling of surface and subsurface soils. A site geologist will be present during all drilling and soil sample collection activities to maintain descriptive logs (using the Unified Soil Classification System for unconsolidated soils) and collect appropriate samples for various analyses. The following section outlines the procedures used to collect subsurface soil samples at IAAAP.

2.2.1 Equipment List

Equipment for Soil Sampling

The following is an equipment list for soil sampling:

- Hand auger equipment or drill rig with appropriate drilling and sampling tools (stainless-steel split spoons)
- Roll-off bins or other bulk storage containers
- Weighted tape measure with 0.1-foot increments
- Surveyor’s stakes and flags
- Ruler marked in 0.1-foot increments
- Field books/field sheets
- Stainless-steel knife, bowl and spoon
- Sample bottles provided by the laboratory
- Sample bottle labels
- Label tape (clear)
- Paper towels
- Aluminum foil
- Camera and film
- Waterproof and permanent marking pens
- Plastic sheeting
- Plastic bags
- Appropriate health and safety equipment, as specified in the HSP
- Appropriate decontamination supplies, as specified in SOP No. 10
- Ice chest with ice

2.2.2 Decontamination

Before drilling or sampling begins, the drilling and sampling equipment will be decontaminated according to the procedures contained in SOP No. 10. Drilling and sampling equipment will be decontaminated between boring and sampling locations. Sampling equipment will also be decontaminated between collection of samples from different depths at the same location.

2.2.3 Drilling Methods

The methods and procedures for subsurface drilling and soil sample collection are provided in the following section.
2.2.3.1 Hand Auger

Hand auger samples will be collected at the specified depth using a stainless-steel hand auger with a minimum 3-inch outside diameter (OD) bucket. Before the augering activities, clear and remove vegetation and any surface debris such as rocks, as necessary. The hand auger will be advanced in 6-inch intervals to the top of the specified sampling depth. The auger bucket will be decontaminated once the target depth has been reached to avoid possible cross-contamination.

When collecting soil for chemical analysis, if additional soil is necessary to fill sample jars, an additional borehole will be dug to the sample target depth. Hand auger borings will be completed in accordance with ASTM D 1452. If chemical analysis of the sample is required, the step-by-step procedure for collecting, labeling, storing, and transporting subsurface soil samples collected by hand auger is described in Section 2.2.3.4.

2.2.3.2 Auger Borings

Auger drilling a boring will be accomplished using machine-driven hollow stem flight augers (HSA) with a 4-1/4-inch minimum inside diameter to accommodate a 3-inch outside diameter stainless-steel split spoon sampler, 5-foot-long continuous core sampler, or NX, NQ, or wire line core sampler. Auger borings will be completed in accordance with ASTM D 1452. Soil cuttings will be treated as IDW, as described in Section 7, IDW Transportation and Disposal Plan.

When sampling with a split-spoon sampler, a HSA finger plug installed in the bit will be used to prevent soil material coming into the interior of the hollow stem augers. This method will use a standard split-spoon to measure the resistance to soil penetration in accordance with ASTM D1586. Penetration resistance (blow counts) for each sampling depth will be recorded on the HTRW field boring log (Figure 1). The coupling head for the split-spoon sampler will be provided with a ball check valve and will have open vents. Where necessary for sample recovery, the sampler will also be equipped with a spring-type sample retainer or an equivalent retainer.

When using the 5-foot long continuous sampler, the tip of the sampler will precede the HSA bit, and special care will be taken to ensure that maximum recovery is obtained on each section of soil core. Runs of 1 or 2 feet may be required to obtain acceptable core recovery. Grinding of the core after the core has been blocked will not be permitted.

When using a core barrel or core sampler all drilling will be in accordance with ASTM D2113.

Soil samples will be obtained according to specifications in future FSAP addenda. The step-by-step procedure for collecting subsurface soil samples from machine-driven HSAs is described in Section 2.2.3.4.

2.2.3.3 Rotary Wash Boring

The rotary wash boring (RWB) method may be used during deep test hole drilling and monitoring well installation activities where heaving sands are encountered. The borehole
diameter for test holes will be 4 inches and a minimum of 8 inches for monitoring well installation. The drilling fluid for RWB monitoring wells will consist of potable water only, and no bentonite or synthetic additives will be allowed. However, bentonite may be added to potable water during test hole drilling using the RWB method. Subsurface soil sampling within a RWB hole will be accomplished using a stainless-steel split spoon, or NX, NQ, or wire line core sampler. Soil cuttings will be treated as IDW, as described in Section 7, IDW Transportation and Disposal Plan.

A standard split-spoon sampler will be used to measure the resistance to soil penetration in accordance with ASTM D1586. Penetration resistance (blow counts) for each sampling depth will be recorded on the field boring log (Figure 1). The coupling head for the split spoon sampler will be provided with a ball check valve and will have open vents. Where necessary for sample recovery, the sampler will also be equipped with a spring-type sample retainer or an equivalent retainer.

When using a NX, NQ, or wire line core sampler, all drilling will be in accordance with ASTM D2113.

Soil samples will be obtained according to specifications in future FSAP addenda. The step-by-step procedure for collecting subsurface soil samples from RWB method is described in Section 2.2.3.4.

### 2.2.3.4 Subsurface Soil Sample Collection

The following step-by-step procedure should be used to collect subsurface soil samples:

- Decontaminate sampling equipment according to SOP No. 10.
- Record the sample location on a site map and in the field logbook.
- Obtain PID background (BG) readings at the sampling location in the breathing zone.
- Collect the soil sample at the depths specified in future FSAP addenda.
- Don a clean pair of gloves.
- Open the sampler, measure the recovery, and scrape off any soil smear zone from the recovered sample with a stainless-steel knife. If the soil is not cohesive or if the smear zone cannot be easily removed, an attempt will be made to remove soil from the portion of the sample that has not come in contact with the sampler.
- Determine and identify the use of the recovered sample. This will always be for soil classification and stratigraphic logging and may be for chemical, geotechnical, or headspace analysis.
SOP NO. 2 Subsurface Drilling, Soil Sampling and Logging

• The sample must be handled quickly, especially if it is loose or crumbling, to avoid losing volatile contaminants.

• Collect any required volatile organic compound (VOC) sample immediately in appropriate sample containers.

• A portion of selected subsurface soil samples will be collected in the appropriate glass container for headspace analysis according to SOP No. 8.

• Composite the remaining soil by thoroughly mixing the soil from the sampler in a decontaminated stainless-steel bowl with a decontaminated stainless-steel spoon. SVOCs will be sampled once the soil has been composited. Fill the remaining bottles with the composited soil for the specified analysis. The required analyses and appropriate volume of containers of soil will be presented in future FSAP addenda.

• Record applicable information on the Sample Collection Field Sheet (Figure 2).

• Complete the description of materials for the recovered sample according to the Unified Soil Classification System.

• Identify, handle, and document the samples (depending on the use of the sample) according to SOP No. 7.

• If no other samples are to be collected from this sampling location, the boring will be abandoned according to SOP No. 11.

• Identify the location for future reference using surveying stakes and flags

2.2.4 Field Quality Assurance/Quality Control Procedures and Samples

Field QA/QC samples are designed to help identify potential sources of external sample contamination and to evaluate potential error introduced by sample collection and handling. All QA/QC samples are labeled with QA/QC identification numbers and sent to the laboratory with the other samples for analyses.

2.2.4.1 Field Blanks

No field blanks or QA split samples will be collected for soil sampling activities.

2.2.4.2 Duplicate Samples

Duplicate samples are samples collected to assess precision of sampling and analysis. For the soil sampling, a duplicate sample will be collected at the same time as the initial sample. The initial sample bottles for a particular parameter or set of parameters will be filled first, then the duplicate sample bottles for the same parameter(s), and so on until all necessary sample bottles
for both the initial sample and the duplicate sample have been filled. The duplicate soil sample will be handled in the same manner as the primary sample. The duplicate sample will be assigned a QA/QC identification number, stored in an iced cooler, and shipped to the laboratory on the day it is collected. Duplicate samples will be collected for all parameters. Duplicate samples will be blind to the laboratory.

2.2.4.3 Matrix Spikes and Matrix Spike Duplicates

Matrix spikes (MS) and matrix spike duplicates (MSD) are used to assess the potential for matrix effects. Samples will be designated for MS/MSD analysis on the chain-of-custody form and on the bottles. It may be necessary to increase the sample volume for samples where this designation is to be made.

2.2.5 Sample Identification, Handling, and Documentation

Samples will be identified, handled and recorded as described in this SOP and SOP No. 7. The parameters for analysis and preservation will be specified in future FSAP addenda.

2.2.6 Documentation

Each field activity must be properly documented to facilitate a timely and accurate reconstruction of events in the field (see SOP No. 7). Sample Collection Field Sheets will be completed for all soil samples submitted for chemical analysis (Figure 2).

2.2.6.1 Sample Collection Field Sheet

A sample collection field sheet for surface water samples (Figure 2) will be completed at each sampling location. The data sheet will be completely filled in. If items on the sheet do not apply to a specific location, the item will be labeled as not applicable (NA). The information on the data sheet includes the following:

- Sample location number
- Date and time of sampling
- Person performing sampling
- Type of sample
- Description of sample
- Number of samples taken
- Sample identification number
- Preservation of samples
- Headspace analysis
- Record of any QC samples from site
- Any irregularities or problems which may have a bearing on sampling quality
2.2.6.2 Field Logbook

The most important aspect of documentation is thorough, organized, and accurate record keeping. All information pertinent to the investigation and not documented on the boring log will be recorded in a bound logbook with consecutively numbered pages. All entries in logbooks will be made in waterproof ink and corrections will consist of line-out deletions that are initialed and dated. Entries in the logbook will include the following, as applicable:

- Project name and number
- Sampler’s name
- Date and time of sample collection
- Sample number, location, and depth
- Sampling method
- Observations at the sampling site
- Unusual conditions
- Information concerning drilling decisions
- Decontamination observations
- Weather conditions
- Names and addresses of field contacts
- Names and responsibilities of field crew members
- Names and titles of any site visitors
- Location, description, and log of photographs (if taken)
- References for all maps and photographs
- Information concerning sampling changes, scheduling modifications, and change orders
- Summary of daily tasks (including costs) and documentation on any cost or scope of work changes required by field conditions
- Signature and date by personnel responsible for observations

Field investigation situations vary widely. No general rules can include each type of information that must be entered in a logbook for a particular site. A site-specific logging procedure will be developed to include sufficient information so that the sampling activity can be reconstructed without relying on the memory of field personnel. The logbooks will be kept in the field team member’s possession or in a secure place during the investigation. Following the investigation, the logbooks will become a part of the final project file.

2.2.6.3 Boring Logs

During drilling activities, the site Geologist will describe all activities on the field boring logs and in the field logbook. Original boring logs will be submitted to USACE as soon as possible following completion. As per USACE Omaha District Geology Scope of Services the following data will be recorded in the boring logs at the drill site. The HTRW Boring Log form is shown on Figure 1.

- The name of the site geologist(s), project name, boring location, and site ID
- Drilling agency
• General description of drilling equipment used, including the rod size, bit type, pump type, rig manufacture, model, drilling personnel, and method
• Start and completion dates for all borings, and chronological time-sequence of all significant events
• Depths in feet and fractions thereof (tenths of feet)
• Soil descriptions, in accordance with the Unified Soil Classification System (USCS) and prepared in the field by the attending site geologist, which includes the following information:
  – Classification
  – USCS symbol
  – Secondary components and estimated percentage
  – Color (using Munsell Color Chart)
  – Plasticity
  – Consistency (cohesive soil) or density (noncohesive soil)
  – Moisture content
  – Texture/fabric/bedding
  – Grain angularity
  – Depositional environment/formation name (e.g., Glasford Formation, Warsaw Formation)
• Cuttings description, including basic classification, secondary components, and other apparent parameters
• Visual estimates of secondary soil constituents (if terms such as “trace”, some are used, their quantitative meanings will be defined in a general legend)
• Blow counts, hammer weight, and length of fall for split spoon samples
• Estimated depth interval and length of sample recovered for each sample interval
• Field screening results for soil headspace, breathing zone, and borehole with PID
• Depth to water first encountered during drilling and the method of determination (any distinct water-bearing zones below the first zone will also be noted)
• Drilling sequence
• Any unusual problems
• Other remarks or observations
### HTRW DRILLING LOG

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**LOCATION SKETCH/COMMENTS**

**SCALE:**

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Sheet 1 of 2
## HTRW DRILLING LOG

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Sheet 2 of 2
Figure 2

SOIL SAMPLE COLLECTION FIELD SHEET

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Comments
Standard Operating Procedure No. 3
Monitoring Well Installation and Development
SOP NO. 3 Monitoring Well Installation and Development

3.1 PURPOSE AND SCOPE

The purpose of this document is to define the Standard Operating Procedure (SOP) for monitoring well installation and development at the Iowa Army Ammunition Plant (IAAAP). These procedures give descriptions of equipment, field procedures and documentation procedures implemented for the installation and development of Monitoring Wells. The procedures described here are sufficiently detailed to allow field personnel to properly install and develop the planned groundwater monitoring wells. Field procedure were developed in accordance with IAC 567 Chapter 49 (IDNR 1998), USACE EM 1110 (USACE 1998) and USACE Omaha District Geology Scope of Services, and are detailed in this SOP. Specific well location will be presented in future Field Sampling and Analysis Plan (FSAP) addenda.

These procedures are intended to be used together with FSAP and other appropriate SOPs. Health and safety procedures and equipment for the investigation are detailed in the IAAAP Health and Safety Plan (HSP). Applicable SOPs are listed below:

- SOP No. 1 Subsurface Drilling, Soil Sampling, andLogging
- SOP No. 8 Headspace Analysis
- SOP No. 9 Water Level Measurement
- SOP No. 10 Equipment and Personnel Decontamination
- SOP No. 11 Boring Abandonment
- SOP No. 12 Permits and Clearances

Reference Standards


3.2 PROCEDURE FOR DRILLING AND MONITORING WELL INSTALLATION

The installation of groundwater monitoring wells (including piezometers) will be done to allow water level measurements, hydraulic conductivity testing, and collection of groundwater samples at IAAAP.
Monitoring wells are scheduled to be installed with hollow-stem augers, placing the well materials through the center of the augers. However, if heaving sands are encountered or bedrock wells are required, rotary wash boring (RWB) methods may be required.

Small diameter injection piezometers will be installed using direct push methodologies which are described in detail in SOP No. 13.

The following equation shall be used to calculate the volume of water to be removed during well evacuation:

**For 2-inch wells:**

One Evacuation Volume (gal) = (Total Well Depth [ft] - Water Level Depth [ft]) x 0.16 gal/ft.

Multiply the volume of one well casing volume by five to obtain the minimum volume of water to be evacuated. Note: if water was added during installation or drilling, at least three times this volume must be removed before well development evacuation begins. This is especially important if RWB methods are used.

### 3.3.3 Documentation

Documentation of observations and data acquired in the field will provide information on well development and also provide a permanent record. These observations and field data will be recorded with waterproof ink in a bound weatherproof field logbook with consecutively numbered pages and on the well development log shown on Figure 3. As part of the development process, the following information will be recorded:

- Well designation
- Well location
- Date(s) and time of well development
- Static water level from top of well casing before and after development
- Volume of water in well prior to development
- Volume of water removed and time of removal
- Depth from top of well casing to bottom of well
- Screen length
- Depth from top of well casing to top of sediment inside well, if present, before and after development
- Field measurements of pH, specific conductance, temperature, turbidity, DO, and redox taken during and after development
- Physical characteristics of removed water throughout development (color and odor)
- Type and size/capacity of pump and/or bailer
- Description of development technique
- Decontamination observations
- Instrument calibration record
SOP NO. 3  Monitoring Well Installation and Development

3.2.1 Equipment List

The following is an equipment list for well installation:
- Well casing and well screen (continuous-slot/PVC wire-wrapped)
- Stainless-steel centralizers (if required)
- Bentonite (pellets, powder, or chips)
- Filter pack and buffer sand
- Potable water
- Portland Type I or II Cement, powdered bentonite for grouting
- 4-inch, square channel, locking protective, 6-foot steel casing
- 2-inch, 6-foot long guard posts
- High-pressure steamer/cleaner
- Long-handled bristle brushes
- Wash/rinse buckets
- Alconox type detergent
- Location map
- Drill rig capable of installing wells to the desired depth with the proper diameter in the expected formation materials and conditions
- Plastic bags
- Self-adhesive sample bottle labels
- Weighted tape measure with 0.1-foot increments
- Water level probe with 0.01-foot increments
- Deionized water and pressure sprayer
- Appropriate health and safety equipment, as specified in the Health and Safety Plan (HSP)
- Field Logbook
- Boring log sheets (USACE Engineering Form 5056-R)
- Well construction form
- Well locks (keyed alike)

3.2.2 Decontamination

Before drilling or sampling begins, the drilling and sampling equipment will be decontaminated according to the procedures contained in SOP No. 10. Drilling and sampling equipment will be decontaminated between boring and sampling locations. Sampling equipment will also be decontaminated between collection of samples from different depths at the same location.

3.2.3 Preparation for Drilling

Several activities must be completed prior to any drilling work including:

- Staking the boring position
- Confirming accessibility of the monitoring well location to the proposed drilling equipment
- Clearing underground utilities or structures at the boring site, according to SOP No. 12
All sites must be checked for access prior to mobilization of the drill crew. Remember to check for overhead utilities or obstructions, security requirements and access to keys to pass through locked gates. SOP No. 12, Permits and Clearances should be reviewed.

### 3.2.3.1 Drilling Methods

Hollow-stem auger and rotary wash boring methods are described in the following sections.

#### Hollow-Stem Auger Drilling

Hollow-stem auger (HSA) methods are commonly used in cohesive soils or in granular soil formations, where the boring walls may be unstable, and the augers form a temporary casing to allow sampling of the “undisturbed soil” below the bit. The hollow-stem augers provide a casing that supports the borehole walls and provides clear access to the bottom of the boring. Samplers can be easily inserted into the central core of the augers to obtain soil samples with a reduced risk of contamination by contact with soil strata at higher elevations. In a similar manner the augers allow installation of the monitoring well materials through the central core greatly reducing the potential for contact with the surrounding soil formations and resulting contamination.

The hollow-stem augers were designed to be advanced with a center bit or plug attached to drill rods. This center bit is intended to prevent soil cuttings from entering the hollow-stem augers during drilling and is removed to allow soil sampling. Use of a center plug or a special retainer basket to keep the core of the augers free of soil is essential.

Significant problems can occur where hollow-stem augers are used to sample soils below the water table. The unbalanced water pressure acting against the soil at the bottom of the boring can significantly disturb the soil, particularly in granular soils or soft clays and silts. Often the soils will heave and plug the auger preventing the sampler from reaching the bottom of the boring. Where heave or disturbance occurs, the penetration resistance or strength of the sample can be significantly reduced and the augers can become contaminated. Use of a retainer basket or filling the center of the augers with water may be required in some soil formations. Any water introduced into the augers must be potable and the quantity used recorded in the logbook. If heaving occurs, contact the site manager for specific instructions to modify the drilling method.

The hollow-stem auger drilling method generally produces limited cuttings for visual observation, thus reducing the information available to detect changes between sample intervals. As the boring is advanced to greater depths a considerable delay may occur before the soil cuttings appear at the ground surface and the large size of the augers may limit the ability of the driller to detect changes in the soil conditions by monitoring the response of the drilling equipment. The field geologist must be aware of these limitations in identification of soil conditions between sample locations. Soil cuttings will be treated as IDW, according to Section 7, IDW Transportation and Disposal Plan.
Rotary Wash Boring

Rotary wash boring (RWB) methods are commonly used in soil formations below the groundwater level where the boring walls are unstable or the formation is too hard to penetrate (i.e., bedrock) using augering methods.

In rotary wash boring, the drilling fluid, consisting of potable water which mixes with natural formation materials, is pumped down the drill rods and through a bit that is attached at the lower end of the drill space between the drill rods and the wall of the borehole. At the surface, the fluid discharges through a pipe or ditch and enters into a segregated or baffled sedimentation tank, pond or pit. The settling pit overflows into a suction pit where a pump recirculates the fluid back through the drill rods.

During rotary wash boring, drilling fluid tends to infiltrate permeable zones. This is why the fluid must be removed prior to well placement and again during the development process. Drilling fluid can interfere with the specific function of a monitoring well and prevent collection of a sample that is representative of the *in situ* groundwater quality. However, in higher yielding formations, this potential problem typically can be alleviated.

For well borings requiring soil sampling, split spoon, thin-wall or wireline core sampling methods will be used. If coring is required, ream the borehole with a 6-inch bit after coring activities have been completed. Soil cuttings will be treated as TDW according to Section 7, IDW Transportation and Disposal Plan.

The amount of potable water used during drilling, and lost to the formation, must be calculated or estimated and recorded in the field logbook. This calculation will be used during the well development activities.

Soil Sampling

Soil samples for material description, chemical analysis, or geotechnical analysis may be required. Where analytical or geotechnical testing is required, the soil samples will be obtained in accordance with SOP No. 2.

The sample will be classified in the field by the field geologist using the methods described in SOP No. 2 and the description recorded on the boring log (Figure 1). The strength of the soil sample will be measured with visual methods, evaluation of the driving resistance, or a hand penetrometer test.

Boring Logs

During drilling activities, the site Geologist will describe all activities on the field boring logs and in the field logbook. Original boring logs will be submitted to USACE as soon as possible following completion. As per USACE Omaha District Geology Scope of Services, the information described in Section 2.2.6.3 of SOP No. 2 will be recorded in the boring logs at the drill site. The HTRW Boring Log form is shown on Figure 1.
3.2.3.2 Well Materials Specifications

Well Casing

Well casing will consist of new, threaded, flush-joint, 2-inch ID, schedule 40 PVC. Teflon O-rings will be used at all joints. Heat-welded joints and or gaskets will not be used. The tops of all well casings will be fitted with locking caps that can be easily removed by hand.

Well casing for injection wells will be 1-inch ID, schedule 40 PVC. Teflon O-rings will be used at all joints.

Well Screen

Well screen will consist of new 2-inch ID PVC continuous-slot/PVC wire-wrapped screen with a bottom screw-type plug. The screen slot size will be 0.010 inches. The screen length of the monitoring wells will be 5 to 10 feet depending upon the saturated thickness and the seasonal fluctuations of the water table. The screen length of monitoring wells will not exceed 10 feet in length. The screen depths will be specified in future FSAP addenda. All well screens will have an inside diameter equal to or greater than that of the well casings.

Centralizers

Stainless-steel centralizers will be used on wells installed using RWB methodology below a depth of 50 feet. Centralizers will be attached at the base and top of the well screen, and every 15 feet thereafter.

Filter Pack

The filter pack material for the monitoring wells will consist of clean, washed, well-rounded silica sand to form a filter between the natural formation material and the well screen. Assume a commercially-available grain-size distribution (e.g., #16-30, #20-40 or other available sizes). Constant probing of pack thickness will be done to prevent bridging. The filter pack will be placed from the bottom of the boring to about 2 to 3 feet above the top of the screen.

Bentonite Seal

A bentonite seal will be installed directly above the filter pack sand in the monitoring wells. The seal will consist of a layer of commercially-available, less than one-half inch, sodium bentonite pellets or chips that are approximately 3 feet thick as measured immediately after placement, without allowance for swelling. The bentonite seal will be allowed to hydrate for a minimum of 4 hours before grouting begins. For bentonite seals above the saturated zone, about one gallon of potable water per foot of chips or pellets will be added to initiate hydration of the bentonite. Each 1-foot lift will be allowed to hydrate for 30 minutes. After the placement of the final lift, the bentonite will be allowed to hydrate for an additional 2 hours prior to placement of the grout. Manufactured, coated, sodium bentonite pellets will be used for wells installed using HSA drilling methods. However, placement of pellets far below the water level, inside HSAs, may be
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problematic. If pellets are not feasible, then a buffer sand seal used.

Buffer Sand Seal

A buffer sand seal shall be installed directly above the filter pack sand for monitoring wells where a bentonite seal is problematic (i.e., seals below the water table). The seal will consist of a 5-foot thick layer of clean fine sand (e.g., #100).

Cement/Bentonite Grout

The annular space between the well casing and the boring in the wells will be filled with a cement/bentonite grout from the top of the bentonite or buffer sand seal to 3-feet below the ground surface. The grout will consist of a mixture that is blended to produce a thick, lump-free, cement/bentonite grout. The grout will be prepared in an aboveground rigid container by first thoroughly mixing the bentonite powder with water and then mixing in the cement. All monitoring wells will be pressure grouted from immediately above the seal by a side discharge tremie pipe. The grout will be pumped through the tremie pipe until undiluted grout flows from the annular space at the ground surface.

Concrete Surface Seal

Following placement of the cement/bentonite grout, the remaining 3 feet of annular space will be at least 1-foot in diameter and will be filled with at least 3000 psi portland cement concrete.

Above ground Completion

Following placement of the concrete surface seal, a minimum 4-inch, square channel, locking protective, 6-foot-long, protective steel casing shall be placed over the monitoring well casing projecting above the ground surface. The protective casing will be placed about 3 feet into the concrete surface seal, leaving about 3 feet above the ground surface. A concrete surface pad will be placed around the protective cover extending a minimum of 1.5 feet (3-foot diameter) from the cover and a minimum of 6 inches thick with a slight mound above the ground surface. All well will have an aboveground completion.

Monitoring wells located in off-site locations may be flush mount surface completions in accordance with the requests of the county or other property owner.

Guard Posts

Four 2-inch-diameter steel posts will be installed around the wells with aboveground completions. The posts will be located radially from the well casing at a distance of about 4 feet. The guard posts will be placed about 3 feet below the ground surface and have a minimum of 3 feet aboveground exposure. The inside of each post will be filled with concrete.
3.2.3.3 Well Installation Procedure

The procedures for installation of shallow, intermediate, and deep monitoring wells are included in the following section:

**Shallow and Intermediate Wells (HSA)**

1. Decontaminate all drilling equipment according to procedures outlined in SOP No. 10.
2. Advance the boring to the planned depth using hollow stem augers or other approved drilling method. Collect any required soil samples using a split spoon sampler or a continuous sampler advanced with the hollow-stem augers.
3. Measure depth of completed boring using a weighted tape.
4. Decontaminate all well materials according to SOP No. 10. Following decontamination, all personnel that handle the well materials will don a clean pair of gloves.
5. Measure the length of each section of well casing and screen to nearest 0.10 foot.
6. Assemble the well screen and casing as it is lowered into the boring inside the hollow stem augers.
7. Lower screen and casing until the screen interval is at the desired depth.
8. Record level of top of casing and calculate screened interval. Adjust screen interval by raising the assembly to the desired interval, if necessary, and add filter pack sand to raise the bottom of the boring to the base of the casing.
9. Calculate and record the volume of the filter pack, bentonite or buffer sand seal, and grout/bentonite chips required for existing boring conditions. (Annular Space Calculation: $V_r = \pi r^2 h$; $V_c = \pi r^2 h$; $V_A = V_r - V_c$ where $V_r$ = Volume of borehole, $V_c$ = Volume of casing, $V_A$ = Volume of annulus, $r$ = Radius of borehole, and $h$ = Vertical length of borehole.)
10. Install the monitoring well filter pack sand, seal, and backfill.
   a. Begin adding filter pack sand around the annulus of the casing. Repeated depth soundings shall be taken to monitor the level of the sand. Record the amount of water (if any) used during filter pack sand placement in field logbook.
   b. Allow sufficient time for the filter pack sand to settle through any water column outside the casing before measuring the sand level.
   c. Extend the filter pack sand to about 2-3 feet above the top of the well screen.
   d. Following filter pack sand placement, install a 3-foot thick annular seal of bentonite.
chips or pellets on top of the filter pack sand. Slowly add the bentonite chips or pellets through the Hollow-Stem Augers to avoid bridging. The bentonite pellet seal will be allowed to hydrate for a minimum of 4 hours.

e. Add one gallon of potable water per one foot lift of bentonite to initiate swelling of the bentonite if annular seal is above the water table. Each 1-foot lift will be allowed to hydrate for 30 minutes. The bentonite seal will be allowed to hydrate for an additional 2 hours prior to placement of the cement/bentonite grout.

f. A 5-foot buffer sand seal will be installed directly above the filter pack sand for monitoring wells where a bentonite seal is problematic (i.e., seals below the water table). Allow sufficient time for the buffer sand to settle through any water column outside the casing before measuring the sand level.

g. Add cement/bentonite grout to the remaining annulus from the top of the bentonite or buffer sand seal to 3 feet below the surface. The grout will be tremied into the borehole until the annulus is completely filled. The base of the side discharge tremie pipe should be placed approximately 3 feet above the seal when grouting begins.

h. After the column of grout has set for at least 24 hours it will be checked for settlement. If necessary, additional grout will be added to accommodate any settlement.

11. After the monitoring well backfill grout sets, the 3-foot thick concrete surface seal will be installed. The excavation will be filled with concrete. A protective casing will be centered on the well casing riser and inserted into the concrete. The well number, depth, and installation date will be inscribed on the well casing cap.

12. See Figures 4 and 5 for the shallow and medium monitoring well construction logs.

**Deep Wells (HSA and RWB)**

1. Decontaminate all drilling equipment according to procedures outlined in SOP No. 10.

2. Advance the boring with HSAs to the top of bedrock. Collect any required soil samples using a split-spoon sampler or a continuous sampler.

3. At the bedrock contact, set a 6-inch PVC double casing inside the HSAs and grout in place. Other techniques include grouting the entire boring and reaming out the grout.

4. Convert to RWB after grout has been allowed to set for 24 hours.

5. Drill through the bottom of the PVC double casing and grout.

6. Borings will be rock cored 20-feet into the bedrock, and then reamed to 6-inch OD. All rock cores will be retained.
7. Measure depth of completed boring using a weighted tape.

8. Flush the borehole with clean, potable water to remove cuttings. Record amount of water lost to formation. If coarse material or cuttings settle to the bottom of the borehole, a split-spoon will be used to remove the material.

9. Decontaminate all well materials according to SOP No. 10. Following decontamination, all personnel that handle the well materials will don a clean pair of gloves.

10. Measure the length of each section of well casing and screen to nearest 0.10 foot.

11. Assemble the well screen and casing as it is lowered into the double casing.

12. Lower screen and casing until the screen interval is at the desired depth.

13. Record level of top of casing and calculate screened interval. Adjust screen interval by raising the assembly to the desired interval, if necessary, and add filter pack sand to raise the bottom of the boring to the base of the casing.

14. Calculate and record the volume of the filter pack, bentonite seal, and grout/bentonite chips required for existing boring conditions. (Annular Space Calculation: \( VR = \pi r^2 h \), \( V_c = VA - V_{~} \), where \( V_{~} = \) Volume of borehole, \( V_c = \) Volume of casing, \( VA = \) Volume of annulus, \( r = \) Radius of borehole, and \( h = \) Vertical length of borehole.)

15. Install the monitoring well filter pack sand, seal, and backfill.
   a. Begin adding filter pack sand around the annulus of the casing. Repeated depth soundings shall be taken to monitor the level of the sand. Record the amount of water used during filter pack sand placement in field logbook.
   b. Allow sufficient time for the filter pack sand to settle through any water column outside the casing before measuring the sand level.
   c. Extend the filter pack sand to about 2-3 feet above the top of the well screen.
   d. A 5-foot buffer sand seal will be installed directly above the filter pack sand for monitoring wells. Allow sufficient time for the buffer sand to settle through any water column outside the casing before measuring the sand level.
   e. Add cement/bentonite grout to the remaining annulus from the top of the buffer sand seal to 3 feet below the surface. The grout will be tremied into the borehole until the annulus is completely filled. The base of the side discharge tremie pipe should be placed approximately 3 feet above the seal when grouting begins.
   f. After the column of grout has set for at least 24 hours it will be checked for settlement. If necessary, additional grout will be added to accommodate any settlement.
16. After the monitoring well backfill grout sets, the 3-foot thick concrete surface seal will be installed. The excavation will be filled with concrete. A protective casing will be centered on the well casing riser and inserted into the concrete. The well number, depth, and installation date will be inscribed on the well casing cap.

17. See Figure 6 for the deep monitoring well construction log.

3.2.4 Documentation

Observations and field data acquired during drilling and installation of the monitoring wells will be recorded to provide a permanent record. These observations will be recorded with waterproof ink in a bound weatherproof field logbook with consecutively numbered pages. Notes will be recorded daily when in the field. The information in the field logbook will include the following as a minimum:

- Project name and number
- Observer’s name
- Drilling and well installation observations as described in Section 3.2.3.3 of this SOP
- Decontamination observations as described in SOP No. 10
- Weather conditions
- Other pertinent information

A boring log (Figure 1) will be completed for each boring. The observations made during the boring will also be recorded in the field logbook. The well installation details will be shown in a diagram that will be completed in the field logbook and on the monitoring well construction log (Figure 2). Each well diagram will consist of the following (denoted in order of decreasing depth from ground surface):

- Bottom of the boring
- Casing depth
- Casing and screen type
- Screen location(s)
- Filter pack
- Bentonite or buffer sand seal
- Well backfill material (chips or grout)
- Cave-in locations
- Depth of riser without cap (below ground surface)
- Concrete surface seal and protective casing details

Additional documentation for well construction noted in the field logbook will include the following:

- Grout, sand, and bentonite volume calculations prior to well installation.
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- The quantity and composition of the grout, seals, and filter pack actually used during construction.
- Screen slot size (in inches), slot configuration, outside diameter, nominal inside diameter, schedule/thickness, composition, and manufacturer.
- Coupling joint design and composition.
- Protective casing composition and nominal inside diameter.
- Start and completion dates.
- Discussion of all procedures and any problems encountered during drilling and well construction.
- Need to add water during well installation. Note the depth that water was added and the quantity.

3.2.5 Well Acceptance Criteria

Well acceptance will be on a case-by-case basis. The following criteria will be used along with individual circumstances in the evaluation process.

a. The well and material placement will meet the specifications of the Project Work Plan, FSAP, and all pertinent SOPs unless modified by any amendments.

b. Wells will not contain portions of drill casing or augers unless they are specified in the Work Plan as permanent casing.

c. All well casing and screen materials will be free of any unsecured couplings, ruptures, or other physical breakage/defects before and after installation.

d. The annular material (filter pack, bentonite, buffer sand, and grout) of the installed well will form a continuous and uniform structure, free of any detectable fractures, cracks, or voids.

e. All risers will be set round, plumb and true to line, allowing the insertion and retrieval of the pump and/or bailer optimally designed for that size casing. A 10-foot long section of pipe will be run through the entire length of well to check alignment.

f. All joints will be constructed to provide a straight, non-constricting, and watertight fit.

g. Completed wells will be free of extraneous objects or materials; e.g., tools, pumps, bailers, packers, excessive sediment thickness, grout, etc. This prohibition should not apply to intentionally installed equipment per the Work Plan.

3.3 WELL DEVELOPMENT PROCEDURE

The purpose of well development is to remove well drilling fluids, solids, or other particulates which may have been introduced or deposited on the boring wall in a recently installed well during drilling and construction activities. This restores the hydraulic conductivity of the aquifer.
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material surrounding the well to near pre-well installation conditions. Properly developed monitoring wells allow for the collection of low turbid ground water samples that are chemically and physically representative of the aquifer of concern, and accurate water level measurements. The procedure is also applicable to older or improperly developed wells that are suspected of not providing representative groundwater samples.

This section describes the equipment, methods, and documentation that shall be used for developing groundwater monitoring wells.

3.3.1 EQUIPMENT LIST

The following items are required to properly develop groundwater monitoring wells:

- Well keys
- Water level probe with 0.01-foot increments
- Weighted tape measure with 0.1-foot increments
- Calculator
- Field notebook and well development log
- Waterproof pen
- Submersible pump
- Teflon disposable bailer (sized appropriately for well)
- Nylon rope or wire line for bailing
- Surge block (sized appropriately for well)
- PVC or stainless-steel pipe for operating surge block (sized appropriately for well)
- Multi-parameter water quality probe with flow-through cell (pH, specific conductance, temperature, Dissolved Oxygen (DO), and Oxidation Reduction Potential (ORP)).
- Turbidity meter
- Calibration solutions
- Polyethylene or glass container (for field parameter measurements)
- Plastic squeeze bottle filled with deionized water
- 5-gallon bucket
- Appropriate IDW containers for storage of development water
- Appropriate health and safety equipment
- Alconox soap (or equivalent)
- Potable tap water
- Distilled or deionized water
- Decontamination buckets/pails
- Plastic brushes
- Well completion information

3.3.2 Procedure

The development of a newly installed monitoring well will proceed only after the cement/bentonite grout or hydrated bentonite chips have been allowed to set for a minimum of
48 hours. Monitoring well development activities will be completed prior to purging and groundwater sampling for analytical testing. Before development begins, the development equipment will be decontaminated according to the procedures described in SOP No. 10. Equipment coming in contact with the well will also be decontaminated between wells.

Before development begins, the field personnel will verify that the water quality probe, and water level probe are operating properly. The water quality probe will be calibrated at the beginning and end of each week. Calibration checks will be done every day prior to use. Calibration times and readings will be recorded in the field logbook. Specific instructions for calibrating the probes are given in the manufacturer’s manual.

Monitoring well development is accomplished using a surge block and/or a bailer, hand pump, or submersible pump to flush the screen, sand pack material, and borehole wall of drilling fluids and fine sediment resulting from well drilling and installation activities. This procedure also allows for the removal of fine sediment which may have accumulated within the inner well casing.

Development consists of removing water during repeated surging and well evacuation episodes. Well surging is the process of causing water to move through the screen and into and out of the sand pack and aquifer formation. This will be accomplished by gently surging the entire length of well screen either mechanically using a surge block or hydraulically utilizing a bailer or pump. **Note: Surging will be done only on wells screened within sand formations.** This allows for the proper packing of the sand pack material. Well evacuation is the process of removing water from throughout the entire water column by periodically lowering and raising the pump intake or the point to which the bailer is lowered. Development water will be collected in drums or portable bulk storage tanks for transportation and disposal. Development water will be treated as IDW, as described in Section 7, IDW Transportation and Disposal Plan.

Development of monitoring wells installed in formations with a relative high hydraulic conductivity (e.g., sand or silty sand) will be completed by alternating between surging and extraction methods with either a hand or submersible pump.

Development of monitoring wells installed in formations with a relatively low hydraulic conductivity (e.g., clay or silt) will be completed with a bailer, hand or submersible pump. The initial development will attempt to remove highly turbid water from the well. Subsequent development will be completed slowly to minimize any surging. Water will be evacuated slowly to allow the filter pack to trap the fine suspended sediment and allow the introduction of lower turbidity formation water into the well.

During the well development activities, field parameters (temperature, pH, specific conductance, turbidity, DO, and ORP) are measured and the clarity, color, any presence of odors, and other comments regarding water quality are noted in the field logbook and on the well development log (Figure 3). The date, time, and volume of water removed are also recorded at this time. A sample of water will be collected for measurement of field parameters at the beginning of well development in order to establish a baseline for comparison with the water quality as well
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development proceeds. Measurements of field parameters along with observations will be recorded after a minimum of one well casing volume of water is removed.

3.3.2.1 Development Duration

Monitoring well development will continue until a minimum of five well volumes are removed. If water was added to the well during drilling or construction activities, at least three times the volume of water added will be removed in excess of the five well volumes of water to be removed for development. Additionally, field water quality parameters will be measured during development purging. Development will continue until parameters have stabilized according to the following:

- pH ± 0.2 units
- Temperature ± 10%
- Specific conductivity ± 10%
- Dissolved Oxygen ± 10%
- Oxidation Reduction Potential +10%
- Turbidity ± 10% (or clear and free of fines)

Regardless of the volume of water removed or the stability of the parameters, development will continue for a minimum of 2-hours. If the well is pumped or bailed dry, it will be allowed to recover. No agents or additives will be used or introduced into the well during development or at any other time.

3.3.2.2 Well Volume Calculations

The volume of water required for removal during development is calculated using the following method:

1. Measure the depth to water in the well from the measuring point. This is usually a notched point on the top of PVC riser pipe that has been surveyed.

2. Measure the total depth of the well from the same measuring point used for measuring the depth to water.

3. Calculate the height of water in the well casing by subtracting the depth of water from the total well depth.

4. Calculate the number of gallons of water corresponding to one well volume. This is done by multiplying the height of water in the well casing by the conversion factor corresponding to the inside diameter of the well casing.
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</table>

<table>
<thead>
<tr>
<th>DEPOSITION OF HOLE</th>
<th>BACKFILLED</th>
<th>MONITORING WELL</th>
<th>OTHER (SPECIFY)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
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<table>
<thead>
<tr>
<th>LOCATION SKETCH/COMMENTS</th>
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<tbody>
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<table>
<thead>
<tr>
<th>SCALE:</th>
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</table>

ENG FORM 5056-R, AUG 94

(Propositor: CECW-EC)
### HTRW DRILLING LOG

<table>
<thead>
<tr>
<th>ELEV a</th>
<th>DEPTH b</th>
<th>DESCRIPTION OF MATERIALS c</th>
<th>FIELD SCREENING RESULTS d</th>
<th>GEOTECH SAMPLE OR CORE BOX NO. e</th>
<th>ANALYTICAL SAMPLE NO. f</th>
<th>BLOW COUNTS b</th>
<th>REMARKS b</th>
</tr>
</thead>
<tbody>
<tr>
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</tbody>
</table>

**PROJECT**

**SHEET**

**INSPECTOR**

**NOTE**
MONITORING WELL CONSTRUCTION LOG

Project Name
Location
Installed By
Inspected By
Method of Installation
Remarks

Piez/Well No.
Project No.
Date
Time

Generalized Stratigraphy

Elevation of top of riser
Height of riser above ground

Ground Elevation

I.D./Type of surface casing

Type of surface seal

Depth of surface seal

I.D./Type of riser pipe

Type of backfill

Depth to top of seal
Type of seal

Depth of top of filter pack

Depth of top of screen
Type of filter pack

I.D./Type of screen

Screen slot size

Depth of bottom of screen
Depth of bottom of plugged blank section

Type of backfill below observation well

Depth of bottom of boring
Diameter of boring
Figure 3

PROPOSED WELL DEVELOPMENT LOG

Project: ___________________________  Well No: ___________________________
Project No: ______________________  Date: ________________________________

WELL MEASUREMENTS

Well inside diameter: ______________________ ft.
Depth of well casing: ______________________ ft.
Initial water level: ______________________ ft. below MP
Measuring point (MP): ____________________
Fluid well casing volume: __________________ gal.
Air temperature: _________________________
Weather conditions: ______________________

SAMPLING MEASUREMENT

<table>
<thead>
<tr>
<th>DISCHARGE</th>
</tr>
</thead>
<tbody>
<tr>
<td>Water level (ft. BMP)</td>
</tr>
<tr>
<td>Time</td>
</tr>
<tr>
<td>Discharge (Gal.)</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>WATER QUALITY DATA</th>
</tr>
</thead>
<tbody>
<tr>
<td>pH</td>
</tr>
<tr>
<td>Conductivity (mS/cm)</td>
</tr>
<tr>
<td>Temperature (°C)</td>
</tr>
<tr>
<td>Dissolved Oxygen (mg/l)</td>
</tr>
<tr>
<td>Redox (mV)</td>
</tr>
<tr>
<td>Color</td>
</tr>
<tr>
<td>Turbidity (NTUs)</td>
</tr>
</tbody>
</table>

Total discharge: ______________________  Casing volumes removed: ______________________
Method of disposal of discharged water: ______________________

QUALITY ASSURANCE

Sampling Method: ______________________
Method to measure water level: ______________________
Boiler ropes new or cleaned? ______________________
pH meter no: ______________________  Calibrated: ______________________
Conductivity meter no: ______________________  Calibrated: ______________________
Comments: ______________________
PROPOSED MONITORING WELL CONSTRUCTION LOG

**Location**: Middletown, IA

**Remarks**: This is a typical monitoring well above ground construction for IAAAP.

**AGS**: Above Ground Surface, **BGS**: Below Ground Surface, *=Typical depths for monitoring well construction*

- **Project Name**: Iowa Army Ammunition Plant
- **Well No.**: Shallow Wells
- **Project No.**: 45-FM9602-WW.00

**Guard post**: (4) 2-inch steel, 6-foot long, filled with concrete

- **Height of protective casing**: AGS* 3.0 feet
- **Slip cap or J-plug**:
- **Height of riser above ground**: 2.5 feet
- **Fill inside casing with filter pack**:
- **Ground Elevation**: 0.0 feet
- **1.0D/Type of surface casing**: BGS* 4-inch, square, steel casing
- **with a lockable steel cap, 6-foot long**:
- **Type of surface seal**: Portland cement concrete
- **Fill inside casing with granular bentonite**: 3.0 feet
- **1.0D/Type of well riser pipe**: 2-inch schedule 40 threaded PVC
- **Type of backfill**: Cement/bentonite grout
- **Depth to top of seal**: 15.5 feet
- **Type of seal**: Coated bentonite pellets
- **Depth of top of filter pack**: 20.5 feet
- **Depth of top of screen**: 22.5 feet
- **Type of filter pack**: Commercially-available size
- **1.0D/Type of screen**: 2-inch continuous slot/PVC wire-wrapped
- **Screen slot size**: 0.01 inch
- **Depth of bottom of screen**: 32.5 feet
- **Depth of bottom of plugged blank**: 33.0 feet
- **Type of backfill below monitoring well**: Filter pack
- **Depth of bottom of boring**: 34.0 feet
- **Diameter of boring**: 8-inch
### Proposed Monitoring Well Construction Log

<table>
<thead>
<tr>
<th>Project Name</th>
<th>Iowa Army Ammunition Plant</th>
<th>Well No.</th>
<th>Intermediate Wells</th>
</tr>
</thead>
<tbody>
<tr>
<td>Location</td>
<td>Middletown, IA</td>
<td>Project No.</td>
<td>45-FM9602WW.00</td>
</tr>
<tr>
<td>Remarks</td>
<td>This is a typical monitoring well above ground construction for IAAAP. AGS=Above Ground Surface, BGS=Below Ground Surface, *=Typical depths for monitoring well construction</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Height of protective casing</th>
<th>AGS* (ft)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>3.0</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Slip cap or J-plug</th>
<th>Height of riser above ground</th>
<th>Fill inside casing with filter pack</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

| Ground Elevation | 0.0                          |

<table>
<thead>
<tr>
<th>I.D./Type of surface casing</th>
<th>BGS* (ft)</th>
</tr>
</thead>
<tbody>
<tr>
<td>4-inch, square, steel casing</td>
<td>Portland cement concrete</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Type of filter pack</th>
<th>Commercially-available size</th>
</tr>
</thead>
</table>

| Depth to top of seal | 32.5      |

<table>
<thead>
<tr>
<th>Type of seal</th>
<th>#100 Buffer sand</th>
</tr>
</thead>
</table>

| Depth of top of filter pack | 37.5      |
| Depth of top of screen       | 39.5   |

<table>
<thead>
<tr>
<th>Type of filter pack</th>
<th>Commercially-available size</th>
</tr>
</thead>
</table>

<table>
<thead>
<tr>
<th>I.D./Type of screen</th>
<th>2-inch continuous slot/PVC wire-wrapped</th>
</tr>
</thead>
</table>

| Screen slot size | 0.01-inch     |

| Depth of bottom of screen | 49.5 |
| Depth of bottom of plugged blank | 50.0 |

| Type of backfill below monitoring well Filter pack | 51.0 |
| Diameter of boring | 8-inch  |
**PROPOSED MONITORING WELL CONSTRUCTION LOG**

<table>
<thead>
<tr>
<th>Project Name</th>
<th>Well No.</th>
<th>Deep Wells</th>
</tr>
</thead>
<tbody>
<tr>
<td>Iowa Army Ammunition Plant</td>
<td>Project No.</td>
<td>45-FM9602WW.30</td>
</tr>
<tr>
<td>Location</td>
<td>Remarks</td>
<td>AGS=Above Ground Surface, BGS=Below Ground Surface, &quot;*=Typical depths for monitoring well construction</td>
</tr>
<tr>
<td>Middletown, IA</td>
<td>This is a typical monitoring well above ground construction for IAAPP.</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Guard posts</th>
<th>Height of protective casing</th>
<th>AGS* (feet)</th>
</tr>
</thead>
<tbody>
<tr>
<td>(4) 2-inch steel, 6-foot long, filled with concrete</td>
<td>3.0</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Slip cap or J-plug</th>
<th>Depth of riser above ground</th>
<th>2.5</th>
</tr>
</thead>
</table>

<table>
<thead>
<tr>
<th>Fill inside casing with filter pack</th>
<th>Ground Elevation</th>
<th>0.0</th>
</tr>
</thead>
</table>

<table>
<thead>
<tr>
<th>1.D./Type of surface casing</th>
<th>BGS* (feet)</th>
</tr>
</thead>
<tbody>
<tr>
<td>4-inch, square, steel casing</td>
<td></td>
</tr>
<tr>
<td>with a lockable steel cap, 6-foot long</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Type of surface seal</th>
<th>Concrete</th>
</tr>
</thead>
</table>

<table>
<thead>
<tr>
<th>Fill inside surface casing with grout</th>
<th>Depth of surface seal inside surface casing</th>
<th>3.0</th>
</tr>
</thead>
</table>

<table>
<thead>
<tr>
<th>1.D./Type of well riser pipe 2-inch schedule 40 threaded PVC</th>
<th>Type of backfill</th>
<th>Cement/bentonite grout</th>
</tr>
</thead>
</table>

<table>
<thead>
<tr>
<th>Type of double casing 6-inch ID PVC</th>
<th>Depth of double casing</th>
<th>60.0</th>
</tr>
</thead>
</table>

<table>
<thead>
<tr>
<th>Depth of top of buffer #100 Buffer sand</th>
<th>Depth of filter pack</th>
<th>67.5</th>
</tr>
</thead>
</table>

<table>
<thead>
<tr>
<th>Depth of top of screen</th>
<th>Type of filter pack</th>
<th>Commerically-available size</th>
</tr>
</thead>
</table>

<table>
<thead>
<tr>
<th>1.D./Type of screen 2-inch continuous sled/PVC wire-wrapped</th>
<th>Screen slot size</th>
<th>0.01-inch</th>
</tr>
</thead>
</table>

<table>
<thead>
<tr>
<th>Depth of bottom of screen</th>
<th>Depth of bottom of plugged blank</th>
<th>80.0</th>
</tr>
</thead>
</table>

<table>
<thead>
<tr>
<th>Type of backfill below monitoring well Filter pack</th>
<th>Depth of bottom of boring</th>
<th>81.0</th>
</tr>
</thead>
</table>

<table>
<thead>
<tr>
<th>Diameter of boring</th>
<th>6-inch</th>
</tr>
</thead>
</table>
Standard Operating Procedure No.4
Hydraulic Conductivity Testing Slug Test Method
4.1 PURPOSE AND SCOPE

This document defines the Standard Operating Procedure (SOP) for measuring hydraulic conductivity in all new monitoring wells at the Iowa Army Ammunition Plant (IAAAP). The wells will be presented in future Field Sampling and Analysis Plan (FSAP) addenda. This procedure is intended to be used together with FSAP and other SOPs. Applicable SOPs are listed below:

- SOP No. - 8 Headspace Analysis
- SOP No. - 9 Water Level Measurement
- SOP No. - 10 Equipment and Personnel Decontamination

4.2 PROCEDURE FOR HYDRAULIC CONDUCTIVITY TESTING

Hydraulic conductivity is to be determined using the slug test method, by measuring the change in water level over time, after a “slug” is instantaneously placed into and/or removed from the monitoring well. Field personnel conducting the tests will be responsible for selecting the test method and gathering the required equipment and materials. At the site, the equipment will be set-up and pre-test checks will be performed. Field personnel will be required to record all measurements and document the test procedure. Results will be plotted and analyzed.

Testing procedures were developed in accordance with ASTM Standard Test Method D4044-91 and USACE Omaha District Geology Scope of Services. Tests may include falling head, rising head, or bail out tests, depending on individual well conditions. Well development data will be used to determine the appropriate test method. If a well is installed in a high hydraulic conductivity formation, a slug will be used. If a well is installed in a low hydraulic conductivity formation, a bailer will be used. In no case will water-added type slug tests be conducted in monitoring wells, even if saturated thicknesses are insufficient for testing. Where a portion of the well screen is above the water table (i.e., in the unsaturated zone), only rising head tests will be conducted.

4.2.1 Equipment List

The following is an equipment list for slug testing:

- Keys to well locks
- Photoinization detector (PID)
- Electronic water level indicator
- Field logbook
- Development data and well construction logs, for each well
- Slug or disposal bailer of known volume
- Pressure transducer
4.2.2 Pre-Test Data Recording

Pre-test data will be collected in accordance with the following procedures:

- The well casing will be approached from upwind with continuous air monitoring using a PID.
- The well cap will be unlocked and removed, and PID readings will be taken in the well.
- Before beginning the slug test, the following information will be recorded in the field logbook:
  1. Monitoring well identification number
  2. Location of the reference point from which water depth measurements are made (top of PVC well casing)
  3. Depth to groundwater and total depth of the well
  4. Date and time of test
  5. Well depth, screen length, well radius, radius of filter pack (from the construction logs)
  6. Aquifer or groundwater zone (stratigraphic profile) being tested (from the construction logs)
  7. Volume of slug or bailer
  8. Type of transducer
  9. Name of personnel conducting test

4.2.3 Testing Procedures

Slug testing will be conducted in accordance with the following procedures.

1. The static water levels in the well and total depth of the well will be determined to the nearest 0.01 foot. Select the test method based on the water column height and development data, as appropriate, and record the selected method in the field logbook.
2. The appropriate pressure transducers will be inserted slowly. The transducer will be set at a maximum depth of 9 feet below the static water level in the well. The water level and the transducer will be allowed to equilibrate in the well for 15 minutes. The data logger will be activated to determine when the water level has equilibrated.

3. The transducer cable will be secured to the well casing with duct tape to ensure that the reference point does not move once the test has started.

4. The pre-run checkout will be done prior to starting the test to ensure that all the cable connections and the initial head reading are correct.

5. Set the measurement time increment on the data logger to suitable increments based on development data. Rapidly recharging wells should use small increments and slowly recharging wells should use larger increments.

6. Slug testing of monitoring wells installed in formations with high hydraulic conductivity (e.g., sand or silty sand) will be completed with a slug of known volume. The slug, secured with nylon rope, will be instantaneously introduced to or removed from the well, taking care to fully submerge or withdraw the slug. It is important to add or remove the volume as quickly as possible because the analysis assumes an “instantaneous” change in volume, in the well.

7. Slug testing of monitoring wells installed in formations with low hydraulic conductivity (e.g., clay or silt) will be completed with a disposable bailer. The bailer will be introduced to the well and allowed to equilibrate. The bailer will be instantaneously removed from the well to start the test. It is important to remove the bailer and volume of water as quickly as possible because the analysis assumes an “instantaneous” change in volume, in the well.

8. With the moment (time) of volume addition or removal assigned time zero, the depth of water will be measured and recorded. The pressure transducer will monitor water level change. Care must be take to ensure that the transducer is submerged throughout the test. Once the test has started, the transducer elevation must not be changed.

9. The test will continue until the water level has stabilized.

10. The slug testing equipment will be removed and decontaminated before the next test, accord to SOP No. 10.

11. The test data will be downloaded from the data logger to a field printer to confirm the successful completion of the test prior to departing the site.

### 4.3 TEST DATA ANALYSIS

Test data will be evaluated using the method of Bouwer and Rice (1976) and Bouwer (1989). The Bouwer and Rice method is applicable to unconfined and confined aquifers, and considers
the effect of partial penetration, radius of the filter pack and the effective radius of influence of the test.

Other methods, such as those provided in ASTM Standard Guide D4043-91, will be used if required by the site hydrogeology.
Standard Operating Procedure No.5
Surface and Seep Water Sampling
5.1 PURPOSE AND SCOPE

This document defines the Standard Operating Procedure (SOP) for collecting surface water samples at the Iowa Army Ammunition Plant (IAAAP). This procedure gives descriptions of equipment, field procedures, and Quality Assurance/Quality Control (QA/QC) procedures necessary to collect surface water samples. These procedures described are sufficiently detailed to allow field personnel to properly collect surface water samples. Field procedures for surface water sampling were developed in accordance with USACE EM 1110 (USACE 1998) and USACE Omaha District Geology Scope of Services, and are detailed in this SOP. The sample locations and frequency of collection will be presented in Field Sampling and Analysis Plan (FSAP) addenda.

This SOP is intended to be used together with FSAP and other appropriate SOPs. Health and safety procedures and equipment that will be required during the investigation are detailed in the Health and Safety Plan (HSP). Applicable SOPs are listed below:

- SOP No. 7 - Sample Identification, Handling, and Documentation
- SOP No. 10 - Equipment and Personnel Decontamination

5.2 SURFACE WATER SAMPLING PROCEDURES

Surface water samples will be collected as grab samples starting at the furthest downstream point and proceeding in an upstream direction. Grab samples characterize a medium at a particular point in space and time. Grab samples are collected by sample container immersion or by using a transfer device, such as a beaker, dipper, or bailer.

Grab water samples are typically collected by filling a container held just beneath the surface of a body of water. If an open bottle is lowered to the bottom and raised to the surface at a uniform rate, and at such a rate as to have the bottle filled when reaching the surface, the resulting sample will roughly approach the collection of what is known as a depth-integrated sample. This approach may be used for grab samples that will be collected or collected and transferred when the depth of water exceeds 1.0 foot. If depth is less than 1.0 foot, the bottle will be held just beneath the surface of the water and filled. Another approach, which may be used for water sampling of any depth, is the use of a bailer that is lowered to just above the bottom of the water column, withdrawn, and used to fill the sample containers. This method probably provides the most representative sample and also prevents preservative loss.

Field water quality parameters of the surface and seep water may be collected if required by future FSAP addenda. Parameters will include: pH, temperature, specific conductance, and turbidity.

5.2.1 Equipment List

The following equipment will be used during surface and seep water sampling:
SOP NO. 5  Surface and Seep Water Sampling

- Laboratory-provided sample containers
- Self-adhesive sample bottle labels
- Teflon, stainless-steel, or glass beakers, dippers, or bailers
- Disposable Teflon bailer or equivalent
- Appropriate health and safety equipment specified in the HSP
- Field Logbook and data sheets (DQCR, Sample Collection Field Sheet, COC)
- Waterproof and permanent marker
- Paper towels
- Clear label and strapping tape
- Plastic bags
- Cooler with ice

5.2.2 Sampling Procedures

Laboratory-provided sample containers will be used to directly collect water samples, if sample containers do not have preservatives. Where required by site conditions, remote sampling into sampling containers will be allowed by clamping the container onto the end of a stainless-steel extension rod.

Beakers or dippers, which may be attached to stainless-steel or aluminum rods, may be used if sampling containers do not have preservatives or remote sampling site conditions prevent sampling by direct sample container immersion. The beakers or dippers will be obtained from a scientific instrument supplier so that the material composition of such a sampling container may be documented in the field notes. The selected type of transfer device, the composition of this device, and the volume of the device will be recorded in the field notes. Bailers may be used if direct access to the sampling point can be reached.

5.2.2.1 Equipment Decontamination

Before any sampling begins, all bailers, beakers, dippers, and other sampling devices shall be decontaminated. Mobile decontamination supplies will be provided so that equipment can be decontaminated in the field. Each piece of sampling equipment shall be decontaminated before sampling operations and between sampling locations. The procedures presented in SOP No. 10, Equipment decontamination, will be followed for decontamination of field equipment and for personnel decontamination.

5.2.2.2 Samples Collected by Container Immersion

Surface water sample collection by container immersion will be done in accordance with the following procedures:

- Samples will be collected from areas that are suspected of being the least contaminated first to minimize the risk of sample cross contamination.
Prior to sampling, the water body characteristics (e.g., size, depth, flow) should be observed and described in the field logbook.

Don a clean pair of gloves.

The outside of all capped sample bottles shall be triple rinsed with the surface water being sampled before filling the bottles with the sample to be analyzed.

Surface debris (i.e., sticks, leaves, vegetation) will be cleared from the sample location prior to sample collection.

Surface and seep water will be collected from an area with low flow and minimal turbulence.

Submerge the sample bottle below the water surface with minimal surface disturbance and with the open end pointed upstream.

Allow container to fill to desired volume.

Remove the container.

Add preservative to the sample, if necessary, and place the cap on the container and tighten.

Identify, handle and document the sample according to SOP No. 7.

Decontaminate the container’s outside surface as required.

Record time of sampling.

Store samples on ice in cooler.

5.2.2.3 Samples Collected by Bailer

Surface water sample collection with a bailer will be done in accordance with the following procedures:

Samples will be collected from areas that are suspected of being the least contaminated first to minimize the risk of sample cross contamination.

Prior to sampling, the water body characteristics (e.g., size, depth, flow) should be observed and described in the field logbook.

A disposable Teflon® bailer or equivalent will be used.

Don a clean pair of gloves.
• Surface debris (i.e., sticks, leaves, vegetation) will be cleared from the sample location prior to sample collection.

• The depth of standing water will be determined, and the bailer will be lowered to the appropriate sampling location in accordance with the sampling plan. The bailer will be lowered no closer than 3 to 6 inches above the bottom sediments.

• The bailer will be inserted and withdrawn very slowly and carefully to avoid agitation of the bottom sediments.

• The required sample containers will be filled in the appropriate sequence from the water in the bailer. VOCs will be collected first, followed by SVOCs. The remaining sample containers will be filled in a parameter-specific order as described in Section 6.2.2.4 of SOP No. 6.

• Identify, handle, and document the samples in accordance with SOP No 7.

• Record time of sampling.

• Store samples on ice in a cooler.

5.2.2.4 Storm Event Sampling

Storm event samples will be collected to determine the amount of contamination in surface runoff and site drainage water following a rain event. Samples will be collected from existing surface water features that receive surface runoff during a storm event. Samples will be collected within the first 30 minutes (or a maximum of 1 hour) after runoff due to rainfall begins. Samples will be collected every hour thereafter for an 8-hour duration. The sample must be collected from a discharge resulting from a storm event that is greater than 0.1 inch in magnitude and that occurs at least 72 hours from the previous storm event of magnitude greater than 0.1 inch. Storm event sampling will be conducted in accordance with the following procedures:

• Prior to sampling, the existing water body will be characterized (e.g., size, depth, flow) and described in the field logbook.

• Don a clean pair of gloves.

• The outside of all capped sample bottles shall be triple rinsed with the surface water being sampled before filling the bottles with the sample to be analyzed.

• Surface debris (i.e., sticks, leaves, vegetation) will be cleared from the sample location prior to sample collection.

• Surface and seep water will be collected from an area with low flow and minimal turbulence.
• Submerge the sample bottle below the water surface with minimal surface disturbance and with the open end pointed upstream.

• Allow container to fill to desired volume.

• Remove the container.

• Add preservative to the sample, if necessary, and place the cap on the container and tighten.

• Identify, handle and document the sample according to SOP No. 7.

• Decontaminate the container’s outside surface as required.

• Record time of sampling.

• Store samples on ice in cooler.

5.2.2.5 Field Quality Assurance/Quality Control Procedures and Samples

QA/QC samples will be collected during surface water sampling. Field QA/QC samples are designed to help identify potential sources of external sample contamination and evaluate potential error introduced by sample collection and handling. All QA/QC samples are labeled with QA/QC identification numbers and sent to the laboratory with the other samples for analyses.

Field Blanks

Field blanks are QC samples that check for potential external contamination of samples and will consist of trip blanks. The sample collection coordinator or the project QA/QC coordinator will designate trip blanks. The samples will be assigned a QA/QC identification number, stored in an iced cooler, and shipped to the laboratory with the other samples.

A trip blank serves as a check on sample contamination originating from the container or sample transport. One trip blank will be sent with each cooler containing water samples for volatile organic analyses.

Duplicate Samples

Duplicate samples are samples collected to assess precision of sampling and analysis. For the surface water sampling, a duplicate sample will be collected at the same time as the initial sample. The initial sample bottles for a particular parameter or set of parameters will be filled first, then the duplicate sample bottles for the same parameter(s), and so on until all necessary sample bottles for both the initial sample and the duplicate sample have been filled. The duplicate surface water sample will be handled in the same manner as the primary sample. The duplicate sample will be assigned a QA/QC identification number, stored in an iced cooler, and
shipped to the laboratory on the day it is collected. Duplicate samples will be collected for all parameters. Duplicate samples will be blind to the laboratory.

**Matrix Spikes and Matrix Spike Duplicates**

Matrix spikes (MS) and matrix spike duplicates (MSD) are used to assess the potential for matrix effects. Samples will be designated for MS/MSD analysis on the chain-of-custody form and on the bottles. It may be necessary to increase the sample volume for samples where this designation is to be made.

**5.2.3 Sample Identification, Handling, and Documentation**

Samples will be identified, handled and documented as described in this SOP and SOP No. 7.

**5.2.4 Documentation**

Each field activity must be documented to facilitate a timely and accurate reconstruction of events in the field (see SOP No. 7). Sample Collection field Sheets will be completed for all surface and seep water samples submitted for chemical analysis (Figure 1).

**5.2.4.1 Sample Collection Field Sheet**

A sample collection field sheet for surface water samples (Figure 1) will be completed at each sampling location. The data sheet will be completely filled in. If items on the sheet do not apply to a specific location, the item will be labeled as not applicable (NA). The information on the data sheet includes the following:

- Sample location number
- Date and time of sampling
- Person performing sampling
- Type of sample
- Number of samples taken
- Sample identification number
- Preservation of samples
- Field water quality parameters (if taken)
- Record of any QC samples from site
- Any irregularities or problems which may have a bearing on sampling quality

**5.2.4.2 Field Notes**

Field notes shall be kept in a bound field logbook using waterproof ink: The following information will be recorded using waterproof ink:

- Names of personnel
- Weather conditions
SOP NO. 5 Surface and Seep Water Sampling

- Sample location number
- Date and time of sampling
- Site conditions
- Decontamination information
- Water depth
- Depth of sample
- Analyses that will be performed by the laboratory
# GROUNDWATER FIELD SAMPLING DATA SHEET

<table>
<thead>
<tr>
<th>Project Name</th>
<th>Project No.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Location</td>
<td>Well No.</td>
</tr>
<tr>
<td>Date/Time Collected</td>
<td>Personnel</td>
</tr>
<tr>
<td>Sampling Method</td>
<td>Sample Media</td>
</tr>
<tr>
<td>Sample QA Split</td>
<td>Split Sample No.</td>
</tr>
<tr>
<td>Sample QC Duplicate</td>
<td>Duplicate Sample No.</td>
</tr>
<tr>
<td>MS/MSD Requested</td>
<td>MS/MSD Sample No.</td>
</tr>
</tbody>
</table>

## SAMPLE CONTAINERS, PRESERVATIVES, ANALYSIS

<table>
<thead>
<tr>
<th>Sample Container</th>
<th>Preservative</th>
<th>Analysis Requested</th>
</tr>
</thead>
<tbody>
<tr>
<td>(1) 500 ml HDPE</td>
<td>NaOH/Zinc Acetate, Cool to 4°C</td>
<td>Sulfide (EPA 376.2)</td>
</tr>
<tr>
<td>(1) 1 L HDPE</td>
<td>H2SO4, Cool to 4°C</td>
<td>TKN, Ammonia (EPA 351.2)</td>
</tr>
<tr>
<td>(1) 1 L HDPE</td>
<td>Cool to 4°C</td>
<td>Alkalinity (EPA 310.1), SO4 (300.0), NO2/NO3 (300)</td>
</tr>
<tr>
<td>(2) 40 ml VOC vials</td>
<td>H3PO4, Cool to 4°C</td>
<td>Total Organic Carbon (EPA 415.1 or EPA 9060)</td>
</tr>
<tr>
<td>(1) 1 L HDPE</td>
<td>HNO3, Cool to 4°C</td>
<td>Metals (601B/6020/7470)</td>
</tr>
<tr>
<td>(2) 1 L Glass Amber</td>
<td>Cool to 4°C</td>
<td>Explosives (8330)</td>
</tr>
</tbody>
</table>

## WELL PURGING DATA

<table>
<thead>
<tr>
<th>Date</th>
<th>Well Depth (ft BTOC)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Time Started</td>
<td>Depth to Water (ft BTOC)</td>
</tr>
<tr>
<td>Time Completed</td>
<td>Water Column Length</td>
</tr>
<tr>
<td>PID Measurements</td>
<td>Volume of Water in Well</td>
</tr>
<tr>
<td>Background</td>
<td>Purge Rate (liters/min)</td>
</tr>
<tr>
<td>Breathing Zone</td>
<td>Level of Drawdown (ft BTOC)</td>
</tr>
<tr>
<td>Well Head</td>
<td>Amount Purged (liters)</td>
</tr>
</tbody>
</table>

## FIELD MEASUREMENTS

<table>
<thead>
<tr>
<th>Time</th>
<th>Amount Purged (liters)</th>
<th>pH (SU)</th>
<th>Temperature (°C)</th>
<th>Conductivity (µS/cm)</th>
<th>ORP (mV)</th>
<th>DO (mg/L)</th>
<th>Turbidity (NTU)</th>
<th>Water Elevation (ft)</th>
<th>Purge Rate</th>
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<tbody>
<tr>
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</tbody>
</table>

## FIELD EQUIPMENT AND CALIBRATION

<table>
<thead>
<tr>
<th>Water Level Probe</th>
<th>Model</th>
<th>Calibration</th>
</tr>
</thead>
<tbody>
<tr>
<td>Slope Indicator</td>
<td></td>
<td>Checked Against Calibrated Length</td>
</tr>
<tr>
<td>Water Quality Meter</td>
<td>YSI Model 556 with FT Cell</td>
<td>Twice Daily Calibration Verification also Calibrated Weekly</td>
</tr>
</tbody>
</table>

## GENERAL COMMENTS

<table>
<thead>
<tr>
<th>Ferrous Iron =</th>
<th>YSI 556 Multi-Parameter Probe Unit #</th>
<th>Field Parameters Measured in Flow Through Cell</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pump Placement Depth =</td>
<td>Well Diameter (in.) =</td>
<td>Screen Interval (ft BTOC) =</td>
</tr>
<tr>
<td>Turbidity of Sample =</td>
<td>Notes:</td>
<td></td>
</tr>
</tbody>
</table>
**WATER SAMPLE COLLECTION LOG**

**GENERAL INFORMATION**

<table>
<thead>
<tr>
<th>PROJ. NAME</th>
<th>PROJECT NO.</th>
</tr>
</thead>
<tbody>
<tr>
<td>SITE NAME</td>
<td>WELL NO.</td>
</tr>
<tr>
<td>DATE/TIME COLLECTED</td>
<td>PERSONNEL</td>
</tr>
<tr>
<td>SAMPLE METHOD</td>
<td></td>
</tr>
</tbody>
</table>

| SAMPLE MEDIA: Groundwater |
| SAMPLE QA SPLIT: | YES | NO |
| SAMPLE QC DUPLICATE: | YES | NO |
| MS/MSD REQUESTED: | YES | NO |

<table>
<thead>
<tr>
<th>Sample Container</th>
<th>Preservative</th>
<th>Analysis Requested</th>
</tr>
</thead>
<tbody>
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</table>

**WELL PURGING DATA**

<table>
<thead>
<tr>
<th>Date</th>
<th>Well Depth (ft. BTOC)</th>
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<table>
<thead>
<tr>
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<th>Depth to Water (ft BTOC)</th>
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</table>

<table>
<thead>
<tr>
<th>Time Completed</th>
<th>Water Column Length</th>
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<tbody>
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<td></td>
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<tr>
<td></td>
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</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>PID Measurements</th>
<th>Volume of Water in Well (liters)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Background</td>
<td>Purge Rate (l;liters/min)</td>
</tr>
<tr>
<td>Breathing Zone</td>
<td>Level of Drawdown (ft. BTOC)</td>
</tr>
<tr>
<td>Well Head</td>
<td>Amount Purged (liters)</td>
</tr>
</tbody>
</table>

**GENERAL COMMENTS**

Ferrous Iron =

YSI 600 XL Multi-Parameter Probe Unit #

Field Parameters Measured =

Pump Placement Depth =

Well Diameter =

Screen Interval =

Turbidity of Sample =
Standard Operating Procedure No.6
Monitoring Well Groundwater Sampling
6.1 PURPOSE AND SCOPE

The purpose of this document is to define the Standard Operating Procedure (SOP) for the collection groundwater samples from monitoring wells at the Iowa Army Ammunition Plant (IAAAP). This procedure gives descriptions of equipment, field procedures, and Quality Assurance/Quality Control (QA/QC) procedures necessary to collect groundwater samples. These procedures described are sufficiently detailed to allow field personnel to properly collect surface water samples. Field procedures for surface water sampling were developed in accordance with USACE EM 1110 (USAGE 1998) and USACE Omaha District Geology Scope of Services, and are detailed in this SOP. The sample locations and frequency of collection will be specified in future Field Sampling and Analysis Plan (FSAP) addenda.

This SOP is intended to be used together with FSAP and other appropriate SOPs. Health and safety procedures and equipment that will be required during the investigation are detailed in the IAAAP Health and Safety Plan (HSP). Applicable SOPs are listed below:

- SOP No. 7 - Sample Identification, Handling, and Documentation
- SOP No. 8 - Headspace Analysis
- SOP No. 9 - Water Level Measurement
- SOP No. 10 - Equipment and Personnel Decontamination

Additionally, purge water will be containerized in accordance with Section 7.0, IDW Transportation and Disposal Plan, of the Work Plan.

6.2 PROCEDURES FOR GROUNDWATER SAMPLING

6.2.1 Equipment List

The following equipment will be used during well purging and sampling:

- Well keys (if required)
- Appropriate health and safety equipment as specified in the HSP
- Water level probe with 0.01-foot intervals
- Assorted tools (ratchet, screwdriver, etc.)
- Grundfos® Redi-Flo 2 pumps or equivalent with check valve
- Well Wizard control box
- Air compressor
- PVC pump pipe, discharge port, and appropriate fittings
- Disposable Teflon bailers or equivalent
- Nylon rope
- Peristaltic pump
• Poly tubing
• Multi-parameter water quality probe with flow-through cell (pH, temperature, specific conductance, dissolved oxygen (DO), oxidation reduction potential (ORP)
• Turbidity meter
• Field test kits for Fe^{2+}, Alkalinity and Sulfide
• Photo ionization detector (PID)
• Aluminum foil
• Calibration fluids
• Plastic squeeze or spray bottle filled with de-ionized water
• Paper towels
• Calculator
• Field logbook and data sheets (DQCR, SCFS, COC)
• Waterproof and permanent marker
• Appropriate containers for holding purged water
• Discharge hose
• Well completion information sheet
• Appropriate decontamination equipment (wash/rinse buckets, brushes, etc.)
• Plastic bags
• Cooler with ice
• Clear label tape and strapping tape
• Self-adhesive sample labels.

Sample bottles with preservatives added will be obtained from the analytical laboratory. Several extra sample bottles will be obtained in case of breakage or other problems.

6.2.2 Sampling Procedure

This section gives the step-by-step procedures for collecting groundwater samples in the field. Observations made during sample collection should be recorded in the field logbook and field data sheet as specified in Section 6.2.4 of this SOP.

6.2.2.1 Equipment Decontamination

Before any purging or sampling begins, all well probes, bailers, and other sampling devices will be decontaminated. Mobile decontamination supplies will be provided so that equipment can be decontaminated in the field. Each piece of non-dedicated purging or sampling equipment will be decontaminated before sampling operations and between each well. The procedures presented in SOP No. 10, Equipment and Personnel Decontamination, will be followed for decontamination of field equipment and for personnel decontamination.

6.2.2.2 Instrument Calibration

Electronic equipment used during sampling includes a multi-parameter water quality probe, data logger, a turbidity meter and a water level measurement probe. Before going into the field, the
sampler will verify that these instruments are operating properly. The multi-parameter probe and turbidity meter require calibration checks prior to use every day and must be recalibrated at the end of each week. Calibration times and readings will be recorded in a field logbook to be kept by the field sampler. Specific instructions for calibrating the instruments are given in the manufacturers’ instruction manuals.

6.2.2.3 Natural Attenuation (NA) Parameters

Purge water will be analyzed in the field for water quality parameters including specific conductance, pH, temperature, turbidity, DO, oxidation-reduction potential, and Fe²⁺, alkalinity and sulfide. In the Fall round of sampling, groundwater samples will also be submitted to an off-site laboratory and analyzed for other geochemical water quality parameters including Alkalinity, Chloride, Nitrate/Nitrite, Phosphate, Sulfate, Sulfide, Carbon Dioxide, Total Organic Carbon, Metals, and Ethane, Ethene, and Methane.

6.2.2.4 Well Purging

The purpose of well purging is to obtain representative, aquifer-quality water from the geologic formation being sampled while minimizing disturbance to the collected samples. Many of the existing wells are equipped with dedicated sampling pumps, which will be used when purging and sampling. Where no dedicated sampling pumps are available, a portable sampling pump, Grundfos® or equivalent will be used. Low-flow purging techniques will be attempted in each well to minimize turbidity. To accomplish this, the wells will be purged at the lowest practical pumping rates. These low pumping rates will cause minimal drawdown, thus inducing laminar flow from the aquifer through the screen and to the pump. This technique does not require purging the entire water column. The goal of low flow purging and sampling is to maintain less than 0.3 foot of drawdown at pumping rates not to exceed 500 ml/mm.

Where recharge is insufficient for this method (i.e., more than 0.3 ft of drawdown occurs during purging), the well will be purged until three to five well volumes have been removed and field parameters have stabilized within ±10 percent between consecutive readings. If the well is evacuated to dryness, the well will be sampled after sufficient recovery has occurred.

The following procedures will be performed at each well:

- The well will be approached from upwind, the well cap unlocked and removed, and the air quality monitored in the casing and breathing zone with a photoionization detector (PID) according to SOP No. 8. Air quality measurements will be recorded in the field logbook.

- The condition of the outer well casing, concrete well pad, and any unusual conditions of the area around the well will be noted in the field logbook.

- The depth of static water level will be measured (to nearest 0.01 foot) according to SOP No. 9. Depth to water will be recorded from a measuring point on the well casing. The measuring point should be identified, and time indicated in the field logbook.
• If low-flow pumping is used, the bottom of the well is not to be measured until all sampling is complete.

• The volume of water to be purged will be calculated in the event that drawdown exceeds 0.3 foot and the low-flow methods are not possible. (See Section 5.4.3 for calculation of volumes.)

• Where no dedicated sampling equipment is installed, a pump will be slowly lowered into the well to minimize the disturbance of the stagnant water column above the screened interval. The pump should be placed at, or slightly above, the midpoint of the screened interval.

• The in-line water quality probe will be attached to the pump discharge line.

• The water level probe will be lowered into the well to determine the drawdown rate.

• The pump will be turned on at the lowest feasible pumping rate. The wells will be purged at pumping rates between 100 and 500 ml/min, not to exceed 500 ml/mm, depending on well condition.

• The depth to groundwater will be monitored during purging. The pump flow rate will be adjusted as required to stabilize the drawdown.

• If drawdown does not exceed 0.3 foot during purging, field parameters of pH, temperature, specific conductance, turbidity, DO, and redox will be monitored to determine when aquifer-quality water is being pumped. Field parameters will be measured at the start of purging and then every 2 to 3 minutes. Field parameters will be monitored using the in-line flow-through cell attached to the pump discharge. Purging will continue until all field parameters have stabilized according to the following:

- pH + 0.2 units
- Temperature + 10%
- Specific conductivity + 10%
- Dissolved Oxygen ± 10%
- Redox + 10%
- Turbidity ± 10% (or clear and free of fines)

Upon stabilization of field parameters, the well will be sampled. Purge water will be containerized as IDW.

• If drawdown does exceed 0.3 ft during purging, three to five volumes of water will be purged and containerized as IDW. Field parameters of pH, temperature, specific conductance, turbidity, DO, and redox will be monitored. Theses measurements will be recorded at a minimum of one set of readings per well casing volume purged to determine whether the water chemistry has stabilized. If the chemistry is not stable, purging will continue,
measuring field parameters after each one-half well volume.

- If the well is pumped dry during purging, it will be assumed that the purpose of removing three to five well volumes of water has been accomplished, that is, removing all stagnant water which had prolonged contact with the well casing or air.

- Once the well has been pumped dry, samples will be collected using a disposable Teflon® bailer, to minimize turbidity of the samples. Before samples are collected a complete set of water quality parameters must be measured from water that has recharged into the well.

- If recovery is very slow, samples may be obtained as soon as a sufficient amount of water recharges into the well.

### 6.2.2.5 Sample Collection

There are three sample collection scenarios that will be used at IAAAP. Each scenario and the appropriate procedures are outlined here within.

#### Air Bladder Pump

The following sampling procedure is to be used when sampling from an air bladder pump (Well Wizard®):

- The pump will be adjusted to its lowest pumping rate for sample collection.
- Identification labels for sample containers will be filled out for each well.
- Any in-line water quality measurement equipment (e.g., flow-through cell) will be disconnected during sample collection.
- Samples for chemical analysis will be collected from the discharge port attached to the pump.
- The individual sample bottles will be filled in the order given below:
  - Metals and Radionuclide
  - VOCs
  - SVOCs, pesticides and PCBs, and herbicides
  - Explosives (Method 8330)
  - Ferrous Iron (Fe2+)
  - All natural attenuation (NA) parameters in the following order:
    1. Total Organic Carbon
    2. Nitrate/Nitrite and Phosphate
    3. Sulfide and Sulfate
    4. Alkalinity and Chloride

- Fill sample containers for metals, semivolatiles, explosives, and NA parameters almost full.

- VOC sample vials should be completely filled so the water forms a convex meniscus at the top, then capped so that no air space exists in the vial. Turn the vial over and tap it to check
for bubbles in the vial, which indicate air space. If air bubbles are observed in the sample vial, repeat the procedure until no air bubbles appear.

- Time of sampling will be recorded.

- Samples will be identified, handled, and documented as described in SOP No. 7.

- The well cap will be replaced and locked.

- Field documentation will be completed, including the chain-of-custody.

**Submersed Pump**

The following sampling procedure is to be used when sampling from a submersed pump (Grundfos® or equivalent):

- The pump will be adjusted to its lowest pumping rate for sample collection.

- Identification labels for sample containers will be filled out for each well.

- Any in-line water quality measurement equipment (e.g., flow-through cell) will be disconnected during sample collection.

- Samples for chemical analysis will be collected from the discharge port attached to the pump.

- The individual sample bottles will be filled in the same order as shown above.

- Fill sample containers for metals, semivolatiles, explosives, and NA parameters almost fill.

- VOC sample vials should be completely filled so the water forms a convex meniscus at the top, then capped so that no air space exists in the vial. Turn the vial over and tap it to check for bubbles in the vial, which indicate air space. If air bubbles are observed in the sample vial, repeat the procedure until no air bubbles appear.

- Time of sampling will be recorded.

- Samples will be identified, handled, and documented as described in SOP No. 7.

- The well cap will be replaced and locked.

- Field documentation will be completed, including the chain-of-custody.
Disposable Bailer

The following sampling procedure is to be used when sampling from a Disposable Bailer (Teflon® or equivalent):

- Identification labels for sample bottles will be filled out for each well.
- A new disposable bailer will be used at each well.
- The protective plastic around the bailer will be removed at the top only, and new nylon rope will be tied to the securing hole.
- Just prior to sample collection the protective plastic will be removed. If VOC samples are required they will be collected from a new bailer filling.
- The bailer will be lowered slowly and gently into contact with the water in the well. The disposable bailer will be lowered to the same depth, which just fills the bailer, in the well each time.
- The bailer will be retrieved smoothly and the water will be slowly drained into the sample containers through the bailer’s bottom discharge control device.
- The individual sample bottles will be filled in the same order as shown above. If VOC samples are required, they will be collected from a new bailer filling.
- Fill sample containers for metals, semivolatiles, explosives, and NA parameters almost fill.
- VOC sample vials should be completely filled so the water forms a convex meniscus at the top, then capped so that no air space exists in the vial. Turn the vial over and tap it to check for bubbles in the vial, which indicate air space. If air bubbles are observed in the sample vial, repeat the procedure until no air bubbles appear.
- Time of sampling will be recorded.
- Samples will be identified, handled, and documented as described in SOP No. 7.
- The well cap will be replaced and locked.
- Field documentation will be completed, including the chain-of-custody.

6.2.2.6 Field Quality Assurance/Quality Control Procedures and Samples

The well sampling order will be dependent on expected levels of contamination in each well, if known, and will be determined prior to sampling. Sampling will progress from the least
SOP NO. 6 Monitoring Well Groundwater Sampling

contaminated well to the most contaminated well. QA/QC samples will be collected during groundwater sampling.

Field QA/QC samples are designed to help identify potential sources of external sample contamination and evaluate potential error introduced by sample collection and handling. All QA/QC samples are labeled with QA/QC identification numbers and sent to the laboratory with the other samples for analyses.

Field Blanks

Field blanks are QC samples that check for potential external contamination of samples and will consist of trip blanks. The sample collection coordinator or the project QA/QC coordinator will designate trip blanks. The trip blanks will be assigned a QA/QC identification number, stored in an iced cooler, and shipped to the laboratory with the other samples.

A trip blank serves as a check on sample contamination originating from the container or sample transport. One trip blank will be sent with each cooler containing water samples for VOC analyses.

Duplicate Samples

Duplicate samples are samples collected to assess precision of sampling and analysis. For the groundwater sampling a duplicate sample will be collected at the same time as the initial sample. The initial sample bottles for a particular parameter or set of parameters will be filled first, then the duplicate sample bottles for the same parameter(s), and so on until all necessary sample bottles for both the initial sample and the duplicate sample have been filled. The duplicate groundwater sample will be handled in the same manner as the primary sample. The duplicate sample will be assigned a QA/QC identification number, stored in an iced cooler, and shipped to the laboratory on the day it is collected. Duplicate samples will be collected for all parameters. Duplicate samples will be blind to the laboratory.

Matrix Spikes and Matrix Spike Duplicates

Matrix spikes (MSs) and matrix spike duplicates (MSDs) are used to assess the potential for matrix effects. Samples will be designated for MS/MSD analysis on the chain-of-custody form and on the bottle. It may be necessary to increase the sample volume for samples where the designation is to be made.

6.2.3 Sample Identification, Handling, and Documentation

Samples will be identified, handled, and recorded as described in this SOP and in SOP No. 7.

6.2.4 Documentation
SOP NO. 6 Monitoring Well Groundwater Sampling

Each field activity must be documented to facilitate a timely and accurate reconstruction of events in the field (see SOP No. 7). Sample Collection field Sheets will be completed for all groundwater samples submitted for chemical analysis (Figure 1).

6.2.4.1 Sample Collection Field Sheet

A sample collection field sheet for groundwater samples (Figure 1) will be completed at each sampling location. The data sheet will be completely filled in. If items on the sheet do not apply to a specific location, the item will be labeled as not applicable (N/A). The information on the data sheet includes the following:

- Site name
- Well number
- Date and time of sampling
- Person performing sampling
- Water level (BTOC)
- Well depth (BTOC)
- Volume of water purged before sampling
- Pump placement depth or sample collection depth (BTOC)
- Specific conductance, temperature, pH, DO, Redox, and turbidity during evacuation (note number of well volumes)
- Number of samples taken
- Sample identification number
- Preservation of samples
- Record of any QC samples from site
- Headspace analysis (if taken)
- Any irregularities or problems which may have a bearing on sampling quality

6.2.4.2 Field Notes

Field notes shall be kept in a bound field logbook. The following information will be recorded using waterproof ink:

- Names of personnel
- Weather conditions
- Location and well number
- Date and time of sampling
- Condition of the well
- Decontamination information
- Initial static water level and total well depth
- Pump placement depth or sample collection depth (BTOC)
- Calculations (e.g., calculation of purged volume)
- Analyses that will be performed by the laboratory
- Equipment calibration information
6.2.5 Well Volume Calculations

The following equation shall be used to calculate the volume of water to be removed during well evacuation:

For 2-inch wells:

Evacuation Volume (gal) =

\[(\text{Total Well Depth (ft)} - \text{Water Level Depth (ft)}) \times 0.16 \text{ gal/ft} = \text{gallons/l well casing volume}\]

For 4-inch wells:

Evacuation Volume (gal) =

\[(\text{Total Well Depth (ft)} - \text{Water Level Depth (ft)}) \times 0.66 \text{ gal/ft} = \text{gallons/l well casing volume}\]

Multiply the volume of one well casing volume by three (3) to obtain the minimum volume of water to be evacuated.
## WATER SAMPLE COLLECTION LOG

### GENERAL INFORMATION

<table>
<thead>
<tr>
<th>PROJ. NAME</th>
<th>PROJECT NO.</th>
</tr>
</thead>
<tbody>
<tr>
<td>SITE NAME</td>
<td>WELL NO.</td>
</tr>
<tr>
<td>DATE/TIME COLLECTED</td>
<td>PERSONNEL</td>
</tr>
<tr>
<td>SAMPLE METHOD</td>
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</table>

<table>
<thead>
<tr>
<th>SAMPLE MEDIA:</th>
<th>Groundwater</th>
<th>SAMPLE QA SPLIT:</th>
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<th>NO</th>
<th>SPLIT SAMPLE NO.</th>
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<tr>
<td>SAMPLE QC DUPLICATE:</td>
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<td>DUPLICATE SAMPLE</td>
<td></td>
<td></td>
</tr>
<tr>
<td>MS/MSD REQUESTED</td>
<td>YES</td>
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<td>MS/MSD SAMPLE NO.</td>
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<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Sample Container</th>
<th>Preservative</th>
<th>Analysis Requested</th>
</tr>
</thead>
</table>

### WELL PURGING DATA

<table>
<thead>
<tr>
<th>Date</th>
<th>Well Depth (ft. BTOC)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Time Started</td>
<td>Depth to Water (ft BTOC)</td>
</tr>
<tr>
<td>Time Completed</td>
<td>Water Column Length</td>
</tr>
<tr>
<td>PID Measurements</td>
<td>Volume of Water in Well (liters)</td>
</tr>
<tr>
<td>Background</td>
<td>Purge Rate (l;iters/min)</td>
</tr>
<tr>
<td>Breathing Zone</td>
<td>Level of Drawdown (ft. BTOC)</td>
</tr>
<tr>
<td>Well Head</td>
<td>Amount Purged (liters)</td>
</tr>
</tbody>
</table>

### GENERAL COMMENTS

Ferrous Iron =
YS1 600 XL Multi-Parameter Probe Unit #
Field Parameters Measured =
Pump Placement Depth =
Well Diameter =
Screen Interval =
Turbidity of Sample =
Standard Operating Procedure No. 7
Sample Identification, Handling, and Documentation
SOP NO. 7  Sample Identification, Handling, and Documentation

7.1 PURPOSE AND SCOPE

This document defines the Standard Operating Procedure (SOP) for sample handling, documentation, and tracking at the Iowa Army Ammunition Plant (IAAAP). This procedure is intended to be used together with Field Sampling and Analysis Plan (FSAP) and other SOPs. Applicable SOPs are listed below:

- SOP No. 1 - Surface Soil Sampling
- SOP No. 2 - Subsurface Drilling and Soil Sampling
- SOP No. 5 - Surface and Seep Water Sampling
- SOP No. 6 - Monitoring Well Groundwater Sampling

7.2 SAMPLE IDENTIFICATION

Samples collected during site activities will have discrete sample identification numbers. These numbers are necessary to identify and track each of the many samples collected for analysis during the life of this project. In addition, the sample identification numbers will be used in the database to identify and retrieve the analytical results received from the laboratory.

Each sample is identified by a unique code that indicates the site number, sample location number, sample method and matrix identifier, and sample depth. The sample locations will be the boring or well number. Sample matrix identifiers include the following:

- SS — Surface Soil
- SB - Subsurface Soil
- GW - Groundwater Sample (from a monitoring well)
- SW - Surface Water
- SP - Seep Water
- RN - Rinsate
- TB-Trip Blank

An example of the sample identification code for a subsurface soil sample collected from Boring 101 at Line 800 from a depth of 5 feet will be: 800-B101-SB-05

Where 800 indicates the Site Number (Line 800), B101 indicates the Boring Number, SB indicates the sampling method and sample matrix, and 05 indicates the sample depth.
SOP NO. 7 Sample Identification, Handling, and Documentation

Groundwater samples will be identified by the monitoring well number only (i.e., JAW-604, G-27, 800-MW-26). If well designations are duplicated throughout the facility, a site name and date will be added to the identification number to delineate the samples.

MS/MSD samples will be given the same sample ID as the analytical sample, but will have “MS/MSD” written on the label. Duplicate samples will be blind samples to the laboratory and will be given a unique sample ID.

The sampling locations, sample type, and sample sequence identifiers will be established prior to field activities for each sample to be collected. On-site personnel will obtain assistance in defining any special sampling requirements from the Project Manager.

7.3 SAMPLE LABELING

Sample labels will be filled out as completely as possible by a designated member of the sampling team prior to beginning field sampling activities each day. All sample labels will be filled out using waterproof ink. At a minimum, each label will contain the following information:

- Sampler’s company affiliation
- Site location
- Sample identification code (i.e., 800-B101-SB-OS)
- Date and time of sample collection
- Analyses required
- Method of preservation (if any) used
- Sample matrix (i.e., soil, groundwater, surface water)
- Sampler’s signature or initials

An example of a completed sample label is shown in Figure 1.

7.4 SAMPLE HANDLING

This section discusses proper sample containers, preservatives, and handling and shipping procedures. The FSAP summarizes the information contained in this section and the QAPP includes the sample holding times for each analyte.

7.4.1 Sample Containers

Certified, commercially clean sample containers will be obtained from the contract analytical lab. The contract laboratory will label the bottles to indicate the type of sample to be collected. Required preservatives will be prepared and placed in the bottles at the laboratory prior to shipment to the site. Appropriate sample containers for the specific analyses required will be listed in future FSAP addenda.
7.4.2 Sample Preservation

Sample preservation efforts will commence at the time of sample collection and will continue until analyses are performed. Samples will be stored on ice at 4°C in an insulated cooler immediately following collection. The ice will be double bagged in plastic storage bags. Additional sample preservation requirements will be given in future ESAP addenda.

7.4.3 Sample Handling and Shipping

The sample containers will be wiped clean of all sample residue and then wrapped in protective packing material (bubble wrap) and taped. Samples will then be placed right side up in a cooler with ice (double bagged using plastic bags). Additional protective packing material will be used around the upright samples as necessary. A chain-of-custody (COC) form will accompany each cooler. The COC will be put in a plastic bag and will be attached to the inside lid of the cooler. The cooler lid will be taped closed with a custody seal for delivery to the laboratory. Samples will be hand delivered or shipped by overnight express carrier for delivery to the analytical laboratory. All samples must be shipped for laboratory receipt and analyses within specific holding times. This may require daily shipment of samples with short holding times. The temperature of all coolers will be measured upon receipt at the laboratory.

7.4.4 Holding Times and Analyses

The holding time is specified as the maximum allowable time between sample collection and analysis and/or extraction, based on the analyte of interest and stability factors, and preservative (if any) used. Allowable holding times will be presented in Section 4, Quality Assurance Project Plan (QAPP). Chemical constituents that will be analyzed and other parameters to be measured during field investigations at IAAAP will be identified in FSAP addenda.

7.5 SAMPLE DOCUMENTATION

This section describes documentation required in the field notes, on the Sample Collection Field Sheets (SCFS), on the Daily Quality Control Reports (DQCR), and on the sample COC forms.

7.5.1 Field Notes

Documentation of observations and data acquired in the field will provide information on the acquisition of samples and also provide a permanent record of field activities. The observations and data will be recorded using pens with permanent waterproof ink in a permanently bound weatherproof field logbook containing consecutively numbered pages.

The information in the field logbook will include the following as a minimum. Additional information is included in the FSAP.

- Project name
- Location of sample
SOP NO. 7 Sample Identification, Handling, and Documentation

- Sampler’s printed name and signature
- Date and time of sample collection
- Sample identification code
- Description of samples (matrix sampled)
- Sample depth (if applicable)
- Number and volume of samples
- Sampling methods or reference to the appropriate SOP
- Sample handling, including filtration and preservation, as appropriate for separate sample aliquots
- Analytes of interest
- Field observations
- Results of any field measurements, such as depth to water, pH, temperature, specific conductance, turbidity, DO, and redox
- Personnel present
- Level of personal protective equipment used during sampling

Changes or deletions in the field logbook should be lined out with a single strike mark, initialed, and remain legible. Sufficient information should be recorded to allow the sampling event to be reconstructed without relying on the sampler’s memory.

Each page in the field books will be signed by the person making the entry at the end of the day, as well as on the bottom of each page. Anyone making entries in another person’s field book will sign and date those entries.

7.5.1.1 Sample Collection Field Sheet

A SCFS for soil, surface water, and groundwater samples (Figures 2A, 2B, and 2C) will be completed at each sampling location. The data sheet will be completely filled in. If items on the sheet do not apply to a specific location, the item will be labeled as not applicable (N/A). The information on the data sheet includes the following:

- Sample location number
- Date and time of sampling
- Person performing sampling
- Type of sample
- Number of samples taken
- Sample identification number
- Preservation of samples
- Record of any QC samples from site
- Any irregularities or problems which may have a bearing on sampling quality
SOP NO. 7  Sample Identification, Handling, and Documentation

7.5.2 Daily Quality Control Report

Each sampling crew will also maintain DQCRs to supplement the information recorded in the field logbook. A blank DQCR is shown on Figure 3. DQCRs will be maintained by members of the field sampling team and cross-checked for completeness at the end of each day by the sampling team members and/or Field Manager. They will be signed and dated by individuals making entries and initials by the reviewer upon completion. Copies of the DQCR will be forwarded to the Quality Assurance Officer for review. The DQCR will include the following information:

- Project name
- Project Number
- Personnel on site
- Visitor on site
- Subcontractors on site
- Equipment on site
- Weather conditions
- Field work performed
- QC and health and safety activities
- Problem, down time, and standby time

7.5.3 Sample Chain-Of-Custody

During field sampling activities, traceability of the sample must be maintained from the time that the samples are collected until laboratory data are issued. Initial information concerning collection of the samples will be recorded in the field logbook as described above. Information on the custody, transfer, handling, and shipping of samples will be recorded on a COC form. An example COC form is shown on Figure 4. The COC is a paginated three-part carbonless form.

The sampler will be responsible for initiating and filling out the COC form. The sampler will sign the COC when the sampler relinquishes the samples to anyone else. One COC form will be completed for each cooler of samples collected daily. The COC will contain the following information:

- Sampler’s signature and affiliation
- Project number
- Date and time of collection
- Sample identification number
- Sample type
- Analyses requested
- Number of containers
- Signature of persons relinquishing custody, dates, and times
- Signature of persons accepting custody, dates, and times
- Method of shipment
- Shipping air bill number (if appropriate)
The person responsible for delivery of the samples to the laboratory will sign the COC form, retain the last copy of the three-part COC form, document the method of shipment, and send the original and the second copy of the COC form with the samples. Upon receipt at the laboratory, the person receiving the samples will sign the COC form and return the second copy to the Project Manager. Copies of the COC forms documenting custody changes and all custody documentation will be received and kept in the central files. The original COC forms will remain with the samples until final disposition of the samples by the laboratory. The analytical laboratory will dispose of the samples in an appropriate manner 60 to 90 days after data reporting. After sample disposal, a copy of the original COC will be sent to the Project Manager by the analytical laboratory to be incorporated into the central files.

7.6 PHOTOGRAPHIC DOCUMENTATION

Photographs will be taken during sampling events to properly document field activities. Photos will be taken of all field activities including: drilling, well installation, well development, slug testing, sample collection, decontamination procedures, and site/well conditions. The description of the photos and the order they were taken in will be recorded in the field logbook or in a photo log. The exposed film will be numbered and recorded. A camera pass is required at the IAAAP facility. Photographs of the production facilities are strictly prohibited. See SOP No. 12, Permits and Clearances for the appropriate procedures.
Figure 1

SAMPLE LABEL

<table>
<thead>
<tr>
<th>Tetra Tech, Inc.</th>
</tr>
</thead>
<tbody>
<tr>
<td>800 Oak Ridge Turnpike</td>
</tr>
<tr>
<td>Suite A-500</td>
</tr>
<tr>
<td>Oak Ridge, TN 37830</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Project:</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sample ID:</td>
</tr>
<tr>
<td>Analysis:</td>
</tr>
<tr>
<td>Preservative:</td>
</tr>
<tr>
<td>Samplers:</td>
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</table>
### FIGURE 2A
**SOIL SAMPLE COLLECTION FIELD SHEET**

<table>
<thead>
<tr>
<th>SITE NAME</th>
<th>PROJECT NO.</th>
</tr>
</thead>
<tbody>
<tr>
<td>SAMPLE NO.</td>
<td>WELL NO.</td>
</tr>
<tr>
<td>DATE/TIME COLLECTED</td>
<td>PERSONNEL</td>
</tr>
</tbody>
</table>

**SAMPLE METHOD AND DEPTH**

<table>
<thead>
<tr>
<th>SAMPLE MEDIA (Circle 1):</th>
<th>Soil</th>
<th>Sediment</th>
<th>Sludge</th>
<th>MS/MSD</th>
</tr>
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<tbody>
<tr>
<td>SAMPLE SPLIT (Circle 1):</td>
<td>Yes</td>
<td>No</td>
<td>SPLIT SAMPLE NUMBER</td>
<td></td>
</tr>
<tr>
<td>FIELD DUPLICATE (Circle 1):</td>
<td>Yes</td>
<td>No</td>
<td>DUPLICATE SAMPLE NUMBER</td>
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</table>

<table>
<thead>
<tr>
<th>Sample Container</th>
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<th>Analysis Requested</th>
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<tbody>
<tr>
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**DESCRIPTION:**

**DEPTH:**

**DESCRIPTION:**

__________________________

Comments
## WATER SAMPLE COLLECTION LOG

### GENERAL INFORMATION

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<thead>
<tr>
<th>PROJ. NAME</th>
<th>PROJECT NO.</th>
</tr>
</thead>
<tbody>
<tr>
<td>SITE NAME</td>
<td>WELL NO.</td>
</tr>
<tr>
<td>DATE/TIME COLLECTED</td>
<td>PERSONNEL</td>
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<td>SAMPLE METHOD</td>
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<table>
<thead>
<tr>
<th>SAMPLE MEDIA:</th>
<th>Groundwater</th>
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<tbody>
<tr>
<td>SAMPLE QA SPLIT:</td>
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<tr>
<td>SAMPLE QC DUPLICATE:</td>
<td>YES</td>
</tr>
<tr>
<td>MS/MSD REQUESTED</td>
<td>YES</td>
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</table>

### SAMPLE CONTAINERS, PRESERVATIVES, ANALYSIS

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<th>Sample Container</th>
<th>Preservative</th>
<th>Analysis Requested</th>
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</table>

### WELL PURGING DATA

<table>
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<tr>
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<th>Well Depth (ft. BTOC)</th>
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<table>
<thead>
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<th>Depth to Water (ft BTOC)</th>
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<tr>
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</table>

<table>
<thead>
<tr>
<th>PID Measurements</th>
<th>Volume of Water in Well (liters)</th>
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</thead>
<tbody>
<tr>
<td>Background</td>
<td>Purge Rate (liters/min)</td>
</tr>
<tr>
<td>Breathing Zone</td>
<td>Level of Drawdown (ft. BTOC)</td>
</tr>
<tr>
<td>Well Head</td>
<td>Amount Purged (liters)</td>
</tr>
</tbody>
</table>

### GENERAL COMMENTS

Ferrous Iron =

YSI 600 XL Multi-Parameter Probe Unit #

Field Parameters Measured =

Pump Placement Depth =

Well Diameter =

Screen Interval =

Turbidity of Sample =
# Daily Quality Control Report

<table>
<thead>
<tr>
<th>Subcontractors on Site:</th>
<th></th>
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</thead>
<tbody>
<tr>
<td>Equipment on Site:</td>
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<tr>
<td>Visitors on Site:</td>
<td></td>
</tr>
<tr>
<td>Tetra Tech Personnel on Site:</td>
<td></td>
</tr>
<tr>
<td>Field Work Performed (including sampling):</td>
<td></td>
</tr>
<tr>
<td>Quality Control Activities (including field calibration):</td>
<td></td>
</tr>
<tr>
<td>Health and Safety and Activities:</td>
<td></td>
</tr>
<tr>
<td>Observations/Problems Encountered/Corrective Action Taken:</td>
<td></td>
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</tbody>
</table>

<table>
<thead>
<tr>
<th>Office Work Performed:</th>
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</table>

---

**Figure 3**

<table>
<thead>
<tr>
<th>Date</th>
<th>Day</th>
<th>On-Site Hours</th>
<th>Travel Time</th>
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<table>
<thead>
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<tr>
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<td>32-50</td>
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<td>Contract No.</td>
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<td>Still</td>
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**Figure 4**

**Chain of Custody Record**

<table>
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<th>Project Name</th>
<th>Project No.</th>
<th>Analytical Parameters</th>
<th>Remarks</th>
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</table>

<table>
<thead>
<tr>
<th>Sampler(s)</th>
<th>Sample Identification</th>
<th>Matrix</th>
<th>Containers</th>
</tr>
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<tbody>
<tr>
<td></td>
<td></td>
<td></td>
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<table>
<thead>
<tr>
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<th>Time</th>
<th>Comp.</th>
<th>Grab</th>
<th>Sample Identification</th>
<th>Matrix</th>
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<th>Type</th>
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</table>

<table>
<thead>
<tr>
<th>Signatures</th>
<th>Date</th>
<th>Time</th>
<th>Shipping Details</th>
<th>Special Instructions</th>
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<tbody>
<tr>
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</tbody>
</table>

Relinquished by:  

Received by:  

Airbill No.  

Relinquished by:  

Lab Address  

Received for Laboratory by:  

COC.xls  

White copy - Laboratory  

Yellow copy - Laboratory  

Pink copy - URS
Standard Operating Procedure No.8
Headspace Analysis
8.1 PURPOSE AND SCOPE

This document defines the Standard Operating Procedure (SOP) for performing headspace analysis of soil and water samples in the field at the Iowa Army Ammunition Plant and gives the description of equipment and procedures for field screening of soil and water samples. These procedures described are sufficiently detailed to allow field personnel to properly collect and perform headspace analysis. Field procedures for headspace analysis were developed in accordance with USACE Omaha District Geology Scope of Services, and are detailed in this SOP. Sample locations and frequency of collection will be presented in future Field Sampling and Analysis Plan (FSAP) addenda.

Applicable SOPs are listed below:

- SOP No. 1 - Surface Soil Sampling
- SOP No. 2 - Subsurface Drilling, Soil Sampling, and Logging
- SOP No. 5 - Surface and Seep Water Sampling
- SOP No. 6 - Monitoring Well Groundwater Sampling

8.2 HEADSPACE ANALYSIS

8.2.1 Equipment List

The following equipment is required for headspace analysis:

- Clean glass sample containers
- Paper towels
- Aluminum foil
- Photoionization detector (PID)
- Field logbook
- Waterproof and permanent marking pens
- Daily Quality Control Report (DQCR) form

8.2.2 Field Screening Procedures

A portion of selected soil samples and selected water sample collected will be placed in the appropriate clean glass sample container for headspace analysis. The container should be filled approximately one-half full. The mouth of the container will be covered with aluminum foil, tightly capped, and the sample matrix will be allowed to equilibrate with the headspace for 30 minutes. Care must be taken in the selection of soils with respect to consistency and sample placement in the container in order to achieve comparability and consistency. The disposition of the sample in the container will be recorded in the field logbook.
The sample headspace in the container shall be analyzed with a PID by removing the lid and inserting the instrument probe through the foil liner. Care must be taken in the selection of appropriate foil, placement of the foil on the container, and removal of the lid so as not to compromise the integrity of the seal. If the seal has been compromised, this will be recorded appropriately or a new sample taken if possible.

8.2.3 Organic Vapor Analyzer Selection

The selection of the appropriate organic vapor analyzer (OVA) shall be based on contaminants of concern and/or ambient conditions at the respective site. The lamp selected for the OVA, where applicable, will be based on the relative ionization potentials of the expected volatile contaminants. The selected instrument will be recorded on the DQCR and in the field logbook. It is anticipated that a PD detector will be used for most or all of the work at IAAAP.

8.2.4 Calibration

The instrument(s) selected for use in accordance with data quality objectives and site requirements shall be calibrated according to the manufacturer’s recommendations and specifications. These procedures will be attached to this SOP where applicable.

8.2.5 Documentation

All procedures, field conditions, and results will be recorded on the DQCR, sample collection field sheet (SCFS), and in the field logbook. The record will include a description of the material being screened as well as site conditions such as humidity and the equilibration time and temperature.
Standard Operating Procedure No.9
Water Level Measurement
9.1 PURPOSE AND SCOPE

This document defines the Standard Operating Procedure (SOP) for measuring water levels in wells at the Iowa Army Ammunition Plant (IAAAP). These procedures described are sufficiently detailed to allow field personnel to properly measure water levels. Field procedures for measuring water levels were developed in accordance with USACE Omaha District Geology Scope of Services, and are detailed in this SOP. The well locations and frequency of measurement will be presented in Field Sampling and Analysis Plan (FSAP) addendum. This procedure is intended to be used together with the FSAP and other SOPs. Applicable SOPs are listed below:

- SOP No. 2 - Subsurface Drilling, Soil Sampling, and Logging
- SOP No. 3 - Monitoring Well Installation and Development
- SOP No. 4 - Hydraulic Conductivity Testing (Slug Test Method)
- SOP No. 6 - Monitoring Well Groundwater Sampling
- SOP No. 10 - Equipment and Personnel Decontamination

9.2 WATER LEVEL MEASUREMENT PROCEDURE

9.2.1 Equipment List

The equipment necessary to measure water levels includes:

- Water level probe with 0.01-foot increments
- Photoionization detector (PID)
- Two 5-gal buckets (with lids) or equivalent for decontamination
- Decontamination brushes
- Alconox soap
- De-ionized or distilled water
- Potable water
- Spray bottle
- Field data sheets
- Field logbook
- Appropriate health and safety equipment

9.2.2 Measurement Procedure

Appropriate health and safety equipment, as described in the Health and Safety Plan (HSP) will be used during well opening, water level measurement, and decontamination. The following procedures will be completed when measuring water levels:
• The water level probe will be decontaminated prior to use in each monitoring well. Decontamination procedures are discussed in SOP No. 10.

• The well will be approached from upwind, the well cap unlocked and removed, and the air quality monitored in the casing and breathing zone with a PID according to SOP No. 8. Air quality measurements will be recorded in the field logbook.

• Observations regarding the condition of the well, including the well pad, and surface or protective casing, will be documented in the field logbook.

• The static water level and the total well depth will be measured using an electronic water level meter. The total depth of the well will not be measured prior to groundwater sampling using low-flow purge techniques. The measuring point for all the wells will be the top of PVC or steel monitoring well casing. For standardization of measurements, all well readings will be referenced to the north rim of the monitoring well riser pipe or to a marked reference point on the casing rim.

• The appropriate measurement will be made with the probe, recorded on in the field logbook, and then immediately rechecked before the probe is removed from the well.

• Information including the depths measured, time and date of measurement, and any unusual problems encountered will be documented in the field logbook. If measurements are taken over a several-day period, the date of each measurement will be clearly indicated in the logbook. Section 9.2.4 of this SOP describes the required documentation.

• Care will be taken to verify the readings during each water level measurement period. Any significant changes in water level will be noted by comparing the most recent measurement with past measurements.

• After any measurement is taken, the water level probe will be decontaminated as described in Section 9.2.3 of this SOP.

• During water level rounds, if dedicated sampling equipment is restricting the water level probe from reaching the water surface in the well, an alternate well will be measured. In no case will any of the dedicated sampling equipment, below the water level be removed. This will disturb the water in the well, which may cause problems when sampling the well using low-flow techniques.

9.2.3 Decontamination

The water level indicator must be decontaminated before use, between wells, and at the conclusion of measurements. The probe will be decontaminated according to the procedure for decontamination of sampling equipment described in SOP No. 10. Probe decontamination will be completed at the wells. Wash and rinse water will be handled as specified by the Field Manager.
9.2.4 Documentation

Documentation will be completed in the field logbook, during each measuring event. The logbook will include date, time, well number, total well depth, water level, static water elevation, decontamination procedures, calibration procedures, monitoring procedures, and other observations during water level measurement. The logbook will be filled out using legible handwriting, and will be signed and dated by the person completing the page.

The measured depth to water will be compared in the field to historic water levels (where available) to make sure the measured water level is reasonable. Large variations or discrepancies will be noted and the water level checked again to verify accuracy.

9.3 CALIBRATION

The length of the water level measurement probe cord will be calibrated at least once per month or more often as needed to ensure the desired accuracy during water level measuring events. The calibration check consists of laying out 100 feet of steel tape next to 100 feet of the probe cord. Note any measurement discrepancies between the two at 1-foot intervals. The probe cord will be rechecked if there is a possibility that it was stretched or damaged during water level measurements.

The procedures followed during calibration and verification of equipment will be documented in the field logbook along with any calculations. If a correction is required, the probe will be tagged to indicate the correction.
Standard Operating Procedure No. 10
Equipment and Personnel Decontamination
10.1 PURPOSE AND SCOPE

This document defines the Standard Operating Procedure (SOP) for decontamination at the Iowa Army Ammunition Plant (IAAAP). These procedures described are sufficiently detailed to allow field personnel to properly decontaminate equipment and personnel. Field procedures for decontamination were developed in accordance with USACE Omaha District Chemistry Scope of Services and USACE Omaha District Geology Scope of Services, and are detailed in this SOP. This procedure is intended to be used together with Field Sampling and Analysis Plan (FSAP) and the other SOPs. Applicable SOPs are listed below:

- No. 1 Surface Soil Sampling
- No. 2 Subsurface Drilling, Soil Sampling, and Logging
- No. 3 Monitoring Well Installation and Development
- No. 5 Surface and Seep Water Sampling
- No. 6 Monitoring Well Groundwater Sampling
- No. 9 Water Level Measurement

Site and/or Sample Cross-Contamination

The overall objective of multimedia sampling programs is to obtain samples that accurately depict the chemical, physical, and/or biological conditions at the sampling site. Extraneous contaminants can be brought onto the sampling location and/or introduced into the medium of interest during the sampling program (e.g. using sampling equipment that is not properly or fully decontaminated). Trace quantities of contaminants can consequently be captured in a sample and lead to false positive analytical results and, ultimately, to an incorrect assessment of the contaminant conditions associated with the site. Decontamination of sampling equipment (e.g., all non-disposable equipment that will come in direct contact with samples) and field support equipment (e.g., drill rigs, vehicles) is, therefore, required prior to, between, and after uses at IAAAP to ensure that sampling cross-contamination is prevented, and that on-site contaminants are not carried off-site.

10.2 EQUIPMENT DECONTAMINATION PROCEDURES

10.2.1 Equipment List

The following is a list of equipment that may be needed to perform decontamination:

- Brushes
- Wash tubs
- Buckets
10.2.2 Decontamination

10.22.1 Personnel

Decontamination consists of removing contaminated clothing and washing the skin to remove contaminants. How extensive the decontamination process must be depends primarily on the types of contaminants and the nature of on-site activities planned. As the toxicity of the contaminants and the magnitude of potential contamination of personnel is increased, the decontamination process becomes increasingly more extensive and thorough.

A temporary personnel decontamination line will be set up around each exclusion zone. If contamination is not encountered, a dry decontamination station may be established which consists of discarding of disposable personal protective equipment (PPE).

If real-time monitoring instruments indicate that contamination has been encountered, (i.e., action levels are exceeded requiring an upgrade from initial PPE levels), a complete personnel decontamination station will be established.

The temporary decontamination line should provide space to wash and rinse boots, gloves, and all sampling or measuring equipment prior to placing the equipment into a vehicle. A container should be available to dispose of used disposable items such as gloves, tape, or Tyvek (if used).

The decontamination procedure for field personnel will include:

1. Glove and boot wash in an Alconox solution
2. Glove and boot rinse
3. Duct tape removal
4. Outer glove removal
5. Coverall removal
6. Respirator removal (if used)
7. Inner glove removal
10.2.2.2 Responsible Authority

Decontamination operations at each hazardous waste site shall be supervised by the Site Safety and Health Officer (SSHO). The SSHO is responsible for ensuring that all personnel follow decontamination procedures and that all contaminated equipment is adequately decontaminated. The SSHO is also responsible for maintaining the decontamination zone and managing the wastes generated from the decontamination process.

Site activities should be conducted with the general goal of preventing the contamination of people and equipment. Using remote sampling techniques, bagging monitoring instruments, avoiding contact with obvious contamination, and employing dust suppression methods that would reduce the probability of becoming contaminated and, therefore, reduce the need and extent of decontamination. However, some type of decontamination will always be required on site. A sample personnel decontamination set-up guideline and a sample decontamination equipment and supplies list are included in Section 6, Health and Safety Plan (HSP).

OSHA requires that proper PPE must be worn when operating steam or pressure washing equipment. A rainsuit, boots, hard hat, and a face shield are recommended to be worn. All personnel must be kept out of the path of steam or water spray.

10.2.2.3 Sampling Equipment

The following steps will be used to decontaminate sampling equipment:

- Personnel will dress in suitable safety equipment to reduce personal exposure as required by the HSP.
- Gross contamination on equipment will be scraped off at the sampling or construction site.
- Equipment that cannot be damaged by water will be placed in a wash tub containing Alconox or low-sudsing non-phosphate detergent along with potable water and scrubbed with a bristle brush or similar utensil. Equipment will be rinsed with tap water in a second wash tub followed by a deionized water rinse.
- Equipment that may be damaged by water will be carefully wiped clean using a sponge and detergent water and rinsed with deionized water. Care will be taken to prevent equipment damage.

Following decontamination, equipment will be placed in a clean area or on clean plastic sheeting to prevent contact with contaminated soil. If the equipment is not used immediately after decontamination, the equipment will be covered or wrapped in plastic sheeting, foil, or heavy-duty trash bags to minimize potential contact with contaminants.
10.2.2.4 Drilling and Heavy Equipment

Drilling rigs and excavating equipment will be decontaminated at the decontamination station located near the staging area. Mobile decontamination trailers may be used to decontaminate heavy equipment at each site. The following steps will be used to decontaminate drilling and heavy equipment:

- Personnel will dress in suitable PPE to reduce personal exposure as required by the HSP.
- Equipment showing gross contamination or having caked-on drill cuttings will be scraped with a flat-bladed scraper at the sampling or construction site.
- Equipment that cannot be damaged by water, such as drill rigs, augers, drill bits, and shovels, will be washed with a hot water, high-pressure sprayer then rinsed with potable water. Care will be taken to adequately clean the insides of the hollow-stem augers.

Following decontamination, drilling equipment will be placed on the clean drill rig and moved to a clean area. If the equipment is not used immediately, it should be stored in a designated clean area.

10.2.2.5 Equipment Leaving the Site

Vehicles used for activities in non-contaminated areas will be cleaned on an as-needed basis using soap and water on the outside and vacuuming the inside. On-site cleaning will be required for very dirty vehicles leaving the area. Construction equipment such as trucks, drilling rigs, trailers, etc., will be pressure washed before the equipment is removed from the site to limit exposure of off-site personnel to potential contaminants.

10.2.2.6 Decontamination solutions

A decontamination solution should be capable of removing, or converting to a harmless substance, the contaminant of concern without harming the object being decontaminated. The preferred solution is a mixture of detergent and water, which is a relatively safe option compared to chemical decontaminants. A solution recommended for decontaminating boot covers and gloves consists of 1 to 1.5 tablespoons of Alconox per gallon of warm water. Skin surfaces should be decontaminated by washing with hand soap and water. The decontamination solution must be changed when it no longer foams or when it becomes extremely dirty. Rinse water must be changed when it becomes discolored, begins to foam, or when the decontamination solution cannot be removed.

10.2.2.7 Wastewater

Liquid wastewater from decontamination will be containerized as IDW, and stored for later disposal as described in Section 7, IDW Transportation and Disposal Plan.
10.2.3 Emergency Decontamination

Hazardous waste facilities should also have in place emergency decontamination procedures, in order to prevent the loss of life or severe injury to site personnel. In the case of threat to life, decontamination should be delayed until the victim is stabilized; however, decontamination should always be performed first, when practical, if it can be done without interfering with essential lifesaving techniques or first aid, or if a worker has been contaminated with an extremely toxic or corrosive material that could cause severe injury or loss of life. During an emergency, provisions must also be made for protecting medical personnel and disposing of contaminated clothing or equipment.

10.2.4 Documentation

Sampling personnel will be responsible for documenting the decontamination of sampling and drilling equipment. The documentation will be recorded with waterproof ink in the sampler’s field logbook with consecutively numbered pages. The information entered in the field logbook concerning decontamination should include the following:

- Date and start and end times
- Decontamination observations
- Weather conditions
- IDW handling
Standard Operating Procedure No. 11
Boring Abandonment
11.1 PURPOSE AND SCOPE

This document defines the Standard Operating Procedure (SOP) for abandoning borings at the Iowa Army Ammunition Plant (IAAAP) and gives descriptions of equipment and field procedures necessary to abandon borings. These procedures described are sufficiently detailed to allow field personnel to properly abandon a boring. Field procedures for boring abandonment were developed in accordance with USACE Omaha District Geology Scope of Services, and are detailed in this SOP. Applicable SOPs are listed below:

Applicable SOPs are listed below:

- SOP No. 1 - Surface Soil Sampling
- SOP No. 2 - Subsurface Drilling, Soil Sampling, and Logging

11.2 BORING ABANDONMENT PROCEDURES

11.2.1 Equipment List

The following is an equipment list for boring abandonment:

- Portland cement (type I or II) and powdered bentonite for grouting
- Bentonite chips
- Potable water
- Drill rig or portable grout station
- Logbook
- Boring log sheets
- Waterproof and permanent marking pens
- Tremie pipe
- Appropriate health and safety equipment

11.2.2 Abandonment Procedures

Following completion of the borings each boring must be abandoned and plugged to provide a low-permeability zone that would retard movement of water through the boring backfill.

Where water was not encountered and the boring sidewalls are stable the boring may be backfilled using hydrated bentonite chips. The dry bentonite chips are poured into the boring from the ground surface filling the boring in 1-foot lifts. Hydration of the bentonite chips with 1 gallon of water is necessary for each lift of bentonite chips.

Where water was encountered in the boring and where the boring sidewalls are unstable the boring must be backfilled with a fluid cement/bentonite grout pumped into the boring. The grout will consist of a mixture that is blended to produce a thick, lump-free, cement/bentonite grout. The grout will be prepared in an above-ground rigid container by mixing the bentonite powder
with potable water. Mix the grout until free of any clumps of powdered material. Pump the grout mixture into the base of the boring using drill rods or tremie pipe placed through the center of the augers. Initially place the drill rods or tremie pipe 3 feet above the bottom of the boring. Pump grout into the boring maintaining a positive head of grout within the central core of the augers at all times. Pull the augers and the tremie pipe or drill rods incrementally until the boring is grouted to the ground surface. After the grout has set for 24 hours check the boring for settlement. Add grout as required to refill the boring.

11.2.3 Pavement Repair

Where borings penetrate surface pavements, walkways or sidewalks, it will be necessary to patch the pavement surface following backfilling. Concrete pavements should be filled with 3,000 psi concrete mix. Asphaltic concrete pavements should be filled with asphaltic concrete patch mix and thoroughly compacted by ramming. The surface of any patch should be leveled upon completion. In freezing weather the concrete mix must be protected with tarps or blankets to keep from freezing for 48 hours after placement.

11.2.4 Documentation

Observations and data acquired in the field during boring abandonment will be recorded to provide a permanent record. These observations will be recorded with waterproof black ink in a bound weatherproof field logbook with consecutively numbered pages.

A boring log/diagram will be completed for each boring with observations and procedures recorded in the field logbook. A description of the well abandonment procedures, including drilling and the placement of well abandonment material, will be included in the field logbook. A description of drilling equipment and quality control procedures will be documented. A note will be placed on the boring log that the boring was abandoned and backfilled with hydrated bentonite chips or grouted with a cement/bentonite mixture to the ground surface or the pavement subgrade. The type of material used to patch the pavement surface will also be noted on the boring log and the field logbook.
Standard Operating Procedure No. 12
Permits and Clearances
12.1 PURPOSE AND SCOPE

This document defines the Standard Operating Procedure (SOP) for obtaining permits and clearances at the Iowa Army Ammunition Plant (IAAAP). Permits and clearances are required for plant security, and for underground utility clearance (drilling, hand augering, excavating, etc.).

12.2 GENERAL REQUIREMENTS

URS and its subcontractors will adhere to the IAAAP security regulations while working at the facility. The Project Manager will inform each employee and subcontractor of the security requirements and ensure that the regulations are strictly maintained. The Project Manager will submit a list of the URS and subcontractor personnel anticipated to work on-site.

12.2.1 Citizenship

Personnel working in restricted security areas will be U.S. citizens. Proof of U.S. Citizenship will be shown before entering any restricted security area. If required, URS will obtain and submit fingerprints of URS and subcontractor personnel working on-site.

12.2.2 Identification Badges

All URS and subcontractor field personnel will obtain construction identification badges with photographs from American Ordnance (AO) Security in coordination with the Plant Protection Division. The identification badge will be displayed while working at the facility. The Project Field Manager will ensure the badges are returned to the AO Security upon completion of the work. Badges will be valid from date of issue through 31 December 2004. They will be exchanged at that time if work is to continue.

URS personnel and subcontractors will display their identification badges to gain access to the facility general area and those limited areas specifically authorized on the face of the badge. URS understands that any employee possessing a badge is bound by the Security Regulations of the Plant. The Plant Protection Division and/or AO Security may deny issuance or revoke any badge from an individual not complying with these rules.

12.2.3 Law Check

The Project Manager will ensure that each employee and all subcontractor personnel on-site have a law check performed and will request subcontractors to have law checks performed for its field staff. The Project Manager will send the form to the employee’s local law enforcement agency to determine whether the employee has a police record. If any employee has a police record, it will be forwarded to the Plant’s security officials for review. Upon review, the security officials may deny issuance of a badge for that employee.
12.2.4 Facility Access

Vehicle “Visitor” placards will not be issued. The construction badges will designate areas of access for the individuals and their vehicles. Vehicles must be visibly identified by a company name (i.e., URS). All vehicles will be subject to search when exiting through access gates of the general plant areas.

URS personnel and subcontractors will access the facility area through Vehicle Gates Number 4 and 5. Material delivered via commercial trucks will enter the facility through Gate No. 3 during the hours of 0700 to 1730 on Monday through Thursday. Special arrangements can be made to accommodate off-time deliveries. The plant gates and their primary uses and operating times are outlined in the following list:

- Gate 1 is a specially designated construction gate used only in the event of facility labor dispute. If a labor dispute occurs, all URS employees and subcontractor personnel must use Gate No. 1 to access the facility (currently, this gate is not utilized).

- Gate 2, the east gate, is currently not utilized.

- Gate 3, the commercial gate, is open Monday through Thursday from 7:00 a.m. to 5:30 p.m.

- Gate 4, the main gate, is open 24 hours daily.

- Gate 5, the south gate, is open Monday through Thursday from 5:45 a.m. to 7:45 a.m. and from 3:45 p.m. to 6:00 p.m.

12.2.5 Camera Pass

URS or subcontractor personnel will obtain a camera pass from AO Security prior to entering IAAAP with a camera. Photographs taken within the installation will include only project sites and operations. No photographs will be taken of production facilities.

12.2.6 Permits and Licenses

URS will comply with the IAAAP requirements of an IAAAP Safety Work Permit. An IAAAP Safety Work Permit will be issued by the IAAAP (AO) Safety Manager after the site safety initiation briefing. If hot work is anticipated, this permit can be modified to include it.

12.3 UTILITY CLEARANCES

Digging permits will be obtained for all subsurface drilling activities prior to initiating the work. URS will notify the facility of on-site subsurface work one week in advance. Digging permits will be obtained through the appropriate U.S. Army representative. When any intrusive work is being performed in the vicinity of utility and/or communication cables/lines, Civil Engineering and/or Communication monitoring personnel, as required, will be present. No work shall start if
the required monitoring personnel are not present. No mechanical digging shall be performed within 5 feet on each side of utilities and/or communication line(s) until they are physically exposed by hand digging. If a utility and/or communication line is damaged, the designated representative of the U.S. Army shall be notified immediately for further directions.

An underground utility search will be conducted for all off-site investigations, borings, and monitoring well locations. The underground utility search will be coordinated with the State/County.

12.4 OTHER PERMITS AND LICENSES

All field personnel, including subcontractors will be OSHA 40-hour trained. One member from the field team will have the 8-hour site supervisor training. One member of each field sampling team will have First Aid and CPR training. All drilling will be done by a State of Iowa Licensed Driller. All surveying will be done by a State of Iowa Licensed Land Surveyor.
Standard Operating Procedure No. 13
Direct-Push Well Installation, Sampling, and Injection
13.1 PURPOSE AND SCOPE

The purpose of this document is to define the Standard Operating Procedure (SOP) for direct-push soil sampling, groundwater sampling and injection well installation and injection at the Iowa Army Ammunition Plant (IAAAP). These procedures give descriptions of equipment, field procedures, and documentation procedures implemented for the collection of direct-push soil and groundwater samples. The procedures described here are sufficiently detailed to allow field personnel to properly collect soil and groundwater samples, as well as install injection wells using direct-push technology. Field procedures were developed in accordance with IAC 567 Chapter 49 (IDNR 1998), USACE EM 1110 (USACE 1998) and USACE Omaha District Geology Scope of Services, and are detailed in this SOP. Specific soil and groundwater sampling location will be presented in future Field Sampling and Analysis Plan (FSAP) addenda.

These procedures are intended to be used together with FSAP and other appropriate SOPs. Health and safety procedures and equipment for the investigation are detailed in the IAAAP Health and Safety Plan (HSP). Applicable SOPs are listed below:

- No. 2 Subsurface Drilling, Soil Sampling, and Logging
- No. 7 Sample Identification, Handling, and Documentation
- No. 8 Headspace Analysis
- No. 10 Equipment and Personnel Decontamination
- No. 11 Boring Abandonment
- No. 12 Permits and Clearances

Reference Standards


General Approach

A multi-phase injection and monitoring approach is planned to be utilized to address groundwater concerns at the IAAAP. A treatability test and subsequent applications will be used to gather the required data necessary to design and implement an in situ-based remedial action for target compounds in groundwater at the IAAAP. It is recognized that the design, guidance, and procedures used for future in situ bioremediation activities can change as new data and
information are collected. As such, the procedures presented herein may be modified based on the most recent data and information.

The planned phases of an in situ bioremediation effort, whether they are for a treatability study, pilot test, or full scale application, are likely to be comprised of the following activities, unless modified by additional information.

**Phase 1**

**Step 1A** – Install injection and/or monitoring network in the treatment and monitoring area. In some locations, existing wells may be used for injection and/or monitoring purposes. In these cases, injection and/or monitoring wells may not need to be installed.

**Step 1B** – Sample monitoring network in treatment area, including existing and/or newly installed wells to establish baseline (pre-injection) aquifer conditions.

**Step 1C** – Inject selected amendment into target zone of aquifer into the selected injection well(s) for the purpose of stimulating anaerobic biodegradation of target compounds.

**Step 1D** – Monitor REDOX potentials periodically (typically biweekly unless another frequency is determined to be appropriate) in monitoring points and injection points to determine aquifer REDOX values and effects of injectate.

**Step 1E** – Decision Point: If REDOX potentials are greater than -50 mV after 4 weeks of monitoring (this value and duration may change as additional data is collected), inject the same amendment as in Step 1C. Vary the injection scheme (number of injection points, distance from monitoring well, injectate concentration) as needed based on REDOX monitoring results to lower REDOX over as much of the treatability area as possible. Continue to monitor REDOX on a biweekly basis for 4 weeks (depending on additional data).

If REDOX potentials are less than -50 mV, collect groundwater analytical samples and monitored natural attenuation (MNA) parameters to monitor degradation of target compounds.

**Phase 2**

**Phase 2A** – Decision Point: If groundwater analytical results from Step 1E do not demonstrate a 25% or greater reduction in target compound concentrations as compared with pre-injection results, evaluate whether reinjection of the same amendment augmented with a slower release carbon source would be beneficial. Also consider reinjection of same fast release carbon source as initially used (perhaps with closer injection spacing or higher injectate concentration), particularly if redox is near -50 mV and target compound concentration reduction is near, but less than 25%. If groundwater analytical data from Step 1E demonstrates greater than 25% reduction in target compound concentrations, evaluate reinjection based on trends in REDOX. If REDOX appears to have stabilized, reinject same carbon source as used in Step 1E to drive aquifer to more reducing state. Vary number of injection points, distance from monitoring well, and injectate concentration, as needed, based on REDOX monitoring results. If REDOX appears
to be steadily declining, continue to monitor its progress and resample when REDOX is at its lowest.

Phase 2B – Repeat Steps 1C, 1D, and 1E.

13.2 PROCEDURES FOR DIRECT-PUSH WELL INSTALLATION

Monitoring well installation will be accomplished by using a direct-push well installation technology by the six main tasks listed below. These procedures will be accomplished according to the general procedures outlined in the Geoprobe® Standard Operating Procedure Technical Bulletin No. 992500. These tasks are:

- Driving the probe rods to the required depth;
- Deploying the screen and riser pipe;
- Installing a sand/grout barrier;
- Installing a bentonite seal above the screen (if required);
- Grouting the well annulus (if required); and
- Installing surface protection (if required).

After the proper depth has been reached, a 1-inch diameter, schedule 40 PVC screen and riser pipe will be properly assembled, inserted into the borehole, and installed. Well construction diagrams will be completed. After installation, measuring points on the direct-push wells will be surveyed to a common datum.

Each direct-push well will be developed by purging. Development will be continued until the water is clear or at least five well volumes are removed.

13.3 PROCEDURES FOR DIRECT-PUSH SAMPLING

Direct-push sampling will be used to collect continuous or discrete soil samples and discrete groundwater samples. Direct push will also be used to install small diameter wells to be used for injection and groundwater sampling. Direct-push technology involves the use of probing tools that are advanced using a combination of static weight of the carrier vehicle and hydraulic hammer percussion. Continuous soil samples will be collected with a Dual Tube Soil Sampler. Discrete soil samples will be collected with a Macro-Core® Sampler (closed-piston system) or equivalent.

Discrete groundwater samples will be collected with a Screen Point Sampler or equivalent. Sample collection methods will be determined by site specific geological conditions. If other sampling equipment and techniques are used, an SOP of the specific methods to be used will be obtained from the subcontractor and inserted as attachments to this SOP.

13.3.1 Equipment List

The following equipment will be needed to complete direct-push soil and groundwater sampling:
13.3.2 Decontamination

Before drilling or sampling begins, the drilling and sampling equipment will be decontaminated according to the procedures contained in SOP No. 10. Drilling and sampling equipment will be decontaminated between boring and sampling locations. Sampling equipment will also be decontaminated between collection of samples from different depths at the same location.

13.3.3 Direct-Push Soil Sampling Procedures

The following procedures apply once the direct-push boring has been advanced to the appropriate depth. The methods and equipment used to advance the rods will be determined based on-site conditions.

13.3.3.1 Collecting Soil Analytical Samples

Analytical soil samples will be collected using continuous sampling methods or a piston-type sampler. Volatile organic compound (VOC) soil samples will be collected once the sampler is opened. Once VOC samples have been collected, the remaining soil will be composited. If required, semi-volatile organic compound (SVOC) samples will be collected first from the composited soil, with any remaining parameters collected after that. Other sample containers for analytical parameters will be specified in future FSAP addenda.
Once the soil sampler has been retrieved:

- Don a clean pair of nitrile gloves.

- Collect any required VOC sample. This should be done immediately upon opening the sampler.

- Scan the length of the sample with the PID and record the readings, measure the recovery, and scrape off any soil smear zone from the recovered sample with a stainless-steel knife. If the soil is not cohesive or if the smear zone cannot be easily removed, an attempt will be made to remove soil from the portion of the sample that has not come in contact with the sampler.

- Composite the remaining soil by thoroughly mixing the soil from the split spoon sampler in a clean stainless-steel bowl with a stainless-steel spoon. Once the soil has been composit ed, fill the appropriate containers for SVOCs. The remaining bottles will then be filled with the composit ed soil for any remaining parameters. The required analyses and appropriate volume of containers of soil will be presented in the future FSAP addenda.

- Complete the description of the recovered sample according to the Unified Soil Classification System.

- Label, store, transport, and document the samples (depending on the use of the sample) according to SOP No. 7.

- If no other samples will be collected, the boring will be abandoned using hydrated bentonite pellets or a cement/bentonite mixture according to SOP No. 11.

13.3.3.2 Collecting Geotechnical Soil Samples

Soil samples for geotechnical analysis will be collected using a split spoon, dual wall, or piston sampler equipped with brass or plastic liners. The liners will be labeled using the sample numbering scheme used for sample identification listed in SOP No. 7.

- Don a clean pair of nitrile gloves.

- Remove the liner from the sampler.

- Cut the liner into the desired lengths and seal the ends with endcaps. Secure the end caps with electrical tape and label accordingly.

- If no other samples will be collected, the boring will be abandoned using hydrated bentonite pellets or a cement/bentonite mixture according to SOP No. 11.
13.3.4 Direct-Push Groundwater Sampling Procedures

Once the borehole has been advanced to the desired sampling depth, the rods will be retracted to separate the disposable drive point from the drive rods, which will allow groundwater to enter the drive rods.

Once sufficient water has entered the rods:

- Don a clean pair of nitrile gloves.
- Lower the mini-bailer into the rods and fill the appropriate containers for VOC analysis.
- Collect all remaining parameters using a peristaltic pump. Prior to sampling using the peristaltic pump, at least one tubing volume should be purged.
- Label, store, transport, and document the samples (depending on the use of the sample) according to SOP No. 7.
- If no other samples will be collected, the boring will be abandoned using hydrated bentonite pellets or a cement/bentonite mixture according to SOP No. 11.

13.3.4.1 Groundwater Sample Filtration

Groundwater samples collected using direct-push sampling methods will be filtered at the laboratory. Filtration will be done only for metals, using a filter with an approximate 20- to 30-micron pore size. The samples will be preserved immediately after filtration.

13.3.5 Small Diameter Injection Well Installation

Small diameter injection wells will be installed using the soil borings created by the direct-push equipment. The wells will be installed in accordance with SOP No. 3, and will be 1-inch diameter wells constructed of schedule 40 PVC. The screen will be a 0.01 inch slotted PVC or continuous wire wrapped screen. The screen length will be determined in the field based on the hydrogeologic and geologic conditions encountered during soil boring. These wells will be used for adding amendments to the soil to encourage biodegradation of contaminants in the vicinity of the wells. These wells will also be used for groundwater sampling as described in SOP No. 6.

13.3.6 Field Quality Assurance Quality Control Procedures and Samples

Field quality assurance/quality control (QA/QC) samples are designed to help identify potential sources of external sample contamination and evaluate potential error introduced by sample collection and handling. All QA/QC samples are labeled with QA/QC identification numbers and sent to the laboratory with the other samples for analyses.
13.3.6.1 Field Blanks

Field blanks are QC samples that check for potential external contamination of samples. No field blanks will be collected for soil samples. For groundwater samples, however, trip blanks will accompany all VOC samples. The sample collection coordinator or the project QA/QC coordinator will designate trip blanks. The trip blanks will be assigned a QA/QC identification number, stored in an iced cooler, and shipped to the laboratory with the other samples.

A trip blank serves as a check on sample contamination originating from the container or sample transport. One trip blank will be sent with each cooler containing water samples for volatile organic analyses.

13.3.6.2 Duplicate Samples

Duplicate samples are samples collected to assess precision of sampling and analysis. For the direct-push soil and groundwater sampling, duplicate samples will be collected at the same time as the initial samples. The initial sample bottles for a particular parameter or set of parameters will be filled first, then the duplicate sample bottles for the same parameter(s), and so on until all necessary sample bottles for both the initial sample and the duplicate sample have been filled. The duplicate samples will be handled in the same manner as the primary samples. The duplicate samples will be assigned a QA/QC identification number, stored in an iced cooler, and shipped to the laboratory on the day they are collected. Duplicate samples will be collected for all parameters. For soil samples, following collection of VOC samples, the remaining soil in the sampler will be composited and containerized for nonvolatile analyses. Duplicate samples are sent blind to the laboratory.

13.3.6.3 Matrix Spikes and Matrix Spike Duplicates

Matrix spikes (MS) and matrix spike duplicates (MSD) are used to assess the potential for matrix effects. Samples will be designated for MS/MSD analysis on the chain-of-custody form and on the bottles. It may be necessary to increase the sample volume for samples where this designation is to be made.

13.3.7 Sample Identification and Handling

Samples will be identified, handled and recorded as described in this SOP and SOP No. 7. The parameters for analysis and preservation will be presented in future FSAP addenda.

13.3.8 Documentation

Each field activity must be properly documented to facilitate a timely and accurate reconstruction of events in the field (see SOP No. 7). Sample Collection Field Sheets will be completed for all analytical samples submitted for chemical analysis (Figures 1 and 2).
13.3.9 Field Logbook

The most important aspect of documentation is thorough, organized and accurate record keeping. All information pertinent to the investigation and not documented on the boring log will be recorded in a bound logbook with consecutively numbered pages. All entries in logbooks will be made in waterproof ink and corrections will consist of line-out deletions that are initialed and dated. Entries in the logbook will include the following, as applicable:

- Project name and number
- Sampler’s name
- Date and time of sample collection
- Sample number, location, and depth
- Sampling method
- Observations at the sampling site
- Unusual conditions
- Information concerning drilling/direct-push decisions
- Decontamination observations
- Weather conditions
- Names and addresses of field contacts
- Names and responsibilities of field crew members
- Names and titles of any site visitors
- Location, description, and log of photographs (if taken)
- References for all maps and photographs
- Information concerning sampling changes, scheduling modifications, and change orders
- Summary of daily tasks (including costs) and documentation on any cost or scope of work changes required by field conditions
- Signature and date by personnel responsible for observations

Field investigation situations vary widely. No general rules can include each type of information that must be entered in a logbook for a particular site. A site-specific logging procedure will be developed to include sufficient information so that the sampling activity can be reconstructed without relying on the memory of field personnel. The logbooks will be kept in the field team member’s possession or in a secure place during the investigation. Following the investigation, the logbooks will become a part of the final project file.

13.3.10 Boring Logs

Boring logs will be completed for each boring by qualified personnel (geologist, geological engineer, or geotechnical engineer). The boring log form is shown on Figure 3.

Boring logs will include the following information:

- Boring location
- Boring identification
13.4 PROCEDURES FOR INJECTION FOR DIRECT-PUSH POINTS

An injection pump designed for the placement of the selected amendments will be used to place the amendments into the subsurface at the selected depths at the well locations. The pump will be gravity-fed from an amendment reservoir. The pre-set pressure relief value will be set to deliver no more than the top end of the pressure range identified in the Work Plan. The amendments will be injected using a pressure activated injection probe (or equivalent) with the lateral injection ports set at the specific depths identified in the Work Plan. After injection activities the pump, injection probe, and tubing will be cleaned in accordance with the specified procedure provided by the pump manufacturer to remove materials out of the pump, probe, and injection tubing.

Specific injection procedures are:

1) Prior to handling material to be injected, familiarize yourself with all safety and health risks associated with the specific compound, including, but not limited to the safe dilution percentages and the handling procedures. Wear appropriate Personal Protective Equipment (PPE). If you are not familiar with the safety and health risks, do not handle any compound.

2) Using a Direct-Push Rig, advance injection tooling to the bottom of the desired injection zone.

3) Once target depth has been reached, install injection cap, attach exterior rod grip handle, and connect injection hose to the injection tooling.

4) Prepare the amendment in the delivery system to insure a steady and consistent injection flow.

5) Activate injection pump and begin the injection process. Simultaneously retract the injection tooling as needed. Adjust the retraction rate of the injection tooling to match the flow rate of
the pump. This is to ensure even vertical distribution of the amendment into the desired injection zone or zones.

6) Once the desired amount of injection amendment has been injected, shut down the pump, and continue to retract the injection tooling.

7) Once the injection tooling has been removed from the borehole, backfill the boring with appropriate backfilling material, and patch the surface to match existing surface material.
### FIGURE 2
WATER SAMPLE COLLECTION FIELD SHEET

<table>
<thead>
<tr>
<th>General Information</th>
<th></th>
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</tr>
</thead>
<tbody>
<tr>
<td>PROJ. NAME</td>
<td>PROJECT NO.</td>
<td></td>
</tr>
<tr>
<td>SITE NAME</td>
<td>WELL NO.</td>
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</tr>
<tr>
<td>DATE/TIME COLLECTED</td>
<td>PERSONNEL</td>
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</tr>
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<td>SAMPLE METHOD</td>
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</tr>
<tr>
<td>SAMPLE MEDIA:</td>
<td>Groundwater</td>
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<tr>
<td>SAMPLE QA SPLIT:</td>
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<td>SAMPLE QC DUPLICATE:</td>
<td>YES</td>
<td>NO</td>
</tr>
<tr>
<td>MS/MSD REQUESTED</td>
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<tr>
<th>Sample Containers, Preservatives, Analysis</th>
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<td>Preservative</td>
<td>Analysis Requested</td>
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</tr>
<tr>
<td>Time Completed</td>
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<td>Breathing Zone</td>
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<td>Well Head</td>
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<tr>
<td>Well Depth (ft. BTOC)</td>
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<tr>
<td>Depth to Water (ft BTOC)</td>
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</tr>
<tr>
<td>Water Column Length</td>
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</tr>
<tr>
<td>Volume of Water In Well (liters)</td>
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</tr>
<tr>
<td>Purge Rate (liters/min)</td>
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<tr>
<td>Level of Drawdown (ft. BTOC)</td>
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<td>Amount Purged (liters)</td>
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<td>Turbidity</td>
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<td>Water Level</td>
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<td>Water Quality Meter</td>
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<td>YSI 600 XL, Multi-Parameter Probe Unit #</td>
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<td>Field Parameters Measured</td>
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<td>Pump Placement Depth</td>
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<td>Turbidity of Sample</td>
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# HTRW DRILLING LOG

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<td>1. COMPANY NAME</td>
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</tr>
<tr>
<td>2. DRILLING SUBCONTRACTOR</td>
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</tr>
<tr>
<td>3. PROJECT</td>
<td>4. LOCATION</td>
</tr>
<tr>
<td>5. NAME OF DRILLER</td>
<td>6. MANUFACTURER'S DESIGNATION OF DRILL</td>
</tr>
<tr>
<td>7. SIZES AND TYPES OF DRILLING AND SAMPLING EQUIPMENT</td>
<td>8. HOLE LOCATION</td>
</tr>
<tr>
<td>9. SURFACE ELEVATION</td>
<td>10. DATE STARTED</td>
</tr>
<tr>
<td>11. DATE</td>
<td>12. OVERBURDEN THICKNESS</td>
</tr>
<tr>
<td>13. DEPTH DRILLED INTO ROCK</td>
<td>14. TOTAL DEPTH OF HOLE</td>
</tr>
<tr>
<td>15. DEPTH GROUNDWATER ENCOUNTERED</td>
<td>16. DEPTH TO WATER AND ELAPSED TIME AFTER DRILLING</td>
</tr>
<tr>
<td>17. OTHER WATER LEVEL MEASUREMENTS (SPECIFY)</td>
<td>18. GEOTECHNICAL SAMPLES</td>
</tr>
<tr>
<td>19. TOTAL NUMBER OF CORE BOXES</td>
<td>20. SAMPLES FOR CHEMICAL ANALYSIS</td>
</tr>
<tr>
<td>21. TOTAL CORE RECOVERY %</td>
<td>22. DISPOSITION OF HOLE</td>
</tr>
<tr>
<td>23. SIGNATURE OF INSPECTOR</td>
<td>LOCATION SKETCH/COMMENTS</td>
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</tbody>
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## SCALE:

---

ENG FORM 5056-R, AUG 94

(P)roponent: CECW-EG
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<th>ELEV</th>
<th>DESCRIPTION OF MATERIALS</th>
<th>FIELD SCREENING RESULTS</th>
<th>GEOTECH SAMPLE NO.</th>
<th>ANALYTICAL SAMPLE NO.</th>
<th>BLOW COUNTS</th>
<th>REMARKS</th>
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RESPONSE TO USAEC COMMENTS
<table>
<thead>
<tr>
<th>Comment No.</th>
<th>Page/Reference</th>
<th>Comment</th>
<th>Response</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Table 2-1, IW-05 Sample ID W05-PT-123.</td>
<td>The date of this sample is 5/23/2005. In the text in section 2-5 on page 2-5, 3rd Paragraph, it discusses the date of sample collection as 5/25/2005.</td>
<td>The date in the text was corrected to reflect the sample date.</td>
</tr>
<tr>
<td>2</td>
<td>Table 2-1, IW-01</td>
<td>The sample data from sampling events c. 5/23/05 and 6/6/05 are not included in the table. Without this information page 2-3, Section 2-4, 4th paragraph and page 2-4, section 2-5, 4th paragraph do not make sense.</td>
<td>The two listed dates for IW-01, Table 2-1 are the first two columns in the table, based on our file copy.</td>
</tr>
<tr>
<td>3</td>
<td>Table 2-1, MW-303</td>
<td>The table lists the baseline value (12/22/04) as 0.52U for TNX. The text, page 2-4, section 2.5, 3rd paragraph conveys it as 0.52J. (Data qualifiers are different)</td>
<td>The data qualifier was corrected to be consistent.</td>
</tr>
</tbody>
</table>
RESPONSE TO USEPA COMMENTS
## Comment Response Matrix

**Draft Treatability Study for In Situ Biodegradation of RDX in Off-Site Groundwater  August 2004**

**Commenter:** EPA Region VII  
**Comments dated:** September 22, 2004

<table>
<thead>
<tr>
<th>Comment No.</th>
<th>Page/Reference</th>
<th>Comment</th>
<th>Response</th>
</tr>
</thead>
</table>
| 1           |                | The Plan should identify the data that will be needed to design the remedial action, consistent with the Off-Post Groundwater Feasibility Study (FS), Proposed Plan, and upcoming Record of Decision. Further, the Plan should insure that this data is collected to the maximum extent possible as part of this Study so that the Remedial Design and ultimately the Remedial Action can be completed in a timely manner. | Data needed for designing a full-scale remedy for the Off-Post Groundwater plume that has not already been collected consists of:  
- Electron Donor Dosage, Frequency, and Cycles (how much, how frequently, and how many times must an electron donor be injected to achieve the objectives outlined in the PP and ROD?)  
- Effective Bioremediation Treatment Radius, Injection Pressure and Injectate Volume – this will determine the minimum spacing of injection points  
- Injection Method – Expendable vs. Reusable points  
- Selection of an Effective Electron Donor – Balance Short Term vs. Long Term Aquifer Needs  

All of these data needs will be fulfilled through data collection as part of the pilot test/field treatability study. |
| 2           |                | The Plan contains little detail and is lacking sufficient decision/evaluation criteria for EPA to determine with much certainty how the Pilot Test will be conducted. Without this information, we are uncertain whether a crew will be able to reliably implement the Plan in the field. Details, including Standard Operating Practices (SOPs), should be incorporated or referenced to insure that the work is performed as intended. In general, rationale supporting the proposed activities is lacking in many instances, as outlined in the Specific Comments.  

The following brief outline could be used in revising the Plan to describe how you intend to conduct the study, and to address a number of EPA’s comments: | Additional detail will be added to the plan to define the specific steps, thought process, evaluation methods, decision points, and performance criteria by which the treatability study will be measured. A step by step approach similar to the one outlined in the comment will be used to facilitate field implementation.  

Additional questions concerning the selection of a treatment area, number of injection points, injection methodology, monitoring network, monitoring scheme, and decision points are summarized below and discussed in more detail in the revised Treatability Study Test Plan |

**Treatability Study Test Area**
## Comment Response Matrix

**Draft Treatability Study for In Situ Biodegradation of RDX in Off-Site Groundwater**  
**August 2004**

**Commenter:** EPA Region VII  
**Comments dated:** September 22, 2004

<table>
<thead>
<tr>
<th>Comment No.</th>
<th>Page/Reference</th>
<th>Comment</th>
<th>Response</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>• Step 1 - Establish test area. Update plume extent based on most recent data sets.</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>• Step 2 - Install monitoring points; How? What depth? Are you planning to install “injection points”, or use a geoprobe?</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>• Step 3 - Inject substrate: Why use sugar in the concentration prescribed? What about “amendments”? What locations? What depth? How much? Injection rate/pressure?</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>• Step 4 - Monitor; For what? When? How? Why (How will the data be used)?</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>• Step 5 - Decision Point; Inject more substrate? Why? Where? When?</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>• Step 6 - Reinject substrate; What? Where? When? How?</td>
<td></td>
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<td></td>
<td></td>
<td>• Step 7 - Back to Step 4.</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>• The test area was chosen based on a review of the available groundwater monitoring data from the off-post area. The available data set contained groundwater monitoring results through 2002 and provided the basis for the FS, PP, and ROD for this area. Since the issuance of the draft treatability test plan, groundwater monitoring data from 2003 and 2004 has become available. Based on a review and comparison of the 2003 and 2004 data with respect to the 2002 data, the choice for a treatability study test area remains unchanged. The treatability study will be conducted in the vicinity of MW-117. This area was selected to optimize treatment in the portion of the off-post plume containing consistently elevated RDX concentrations. The area around MW-309 provides a secondary candidate for the treatability study, but is substantially more difficult to implement from a logistic perspective. It is on the shoulder of US Highway 61 (a very busy highway) and flanked to the north by a fairly steep embankment. Access to areas surrounding MW-309 would be problematic and potentially cause Tetra Tech to space injection and monitoring points too far apart to observe meaningful RDX and HMX results during the projected treatability study timeframe.</td>
<td></td>
</tr>
</tbody>
</table>

### Injection and Monitoring Points

- Injection and monitoring points will be installed using DPT with a Geoprobe D66 rig. Monitoring wells will be constructed of 1” PVC screen and riser installed inside of 3.25 nominal ID DPT rods. DPT rods will be pulled as the well is constructed. Sand
<table>
<thead>
<tr>
<th>Comment No.</th>
<th>Page/Reference</th>
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<th>Response</th>
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<tbody>
<tr>
<td></td>
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<td></td>
<td>pack will be flowed/pumped into place to an elevation of at least 2 feet higher than the top of the screen. The remainder of the borehole will be filled with a bentonite slurry mixture and a flush mount well completion constructed. An SOP for the installation of this type of monitoring point is being issued as an addendum to the Installation-Wide QAPP to facilitate its future use on other parts of the IAAAP environmental restoration project.</td>
</tr>
<tr>
<td></td>
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<td>• Expendable injection points will initially be used. Expendable points are being used to increase flexibility associated with the location of subsequent injection events. Data from each monitoring event will be reviewed by the lead Tetra Tech hydrogeologist/explosives bioremediation specialist to determine the optimal location for subsequent injections as well as the need to modify the composition of the injectate. Please see additional information pertaining to injection point construction under the Injectate response below. Should the number of injection rounds necessary to reduce RDX concentrations to the treatability study goals exceed three, expendable injection points will be replaced with injection wells. Injection wells will be constructed identically to the DPT monitoring wells.</td>
</tr>
<tr>
<td></td>
<td></td>
<td><strong>Injectate</strong></td>
<td>A dextrose solution was selected as the initial injectate based on past experience by Tetra Tech, industry practitioners, and researchers. Dextrose provides an effective short-term electron donor to drive oxidation-reduction potentials to moderately to</td>
</tr>
<tr>
<td>Comment No.</td>
<td>Page/Reference</td>
<td>Comment</td>
<td>Response</td>
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</tbody>
</table>
|            |                | strongly reducing conditions in the aquifer. The raw dextrose product (corn syrup) is provided by the manufacturer as a liquid consisting of 71% solids (95% dextrose mixed with lesser amounts of maltose and saccharides). This mixture will be diluted at a ratio of 5 parts tap water to 1 part raw dextrose syrup. This will produce a mixture consisting of approximately 12% corn syrup solids. This process facilitates the biodegradation of RDX, HMX, and TNT. In the case of RDX, intermediate byproducts such as MNX, DNX, TNX, and ultimately innocuous mineralization endproducts (e.g., water and nitrous oxide) are produced. Please see the transformation pathway diagram presented as Figure 3-1 in the test plan.  
• Industry experience indicates that micronutrient amendments are not typically required to facilitate biodegradation of RDX, HMX, and TNT.  
• Injections will be performed using expendable DPT points and injection into existing hot spot monitoring well MW-117. For expendable DPT injection points, a D66 Geoprobe rig will advance the injection rods to the target total depth (depth interval equivalent to plume thickness observed around MW-117-approximately 490 to 505 ft amsl). The number of planned injection and monitoring points is described in Section 4.0 and illustrated on Figure 4-1. Injection points will also be illustrated on the cross section shown on Figure 4-2.  
• The composition of the injectate may be modified during the treatability study based on performance monitoring data. |
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<td>3</td>
<td>The Sampling Analysis Plan and Quality Assurance Project Plan (SAP/QAPP) by which the effort will be</td>
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<td>Additional references to the existing Installation-Wide SAP/QAPP by which the Off-Post Groundwater Treatability</td>
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<td>conducted should be specified and referenced where appropriate.</td>
<td>Study will be conducted will be added to the plan.</td>
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<td>4</td>
<td></td>
<td>The Treatability Study needs to include specific quantitative criteria that will be used to judge its success or failure. These criteria could include the amount of contaminant mass treated, the rate of treatment, the radius of treatment, the mass of nutrient required, verification of full-breakdown to innocuous end products, and any other specific criteria that will be used to demonstrate the viability of the remedy.</td>
<td>See response to General Comment 2.</td>
</tr>
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<td>5</td>
<td></td>
<td>The Treatability Study relies on 2002 groundwater monitoring data for selecting the area to inject a bioavailable carbon source solution. More recent data should be evaluated/presented to assist in determining the test area. It would be beneficial to conduct at least one round of groundwater monitoring to evaluate RDX plume migration. This will ensure that the Treatability Study focuses on the area with the highest RDX contamination.</td>
<td>Data from 5 sampling events (Spring 2002 through Spring 2004) have been evaluated to determine the . Given the seasonal fluctuations in the two most impacted wells, it is unlikely that an additional sampling event will be needed to locate the highest concentration area of the RDX plume.</td>
</tr>
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## Comment Response Matrix

**Draft Treatability Study for In Situ Biodegradation of RDX in Off-Site Groundwater**  
**August 2004**

**Commenter:** EPA Region VII  
**Comments dated:** September 22, 2004

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<td>6</td>
<td></td>
<td>Sections 2.2 and 2.3 contain a great deal of information regarding various aquifer-related properties (such as flow velocities, hydraulic conductivity, hydraulic gradient, etc...). The references from which this information has been obtained should be cited to insure that the data was adequately evaluated/reviewed. Otherwise, please provide all information required to verify that the aquifer information presented is accurate. Further, the significance of the aquifer information relative to the ultimate design of the remedy should be discussed. Temporal variations should also be evaluated since they may be significant and could impact the design of the remedy.</td>
<td>Additional references to historical documents will be added to the test plan.</td>
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### Specific Comments

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| 1 | Section 1.0, page 1-1. | a. The second paragraph in this section states that off-site, upgradient wells have been sampled and are “clean”. Please revise the Treatability Study to reference concentration ranges in lieu of subjective terminology.  
b. The third paragraph refers to “biodegradable carbon sources and other amendments”. Since a primary objective of the treatability study is to determine the most appropriate/effective biodegradation substrate, the details of any amendments or other carbon sources should be described in the Plan.  
c. Important considerations for the remedy that this Study addresses, as discussed in the FS and Proposed Plan, should be summarized. | a. Changed sentence to “Off-site, upgradient wells closer to the IAAAP site have been sampled and have RDX levels that are below the reporting limits.”  
b. The initial carbon source injected in the aquifer will be a 12% solution of dextrose (see response to comment 12a). The effectiveness of this carbon source will be monitored initially by the REDOX potential in the aquifer. REDOX potentials of -50mV or lower will signify that anaerobic biodegradation is occurring and that groundwater sampling and analysis is warranted for the detection of explosives and explosives breakdown products. If after two rounds of dextrose injection, a REDOX potential of lower than -50 mV is not measured, groundwater analytical samples will be collected as confirmation that RDX and HMX degradation has not occurred to a substantial degree (>25% concentration... |
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<td>2</td>
<td>Section 2.1.1, page 2-2.</td>
<td>In the 4th bullet, please revise to describe “OU4” as the “Miscellaneous Sites” operable unit.</td>
<td>The suggested change has been made.</td>
</tr>
<tr>
<td>3</td>
<td>Section 2.1.3, page 2-3.</td>
<td>a. Paragraph 3 indicates that the FS concluded that a field-scale treatability study should be conducted to determine the most effective bioremediation substrate (and to evaluate the effectiveness of bioremediation). The Study calls for the evaluation of only a single substrate, thus it is unclear how the most effective substrate will be identified. Please discuss. b. The text should identify that the performance standard/remediation goal for RDX in groundwater, as outlined in the FS and Proposed Plan, is 2 ug/L. References to appropriate figures illustrating site reduction). If an RDX/HMX concentration reduction greater than 25% is measured, dextrose injections and monitoring will continue and the dextrose will be deemed a successful and viable carbon source for further applications. If an RDX/HMX concentration reduction greater than 25% is NOT measured, an alternative carbon source will be selected which possesses short and long lasting carbon sources such as EOS® or HRC®. EOS® and HRC® are patented combinations of quick and slow consumable carbon sources observed to remain available in the aquifer for up to 3 years. Both products have been proven on the anaerobic bioremediation of RDX and TNT. Due to their long lasting capabilities and the limited duration of the pilot test (less than 1 year), the full benefits of the slow release component of EOS® and HRC® are beyond the scope of the treatability study. c. The suggested changes have been made.</td>
<td>a. The treatability study will be conducted in phases. The first phase is described in the treatability test plan and utilizes a rapid consumable carbon source (dextrose). Given the relatively low concentrations present (10s of ppb rather than 100s to 1,000s of ppb) in the off-post plume, the rapid consumable carbon source will likely reduce concentrations substantially within the treatment area after only one to two applications. As described in response to specific comment 1 above, phase 2 will be implemented if phase 1 fails. Phase 2 will consist of injection of combined slow and fast consumable carbon sources. Phase 1 (sugar solution) and 2</td>
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### Comment Response Matrix

**Draft Treatability Study for In Situ Biodegradation of RDX in Off-Site Groundwater  August 2004**

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**Comments dated:** September 22, 2004

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<td>4</td>
<td>Section 2.2.2.2, page 2-7.</td>
<td>This section contains numerous subsections that describe the subsurface geologic profile. However, the geologic descriptions presented in this section do not match the descriptions presented in Figure 2-4. For example, subsection titles of “Intermediate Terrace Alluvial Sands,” “Intermediate Terrace Sandy Gravel Alluvium,” and “Intermediate Glacial Till” are included in Section 2.2.2.2, however, “intermediate” is not used in any geologic descriptions shown on Figure 2-4. Revise either Section 2.2.2.2 or Figure 2-4 so that correct and consistent geologic descriptions are used throughout the Treatability Study.</td>
<td>The legend in Figure 2-4 was changed to reflect the terminology used in the text. The figure and text are now consistent.</td>
</tr>
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<td>5</td>
<td>Section 2.2.2.2, page 2-7.</td>
<td>The subsection titled “Weathered Bedrock” refers to bedrock that was encountered at approximately 160 feet below ground surface (bgs) in MW509D. However, MW509D is not shown on Figure 2-4. Please revise the text to refer to the correct well or add MW509D to Figure 2-4.</td>
<td>Reference to MW-509D was removed from the text in most places. Where references to MW-509D were relevant, another figure was cited to indicate its location.</td>
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| 6           | Section 3.2, page 3-1. | a. Citations of other applications or successes for in-situ (enhanced) bioremediation of RDX in groundwater should be provided. Details of successful applications, including the nature of successful substrates should be discussed.  

b. Please present the complete pathway for the metabolism/destuction of RDX to innocuous end products. | a. Additional references of RDX bioremediation successes will be provided in the revised treatability test plan.  
b. Additional biotransformation pathway information will be provided in the revised treatability test plan. The fate and toxicity of intermediary breakdown products such as MNX, DNX, and TNX are not known. However, mineralization of RDX and HMX has been demonstrated along with the ... |
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<td>7</td>
<td>Section 4.1, page 4-1.</td>
<td>Permits are not required for “on-site” CERCLA response actions. Since the “site” is generally defined as any area where contaminants have come to be located, the off-post area would be considered on-site for purposes of the CERCLA permit exclusion. We do suggest that you coordinate with the State immediately to identify any issues or concerns they may have regarding the underground injection activities associated with this Study.</td>
<td>Any necessary clearances or permits will be obtained in advance of injection activities. County and State DOT departments as well as the One-Call utilities clearance organization will be contacted for appropriate right-of-way agreements and utilities clearance. The Iowa DNR will be contacted to determine state underground injection control requirements. Local residents will be contacted to inform the public of impending activities.</td>
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<tr>
<td>8</td>
<td>Section 4.2, page 4-1.</td>
<td>This section states that as many as four injection points will be installed at varying distances apart, and that additional injection points may be installed, depending on the groundwater monitoring results obtained after the first injection event. However, the text does not describe the criteria to be evaluated in determining injection point spacing and the need for additional injection points. Please expand the text to discuss the criteria to be evaluated in determining injection point.</td>
<td>Three upgradient points and one downgradient point will be installed surrounding MW-117. The spacing of injection points will take advantage of groundwater flow under summer and winter conditions to disperse the injection fluid. The criteria for choosing these locations is discussed in Section 4.3.</td>
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products. Discuss the fate and toxicity of the various RDX breakdown products.  
c. While metals and HMX are not considered contaminants of concern in the off-post area, the potential impacts of these constituents should be considered in the Pilot Study. Some metals may inhibit microbial growth if present at sufficient levels. Further, HMX will act as a food source for microbial populations and could impact the degradation rate of RDX. HMX degradation products should be evaluated and their toxicity discussed.

c. RDX and HMX will be cometabolized in the subsurface based on previous laboratory and field studies performed. HMX is more recalcitrant than RDX, so HMX is anticipated to degrade more slowly than RDX. HMX and RDX degradation products are the same. Metals inhibition is not anticipated in the off-site plume area and has not been shown to be a significant issue in other bioremediation applications and studies.
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| 9           | Section 4.3, page 4-2. |a. Details of the injection program should be provided. For example, the location of the injection points, the depth at which injection will occur, the injection pressure, the amount of substrate to be injected, etc... should all be described in the Plan. 
b. It is not obvious why injection points should be installed 20 - 50 feet upgradient of monitoring points. Please discuss. 
c. The second paragraph of this section states that injection points will be created using an “expendable borehole.” Please describe the term “expendable borehole.” | a. See Figure 4-2 for locations. The depth, injection pressure and amount of substrate is detailed in the text for Section 4.3. A table will be added to facilitate review and field implementation. Nomenclature and construction details associated with injection and monitoring wells/expendable points will be tabulated. 
b. The location of the points was based on a rate of seepage 80-130 feet per year, which is discussed in Section 4.3. 
c. Expendable denotes the one-time use of injection points as compared with injection wells which provide a means to inject multiple times at the same location. As described in response to general comment 2 above, expendable injection points will be used for up to 3 injection events. This will provide a more flexible injection scheme that can be easily modified to accommodate changes dictated by injection/monitoring results. Should the required number of injection events exceed 3, it may be necessary to install injection wells as described above to provide a more cost-effective longer term carbon delivery system. |
<p>| 10          | Section 4.3, pages 4-1 and 4-2. |a. The first full paragraph on this page states that a series of up to five monitoring piezometers will be installed. However, the text does not describe the criteria that will be used to determine the exact number of monitoring piezometers to be installed. Please expand the text to discuss the criteria to be evaluated to determine the exact number of monitoring piezometers to be installed. | a. The term “up to” was used to qualify the number of monitoring points, to cover potential logistical constraints (access agreements, utilities clearance, and topographic limitations) unknown to Tetra Tech at the time of the test plan issuance. The paragraph will be revised to state that 5 monitoring wells will be installed for bioremediation performance monitoring purposes. Their approximate locations are shown on Figure 4-1 and may require... |</p>
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<td>b.</td>
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<td>The Study refers to “holes in pavement”. Based on the figures included, it appears that you may be proposing to inject thru/beneath Highway 61. Suggest that you coordinate with the appropriate State or Federal agencies prior to undertaking operations that may cause damage to the highway.</td>
<td>modification based on site logistics such as access agreements, utilities clearance, and topographic limitations. The five new monitoring wells are being installed at variable distances and vectors from injection points to determine the effective radius and directionality of biodegradation and production of biotransformation byproducts. Predominant groundwater flow directions change from the summer to winter in this area, as reported by URS (URS, 2004) and shown on Figure 4-1 of the treatability test plan.</td>
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<td>11</td>
<td>Section 4.4, page 4-2.</td>
<td>You appear to describe a step in the Study called “injection point (and monitoring piezometer) installation”. We are unclear what would comprise the “injection point installation”. Please describe.</td>
<td>An SOP will be constructed for injection point and monitoring well installation using a DPT rig. An SOP will be submitted for EPA review and concurrence prior to the onset of injection and monitoring well installation. The SOP will be submitted as an addendum to the installation-wide QAPP/SAP.</td>
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<tr>
<td>12</td>
<td>Section 4.4.1, page 4-2.</td>
<td>a. The first paragraph of this section states that the injection solution will consist of sugar mixed with potable water using a 1:2 mixture (i.e., four liters of sugar for every eight liters of water) prior to injection.</td>
<td>a. The text will be modified to reflect the following. A dextrose solution was selected as the injectate based on past experience by Tetra Tech, industry practitioners, and researchers. A simple carbon source (sugar solution) has</td>
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### Comment Response Matrix

**Draft Treatability Study for In Situ Biodegradation of RDX in Off-Site Groundwater  August 2004**

**Commenter:** EPA Region VII  
**Comments dated:** September 22, 2004

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<td>Please describe how you have selected this substrate and concentration.</td>
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<td>b. Information in Section 4.4.2 states that the injection solution will consist of a 1:20 mixture (i.e., four liters of water for every 80 liters of potable water) rather than a 1:2 mix as discussed in this section. Please revise/clarify appropriately.</td>
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<td>c. It is unclear whether the substrate chosen in this evaluation will provide a carbon source that is sufficiently persistent to promote microbial activity over the time period needed to treat RDX to the levels required. Please discuss.</td>
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<td>d. It is unclear what information will be used to determine whether sodium bicarbonate will be added to the donor solution, and in what quantities. Please clarify.</td>
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<td>e. The Plan states that the composition of the substrate may be adjusted during subsequent pilot test injections. The basis for such additional injections and adjustments to the substrate composition should be discussed.</td>
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<td>been used successfully as an in situ bioremediation supplement for years where anaerobic biodegradation is required. Dextrose provides an effective short-term electron donor/carbon source to drive oxidation-reduction potentials to moderately to strongly reducing conditions (-50 to -150 mV) in the aquifer. The raw dextrose product (corn syrup) is provided by the manufacturer as a liquid concentrate consisting of 71% solids (95% dextrose mixed with lesser amounts of maltose and saccharides). This mixture will be diluted at a ratio of 5 parts tap water to 1 part raw dextrose corn syrup. This will produce a mixture consisting of approximately 12% corn syrup solids. This process facilitates the biodegradation of RDX, HMX, and TNT. In the case of RDX and HMX, intermediate byproducts such as MNX, DNX, TNX, and ultimately innocuous mineralization endproducts (e.g., water, nitrous oxide, and methane) are produced. Please see the transformation pathway diagram presented as Figure 3-1 in the test plan.</td>
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<td>b. The typo will be fixed. Please see the response to comment 12a above.</td>
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<td>c. Please see responses to specific comments 1 and 3 above.</td>
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<td>d. Alkalinity additions through use of sodium bicarbonate are used to ensure aquifer pH remains in a range favorable for biological activity (typically in the pH range of 4 to 8). However, ambient microbiota have often adapted to environmental conditions (such as low pH). Therefore, historical groundwater analytical data, incorporating pH and alkalinity measurements will be used to guide the initial decision about addition of sodium bicarbonate. Subsequent</td>
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| 13          | Section 4.4.2, page 4-3. | a. Please describe how the “appropriate solution feed rate” will be determined.  
   b. How has it been established that a carbohydrate concentration of 60 mg/L is desirable? How will you measure this?  
   c. Describe how you have determined that 200 gallons sugar water/injection point is appropriate. | a. The goal is to inject the feed solution under relatively low pressure. The solution feed rate will be determined by field conditions and are a balance among the safe injection pressure limits of the equipment and the rate of aquifer acceptance of feed solution.  
   b. The concentration of available carbon in the feed solution (60 mg dextrose [C₆H₁₂O₆] per liter or 22.5 mg C/L) is based on a range of published studies using multiple types of carbohydrate (e.g., acetate at 6 mg C/L by Pombo, et al., 2002; acetate at 56 mg C/L by Kleikemper et al., 2002; lactic acid at 40 mg C/L in a case study summarized by EPA, 2000).  
   c. A range of 200 to 400 gallons per injection point have been used in other environments. The proposed injection volume is a balance among: 1) minimizing the amount of injection fluid to inject; 2) getting the maximum amount of carbohydrate in the aquifer; 3) maximizing the area of influence from the injection; and 4) minimizing the time required to complete the injection. |
| 14          | Section 4.4.3, page 4-3. | a. Please describe how you will determine the injection pressure (or solution feed rate, as above).  
   b. How will you measure the radius of influence of each injection? | a. The injection pressure will be determined in the field based on the resistance of the formation to accept low viscosity aqueous fluids. Since Tetra Tech will be injecting approximately 40 feet below the static potentiometric elevation of the water table, sufficient pressure will have to be... |
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<td>Section 5.0, page 5-1.</td>
<td>a. The text states that trained personnel will conduct field monitoring and sample collection. Please specify the methods that will be employed to conduct the monitoring and sample collection. b. The text also indicates that the data will be evaluated to determine whether the objectives of the Pilot Test have been achieved. We could not determine that the</td>
<td>a. Standard operating procedures (SOP) have been added as appendices to the test plan to clarify field procedures related to groundwater sampling, monitoring well installation, injection point installation, equipment decontamination, and other pertinent field activities. b. The objectives of the treatability study will be more clearly indicated in the revised treatability test plan. Specific</td>
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applied to overcome the hydrostatic pressure exerted by the overlying column of groundwater. This pressure is less than 20 psi. In practicality, the injection pressure is determined more by the lithology, sorting, hydraulic conductivity, and other physical properties of the geologic formation. As such, we anticipate injecting at approximately 100 psi into expendable DPT points. The actual injection pressure may vary from this based on field conditions encountered at the time of the injection. However, the goal remains the same which is to introduce the maximum amount of injectate per injection point/interval in a reasonable amount of time.

b. The radius of influence of each injection will be indirectly measured by the reduction in RDX and HMX concentrations in downgradient and cross-gradient monitoring wells. It will also be measure directly through TOC analyses which will indicate the incursion of additional carbon (dextrose injectate) into the well. As indicated in the test plan, monitoring wells have been positioned at varying distances and vectors from the injection points to evaluate the maximum effective biodegradation radius, primarily to determine the optimal future spacing of injection points for full scale remedy implementation.
### Comment Response Matrix

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<td>16</td>
<td>Section 5.1, page 5-1.</td>
<td>objectives of the test have been articulated in the Plan. Please clarify.</td>
<td>objectives are detailed in response to general comment 1 above.</td>
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<td></td>
<td>a. The Plan states that the test will last up to 9 months. Please indicate the minimum duration of the test.</td>
<td>a. The minimum duration of the pilot test is linked to achieving the performance objectives of the treatability study. Specifically, if the objectives listed in response to general comment 1 are achieved after 1 treatment and monitoring cycle (approximately 6 weeks duration), the treatability study would cease, the results documented, and a remedial design initiated. A more pragmatic minimum duration is anticipated to be 2 injection cycles (approximately 12 weeks).</td>
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<td>b. The Plan states that the period of performance will allow adequate time to demonstrate the effectiveness of the technology and provide engineering data for potential subsequent applications. Please identify the specific criteria that will be used to evaluate the effectiveness of the technology, and the engineering data that will be required/collected from the test.</td>
<td>b. Please see response to general comment 1 and specific comments 3 and 9 above.</td>
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<td>c. In the last sentence of this section, you indicate that the test may achieve anaerobic conditions, but not degrade RDX to meet cleanup criteria at the conclusion of the test. This highlights the need to establish specific evaluation criteria for the test.</td>
<td>c. Noted. Please see response to specific comment 1 above where the percent degradation (25%) is defined as a goal of the treatability study.</td>
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<td>17</td>
<td>Section 5.2, page 5-1.</td>
<td>The details of the monitoring program are unclear.</td>
<td>As stated in response to general comment 2 above, additional details will be added to the injection, monitoring, and decision logic portions of this plan.</td>
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<tr>
<td>18</td>
<td>Table 5-1, page 5-2.</td>
<td>a. The adequacy of “test kits” for measuring various parameters (iron, sulfide, alkalinity) is unclear. Please clarify if the use of test kits is consistent with the SAP/QAPP, and will satisfy the Data Quality Objectives.</td>
<td>a. Verified field procedures are consistent with Installation-wide SAP/QAPP that we are using as a foundation for this and future work.</td>
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<td>b. Since HMX is present in the aquifer, we suggest that you report the entire suite of explosives which are evaluated in SW-846, method 8330. HMX degradation products should be identified and assessed analytically.</td>
<td>b. The entire suite of nitroaromatic explosives will be reported, including the RDX and HMX degradation products MNX, DNX, and TNX. Based on published literature the formation of breakdown products and the degradation pathways are essentially the same for cyclic nitramine compounds such as RDX and HMX (Hawari, 2000). These include the readily analyzed MNX, DNX, and TNX</td>
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### Comment Response Matrix

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| 19 | Section 5.3.1, page 5-3. | a. In general, all methods referenced here should be described in the SAP/QAPP. Please verify that this is the case.  
b. Under “RDX” you indicate that analysis will be conducted by SW-846, method 8330, or approved modification. Please clarify your reference to “approved modification”. Are such modifications described in the QAPP? How do you intend to seek “approval” for such modifications? | a. Verified with Installation-wide URS SAP/QAPP that Tetra Tech is using methods and procedures outlined in the Installation-Wide SAP/QAPP as a basis. SOPs related to DPT injection and DPT well installation will be submitted as addenda to the Installation-Wide plan and referenced in the treatability study test plan.  
b. All nitroaromatic explosives analyses will be performed using SW846, Method 8330. Additionally, the RDX/HMX degradation products MNX, DNX, and TNX will be analyzed using Method 8330. |
| 20 | Section 5.3.3, page 5-4. | a. The text in this section states that alternate approaches to sampling, such as the use of bailers, may be used when total organic carbon is required to guide system operations. However, the text does not state why the use of bailers may be necessary. Please revise the text to explain why bailers may be used as an alternate method for groundwater sampling.  
b. Appropriate procedures from the SAP/QAPP should be referenced. | a. The text will be revised to add clarification. Bailers will be used if progress parameters not affected by purge volume (e.g. total organic carbon) are needed during the treatability study. They will essentially be used to collect grab samples, if necessary to access injectate progress.  
b. Procedures and SOPs from the installation-wide SAP/QAPP and revisions thereto will be referenced throughout the document. |