AMEC Geomatrix

SAMPLING AND ANALYSIS PLAN

FOR EVALUATING POTENTIAL SOURCES OF LOW-LEVEL PETROLEUM HYDROCARBON COMPOUND DETECTIONS

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SAMPLING AND ANALYSIS PLAN
for

EVALUATING POTENTIAL SOURCES OF LOW-LEVEL PETROLEUM HYDROCARBON COMPOUND DETECTIONS

PINEDALE ANTICLINE OIL AND GAS EXPLORATION AND DEVELOPMENT PROJECT

Sublette County, Wyoming

Prepared for:

U.S. Department of Interior, Bureau of Land Management, Pinedale Field Office
Wyoming Department of Environmental Quality, Water Quality Division
U.S. Environmental Protection Agency, Region 8
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GLOSSARY OF ACRONYMS

Acronym	Details
%O2	percent oxygen
µg/L	micrograms per liter
APD	Applications for a Permit to Drill
B	boron
BDE	BLM/DEQ/EPA
BLM	US Department of the Interior Bureau of Land Management
BTEX	benzene, toluene, ethylbenzene, and xylenes
C	carbon
CFR	Code of Federal Regulations
CGI	combustible gas indicator
CLP	Contract Laboratory Program
COA	Condition of Approval
CoC	Chain of Custody
DQO	Data Quality Objective
EPA	U.S. Environmental Protection Agency
EPNG	El Paso Natural Gas
F	fluoride
FRC	flame resistant clothing
GC/MS	gas chromatography / mass spectrometry
Geomatrix	AMEC Geomatrix, Inc.
Gov't I	Government I
H	hydrogen
HSUs	hydrostratigraphic units
LNAPL	light non-aqueous phase liquid
MDL	method detection limit
mg/L	milligrams per liter
MS	Matrix spike
MS/MSD	matrix spike/matrix spike duplicate
MSD	Matrix spike duplicate
O	oxygen
PAPA	Pinedale Anticline Project Area
PCS	petroleum-contaminated soil
PHC	petroleum hydrocarbon compounds
PoS	Plan of Study

GLOSSARY OF ACRONYMS

Acronym	Details
PQL	practical quantitation limit
QA/QC	quality assurance and quality control
QEP	QEP Resources, Inc.
RL	reporting limit
ROD	Record of Decision
RPD	relative percent difference
SAP	Sampling and Analysis Plan
SAR	sodium adsorption ratio
SCCD	Sublette County Conservation District
SEIS	Supplemental Environmental Impact Statement
Shell	Shell Exploration and Production Company
Si	silicon
SOP	Standard Operating Procedure
Sr	strontium
SVOC	semivolatile organic compounds
TAL	Target Analyte List
TDS	total dissolved solids
TICs	Tentatively identified compounds
TPH	Total petroleum hydrocarbons
TPH-DRO	TPH in the diesel range
TPH-GRO	TPH in the gasoline range
UGRB	Upper Green River Basin
Ultra	Ultra Resources, Inc.
USGS	U.S. Geological Survey
VOC	volatile organic compounds
WDW	water disposal wells
WOGCC	Wyoming Oil and Gas Conservation Commission
WPDES	Wyoming Pollutant Discharge Elimination System
WSWs	water supply wells

1.0 INTRODUCTION

AMEC Geomatrix, Inc. (Geomatrix) prepared this Sampling and Analysis Plan (SAP) for the evaluation of low-level detections of petroleum hydrocarbons (PHC) in industrial water supply wells (WSWs) located in the Pinedale Anticline Oil and Gas Exploration and Production Area (also known as the Pinedale Anticline Project Area, or PAPA) in Sublette County, Wyoming (**Figure 1**). Operators have conducted annual groundwater monitoring since 2004. PHC (e.g., benzene, toluene, ethylbenzene, and xylenes) have been detected in water samples from a number of industrial WSWs since 2007. Although applicable water quality standards have been temporarily exceeded at a few WSWs, and persistently exceeded at only two locations, most detections of PHC are much lower than applicable standards.

The locations of WSWs where low levels of petroleum hydrocarbons have been detected in the PAPA are illustrated on **Figure 2**. A recent US Department of the Interior Bureau of Land Management (BLM) Record of Decision (ROD) for the Supplemental Environmental Impact Statement (SEIS) (BLM 2008) states that no new rights-of-way or other approvals will be granted for installation of new industrial WSWs in the PAPA until the sources of these PHC detections have been identified and mitigated. This SAP describes a field sampling and analysis program designed to identify and evaluate potential source(s) of PHC detections.

1.1 REGULATORY FRAMEWORK AND PURPOSE OF SAP

This SAP has been developed in cooperation with several State and Federal agencies (referred to as BDE [BLM/DEQ/EPA]) and the three oil and gas companies referred to as the Operators (Ultra Resources, Inc. [Ultra], Shell Exploration and Production Company [Shell] and QEP Resources, Inc. [QEP]) (USQEP). To fulfill requirements of the 2008 ROD (BLM, 2008), Geomatrix prepared an Interim Groundwater/Aquifer Pollution Prevention, Mitigation and Monitoring Plan (Interim Plan; Geomatrix, 2008a) that defined a general strategy to characterize the hydrogeology of the PAPA, evaluate Operator practices with respect to potential for impacts to groundwater resources, and identify monitoring and mitigation strategies to address known hydrocarbon occurrences in groundwater.

The Interim Plan required development of a Plan of Study for Evaluating Potential Sources of Low-Level Petroleum Hydrocarbon Compound Detections (PoS for Low-Level PHC; Geomatrix, 2009a), which described the approach for the plan of study. The objectives of the PoS were to:

- To the extent possible, identify potential sources of low-level PHC detections within the PAPA using readily available information.
- Perform spatial and temporal analyses of groundwater PHC data with respect to potential sources to identify the most likely sources of PHCs at each well location where they occur.
- Identify data gaps for each location and develop a SAP to fill gaps.
- In order to determine PHC source(s) at individual well locations, conduct additional environmental sampling at individual locations where PHCs occur. Evaluate new environmental samples for a list of analytes determined by the identification of likely sources.
- Recommend additional mitigation measures, if necessary.

The purpose of the SAP is to describe the methodology for additional environmental data collection that will aid in evaluating the sources of low-level PHC detections in industrial WSWs. Results of the sampling and analysis program will be used to meet the objectives of the PoS (Geomatrix, 2009a).

1.2 SAP ORGANIZATION

This SAP specifies sample collection methodology, analytical requirements, and quality assurance / quality control measures and consists of the following sections:

- Section 1.0 provides introductory project information, including the purpose of the SAP.
- Section 2.0 presents a brief background of the project area and gas field development in the PAPA, provides a description of the hydrogeologic setting, summarizes general groundwater quality and the occurrence and distribution of PHC in groundwater samples collected from WSWs, and discusses stray gas occurrence in industrial WSWs, and identifies potential sources of PHCs detected in groundwater samples.
- Section 3.0 describes the technical approach to the sampling and analysis program.
- Section 4.0 describes the project data quality objectives.
- Section 5.0 describes field methods and procedures for sample collection.
- Section 6.0 describes sample container and sample preservation requirements.
- Section 7.0 describes sample documentation and handling procedures.
- Section 8.0 specifies laboratory analytical methods.
- Section 9.0 describes quality assurance and quality control measures for the project.
- Section 10.0 references the implementation schedule for the SAP.
- Section 11.0 lists personnel for the implementation of the SAP.
- Section 12.0 lists references cited in this SAP.

Supporting information is contained in several appendices. Figures and tables are contained in Appendices A and B, respectively. Standard operating procedures, field forms and example health and safety forms are included in Appendices C through E. A chronology of PAPA development and regulatory milestones is contained in Appendix F.

2.0 BACKGROUND

The Pinedale Anticline is a northwest-southeast oriented structural gas trap in Cretaceous-age Lance and Mesaverde Formations sedimentary formations, which are buried beneath approximately 8,000 feet of Teritary-age Wasatch, Fort Union, and a third unnamed Tertiary geologic formation. The PAPA is located south of Pinedale, WY (**Figure 1**), lies adjacent to and north of the Jonah Field, and encompasses an area of approximately 308 square miles.

2.1 HISTORY OF GAS FIELD DEVELOPMENT IN THE PAPA

The history of natural gas E&P activities in the Pinedale Anticline began in 1939 with drilling of the Government 1 (Gov't 1) well by the California Company. By 1982, twenty (20) gas wells had been installed within the boundaries of the PAPA. These early gas well locations are depicted on **Figure 2**, and ownership, location, depth, and installation date information is summarized below:

Well Name	Operator	Location				Depth	Spud
		T	R	S	1/4 1/4	(ft)	Date
Gov't 1	California Co.	31	109	14	SWNE	10,000	4/29/1939
Unit 1	Stanolind	33	109	17	NWSE	7,797	1/2/1949
Pinedale 1	El Paso Natural Gas	30	108	9	NESE	10,550	7/14/1954
Pinedale 2	El Paso Natural Gas	31	108	29	SE	10,694	2/14/1955
Pinedale 3	El Paso Natural Gas	31	109	13	C NW	11,009	3/7/1955
Pinedale 4	El Paso Natural Gas	32	109	34	C NW	11,123	8/30/1955
Pinedale 5	El Paso Natural Gas	30	108	5	C SE	15,018	9/12/1955
Pinedale 6	El Paso Natural Gas	30	108	21	SENW	11,057	3/8/1957
Pinedale 7	El Paso Natural Gas	30	108	15	SENE	10,270	6/5/1960
Unit 1	Texaco	29	107	25	NESW	11,008	1/16/1963
Pinedale 8	Mountain Fuel	33	109	20	NESW	10,500	9/29/1963
Wagon Wheel 1	El Paso Natural Gas	30	108	5	SENW	19,000	10/3/1969
Mesa 1	Wexpro	32	109	7	NENE	12,050	9/6/1980
Jensen 1	Leonard Hay	31	109	11	SWNW	10,320	11/22/1980
Mesa 2	Wexpro	32	109	16	SENW	12,190	1/3/1981
New Fork 1	American Hunter	30	108	25	SWNE	10,989	2/25/1981
New Fork 2	American Hunter	30	108	2	SWNE	11,986	3/30/1981
New Fork 4	American Hunter	31	109	35	NWSE	11,550	5/27/1981
Baumgartner Fed. 21-24	Black Hawk Resources	33	110	24	NENW	11,238	11/5/1981
Jensen 2	Leonard Hay	31	109	11	SESE	10,310	11/24/1982

Although file reviews did not result in obtaining complete information regarding these wells, several natural gas projects appear to have been at least partially funded by the U.S. Department of Energy to research development of tight sand formations. These included wells installed by El Paso Natural Gas (EPNG) in the 1950s and 1960s and Wexpro wells Mesa 1 and 2. The most well known example is the EPNG Wagon Wheel #1 location, at which nuclear detonations were planned in order to fracture the

gas-bearing formations. This test was never conducted. WSWs WW1 and WW2, both relatively deep at 2,500 feet and 5,108 feet, respectively, were installed to support the Wagon Wheel #1 project. An airstrip located north of the intersection of Middle Crest Road and Jonah North Road (**Figure 2**), which was likely built to support the EPNG drilling program, is depicted on aerial photographs.

Most early gas wells were installed, tested, and either brought into production or shut in. Based on available records, these wells were periodically re-stimulated, and some were apparently shut in for a decade or more without activity. According to BLM records, stimulation fluids used at these locations included fuel oil, kerosene, and condensate in quantities up to 212,000 gallons. No documentation regarding disposal of flowback or other waste fluids was found for these early wells. Operational practices likely included use of unlined pits at these locations.

Based on available information, no new gas wells were installed between 1983 and 1993. Between 1994 and present, natural gas E&P activities in the PAPA have increased due to improvements in hydraulic fracturing technology. Some of these techniques have been used on the pre-1983 gas wells; however, many new gas wells were drilled in the PAPA to recover the vast amount of natural gas that can be liberated using the new stimulation techniques. The new gas wells are distributed along the entire length of the anticline crest in the PAPA. Many gas pads have or had an industrial WSW associated with it to support drilling and completion activities.

A chronological listing of regulatory milestones and PAPA gas field development was prepared by BLM and is included as **Appendix F**.

2.2 HYDROGEOLOGIC FRAMEWORK

The Upper Green River Basin (UGRB) is a structural geologic basin that formed during the Laramide Orogeny, beginning approximately 70-80 million years ago during the late Cretaceous. Cretaceous sediments that formed the source material for present gas accumulations were deposited in marine and fluvial environments and, with regard to natural gas E&P, are collectively referred to as the Lance Pool. These Cretaceous-age formations are listed below in order of oldest to youngest, and indicate a transition from marine to alluvial plain depositional environments:

- Hilliard Shale - siltstone, shale;
- Rock Springs Formation - fine- to medium-grained sandstone, siltstone, shale, carbonaceous mudstone;
- Ericson Sandstone - sandstone, minor siltstone/shale; and,
- Lance Formation - fine- to medium-grained sandstone siltstone, carbonaceous mudstone.

El Paso Natural Gas's Wagon Wheel gas well (see Section 2.1 and **Figure 2**), penetrated approximately 11,500 feet of these Cretaceous formations (Law and Johnson, 1989). Overlying these Cretaceous formations at the Wagon Wheel gas well location are approximately 7,250 feet of Tertiary-age sedimentary rock formations. The lithology of these Tertiary-age formations is indicative of fluvial deltaic and alluvial plain depositional environments. These formations are, in order of oldest to youngest:

- Unnamed Unit – conglomerate, sandstone, siltstone, and mudstone;
- Fort Union Formation – sandstone, siltstone, mudstone, carbonaceous mudstone; and,
- Wasatch Formation – sandstone, siltstone, mudstone, carbonaceous mudstone.

Natural gas E&P in the PAPA is centered on the Pinedale Anticline, which is a northwest-oriented anticline geologic structure approximately 35 miles long and six (6) miles wide. The Anticline has approximately 2,000 feet of structural relief in the Cretaceous-age rocks (Law and Johnson, 1989). It is bounded to the west by a high angle, east-dipping, reverse or thrust fault that apparently terminates in the overlying Tertiary-age formations, and on the east by the Wind River Thrust Fault (Law, 1984). According to Law and Johnson (1989), surface expression of the Anticline is subtle in the Wasatch Formation, with observed dips of only 1° to 2° on the flanks of the structure.

The Lance Pool is described as an over-pressurized, tight gas reservoir because it displays a pressure gradient over 0.5 psi/ft. Spencer (1989) indicated that 1) over-pressurization generally occurs because active gas production exceeds the rate at which gas can escape through diffusion or gas-phase migration; 2) local structure and stratigraphy are of secondary importance for the formation of over-pressuized conditions; and, 3) normally pressurized wells can occur in areas of overpressured conditions, possibly due to extensive vertical fracturing. The model for tight gas reservoirs such as the Lance Pool does not require a sealing geologic material to account for development of the over-pressurized condition. Spencer (1984) describes an overlying "inactive zone" of gas accumulation where the rate of gas production is less than the rate of gas leakage out of the reservoir.

Most PAPA industrial, domestic and stock WSWs are completed in the Wasatch Formation. A few domestic and/or stock wells are completed in or partially open to alluvium associated with the New Fork River. Based on available information, the maximum depths for domestic, stock, and industrial wells in the PAPA are approximately 320 feet, 600 feet, and 1210 feet, respectively. Average depths of the three well types are approximately 116 feet, 195 feet, and 644 feet, respectively.

A hydrogeologic conceptual model developed by Geomatrix (2008b) differentiated the Wasatch Formation into the following hydrostratigraphic units (HSUs):

- Shallow Wasatch HSU
- Regional Wasatch HSU

The Shallow Wasatch HSU is topographically elevated above the Green River and New Fork River valleys within the PAPA (e.g., the Mesa). Based on information from driller's logs, this HSU does not appear to be continuously saturated and may be separated from the underlying Regional Wasatch HSU by unsaturated intervals at some locations. Groundwater, where encountered in the Shallow Wasatch HSU, occurs in discontinuous sandstone units or lenses within siltstone or mudstone/shale units. Groundwater flow in this HSU is primarily directed downward.

The Regional Wasatch HSU is fully-saturated and is expected to exist under semi-confined conditions due to the heterogeneous nature of the formation. Bedrock WSWs located adjacent to the New Fork River are commonly artesian. The predominate northeast to southwest direction of groundwater flow in this HSU is from recharge areas in the Wind River Range to discharge at the New Fork and Green Rivers.

The Wasatch Formation is underlain by the Fort Union Formation. Information on the geologic log for the Warbonnet 14-24 WDW injection well indicates the top of the Fort Union is at 5,016 feet at this location. Very little information exists with regard to the hydrogeology of the Fort Union formation within the PAPA. Martin (1996) indicates that groundwater flow within the Fort Union formation is directed predominately south and west toward the lower Green River valley and Flaming Gorge

Reservoir. No WSWs within the PAPA penetrate the Fort Union formation; the deepest industrial WSWs are separated from the Fort Union formation by about 4,000 vertical feet.

In addition to the LLPHC Study, additional hydrogeologic characterization (Geomatrix, 2009b) is currently being conducted to fill data and information gaps identified in the Hydrogeologic Conceptual Model Report (Geomatrix, 2008).

2.3 GROUNDWATER QUALITY

Per requirements of the 2000 ROD, groundwater quality in WSWs within one (1) mile of E&P activities is monitored on an annual basis. Monitoring is currently conducted by the Sublette County Conservation District (SCCD) on behalf of the Operators. Analytical parameters include general water quality constituents, common ions, metals, and petroleum hydrocarbons.

Water quality is generally good and characterized by low to moderate concentrations of dissolved solids. Average TDS, chloride, fluoride, and sulfate concentrations generally trend higher with depth. Chloride, fluoride, sulfate and sodium adsorption ratio (SAR) exceed applicable standards in some industrial WSWs. Lowham et. al. (1985) reported that elevated TDS and fluoride concentrations are common in the regional area that includes the Upper Green River Valley.

PHC have been detected in groundwater samples collected from industrial WSWs located in the PAPA. PHC have also been detected in three (3) domestic wells and one (1) stock well; however, detections in non-industrial WSWs do not appear to have been associated with natural gas E&P activities. The following PHCs have been detected in groundwater samples collected in the PAPA:

- Total petroleum hydrocarbons (TPH);
- TPH in the diesel range (TPH-DRO);
- TPH in the gasoline range (TPH-GRO);
- Benzene;
- Toluene;
- Ethylbenzene; and,
- Xylenes.

Table 1 summarizes PHC data for all industrial, domestic, and stock WSWs where at least one hydrocarbon constituent has been detected. The applicable Wyoming groundwater quality standards are also indicated in **Table 1.** Locations of these PHC occurrences are illustrated on **Figure 2**. Concentrations exceeding applicable standards are highlighted. Concentrations of most PHC constituents are well below their respective standard. Additionally, most PHC concentrations exhibit an overall decreasing trend. *Note: TPH-DRO concentrations greater than 1.1 mg/L are conservatively highlighted in **Table 1** and depicted on **Figure 2** as exceedences due to the absence of additional information that would indicate an action level of 10 mg/L.*

2.4 STRAY GAS ANALYSES

The presence of natural gas in water supply wells is not necessarily indicative of dissolved petroleum hydrocarbons in groundwater; however, it may be an indication that a pathway exists (natural or manmade) between the hydrocarbon-bearing zones and shallow aquifers. Natural gas produced in the PAPA is thermogenic (i.e., produced by alteration of organic material under conditions of high pressure/temperature) rather than biogenic (i.e., produced by microbial activity at relatively shallow depths) in origin and also produces heavier petroleum hydrocarbon compounds (e.g., BTEX). These heavier PHC are not associated with biogenic gas.

The SCCD monitors for the presence of combustible gases when conducting groundwater sampling activities, resulting in identification of 14 PAPA industrial WSWs from which combustible gas was found to be emanating. Geomatrix identified similar conditions at an additional five (5) industrial WSWs and one (1) stock well. These locations are included on **Figure** 2 and summarized as follows:

Well Name	Status **
Sherlock Federal 15-8	Plugged & Abandoned
Gannet 11-16	Plugged & Abandoned
Mesa 14-16 Water Source Well	Active
Mesa 3-27	Plugged & Abandoned
Mesa 5-33	Active
Riverside 11-14	Active
Boulder 12A-33	Active
Warbonnet 7-4 Water Well	Active
Warbonnet 7-5	Active
Warbonnet 16-10	Plugged & Abandoned
Warbonnet 13-11	Plugged & Abandoned
Warbonnet 9-15	Active
Warbonnet 1-21	Plugged & Abandoned
Warbonnet 5-25	Plugged & Abandoned
Warbonnet 8-25	Active
Blue Rim Well #4084 (stock well)	Active
Rainbow 13-30	Active
Antelope 11-10D	Active
Antelope 1-16	Active
Highway #7	Active

** - status on November 9, 2010

In January 2009, Geomatrix collected gas samples from the Riverside 11-14, Boulder 12A-33, and Rainbow 13-30 water well casings in order to characterize the gas. Samples were analyzed for gas composition (also analyzed again in May 2009) and stable isotopes of carbon (^{13}C) and hydrogen (^{2}H) in methane. Compositions of gas collected from water supply wells were compared to the composition of natural gas produced at each pad. Results indicated that:

- Gas from the WSWs is thermogenic in origin;
- Hydrocarbon compositions of the two gas types were similar;
- Benzene, toluene, ethylbenzene, and xylenes (BTEX) were found to be lower in gas samples collected from water well casings relative to those collected from gas wells;
- Methane concentrations were found to be higher in gas samples collected from water well casings relative to those collected from gas wells; and
- Gas sampled from production wells should be analyzed for stable isotopes of methane and compared to isotope data from the WSWs to provide an additional basis for comparison regarding the origin of the gas in the WSWs.

2.5 POTENTIAL PHC SOURCES

Table 1 of the Interim Plan (Geomatrix, 2008a), referred to as the "Rainbow Matrix", was developed by BDE and summarizes potential PHC sources in the PAPA. Geomatrix reviewed information in the existing project database, available literature, and public databases to identify and further describe potential sources of PHC in groundwater within or proximal to the PAPA. Operators, water well drilling contractors, and water pump installation contactors have been interviewed and operations with respect to the installation (i.e., drilling techniques) and sampling (i.e., pump installation) of WSWs have been observed. Based on the review of available information, the following potential sources were identified:

- Current and historic E&P activities, including historic utilization of unlined pits during operations and potentially for waste disposal, excursions from lined pits, leakage and/or spills from processing equipment and condensate and/or produced water storage tanks, inadequate backflow prevention between equipment and WSWs;
- Stray gas and associated hydrocarbons, including gas migration along natural pathways (faults, fractures, diffusion) from natural gas reservoirs in the Lance Formation (and/or deeper formations), gas generation in gas-bearing Tertiary formations, and leakage from inadequately sealed natural gas wells;
- Artifacts of water well and pump installation practices, including use of petroleum-based pipe dope and other PHC materials on downhole equipment, oil leakage from air compressors, and hydraulic line leakage;
- Spills or releases from sites not related to historic or current oil and gas activities within or proximal to the PAPA (e.g., DEQ-listed remedial sites, landfills, injection wells, permitted oil disposal facilities); and,
- Artifacts of sampling practices and laboratory analytical issues/discrepancies.

Table 2 summarizes characteristics of the identified potential sources, associated potential contaminants, and target analytes. **Table 3** summarizes locations of potential PHC sources with respect to the WSWs in the PAPA. **Figure 2** illustrates the locations of identified potential point sources of PHCs, as appropriate, within and in the immediate vicinity of the PAPA. Characteristics of potential PHC sources are discussed in the following sections.

Natural Sources

Within the PAPA, natural gas and associated condensate is known to contain BTEX as well as other petroleum hydrocarbons that could contribute to PHC detections in shallow groundwater. Natural gas reservoirs are typically leaky, and some vertical seepage from the target formations in the PAPA is expected over long periods of time. This seepage could occur as macroseepage (e.g., along geologic faults) or microseepage (e.g., diffusion through the overlying geologic material). Natural gas also may have originated in the shallower Tertiary-age formations, and/or have migrated into these formations from elsewhere within the basin. Evidence of natural occurrences of natural gas and/or PHC in the Tertiary formations inside the PAPA include:

- A soil gas survey performed by Questar, which measured numerous PHC including BTEX in the shallow subsurface (<12 feet) at several locations (proprietary document);
- Measurements of shallow gas encountered at depths as shallow as approximately 185 feet in the Wasatch Formation that are documented on a driller's mud log for the Yates Highway #11 gas well location;
- Discovery of natural gas by Geomatrix during installation of hydrogeologic data gap study wells at the Antelope 10-11D and Warbonnet 7-15D locations, and subsequent measurement of toluene in groundwater collected from one of the borings at Antelope 10-11D location;
- A letter report by the Wyoming Oil and Gas Conservation Commission (WOGCC) that documents shallow gas encountered at the Yate's Highway #4 water well and Highway #10 shallow gas well locations (WOGCC, 2009);
- A notation on the geologic completion report for the Pinedale 7 gas well, which was installed in 1960, indicating that mud logging was commenced at a depth of 1,000 feet to evaluate gas shows observed throughout the Wasatch Formation in other Pinedale wells; and
- Reports of condensate production and measured TPH concentrations as high as 1,330 milligrams per liter (mg/L) (Warbonnet 10-26D, Lizard Head 11-8) in samples of groundwater collected from the Fort Union Formation in support of injection well applications.

Migrating gas is expected to be altered as it moves through the subsurface. Potential alterations include dissolution of heavier hydrocarbons (with respect to methane) into groundwater (e.g., BTEX), methane enrichment due to its high mobility, ethane depletion relative to methane due to its greater solubility in water, and enrichment/depletion of other non-PHC gases (CO_2, N) due to biological processes. The degree of alteration will depend on the distance of migration, the subsurface characteristics encountered, and time.

Water Well Drilling and Pump Installation Artifacts

WSW and pump installation may affect the quality of water inside the well casing if clean practices are not observed. Although USQEP currently requires water well contractors to use clean practices, this was not an explicit requirement in the recent past, and past practices may be responsible for some PHC detections. Examples of well and pump installation practices that might result in PHC detections in well water samples are:

- Unfiltered compressed air from air rotary drill rigs;
- Hydraulic oil leaks from drilling equipment during drilling and/or installation;

- Not cleaning well casing or drilling tools prior to installation;
- Use of petroleum-based pipe dope drill rods, tools, and bits during drilling, and on drop pipe threads and fittings during pump installation; and
- Not cleaning submersible pumps and/or drop pipe between wells.

Geomatrix has observed grease and/or pipe dope on wellheads and pipe fittings, and has observed a substance similar to pipe dope discharging from wells during well sampling activities. Geomatrix collected samples of weathered pipe dope from a PAPA water supply wellhead and unweathered pipe dope (Bestolife Copper Supreme Special Blend Plus) from a PAPA water well contractor and had both samples analyzed for PHC. Analytical results for both samples indicated the presence of benzene, xylenes, toluene, TPH in the gasoline range, and total purgeable hydrocarbons, and longer chain hydrocarbons in the C12 to C35 range.

PHC detections resulting from well drilling and pump installation practices may primarily affect the well bore with minimal impact to formation water. Removal of this material (e.g., via pumping and/or other cleaning methods) should mitigate these impacts.

Historic and Current Oil and Gas Activities

Current and historic field development practices relevant to this LLPHC Study include:

- *Well construction and abandonment practices* – Based on information available and Operator interviews, early natural gas wells were often constructed with minimum lengths of surface casing and long intervals of uncased, uncemented open hole. The uncemented sections of these wells may allow vertical migration of fluid and/or gas. Additionally, relatively lightweight steel casing (relative to modern) used in these wells might be susceptible to failure and corrosion. A PAPA-specific example is the Pinedale 2, which was installed in 1955 with 450 feet of surface casing and open hole to a depth of 7,748 feet. Available records for Pinedale 2 indicate a history of intermittent production. It was plugged and abandoned on October 8, 2004, approximately 49 years after its spud date.

  Modern casing and cementing programs and quality control measures are very different from early practices; therefore, relative to early gas wells, modern gas wells are unlikely conduits for gas or fluid migration. Modern PAPA gas wells are constructed using continuous casing from ground surface to a depth below the fresh groundwater. In the PAPA, this is typically 2,500 feet or more below ground surface._The annulus between the surface casing and borehole is sealed by circulating cement from bottom to top. Cement bonding logs are sometimes run for quality control to ensure that no gaps are present. If gaps are found, that section of the casing is perforated and cement is squeezed through the perforations into the annulus. The adequacy of the repair is typically checked with another cement bonding log and the process is repeated, if necessary. The remainder of the well is installed using subsequently smaller and overlapping casings that are cemented at least as high as the bottom of the surface casing. Cement bonding logs may be run after each casing installation. Other quality control checks (e.g., pressure checks) are also routinely employed.

  Another type of potential vertical conduit for fluid and gas migration is improperly constructed WSWs. The early gas well Wagon Wheel #1 had two associated WSWs that were, based on available records, installed to depths of 2500 and 5180 feet. Both wells were perforated over

multiple intervals, and the lowest perforated interval of the shallower well (Wagon Wheel 1 WSW) coincided with the uppermost perforated interval of the deeper well (Wagon Wheel 2 WSW). Even under static (i.e., non-pumping) conditions, vertical movement of fluids could occur through these wells and alter water quality in shallower groundwater. The status of these wells is uncertain, and water quality data was not found in the project database for either well.

- *Historic management of E&P fluids* – Information collected from BLM and WOGCC files indicate that mixtures containing thousands of gallons of kerosene, fuel oil, and/or natural gas condensate were used in PAPA hydraulic fracturing operations as early as 1954. A PAPA-specific example is a 1955 fracture stimulation of the Pinedale 2 gas well, which used a total of 55,000 gallons of kerosene and fuel oil. There is no information on how these materials and resulting waste fluids were handled or disposed.
- *Historic surface releases of E&P fluids and fuels* – Historic spills of fuel and E&P fluids may not have been adequately addressed due to less stringent environmental regulation. Apparent discharges of fluid of unknown composition from the Pinedale 2 and Pinedale 3 locations were observed on 1955 aerial photographs, which show the locations shortly after and during drilling, respectively. Currently, surface releases are reported to the appropriate regulatory agency(s) (BLM, WOGCC, Wyoming Department of Environmental Quality [DEQ]), which provide regulatory oversight of cleanup efforts.
- *Spills and leaks of condensate and/or produced water from production units and above ground storage tanks* – Modern secondary containment systems for tank batteries include a berm and impermeable liner; however, this was not required in the past. Spill containment is typically built into modern production units or consists of HDPE liner installed beneath the unit. Methanol is typically dispensed from poly-tanks that are constructed with built-in secondary containment. It is uncertain to what extent secondary containment measures were employed at production units in the past.
- *Oilfield Pits* – Pits may be used to contain oil- and water-based drill cuttings and completions and workover fluids (e.g., hydraulic fracturing fluids, condensate, produced water). Oil-based and water based cuttings are typically segregated in separate pits, and cuttings containing oil-based drilling mud may be solidified within the pit liner and subsequently buried. There is often a separate lined pit for completions fluids. Chapter 4 of WOGCC rules currently requires pits to be lined if they are located in sensitive areas or are used to contain oil-based muds, high density brines, and/or completions fluids. Additionally, the 2000 PAPA ROD (BLM, 2000) required produced water and reserve pits to be constructed in a manner that ensured protection of surface water and groundwater resources, including use of liners where warranted based on distances to surface water and groundwater resources and/or soil permeability characteristics. Based on information communicated by BLM (email communication from Bill Lanning, BLM Pinedale Field Office, September 19, 2010), liners have been a Condition of Approval (COA) for approval of all Applications for a Permit to Drill (APD) since shortly after the 2000 PAPA ROD was issued. The extent to which synthetic liners were utilized in the PAPA prior to 2000 is uncertain. The current trend is away from the use of pits and toward the use of closed-loop drilling and completions systems.
- *Accidental introduction of PHC directly into water wells* – Operators have identified backflow of PHC-contaminated fluids directly into WSWs as being responsible for some PHC detections. WSWs where backflow is known or suspected to have occurred are North Pinedale 14-8, North Mesa 4-7, Warbonnet 8-6, and Riverside 15-12. PHC have been removed from these wells by overpumping and/or implementing procedures to clean the well casing and remove

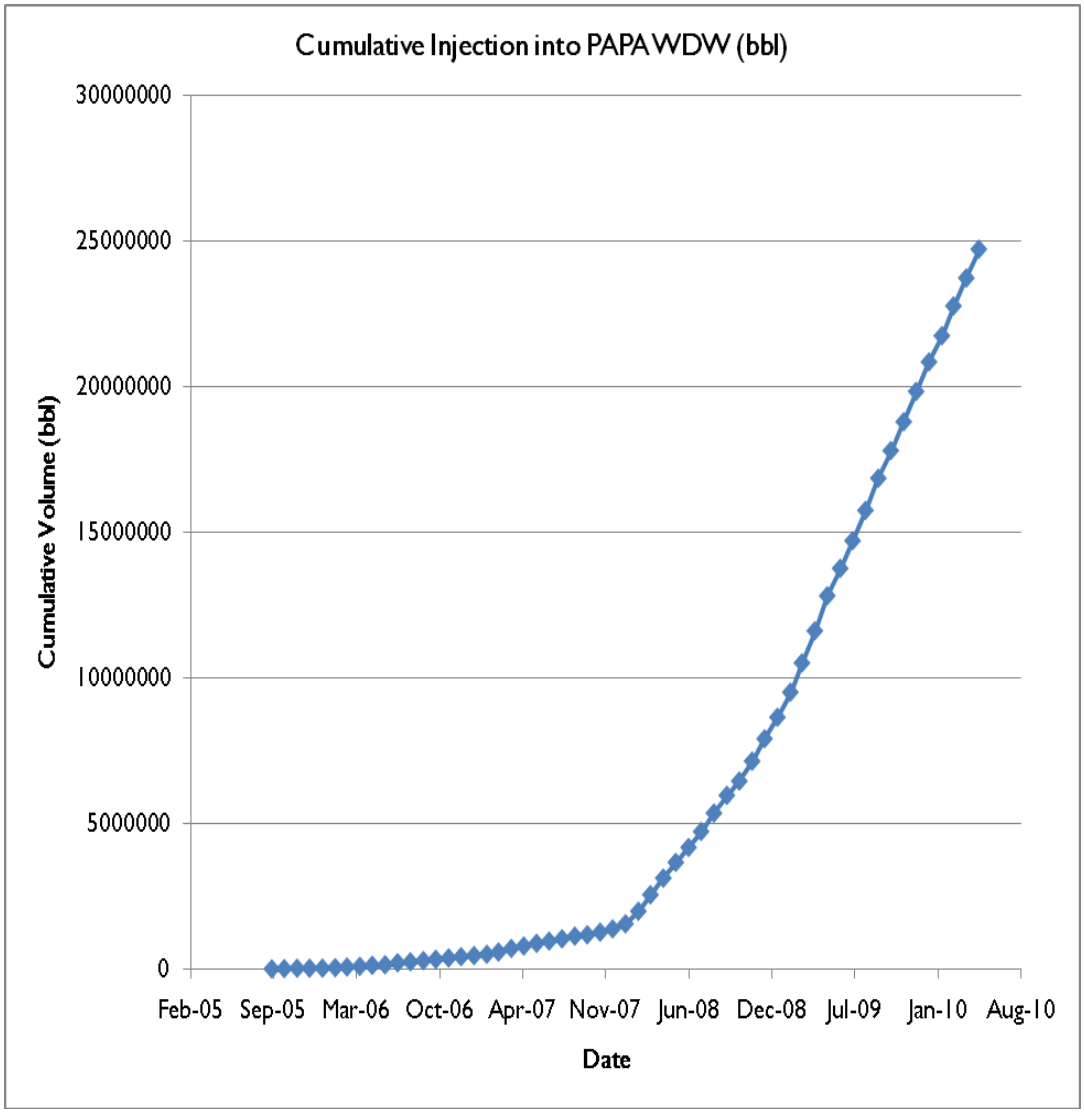
contaminated water above the perforated intervals. Fluid removed from these wells was properly disposed.

- *Underground injection of produced water* – According to WOGCC records, permitted Class II water disposal wells (WDW) have been utilized for subsurface injection of produced water in the PAPA since September 2005. All WDW are completed in the Fort Union Formation at depths of 4,589 feet or deeper, and are cased and cemented through the overlying freshwater formations (maximum depths for domestic, stock, and industrial wells in the PAPA are approximately 320 feet, 600 feet, and 1210 feet, respectively; average depths of the three well types are approximately 116 feet, 195 feet, and 644 feet, respectively). At the end of 2007, only three injection wells were active: PG State 36-1, Hwy SWD #11, and RS 6-16 WDW. These wells are located away from the main field development (see Figure 2). By May 2007, most WSWs with PHC detections had been discovered by the SCCD and the Operators. The timing of injection well activity relative to the timing of PHC discovery indicates that these wells are not likely sources of most, if any, PHC detections.

  A marked increase in water injection occurred in January 2008, with injection amounts averaging approximately one (1) million barrels per month since March 2009. The current number of permitted WDW is 21 (see Figure 2). The volume of produced water disposed via WDW through May 2010 is 24,729,064 bbl. Cumulative injection of produced water in the PAPA is illustrated below (see next page).

- *Well completion operations* – As previously stated, hydraulic fracturing was performed on PAPA gas wells as early as 1954. Based on review of BLM files, fuel oil, kerosene, natural gas condensate, and diesel and/or condensate emulsions were commonly used in completions fluids. One major PAPA Operator indicated that diesel fuel was phased out in 2007. A typical formulation in 2005 reportedly contained >99.5% by volume water, sand, and inert solids such as aluminum silicate, aluminum oxide and silicon dioxide. The amount of diesel used in completions fluids was approximately 0.09% by volume. Modern completions fluid used by this Operator consists of >99% water, sand, and similar inert solids. Although the use of diesel fuel has been discontinued by this Operator, other Operators may still use diesel fuel in their completions fluids. Furthermore, recycled water (e.g., produced water) used in completions fluids may contain PHC. Based on information supplied by the Operator, non-PHC additives that comprise <0.5% by volume of completions fluids may include a combination of the following non-petroleum hydrocarbon compounds:

  - guar gum
  - alkylated quaternary chloride
  - ammonium acetate
  - acetic acid
  - EDTA/copper chelate
  - sodium persulfate
  - sodium chloride
  - potassium metaborate
  - sodium hypochlorite
  - potassium formate
  - chlorous acid / sodium salt
  - ethoxylated nonylphenol
  - isopropanol
  - borate salts
  - methanol
  - potassium carbonate
  - 2-bromo-2-nitro-1,3-propanediol
  - ammonium persulfate
  - sodium hydroxide



Source: http://wogcc.state.wy.us/

Spills or Releases from Sites not Related to Historic or Current Oil and Gas Activities

The following public databases were accessed in order to evaluate potential PHC sources not associated with natural gas E&P activities:

- EPA RCRA 2020 Corrective Action Universe;
- EPA Envirofacts database;
- Wyoming DEQ Storage Tank Program database;
- Wyoming DEQ and WOGCC spill databases;
- Wyoming DEQ's solid and hazardous waste site listings; and
- BLM's "Undesirable Events" database.

The following information was obtained from these sources:

- No sites were listed in Sublette County from the EPA RCRA 2020 Corrective Action Universe.
- The EPA Envirofacts database did not return any entries for Sublette County additional to entries that were found in State and Federal databases.
- Seven unresolved sites and 11 resolved sites are found in the vicinity of the PAPA in a search of the Wyoming DEQ Storage Tank Program database (**Figure 2**). One resolved site was found to be located inside the PAPA boundary.
- Seven sites were found in Wyoming DEQ's solid and hazardous waste site listings in Sublette County. Three of these sites are operating or historic municipal landfills, two of which are located inside the PAPA boundary (**Figure 2**).
- Numerous listings were found for spills in the BLM "Undesirable Events" database. These listings were not considered likely sources of PHC in groundwater, as each received regulatory oversight in resolving the reported release.

With the exceptions of those facilities discussed below, most facilities listed above are not considered likely sources for PHC based on their locations and/or degree of regulatory oversight. However, all potential sources, including recorded spills and releases within the PAPA that received regulatory oversight during cleanup, will be considered when evaluating data generated by execution of this SAP.

Landfills and Permitted Oil-Disposal Facilities

Three existing or former landfills are located within or proximal to the PAPA: the Pinedale #1, Pinedale #2, and the Old Boulder Landfill (**Figure 2**). Pinedale #1 is a historic municipal landfill located below Freemont Lake approximately three (3) miles northeast of the PAPA. Due to its location, Pinedale #1 is not a likely source of PHC occurrences in the PAPA. Pinedale #2 and the Old Boulder Landfill are located within the PAPA boundary. Pinedale #2 is a closed municipal landfill and the site of an active transfer station, and is located in the northern PAPA in T30N R110W Section 2. No additional information on this landfill was made available to Geomatrix.

The Old Boulder Landfill is located south of the New Fork River in the vicinity of the Boulder South Road / Highway 191 intersection. Information concerning the groundwater monitoring network at the landfill, which was obtained from the WDEQ, did not indicate that the landfill is affecting groundwater quality; however, at the time of the inquiry, a new, downgradient monitoring well was being installed in order to further evaluate potential impacts. PHCs have been detected in water samples from the Boulder 15-4 WSW, which is located approximately one ½ mile north-northwest of the landfill.

Municipal landfills may contain a wide variety of organic and inorganic substances that could impact groundwater. Typical landfill monitoring programs include analyses for methane, metals (arsenic, barium, beryllium, cadmium, chromium, cobalt, copper, lead, nickel, selenium, silver, thallium, vanadium, zinc), volatile organic compounds (VOC), and semivolatile organic compounds (SVOC).

Two WDEQ-permitted oil-disposal facilities are located within or at the boundary of the PAPA: the Anticline Disposal facility and the Newpark Facility. The Newpark Facility, located in Sand Springs Draw Industrial Park, was constructed in 2002. The facility was permitted to accept and treat produced water and petroleum-contaminated soil (PCS), but has been closed since 2006. The facility is equipped with a double-liner and interstitial monitoring system to detect leaks through the primary liner, as well as a

groundwater monitoring network. Based on information from WDEQ, no leaks through the primary liner have been detected, thus the groundwater monitoring well network has not been sampled. The location of this facility adjacent to the PAPA eastern boundary and the distance from PAPA development make it an unlikely source for PHC detected in PAPA WSWs.

Anticline Disposal was constructed in 2002 to treat flowback and produced water. The facility includes an oil/water separator, evaporation ponds, water treatment system, and fresh water storage pit. The facility maintains a Wyoming Pollutant Discharge Elimination System (WPDES) discharge permit for the New Fork River and Sand Draw. The cells of the water-evaporation system are tripled-line and have an interstitial leak-detection monitoring system. A groundwater monitoring network has been established at the facility. According to information obtained from WDEQ, groundwater monitoring performed at the facility does not indicate that a release from the facility has occurred.

Sampling Methods, Laboratory Analytical Issues/Discrepancies

Groundwater samples can become compromised if correct sampling procedures are not employed. These procedures include use of clean, new, disposable equipment or thoroughly decontaminated reusable equipment. Since 2004, groundwater samples have been collected by many individuals representing numerous entities; consequently, it would be very difficult to comprehensively evaluate the sampling procedures that have been employed in the PAPA after the fact. However, a few procedures and conditions that might bias samples or result in false positives include the following:

- Inserting and retrieving a bailer through the stagnant water between the static water level and the perforated interval without first checking the top of the water column for substances (e.g, floating hydrocarbons) that may have been introduced into the WSW.
- Retrieving a standard bailer equipped with a ball-seat check valve in an attempt to collect a grab sample of fresh formation water. Movement of the ball-seat valve during bailer retrieval likely results in the sample actually being collected from near the top of the water column within the casing.
- Difficulty associated decontaminating the braided steel cable previously used to retrieve bailers from the WSW.
- Insufficient decontamination of pumping equipment prior to inserting into the WSW for sample collection.
- Contamination of a sample due to oil residues on the WSW wellhead or in ambient air at the time of sample collection.
- Use of laboratory analytical methodologies that are unable to distinguish interfering compounds from target analytes (e.g., EPA 8021 vs. EPA 8260).

Procedures described in this SAP are designed to avoid sample biases due to these and other potential influences.

2.6 ANALYTE SCREENING FOR PHC-IMPACTED INDUSTRIAL WSW

Once the potential sources of PHC were researched, a site-specific potential PHC source matrix was developed, which is provided as **Table 3**. The matrix lists the sources that could potentially have impacted the industrial WSWs that contain, or have contained, PHCs in water well samples. Pre-1984 gas wells and associated facilities were considered a potential source for WSWs located within a two-

mile radius. Permitted oil disposal facilities, Class II injection wells, landfills, and Wyoming DEQ-listed sites from the Storage Tank Program or Hazardous and Solid Waste listings were considered a potential source for WSWs if located within a one-mile radius, even though the probability of impact was considered low or very low. No sites from the Hazardous and Solid Waste listings were located within one mile of a WSW. WSWs were not compared against locations where releases occurred as listed in the BLM Undesirable Events database. Mitigation measures (e.g., removal of contaminated soil) for each release are detailed in the database and the likelihood of these reported releases affecting a WSW is considered low. The following were considered potential sources for all WSWs and not included in the matrix:

- Natural sources;
- Artifacts of water well drilling and pump installation practices;
- Current oil and gas activities; and
- Laboratory artifacts/discrepancies.

Upon review of the matrix, pre-1984 gas wells and associated facilities appear to be the most commonly associated potential source of PHCs in industrial WSWs, in addition to the sources listed above.

The WSWs in **Table 3** were also placed into the following categories:

- Wells with PHC detections during the last round of sampling;
- Well with historic PHC detections where PHCs were not detected during the last round of sampling;
- Wells with one-time (or sporadic) detections of PHC (typically DRO and/or toluene); and
- Wells with historic PHC detections that have been plugged and abandoned.

The wells were categorized in this manner to assist in evaluating which wells were to be sampled as part of the sampling and analysis program. For example, industrial WSWs that have been plugged and abandoned cannot be sampled; however, data collected from them previous to abandonment may be useful in evaluating potential sources.

2.7 CORRELATION ANALYSES

Correlation coefficients were calculated for analytical data pairs (e.g., benzene and chloride) in order to evaluate potential relationships between monitored constituents. Spatial relationships were also evaluated by calculating correlation coefficients between individual analytes and geographic position (northings and eastings). Results of this analysis are summarized as follows:

- Strong positive correlations (>0.9) were apparent between paired PHCs (e.g., benzene and TPH-GRO).
- Positive correlations between pairs of common ions (e.g., calcium and magnesium; potassium and sodium) and related general water quality parameters (e.g., total dissolved solids [TDS] and sulfate) were found to be relatively strong (>0.8).

- Positive correlation coefficients greater than 0.5 and negative correlations less than -0.5 were calculated for several inorganic/PHC pairs (e.g., magnesium/xylene-isomers, sulfate/xylenes, sodium/xylenes, fluoride/xylenes, TDS/xylenes). However, based on an examination of the dataset, these calculated coefficients appear to be due to the limited number of xylene detections rather than true relationships.
- Fluoride and sodium absorption ratio exhibited negative correlations with latitude (-0.54).

The remainder of the data pairs exhibited correlation coefficients approaching zero, indicating weak or nonexistent relationships.

Figure 2 illustrates the locations of all identified potential sources as well as the history of PHC detections in groundwater throughout the PAPA, including locations of "LEL wells" identified by the SCCD and wells where methane in well casings has been detected by Geomatrix. Examination of **Figure 2** indicates some apparent clustering of PHC detections, current and past exceedences of regulatory standards, the presence of methane gas in water wells, and locations of early (1980s and earlier) E&P activities. Clustering of these features is particularly apparent in the following areas:

- Northern Warbonnet area in and around Section 5;
- Middle Warbonnet area in and around Section 15; and,
- Antelope area in Sections 3, 4, 9, and 10.

The spatial distribution of water quality is discussed in the Hydrogeologic Conceptual Model Report (Geomatrix, 2008). Sodium-carbonate/bicarbonate type groundwater is more prevalent north of the New Fork River. South of the New Fork River, sodium chloride and sodium-sulfate groundwater types are more prevalent. Chloride concentrations near the common corner of the Warbonnet, Boulder, and Riverside areas, an area in which concentrated, early (1980s and earlier) gas E&P activity occurred, are elevated relative to other PAPA wells and have been reported as high as 258 mg/L. The median and average chloride concentrations reported by Geomatrix (2008b) for deep (bottom elevations <6900 feet) Wasatch wells are 15 mg/L and 29 mg/L, respectively.

Based on information from Chafin and Kimball (1983), expected sulfate concentrations in Wasatch WSWs are as high as 200 mg/L. The highest sulfate concentrations in PAPA wells (approximately 900 mg/L to 1,600 mg/L) were measured in samples from the north Warbonnet area near early gas wells Pinedale 5 and Pinedale 1, and in the south Boulder area near Pinedale 2.

Based on currently available information, it is unclear if these water quality characteristics and apparent correlations are due to natural or anthropogenic activities. A sampling program has been developed to augment the existing data set in order to further evaluate potential PHC sources identified above with respect to water quality parameters. The following sections describe the technical approach that will be used to collect additional data.

3.0 TECHNICAL APPROACH

Various potential source media, in addition to environmental media, will be sampled and analyzed for key parameters for characterization purposes, which will aid in the determination of the likely source(s) for individual PHC detections in WSWs. It is expected that the probability of determining the source(s) of PHC in a WSW will be greater at locations with higher PHC concentrations and consistent PHC detections. Therefore, the initial sampling and analysis effort (Phase 1) will target WSW with these characteristics. The sampling program can then be modified, if necessary, based on results of the initial effort and expanded to include additional PHC wells during subsequent sampling events (Phase 2).

3.1 SAMPLING AND ANALYSIS PLAN WELL NETWORK

WSWs included in the initial sampling effort will include:

1) a Control Group comprised of industrial WSWs where PHC have never been detected, as well as a study well (T-5-RW) installed upgradient of active E&P activities by Geomatrix as part of the Hydrogeological Data Gaps Study (Geomatrix, 2009b);

2) a PHC Group comprised of industrial WSWs where PHC have been detected; and

3) a Study Well Group comprised of study wells constructed in accordance with environmental industry standards and installed on natural gas production pads by Geomatrix as part of the Hydrogeological Data Gaps Study.

(Note: Study wells that are not included in this SAP will be sampled for PHC as part of the Hydrogeologic Data Gaps study).

The Control Group is comprised of seven (7) WSW (**Table 4** and **Figure 3**). The locations of, and construction and installation techniques used for, WSWs in this group were similar to the PHC Group; however, PHC have not been detected in water samples collected from these wells. Criteria for selection of WSW included in the Control Group were:

- No PHC detections for the period of record;
- Proximity to PHC Group WSW and/or potential sources; and,
- Good geographic distribution throughout the PAPA.

The PHC Group is comprised of twenty (20) WSWs (**Table 4** and **Figure 3**). Criteria for selection of WSWs included in the PHC Group were:

- Elevated PHC concentrations relative to other PAPA PHC WSWs;
- Consistent PHC detections;
- Representative of the variety of PHC detections throughout the PAPA (includes "LEL wells");
- Proximity to potential sources in addition to modern natural gas E&P activities; and,
- Broad geographic distribution.

The Study Well Group is comprised of ten (10) study wells (**Table 4** and **Figure 3**). These wells were installed to environmental industry standards; therefore, data collected from them will be used, in part, to evaluate the influence of WSW and pump installation practices.

3.2 SAMPLING AND ANALYSIS PROGRAM

The planned sampling and analysis program includes PHC source characterization, groundwater sampling and analysis, and unprocessed natural gas sampling and analysis. The following table summarizes the types of samples to be collected during Phase I sampling, the analyses to be performed, and the anticipated uses of the resulting data:

Media	Data Parameters	Data Uses
Groundwater Produced Water Completions Fluid/Flowback Oil-Based Drilling Mud (as appropriate) Pipe Dope (as appropriate)	Common anions (Cl, SO_4, NO_3, NO_2, HCO_3, CO_3, PO_4), fluoride (F), bromide (Br), total TAL metals, silica (Si), strontium (Sr), boron (B), total dissolved solids (TDS), alkalinity	-Identify potential impacts from exploration and production activities -Identify potential impacts from well drilling and installation practices -Distinguish between the types of groundwater in the PAPA
Groundwater Produced Water Condensate Completions Fluid/Flowback Oil-Based Drilling Mud Pipe Dope	TPH-GRO/DRO by GC/FID VOC analysis by GC/MS + Tentatively Identified Compounds (TICs) SVOC analysis by Methods 3510/8015 + TICs	-Identify (or prevent misidentification) of VOCs detected in groundwater in the gasoline organics range by coupling gas chromatography with mass spectroscopy -Source determination
Groundwater	Dissolved gas composition: C1-C5 gases, fixed gases	-Compare general compositional characteristics to evaluate correlation between gases present in groundwater, natural gas, and well casing headspace. -Calculate C1/C2 + C3 ratios to compare between gases and to evaluate the potential for migration of gas -Identify wells to be sampled for stable isotope analysis of methane
Produced Gas Well Headspace Gas	Gas composition: C1-C5 gases, fixed gases, benzene, toluene, ethylbenzene, xylenes (BTEX)	
Groundwater Produced Gas Well Headspace Gas	Stable isotopes of methane: ^{13}C and deuterium	-Determine the origin of dissolved methane in groundwater and well headspace gas (thermogenic or biogenic)
Groundwater Condensate Produced Water	Stable isotopes of benzene, if possible: ^{13}C and deuterium	-Evaluate the origin of benzene
Groundwater Produced Water	Stable isotopes of water: ^{18}O and deuterium	-Compare to global meteoric water line and Tertiary meteoric water line to identify sources or mixing of water
Carbonaceous Strata	Vitrinite reflectance	-Evaluate thermal maturity of formation

3.2.1 Source Material Characterization

Samples will be collected of materials used or produced in the PAPA that are most likely to be sources for PHC detections in WSWs. The petroleum chemical characteristics of these materials will be determined by subjecting them to laboratory analyses. The laboratory will prepare reference samples using uncontaminated Wasatch Formation water and the source materials for analysis of volatile and semi-volatile organic compounds (VOC, SVOC). Chromatograms of the reference material/formation water preparations will be compared to chromatograms of groundwater samples collected from WSWs. Using retention times and peak height, comparisons will be made as to the best fit of the hydrocarbons present in groundwater samples from WSWs to the hydrocarbons present in source materials.

These characterizations will include the following source materials:

Natural Gas Condensate

One sample of natural gas condensate will be collected from the PAPA and analyzed for volatile and semi-volatile organic compounds (VOC, SVOC) via gas chromatography / mass spectrometry (GC/MS). Results will be compared to results of WSW samples, which will be subjected to the same analysis.

Operators will assist with collection of these samples.

Produced Water

One sample of produced water from each of the Stewart Point, Mesa, Riverside, Rainbow, Warbonnet, and Antelope areas will be collected and analyzed for the following:

- VOC and SVOC via GC/MS;
- TPH-DRO and TPH-GRO;
- Metals (total) - Target Analyte List (TAL) metals (see **Table 5**) plus boron (B), strontium (Sr), and silicon (Si) (total); and,
- Stable isotopes of oxygen (^{18}O) and hydrogen (deuterium (D)) in water.

Operators will assist with collection of these samples.

Completions Fluids / Flowback

One sample of early flowback fluids will be collected from each of the three Operators participating in this study and analyzed for the following:

- VOC and SVOC via GC/MS;
- TPH-DRO and TPH-GRO via GC/FID; and,
- Metals (total) - TAL metals (see **Table 5**) plus boron (B), strontium (Sr), and silicon (Si) (total).

Pipe Dope

A representative number of pipe dope samples will be collected from drilling and pump installation contractors and analyzed for the following:

- VOC and SVOC via GC/MS;
- TPH-DRO and TPH-GRO via GC/FID; and,
- Metals (total) - TAL metals (see **Table 5**) plus boron (B), strontium (Sr), and silicon (Si) (total).

If pipe dope is observed on pipes and/or fittings when submersible pumps are removed from a WSW, a grab sample will be collected and subjected to the above analyses.

Oil-Based Drilling Mud

A representative number of drilling mud samples will be obtained from each of the three Operators participated in this study and analyzed for the following:

- VOC and SVOC via GC/MS;
- TPH-DRO and TPH-GRO via GC/FID; and,
- Metals (total) - TAL metals (see **Table 5**) plus boron (B), strontium (Sr), and silicon (Si) (total).

Operators will assist with collection of these samples.

Diesel, Gasoline, Hydraulic Oil and Compressor oil

These source materials will not be characterized since sufficient information, including type chromatograms, should be readily available.

3.2.2 Natural Source Characterization

Natural sources will largely be evaluated through a weight-of-evidence approach using existing data and information. Additionally, vitrinite reflectance analyses will be performed on formation samples associated with natural gas encountered in the Wasatch Formation during installation of study wells. This analysis will determine if the carbonaceous shale strata where gas was encountered was subjected to sufficient temperature and pressure to produce gas and/or oil (i.e., gas and associated PHC may have formed in the Wasatch Formation).

3.2.3 Light Non-Aqueous Phase Liquids

The presence of light non-aqueous phase liquid (LNAPL) will be evaluated prior to collecting water samples from each WSW by obtaining a sample from the air-water interface at the top of the water column with a clear bailer. If present, a sample will be collected and subjected to the following analysis:

- VOC and SVOC;
- TPH-DRO and TPH-GRO; and,
- Metals (total) - TAL metals (see **Table 5**) plus boron (B), strontium (Sr), and silicon (Si) (total).

3.2.4 Groundwater

Groundwater will be collected from each WSW in the PHC Group, Control Group, and Study Well Group, and analyzed for the following parameters:

- VOC and SVOC;

- TPH-DRO and TPH-GRO;
- Metals (total) - TAL metals (see **Table 5**) plus boron (B), strontium (Sr), and silicon (Si) (total);
- Stable isotopes of oxygen (^{18}O) and hydrogen (deuterium (D)) in water;
- Dissolved gases (methane, ethane, ethane, iso-butane, n-butane, propane, propene);
- Alkalinity;
- Anions (bicarbonate, chloride, fluoride, sulfate, phosphate, bromide); and,
- Nitrate-N, nitrite-N, ammonia.

Groundwater samples will be analyzed for VOCs by EPA Method 8260 and for SVOCs by EPA Method 8015 in order to identify the specific compounds that make up the petroleum hydrocarbons detected in groundwater collected from the wells. Tentatively identified compounds (TICs) will be evaluated in order to more accurately characterize the sample and aid in source identification. If benzene is detected at concentration $\geq$5 micrograms per liter (µg/L), compound specific isotopic analysis may be performed during Phase 2 to further characterize the its origin, if warranted. Groundwater samples will also be analyzed for TPH-GRO and TPH-DRO. Reporting limits of 0.02 mg/l and 0.30 mg/l will be targeted for TPH-GRO and TPH-DRO, respectively, to ensure the quantification of low PHC concentrations.

The composition of dissolved gases in groundwater will be compared to the composition of gas in well casings and natural gas production wells (see Section 3.2.3). The presence of these gasses (C1 through C4) in groundwater may provide additional evidence that natural gas is migrating upward from reservoirs and into the Regional Wasatch HSU, possibly in conjunction with associated light aromatic hydrocarbons (e.g., BTEX). However, the presence of these gases will not rule out gas migration due to anthropogenic effects, such as unsealed or poorly sealed active or abandoned natural gas wells or excursions into the formation while drilling. Wells containing adequate concentrations of methane in groundwater will be targeted for sampling and analysis of stable isotopes of carbon (^{13}C) and hydrogen (^{2}H) in methane during the Phase 2 sampling efforts. This analysis will be used to identify the origin of methane (i.e., thermogenic or biogenic) and evaluate any possible changes (i.e., enrichment or depletion) in the carbon and hydrogen isotopes due to gas migration.

Stable isotopes of hydrogen (^{2}H) and oxygen (^{18}O) in groundwater will be used to evaluate the origin of waters from each sample group (Control, PHC, Study Well) by comparison to reference meteoric water lines (e.g., global, tertiary).

The presence of certain inorganic parameters has been identified as possible indicators of E&P activities related to potential PHC sources. The presence and concentrations of these constituents in groundwater will be evaluated against source materials (see **Table 5**). Standard techniques such as Stiff and Piper diagrams will be used to compare water obtained from WSW to other water types (e.g., produced water, Fort Union Formation water) as part of the source evaluation.

3.2.3 Stray Gas Evaluation

Because the presence of natural gas in WSWs indicates a pathway for migration of associated PHC, its origin should be evaluated. Gas samples will be collected from those WSWs in the PHC Group where combustible gas has been detected (see **Table 4**). Samples will only be collected from those wells where a gas flow rate can be measured. This determination will be made using the methods outlined in Section 5.3, below. An unprocessed gas sample will also be collected from the nearest active gas well on the associated pad. In order to provide a basis for comparison of the two gases, paired samples will be subjected to the following analyses:

- Extended gas analysis for PHC, C1 through C10, as well as other noncombustible gases (e.g., CO2, H2S, N); and
- Stable isotopes of carbon (^{13}C) and hydrogen (deuterium) in methane.

Additional evaluations that may be performed during Phase 2 sampling efforts include soil gas surveys at locations sampled during Phase 1 and early gas well locations.

4.0 DATA QUALITY OBJECTIVES

The Data Quality Objective (DQO) process is used to establish performance or acceptance criteria for data collection activities. These criteria in turn serve as the basis for designing a plan for collecting data of sufficient quality and quantity to support goals of the study. The DQO process is systematic and begins by defining the problem and identifying the goals and objectives of the sampling and analysis plan. Subsequent steps identify information inputs and measurement performance criteria. Data collection methods and the analytic approach are designed to satisfy study goals and objectives of the sampling and analysis program.

4.1 MEASUREMENT PERFORMANCE CRITERIA

Measurement performance criteria are established for each field and laboratory parameter or similar group of parameters. Measurement performance criteria are established by defining acceptance criteria and quantitative or qualitative goals (e.g., control limits) for precision, accuracy, and completeness. Quality control acceptance criteria for accuracy and precision of data to meet DQOs for the sampling and analysis program are presented in **Table 6**. Requirements for laboratory analytical data precision, accuracy, and completeness are provided in the following sections.

4.1.1 Precision

Precision is a measure of the degree to which two or more measurements are in agreement. Determining the agreement among replicate measurements of the same sample assesses the precision of the analytical method; combined precision of sampling and analysis methods is assessed from the agreement between measurements of duplicate samples.

Precision of sampling and analysis methods will be assessed through the collection of field duplicate samples at a minimum rate of one field duplicate per 10 samples for each sample media. The relative percent difference (RPD) in the results for each analyte will be computed for each field duplicate pair using the equation provided below. The goal for precision of field duplicate results is ± 35 percent RPD for water samples. However, if one or both samples in a field duplicate pair have a concentration less than 10 times the method detection limit (MDL), the field precision goal will be ± 5 x MDL.

$$RPD = [(\text{sample} - \text{duplicate value}) \div [(\text{sample} + \text{duplicate value}) \div 2]] \times 100$$

Precision of the analytical method for PHC and inorganic parameters in water will be assessed through duplicate analyses of laboratory QC and field samples. The RPD for each analyte will be computed for each analytical duplicate pair. Data for duplicate analysis will be evaluated only if the both of the samples in the duplicate pair have a concentration greater than the laboratory MDL. The laboratory precision goal for water samples is ± 20 percent RPD.

Precision of laboratory analytical results for dissolved gases in groundwater samples will be evaluated using field duplicate samples. For headspace samples of extended gas and stable isotopes of methane, precision will be quantified using field duplicates.

4.1.2 Accuracy

Accuracy is the degree of agreement between an observed value and an accepted reference or true value. Data accuracy will be evaluated using results from laboratory control samples and matrix spike samples, expressed as percent recovery or percentage of the true (known) concentration that is measured. Accuracy is controlled by proper use, calibration, and maintenance of both field and laboratory equipment for measurement of physical and chemical parameters.

Accuracy in the field will be assessed through collection of equipment blanks and field blanks and adherence to all sample handling, preservation and holding time requirements. The accuracy objective for equipment and field blanks will be non-detect results (<MDL) for all analytical parameters of interest.

Laboratory accuracy may be evaluated by the analysis of laboratory control and matrix spike samples, with results expressed as a percentage of recovery measured relative to the true (known) concentration. For water samples, laboratory control and matrix spike samples should be in the recovery range of 80 to 120 percent (75 to 125 percent for dissolved gas samples) and 75 to 125 percent (70 to 130 percent for dissolved gas samples), respectively. In addition, laboratory preparation blank results may be used to measure any contamination introduced during the analytical process. The accuracy objective for laboratory preparation blanks will be non-detect results (<MDL).

For extended gas and stable isotope analyses of headspace samples collected from well casings, accuracy will be assessed by comparing results for a laboratory control sample to a calibration standard. Results should be within 3 percent and less than 9 percent of the standard values for extended gas and isotope analyses, respectively.

4.1.3 Completeness

Completeness is the percentage of valid measurements or data points obtained, as a proportion of the number of measurements or data points planned for the project. Completeness is affected by such factors as sample bottle breakage and acceptance/non-acceptance of analytical results. Percentage completeness (C) is calculated by the following equation:

$$C\ (\%) = V \div P \times 100$$

where: V = number of valid measurements/data points obtained; and

P = number of measurements/data points planned.

Laboratory completeness will be affected by factors such as sample bottle breakage and acceptance/rejection of the analytical results during the data validation process. The percentage of completed analyses required will depend on the sampling design and data use. Expectations of completeness should be higher when fewer samples are collected per event or site. The laboratory completeness goal is 95 percent.

5.0 FIELD METHODS AND PROCEDURES

5.1 FIELD EQUIPMENT

The following sections detail the field equipment that will be necessary to execute this SAP and calibration of equipment, as applicable, to ensure collection of defensible data.

5.1.1 Equipment List

The following field equipment is needed to complete the sampling and analysis program:

Field Notebook	☐	Health and Safety Plan	☐
Job Safety Analysis	☐	Groundwater and Gas Sampling Forms	☐
Chain-of-Custody Forms	☐	Indelible Markers and Pencils	☐
Personal Protective Equipment – hard hats , safety glasses, steel toe boots, flame resistant clothing (FRC), gas monitor	☐	Latex or Nitrile Gloves	☐
J-Plugs w/ Barbed Fittings	☐	Flexible Tubing	☐
Air Flow Meter	☐	Combustible Gas Indicator (CGI) - %LEL, % O_2	☐
Decontamination Equipment and Fluids – Alconox or similar product, distilled water, spray bottles, and brushes	☐	HydraSleeves™- suspension lines, polyethylene sampling sleeves, stainless steel weight with clip, discharge tube	☐
Sample Port Fittings	☐	Crescent and Pipe Wrenches (2 each)	☐
5-gallon buckets	☐	Discharge Hose	☐
Stopwatch	☐	Water Level Indicator – Sonic and Electronic	☐
Water Quality Meter - pH, Temperature, Conductivity	☐	Laboratory-Supplied Sample Containers and Labels	☐
Coolers and Ice Sample Preservatives	☐	Syringes and/or Air Pump	☐

5.1.2 Field Instrument Calibration

All electronic field instruments (e.g., water quality meter, CGI) must be calibrated daily prior to use, or at the frequency recommended by the manufacturer. Calibration must be documented in the instrument calibration and/or project logbook (as applicable). Calibration must be conducted in accordance with the manufacturer's instructions. Each instrument must calibrate to within ±10% of the manufacturer's standard, otherwise it must be removed from service until it is functioning properly.

5.2 GROUNDWATER SAMPLE COLLECTION

The following section provides methodology for the collection of groundwater samples from wells, which will include removing any existing pumps from industrial WSW, checking for floating product at the top of the water columns using disposable bailers, and collecting grab samples of water from the perforated intervals using Hydrasleeves™ (**SOP-6**).

5.2.1 Pump Removal

Prior to Phase I sampling, Operators with industrial WSWs in the SAP well network will be contacted to determine whether any of the wells contain pumps. The Operators, with Geomatrix's assistance, will coordinate and arrange for the removal of pumps from these wells using their respective pump installation contractors.

Geomatrix personnel will observe pump removals from the wells to be sampled. If pipe dope or other petroleum-type substances are observed on the threads of drop pipe, valves or fittings, Geomatrix will collect a sample of this substance for laboratory analysis.

5.2.2 Combustible Gas Survey

The workspace at and around the well head will be surveyed with a CGI prior to collecting a water level measurement. If readings are≥ 20% of the LEL, sampling activities must cease until the source of the combustible vapors are identified and mitigated. If the source of combustible gases is the well casing, sampling personnel will inert the well casing following Standard Operating Procedure (SOP) 7 in **Appendix C** to inert the well casing. If the source of combustible gases is the workspace surrounding the well casing (e.g., emanating from production facilities), sampling personnel will leave the site and contact the respective Operator to clear the combustible gas.

5.2.3 Water Level Measurement

Once the LEL survey has been performed and the workspace and/or well casing has been cleared of combustible gases (if necessary), the water level will be measured at the well using an electronic water level indicator (e-tape) or sonic water level meter. Field measurement of water levels will follow SOP 3 in the **Appendix C**. Water levels will be recorded on a water level monitoring record (**Appendix D**).

5.2.4 Floating Non-Aqueous Phase Liquid Survey

Prior to collecting a groundwater sample from the industrial WSWs, a bailer will be sent down the well to top of the water column and immediately retrieved. If LNAPL is noted on the inside/outside of the bailer, a sample will be collected in laboratory-supplied containers, labeled appropriately and placed on ice in a cooler pending transport to the laboratory. No additional sampling activities will be conducted until analytical results are evaluated.

5.2.5 Sample Collection

HydraSleeves™, no-purge (passive), single-use, grab sampling devices, will be deployed in the wells to collect a representative groundwater sample without purging the industrial WSWs. This sampling device allows the collection of a whole water sample from a user-defined interval (i.e., mid-point of the perforated interval) with no drawdown and minimum agitation. The sampling device contains a self-sealing check valve, which excludes water from the part of the water column not targeted for sample collection. Once the sampling device is full, a one-way valve collapses, preventing the mixing of fluids during recovery of the HydraSleeves™ deployed in the wells.

The assembly, deployment, retrieval, and discharge of the HydraSleeves™, will follow the *HydraSleeve™ Standard Operating Procedure: Sampling Ground Water with a HydraSleeve,* which is appended to this SAP (**Appendix C**). At each well location, the HydraSleeve™, or likely series of HydraSleeves™ due to anticipated sampling volume requirements, will be placed into the well to the mid-depth of the perforated interval per SCCD's procedure. The perforated interval at each industrial WSW is listed in **Table 4**. If the depth of the perforated interval is unknown, the HydraSleeve™ will be set approximately 40 feet above the bottom of the well. If both the total depth and perforated interval of the well are unknown, SCCD field data records of sampling at the well will be reviewed to determine approximate depths of previous sample collection at the well.

Due to the anticipated deployment depths of the wells, the following may be used to ensure the proper depth of HydraSleeve™ deployment:

- A factory prepared, custom suspension line and attachment point;
- A pre-measured and cut suspension line prepared for each well prior arriving on-site for groundwater sampling;
- A pre-measured anchor line with weight to be suspended from the bottom of the HydraSleeve™.

The well will be allowed to re-equilibrate before activating the HydraSleeve™ for sample collection. Samples will be collected in appropriate sample containers provided by the analytical laboratory (see **Table 5**) upon retrieval of the HydraSleeve™. The sampler will wear new disposable latex or nitrile gloves when collecting samples. Due to sampling volume requirements and depth of sample collection, HydraSleeves™ may need to be deployed more than once in each well. Dissolved gas, VOCs and TPH-GRO samples will be collected first; field parameters will be measured last.

5.2.6 Groundwater Sampling with Existing Pump

In the event that a pump has been re-installed in an industrial WSW after the first phase of groundwater sample collection, the existing pump may be used to collect the sample for isotope analysis. Prior to purging, the water level will be measured using a sonic water level indicator in accordance with SOP-3 (**Appendix C**). It is possible that wellhead setup will prevent any reliable water level measurements to be obtained from wells with installed pumps. Observed or known pump activity prior to obtaining the water level measurement will be recorded on the sampling form. If the pump is running upon arrival at the location, a water level measurement will not be attempted. Fittings necessary to conduct water quality parameter monitoring and subsequent sample collection will be connected to the discharge piping prior to well purging.

At least three (3) well volumes will be pumped from the well to ensure fresh formation water is sampled. Purge water will be contained in on-site storage tanks or discharged to the ground. During purging, field parameter values (e.g., pH, temperature, specific conductance) will be monitored to demonstrate that a sufficient volume of water has been purged from the well; the measurements will be recorded on the field sampling form (**Appendix D**). The first measurement of field parameters will occur after one casing volume has been removed. Parameters will then be recorded at a frequency of approximately once per ½-casing volume removed. Field parameter measurement will follow SOP-4 and SOP-5 (**Appendix C**). After purging, samples will be collected in appropriate sample containers provided by the analytical laboratory (see **Table 5**). The sampler will wear new disposable latex or nitrile gloves when collecting samples. To the extent possible, the flow control valve on sample fittings will be adjusted to produce a discharge rate that will minimize loss of dissolved gases in groundwater.

5.3 AMBIENT AIR SAMPLING FROM WELL CASINGS

If a pump is installed in the WSW, the pump will need to be removed prior to proceeding. A six-inch diameter expandable j-plug will be installed at the top of each water well casing in order to collect a sample of gas that has accumulated inside the well casing. If the top of the well casing is otherwise inaccessible, an alternative method of gas sample collection may be devised under guidance of the project manager.

The j-plug will be equipped with threaded brass barbs that are fitted (and sealed) through the plastic discs that comprise the top and bottom of the j-plug. Petrolatum will be placed on the rubber gasket of the j-plug prior to insertion in the casing to ensure an airtight seal between the j-plug and the inside of the steel casing. The j-plug will be installed at least one day before samples are to be collected, and the gas will be allowed to vent through one of the threaded barbs during that time.

Prior to sample collection, a multi-gas combustible gas indicator (CGI) will be attached to the j-plug's barb fitting via flexible tubing to identify the presence of combustible gases in the WSW. The percent LEL and percent oxygen (%O2) readings will be recorded on a field form. If combustible gases are not detected in the well casing, a gas sample will not be collected. Gas flow will be measured using an in-line, mechanical (floating ball) air flow meter prior to sample collection in order to identify the presence of gas in the well and verify the integrity of the j-plug seal. The meter will be connected to the barb fitting on each j-plug via flexible tubing. If the gas is present and the seal is adequate, gas flow should increase over time as pressure builds up and equalizes inside the well casing. The gas flow rate will be recorded on a field form once the gas flow has stabilized. The gas flow rate will be multiplied by the period of time vented to calculate the volume of gas vented. If this volume is greater than the volume of well headspace in the casing, a sample will be collected. If the vented volume is less, this location will not be sampled until at least one casing volume has been vented.

Samples for gas composition analysis will be collected by connecting the GC unit in an on-site mobile laboratory directly to the barb fitting on each wellhead with flexible tubing. A continuous gas stream is pumped from the well casing into the GC unit at a rate of one liter per minute. After sample collection for gas composition is completed, a gas sample will be collected for stable isotope analysis. A one-liter or six-liter Summa canister equipped with a pressure gauge will be attached to the flexible tubing connected to the barbed fitting on the j-plug. The valve on canister will be opened to collect the sample. Once the pressure gauge indicates that the canister is full, the canister valve will be closed. The canister pressure will be recorded on the sample identification tag for that canister and on a gas sampling field form. Sample components will be disassembled in reverse order, returned to original canister cartons, and repackaged as received in preparation for transport to the laboratory.

5.4 GAS SAMPLE COLLECTION AT NATURAL GAS WELLS

It is assumed that gas will be readily flowing from each natural gas well thus flow rate will not be measured and the wellhead will not be screened for combustible gases. Natural gas wells are permanently equipped for gas sample collection and will not require j-plug installations or other prior preparations. Samples for gas composition analysis will be collected in the manner outlined in Section 5.3 by connecting the GC unit in the on-site mobile laboratory directly to the fitting on the natural gas production wellhead with flexible tubing. After sample collection for gas composition is complete, mobile laboratory personnel will assist with the collection of a gas sample for stable isotope analysis in a vessel suitable for high-pressure sample collection.

5.5 DECONTAMINATION

The need for decontamination in the field is minimized by using disposable equipment and drawing samples directly from the water and gas sources, where possible. All non-disposable sampling equipment that contacts sample media will be decontaminated between sites in order to avoid cross-contamination during the field sampling process.

All reusable sample collection equipment, such as sample port fittings (if pumps are used for sample collection), field water quality meters and probes, and containers used for transferring samples (e.g. buckets) will be decontaminated prior to use and between each sampling location in accordance with SOP-2 (**Appendix C**). All probes and transfer containers are first rinsed with deionized or distilled water between samples. If non-disposable parts of filtration equipment come into contact with the water samples, these parts are cleaned between samples with mild soapy water, followed by a deionized or distilled water rinse. Disposable supplies will be placed in a trash receptacle for disposal at a sanitary landfill. Decontamination water will be disposed on the ground at the location where it is generated.

6.0 SAMPLE CONTAINERS AND PRESERVATION

Sample container type, size, and preservation must be consistent with United States Environmental Protection Agency (EPA) requirements for the analysis of the target compounds, which are identified in **Table 5**. New sample containers will be obtained directly from the analytical laboratory and will be verified as pre-cleaned by the analytical laboratory with the appropriate certificates. Extra containers will be available in case of breakage, inadvertent contamination, and for collection of additional samples, if necessary.

Samples will be preserved according to requirements of the specified analytical method. Preservation for groundwater samples, at a minimum, will include chilling samples to at least 4°C as soon as possible following sample collection, and may also include addition of chemical preservatives. This temperature requirement must be maintained in the field, during transport to the laboratory, and during storage at the laboratory.

7.0 SAMPLE DOCUMENTATION AND HANDLING

The following sections describe the documentation of field activities and documentation and handling of samples. Field and sample documentation will follow SOP-1, SOP-9, and SOP-10 (**Appendix C**).

7.1 FIELD DOCUMENTATION

Field logbooks, daily field records, and photographs will be used to document field activities.

7.1.1 Field Logbooks

All field logbooks will be constructed from bound, waterproof, sequentially numbered pages and will be used to record daily field activities. Typically, one field logbook will be maintained. The project name, project number, and company contact information will be listed on the inside cover of all field logbooks. The logbook will only be used to document daily field activities in sufficient detail to allow field personnel to reconstruct events that transpired during the project. This document will contain information pertaining to the following:

- Daily activities and chronology,
- Observations made during the well evaluation, and
- Significant events.

Only field team members may be in custody of the logbook during field activities. Logbook entries must be dated; legible; made in black, indelible ink; and contain accurate documentation. Language used will be objective, factual, and free of personal opinions. Corrections to erroneous data will be made by crossing through the entry and entering the correct information. The person making the correction must initial and date where the error occurred.

7.1.2 Field Forms

Field forms that will be used to document sampling activities are included in **Appendix D**. Forms will be preprinted and completed in the field in addition to the field logbook. These include:

- Equipment Checklist
- Daily Field Record
- Water Level Monitoring Record
- Well Sampling and/or Development Record
- Well Casing/Production Well Gas Sample Control Log
- Photograph Log
- Field Instrument Calibration Sheet
- Chain of Custody Forms

7.1.3 Photographs

Photographs will be taken at each industrial water supply and natural gas production wellhead, and source where PHC-containing substances were sampled (e.g., material packaging, separators, storage tanks) to supplement written descriptions of field activities, as necessary. All photographs will have a date and time stamp.

7.2 SAMPLE LABELING

Labels supplied by the analytical laboratory will be affixed to each sample container. Sample location, date and time, required analyses, preservative, and the sampler's initials will be recorded on the label with an indelible marker at the time the sample is collected.

The labeling for gas samples will be completed in pen to avoid potential cross-contamination from permanent marker.

7.3 CHAIN OF CUSTODY

Proper Chain of Custody (CoC) will be maintained from the time of sample collection through analysis at a fixed-base laboratory in accordance with SOP-11 (**Appendix C**). CoC will be documented on forms provided by the analytical laboratory or the form included in **Appendix D**. The CoC will include sample location identification, date and time of sample collection, number and type of sample containers, sample media, analyses requested, sampler(s) name and affiliation, name and signature of relinquishing and receiving personnel, as well as the date and time of each custody transfer (an exception to the signature requirements will be made for common courier transporting samples to the analytical laboratory). All entries on the CoC must be recorded with indelible ink. Any corrections to an entry on the CoC will be made by striking through the entry with a single straight line and entering the correct information. The corrected entry will be initialed and dated by the person making the change.

Copies of completed CoC forms will be retained by sampling personnel responsible for sample shipment. Courier receipts will be attached to the copy of the CoC.

7.4 SAMPLE PACKAGING AND SHIPMENT

After groundwater sample collection, field personnel will package samples such that the containers will not be damaged during handling and shipment. Quantities of ice sufficient to maintain samples at a temperature of <4 ◦C prior to and during shipment to the analytical laboratory shall be placed in sample coolers in sealable plastic bags in the manner outlined in SOP-11 (**Appendix C**).

Summa canisters, if used, will be delivered or shipped to the laboratory in the original protective carton supplied by the laboratory and sealed with tamper-evident tape. If Summa canisters are to be shipped to the laboratory, the completed chain-of-custody form will be sealed in one of the canister cartons.

The CoC and all field documentation will be reviewed to ensure that instructions to the analytical laboratory are clear, complete, and accurate. Prior to sample shipment, the analytical laboratory will be notified of the pending shipment so it is prepared to receive the shipment and meet the holding times specified for each analytical method requested.

8.0 ANALYTICAL METHODS

Samples will be analyzed for the parameters and by the methods specified in **Table 5**. Groundwater samples for PHC and inorganic analysis will be analyzed by standardized EPA methods, including Safe Drinking Water Act-approved methods, those described in the most recent Standard Methods for the Analysis of Water and Wastewater, and SW 846: Test Methods for Evaluation Solid Waste, Physical / Chemical Methods. Stable isotopes will be analyzed using internal methods developed by the analytical laboratory.

Samples of the gas stream from well casings and natural gas production wells will be analyzed on-site for gas composition using a mobile laboratory operated by Precision Analysis from Riverton, Wyoming. The samples will analyzed in accordance with Gas Processors Association (GPA) Method 2261-00 *Analysis for Natural Gas and Similar Gaseous Mixtures by Gas Chromatography*.

9.0 QUALITY ASSURANCE AND QUALITY CONTROL

The quality assurance and quality control (QA/QC) program described herein has been developed to ensure the usability and reliability of sampling and analysis data, and provides for routine application of procedures for controlling the measurement process. Standard procedures described in this section ensure that data collected in the field, analyzed by the laboratory, and entered into the PAPA database will be of appropriate quality to meet the data needs and data quality objectives (see Section 4).

Quality control is a system of routine technical activities that accounts for and quantifies as many potential measurement errors as possible in order to evaluate uncertainties associated with any given measurement. Errors that influence environmental measurements can be introduced in the field during sample collection, during shipment, in the laboratory, and during database entry.

9.1 FIELD QUALITY CONTROL

Field quality control consists of collecting quality control samples, decontaminating field sampling equipment, operating/maintaining/calibrating field equipment in accordance with manufacturer's instructions, using disposable equipment where possible, following standard operating procedures (SOPs – **Appendix C**), using standard field forms (**Appendix D**), using skilled personnel for sampling, and adherence to this Plan of Study. The SOPs in **Appendix C** of this SAP are unique to the tasks described in Section 5.

The following quality control samples will be collected, label in accordance with SOP-8 (**Appendix C**) and submitted to the analytical laboratories:

Field Duplicate Sample: Field duplicates are two samples taken from the same media at the same time and under similar conditions, both sets of which are submitted to the same laboratory. The duplicate sample bottles are labeled in a way that does not reveal their identity to the laboratory. Field duplicate samples will be collected at a frequency of 1 per 10 natural samples collected. Based on 39 industrial WSWs and study wells to be sampled, three field duplicate samples, at a minimum, will be collected and analyzed for PHC and inorganics.

Field Split Sample: Field split samples are the same as "field duplicate samples", with the exception that the duplicate sample is submitted to a different laboratory. Field split samples are not planned for this sampling and analysis program, but may be incorporated if a situation arises that warrants their use.

Trip Blank Sample: Trip blanks will consist of deionized water in VOA vials and will be included in each cooler containing samples for VOC and TPH-GRO analysis. Trip blanks will be supplied by the laboratory.

Field Equipment Blank Sample: Field equipment blank will be prepared in the field by running deionized water through decontaminated reusable sampling equipment (i.e. discharge pipe fittings, HydraSleeve™) and collected in laboratory-supplied sample containers. One equipment blank, at a minimum, will be submitted for each type of method of groundwater sampling employed. Equipment blank bottles will be labeled in a manner that does not reveal their status to the laboratory. Equipment

blanks will not be used for gas sampling from water supply well casings and production wells, or groundwater sampling for isotope analysis.

Field Blanks: Field blanks will be prepared using deionized water provided by the analytical laboratory and submitted with the natural samples. Field blanks will be collected during the first phase of groundwater sampling. Field blanks will be labeled in a manner that does not reveal their status to the laboratory.

Standard Reference Sample: Standard reference samples are certified liquids with known concentrations of selected constituents that are prepared by an agency or private laboratory. These samples are submitted to the laboratory at the same time as the natural samples. Although the laboratory may be able to recognize the standard reference samples, it would not know the acceptable concentration range for each constituent. Accuracy statements about the analysis can be generated by comparing laboratory results to the acceptable range of each constituent provided by the supplier of the blind standard reference samples.

9.2 LABORATORY QUALITY CONTROL

Laboratories are requested to provide the following information to support analytical results for each parameter:

- Sample preparation method reference
- Analytical method reference
- Method detection limit (MDL)
- Reporting or practical quantitation limit (PQL)
- Units of measure
- Sample collection and analysis dates
- Chain-of-custody record initiated by the sampler
- Sample condition upon receipt, including temperature
- Adherence to designated holding time
- Method blank results
- Laboratory duplicate results and relative percent difference
- Laboratory control standard recovery
- Matrix spike (MS) recovery
- Matrix spike duplicate (MSD) recovery
- Initial and continuing calibration checks

Laboratories are requested to meet and document certain certification, licensing, accreditation, and/or auditing requirements, such as adherence to EPA requirements and/or ISO Standard 17025. The laboratories are also requested to provide documentation for their quality control programs.

Laboratory quality control samples will be prepared and analyzed in accordance with procedures described in the analytical laboratory's Quality Assurance Manual. At a minimum, these will include:

- Method Blanks

- Matrix Spike / Matrix Spike Duplicate Samples
- Certified Reference Materials or Laboratory Control Samples; and,
- Laboratory Duplicates.

Criteria for acceptance of laboratory data with respect to precision and accuracy include the following:

Laboratory Method Blank Sample: No target analytes should be detected in laboratory blanks. The method blank is processed through the entire analytical procedure in a manner identical to the natural samples. Under certain conditions, corrective action will be performed by the laboratory to identify and eliminate the source(s) of contamination and samples shall be re-digested and analyzed, as appropriate. If eliminating the blank contamination is not possible, all impacted analytes in the sample batch will be qualified in accordance with EPA guidance for the Contract Laboratory Program (CLP) (EPA 2004a, 2004b).

Laboratory Matrix Spike Sample: The laboratory shall use both pre-digestion and, when warranted, post-digestion matrix spike samples for inorganic analytes, and matrix spike/matrix spike duplicate (MS/MSD) samples for organic analytes to evaluate potential sample matrix interferences. The laboratory shall conform to sample frequencies, control limits, and data qualifiers specified in EPA guidance for the CLP (EPA 2004a, 2004b).

Certified Reference Materials or Laboratory Control Sample: These samples contain certified concentrations of the analytes of interest, as determined through replicate analyses by a reputable certifying agency using two independent measurement techniques for verification. Control limits on analyte percent recoveries are lab-specific, and are stated in each laboratory's Quality Control Manual. As a general requirement, laboratory control limits should meet or exceed those specified by the EPA for the CLP (EPA 2004a, 2004b).

Laboratory Analytical Duplicate Sample: Agreement between analytical results for laboratory duplicate samples is evaluated using the relative percent difference (RPD) between the two results. In accordance with EPA CLP guidelines EPA 2004a, 2004b) a RPD of 20 percent or less is considered an acceptable control limit without data qualification if concentrations of both samples are $\geq$5x the PQL. If results are <5x the PQL, the PQL will be the control limit.

The RPD is defined by the following equation:

$$RPD = [(\text{sample} - \text{duplicate value}) \div [(\text{sample} + \text{duplicate value}) \div 2]] \times 100$$

Continuing Calibration Checks: Calibration check solutions traceable to a recognized organization are inserted as part of the sample stream on a routine basis. Source of the calibration check solution shall be independent from the standards used for calibration. Calibration check solutions used for the continuing calibration checks will contain all analytes of interest.

Participation in Inter-Laboratory Comparison: These exercises provide a tool for continuous improvement of laboratory measurements by helping the analysts identify and resolve problems of methodology and/or quality control. Results of these exercises are also used to evaluate both the individual and collective performance of the participating analytical laboratories on a continuing basis,

and to insure that ongoing measurements are meeting standards. The participating laboratories should initiate corrective action if their performance in the comparison exercises falls below certain pre-determined minimal standards.

9.3 DATABASE AND REPORTING

Laboratories report analytical data in paper and electronic formats (database spreadsheet and PDF). Paper copies are placed in appropriate project files, whereas electronic field and laboratory data are stored in a computer database specific for the project. The laboratory method detection limit (MDL) is used to define the analytical limit or sensitivity of detectability. The Code of Federal Regulations (40 CFR Part 136, 1993) provides the following definition:

> The MDL is the minimum concentration of a substance that can be measured and reported with 99% confidence that the analyte concentration is greater than zero.

Normally, the MDL is set at three times the standard deviation, or the t-distribution times the standard deviation, of a minimum of seven replicate measurements of a given spiking concentration. Values at the MDL may not reflect a signal much above zero, and therefore, are quantitatively not very meaningful.

The practical quantitation limit (PQL) is considered the lowest concentration that can be reliably measured within specified limits of precision and accuracy during routine laboratory operating conditions. The PQL is determined either through the use of inter-laboratory study data, or through the use of a multiplier of 5 to 10 times the MDL. Using these definitions, measurements below an MDL are not believable, measurements between the MDL and PQL are semi-quantifiable, and measurements above the PQL have a high degree of confidence.

Some laboratories use the term reporting limit (RL), which is a limit imposed upon the reporting laboratory by a client or regulatory agency. The reporting limit typically is associated with either the MDL or PQL.

Concentrations of chemicals that exceed the MDL but do not exceed the PQL are often reported as "estimates". A value reported by the laboratory that is less than the detection limit, which is either the MDL or PQL depending on the needs of the end-user, is an estimated concentration. For statistical purposes, non-detect values most commonly are represented as one-half the detection limit. The EPA (2006) specifies guidelines for evaluating data that includes values below the detection limit. The suggested procedures depend upon the amount of data below the detection limit.

9.4 DATA REVIEW

The objective of data validation is to identify any unreliable or invalid field and laboratory measurements, and qualify data for interpretive use. Data validation is performed using EPA guidelines for organics and inorganics (EPA 2004a, 2004b) and QC criteria in interval laboratory procedures. The following steps are used to validate the laboratory analytical data:

- Chain-of-custody forms and laboratory reports are checked to verify that samples were analyzed for the requested parameters, using the required preservatives, and within specified

holding times (i.e., time between sample collection and laboratory analysis). Results from samples that do not satisfy holding time and/or preservation requirements are noted or flagged.

- Laboratory sample receipt forms are reviewed to determine if sample coolers were received with an internal temperature 1 to 4°C. With the exception of preserved sample bottles for metals analysis, sample containers that are received above the recommended temperature are noted or flagged.
- Whenever a sample has both total and dissolved metal concentrations reported, the dissolved values should be equal to or less than the total values. Results from samples with dissolved metal concentrations greater than corresponding total values are noted or flagged.
- Percent recoveries calculated by the laboratory for control samples and matrix spikes are reviewed to verify that they are within acceptable limits (80 to120 percent for laboratory control samples; 75 to 125 percent for matrix spike samples). Laboratory-specified limits may be more stringent than these acceptable limits based on parameter type and concentration. If recoveries are outside the limits, the results are noted or flagged as estimated for all natural samples in the analytical batch, and action should be taken by the laboratory to improve accuracy of analytical results.
- Standard reference sample results are compared to the acceptable range of each constituent provided by the supplier of the blind standard reference samples. Any constituents outside the acceptable range are noted or flagged as estimated for all natural samples in the analytical batch.
- Relative percent difference (RPD) values are calculated for laboratory and field duplicate or split samples to determine if they are less than or equal to the acceptable control limit. If concentrations of both samples (natural and associated duplicate) are <5X the PQL, the PQL will be the control limit, rather than the 20 percent control limit. When the RPD control limits are exceeded, data will be noted or flagged as estimated for all natural samples in the analytical batch, and action should be taken by the laboratory to improve precision of analytical results.
- For laboratory and field blank samples, any parameter detected above the laboratory reporting limit (i.e. PQL) will be noted or flagged as estimated for all natural samples in the analytical batch.
- Field measurements (e.g., depth to water, pH, specific conductance, temperature) are compared to previous data for accuracy. Anomalous or suspect values are noted and an explanation provided.
- All data are reviewed promptly for potential transcription errors, reporting limit discrepancies, data omissions, and suspect or anomalous values. Such problems are noted and reported to the proper personnel to take appropriate corrective action.

Once field and laboratory data have been reviewed and validated according to the steps described above, final qualified results are entered into the project database, along with field measurements and other sample collection information. Flagged or noted data are those results that do not meet acceptance criteria without qualification; flags are letter codes that alert the reviewer to these quality control considerations. With the exception of letter code "R" (rejected), all letter codes indicate the parameter(s) are considered "estimated". The R-designation is determined by the end-user of the data based on a review of all other data qualifier results in the validated database.

Common data validation flagging letter codes are presented in the following table.

<	The parameter was analyzed for but not detected at the practical quantitation limit (PQL) used for the method.
H	The required holding time for laboratory analysis was exceeded. Only parameters that do not meet the holding time for particular sample(s) will be flagged as "H".
F%	Field duplicate analysis has parameter concentration exceeding acceptable limits (relative percent difference determination). For any parameters that do not meet this criterion, all same parameters for all samples in the analytical batch will be flagged as estimated "JF%".
F	Field duplicate analysis has parameter concentration exceeding acceptable limits (PQL determination). For any parameters that do not meet this criterion, all same parameters for all samples in the analytical batch will be flagged as estimated "JF".
L%	Laboratory duplicate analysis has parameter concentration exceeding acceptable limits (relative percent difference determination). For any parameters that do not meet this criterion, all same parameters for all samples in the analytical batch will be flagged as estimated "JL%".
L	Laboratory duplicate analysis has parameter concentration exceeding acceptable limits (PQL determination). For any parameters that do not meet this criterion, all same parameters for all samples in the analytical batch will be flagged as estimated "JL".
M%	Laboratory matrix spike recovery has parameter concentration outside acceptable range. For any parameters that do not meet this criterion, all same parameters for all samples in the analytical batch will be flagged as estimated "JM%".
B	Laboratory method blank or field blank has parameter concentration detected above PQL. For any parameters that do not meet this criterion, all same parameters for all samples in the analytical batch will be flagged as estimated "JB".
S	Standard reference has parameter concentration outside acceptable range. For any parameters that do not meet this criterion, all same parameters for all samples in the analytical batch will be flagged as estimated "JS".
T	Total concentration for a parameter is lower than the corresponding dissolved concentration. Paired values where the total concentration is lower than the dissolved concentration will be flagged as "T".
J	The associated parameter value is an estimated quantity.
R	The associated parameter value is unusable (rejected).

If the water quality database is ever subject to statistical analysis, the rejected (R-flagged) data are not used. Duplicate samples are not included in the statistical analysis. Samples with reported values below the laboratory detection limit are calculated statistically using the value of the detection limit, or alternatively, using one-half the detection limit value, whichever is deemed appropriate by WDEQ.

In reporting the sampling and analysis results, it is important to recognize and characterize uncertainties associated with the results, recognizing that each sampling or monitoring program will have different "noise" sources and uncertainties. Data limitations can include the following:

- Missing values
- Sampling frequency that changes over the period of record
- Multiple observations within one sampling period
- Uncertainty in measurement procedures
- Laboratory analytical methods and/or detection limits that change over the period of record
- Small sample sizes
- Outliers
- Lack of quality control procedures and data validation
- Problems related to data presentation and/or transcription

The process of minimizing and documenting error or noise control consists primarily of QA/QC programs developed for both sample collection and laboratory analysis, together with data interpretation and handling procedures. Professional judgment is required and used to assess the impact of field QC on the overall quality and usability of the field data. Knowing limitations of the data assists the data user when making interpretations. Data with limitations are usable for evaluation as long as the limitations are considered.

10.0 SCHEDULE

The following tentative schedule is developed for the two SAP implementation phases as described above in Section 4:

Phase 1

The first phase of the SAP will be executed upon completion of the installation of the study wells for the Hydrogeological Data Gaps Study, and pending the approval of the SAP by the BDE. It is estimated that this phase of SAP implementation will occur from September - October 2010.

Phase 2

The second phase of the SAP will be executed upon receipt and review of the groundwater and PHC chemical data collected during the first phase of SAP implementation, revision of the SAP to include any additional evaluations and methods, and approval of these revisions by the Operators and BDE.

11.0 PERSONNEL

The following key personnel from Geomatrix will complete the tasks described in this SAP:

- Steve Wright (Helena, MT) and K. Bill Clark (Missoula, MT) – project study and task managers
- Steve Wright (Helena) & Beth Johnson (Helena) – field task managers
- Tom Hakonson & Carrie Hatch (Pinedale, WY); Adam Johnson, Tom McManus, Joel Jacobson and Levi McKay (Missoula, MT) – field staff
- Kevin Van Hook (Houston, TX) – quality assurance and quality control

Additional information about the project team is contained in the "Project Administration Plan" (Geomatrix 2009c). All personnel who participate in field activities will be properly trained in the site-specific health and safety issues. During the period of field activities, weekly site meetings and/or conference calls will be conducted to discuss progress completed the previous week, and planned activities for the upcoming week.

12.0 REFERENCES

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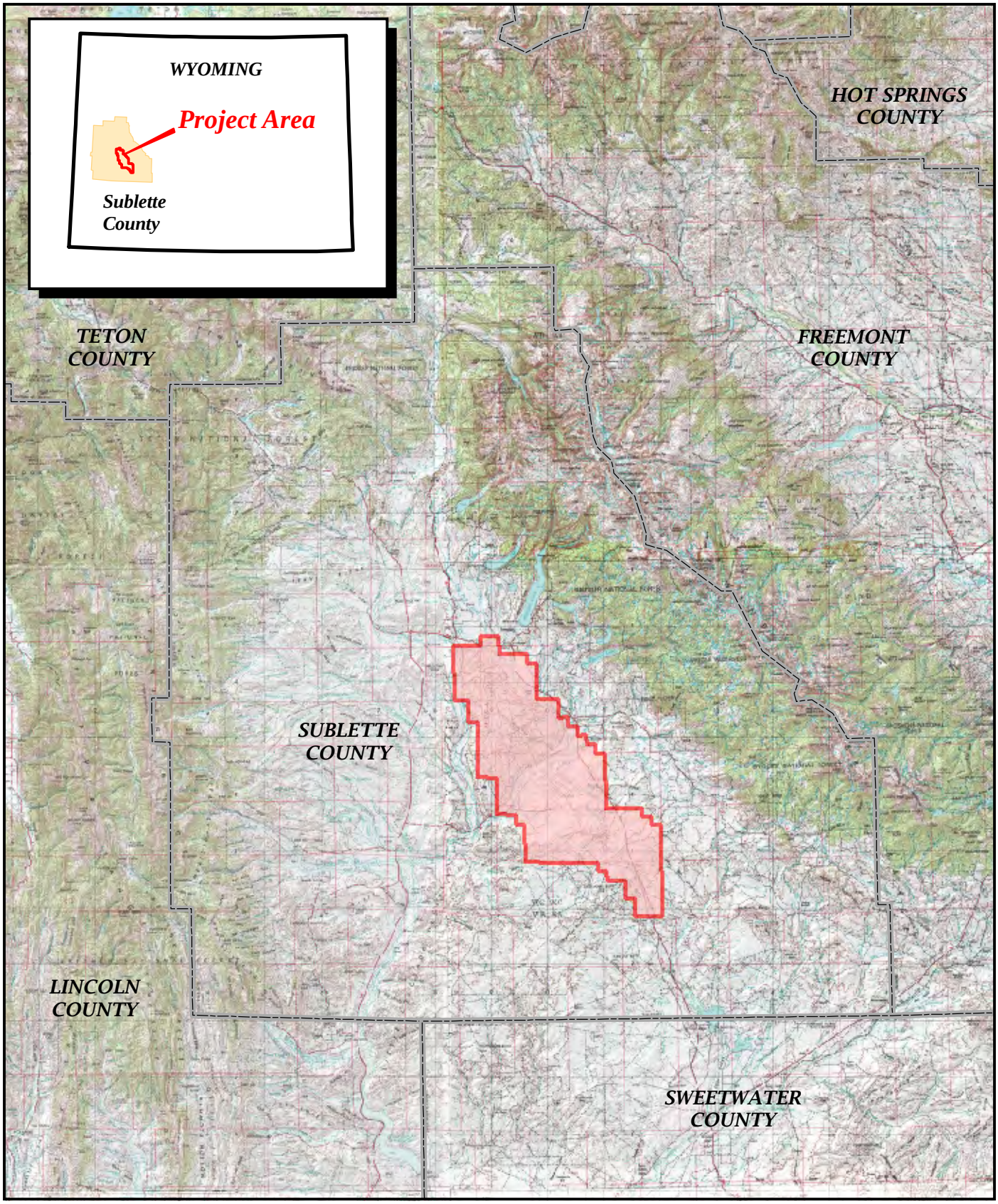
APPENDIX A

FIGURES



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Source: 250K WYGISC, BLM

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Project Area

AMEC Geomatrix

Project Location Map
Pinedale Anticline Project Area
Sublette County, Wyoming
FIGURE 1

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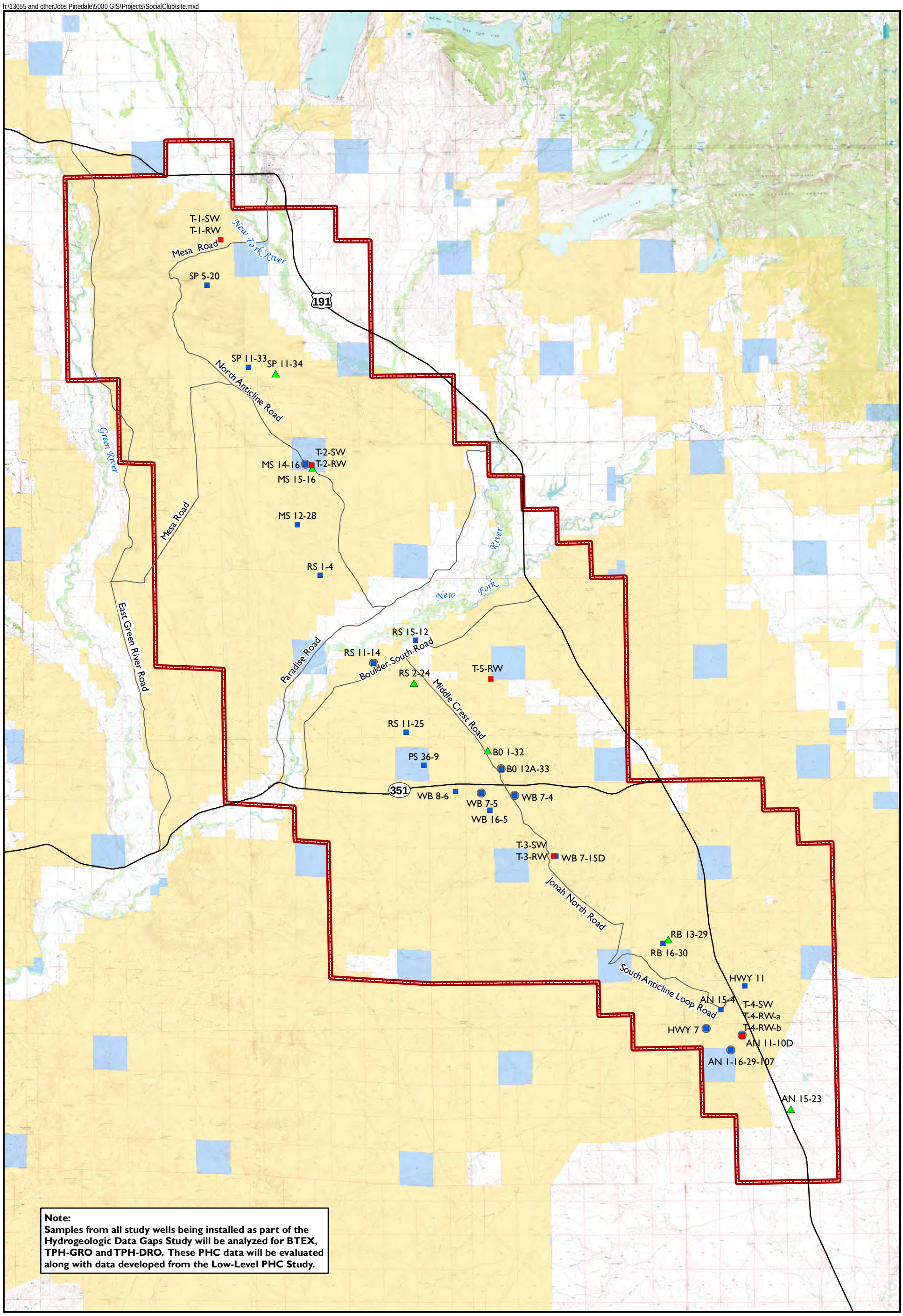

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AMEC Geomatrix

PHC Well with LEL exceedence
Control Well
PHC Well
Study Well
Bureau of Land Management
State
Pinedale Anticline Project Area

Wells To Be Sampled
Low-Level PHC Sampling and Analysis Plan
Sublette County, Wyoming
FIGURE 3

APPENDIX B

TABLES

Table 1

Summary of Water Wells with One or More PHC Detection

LLPHC Sampling and Analysis Plan

Well ID	Well Name	Date	Benzene (ug/L)	Toluene (ug/L)	Ethylbenzene (ug/L)	m+p-Xylene (ug/L)	o-Xylene (ug/L)	total Xylenes (ug/L)	GRO (mg/L)	DRO (mg/L)	NPM (mg/L)
DEQ Water Quality Standard			5	1000	700	10000	10000	10000	7.3	1.1[A], 10[B]	NE
AD213	Corwin #2	09/11/08							**0.649**	< 1 J	
AD213		10/15/08	< 0.5 J	< 0.5 J	< 0.5	< 0.5	< 0.5 J		**0.262**	< 1	
AD213		10/15/08	< 0.5 J	< 0.5 J	< 0.5	< 0.5	< 0.5 J		**0.206**	< 1	
AD213		08/06/09	< 1	< 1	< 1	< 1	< 1		< 0.08	< 1.1	
AD223	Tri County	10/29/08							< 0.04	<1.1 J	
AD223	Sanit. #1	08/04/09							< 0.08	**1.5**	
AD223		12/15/09	< 1	< 1	< 1	< 1	< 1		< 0.04	< 1	
AD238	DC-6	06/23/09	**18**	< 10	< 10	< 10	**120**		**15.7**	**4.1**	
AD238		07/22/09	**6.4**	< 5	< 5	< 5	**200**		**21.4**	**4.4**	
AD238		11/03/09	< 1	< 1	< 1	< 1	< 1		**0.05**	< 1	
AD238		11/03/09	< 1	< 1	< 1	< 1	< 1		**0.042**	< 1	
AD238		11/03/09	< 1	< 1	< 1	< 1	< 1		< 0.04	< 1	
AS014	N.W.	06/29/07									< 5
AS014	Squaretop	07/03/08	< 0.5	**13**	< 0.5	< 0.5	< 0.5		< 0.04	< 1	
AS014		07/31/08	< 0.5	< 0.5 J	< 0.5	< 0.5	< 0.5		< 0.04		
AS014		07/31/08	< 0.5	**0.79**	< 0.5	< 0.5	< 0.5		< 0.04	< 1	
AS014		07/31/08	< 0.5	**0.84**	< 0.5	< 0.5	< 0.5		< 0.04	< 1	
AS014		08/01/08	< 0.5	**0.79**	< 0.5	< 0.5	< 0.5		< 0.04	< 1	
AS014		08/01/08	< 0.5	**0.84**	< 0.5	< 0.5	< 0.5		< 0.04	< 1	
AS014		11/05/09	< 1	< 1	< 1	< 1	< 1		< 0.04	< 1	
AMI006	SHB 7-23	1/19/2007	< 1	< 5	< 1			< 3	< 0.1	**0.13**	
AMI008	WB 9-23	12/29/2004									ND
AMI008		1/17/2007	< 1	< 5	< 1			< 3	< 0.1	**0.12**	
AMI008		8/28/2008							< 0.04	< 1	
AMI009	LZ 13-28	8/27/2004									ND
AMI009		8/19/2005									ND
AMI009		1/16/2007	< 1	< 5	< 1			< 3	< 0.1	**0.11**	
AMI009		8/20/2008							< 0.04	< 1	
AMI009		5/19/2009							< 0.08	< 1	
AMI010	LZ 11-8	8/27/2004									ND
AMI010		1/16/2007	< 1	< 5	< 1			< 3	< 0.1	**0.12**	
AMI015	AN 14-22	6/5/2006									ND
AMI015		11/17/2006	< 0.5	< 0.5	< 0.5	< 0.5	< 0.5		< 0.036 D	< 1	
AMI015		1/16/2007	< 1	**31**	< 1			< 3	< 0.1	**0.91**	
AMI015		11/19/2007	< 0.5	< 0.5	< 0.5	< 0.5	< 0.5		< 0.036 D	< 1	
AMI017	AN 15-4	12/21/04									ND
AMI017		12/13/06	< 1	**99.2**	< 1			< 10	< 0.5	< 0.5	
AMI017		10/16/08							**0.173**	**2.60**	
AMI017		12/2/08	< 1	**15**	< 1	< 1	< 1		< 0.08 J	< 1 J	
AMI017		8/5/09	< 1	**18**	< 1	< 1	< 1		< 0.08	< 1.4	
AMI017		11/10/09	< 1	**8.9**	< 1	< 1	< 1		**0.046**	< 1	
AMI026	NFU 11-24	8/26/04									ND
AMI026		11/16/06	< 0.5	**5.8**	< 0.5	< 0.5	< 0.5		< 0.036 D	< 2.4	
AMI026		2/14/07	< 1	**2.53**	< 1	< 2	< 1	< 3	< 0.05	< 0.25	
AMI026		2/14/07	< 0.5	**2.4**	< 0.5	< 0.5	< 0.5		< 0.036 D	< 1	
AMI026		10/30/07	< 0.5	< 0.5	< 0.5	< 0.5	< 0.5		< 0.036 D	< 1	

Table 1

Summary of Water Wells with One or More PHC Detection

LLPHC Sampling and Analysis Plan

Well ID	Well Name	Date	Benzene (ug/L)	Toluene (ug/L)	Ethylbenzene (ug/L)	m+p-Xylene (ug/L)	o-Xylene (ug/L)	total Xylenes (ug/L)	GRO (mg/L)	DRO (mg/L)	NPM (mg/L)
DEQ Water Quality Standard			5	1000	700	10000	10000	10000	7.3	1.1[A], 10[B]	NE
AMI027	MS 3-20	10/14/04									ND
AMI027		10/14/04									ND
AMI027		10/22/04									ND
AMI027		10/19/06									ND
AMI027		2/14/07							< 0.02	< 0.5	
AMI027		8/9/07									< 5
AMI027		11/8/07	**1.2**	< 0.5	< 0.5	< 0.5	< 0.5		< 0.036	< 1	
AMI027		9/18/08							< 0.04 H	< 1	
AMI027		9/18/08							< 0.04 H	< 1	
AMI027		8/25/09							< 0.04	< 1.1	
AMI027											ND
AMI028	SP 11-33	10/13/04									ND
AMI028		2/21/07	< 1	**3.8**	< 2			< 2	< 0.02	< 0.5	
AMI028		11/6/07	< 0.5	**3.5**	< 0.5	< 0.5	< 0.5		< 0.036	< 1	
AMI028		9/18/08							< 0.04 H	< 1	
AMI028		8/24/09							< 0.04	< 1.1	
AMI029	MS 13-5	10/13/04									ND
AMI029		5/10/06									ND
AMI029		10/19/06									ND
AMI029		2/21/07	< 1	< 2	< 2			< 2	< 0.02	< 0.5	
AMI029		8/9/07									< 5
AMI029		11/6/07	**0.96**	< 0.5	< 0.5	< 0.5	< 0.5		< 0.036	< 1	
AMI029		9/22/08							< 0.04	< 1	
AMI029		8/24/09							< 0.04	< 1	
AMI029											ND
AMI030	SP 5-20	8/23/04									ND
AMI030		2/14/07							**0.028**	< 0.5	
AMI030		11/9/07	< 0.5	**0.56**	< 0.5	< 0.5	< 0.5		< 0.036	< 1	
AMI030		9/18/08							< 0.04 H	< 1	
AMI030		8/24/09							< 0.04	< 1.1	
AMI033	Hwy #11	8/27/04									ND
AMI033		10/6/08							< 0.04	**1.7**	
AMI033		11/6/08	< 1 J	< 1 J	< 1	< 1	< 1		< 0.08	< 1.1	
AMI033		12/7/09	< 1	**6.3**	< 1	< 1	< 1		< 0.04	< 1.3	
AMI033		12/7/09	< 1	**4.9**	< 1	< 1	< 1		< 0.04	< 1.4	
AMI034	AN 11-4	8/26/2004									ND
AMI034		10/6/2005									ND
AMI034		9/22/2006									ND
AMI034		11/15/2006	< 0.5	**1.6**	< 0.5	< 0.5	< 0.5		< 0.036 D	< 2.4	
AMI034		2/13/2007	< 0.5	< 0.5	< 0.5	< 0.5	< 0.5		< 0.036 D	< 1	
AMI034		8/27/2007									< 5
AMI034		11/6/2007	< 0.5	< 0.5	< 0.5	< 0.5	< 0.5		< 0.036 D	< 1	
AMI034		9/19/2008							< 0.04	< 1 J	
AMI037	RB 7-31	08/26/04									ND
AMI037		11/01/04									ND
AMI037		11/16/06	< 0.5	**5.8**	< 0.5	< 0.5	< 0.5		< 0.036 D	< 2.4	
AMI037		02/13/07	< 1	**1.35**	< 1	< 2	< 1	< 3	< 0.05	< 0.25	
AMI037		02/13/07	< 0.5	**1.3**	< 0.5	< 0.5	< 0.5		< 0.036 D	< 1	
AMI043	MS 15-8	08/24/04									ND
AMI043		7/1/08							< 0.04	< 1	
AMI043		9/10/09							**0.15**	< 1	

Table 1

Summary of Water Wells with One or More PHC Detection

LLPHC Sampling and Analysis Plan

Well ID	Well Name	Date	Benzene (ug/L)	Toluene (ug/L)	Ethylbenzene (ug/L)	m+p-Xylene (ug/L)	o-Xylene (ug/L)	total Xylenes (ug/L)	GRO (mg/L)	DRO (mg/L)	NPM (mg/L)
DEQ Water Quality Standard			5	1000	700	10000	10000	10000	7.3	1.1[A], 10[B]	NE
AMI078	RS 1-4	12/15/04									ND
AMI078		9/22/06	ND	ND	ND	ND	ND		ND		ND
AMI078		1/16/07	< 1	**22**	< 1			< 3	< 0.1	**5.2**	
AMI078		9/12/07									< 5
AMI078		11/28/07	< 0.5	**19**	< 0.5	**0.61**	< 0.5		**0.08**	< 1	
AMI078		8/29/08							< 0.04	< 1	
AMI078		8/29/08							< 0.04	< 1	
AMI078		8/3/09							< 0.08	< 1.1	
AMI078		8/3/09							< 0.08	< 1.1	
AMI079	RS 2-2	8/25/04									ND
AMI079		6/6/06									ND
AMI079		8/26/08	< 0.5	< 0.5	< 0.5	< 0.5	< 0.5		< 0.04	**2.2**	
AMI079		9/5/08							< 0.04		
AMI079		9/12/08	< 0.5	< 0.5	< 0.5	< 0.5	< 0.5		< 0.04	**2.6**	
AMI079		5/20/09	< 1	< 1	< 1	< 1	< 1		< 0.08	< 1.1	
AMI089	WB 6-26	8/27/2004									ND
AMI089		1/17/2007	< 1	< 5	< 1			< 3	< 0.1	**0.17**	
AMI089		8/27/2008							< 0.04	< 1	
AMI090	MS 4-28	6/1/06									ND
AMI090		11/14/06	< 0.5	**0.66**	< 0.5	**4.8**	< 0.5		**0.107** D	< 2.4	
AMI090		2/15/07	< 0.5	< 0.5	< 0.5	**1.6**	< 0.5		< 0.036 D	< 1	
AMI090		5/17/07									
AMI090		10/29/07	< 0.5	< 0.5	< 0.5	< 0.5	< 0.5		< 0.036	< 1	
AMI090		5/28/08							< 0.04	< 1	
AMI107	RS 9-2	12/29/2004									ND
AMI107		1/16/2007	< 1	< 5	< 1			< 3	< 0.1	**0.30**	
AMI113	SP 11-21	11/8/2004									ND
AMI113		2/14/2007							< 0.02	< 0.5	
AMI113		11/8/2007	< 0.5	**0.78**	< 0.5	< 0.5	< 0.5		< 0.036	< 1	
AMI113		9/18/2008							< 0.04 H	< 1	
AMI113		8/24/2009							< 0.04	< 1.1	
AMI113		8/24/2009							< 0.04	<1.1	
AMI117	MS 9-16	10/28/2004									ND
AMI117		2/20/2007	< 1	< 2	< 2			< 2	< 0.02	< 0.5	
AMI117		11/16/2007	< 0.5	**1.9**	< 0.5	< 0.5	< 0.5		< 0.036	< 1	
AMI117		9/15/2008							< 0.04 H	< 1 J	
AMI117		9/1/2009							< 0.04 <	< 1	
AMI118	MS 10-16	10/27/2004									ND
AMI118		2/20/2007	< 1	< 2	< 2			< 2	< 0.02	< 0.5	
AMI118		11/16/2007	< 0.5	**2**	< 0.5	< 0.5	< 0.5		< 0.036	< 1	
AMI118		9/12/2008							< 0.04	< 1	
AMI118		9/1/2009							< 0.04	< 1.1	
AMI122	RS 3-3	12/13/2004									ND
AMI122		9/30/2006									ND
AMI122		1/16/2007	< 1	< 5	< 1			< 3	< 0.1	**0.12**	
AMI122		8/26/2008							< 0.04	< 1	
AMI122		5/20/2009							< 0.08	< 1.1	
AMI124	RS 8-3	11/1/2004									ND
AMI124		11/13/2006	< 0.5	< 0.5	< 0.5	< 0.5	< 0.5		< 0.036 D	< 2.4	
AMI124		10/26/2007	< 0.5	**0.55**	< 0.5	< 0.5	< 0.5		< 0.036 D	< 1	
AMI124		8/28/2008							< 0.04	< 1	
AMI124		8/3/2009							< 0.08	< 1.1	

Table 1

Summary of Water Wells with One or More PHC Detection

LLPHC Sampling and Analysis Plan

Well ID	Well Name	Date	Benzene (ug/L)	Toluene (ug/L)	Ethylbenzene (ug/L)	m+p-Xylene (ug/L)	o-Xylene (ug/L)	total Xylenes (ug/L)	GRO (mg/L)	DRO (mg/L)	NPM (mg/L)
DEQ Water Quality Standard			5	1000	700	10000	10000	10000	7.3	1.1[A], 10[B]	NE
AMI127	MS 7-34	12/8/2004							< 0.1		ND
AMI127		1/16/2007	< 1	< 5	< 1			< 3	< 0.1	**0.25**	
AMI128	MS 9-34	12/8/2004									ND
AMI128		1/16/2007	< 1	**70**	< 1			< 3	< 0.1	**0.14**	
AMI128		1/16/2007	< 1	**67**	< 1			< 3	< 0.1	**0.13**	
AMI128		7/23/2007									< 5
AMI130	RS 4-10	8/24/2004									ND
AMI130		1/16/2007	< 1	< 5	< 1			< 3	< 0.1	**0.66**	
AMI131	AN 5-4	6/13/2005									ND
AMI131		5/9/2006									ND
AMI131		12/14/2006	< 1	**1.2**	< 1			< 10	< 500	< 0.5	
AMI131		6/27/2008							< 0.04	< 1	
AMI131		6/30/2009							< 0.08	< 1.1	
AMI132	RS 15-12	12/9/04									ND
AMI132		1/16/07	< 1	**11**	< 1			< 3	< 0.1	**0.34**	
AMI132		1/16/07	< 1	**16**	< 1			< 3	< 0.1	**0.16**	
AMI132		7/8/08	**0.76**	**100**	**1.8**	**8.9**	**4.4**		**0.346**	**8.8**	
AMI132		7/8/08	**0.58**	**68**	**1.3**	**6.5**	**3.2**		**0.247**	**4.3**	
AMI132		7/24/08	**7600**	**34000**	**1600**	**17000**	**3300**		**143**	**210**	
AMI132		7/24/08	**6400**	**34000**	**2500**	**25000**	**4900**		**241**	**380**	
AMI132		9/26/08	**0.56**	**46**	**1.5**	**16**	**3.7**		**0.228**	**3.1**	
AMI132		10/23/08	< 1 JH	**59 H**	**1.8 H**	**21 H**	**4.7 H**		**0.266**	**3.7**	
AMI132		5/21/09	< 1	**9.7**	< 1	< 1	< 1		< 0.08	< 1.1	
AMI132		11/12/09	< 1	< 1	< 1	< 1	< 1		< 0.04	< 1.1	
AMI134	RB 13-32	11/2/04									ND
AMI134		9/6/06									ND
AMI134		11/16/06	< 0.5	**3.2**	**0.52**	**7.3**	**1.7**		< 0.036 D	< 2.4	
AMI134		2/13/07	< 0.5	**0.96**	< 0.5	**2.8**	**0.54**		< 0.036 D	< 1	
AMI134		8/29/07									< 5
AMI134		11/6/07	< 0.5	< 0.5	< 0.5	**1.3**	< 0.5		< 0.036 D	< 1	
AMI134		9/19/08							< 0.04	< 1 J	
AMI134		8/31/09							**0.064**	< 1.1	
AMI137	WB 9-26	12/6/04									ND
AMI137		1/17/07	< 1	< 5	< 1			< 3	< 0.1	**0.10**	
AMI140	NM 4-7	11/1/04									ND
AMI140		9/7/06									**456**
AMI140		9/7/06	**290**	**4400**	**1200**	**16000**	**3000**	**19000**	**46**		
AMI140		9/18/06	**21**	**640**	**240**	**2300**	**560**	**2800**	**8.42**		ND
AMI140		10/25/06	**6.9**	**83**	**14**			**325**			
AMI140		2/15/07	< 0.5	< 0.5	< 0.5	< 0.5	< 0.5		< 0.036 D	< 1	
AMI140		7/16/07	< 0.5	< 0.5	< 0.5	**1.6**	< 0.5		< 0.036 D	< 1	
AMI140		8/28/07	**1.2**	**3.5**	**2.1**	**22**	**4.2**		**0.149**		< 5 U
AMI140		11/7/07	< 0.5	< 0.5	< 0.5	< 0.5	< 0.5		< 0.036	< 1	
AMI140		9/3/08							< 0.04	< 1	
AMI140		9/2/09	< 1	< 1	< 1	< 1	< 1		< 0.04	< 1.3	
AMI145	WB 11-10	11/1/04									ND
AMI145		10/6/05									ND
AMI145		9/29/06									ND
AMI145		11/16/06	< 0.5	< 0.5	< 0.5	< 0.5	< 0.5		< 0.036 D	< 2.4	
AMI145		8/29/07									< 5
AMI145		11/6/07	0.57	**4.3**	< 0.5	**0.72**	< 0.5		< 0.036 D	< 1	
AMI145		8/28/08							< 0.04	< 1	
AMI145		7/29/09							< 0.08	< 1.1	
AMI145		7/29/09							< 0.08	< 1	

Table 1

Summary of Water Wells with One or More PHC Detection

LLPHC Sampling and Analysis Plan

Well ID	Well Name	Date	Benzene (ug/L)	Toluene (ug/L)	Ethylbenzene (ug/L)	m+p-Xylene (ug/L)	o-Xylene (ug/L)	total Xylenes (ug/L)	GRO (mg/L)	DRO (mg/L)	NPM (mg/L)
DEQ Water Quality Standard			5	1000	700	10000	10000	10000	7.3	1.1[A], 10[B]	NE
AM1146	AN 11-10	11/2/04									ND
AM1146		9/19/08							**0.206**	< 1	
AM1146		10/20/08							**0.212**	< 1	
AM1146		10/27/08	**7.5 H**	**1.2** H,C	< 1 H	< 1 H	< 1 H		**0.245**	< 1	
AM1146		11/20/08	**5.3**	< 1 J,C	< 1	< 1	< 1		**0.16**	< 1.1	
AM1146		8/5/09	**7.8**	< 1 C	< 1	< 1	< 1		**0.19**	< 1	
AM1146		10/28/09	**6.8**	< 1 C	< 1	< 1	< 1		**0.21**	< 1.1	
AM1147	WB 13-11	5/25/05									ND
AM1147		1/19/07	< 1	**43**	< 1			< 3	< 0.1	**230**	
AM1147		5/10/07	ND	ND	ND	ND	ND		ND		ND
AM1148	WB 13-14	6/17/05									ND
AM1148		11/16/06	< 0.5	**1.9**	< 0.5	< 0.5	< 0.5		< 0.036 D	< 2.4	
AM1148		2/12/07	< 1	**10.6**	< 1	< 2	< 1	< 3	< 0.05	< 0.25	
AM1148		2/12/07	< 0.5	**8.6**	< 0.5	< 0.5	< 0.5		< 0.036 D	< 1	
AM1148		5/18/07									
AM1148		11/6/07	< 0.5	< 0.5	< 0.5	< 0.5	< 0.5		< 0.036 D	< 1	
AM1148		5/29/08							< 0.04	< 1	
AM1148		7/15/09							< 0.08	< 1	
AM1149	Blue Rim	5/17/05									ND
AM1149	State #2	10/9/07	**4.8**	**27**	< 0.5	< 0.5	< 0.5		**0.101**	0.00	< 5
AM1149		11/5/07	**4.8**	**13**	< 0.5	< 0.5	< 0.5		**0.052**	< 1	< 5
AM1149		11/5/07	**5.2**	**13**	< 0.5	< 0.5	< 0.5		**0.051**	< 1	< 5
AM1149		9/23/08							< 0.04	< 1	
AM1151	BO 7-19	12/7/04									ND
AM1151		12/7/04									ND
AM1151		1/16/07	< 1	< 5	< 1			< 3	< 0.1	**0.52**	
AM1151		8/7/08							< 0.04	**1.0**	
AM1151		9/5/08	< 1	**1.8**	< 1	< 1	< 1	< 1		< 1	
AM1151		9/5/08	< 1	< 1	< 1	< 1	< 1	< 1	< 0.04	< 1	
AM1159	MS 11-28	8/25/04									ND
AM1159		11/14/06	< 0.5	**0.62**	< 0.5	< 0.5	< 0.5		< 0.036 D	< 2.4	
AM1159		2/14/07	< 0.5	< 0.5	< 0.5	< 0.5	< 0.5		< 0.036 D	< 1	
AM1159		11/5/07	< 0.5	< 0.5	< 0.5	< 0.5	< 0.5		< 0.036 D	< 1	
AM1159		5/23/08	< 0.5	< 0.5	< 0.5	< 0.5	< 0.5		< 0.04	< 1	
AM1159		7/14/09							< 0.08	< 1.1	
AM1160	MS 12-28	11/4/04									ND
AM1160		11/13/06	< 0.5	**69**	< 0.5	**0.85**	< 0.5		**0.103 D**	**7.4**	
AM1160		2/14/07	< 0.5	**8.5**	< 0.5	**0.97**	< 0.5		< 0.036 D	**3.4**	
AM1160		5/17/07									ND
AM1160		10/26/07	< 0.5	**0.95**	< 0.5	**2.1**	< 0.5		< 0.036 D	< 1	
AM1160		6/4/08							**0.165**	< 1	
AM1160		7/1/08	**1.3**	**0.98**	**4.6**	**57**	**10**		**0.208**	< 1	
AM1160		5/20/09	< 1	**2.3**	< 1	< 1	< 1		< 0.08	< 1.1	
AM1160		11/12/09	< 1	< 1	< 1	< 1	< 1		< 0.04	< 1.1	
AM1161	SP 5-29	11/9/2004									ND
AM1161		2/21/2007	< 1	< 2	< 2			< 2	< 0.02	< 0.5	
AM1161		11/8/2007	< 0.5	**0.77**	< 0.5	< 0.5	< 0.5		< 0.036	< 1	
AM1161		9/18/2008							< 0.04 H	< 1	
AM1161		9/1/2009							< 0.04	< 1.2	

Table 1

Summary of Water Wells with One or More PHC Detection

LLPHC Sampling and Analysis Plan

Well ID	Well Name	Date	Benzene (ug/L)	Toluene (ug/L)	Ethylbenzene (ug/L)	m+p-Xylene (ug/L)	o-Xylene (ug/L)	total Xylenes (ug/L)	GRO (mg/L)	DRO (mg/L)	NPM (mg/L)
DEQ Water Quality Standard			5	1000	700	10000	10000	10000	7.3	1.1[A], 10[B]	NE
AMI162	RB 3-31	5/9/06									ND
AMI162		6/13/05									ND
AMI162		6/13/05									ND
AMI162		1/15/07	< 1	< 1	< 1			< 10	< 500	< 0.5	
AMI162		7/24/08	< 0.5	< 0.5	< 0.5	< 0.5	< 0.5		< 0.04	< 1	
AMI162		6/27/08							< 0.04	1.4	
AMI162		6/27/08							< 0.04	< 1	
AMI162		10/1/09	< 1	< 1	< 1	< 1	< 1		< 0.04	< 1.2	
AMI164	MS 1-33	12/8/2004									ND
AMI164		8/16/2005									ND
AMI164		9/30/2006									ND
AMI164		1/16/2007	< 1	< 5	< 1			< 3	< 0.1	0.12	
AMI164		7/19/2007									< 5
AMI164		8/27/2008							< 0.04	< 1	
AMI166	MS 10-33	12/15/2004									ND
AMI166		1/16/2007	< 1	< 5	< 1			< 3	< 0.1	1.7	
AMI166		12/11/2007	< 0.5	< 0.5	< 0.5	< 0.5	< 0.5		< 0.036	< 1	
AMI166		8/26/2008	< 0.5	< 0.5	< 0.5	< 0.5	< 0.5		< 0.04	< 1	
AMI166		5/20/2009							< 0.08	< 1.1	
AMI167	MS 12-33	11/1/2004									ND
AMI167		11/13/2006	< 0.5	17	< 0.5	< 0.5	< 0.5		< 0.036 D	< 2.4	
AMI167		2/14/2007	< 0.5	< 0.5	< 0.5	< 0.5	< 0.5		< 0.036 D	< 1	
AMI167		7/12/2007									< 5
AMI167		10/29/2007	< 0.5	< 0.5	< 0.5	< 0.5	< 0.5		< 0.036 D	< 1	
AMI167		8/28/2008							< 0.04	< 1	
AMI167		8/3/2009							< 0.08	< 1.1	
AMI182	Hwy #7	12/15/04									ND
AMI182		1/1/07	5.9	< 0.5	< 0.5	< 0.5	< 0.5		< 1	0.052	
AMI182		12/12/08							0.189	< 1.1	
AMI182		12/12/08							0.165	< 1.1	
AMI182		1/20/09	6.9	< 1	< 1	< 1	< 1		0.192	< 1	
AMI182		12/8/09	< 1	1.4	< 1	< 1	< 1		0.15	< 1.5	
AMI182		12/8/09	< 1	1.4	< 1	< 1	< 1		0.16	< 1.3	
AMI186	WB 8-6	6/14/05									ND
AMI186		9/29/06	3.4	27	3.8	54	12	66	0.358		22
AMI186		10/4/06	0.5	2.4	0.5	3.6	0.75	4.35	ND		ND
AMI186		2/13/07									
AMI186		7/16/07	< 0.5	< 0.5	< 0.5	0.55	< 0.5		< 0.036 D	< 1	
AMI186		8/29/07	< 0.5	0.91	< 0.5	< 0.5	< 0.5		< 0.036		< 5
AMI186		11/6/07	< 0.5	45	< 0.5	3.7	1		0.204 D	1.80	
AMI186		8/28/08							< 0.04	< 1	
AMI186		7/29/09	< 1	< 1	< 1	< 1	< 1		< 0.08	< 1.1	
AMI187	AN 1-16	5/10/07	2.9	ND	ND	ND	ND		ND		70
AMI187		6/8/07	25	1.3	ND	ND	ND		0.078		53
AMI187		12/15/08	6.6	< 1 J	< 1 J	< 1 J	< 1 J		0.137	78	
AMI187		12/15/08	5.5	< 1 J	< 1 U	< 1 J	< 1		0.118	11.7	
AMI188	NP 14-8	6/1/06									ND
AMI188		11/17/06	6.6	63	1.7	17	4.3		0.12	< 2.4	
AMI188		2/12/07	5.58	58	1.53	14	3.44	17.7	0.209	0.31	
AMI188		2/12/07	5	48	1.3	13	3.3		0.094	< 1	
AMI188		6/5/07	ND	ND	ND	ND	ND		ND		ND
AMI188		6/5/07	ND	ND	ND	ND	ND		ND		ND
AMI188		7/16/07	< 0.5	1.7	< 0.5	< 0.5	< 0.5		< 0.036 D	< 1	
AMI188		10/26/07	< 0.5	0.92	< 0.5	< 0.5	< 0.5		< 0.036 D	< 1	
AMI188		5/28/08							< 0.04	< 1	
AMI188		5/21/09							< 0.08	< 1.1	

Table 1

Summary of Water Wells with One or More PHC Detection

LLPHC Sampling and Analysis Plan

Well ID	Well Name	Date	Benzene (ug/L)	Toluene (ug/L)	Ethylbenzene (ug/L)	m+p-Xylene (ug/L)	o-Xylene (ug/L)	total Xylenes (ug/L)	GRO (mg/L)	DRO (mg/L)	NPM (mg/L)
DEQ Water Quality Standard			5	1000	700	10000	10000	10000	7.3	1.1[A], 10[B]	NE
AMI190	RS 11-14	7/1/05									ND
AMI190		9/22/06									ND
AMI190		1/16/07	< 1	< 5	< 1			< 3	< 0.1	**7.4**	
AMI190		1/16/07	< 1	< 5	< 1			< 3	< 0.1	**7.6**	
AMI190		12/11/07	< 0.5	**4.4**	< 0.5	< 0.5	< 0.5		**0.08**	< 1	
AMI190		1/13/09							< 0.08	< 1	
AMI190		5/19/09							< 0.08	< 1.1	
AMI191	VB 1-11	11/13/06	< 0.5	**1.4**	< 0.5	**1.6**	< 0.5		< 0.036 D	< 2.4	
AMI191		10/26/07	< 0.5	< 0.5	< 0.5	< 0.5	< 0.5		0.036 D	< 1	
AMI192	RB 13-30	5/26/05									ND
AMI192		9/16/08	< 0.5	**6.2**	< 0.5	< 0.5	< 0.5		< 0.04	< 1	
AMI192		1/16/09	< 1	< 1 J	< 1	< 1	< 1		< 0.08	< 1.1	
AMI192		1/16/09	< 1	< 1 J	< 1	< 1	< 1		< 0.08	< 1.1	
AMI192		5/19/09	< 1	< 1	< 1	< 1	< 1		< 0.08	< 1.1	
AMI196	WB 8-22	6/29/05									ND
AMI196		1/17/07	< 1	< 5	< 1			< 3	< 0.1	**0.15**	
AMI196		5/10/07									ND
AMI196		6/10/08							< 0.04	< 1	
AMI198	WB 16-5	5/25/05									ND
AMI198		1/18/07	< 1	< 5	< 1			< 3	< 0.1	**0.13**	
AMI198		5/10/07									ND
AMI198		6/13/08							**0.056**	< 1	
AMI198		7/17/08	**1**	**1**	< 0.5	**0.94**	< 0.5		< 0.04	< 1	
AMI198		7/7/09	**5.5**	**3**	< 1	**4.7**	< 1		< 0.08	< 1	
AMI198		11/12/09	< 1	**3.4**	< 1	< 1	< 1		< 0.04	< 1.1	
AMI198		11/12/09	< 1	**2.9**	< 1	< 1	< 1		< 0.04	< 1.1	
AMI199	MS 16-28	7/21/2005									ND
AMI199		1/16/2007	< 1	< 5	< 1			< 3 U	< 0.1	**0.40**	
AMI199		7/19/2007	< 0.5	< 0.5	< 0.5	**0.89**	< 0.5		< 0.036		< 5
AMI199		8/6/2007	< 0.5	**0.79**	< 0.5	< 0.5	< 0.5		< 0.036		< 5
AMI199		8/26/2008	< 0.5	< 0.5	< 0.5	< 0.5	< 0.5		< 0.04	< 1	
AMI199		5/20/2009	< 1	1	< 1	< 1	< 1		< 0.08	< 1.1	
AMI199		5/20/2009	< 1	1	< 1	< 1	< 1		< 0.08	< 1.1	
AMI202	WB 3-3	7/21/2005									ND
AMI202		1/16/2007	< 1	**140**	< 1			< 3	**0.24**	**0.70**	
AMI202		8/19/2008							< 0.04	< 1	
AMI203	WB 16-4	7/6/2005									ND
AMI203		7/19/2006									ND
AMI203		1/18/2007	< 1	< 5	< 1			< 3	< 0.1	**0.42**	
AMI203		1/18/2007	< 1	< 5	< 1			< 3	< 0.1	**0.60**	
AMI203		6/5/2008							< 0.04	< 1	
AMI204	WB 16-10	7/21/2005									ND
AMI204		7/21/2005									ND
AMI204		8/23/2006									ND
AMI204		1/17/2007	< 1	< 5	< 1			< 3	< 0.1	**0.95**	
AMI204		8/28/2008							< 0.04	< 1	
AMI205	SP 8-32	5/18/2005									ND
AMI205		5/10/2006									ND
AMI205		2/21/2007	< 1	< 2	< 2			< 2	< 0.02	< 0.5	
AMI205		5/31/2007									ND
AMI205		11/6/2007	< 0.5	**0.7**	< 0.5	< 0.5	< 0.5		< 0.036	< 1	
AMI205		5/22/2008							< 0.04	< 1	
AMI205		5/26/2009							< 0.08	< 1	

Table 1

Summary of Water Wells with One or More PHC Detection

LLPHC Sampling and Analysis Plan

Well ID	Well Name	Date	Benzene (ug/L)	Toluene (ug/L)	Ethylbenzene (ug/L)	m+p-Xylene (ug/L)	o-Xylene (ug/L)	total Xylenes (ug/L)	GRO (mg/L)	DRO (mg/L)	NPM (mg/L)
DEQ Water Quality Standard			5	1000	700	10000	10000	10000	7.3	1.1[A], 10[B]	NE
AMI209	WB 15-26	7/6/05									ND
AMI209		7/17/06									
AMI209		1/17/07	< 1	< 5	< 1			< 3	< 0.1	**0.11**	
AMI209		5/22/07									ND
AMI209	WB 15-26	6/5/08							**0.169**	**2.0**	
AMI209		7/1/08	< 0.5	**85**	< 0.5	**2.2**	**0.52**		**0.311**	< 1	
AMI209		7/7/09	< 1	**1.8**	< 1	**1.5**	< 1		0.08	**1.3**	
AMI209		11/12/09	< 1	< 1	< 1	< 1	< 1		< 0.04	< 1.1	
AMI210	WB 10-9	7/6/05									ND
AMI210		7/17/06									
AMI210		1/17/07	< 1	< 5	< 1			< 3	< 0.1	< 0.1	
AMI210		5/11/07									
AMI210		5/29/08							**0.055**	< 1	
AMI210		8/20/08							**0.102**	< 1 J	
AMI212	WB 9-15	5/26/2005									ND
AMI212		1/17/2007	< 1	< 5	< 1			< 3	< 0.1	**0.40**	
AMI212		6/26/2007									< 5
AMI212		5/29/2008							< 0.04	< 1	
AMI212		7/7/2009							< 0.08	< 1	
AMI213	PS 36-9	12/30/04									ND
AMI213		10/07/08							**0.083**	< 1	
AMI213		11/20/08	< 1	**20**	< 1	< 1	< 1		< 0.08 J	< 1.1 J	
AMI213		11/10/09	< 1	**6.3**	< 1	< 1	< 1		< 0.04	< 1	
AMI214	WB 12-9	06/17/05									ND
AMI214		06/02/06									
AMI214		11/16/06	**1**	**0.76**	< 0.5	< 0.5	< 0.5		< 0.036 D	< 2.4	
AMI214		02/13/07	< 0.5	< 0.5	< 0.5	< 0.5	< 0.5		< 0.036 D	< 1	
AMI214		05/17/07									ND
AMI214		11/06/07	**0.59**	**1.7**	< 0.5	< 0.5	< 0.5		< 0.036 D	< 1	
AMI214		05/28/08							< 0.04	< 1	
AMI214		05/19/09							< 0.08	< 1.1	
AMI228	RB 16-30	06/13/05									ND
AMI228		05/09/06									ND
AMI228		12/14/06	< 1	1 U	< 1			10 U	< 500	< 0.5	
AMI228		06/26/08							< 0.04	< 1	
AMI228		06/29/09							< 0.08	**2.9**	
AMI228		10/01/09	< 1	**4.9**	< 1	0.00	< 1 <		< 0.04	**1.4**	
AMI232	WB 5-25	7/18/2006									ND
AMI232		1/18/2007	< 1	< 5	< 1			< 3	< 0.1	**0.13**	
AMI233	BO 15-4	7/5/05									ND
AMI233		7/11/06									
AMI233		1/16/07	< 1	< 5	< 1			< 3	**0.17**	< 0.1	
AMI233		5/8/07									ND
AMI233		6/13/08							**0.347**	< 1	
AMI233		7/17/08	< 0.5	**2.3**	< 0.5	< 0.5	< 0.5		**0.28**	< 1	
AMI233		7/1/09	< 1	**2**	< 1	< 1	< 1		**0.246**	< 1	
AMI235	WB 2-8	5/25/05									ND
AMI235		8/23/06									**21**
AMI235		10/13/06	ND	**1.7**	ND	ND	ND		ND		ND
AMI235		10/13/06	ND	**1.8**	ND	ND	ND		ND		ND
AMI235		10/30/06	ND	**1**	ND	ND	ND		ND		ND
AMI235		1/17/07	< 1	< 5	< 1			< 3	< 0.1	**0.46**	
AMI235		7/10/07	< 0.5	< 0.5	< 0.5	< 0.5	< 0.5		< 0.036		< 5
AMI235		7/10/07	< 0.5	< 0.5	< 0.5	< 0.5	< 0.5		< 0.036		< 5
AMI235		8/28/08							< 0.04	< 1	
AMI235		5/19/09	< 1	< 1	< 1	< 1	< 1		< 0.08	< 1.1	

Table 1

Summary of Water Wells with One or More PHC Detection

LLPHC Sampling and Analysis Plan

Well ID	Well Name	Date	Benzene (ug/L)	Toluene (ug/L)	Ethylbenzene (ug/L)	m+p-Xylene (ug/L)	o-Xylene (ug/L)	total Xylenes (ug/L)	GRO (mg/L)	DRO (mg/L)	NPM (mg/L)
DEQ Water Quality Standard			5	1000	700	10000	10000	10000	7.3	1.1[A], 10[B]	NE
AMI237	WB 7-15	1/18/07	52	93	2			18	0.33	< 0.1	
AMI237		6/1/07	85	95	2.4	18	2.5		0.696		ND
AMI237		6/25/07	77	92	2.4	18	2.4		0.648		< 5
AMI237		7/24/07	34	37	1	7.5	1.1		0.265		< 5
AMI237		5/29/08							0.761	< 1	
AMI237		7/29/09	84	150	4	31	4		0.665	<1.1	
AMI237		11/12/09	79	140	4.2	32	4.3		0.65	< 1.1	
AMI242	WB 8-25	1/17/2007	< 1	< 5	< 1			< 3	< 0.1	0.36	
AMI242		1/17/2007	< 1	< 5	< 1			< 3	< 0.1	0.29	
AMI242		6/1/2007									ND
AMI242		6/5/2008							< 0.04	< 1	
AMI242		5/19/2009							< 0.08	< 1.1	
AMI247	BO 15-18	7/1/2005									ND
AMI247		7/1/2005									ND
AMI247		1/16/2007	< 1	< 5	< 1			< 3	< 0.1	0.53	
AMI247		7/24/2007									< 5
AMI248	BO 12A-33	1/16/2007	< 1	< 5	< 1			< 3	< 0.1	0.18	
AMI248		9/16/2008	< 0.5	< 0.5	< 0.5	< 0.5	< 0.5		< 0.04	< 1	
AMI248		9/16/2008	< 0.5	< 0.5	< 0.5	< 0.5	< 0.5		< 0.04	< 1	
AMI248		7/29/2009							< 0.08	< 1.1	
AMI249	WB 2-3	7/10/2006									ND
AMI249		1/18/2007	< 1	< 5	< 1			< 3	< 0.1	0.21	
AMI249		5/10/2007									ND
AMI249		5/29/2008							< 0.04	< 1	
AMI249		5/19/2009							< 0.08	< 1	
AMI251	BO 14-34	7/10/2006									ND
AMI251		1/16/2007	< 1	< 5	< 1			< 3	< 0.1	0.23	
AMI251		5/8/2007									ND
AMI251		6/4/2008							< 0.04	< 1	
AMI252	BO 15-7	7/11/06									20
AMI252		7/21/06									ND
AMI252		7/25/06							ND		
AMI252		1/16/07	< 1	110	< 1			< 3	0.31	4.0	
AMI252		1/16/07	< 1	110	< 1			< 3	0.35	2.8	
AMI252		7/27/07	0.81	55	< 0.5	0.71	< 0.5		0.206		< 5
AMI252		7/27/07	< 0.5	27	< 0.5	< 0.5	< 0.5		0.104	1.1	< 5
AMI252		8/17/07	< 0.5	44	< 0.5	1	< 0.5		0.188	0.00	< 5
AMI255	MS 15-27	7/24/06									ND
AMI255		1/16/07	< 1	< 5	< 1			< 3	< 0.1	< 0.1	
AMI255		8/28/08	< 0.5 J	< 0.5	< 0.5	< 0.5	< 0.5		< 0.04	4.9	
AMI255		9/12/08	< 0.5 J	< 0.5	< 0.5	< 0.5	< 0.5		< 0.04	3.0	
AMI255		5/21/09	< 1	< 1	< 1	< 1	< 1		< 0.08	3.2	
AMI258	RS 11-25	6/2/06									ND
AMI258		9/27/06	ND	ND	ND	ND	ND		ND		ND
AMI258		11/13/06	< 0.5	< 0.5	< 0.5	1	< 0.5		< 0.036 D	< 2.4	
AMI258		2/13/07	< 0.5	11	< 0.5	< 0.5	< 0.5		< 0.036 D	< 1	
AMI258		8/29/07									
AMI258		10/30/07	< 0.5	2.3	1.2	8.1	3.9		0.122 D	< 1	
AMI258		9/5/08	0.9	50	16	110	44		0.906	24	
AMI258		10/17/08							0.15	< 1 J	
AMI258		9/2/09	< 1	< 1	< 1	2.6	1.1		0.058	< 1.1	
AMI258		12/18/09	< 1	2	1.8	17	7		0.22	6	

Table 1

Summary of Water Wells with One or More PHC Detection

LLPHC Sampling and Analysis Plan

Well ID	Well Name	Date	Benzene (ug/L)	Toluene (ug/L)	Ethylbenzene (ug/L)	m+p-Xylene (ug/L)	o-Xylene (ug/L)	total Xylenes (ug/L)	GRO (mg/L)	DRO (mg/L)	NPM (mg/L)
DEQ Water Quality Standard			5	1000	700	10000	10000	10000	7.3	1.1[A], 10[B]	NE
AMI259	RS 13-4	6/2/06									ND
AMI259		11/17/06	< 0.5	**3.8**	< 0.5	< 0.5	< 0.5		< 0.036 D	< 1	
AMI259		2/14/07	< 0.5	**1.9**	< 0.5	< 0.5	< 0.5		< 0.036 D	< 1	
AMI259		6/11/07									
AMI259		11/6/07	< 0.5	< 0.5	< 0.5	< 0.5	< 0.5		< 0.036 DS	< 1	
AMI259		5/27/08							< 0.04	< 1	
AMI259		5/20/09							< 0.08	< 1.2	
AMI261	RS 4-1	7/13/06									ND
AMI261		5/7/07	**0.51**	ND	ND	ND	ND		ND		ND
AMI261		6/8/07	ND	ND	ND	ND	ND		ND		ND
AMI261		5/5/08							< 0.04	< 1	
AMI261		5/20/09	< 1	< 1	< 1	< 1	< 1		< 0.08	< 1.1	
AMI262	RS 4-25	8/23/2006									ND
AMI262		1/16/2007	< 1	< 5	< 1			< 3	< 0.1	**0.10**	
AMI262		8/19/2008							< 0.04	< 1	
AMI262		5/21/2009							< 0.08	< 1	
AMI265	WB 5-15	9/29/2006									ND
AMI265		1/17/2007	< 1	< 5	< 1			< 3	**0.12**	**0.34**	
AMI265		1/16/2009							< 0.08	< 1.1	
AMI265		7/8/2009							< 0.08	**1.00**	
AMI266	WB 6-5	7/12/2006									ND
AMI266		7/12/2006									ND
AMI266		1/17/2007	< 1	< 5	< 1			< 3	< 0.1	**0.14**	
AMI266		5/10/2007									ND
AMI266		6/5/2008							< 0.04	< 1	
AMI270	2 Buttes	11/9/2006	ND	**1.6**	ND	ND	ND		ND		
AMI270	16-15	10/17/2007									< 5
AMI270		8/14/2008							< 0.04	< 1	
AMI270		11/3/2009	< 1	1	< 1	< 1	< 1		< 0.04	< 1.1	
AMI274	RS 7-13	11/13/06	< 0.5	**1.3**	< 0.5	< 0.5	< 0.5		< 0.036 D	< 2.4	
AMI274		2/13/07	< 0.5	**2.7**	< 0.5	< 0.5	< 0.5		< 0.036 D	< 1	
AMI274		5/18/07									ND
AMI274		10/29/07	< 0.5	< 0.5	< 0.5	< 0.5	< 0.5		< 0.036 D	< 1	
AMI274		5/28/08							< 0.04	< 1	
AMI274		7/15/09							< 0.08	< 1.1	
AMI279	WB 1-9	5/18/07									ND
AMI279		10/30/07	< 0.5	< 0.5	< 0.5	< 0.5	< 0.5		< 0.036 D	< 1	
AMI279		5/28/08							< 0.04	< 1	
AMI279		7/20/09	< 1	< 1	< 1	< 1	< 1		< 0.08	**2.1**	
AMI279		12/22/09	< 1	**1.8**	< 1	< 1	< 1		< 0.04	< 1.1	
AMI280	BO 14-32	11/13/06	< 0.5	**12**	< 0.5	< 0.5	< 0.5		< 0.036 D	**3.9**	
AMI280		2/13/07	< 1	< 1	< 1	< 2	< 1	< 3	< 0.05	< 0.25	
AMI280		2/13/07	< 0.5	< 0.5	< 0.5	< 0.5	< 0.5		< 0.036 D	< 1	
AMI280		5/17/07									ND
AMI280		5/18/07									ND
AMI280		10/30/07	< 0.5	< 0.5	< 0.5	< 0.5	< 0.5		< 0.036 D	< 1	
AMI280		5/28/08							< 0.04	< 1	
AMI280		5/19/09							< 0.08	< 1	
AMI280		5/19/09							< 0.08	< 1	
AMI285	WB 7-5	5/18/07									ND
AMI285		10/30/07	**28**	**25**	**0.63**	**5.2**	< 0.5		**0.193 D**	< 1	
AMI285		11/26/07	**3**	**2.4**	< 0.5	**0.55**	< 0.5		**0.074 D**	< 1	
AMI285		5/28/08							**0.045**	< 1	
AMI285		7/29/09	< 1	< 1	< 1	< 1	< 1		< 0.08	< 1.1	

Table 1

Summary of Water Wells with One or More PHC Detection

LLPHC Sampling and Analysis Plan

Well ID	Well Name	Date	Benzene (ug/L)	Toluene (ug/L)	Ethylbenzene (ug/L)	m+p-Xylene (ug/L)	o-Xylene (ug/L)	total Xylenes (ug/L)	GRO (mg/L)	DRO (mg/L)	NPM (mg/L)
DEQ Water Quality Standard			5	1000	700	10000	10000	10000	7.3	1.1[A], 10[B]	NE
AM1301	WB 11-4	7/20/09							**0.175**	**1.10**	
AM1301		12/18/09	< 1	< 1	< 1	**3.3**	< 1		< 0.04	< 1	
SM 14-12		10/26/07	< 0.5	**0.58**	< 0.5	< 0.5	< 0.5	NM	< 0.036	< 1	NM

This summary includes SCCD and Geomatrix records through December 2009.

Shading indicates concentration exceeds DEQ standard or action level. Note that TPH-DRO concentrations are only shaded if over 10 mg/L.

DEQ = Wyoming Department of Environmental Quality; NPM = Non-Polar Materials

ND = Not Detected; NM = Not Measured; NE = Not Established; ug/l = micrograms per liter; mg/l = milligrams per liter

J - Indicates parameter was detected at a concentration between the method detection limit and the reporting limit. The stated value is an estimate.

H - Indicates the sample was analyzed outside the method recommended hold time.

A - Applicable cleanup level for TPH-DRO is 1.1 mg/l if BTEX, naphthalene and/or 2-methylnaphthalene exceed cleanup levels.

B - If BTEX, naphthalene and/or 2-methylnapthalene are below cleanup levels and no free product is present, the applicable cleanup level for TPH-DRO is 10 mg/l.

C - Re-analysis of groundwater samples collected from AM1146 on 10/27/08 and 11/20/08 by Method 8260 indicated that benzene was misidentified. The compound detected was 2-methylcyclohexane. There are likely no exceedances of the benzene standard at this well.

TABLE 2
PAPA-Wide Potential Source Screening Matrix
Low-Level Petroleum Hydrocarbon Sampling and Analysis Plan

Source Type	General Description	Potential Contaminants of Concern	Target Analytes	Source	Source Location [1]		Source Depth (ft)
					Northing	Easting	
Class II Injection Well[2]	Excursions in Regional Wasatch HSU due to improperly constructed injection wells or conduits intercepting injected water	produced water condensate	common ions, general water quality parameters, metals, silica, VOCs, TPH-GRO	**Petrogulf State 1-36 WDW**	4718400	600000	4,318-4,844
				Riverside 6-16 WDW	4723954	595030	4,589-6,333
				Riverside 11-16 WDW	4723524	594838	5,508-6,300
				Riverside 12-16D WDW	4723520	594836	6,082-6,394
				Riverside 13-16d WDW	4723516	594833	6,554-6,804
				Ross Butte 3-5 WDW	4717920	592929	5,760-6,916
				Ross Butte 4-5 WDW	4717920	592929	6,101-6,790
				Lizard Head 11-8	4724792	602671	5,200-7,350
				Mesa 10-30	4701854	592171	7,684 (TD)
				Mesa 11-30	4701854	592171	7,602 (TD)
				WDW No. 1 NFX	4701932	615185	6,464 (TD)
				Warbonnet 10-26D WDW	4718930	600238	7,735 (TD)
				Warbonnet 11-26D WDW	4709870	608120	6,445-7,640
				Warbonnet 14-26D WDW	4718930	600238	6,308-7,640
				Warbonnet 15-26 WDW	4709870	608120	6,800-7,244
				South Mesa 12-14 IDW1	4713800	597870	5,908-6,124
				South Mesa 12-14 IDW2	4713800	597870	6,113-6,352
				South Mesa 12-14 IDW3	4713800	597870	6,143-6,511
				South Mesa 12-14 IDW4	4713800	597870	6,139-6,466
				South Mesa 12-14 IDW5	4713800	597870	5,501-6,340
				Highway SWD #11 (Highway Fed No.11)	4708050	615890	6,032-7,072

TABLE 2
PAPA-Wide Potential Source Screening Matrix
Low-Level Petroleum Hydrocarbon Sampling and Analysis Plan

Source Type	General Description	Potential Contaminants of Concern	Target Analytes	Source	Source Location [1]		Source Depth (ft)
					Northing	Easting	
Actively Producing, Shut-In, or Improperly Abandoned Gas Wells[2,3]	Drilling, completions, production, and abandonment activities	natural gas, condensate, produced water, oil-based mud, diesel, fuel oil and other completions fluids	dissolved gases (C1 - C5), VOCs & SVOCs by GC/MS, TPH-GRO, TPH-DRO, common ions, general water quality parameters, metals	**Wagon Wheel 1 (WW1)**	4717158	602853	Depths ranging from ground surface to 19,000 feet
				Government 1 (Govt1)	4723700	598543	
				Jensen 1 (Jen 1)	4725336	597720	
				Jenson 2 (Jen 2)	4724359	598943	
				Pinedale 1 (PD 1)	4715197	605304	
				Pinedale 2 (PD 2)	4719765	603205	
				Pinedale 3 (PD 3)	4724563	599538	
				Pinedale 4 (PD 4)	4728828	596311	
				Pinedale 5 (PD 5)	4716605	602963	
				Pinedale 6 (PD 6)	4712369	604547	
				Pinedale 7 (PD 7)	4714200	606691	
				Pinedale 8 (PD 8)	4740762	590572	
				Mesa 1 (MS 1)	4735513	592323	
				Mesa 2 (MS 2)	4733504	594890	
				New Fork 1 (NF 1)	4710823	609800	
				New Fork 2 (NF 2)	4717261	608023	
				New Fork 4 (NF 4)	4718517	598620	
				Tex Unit 1	4700912	619250	
				Stan Unit 1	4742285	591090	
				Baumgartner Fed. 21-24 (BF 21-24)	4741522	587368	

TABLE 2
PAPA-Wide Potential Source Screening Matrix
Low-Level Petroleum Hydrocarbon Sampling and Analysis Plan

Source Type	General Description	Potential Contaminants of Concern	Target Analytes	Source	Source Location [1]		Source Depth (ft)
					Northing	Easting	
Gas Field Pits[3,4]	Pits used for drilling, completions, work-over and production	condensate, produced water, oil-based mud, diesel, fuel oil and other completions fluids	VOCs & SVOCs by GC/MS, TPH-GRO, TPH-DRO, common ions, general water quality parameters, metals	**Active or Former Gas Well Pads**	Throughout PAPA		~ 3 - 5 feet
Contaminated Tanks, Tankers, & Equipment; Lack of Back-Flow Preventors[4]	Use of contaminated tanks to transfer fresh water; lack of back-flow prevention on wells connected to contaminated tanks	contaminated water	VOCs & SVOCs by GC/MS, TPH-GRO, TPH-DRO	**Operator Water Supply Wells**	Throughout PAPA		Perforated zones in wells (>200 ft to <1,000 ft)
Natural Sources[5]	Macroseepage and microseepage	Natural gas and condensate	dissolved gases (C1 - C5), VOCs & SVOCs by GC/MS, TPH-GRO, TPH-DRO	**Wasatch, Fort Union, and/or Lance Formations**	Throughout PAPA, more likely in southern portion		0 to ~ 12,000 ft depending on location in PAPA

TABLE 2
PAPA-Wide Potential Source Screening Matrix
Low-Level Petroleum Hydrocarbon Sampling and Analysis Plan

Source Type	General Description	Potential Contaminants of Concern	Target Analytes	Source	Source Location [1]		Source Depth (ft)
					Northing	Easting	
Well/Pump Installation Practices[4]	Use of lubricants during drilling and well installation, no decontamination of well construction materials or pumps	compressor oil, hydraulic oil, pipe dope	VOCs & SVOCs by GC/MS, TPH-GRO, TPH-DRO, metals	**Well Drilling and Well/Pump Installation Equipment**	Throughout PAPA		NA
Permitted Oil Disposal Facility[6,7]	Liner for evaporation ponds perforated and leaking; malfunction of leak-detection monitoring system malfunction; improper landfarming practices	Produced water, condensate, and petroleum-contaminated soil	VOCs & SVOCs by GC/MS, TPH-GRO, TPH-DRO, common ions, general water quality parameters, metals	**Anticline Disposal LLC**	4722800	601300	14-34 (base of cells)
				Newpark Sand Draw Facility	4718000	611400	< 40

TABLE 2
PAPA-Wide Potential Source Screening Matrix
Low-Level Petroleum Hydrocarbon Sampling and Analysis Plan

Source Type	General Description	Potential Contaminants of Concern	Target Analytes	Source	Source Location [1]		Source Depth (ft)
					Northing	Easting	
Landfill[8,9]	Liner perforated and leaking; malfunction of leak-detection monitoring system malfunction; unlined cells	Leachate and landfill gas	methane, ammonia, chloride, TDS, VOCs, metals	**Boulder Landfill Abandoned**	4725753	605506	3-6
				Pinedale #1 Historic Municipal Landfill	4748800	597100	unknown
				Pinedale #2 Closed Municipal Landfill/ Active Transfer Station	4745400	585800	unknown

Notes:

1 - locations expressed in UTM coordinates.

2-Wyoming Oil and Gas Conservation Commission online database search: http://wogcc.state.wy.us/

3-Bureau of Land Management file review; Undesirable Events database search

4-Operator data and information; previous investigations

5-Shell Internship Final Report, Pinedale Groundwater Characterization Project, Compiled for AMEC Geomatrix, Jessica Malone, July 2009;
Shallow Gas Found at the Yates Petroleum Highway 4 Well Pad SW NE 16-29-107, Pinedale Field, Sublette County, WY Memo, Gary Strong, WOGCC, dated 3/30/09.

6-WYDEQ Water and Wastewater Program; http://deq.state.wy.us/wqd/www/Permitting/Downloads/Produced%20Water/Oil-Field-Pits_Active.pdf.

7-Application for Transfer/Treatment/Storage Permit, Newpark PCS Treatment Facility, Inberg-Miller Engineers, Riverton, WY, Revised November, 12 2003.

8-Wyoming Department of Environmental Quality (WYDEQ) Solid and Hazardous Waste Site listings

9-Phase I Groundwater Monitoring Program, Boulder Abandoned Landfill, Sublette County, Wyoming, dated December 19, 2007.

TABLE 3
Location-Specific Source Screening Matrix
Low-Level PHC Sampling and Analysis Plan

Well Name	Well ID	Easting[1]	Northing[1]	Pre-1984 Gas Wells & Associated Facilities[2]	Permitted Oil Disposal Facility[2,3]	Class II Injection Well[3]	Landfill[2,4]	DEQ Storage Tank Program Sites[2]
Wells with PHC detects during last round of sampling								
Antelope 15-4	AMI017	614636	4706860			X		
Highway #11	AMI033	615774	4708011			X		
Mesa Lovatt Draw 15-8	AMI043	593612	4724721			X		
Rainbow 13-32	AMI134	612147	4708453	X				
Antelope 11-10D	AMI146	615649	4705689					
Highway #7 Water Well	AMI182	613938	4705986					
Antelope 1-16-29-107	AMI187	615101	4704954					
Warbonnet 16-5	AMI198	603643	4716368	X		X		
Petrogulf State 36-9	AM213	600494	4718477	X		X		
Rainbow 16-30	AMI228	611871	4710041	X				
Boulder 15-4	AMI233	604844	4726159				X	
Warbonnet 7-15D	AMI237	606789	4714178	X				
Mesa 15B-27D	AMI255	596781	4729400	X				
Riverside 11-25	AMI258	599659	4720069	X		X		
Warbonnet 5D-15D	AMI265	605878	4713892	X				
Warbonnet 1-9	AMI279	605122	4715896	X				
Warbonnet 11-4	AMI301	604516	4716382	X		X		
Wells with historic PHC detects; no detects during last round of sampling								
Corwin 2	AD213	588452	4745008					X
Tri County Sanit. #1	AD223	588789	4745371					X
DC-6	AD238	589335	4745869					X

TABLE 3
Location-Specific Source Screening Matrix
Low-Level PHC Sampling and Analysis Plan

Well Name	Well ID	Easting[1]	Northing[1]	Pre-1984 Gas Wells & Associated Facilities[2]	Permitted Oil Disposal Facility[2,3]	Class II Injection Well[3]	Landfill[2,4]	DEQ Storage Tank Program Sites[2]
Wells with historic PHC detects; no detects during last round of sampling (cont'd)								
N.W. Squaretop	AS014	611680	4711595	X				
Stewart Point 11-33	AMI028	592152	4737427	X				
Stewart Point 5-20	AMI030	590173	4741342	X				
Riverside 1-4	AMI078	595561	4727526	X				
Pinedale 2-2	AMI079	597970	4727444	X				
Mesa 4-28-32-109W	AMI090	594187	4730577	X				
Riverside 15-12	AMI132	600090	4724457	X				
North Mesa 4-7-32-109W	AMI140	590915	4735685	X				
Warbonnet 11-10	AMI145	606084	4715279	X				
Warbonnet 13-14	AMI148	607237	4713171	X				
Blue Rim State #2	AMI149	604966	4714354	X				
Mesa 12-28	AMI160	594484	4729952	X				
Warbonnet 8-6	AMI186	602003	4717261	X		X		
North Pinedale 14-8	AMI188	590463	4743567	X				
Riverside 11-14	AMI190	598099	4723362	X				
Vible 1-11D	AMI191	598895	4725266	X				
Mesa 16-28	AMI199	595539	4729321	X				
Warbonnet 15-26	AMI209	608088	4709805	X		X		
Warbonnet 12-9	AMI214	603987	4715215	X				
Warbonnet 2-8	AMI235	603261	4715909	X		X		

TABLE 3
Location-Specific Source Screening Matrix
Low-Level PHC Sampling and Analysis Plan

Well Name	Well ID	Easting[1]	Northing[1]	Pre-1984 Gas Wells & Associated Facilities[2]	Permitted Oil Disposal Facility[2,3]	Class II Injection Well[3]	Landfill[2,4]	DEQ Storage Tank Program Sites[2]
Wells with historic PHC detects; no detects during last round of sampling (cont'd)								
Riverside 13-4	AMI259	594576	4726470	X				
Riverside 4D-1D	AMI261	599348	4726693	X				
Riverside 7-13	AMI274	600101	4723661	X	X			
Warbonnet 7-5	AMI285	603232	4717174	X		X		
Wells with a one-time detect or sporadic detects of PHCs								
Warbonnet 9-23	AMI008	608526	4711939	X				
Lizard Head 13-28	AMI009	604013	4719499	X				
Mesa 3-20	AMI027	593166	4732419	X				
Mesa 13-5	AMI029	592746	4736017	X				
Stewart Point 11-21	AMI113	592178	4740822	X				
Mesa 9-16	AMI117	595594	4733003	X				
Mesa 10-16	AMI118	595240	4733065	X				
Riverside 3-3	AMI122	596480	4727367	X				
Riverside 8-3	AMI124	597339	4726892	X				
Antelope 5-4	AMI131	613873	4707563					
Mesa 11-28-32-109W	AMI159	594838	4729872	X				
Stewart Point 5-29D	AMI161	589624	4740068	X				
Rainbow 3-31	AMI162	610982	4709537	X				
Mesa 10-33	AMI166	595330	4728214	X				
Mesa 12-33	AMI167	594413	4728309	X				

TABLE 3
Location-Specific Source Screening Matrix
Low-Level PHC Sampling and Analysis Plan

Well Name	Well ID	Easting[1]	Northing[1]	Pre-1984 Gas Wells & Associated Facilities[2]	Permitted Oil Disposal Facility[2,3]	Class II Injection Well[3]	Landfill[2,4]	DEQ Storage Tank Program Sites[2]
Wells with a one-time detect or sporadic detects of PHCs (cont'd)								
Rainbow 13-30	AMI192	611347	4708389	X				
Stewart Point 8-32D	AMI205	591412	4737780	X				
Warbonnet 9-15	AMI212	606855	4713605	X				
Warbonnet 8-25	AMI242	610177	4710788	X				
Boulder 12A-33	AMI248	604183	4718326	X		X		
Warbonnet 2D-3D	AMI249	606435	4717111	X		X		
2 Buttes 16-15CD	AMI270	596946	4732674	X				
Boulder 14-32	AMI280	602879	4718043	X		X		
Wells with historic PHC detects,that have been abandoned								
Lizard Head 11-8	AMI010	602671	4724792					
Antelope 14-22	AMI015	616002	4702192					
New Fork Unit #11-24W	AMI026	599788	4721648	X				
Antelope 11-4	AMI034	614171	4707304					
Rainbow 7-31	AMI037	611364	4709188	X				
Warbonnet 6-26	AMI089	607577	4710842	X		X		
Riverside 9-2	AMI107	598917	4726522	X				
Mesa 7-34	AMI127	597088	4728594	X				
Mesa 9-34	AMI128	597207	4728224	X				
Riverside 4-10	AMI130	596055	4725847	X				
Warbonnet 9-26	AMI137	608594	4710224	X		X		

TABLE 3
Location-Specific Source Screening Matrix
Low-Level PHC Sampling and Analysis Plan

Well Name	Well ID	Easting[1]	Northing[1]	Pre-1984 Gas Wells & Associated Facilities[2]	Permitted Oil Disposal Facility[2,3]	Class II Injection Well[3]	Landfill[2,4]	DEQ Storage Tank Program Sites[2]
Wells with historic PHC detects,that have been abandoned (cont'd)								
Warbonnet 13-11	AMI147	607261	4714772	X				
Boulder 7-19	AMI151	601514	4721941	X	X			
Mesa 1-33	AMI164	595516	4729115	X				
Warbonnet 8-22	AMI196	607032	4712394	X				
Warbonnet 3-3	AMI202	605967	4717487	X				
Warbonnet 16-4	AMI203	605175	4716335	X				
Warbonnet 16-10	AMI204	606865	4714713	X				
Warbonnet 10-9D	AMI210	604987	4715099	X				
Warbonnet 5-25	AMI232	609021	4710841	X		X		
Boulder 15-18	AMI247	601517	4722715	X	X			
Boulder 14-34	AMI251	605942	4717849	X				
Boulder 15D-7D	AMI252	601714	4724650	X				
Riverside 4D-25D	AMI262	599277	4720683	X				
Warbonnet 6-5	AMI266	602836	4717143	X		X		
South Mesa 14-12	SM 14-12	UNK	UNK	UNK	UNK	UNK	UNK	UNK

Notes:

1 - Locations expressed in UTM coordinates.

2- Assume potential source is located within approximately one mile of water supply well, except in the case of pre-1984 gas wells, which is within approximately two miles.

3-Wells within one mile of permitted oil disposal facility are for Anticline Disposal Facility; no wells are within one mile of the Newpark Facility.

4-Well within one mile of landfill is for Old Boulder Landfill; no wells are within one mile of the Pinedale #1 and #2 Landfills.

TABLE 4
Sampling and Analysis Well Network
Low Level Petroleum Hydrocarbon Sampling and Analysis Plan

SCCD Well ID	Well Name/ Production Area	Owner	Well Status [1]	Easting [2]	Northing [2]	Reference Elevation [2]	SAP Well Type	LEL Well	Date Drilled	Total Depth	Type of Seal	TOP of Seal	Bottom of Seal	Multiple Casings	Production Casing Diameter	Casing Depth	Perforated (P) or Screened (S)	Top of Perforated or Screened Interval	Bottom of Perforated or Screened Interval
AMI017	Antelope 15-4 WSW	BP America Production Company	UNK	614636.4735	4706866.346	7155.71	PHC		UNK	712	UNK	UNK	UNK	UNK	UNK	UNK	UNK	UNK	UNK
AMI018	Antelope 15-23 WSW	Newfield Production Company	UNK	617960.7814	4702144.021	7112.20	Control		2/15/2000	650	UNK	UNK	UNK	UNK	6.625	650	P	180	650
AMI019	Stewart Point 11-34	QEP Energy	A	593450.3333	4737141	7529.67	Control		7/6/1999	930	UNK	UNK	UNK	NO	6	910	P	890	930
AMI028	Stewart Point 11-33	QEP Energy	A	592152	4737436.333	7559.00	PHC		8/28/2000	980	UNK	0	500	YES	6.625	980	P	690	965
AMI030	STEWART POINT WATER WELL #05-20	QEP Energy	A	590174.1446	4741351.406	7346.55	PHC		9/26/2000	745	Cement	0	480	YES	6	745	P	493	745
AMI033	Highway #11	Yates Petroleum Company	A	615774.266	4708010.91	7229.52	PHC		3/4/2001	700	Cement	0	580	YES	6.625	700	P	580	700
AMI078	Riverside 1-4	Ultra Resources	A	595563.7177	4727534.608	7108.06	PHC		8/7/2001	610	Grout Mix	0	500	YES	6.625	610	SLOTTED	530	610
AMI116	Mesa 14-16 Water Source Well	QEP Energy	A	594866.3333	4732833.667	7471.67	PHC	x	2/14/2002	930	Cement	0	450	YES	6.625	930	P	730	930
AMI119	Mesa 15-16 Water Source Well	QEP Energy	A	595191	4732631	7458.00	Control		11/15/2001	1000	Cement	0	460	YES	6.625	1000	P	700	1000
AMI132	Riverside 15-12 Water Well	Ultra Resources	A	600093	4724471	6970.00	PHC		9/14/2003	410	Bentonite	0	200	YES	6.625	410	P	250	410
AMI135	Warbonnet 7-4 Water Well	Ultra Resources	A	604808	4717084	7149.00	PHC	x	11/12/2001	470	Grout Mix	0	120	YES	6.625	470	SLOTTED	350	470
AMI146	Antelope 11-10D	Shell Rocky Mountain Production	A	615649	4705688.5	7214.00	PHC	x	3/5/2003	680	Cement and Bentonite	0	200	YES	6	680	P	470	660
AMI156	Riverside 2-24	Shell Rocky Mountain Production	A	600027.5	4722417.5	6989.00	Control		6/15/2003	700	Bentonite	0	200	YES	6	700	P	448	658
AMI160	MESA 12-28	Shell Rocky Mountain Production	A	594484	4729951.5	7440.00	PHC		7/6/2006	1020	Tremie - Pumped Bentonite	0	500	YES	6	1020	P	820	1000
AMI182	HIGHWAY #7 WATER WELL	Yates Petroleum Company	A	613929	4705998.5	7292.50	PHC	x	6/7/2003	610	Bentonite	0	300	NO	6.625	610	P	490	610
AMI186	WARBONNET 8-6	Shell Rocky Mountain Production	A	602004.8333	4717275.333	7051.50	PHC		10/12/2004	740	Cement	0	200	YES	6	740	P	530	715
AMI187	ANTELOPE 1-16-29-107	Neo Exploration Inc.	Not drilled?	615101	4704954	7279.50	PHC	x	UNK	UNK	UNK	UNK	UNK	UNK	UNK	UNK	UNK	UNK	UNK
AMI190	RIVERSIDE 11-14	Ultra Resources	A	598100	4723371.5	6963.00	PHC	x	8/12/2003	510	Bentonite	0	110	NO	6.625	410	P	165	410
AMI198	WARBONNET 16-5	Ultra Resources	A	603643.3333	4716368	7081.67	PHC		9/30/2003	390	Bentonite	0	200	NO	6.625	390	P	270	390
AMI213	PETROGULF STATE 36-9	Rosetta	UNK	600494.3333	4718477.333	7048.67	PHC		3/21/2004	730	Neat Cement	0	500	YES	6.625	730	P	638	730
AMI228	Rainbow 16-30 Water Well	Newfield Production Company	UNK	611871	4710041	7329.33	PHC		UNK	UNK	UNK	UNK	UNK	UNK	UNK	UNK	UNK	UNK	UNK
AMI237	Warbonnet 7-15D	Ultra Resources	A	606794.75	4714189.25	7387.25	PHC		10/21/2004	750	Bentonite Pellets	0	200	NO	6.625	750	P	590	750
AMI248	Boulder 12A-33	Ultra Resources	A	604184	4718338.5	7191.00	PHC	x	11/16/2004	450	Bentonite Pellets	0	200	NO	6.625	450	P	330	450
AMI250	Boulder 1-32	Shell Rocky Mountain Production	A	603532.5	4719193.5	7093.50	Control		10/4/2006	770	Bentonite	0	200	YES	6.625	770	P	240	700
AMI258	Riverside 11-25	Shell Rocky Mountain Production	A	599654.5	4720081.5	7036.50	PHC		9/8/2005	800	Cement	0	20	YES	6	800	P	350	760
AMI285	WARBONNET 7-5	Shell Rocky Mountain Production	A	603230	4717182	7091.00	PHC	x	12/27/2006	700	Neat Cement Slurry (tremied)	0	200	YES	6.625	700	P	300	680
AMI297	Rainbow 13-29	Shell	A	UNK	UNK	UNK	Control		7/2/2007	900	Cement	0	200	YES	6	900	P	500	890
T-1-SW	North Pinedale	Bureau of Land Management	A	-	-	-	Study		7/31/2010	-	-	-	-	-	-	-	S	147	187
T-1-RW	North Pinedale	Bureau of Land Management	A	-	-	-	Study		7/31/2010	683	-	-	-	-	-	-	S	620	650
T-2-SW	Mesa	State of Wyoming	A	-	-	-	Study		6/29/2010	375	-	-	-	-	-	-	S	335	375
T-2-RW	Mesa	State of Wyoming	A	-	-	-	Study		6/27/2010	790	-	-	-	-	-	-	S	730	770
T-3-SW	Warbonnet	Bureau of Land Management	A	-	-	-	Study		7/1/2010	460	-	-	-	-	-	-	S	405	445
T-3-RW	Warbonnet	Bureau of Land Management	A	-	-	-	Study		7/17/2010	770	-	-	-	-	-	-	S	705	745
T-4-SW	Antelope	Bureau of Land Management	A	-	-	-	Study		5/18/2010	200	-	-	-	-	-	-	S	175	190
T-4-RW-a	Antelope	Bureau of Land Management	A	-	-	-	Study		6/2/2010	475	-	-	-	-	-	-	S	430	460
T-4-RW-b	Antelope	Bureau of Land Management	A	-	-	-	Study		7/27/2010	675	-	-	-	-	-	-	S	635	655
T-5-RW	Sand Draw Spring	Bureau of Land Management- Ultra	A	-	-	-	Study		-	615	-	-	-	-	-	-	S	550	590
	Total No. of Wells																		
	37																		

Notes:
SCCD Sublette County Conservation District Original Source: SCCD (September 10, 2008)
1 - A = active (or soon active); PA = plugged and abandoned; UNK = unknown
2 - Value based on SCCD location/elevation information; coordinates and reference elevation for study wells to be determined.
3- SAP = Sampling and Analysis Plan; PHC = Wells with Petroleum Hydrocarbon Detects; Control = Well in control group; Study = Well installed as part Hydrogeological Data Gaps Study

TABLE 5
Media-Specific Parameters for Laboratory Analysis
Low-Level PHC Sampling and Analysis Plan

Parameter [1]	Analytical Method or Equivalent	Laboratory Reporting Limit [2,3]	Preservation Method [4]	Holding Time	Container Type & Size [5]
Water Parameters					
Methane	Isotech [6]	0.025 µg/l	<6 °C, TSP (pH >10)	14 days	P, 1 - 1L w/ septum
Ethane	Isotech [6]	0.025 µg/l	<6 °C, TSP (pH >10)	14 days	P, 1 - 1L w/ septum
Ethene, Iso-butane, n-butane, propane, propene	Isotech [6]	0.05 µg/l	<6 °C, TSP (pH >10)	14 days	P, 1 - 1L w/ septum
TPH-GRO	EPA Method 8015	0.02 mg/L	<4˚C, HCL (pH<2)	14 days	G, 3-40 mL VOA
TPH-DRO	EPA Method 8015	0.3 mg/L	<4˚C, HCL (pH<2)	14 days	AG, 2 - 1L
VOC	EPA Method 8260	1-20 µg/l	<4˚C, HCL (pH<2)	14 days	G, 3-40 mL VOA
SVOC	EPA Method 8270	10-100 µg/l	<4˚C, Na-thio	7 days	AG, 2 - 1L
TAL Metals (total) + B, Sr, Si	EPA Method 200.7/6010	0.1 mg/l (cations up to 5 mg/l)	<4˚C, HNO_3 (pH<2)	6 months	P, 250 ml
TDS	SM 2540C	10 mg/l	none	7 days	P, 250 ml
Alkalinity	SM 2320 B	1 mg/l	none	14 days	P, 250 ml
Anions: Cl, SO_4, F, PO_4, Br	EPA Method 300.0	Up to 1 mg/l	<4˚C	28 days	P, 250 ml
Nitrate, nitrite, ammonia	EPA Method 353.2/350.1	0.05 mg/l	<6 °C, H2SO4	28 days	P, 500 ml
Methane: Carbon (^{13}C) & Hydrogen (D) isotopes	Isotech [7]	-1000 ‰ [8]	Benzalkonium Chloride	14 days	P, 1L w/ septum & bacteriocide
Water: Oxygen (^{18}O) & Hydrogen (D) isotopes	Isotech [7]	-1000 ‰ [8]	Benzalkonium Chloride	28 days	P, 1L w/ septum
Gas Parameters					
Hydrogen Sulfide, Carbon Dioxide, Nitrogen	S2_BTEX,H2S(low) [10]	0.0001 Mole%	None	NA [11]	NA [11]
Methane, Ethane, Propane, iso-Butane, n-Butane, iso-Pentane, n-Pentane, Hexanes, Heptanes, Octanes, Nonanes, Decanes	S2_BTEX,H2S(low) [10]	0.0001 Mole%	None	NA [11]	NA [11]
Benzene, Toluene, Ethylbenzene, Xylenes	S2_BTEX,H2S(low) [10]	0.0001 Mole%	None	NA [11]	NA [11]
Carbon (^{13}C) & Hydrogen (D) isotopes: Methane	Isotech [9]	-1000 ‰ [10]	None	14 days	Summa Canister, 1 L or simiilar

TABLE 5
Media-Specific Parameters for Laboratory Analysis
Low-Level PHC Sampling and Analysis Plan

Notes:
1 – TPH = total petroleum hydrocarbons; DRO = diesel range organics; GRO = gasoline range organics; VOC = volatile organic compounds; SVOC = semi-volatile organic compounds; NA = not applicable
2 – Stated laboratory reporting limits are method detection limits or practical quantitation limits and are minimum requirements for project; reporting limits for dissolved gases in groundwater per Microseeps, Inc.; reporting limits for well headspace gases, and production well gases per Precision Analysis; and stable Isotopes per Isotech
3 – mg/l = milligrams per liter; µg/l = micrograms per liter; µmhos/cm = micromhos per centimeter; s.u. = standard units.
4 – C = degrees Celsius; TSP = trisodium phosphate; HCL = hydrochloric acid; Na-thio = sodium thiosulfate
5 – Container types and sizes are abbreviated as: VOA = volatile organic analysis vials; G = glass; A = amber; L = liter; ml = milliliters.
6 – Analytical Method AM20GAx, Standard Operating Procedure for Analysis of Biodegradation Indicator Gases, Microseeps, Inc., Revision 9.0, November 21, 2008.
7 - Isotech Laboratories Inc. internal laboratory procedure for isotope analysis.
8 – Reporting limits in parts per thousand calculated versus a standard. -1000 ‰ indicates no isotope present is present, 0 would indicate concentration is equivalent to standard concentration.
9 – Isotech internal laboratory procedure for compound specific isotope analysis.
10 – Precision Analysis internal laboratory procedure for extended gas analysis.
11 – Gas samples are analyzed immediately; no holding time or container applicable.

TABLE 6
Precision, Accuracy, and Completeness Goals
Low-Level PHC Sampling and Analysis Plan

Measurement Parameter	Precision	Accuracy	Completeness
Field Water Quality Parameters (pH, temperature, specific conductance)	± 20% (compare to lab data, where applicable)	Variable (depends on parameter)	90%
Laboratory Analysis (inorganic common ions in water)	±20% RPD [1]	80 – 120% [2] 75 – 125% [2]	95% [3]
Laboratory Analysis (PHC in water)	±20% RPD [1]	80 – 120% [2] 75 – 125% [2]	95% [3]
Laboratory Analysis (dissolved gases in water)	no analytes in method blanks; ±20% RPD [1]	70-130% [2] 75-125% [2]	95% [3]
Laboratory Analysis (extended gases in headspace)	±20% RPD [1]	±3% compared to calibration standard	95% [3]
Laboratory Analysis (stable isotopes of methane in headspace)	±20% RPD [1]	≤0.09‰	95% [3]

Note:
1 – Refer to Section 4.1.1; RPD = relative percent difference.
2 – Refer to Section 4.1.2
3 – Refer to Section 4.1.3

APPENDIX C

STANDARD OPERATING PROCEDURES

STANDARD OPERATING PROCEDURE

FIELD FORMS

SOP-1

All pertinent field investigation and sampling information shall be recorded on a field form during each day of the field effort and at each sample site. The field crew leader shall be responsible for ensuring that sufficient detail is recorded on the field forms. Field forms shall contain sufficient information such that someone could reconstruct all field activities without relying on the memory of the field crew. All entries shall be made in indelible ink weather conditions permitting. Each day's or site's entries will be initialed and dated at the end by the author.

At a minimum, entries on the field sheet or in field notebook shall include:

- Date and time of starting work and weather conditions.
- Names of field crew leader and team members.
- Project name and type.
- Description of site conditions and any unusual circumstances.
- Location of sample site, including map reference, if relevant.
- Details of actual work effort, particularly any deviations from the field work plan or standard operating procedures.
- Field observations.
- Any field measurements made (e.g., PID readings, pH, temperature).

For sampling efforts, specific details for each sample should be recorded using Geomatrix standardized field forms. Surface water and groundwater field forms contain fill-in-the-blank type information in order that all pertinent information shall be recorded. In addition to the items listed above, the following information is recorded on field forms during sampling efforts:

- Time and date samples were collected.
- Number and type (natural, duplicate, QA/QC) of samples collected.
- Analysis requested.
- Sampling method, particularly deviations from standard operating procedures.

Strict custody procedures shall be maintained with the field forms. Field forms shall remain with the field team at all times while being used in the field. Upon completion of the field effort, photocopies of the original field forms will be made and used as working documents; original field forms shall be filed in an appropriately secure manner.

STANDARD OPERATING PROCEDURE

EQUIPMENT DECONTAMINATION

SOP-2

The purpose of this section is to describe general decontamination procedures for field equipment. Decontamination will be performed on all non-dedicated and non-disposable sampling equipment that may contact potentially contaminated media. Field personnel must wear disposable latex or Nitrile gloves while decontaminating equipment at the project site, and shall change gloves between samples. Every precaution must be taken by personnel to prevent contaminating themselves with the wash water and rinse water used in the decontamination process.

Table A-1 lists equipment and liquids necessary to decontaminate field equipment.

The following should be done in order to complete thorough decontamination:

1. Set up the decontamination zone upwind from the sampling area to reduce the chances of windborne contamination.

2. Visually inspect sampling equipment for contamination; use stiff brush to remove visible material.

3. The general decontamination sequence for field equipment includes: wash with Liquinox or an equivalent degreasing detergent; deionized water rinse; 10% dilute nitric acid rinse; rinse with deionized water three times.

4. Rinse equipment with methanol in place of the nitric rinse if sampling for organic contamination. Follow with a deionized water rinse.

5. Decontaminated equipment that is used for sampling organics should be wrapped in aluminum foil if not used immediately.

6. Clean the outside of sample container after filling sample container.

Alternatively, field equipment can be decontaminated by steam cleaning, rinsing with 10% dilute nitric acid, and rinsing with deionized water.

All disposable items (e.g., paper towels, latex gloves) should be deposited into a garbage bag and disposed of in a proper manner. Handling and disposal procedures for the rinse and wash water will be specified in the project work plan.

TABLE A-1. EQUIPMENT LIST FOR DECONTAMINATION

5-gallon plastic tubs	Liquinox (soap)
5-gallon plastic water container	Hard bristle brushes
5-gallon carboy DI water	Garbage bags
1-gallon cube of 10% HNO_3	Latex gloves
1-gallon container or spray bottle of 10% Methanol or pesticide grade acetone for organics	Spray bottles
	Paper towels, aluminum foil

STANDARD OPERATING PROCEDURE

FIELD MEASUREMENT OF DEPTH TO GROUND WATER

SOP-3

1. Test electric water level meter prior to leaving for field for defects by placing probe in clean water (not distilled or deionized water). Both audible and visible signals should work. Repair as necessary.

2. Measure from the probe tip to the first whole depth increment marked on the probe's cable. Note any discrepancy on the field form.

3. Make certain the well probe, a tape measure calibrated to tenths of feet and extra batteries are in the carrying case.

4. All measurements should be referenced a point in the north quadrant on the well casing or riser. Mark the measuring point on the well casing so future measurements can be made from the same location.

5. Measure and record distance from measuring point to ground level using the tape measure.

6. Obtain a depth to water from measuring point to the nearest hundredth of a foot. Record data on appropriate field forms.

7. Decontaminate well probe between each measurement by rinsing with deionized water. Additional decontamination, such as liquinox scrubbing, may be required if the well is known or suspected to contain contaminants that could be transferred to another well(s) during subsequent measurements; consult the project work plan.

STANDARD OPERATING PROCEDURE

FIELD MEASUREMENT OF ELECTRIC OR SPECIFIC CONDUCTANCE (EC/SC)

SOP-4

INSTRUMENT CALIBRATION

1. Meter should be calibrated with appropriate standards and checked per manufacturer's recommendations. If instrument is a multi-parameter meter follow instructions for measurement of electric or specific conductance from manual.

FIELD PROCEDURE

1. Rinse decontaminated glass beaker with approximately 50 milliliters of sample water three times.

2. Place approximately 150 ml. of sample in decontaminated glass beaker.

3. Rinse probe with deionized water and place conductivity probe or multi-parameter probe in sample water.

4. Immerse probe in sample so that probe is submerged. Move probe around in sample to displace any air bubbles. The probe should not be touching the sides of the beaker. Record conductivity reading taking note of scale of reading, microseimens/centimeter (µs/cm), micromhos/centimeter (µmhos/cm), or milliseimens/centimeter (ms/cm). If reading is being taken in-situ or with flow-through evacuation from a well, wait until reading stabilizes and record. Record conductivity reading on the sample field form.

7. Remove probe from sample and rinse probe with dionized water. Store probe per manufacturer's recommendations.

STANDARD OPERATING PROCEDURE

FIELD MEASUREMENT OF pH

SOP-5

INSTRUMENT CALIBRATION

1. Meter should be calibrated with appropriate standards and checked per manufacturer's recommendations. The two point standard method should be used for calibration. If instrument is a multi-parameter meter follow instructions for measurement of pH from manual.

FIELD PROCEDURES

1. Rinse decontaminated glass beaker with approximately 50 milliliters of sample water three times.

2. Rinse pH electrode with deionized water.

3. Check meter using 7.0 pH buffer. Re-calibrate meter, if not within 0.1 pH standard units (s.u.).

4. Fill beaker with sample water.

5. Immerse probe in sample, agitate probes to provide thorough mixing. Continue to agitate until reading has stabilized. Read pH to nearest 0.1 s.u. If reading is being taken in-situ or with flow-through evacuation from a well, wait until reading stabilizes and record.

6. Record the sample pH on field measurement form. Note any problems such as erratic readings. If previous readings are available compare current measurement to previous reading to check that current reading is within reasonable limits.

7. Rinse probe with deionized water and store according to manufacturer's directions.

STANDARD OPERATING PROCEDURE

GROUNDWATER SAMPLING

SOP-6

EQUIPMENT:

Electric water level indicator or sonic meter	Field sampling form
Hydrasleeve™ Sampler(s)	Hydrasleeve™ weight(s)
Nylon cord or tether	Rope counter
New or Decontaminated Plastic Cup	pH meter
Specific conductance (SC) meter	Filter apparatus (optional)
Sample bottles	Sample preservatives
Sample bottle labels	Custody seal (optional)
Indelible marker	Chain of Custody Form
Cooler, ice	

General

All sampling equipment and supplies shall be inspected for damage, and repaired if necessary, prior to arriving on-site. Field water quality meters (e.g., pH, SC) will be calibrated per manufacturer's instructions prior to collecting samples. Potential sources of contaminating substances that might bias groundwater samples (e.g., vehicle exhaust) should be removed from the sample area and positioned so that the potential for bias is minimized (e.g., position vehicles downwind).

1. Deploy Hydrasleeve™ Sampler

a. Well construction and sample volume requirements will be reviewed prior to arrival on site and the appropriate length and diameter Hydrasleeve™ selected.
b. Measure water level using an electric water level indicator, sonic meter, or other device, as appropriate.
c. Determine the target deployment depth, which will generally be the midpoint of the submerged portion of the well's perforated/screened interval(s).
d. Assemble Hydrasleeve™ per the manufacturer's instructions (see attached). Open the top of the sampler and crimp the plastic strips at the top of the sampler by folding at the holes. Attach the nylon cord to one of the holes at the top of the sampler. **The cord must be attached to only one of the holes or the sampler top may not stay open and fail to fill when retrieved.** Fold the tabs at the bottom of the sampler together to line of the holes and attach weight.
e. If multiple Hydrasleeves™ are to be deployed simultaneously (e.g., when sampling multiple intervals or to meet sample volume requirements), they must

be tied together tail-to-head. In this situation, the weight will be attached to the bottom of the last (lowest) sampler and the samplers attached using the appropriate length of nylon cord.

f. Deploy the sampler(s) to the target depth(s) by metering the cord through a rope counter or by using a tether marked in 1-foot increments. Do not pull the sampler upward at any time during deployment as this will cause water to enter.
g. Secure the cord at the wellhead once the sampler reaches the target depth.

2. Allow Well to Equilibrate

Well equilibration time will vary based on well construction and hydrogeologic conditions. In general, equilibration times greater than three (3) hours are not required. Concurrence from the appropriate regulatory agency on well equilibration time should be obtained prior to sampling.

3. Retrieve Hydrasleeve™ Sampler

The sampler is to be retrieved at a constant rate equal to or greater than one (1) foot per second. The sample will fill completely within approximately 2X the sampler length after starting retrieval.

4. Measure Field Water Quality Parameters

Water quality parameters pH and specific conductance will be measured in the field with a portable water quality meter. These measurements will be obtained from a portion of the sample that has been dispensed into a new or decontaminated plastic cup.

5. Place Samples in Laboratory Containers

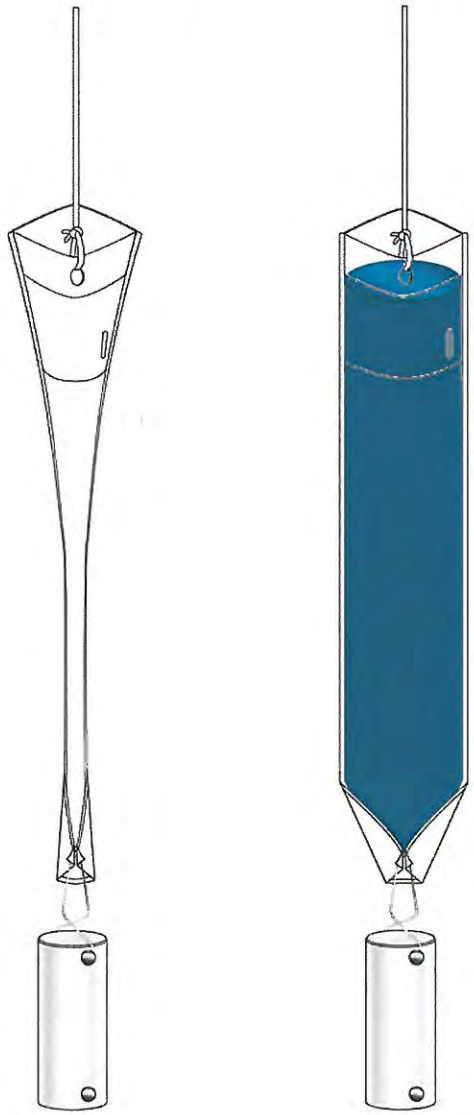
a. Place samples in appropriate, laboratory-supplied containers and add appropriate preservative, if necessary, in accordance with the project Sampling and Analysis Plan.
b. Use an indelible marker to fill out the sample label with respect to project number, sample location, well owner, date, military time, sampler's initials, preservative, and analysis required. Do not write directly on the sample container. Allow marker ink to dry completely before affixing label to sample container.
c. Complete the necessary shipping and handling paperwork, and record all pertinent information on Field Sampling Form in accordance with SOP-1.

HYDRASleeve™

Simple by Design

US Patent No. 6,481,300; No. 6,837,120 others pending

Standard Operating Procedure: Sampling Ground Water with a HydraSleeve



This Guide should be used in addition to field manuals appropriate to sampling device (i.e., HydraSleeve or Super Sleeve).

Find the appropriate field manual on the HydraSleeve website at http://www.hydrasleeve.com.

For more information about the HydraSleeve, or if you have questions, contact: GeoInsight, 2007 Glass Road, Las Cruces, NM 88005, 1-800-996-2225, info@hydrasleeve.com.

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Introduction

The HydraSleeve is classified as a no-purge (passive) grab sampling device, meaning that it is used to collect ground-water samples directly from the screened interval of a well without having to purge the well prior to sample collection. When it is used as described in this Standard Operating Procedure (SOP), the HydraSleeve causes no drawdown in the well (until the sample is withdrawn from the water column) and only minimal disturbance of the water column, because it has a very thin cross section and it displaces very little water (<100 ml) during deployment in the well. The HydraSleeve collects a sample from within the screen only, and it excludes water from any other part of the water column in the well through the use of a self-sealing check valve at the top of the sampler. It is a single-use (disposable) sampler that is not intended for reuse, so there are no decontamination requirements for the sampler itself.

The use of no-purge sampling as a means of collecting representative ground-water samples depends on the natural movement of ground water (under ambient hydraulic head) from the formation adjacent to the well screen through the screen. Robin and Gillham (1987) demonstrated the existence of a dynamic equilibrium between the water in a formation and the water in a well screen installed in that formation, which results in formation-quality water being available in the well screen for sampling at all times. No-purge sampling devices like the HydraSleeve collect this formation-quality water as the sample, under undisturbed (non-pumping) natural flow conditions. Samples collected in this manner generally provide more conservative (i.e., higher concentration) values than samples collected using well-volume purging, and values equivalent to samples collected using low-flow purging and sampling (Parsons, 2005).

Applications of the HydraSleeve

The HydraSleeve can be used to collect representative samples of ground water for all analytes (volatile organic compounds [VOCs], semi-volatile organic compounds [SVOCs], common metals, trace metals, major cations and anions, dissolved gases, total dissolved solids, radionuclides, pesticides, PCBs, explosive compounds, and all other analytical parameters). Designs are available to collect samples from wells from 1" inside diameter and larger. The HydraSleeve can collect samples from wells of any yield, but it is especially well-suited to collecting samples from low-yield wells, where other sampling methods can't be used reliably because their use results in dewatering of the well screen and alteration of sample chemistry (McAlary and Barker, 1987).

The HydraSleeve can collect samples from wells of any depth, and it can be used for single-event sampling or long-term ground-water monitoring programs. Because of its thin cross section and flexible construction, it can be used in narrow, constricted or damaged wells where rigid sampling devices may not fit. Using multiple HydraSleeves deployed in series along a single suspension line or tether, it is also possible to conduct in-well vertical profiling in wells in which contaminant concentrations are thought to be stratified.

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As with all groundwater sampling devices, HydraSleeves should not be used to collect groundwater samples from wells in which separate (non-aqueous) phase hydrocarbons (i.e., gasoline, diesel fuel or jet fuel) are present because of the possibility of incorporating some of the separate-phase hydrocarbon into the sample.

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Description of the HydraSleeve

The HydraSleeve (Figure 1) consists of the following basic components:

- A suspension line or tether (A.), attached to the spring clip or directly to the top of the sleeve to deploy the device into and recover the device from the well. Tethers with depth indicators marked in 1-foot intervals are available from the manufacturer.
- A long, flexible, 4-mil thick lay-flat polyethylene sample sleeve (C.) sealed at the bottom (this is the sample chamber), which comes in different sizes, as discussed below with a self-sealing reed-type flexible polyethylene check valve built into the top of the sleeve (B.) to prevent water from entering or exiting the sampler except during sample acquisition.
- A reusable stainless-steel weight with clip (D.), which is attached to the bottom of the sleeve to carry it down the well to its intended depth in the water column. Bottom weights available from the manufacturer are 0.75" OD and are available in three sizes: 5 oz. (2.5" long); 8 oz. (4" long); and 16 oz. (8" long). In lieu of a bottom weight, an optional top weight may be attached to the top of the HydraSleeve to carry it to depth and to compress it at the bottom of the well (not shown in Figure 1);
- A discharge tube that is used to puncture the HydraSleeve after it is recovered from the well so the sample can be decanted into sample bottles (not shown).
- Just above the self-sealing check valve at the top of the sleeve are two holes which provide attachment points for the spring clip and/or suspension line or tether. At the bottom of the sample sleeve are two holes which provide attachment points for the weight clip and weight.

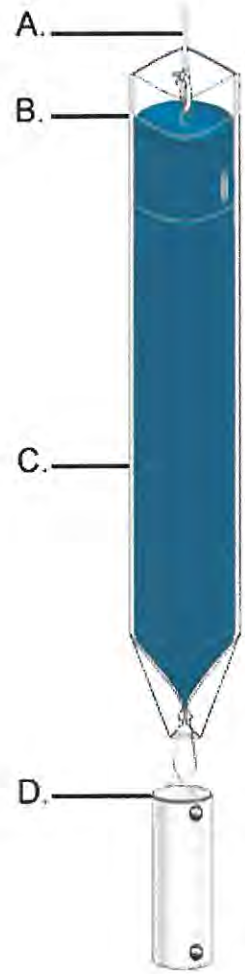

Figure 1. HydraSleeve components.

Note: The sample sleeve and the discharge tube are designed for one-time use and are disposable. The spring clip, weight and weight clip may be reused after thorough cleaning. Suspension cord is generally disposed after one use although, if it is dedicated to the well, it may be reused at the discretion of the sampling personnel.

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Selecting the HydraSleeve Size to Meet Site-Specific Sampling Objectives

It is important to understand that each HydraSleeve is able to collect a finite volume of sample because, after the HydraSleeve is deployed, you only get one chance to collect an undisturbed sample. Thus, the volume of sample required to meet your site-specific sampling and analytical requirements will dictate the size of HydraSleeve you need to meet these requirements.

The volume of sample collected by the HydraSleeve varies with the diameter and length of the HydraSleeve. Dimensions and volumes of available HydraSleeve models are detailed in Table 1.

Table 1. Dimensions and volumes of HydraSleeve models.

Diameter	Volume	Length	Lay-Flat Width	Filled Dia.
2-Inch HydraSleeves				
Standard 625-ml HydraSleeve	625 ml	< 30"	2.5"	1.4"
Standard 1-Liter HydraSleeve	1 Liter	38"	3"	1.9"
1-Liter HydraSleeve SS	1 Liter	36"	3"	1.9"
2-Liter HydraSleeve SS	2 Liters	60"	3"	1.9"
4-Inch HydraSleeves				
Standard 1.6-Liter HydraSleeve	1.6 Liters	30"	3.8"	2.3"
Custom 2-Liter HydraSleeve	2 Liters	36"	4"	2.7"

HydraSleeves can be custom-fabricated by the manufacturer in varying diameters and lengths to meet specific volume requirements. HydraSleeves can also be deployed in series (i.e., multiple HydraSleeves attached to one tether) to collect additional sample to meet specific volume requirements, as described below.

If you have questions regarding the availability of sufficient volume of sample to satisfy laboratory requirements for analysis, it is recommended that you contact the laboratory to discuss the minimum volumes needed for each suite of analytes. Laboratories often require only 10% to 25% of the volume they specify to complete analysis for specific suites of analytes, so they can often work with much smaller sample volumes that can easily be supplied by a HydraSleeve.

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HydraSleeve Deployment

Information Required Before Deploying a HydraSleeve

Before installing a HydraSleeve in any well, you will need to know the following:

- The inside diameter of the well
- The length of the well screen
- The water level in the well
- The position of the well screen in the well
- The total depth of the well

The inside diameter of the well is used to determine the appropriate HydraSleeve diameter for use in the well. The other information is used to determine the proper placement of the HydraSleeve in the well to collect a representative sample from the screen (see HydraSleeve Placement, below), and to determine the appropriate length of tether to attach to the HydraSleeve to deploy it at the appropriate position in the well.

Most of this information (with the exception of the water level) should be available from the well log; if not, it will have to be collected by some other means. The inside diameter of the well can be measured at the top of the well casing, and the total depth of the well can be measured by sounding the bottom of the well with a weighted tape. The position and length of the well screen may have to be determined using a down-hole camera if a well log is not available. The water level in the well can be measured using any commonly available water-level gauge.

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HydraSleeve Placement

The HydraSleeve is designed to collect a sample directly from the well screen, and it fills by pulling it up through the screen a distance equivalent to 1 to 1.5 times its length. This upward motion causes the top check valve to open, which allows the device to fill. To optimize sample recovery, it is recommended that the HydraSleeve be placed in the well so that the bottom weight rests on the bottom of the well and the top of the HydraSleeve is as close to the bottom of the well screen as possible. This should allow the sampler to fill before the top of the device reaches the top of the screen as it is pulled up through the water column, and ensure that only water from the screen is collected as the sample. In short-screen wells, or wells with a short water column, it may be necessary to use a top-weight on the HydraSleeve to compress it in the bottom of the well so that, when it is recovered, it has room to fill before it reaches the top of the screen.

Example

2" ID PVC well, 50' total depth, 10' screen at the bottom of the well, with water level above the screen (the entire screen contains water).

Correct Placement (figure 2): Using a standard HydraSleeve for a 2" well (2.6" flat width/1.5" filled OD x 30" long, 650 ml volume), deploy the sampler so the weight (an 8 oz., 4"-long weight with a 2"-long clip) rests at the bottom of the well. The top of the sleeve is thus set at about 36" above the bottom of the well. When the sampler is recovered, it will be pulled upward approximately 30" to 45" before it is filled; therefore, it is full (and the top check valve closes) at approximately 66" (5 ½ feet) to 81" (6 ¾ feet) above the bottom of the well, which is well before the sampler reaches the top of the screen. In this example, only water from the screen is collected as a sample.

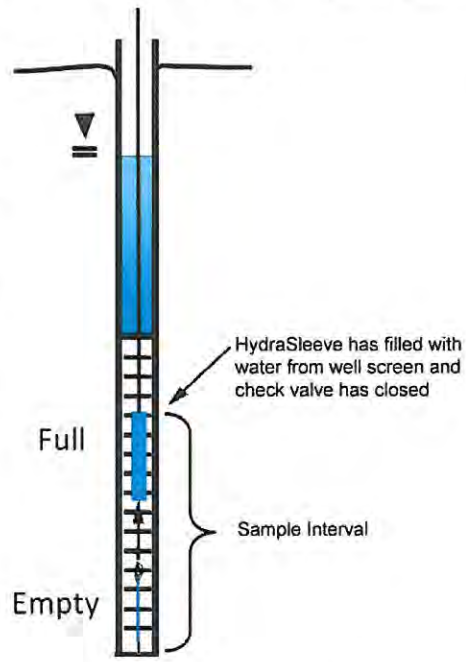

Figure 2. Correct placement of HydraSleeve.

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Incorrect Placement (figure 3): If the well screen in this example was only 5' long, and the HydraSleeve was placed as above, it would not fill before the top of the device reached the top of the well screen, so the sample would include water from above the screen, which may not have the same chemistry.

The solution? Deploy the HydraSleeve with a top weight, so that it is collapsed to within 6" to 9" of the bottom of the well. When the HydraSleeve is recovered, it will fill within 39" (3 ¼ feet) to 54" (4 ½ feet) above the bottom of the well, or just before the sampler reaches the top of the screen, so it collects only water from the screen as the sample.

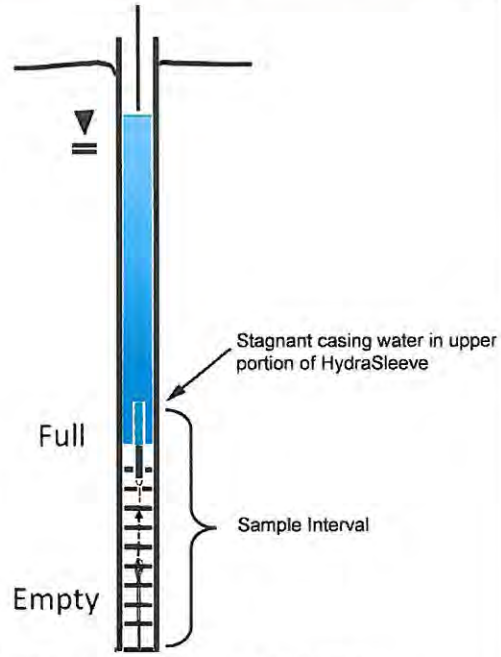

Figure 3. Incorrect placement of HydraSleeve.

This example illustrates one of many types of HydraSleeve placements. More complex placements are discussed in a later section.

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Procedures for Sampling with the HydraSleeve

Collecting a ground-water sample with a HydraSleeve is a simple one-person operation.

Note: Before deploying the HydraSleeve in the well, collect the depth-to-water measurement that you will use to determine the preferred position of the HydraSleeve in the well. This measurement may also be used with measurements from other wells to create a ground-water contour map. If necessary, also measure the depth to the bottom of the well to verify actual well depth to confirm your decision on placement of the HydraSleeve in the water column.

Measure the correct amount of tether needed to suspend the HydraSleeve in the well so that the weight will rest on the bottom of the well (or at your preferred position in the well). Make sure to account for the need to leave a few feet of tether at the top of the well to allow recovery of the sleeve

Note: Always wear sterile gloves when handling and discharging the HydraSleeve.

I. Assembling the HydraSleeve

1. Remove the HydraSleeve from its packaging, unfold it, and hold it by its top.
2. Crimp the top of the HydraSleeve by folding the hard polyethylene reinforcing strips at the holes.
3. Attach the spring clip to the holes to ensure that the top will remain open until the sampler is retrieved.
4. Attach the tether to the spring clip by tying a knot in the tether.

Note: Alternatively, attach the tether to one (NOT both) of the holes at the top of the Hydrasleeve by tying a knot in the tether.

5. Fold the flaps with the two holes at the bottom of the HydraSleeve together and slide the weight clip through the holes.
6. Attach a weight to the bottom of the weight clip to ensure that the HydraSleeve will descend to the bottom of the well.

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II. Deploying the HydraSleeve

1. Using the tether, carefully lower the HydraSleeve to the bottom of the well, or to your preferred depth in the water column

   During installation, hydrostatic pressure in the water column will keep the self-sealing check valve at the top of the HydraSleeve closed, and ensure that it retains its flat, empty profile for an indefinite period prior to recovery.

Note: Make sure that it is not pulled upward at any time during its descent. If the HydraSleeve is pulled upward at a rate greater than 0.5'/second at any time prior to recovery, the top check valve will open and water will enter the HydraSleeve prematurely.

2. Secure the tether at the top of the well by placing the well cap on the top of the well casing and over the tether.

Note: Alternatively, you can tie the tether to a hook on the bottom of the well cap (you will need to leave a few inches of slack in the line to avoid pulling the sampler up as the cap is removed at the next sampling event).

III. Equilibrating the Well

The equilibration time is the time it takes for conditions in the water column (primarily flow dynamics and contaminant distribution) to restabilize after vertical mixing occurs (caused by installation of a sampling device in the well).

- Situation: The HydraSleeve is deployed for the first time or for only one time in a well

  The HydraSleeve is very thin in cross section and displaces very little water (<100 ml) during deployment so, unlike most other sampling devices, it does not disturb the water column to the point at which long equilibration times are necessary to ensure recovery of a representative sample.

  In most cases, the HydraSleeve can be recovered immediately (with no equilibration time) or within a few hours. In regulatory jurisdictions that impose specific requirements for equilibration times prior to recovery of no-purge sampling devices, these requirements should be followed.

- Situation: The HydraSleeve is being deployed for recovery during a future sampling event

  In periodic (i.e., quarterly or semi-annual) sampling programs, the sampler for the current sampling event can be recovered and a new sampler (for the next sampling event)

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deployed immediately thereafter, so the new sampler remains in the well until the next sampling event.

Thus, a long equilibration time is ensured and, at the next sampling event, the sampler can be recovered immediately. This means that separate mobilizations, to deploy and then to recover the sampler, are not required. HydraSleeves can be left in a well for an indefinite period of time without concern.

IV. HydraSleeve Recovery and Sample Collection

1. Hold on to the tether while removing the well cap.

2. Secure the tether at the top of the well while maintaining tension on the tether (but without pulling the tether upwards)

3. Measure the water level in the well.

4. In one smooth motion, pull the tether up between 30" to 45" (36" to 54" for the longer HydraSleeve) at a rate of about 1' per second (or faster).

   The motion will open the top check valve and allow the HydraSleeve to fill (it should fill in about 1 to 1.5 times the length of the HydraSleeve). This is analogous to coring the water column in the well from the bottom up.

   When the HydraSleeve is full, the top check valve will close. You should begin to feel the weight of the HydraSleeve on the tether and it will begin to displace water. The closed check valve prevents loss of sample and entry of water from zones above the well screen as the HydraSleeve is recovered.

5. Continue pulling the tether upward until the HydraSleeve is at the top of the well.

6. Decant and discard the small volume of water trapped in the Hydrasleeve above the check valve by turning the sleeve over.

V. Sample Collection

Note: Sample collection should be done immediately after the HydraSleeve has been brought to the surface to preserve sample integrity.

1. Remove the discharge tube from its sleeve.

2. Hold the HydraSleeve at the check valve.

3. Puncture the HydraSleeve just below the check valve with the pointed end of the discharge tube

4. Discharge water from the HydraSleeve into your sample containers.

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Control the discharge from the HydraSleeve by either raising the bottom of the sleeve, by squeezing it like a tube of toothpaste, or both.

5. Continue filling sample containers until all are full.

Measurement of Field Indicator Parameters

Field indicator parameter measurement is generally done during well purging and sampling to confirm when parameters are stable and sampling can begin. Because no-purge sampling does not require purging, field indicator parameter measurement is not necessary for the purpose of confirming when purging is complete.

If field indicator parameter measurement is required to meet a specific non-purging regulatory requirement, it can be done by taking measurements from water within a HydraSleeve that is not used for collecting a sample to submit for laboratory analysis (i.e., a second HydraSleeve installed in conjunction with the primary sample collection HydraSleeve [see Multiple Sampler Deployment below]).

Alternate Deployment Strategies

Deployment in Wells with Limited Water Columns

For wells in which only a limited water column exists to be sampled, the HydraSleeve can be deployed with an optional top weight instead of a bottom weight, which collapses the HydraSleeve to a very short (approximately 6" to 9") length, and allows the HydraSleeve to fill in a water column only 36" to 45" in height.

Multiple Sampler Deployment

Multiple sampler deployment in a single well screen can accomplish two purposes:

- It can collect additional sample volume to satisfy site or laboratory-specific sample volume requirements.
- It can accommodate the need for collecting field indicator parameter measurements.
- It can be used to collect samples from multiple intervals in the screen to allow identification of possible contaminant stratification.

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It is possible to use up to 3 standard 30" HydraSleeves deployed in series along a single tether to collect samples from a 10' long well screen without collecting water from the interval above the screen.

The samplers must be attached to the tether at both the top and bottom of the sleeve. Attach the tether at the top with a stainless-steel clip (available from the manufacturer). Attach the tether at the bottom using a cable tie. The samplers must be attached as follows (figure 4):

- The first (attached to the tether as described above, with the weight at the bottom) at the bottom of the screen
- The second attached immediately above the first
- The third (attached the same as the second) immediately above the second

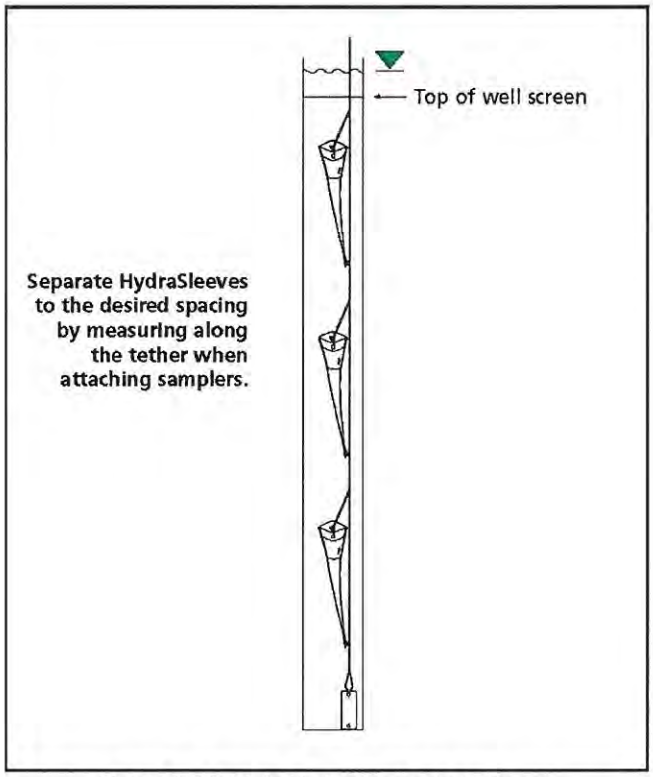

Figure 4. Multiple HydraSleeve deployment.

Alternately, the first sampler can be attached to the tether as described above, a second attached to the bottom of the first using a short length of tether (in place of the weight), and the third attached to the bottom of the second in the same manner, with the weight attached to the bottom of the third sampler (figure 5).

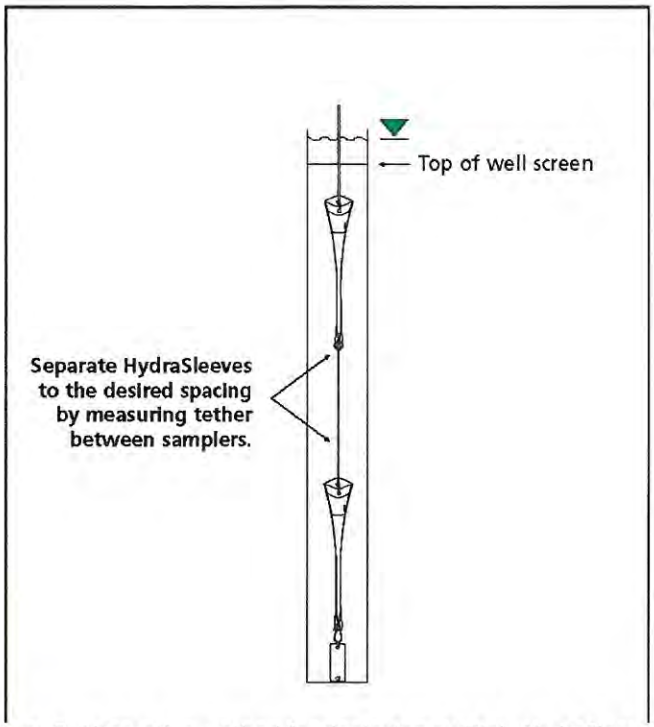

Figure 5. Alternative method for deploying multiple HydraSleeves.

In either case, when attaching multiple HydraSleeves in series, more weight may be required to hold the samplers in place in the well than would be required with a single sampler. Recovery of multiple samplers and collection of samples is done in the same manner as for single sampler deployments.

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Post-Sampling Activities

The recovered HydraSleeve and the sample discharge tubing should be disposed as per the solid waste management plan for the site. To prepare for the next sampling event, a new HydraSleeve can be deployed in the well (as described previously) and left in the well until the next sampling event, at which time it can be recovered.

The weight and weight clip can be reused on this sampler after they have been thoroughly cleaned as per the site equipment decontamination plan. The tether may be dedicated to the well and reused or discarded at the discretion of sampling personnel.

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References

McAlary, T. A. and J. F. Barker, 1987, Volatilization Losses of Organics During Ground-Water Sampling From Low-Permeability Materials, Ground-Water Monitoring Review, Vol. 7, No. 4, pp. 63-68

Parsons, 2005, Results Report for the Demonstration of No-Purge Ground-Water Sampling Devices at Former McClellan Air Force Base, California; Contract F44650-99-D-0005, Delivery Order DKO1, U.S. Army Corps of Engineers (Omaha District), U.S. Air Force Center for Environmental Excellence, and U.S. Air Force Real Property Agency

Robin, M. J. L. and R. W. Gillham, 1987, Field Evaluation of Well Purging Procedures, Ground-Water Monitoring Review, Vol. 7, No. 4, pp. 85-93

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STANDARD OPERATING PROCEDURE

COLLECTING VAPOR AND WATER SAMPLES WHEN COMBUSTIBLE GAS CONCENTRATIONS IN WATER WELL CASING EXCEED THE LEL

SOP-7

PURPOSE

The Sublette County Conservation District (SCCD) collects groundwater samples from water supply wells within the Pinedale Anticline Production Area (PAPA) on behalf of the United States Department of Interior Bureau of Land Management (BLM) to meet requirements stipulated in the 2000 Record of Decision (ROD) for the PAPA. As a routine part of the sampling procedure, SCCD surveys the wellhead with a combustible gas indicator (CGI) prior to inserting water monitoring and sampling equipment into a well. CGI readings of 10 percent (%) of the lower explosive limit (LEL) or higher are sometimes measured, and SCCD does not collect water samples using bailers from these wells when this situation occurs. At these well locations (i.e. LEL $\geq$10%), the groundwater monitoring requirements of the 2000 ROD are not being met. This procedure was developed to specify a method for collecting vapor and groundwater samples from these wells.

ASSUMPTIONS

The SCCD historically has monitored for potentially explosive conditions at the wellhead. It is assumed that the resulting CGI readings reflect conditions at the top of the wellhead where vapors present in the well casing are mixing with ambient atmospheric air. It is further assumed that conditions within the well casing below the depth of atmospheric influence are oxygen deficient, and that by sealing off the wellhead from ambient atmospheric influences, explosive conditions will not exist within the casing or at land surface around the wellhead.

NECESSARY EQUIPMENT

The following equipment/supplies will be necessary to implement this procedure.

1. Well cap (PVC, expandable j-plug, or similar) sized to form an airtight seal with the steel well casing and fitted with:

    a. A monitoring port for a CGI with a five-foot length of polyethylene (PE) tubing affixed to the inside, for the purpose of monitoring explosive conditions inside the well casing;

    b. A sampling port with a 10-foot length of PE tubing affixed to the inside, for the purpose of collecting vapor samples from within the well casing;

    c. A 5/8-inch diameter port through which water level meter and nylon bailer cord can pass.

2. Nylon cord

3. Disposable PE bailer or similar grab sampler (e.g., Hydrasleeve™ sampler)

4. A combination combustible gas indicator and oxygen concentration meter (the type that accommodates a sampling line or probe will be necessary) that is calibrated at the beginning of each work shift in accordance with manufacturer's instructions (calibrated for both flammable gas and oxygen concentration)

5. Summa canisters for collecting vapor samples

6. Intrinsically safe air pump to evacuate PE tubing

7. Flexible tubing to connect CGI and Summa canisters to monitoring/sampling ports

8. Compressed nitrogen or carbon dioxide gas cylinders (standard K-size) , regulator, and air hose (enough to reach within 10 feet of the static water level)

PROCEDURE

- Survey workspace at and around the well head with CGI. If readings are ≥20% of the LEL, additional sampling activities should not be performed until the source the combustible vapors are identified and mitigated.

- Install the well cap fitted with ***monitoring/sampling ports*** and PE drop tubing on the wellhead. Prior to installation, suspend a disposable PE bailer attached to the nylon cord from the underside of the cap by passing the bailer cord through the 5/8-inch diameter ***access port*** in the cap.

- After installing the well cap, survey the work space around the wellhead for potentially explosive conditions. While it is safe to proceed if CGI readings are ≤20% of the LEL, the source of CGI readings in the 1% to 20% range should be investigated and mitigated, if possible, since appreciable vapors should not be escaping from the well casing with the cap attached. Investigation and mitigation are beyond the scope of this procedure, and should be performed by the Operator.

- Connect the CGI to the ***monitoring port*** with the 5 foot-long flexible tubing and measure for potentially explosive conditions within the well casing. Allow sufficient running time for the tubing to be completely purged to ensure the atmosphere within the well casing is being monitored.

- Connect the air pump to the ***sampling port*** and purge the 10 foot-long sample tubing for sufficient period of time to purge air from the tubing. Purge time will depend on pumping rate.

- Disconnect the air pump and connect the Summa canisters to ***sample port***. Collect vapor samples in accordance with laboratory instructions.

- If conditions within the well casing measured through the ***monitoring port*** are ≤20% of the LEL, proceed with collecting the groundwater sample by lowering the bailer via the nylon cord passing through the 5/8-inch ***access port*** in the well cap.

- If conditions within the well casing, as indicated by readings from the CGI attached to the monitoring port, are >20% of the LEL, STOP WORK. The well casing will have to be inerted before a groundwater sample can be safely collected (again, it is assumed that readings >20% of the LEL are due to mixing of vapors emanating from the well with ambient air around the wellhead). Remove the well cap to allow vapors to dissipate as the well is being inerted. Discharge nitrogen or carbon dioxide gas from a hose as it is being lowered into the well to a depth of approximately 30 feet. After inerting is completed, remove the hose from the well and reinstall the well cap. Monitor continuously for potentially explosive conditions with the CGI. Proceed with groundwater sampling once CGI readings remain ≤20% of the LEL for at least 10 minutes.

- Monitor the well casing continuously with the CGI during groundwater sample collection to ensure readings remain below 20% of the LEL. If necessary, repeat the inerting process.

- Depth to water measurements can be made after sampling by inserting an electric water level meter probe through the 5/8-inch port, provided that CGI readings remain ≤20% LEL.

STANDARD OPERATING PROCEDURE

QUALITY CONTROL SAMPLES

SOP-8

Quality Control (QC) samples are submitted along with natural samples to provide supporting laboratory data to validate laboratory results. QC samples are submitted blind, and do not have any unique identifying codes that would enable the lab or others to bias these samples in any way. Usually, the time or sampling location is modified in a way which will separate blank and standard samples from the rest of the sample train. QC samples are identified only on field forms and in field notebooks. The following codes are typically used:

N	Natural Sample	Soil, water, air, or other of interest material from a field site
SP	Split Sample	A portion of a natural sample collected for independent analysis; used in calculating laboratory precision
D	Duplicate Sample	Two samples taken from the same media under similar conditions; also used to calculate precision
BB	Bottle Blank	Deionized water collected in sample bottle; used to detect contamination sampling containers
CCB	Cross Contamination	Deionized water run through decontaminated equipment and analyzed for Blank residual contamination and deionized water contamination
BFS	Blind Field Standard	Certified materials of known concentration; used to determine laboratory accuracy
TB	Travel or Trip Blank	Inert material (deionized water or diatomaceous earth) included in sample cooler; sent by the lab, the sample is used to determine if contamination by volatiles is present during collection or shipping

In general, selected QC samples will be inserted into the sample train within a group of twenty samples. Unless otherwise specified, QC samples will be prepared in the field. Deionized water blanks will be collected from carboys and cubitainers used in the field. An exception to field preparation of QC samples is the preparation of some blind field standards. Since the concentration of analytes in the sample is to be mixed according to specific manufacturer's instructions, field conditions may not provide the needed laboratory atmosphere. This is especially true for volatile organic compounds, which need to be prepared just before analyzing. Under these circumstances, standards will be shipped to the laboratory for preparation, keeping the concentration or manufacturer's QC Lot Number as blind as possible.

The number and types of samples submitted for each group of natural samples will be determined by the project manager and others, including state or Federal agencies, and will be defined in the project work plan. Each field crew leader will be responsible for all QC samples prepared by that crew.

Methods for computing data validation statements can be found in EPA documents or obtained from Geomatrix.

STANDARD OPERATING PROCEDURE

SAMPLE DOCUMENTATION

SOP -9

Sample documentation is an important step to ensure the laboratory, project manager, and field personnel are informed on the status of field samples. Depending on the specifics required for each project, a number of forms will need to be filled out. Most sample documentation forms are preprinted carbonless triplicates, enabling copies to be filled or mailed from labs or offices. The forms will be completed by field personnel, who have custody of the samples. The office copy will be kept in the project file and subsequent copies sent to the laboratory, or other designated parties.

Responsibility for completing the forms will be with each field crew leader. It is important the field crew leader is certain field personnel are familiar with the completion process for filling out forms, and the expected information is included.

Potential documents to be completed clearly in ink for each sample generated include:

- Field Form
- Chain-of-Custody
- Custody Seal

STANDARD OPERATING PROCEDURE

SAMPLE CHAIN-OF-CUSTODY

SOP-10

A chain-of-custody form will be generated for all samples collected in the field for laboratory analysis. The sampler may use Geomatrix' chain-of-custody form (example attached) or a chain-of-custody form provided by the laboratory.

FIELD EQUIPMENT

- Indelible ink pen
- Chain-of-custody forms
- Custody seals

PROCEDURES

Sample custody records must be maintained from the time of sample collection until the time of sample delivery to the analytical laboratory and should accompany the sample through analysis and final disposition. The information to be included on the chain-of-custody form will include, but is not limited to:

- Project number/site name
- Sampler's name and signature
- Date and time of sample collection
- Unique sample identification number or name
- Number of containers
- Sample media (e.g., soil, water, vapor, etc.)
- Sample preservative (if applicable)
- Requested analysis
- Comments or special instructions to the laboratory

Each sample will be assigned a unique sample identification number or name. The information on the chain-of-custody form, including the sample identification number or name, must correspond to the information recorded by the sampler on the field forms (refer to SOP 1) and the label on the sample container.

A sample is considered under a person's control when it is in their possession such that tampering is prevented. This includes placing the samples in an area of controlled access such as building, or locking the samples in a vehicle. When custody of a sample is relinquished by the sampler, the sampler will sign and date the chain-of-custody form and note the time that custody was relinquished. The person receiving custody of the sample will also sign and date the form and note the time that the sample was accepted into custody. Samples will be shipped to the analytical laboratory following the

procedures in SOP 15. If an overnight shipping service is used to transport the samples to the laboratory, custody of the samples will be relinquished to the shipping service. The shipping service will not sign the chain-of-custody form; however, the samples can be tracked while in the custody of the shipping service.

More than one sample may be included on a chain-of-custody form, as long as all of the samples are for the same project. Copies of the chain-of-custody form will be maintained in the project file

STANDARD OPERATING PROCEDURE

SAMPLE PACKAGE AND SHIPPING

SOP-11

All environmental samples collected should be packaged and shipped using the following procedures:

PACKAGING

1. Label all sample containers with indelible ink (on the side, not on the cap or lid). Place labeled sample bottles in a high quality cooler containing an adequate amount of ice and/or frozen blue ice (appropriate for the season), making sure the cooler drain plug is taped shut.

2. Place the samples in an upright position and wrap the samples with absorbent, cushioning material for stability during transport. Samples should not be loose; the cooler should be able to withstand tough handling during shipment without sample breakage.

3. To the extent practicable, the number of different sampling locations included in any one cooler should be minimized.

4. Fill out the appropriate shipping forms, and place the paperwork in a Ziploc bag and tape it to the inside lid of the shipping container. Shipping forms usually include: 1) a chain-of-custody form, documenting the samples including in the shipment; 2) an analysis request form, specifying the laboratory analyses for each sample. If more than one cooler is used per chain of custody, put a photocopy in the other coolers and mark them as a copy.

5. Close and seal the cooler using fiberglass strapping tape.

6. Secure the shipping label with address, phone number, and return address clearly visible.

SHIPPING HAZARDOUS MATERIALS/WASTE

Hazardous materials need to be shipped using procedures specified under Federal Law. Samples need to be shipped in Ziploc bags or paint cans filled with packing material, depending on the level of hazard. Special package labeling may be needed. Consult the project manager for specific shipping procedures.

APPENDIX D

STANDARD FIELD FORMS

DAILY FIELD RECORD

GEOMATRIX

Project and Task Number:	Date:
Project Name:	Field Activity:
Location:	Weather:

PERSONNEL: Name	Company	Time In	Time Out

PERSONAL SAFETY CHECKLIST

	Steel-toed Boots		Hard Hat		Other:_____
	Rubber Gloves		Safety Goggles		Other:_____

TIME	DESCRIPTION OF WORK PERFORMED

WELL SAMPLING AND/OR DEVELOPMENT RECORD

Well ID: _____

Sample ID: _____ **Duplicate ID:** _____

Sample Depth: _____

Project and Task No.: _____

Project Name: _____

Date: _____

Sampled By: _____

Method of Purging: _____

Method of Sampling: _____

Initial Depth to Water: _____

Depth to Water after Sampling: _____

Total Depth of Well: _____

Well Diameter: _____

1 Casing/Borehole Volume: _____
(Circle one)

4 Casing/Borehole Volumes: _____
(Circle one)

Total Casing/Borehole Volumes Removed: _____

Time	Intake Depth	Rate (gpm)	Cum. Vol. (gal.)	Temp. (°C)	pH (units)	Specific Electrical Conductance (µS/cm)	Dissolved Oxygen (mg/l)	Redox Potential (mV; SSCE)	Remarks (color, turbidity, and sediment)

pH CALIBRATION (choose two)					Model or Unit No.:
Buffer Solution	pH 4.0	pH 7.0	pH 10.0		
Field Temperature °C					
Instrument Reading					

SPECIFIC ELECTRICAL CONDUCTANCE – CALIBRATION				Model or Unit No.:
KCL Solution (µS/cm=µmhos/cm)	1413 at 25°C	12880 at 25°C		
Field Temperature °C				
Instrument Reading				

REDOX CALIBRATION		DISSOLVED OXYGEN CALIBRATION		Notes:
Standard Solution	468 mV	Salinity %		
Field Temperature °C		Altitude		
Instrument Reading		Instrument Reading		
Model or Unit No.:		Model or Unit No.:		
Ag/AgCl Electrode (SSCE)				

GEOMATRIX

PHOTOGRAPH LOG

Project Name: _____ **Project No.** _____

_____

_____ **Roll No.** _____

Photo No.	Date	Subject, Location, and Direction of View	Taken by

FIELD INSTRUMENT CALIBRATION SHEET

GEOMATRIX

Project Name: _____ **Project Number:** _____

_____ _____

Date: _____

Equipment Type: _____

Manufacturer: _____

Model Number: _____ **Serial Number:** _____

Calibration (as necessary, minimum twice per day):

Calibration #1 **Time:** _____

Calibration Standard: _____

Instrument Reading: _____

Calibration #2 **Time:** _____

Calibration Standard: _____

Instrument Reading: _____

Calibration #3 **Time:** _____

Calibration Standard: _____

Instrument Reading: _____

Calibration #4 **Time:** _____

Calibration Standard: _____

Instrument Reading: _____

Date of Last Calibration: _____ Date(s) Instrument Used: _____

Name of person(s) who calibrated instruments: _____

Calibration Standards Used:

(1) _____

(2) _____

(3) _____

(4) _____

Source of Calibration Standards: _____

Misc. Comments:

_____

_____

Calibrated by: _____

CHAIN-OF-CUSTODY RECORD

MIS 10012

PROJECT NAME:			DATE:	PAGE OF
PROJECT NUMBER:	LABORATORY NAME:	CLIENT INFORMATION:	REPORTING REQUIREMENTS:	
RESULTS TO:	LABORATORY ADDRESS:			
TURNAROUND TIME:				
SAMPLE SHIPMENT METHOD:	LABORATORY CONTACT:		GEOTRACKER REQUIRED	YES NO
	LABORATORY PHONE NUMBER:		SITE SPECIFIC GLOBAL ID NO.	

SAMPLERS (SIGNATURE):

DATE	TIME	SAMPLE NUMBER	ANALYSES														CONTAINER TYPE AND SIZE	Soil (S), Water (W), Vapor (V), or Other (O)	Filtered	Preservative Type	Cooled	MS/MSD	No. of Containers	ADDITIONAL COMMENTS

RELINQUISHED BY:	DATE	TIME	RECEIVED BY:	DATE	TIME	TOTAL NUMBER OF CONTAINERS:
SIGNATURE:			SIGNATURE:			SAMPLING COMMENTS:
PRINTED NAME:			PRINTED NAME:			
COMPANY:			COMPANY:			
SIGNATURE:			SIGNATURE:			
PRINTED NAME:			PRINTED NAME:			
COMPANY:			COMPANY:			
SIGNATURE:			SIGNATURE:			
PRINTED NAME:			PRINTED NAME:			
COMPANY:			COMPANY:			

1001 South Higgins Avenue, Building B-1
Missoula, Montana 59801-4144
Tel 406.542.0129 Fax 406.542.0130

Geomatrix

WATER LEVEL MONITORING RECORD

Geomatrix

Project Name: _____ Project and Task Number: _____

Date: _____ Measured by: _____ Instrument Used: _____

Note: For you convenience, the following abbreviations may be used.

P = Pumping I = Inaccessible D = Dedicated Pump
ST = Steel Tape ES = Electric Sounder MP = Measuring Point WL = Water Level

Well No.	Time	MP Elevation (meters)	Water Level Below MP (meters)	Water Level Elevation (meters)	Previous Water Level Below MP	Remarks

APPENDIX E

EXAMPLE HEALTH AND SAFETY PLAN

EXAMPLE HEALTH & SAFETY PLAN (HASP)

[Note: This HASP will modified for the site-specific activities when final approval is given to the Sampling and Analysis Plan]

SITE SPECIFIC HEALTH AND SAFETY PLAN

Approvals		
	Initials	Date
Prepared By	SAW	
Approved By	KBC	

PROJECT INFORMATION

Date(s) of Field Work: _____
Project Name: _____ Project Number: _____
Client: _____ Site Phone: _____
Site Address: *PAPA, Sublette Co., WY* ☐ Site Plan Attached
Scope of Work: _____

Type of Project: ☒Environmental; ☐Geotechnical; ☐Industrial Process; ☐Other: _____
☒HAZWOPER Project: Training & Medical Surveillance must conform to 29 CFR 1910.120 & Geomatrix Guidelines.
☐Client Specific Requirements (Attached)

KEY CONTACTS

Project Manager: _____ Phone: _____ Cell: _____
Project H&S Manager: _____ Phone: _____ Cell: _____
Site H&S Manager: _____ Phone: _____ Cell: _____
Client Contact: _____ Phone: _____ Cell: _____
Client's Site Contact: _____ Phone: _____ Cell: _____
Corporate Health & Safety Manager: *Don Kubik Jr., CIH* Phone: _____ Cell: _____
Other: _____

Emergency Medical Facility 1: ***Pinedale Medical Clinic***
Address: *619 E Hennick, Pinedale, WY*
Phone Number (general): *307-367-4133* Phone Number (emergency): *911*
☒Emergency Medical Facility Confirmed ☒Map to the hospital is attached

Emergency Medical Facility 2: ***Marbleton-Big Piney Clinic***
Address: *17 W 3rd, Big Piney, WY*
Phone Number (general): *307-276-3306* Phone Number (emergency): *911*
☒Emergency Medical Facility Confirmed ☒Map to the hospital is attached

Emergency Medical Facility 1:
Address:
Phone Number (general): Phone Number (emergency): *911*
☒Emergency Medical Facility Confirmed ☐Map to the hospital is attached

Police: 911 Fire: 911 Paramedic/Ambulance: 911
Poison Control Center: 1-800-222-1222

EMERGENCY PROCEDURES

Medical Emergencies

1. Remove injured or exposed person(s) from immediate danger if possible.
2. Evacuate other on-site personnel to a safe place in an upwind direction until it is safe for work to resume.
3. If serious injury or life-threatening condition exists, call 911 - Paramedics, fire department, police Hospital emergency room Clearly describe location, injury and conditions to dispatcher/hospital. Designate a person to direct emergency equipment to the injured person(s).
4. Provide first aid if necessary. Remove contaminated clothing only if this can be done without endangering the injured person.
5. Call the project manager and/or project health and safety officer.
6. Immediately implement steps to prevent recurrence of the accident.

Accidental Release of Hazardous Materials or Wastes

1. Evacuate all on-site personnel to a safe place in an upwind direction until the PM or PHSO determines that it is safe for work to resume.
2. Immediately instruct a designated person to contact the PM or PHSO.
3. Contain spill, if it is possible and it can be done safely.
4. Initiate cleanup.

General Emergencies

In the case of fire, flood, explosion, or other hazard, work shall be halted and the local police/ fire department shall be notified by calling 911. All on-site personnel will be immediately evacuated to a safe place.

Emergency Equipment Onsite

☒First Aid Kit; ☒Fire Extinguisher; ☒Eye Wash; ☐Other: _____

CHEMICAL HAZARDS

CHEMICAL	EXPOSURE LIMITS		LEL (%)	KNOWN/EXPECTED CONCENTRATIONS	HEALTH HAZARDS
	OSHA	ACGIH			
Benzene	1 ppm S 5 ppm	0.5 ppm	1.2	Unknown	Irritant to resp. system; giddiness, headache, nausea, staggered gait
Toluene	200 ppm	50ppm	1.1	Unknown	Irritation eyes, nose; lassitude (weakness, exhaustion), confusion, euphoria, dizziness, headache; dilated pupils, lacrimation (discharge of tears); anxiety, muscle fatigue, insomnia; paresthesia; dermatitis; liver, kidney damage
Ethyl benzene	100 ppm	100 ppm S125 ppm	0.8	Unknown	Irritation eyes, skin, mucous membrane; headache; dermatitis; narcosis, coma
Xylenes	100 ppm C 200 ppm	100 ppm	0.9	Unknown	Irritation eyes, skin, nose, throat; dizziness, excitement, drowsiness, incoordination, staggering gait; corneal vacuolization; anorexia, nausea, vomiting, abdominal pain; dermatitis
Naphthalene	10 ppm (50 g/m^3)	10 ppm (50 mg/m^3)	NA	Unknown	Irritation eyes; headache, confusion, excitement, malaise (vague feeling of discomfort); nausea, vomiting, abdominal pain; irritation bladder; profuse sweating; jaundice; hematuria (blood in the urine), renal shutdown; dermatitis, optical neuritis, corneal damage

If not specified, exposure limit is the PEL or the TLV-TWA, Exposure limit preceded by a “S” is a Short Term Exposure Limit and by a “C” is the Ceiling Limit

PHYSICAL HAZARDS:

☐Heat Stress ☒Cold Stress ☒Wet ☒Noise
☒Slip,Trip, & Fall ☒Heavy Equipment ☐Electrical Hazards
☒Underground Hazards: One Call Ticket #083010404_ Date Called: 10/27/08
☐Private Locator Utilized: _____ ☒Overhead Hazards
☒Traffic ☒Excavations/Trenching ☐Confined Space
☒Other: Driving Well Points

BIOLOGICAL HAZARDS:

☐Pathogens: _____ ☐Mold: _____
☐Plants: _____ ☐Insects: _____
☐Other Fauna: _____ ☐Other: _____

SITE CONTROLS:

PERSONAL DECONTAMINATION PROCEDURES:_____

PERSONAL PROTECTIVE EQUIPMENT – R = REQUIRED, A = HAVE AVAILABLE

R Eye Protection: ***R*** Safety Glasses; __ Splash Goggles; __ Face Shield; __Other: _____
R Hard Hat ***R***Steel-Toed Boots __ Chemical Resistant Boots
__ Traffic Safety Vest ***A*** Hearing Protection: *When noise level exceeds 80 dBA*
R Protective Clothing: ☐Tyvek®; ☐Coated Tyvek®; ☐Sarinex; ☒Other: *Flame resistant clothing (FRC)*
R Gloves: ☒Nitrile; ☐PVC; ☐Neoprene; ☒cloth/leather; ☐Other
A Respiratory: ☐Full-Face APR; ☒Half-Face APR
__ Filter: ☒Organic Vapor; ☐Acid Gas; ☐HEPA; ☐Other: _____
R Other: *Hardhat, Safety glasses, hearing protection & steel-toed boots if working around heavy equipment*

If air monitoring in the workers' breathing zone exceeds *XXX ppm* for 60 seconds or longer, upgrade to Level C (APR) or vacate the immediate area.

MONITORING EQUIPMENT

☒Photo Ionization Detector with *10.6* eV lamp ☐Flame Ionization Detector
☐Combustible Gas Indicator ☐Oxygen Meter
☐Detector Tube (Brand: _____) – Tubes: _____
☐Hydrogen Sulfide Meter
☐Passive Dosimeter _____
☐Air Sampling Pump – Filter Media: _____
☐Other: _____
Frequency of monitoring: *While excavating*

TAILGATE SAFETY MEETING

Date:

Project Name:

Project Number:

Site Location:
PAPA, Sublette County, Wyoming

Scope of Work for Day:

Lead By:

Name (printed)	Signature

EXAMPLE JOB SAFETY ANALYSIS (JSA)

[Note: This JSA will modified for the site-specific activities when final approval is given to the Sampling and Analysis Plan]

AMEC Geomatrix

JOB SAFETY ANALYSIS

Project Name:		***Project No:***		***Date:***	
Tasks:	1. Vapor Monitoring/Sampling 2. Groundwater Sampling	***Task Location:***	Pinedale Anticline Production Area Sublette Co., WY		
For this Project and Task, this document is a Certification of Hazard Assessment					
Completed by:	Steve Wright	***Reviewed by:***	DK		
Notes:					

Task	Hazard	Risk Control Method
Mobilize to site	Driving accidents	❒ Vehicle should be in good condition and well maintained ❒ Check weather forecast, bring tire chains if warranted ❒ Seat belt will be worn while driving ❒ Driver will be licensed, trained, and medically fit ❒ Driver will be rested and alert ❒ NO CELL PHONE USE WHILE DRIVING ❒ Route to be planned in advance ❒ Driver must not be under the influence of alcohol, drugs, or medication that impairs ability to drive ❒ Park so that first move is forward (i.e. back into space or allow room for driving forward)
Set up work site	Pad traffic	❒ If applicable, coordinate with other work at location ❒ If applicable, notify PIC of work activities and location ❒ Obey all Ultra traffic rules while on site ❒ Wear flame resistant clothing as the outer layer, steel toe boots, long sleeves, pants, hardhat, and safety glasses at all times while on the pad
Measure static water level	Explosion Hazard	❒ Eliminate all potential ignition sources ❒ Monitor ambient air in the aboveground work space with a combustible gas indicator ❒ Seal the top of casing and monitor ambient conditions inside the well casing with a combustible gas indicator ❒ Work may proceed with concentrations up to 20% of the LEL ❒ Stop work if concentrations in aboveground work space meets or exceeds 20% of the LEL ❒ Each location will be explored by hand tool to a depth of approximately 5 feet before power equipment is used.
	Injury from using installation tools (post-pounder, sledge hammer)	❒ Wear hard hat, safety glasses, steel toes, hearing protection, and leather gloves during installation ❒ Use post-pounder to install well points, if possible. ❒ Operate post-pounder using two people ❒ Use installation tools from a position of firm footing ❒ When using post-pounder, do not lift tool higher than the top of the well point on the up-stroke ❒ Keep fingers, hands, arms, and other body parts clear of impact areas. ❒ Inspect all hand tools prior to use. If faulty or inappropriate, do not use until repaired or replaced.
	Pinch points	❒ Watch for pinch points when assembling / installing well casing

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JOB SAFETY ANALYSIS

Project Name:		***Project No:***		***Date:***	
Tasks:	1. Vapor Monitoring/Sampling 2. Groundwater Sampling	***Task Location:***	Pinedale Anticline Production Area Sublette Co., WY		
For this Project and Task, this document is a Certification of Hazard Assessment					
Completed by:	Steve Wright	***Reviewed by:***	DK		
Notes:					

Task	Hazard	Risk Control Method
	Slip, trip, and fall	❒ Keep work area clean – including removal of excess cuttings / mud
Sample vapor/gas inside well casing		❒ Keep work areas dry when possible ❒ Stay aware of footing and do not run
	Cold stress	❒ Wear appropriate clothing for Wyoming fall weather conditions – e.g. insulated coveralls, winter gloves, hard hat liner, etc. ❒ Seek warmth out of weather (e.g. inside vehicle), if necessary ❒ Consume adequate amounts of food and beverages
	Working at heights	❒ No work will be conducted at heights greater than 6 feet without fall restraint / arrest safety equipment
	UV exposure	❒ Wear neck to toe clothing and sun block
	Lifting heavy equipment/materials	❒ Do not lift or move heavy equipment without assistance ❒ Use proper lifting techniques. Lift with arms and legs, keep back straight. ❒ If possible, use a powered lift truck, drum cart, or other mechanical means.
Well Point Installation	Underground Utilities	❒ Confirm with Shell that no overhead or underground utilities are present in the monitoring well location(s); ❒ Confirm subsurface utilities with Wyoming One Call – (800) 849-2476
	Injury from using installation tools (post-pounder, sledge hammer)	❒ Wear hard hat, safety glasses, steel toes, hearing protection, and leather gloves during installation ❒ Use post-pounder to install well points, if possible. ❒ Operate post-pounder using two people ❒ Use installation tools from a position of firm footing ❒ When using post-pounder, do not lift tool higher than the top of the well point on the up-stroke ❒ Keep fingers, hands, arms, and other body parts clear of impact areas. ❒ Inspect all hand tools prior to use. If faulty or inappropriate, do not use until repaired or replaced.
	Pinch points	❒ Watch for pinch points when assembling / installing well casing
	Slip, trip, and fall	❒ Keep work area clean – including removal of excess cuttings / mud ❒ Keep work areas dry when possible

AMEC Geomatrix

JOB SAFETY ANALYSIS

Project Name:		***Project No:***		***Date:***	
Tasks:	1. Vapor Monitoring/Sampling 2. Groundwater Sampling	***Task Location:***	Pinedale Anticline Production Area Sublette Co., WY		
For this Project and Task, this document is a Certification of Hazard Assessment					
Completed by:	Steve Wright	***Reviewed by:***	DK		
Notes:					

Task	Hazard	Risk Control Method
		❒ Stay aware of footing and do not run
	Cold stress	❒ Wear appropriate clothing for Wyoming fall weather conditions – e.g. insulated coveralls, winter gloves, hard hat liner, etc. ❒ Seek warmth out of weather (e.g. inside vehicle), if necessary ❒ Consume adequate amounts of food and beverages
	Working at heights	❒ No work will be conducted at heights greater than 6 feet without fall restraint / arrest safety equipment
	UV exposure	❒ Wear neck to toe clothing and sun block
	Lifting heavy equipment/materials	❒ Do not lift or move heavy equipment without assistance ❒ Use proper lifting techniques. Lift with arms and legs, keep back straight. ❒ If possible, use a powered lift truck, drum cart, or other mechanical means.
Groundwater Sampling and Aquifer Testing	Handling contaminated groundwater and sample preservatives	❒ Coordinate with other work at location ❒ Wear appropriate PPE (e.g. nitrile gloves, safety glasses) ❒ Handle sample containers with preservatives with care to avoid spills/breakage of preservatives. ❒ Have water available to rinse skin in case of accidental contact with preservative.

APPENDIX F

CHRONOLOGY OF PAPA DEVELOPMENT AND REGULATORY MILESTONES

PINEDALE ANTICLINE DEVELOPMENT TIMELINE

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1920: Mineral Leasing Act Passed
1939: First well Drilled on the Pinedale Anticline (Government #1)
1949-1963: 11 additional wells drillrf on the Pinedale Anticline
1969: National Environmental Policy Act passed
1970: Mining and Minerals Policy Act
--established modern policy regarding mineral development in the United States of encouraging private enterprise while mitigating adverse environmental impacts
1976: Federal Land Policy Management Act passed (FLPMA)
--Defined the Roles and Responsibilities of the BLM for O&G activities
1976: Resource Conservation and Recovery Act passed
1980: Comprehensive Environmental Response, Compensation, and Liability Act passed
1980-1982: 8 additional wells drilled on the Pinedale anticline
1987: Federal Oil and Gas Leasing Reform Act (FOOGLRA)
1988: Pinedale Resource Management Plan (RMP)
1997: Interim Drilling program (45 wells) approved to gather data for the PAPA EIS process
2000: Pinedale Anticline Project Area EIS ROD, which also established the PAWG
2001: PAWG Chartered under FACA
2004: EPA concludes 5 year study which supports that fraccing should be exempt from regulation under the Safe Water Drinking Act
2005: BLM approves Questar Year Round Drilling Proposal
2006: BLM approves ASU Year Round Drilling Proposal
2006: New PAPA development proposal received
2007: Ultra receives approval to drill "Deep Well"
2007: First low-level hydrocarbon detections found
2008: Supplemental Pinedale Anticline Project Area ROD

Source: Merry Gamper, Physical Scientist, BLM Wyoming State Office. September 14, 2010.