FINAL

AMEC Geomatrix

PLAN OF STUDY

HYDROGEOLOGIC DATA GAPS

MAY 2009

FINAL

PLAN OF STUDY
for
HYDROGEOLOGIC DATA GAPS

INTERIM PLAN, PAPA ROD

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
Shell Rocky Mountain Production
Questar Market Resources
Ultra Resources, Inc.

Prepared by;

AMEC Geomatrix, Inc.
1001 South Higgins Avenue, B-1
Missoula, Montana 59801

AMEC Geomatrix

May 15, 2009

TABLE OF CONTENTS

1.0 INTRODUCTION 4
1.1 Background 4
1.2 Document Organization 6

2.0 STUDY AREA DESCRIPTION 7
2.1 Physiographic Setting 7
2.2 Climate 7
2.3 Geologic Setting 8
2.4 Hydrostratigraphic Units 8
2.5 Groundwater Recharge And Discharge 9
2.6 Groundwater Flow 9
2.7 Groundwater – Surface Water Interaction 10
2.8 Groundwater Quality 10
2.9 Surface Water Flow 10
2.10 Surface Water Quality 12

3.0 DATA QUALITY OBJECTIVES 13
3.1 Study Goals And Objectives 13
3.2 Information Inputs 13
3.3 Measurement Performance Criteria 14
3.4 Precision 15
3.5 Accuracy 15
3.6 Completeness 16

4.0 APPROACH 17
4.1 Task 1 – Establish Contemporaneous Water Elevation Data 17
4.2 Task 2 – Determine Gain-Loss Characteristics Of New Fork River 17
4.3 Task 3 – Evaluate Surface Water – Groundwater Interconnection 23
4.4 Task 4 – Determine Hydraulic Properties For Each Hydrostratigraphic Unit 29
4.5 Task 5 – Establish Data Collection System Needed To Generate Hydrographs 33
4.6 Task 6 – Characterize Mesa, Antelope, And PARADISE Springs 33
4.7 Task 7 – Investigate Hydraulic Connection Between Each Hydrostratigraphic Unit 34
4.8 Task 8 – Revise Hydrogeologic Conceptual Model 35

5.0 QUALITY ASSURANCE AND QUALITY CONTROL 37
5.1 Field Quality Control 37
5.2 Laboratory Quality Control 38
5.3 Database And Reporting 40
5.4 Data Review 41

TABLE OF CONTENTS
Continued

6.0 SCHEDULE 45
7.0 PERSONNEL 47
8.0 REFERENCES 48

LIST OF FIGURES (Appendix A)

Figure 1 Project Location Map
Figure 2 Existing Wells Monitored by SCCD
Figure 3 Proposed Surface Water Study Locations
Figure 4 Proposed Study Well Locations
Figure 5 Study Well Conceptual Diagram
Figure 6 Cluster Study Well Completion Schematic

LIST OF TABLES (Appendix B)

Table 1 Summary of Monthly Climate Data for Pinedale, Wyoming
Table 2 Mean Monthly Stream Discharge at USGS Gaging Stations
Table 3 Precision, Accuracy, and Completeness Goals
Table 4 Surface Water Quality Parameter for Laboratory Analysis
Table 5 Proposed Study Well and Piezometer Locations
Table 6 Groundwater Quality Parameters for Laboratory Analysis

LIST OF APPENDICES

Appendix A Figures
Appendix B Tables
Appendix C Standard Operating Procedures
Appendix D Standard Field Forms
Appendix E Health & Safety Plan

1.0 INTRODUCTION

A consortium of agencies and companies prepared an Interim Plan (Geomatrix 2008a) that was designed to fulfil certain requirements of a recent U.S. Department of Interior, Bureau of Land Management (BLM) Record of Decision (ROD; BLM 2008) for 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**). The group is comprised of representatives and technical specialists with BLM, Wyoming Department of Environmental Quality's Water Quality Division (DEQ/WQD), and Region 8 of the U.S. Environmental Protection Agency (EPA), as well as Shell Exploration and Production Company (Shell), Questar Market Resources (Questar), and Ultra Resources, Inc. (Ultra). AMEC Geomatrix, Inc. (Geomatrix) is providing technical support to the group. Collectively, the agencies are referred to herein as the "BDE" (BLM/DEQ/EPA) and the three oil and gas companies are referred to as the "Operators".

1.1 BACKGROUND

To fulfill the requirements of the 2000 ROD, the Operators contracted the Sublette County Conservation District (SCCD) to develop a surface water and groundwater monitoring program and to collect and manage resulting data. The SCCD began collecting surface water and groundwater data in the PAPA in 2000-2001. Data are stored in a Microsoft Access database constructed and maintained by the SCCD. Data contained in the database include:

- Results of initial field inventory of water supply wells that required monitoring in accordance with the ROD;
- Water well permit information, including ownership, location, depth and a summary table cross-referencing permit numbers and SCCD well IDs;
- Well locations determined using survey grade and non-survey (e.g., recreational) grade GPS units;
- Well construction information, including type and size of casing, screened or perforated intervals, and total depth;
- Lithologic descriptions recorded on driller's well logs;
- Static water level measurements from monitored wells; and
- Water quality sampling results, including field measurements and laboratory analytical results for general chemical parameters and petroleum hydrocarbon compounds. To date, laboratory analytical data for groundwater have been collected at 167 industrial wells, 50 domestic wells, and 22 stock wells. Surface water samples have been collected at eight stations along the New Fork River and some tributary streams.

The Operators retained Geomatrix to compile and analyze existing groundwater data in the PAPA, and develop a hydrogeologic conceptual model. Geomatrix (2008b) presents the results of that work and describes:

- Correlation between water-bearing units;
- Groundwater flow;
- Interaction between groundwater and surface water;
- Variability/zonation of natural water quality; and
- Relationships between domestic, stock, and industrial wells.

Geomatrix (2008b) identified several data gaps, including the following.

- Contemporaneous groundwater and surface water elevation data, using accurate positional and reference elevation data;
- Surface water flow data to determine influent/effluent characteristics of the New Fork River;
- Data to define groundwater/surface water interconnection;
- Hydraulic data to characterize hydrostratigraphic units (HSUs);
- Water level data to generate surface water and groundwater hydrographs;
- Water quality, flow, and elevation data to characterize springs; and
- Data to investigate the hydraulic connection between each HSU.

Geomatrix 2008 also reviewed and offered recommendations for revising the current monitoring program. Existing wells monitored by SCCD in the PAPA, including domestic, stock, and industrial wells, are shown on **Figure 2**.

In the process of developing the conceptual model, Geomatrix added to the SCCD database additional wells that are reported in U.S. Geologic Survey (USGS) documents. These wells are not owned by the USGS and are identified according to their USGS nomenclature (e.g., USGS-32-110-13ab01). In addition, Geomatrix amended the SCCD database with additional data obtained for the PAPA. Geomatrix reviewed SCCD data and any apparent anomalous data were identified, examined, and either rejected or retained in the database. SCCD monitoring data are currently available through 2008.

Geomatrix requested and received copies of additional water well permits and water quality data from the Operators that were not included in the SCCD database. Permit information that was not included in the SCCD database was added to the project database, including

lithologic and well construction information. Some additional water quality data resulted from DEQ's October 2006 requirement (DEQ 2006) that Operators sample all water supply wells for gasoline-range and diesel-range total petroleum hydrocarbons, and benzene, toluene, ethylbenzene, and xylenes (TPH-GRO, TPH-DRO, and BTEX, respectively), as well as subsequent monitoring efforts through the end of 2007. These additional data, which were entered into the project database, include:

- All analytical data collected by Shell, Questar, and BP through the end of 2007.
- Data collected by Ultra through the end of 2007 from three water wells enrolled in DEQ's Voluntary Remediation Program. The remaining Ultra wells are sampled by SCCD.
- Data collected by SCCD for Yates from Blue Rim State #2 well.

1.2 DOCUMENT ORGANIZATION

This Plan of Study was prepared to guide investigative and monitoring tasks that will be completed to fill the hydrogeologic data gaps identified by Geomatrix (2008b). Section 2 of this Plan of Study describes the hydrologic and hydrogeologic setting of the PAPA. Data quality objectives are described in Section 3. Section 4 describes eight specific tasks that are proposed to fill identified hydrogeologic data gaps for the PAPA project. Quality assurance and quality control are described in Section 5. A tentative schedule for completing the eight tasks is presented in Section 6. Key personnel identified to complete the tasks are listed in Section 7. Figures and tables associated with this Plan of Study are compiled in **Appendices A** and **B**, respectively. Standard operating procedures (SOPs) and field forms are in **Appendices C** and **D**, respectively. A preliminary Health and Safety Plan is in **Appendix E**.

2.0 STUDY AREA DESCRIPTION

Natural gas exploration and production targets natural gas accumulations in a subsurface geologic trap called the Pinedale Anticline. The uppermost gas-bearing geologic formations of economic significance are located approximately 8,000 to 12,000 feet below ground surface. The Anticline Crest is approximately 2 to 3 miles wide, and is oriented northwest to southeast parallel to the Wind River Range located to the east. The PAPA encompasses an area of approximately 308 square miles, and is about 12 miles wide by 26 miles long (**Figure 1**). The following subsections summarize the environmental and geologic setting of the PAPA. More detailed information about the PAPA is presented in the Hydrogeologic Conceptual Model report (Geomatrix 2008b).

2.1 PHYSIOGRAPHIC SETTING

The PAPA is located in a northwest to southeast oriented valley between the Wind River and Wyoming mountain ranges. The valley is characterized by a semi-arid landscape, rocky soil, and sparse vegetation, with numerous ephemeral drainages dissecting ridges and buttes. Topographic elevations range from approximately 6,850 feet above mean sea level where the New Fork River exits the PAPA to over 7,700 feet on top of The Mesa in the north-central portion of the PAPA. The New Fork River and Green River are the major drainages and, in the northern half of the PAPA, generally serve as the northern, eastern and western boundaries. No other significant perennial streams are located within the PAPA.

2.2 CLIMATE

Precipitation in the mountains northeast and west of Pinedale is significantly greater than in the lower portions of the Sublette County which includes the PAPA. Statewide, precipitation averages between 12 and 13 inches annually (Western Regional Climate Center 2007). Based on available SNOTEL data, the mountain ranges in vicinity of Pinedale receive between 20 and 24 inches of annual precipitation, while Pinedale receives an average of 10.82 inches of annual precipitation (Western Regional Climate Center 2007). Precipitation data for Pinedale are summarized in **Table 1**. Average monthly data indicate more precipitation occurs during the period May through September (5.9 inches) than during the period October through April (3.9 inches).

Mean evaporation potentials for Wyoming calculated from pan evaporation data range from 39.1 inches to 47.9 inches (Wyoming Climate Atlas 2004). No published evaporation potential data for Pinedale were found. Even at the lower end of the range (39.1 inches), average annual evaporation potential is approximately four times higher than the mean annual precipitation amount at Pinedale. Although total annual potential evapotranspiration exceeds total annual precipitation, infiltration of precipitation can occur when evapotranspiration rates are low. A comparison of evaporation potential and the average precipitation amount indicates the majority of groundwater recharge does not occur via direct infiltration of precipitation.

2.3 GEOLOGIC SETTING

Near-surface geology within and adjacent to the PAPA consists of the Tertiary-age Wasatch and Green River sedimentary formations, unconsolidated glacial outwash, and alluvium along surface water courses. The Wasatch Formation generally underlies the entire PAPA. It was deposited in a piedmont environment in an internally-drained depositional basin contemporaneous with the Green River Formation, which represents lacustrine (lake) deposition. The Wasatch Formation primarily consists of discontinuous, lenticular arkosic sandstone beds representing river channel deposits, and sandy shale and siltstone representing overbank and floodplain deposits. Due to changes in the position of the lake shoreline over time, Wasatch sediments intertongue with Green River sediments. The Green River Formation is comprised predominantly of lacustrine deposits of fine sandstone, siltstone, and shale. Beds in both of these formations are generally horizontal.

Overlying the Wasatch Formation on the Mesa are coarse alluvial glacial outwash gravels of Quaternary age that originate from the Wind River Range. Based on well logs, these terrace gravels are approximately 10 to 35 feet thick. Recent alluvial deposits of unconsolidated sand, gravel, and some clay occur in the valleys of the Green River, New Fork River and their tributaries. Alluvial deposits in the PAPA are up to 80 feet thick.

2.4 HYDROSTRATIGRAPHIC UNITS

Groundwater intercepted by industrial, stock and domestic wells occurs in three principal hydrostratigraphic units (HSUs) within the PAPA: River Alluvium, Mesa Gravel, Shallow Wasatch Formation bedrock, and Regional Wasatch Formation bedrock. There is not concurrence about separation of the Wasatch Formation into shallow and regional HSUs. Groundwater in the River Alluvium HSU occurs in sand and gravel deposits adjacent to the principal water courses in the PAPA and is hydraulically connected to both rivers and streams and to the underlying Wasatch Formation. Where present, groundwater in terrace gravels on the Mesa, is likely of limited quantity and extent, but may be the source of some springs along the edge of the Mesa. Both of these unconsolidated units (River Alluvium and Mesa Gravel) are expected to have high permeability relative to bedrock HSUs.

The Regional Wasatch Formation HSU consists of laterally and vertically discontinuous porous sandstone beds interbedded with less permeable shale, siltstone, and mudstone. It is characterized as a heterogeneous or compound system as the water-bearing sandstone beds are not continuous. Because sandstone beds are lenticular and variable in location, it is not possible to correlate individual beds between boreholes based on existing well spacing in the PAPA. Due to expected hydraulic conductivity contrasts between fine-grained units and sandstone, and the discontinuous nature of the individual sandstone beds, this HSU is probably best described as a semi-confined or leaky confined aquifer. Most private wells and most industrial water supply wells that support natural gas exploration and development activities are completed in this HSU.

Groundwater in the Shallow Wasatch Formation HSU also occurs in discontinuous sandstone units or lenses within finer-grained siltstone or mudstone/shale units. Generally within the PAPA, the Shallow Wasatch Formation HSU is present above the Green River and New Fork River valleys. 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 flow in the Shallow Wasatch is primarily directed vertically downward to the Regional Wasatch Formation HSU, although some water emerges from hill slopes in the form of springs or seeps. Most stock wells are completed in the Shallow Wasatch Formation HSU.

2.5 GROUNDWATER RECHARGE AND DISCHARGE

The majority of recharge occurs outside the PAPA adjacent to mountain ranges located to the northeast, north and west. Some recharge also appears to originate from the New Fork and Green Rivers in the northern portion of the PAPA. The Mesa, Ross Ridge and Blue Rim, possibly due to their topographic elevations, may receive more recharge than lower elevation portions of the PAPA. Other possible sources of groundwater recharge include leakage from irrigation ditches located on the north side of the New Fork River and from excess water irrigated to crops.

Discharge of groundwater in the PAPA occurs primarily to streams and river, including the New Fork and Green Rivers. Several small springs occur along the slopes of topographic features within the PAPA. Evapotranspiration also is a source of discharge in the PAPA.

2.6 GROUNDWATER FLOW

The overall pattern of groundwater flow within the PAPA is from northeast to southwest away from primary recharge areas adjacent to the Wind River Range. Groundwater is somewhat mounded under the Mesa, Ross Ridge and the Blue Rim due to secondary recharge in these areas, forming a groundwater ridge.

Groundwater in the Shallow Wasatch Formation HSU is expected to migrate vertically to the underlying Regional Wasatch Formation HSU, while a portion travels laterally on top of siltstone/mudstone and discharges along the slopes of topographic features in the form of springs and seeps. Groundwater in the Regional Wasatch Formation HSU flows through the aquifer in sandstone units and along joints and fractures in sandstone, mudstone, and siltstone. The heterogeneous and fractured nature of the aquifer indicates that groundwater probably flows along tortuous preferential paths from recharge areas to discharge areas.

Upward vertical gradients are present in the Regional Wasatch Formation HSU proximal to the lower New Fork River. Numerous flowing wells are located adjacent to the New Fork River between the mouth of the East Fork River and the confluence with the Green River indicating

an upward vertical potential. Groundwater in the Shallow Wasatch Formation HSU migrates downward to the Regional Wasatch Formation HSU under variable degrees of saturation.

2.7 GROUNDWATER – SURFACE WATER INTERACTION

The New Fork, East Fork, and Green Rivers exert an influence on groundwater flow in the northern and central portions of the PAPA. Groundwater exchange with rivers probably occurs through the Alluvium HSU and at areas where Wasatch Formation bedrock is exposed in the river channels. Available flow data for the New Fork River, East Fork River, and Boulder Creek indicate the New Fork River gains flow from groundwater through the PAPA. In the southern portions of the PAPA (south of the New Fork River), groundwater flow appears to be roughly parallel to the New Fork and Green Rivers except in close proximity to the New Fork River, where it is directed toward the river.

2.8 GROUNDWATER QUALITY

Geochemical data available for the PAPA reflect the flow regime with groundwater recharge occurring primarily in the north and east and groundwater movement generally to the south and west. Similarities between water in the New Fork River and shallow wells west and south of Pinedale (both calcium bicarbonate-type) may indicate the river is recharging groundwater in the northern part of the PAPA. Sodium bicarbonate becomes the dominant water type, increasing with depth and distance from recharge areas as ion exchange reactions remove calcium and magnesium from groundwater and replace them with sodium from formation materials. Sulfate- and chloride-rich groundwater occurs in the southern portion of the PAPA due to longer groundwater residence times and possibly contact with different mineral assemblages.

Groundwater samples have been analyzed for petroleum hydrocarbon compounds including BTEX, TPH-GRO, and TPH-DRO. According to the SCCD (2008), TPH-DRO was detected in three wells (all industrial); TPH-GRO was detected in 11 wells (all industrial); and BTEX were detected in 12 wells (11 industrial and one stock).

2.9 SURFACE WATER FLOW

Perennial streams within and adjacent to the PAPA include (**Figure 3**):

- Green River located near the western PAPA boundary, primarily in the north.
- New Fork River located adjacent to the eastern PAPA boundary in the north, and bisecting the middle of the PAPA from approximately east to west.
- East Fork River, a tributary to the New Fork River, which enters the PAPA from the east near the town of New Fork.

Headwaters for these rivers are located to the north and east of the PAPA in the Wind River Range. The confluence of the East Fork and New Fork Rivers is within the PAPA, near the east-central PAPA boundary. The New Fork River joins the Green River approximately six miles west of the west-central PAPA boundary. The Green River continues flowing southward through Fontenelle Reservoir and Flaming Gorge Reservoir, and ultimately discharges to the Colorado River in Utah.

Several perennial streams join the New Fork River east and north of the PAPA, including Duck Creek, Pine Creek, Pole Creek, Boulder Creek, and East Fork River (**Figure 3**). Numerous intermittent drainages are present in the PAPA, many of which Geomatrix observed to be dry in August 2007. No lakes are present within the PAPA; however, several significant lakes occur east and northeast of the PAPA, including Freemont Lake and Boulder Lake near the western front of the Wind River Range. Several small water storage reservoirs are present within the PAPA where ephemeral drainages are dammed. Irrigation ditches inside the PAPA divert water from and are generally parallel to the Green and New Fork rivers. A few springs occur within the PAPA, including Mesa Spring and Antelope Spring (**Figure 3**), both of which apparently flow at relatively low rates. Flow from Mesa Spring, located along the west side of the Mesa, was estimated to be flowing at ¼ gallon per minute (gal/min) in August 2007. Another group of small springs reportedly discharge along the Paradise road on the north side of the New Fork River, herein referred to as the "Paradise" springs (**Figure 3**).

Table 2 lists mean monthly discharge data reported by the USGS for stream gaging stations on the New Fork River and Green River, including tributaries to the New Fork River (Duck Creek, Pine Creek Pole Creek, Boulder Creek, and East Fork River). Only the lower New Fork River station (09205000) and the two Green River stations (**Table 2)** are still being monitored by the USGS. Lowest monthly flows in the New Fork River generally occur during the period of December through March, and highest flows occur in June, followed by July and May. Low mean monthly flows for the New Fork River at Pinedale and Big Piney are approximately 25 and 200 cubic feet per second (ft^3/sec), respectively. High mean monthly flows for the New Fork River at Pinedale and Big Piney are approximately 200 and 3,000 ft^3/sec, respectively. Low mean monthly flows in the Green River near Daniel and La Barge are approximately 100 and 500 ft^3/sec, respectively; whereas high mean monthly flows at these Green River stations are approximately 1,800 and 5,500 ft^3/sec, respectively.

Mean monthly discharge data for the three New Fork River gaging stations indicate a consistent increase in flow from upstream to downstream (**Table 2**). However, Geomatrix could not locate synoptic flow data for these stations (including the tributary streams) for which to compare single base flow measurements on a common day.

The following average flows were calculated using the 90th percentile of average daily discharge for the January during the period of record for each station:

- New Fork River near Boulder: 143 ft^3/sec
- Boulder Creek near Boulder: 34 ft^3/sec
- East Fork River near New Fork: 55 ft^3/sec
- New Fork River near Big Piney: 261 ft^3/sec

Based on available flow data for January, there is a gain in average stream base flow at the Big Piney (downstream) gaging station of approximately 30 ft^3/sec that is not accounted for by summing average stream flows at the three upstream stations (New Fork River, East Fork River, and Boulder Creek). This analysis suggests the New Fork River is gaining flow from groundwater in this portion of the PAPA, and also supports conclusions of previous studies (e.g., Martin 1996) that identified the upper Green River and its tributaries to be gaining streams.

2.10 SURFACE WATER QUALITY

Surface water samples have been collected by the SCCD from eight locations along the New Fork River and some tributaries since 2000. The following parameters are measured in the field: pH, turbidity, conductivity, total dissolved solids, temperature, and dissolved oxygen. Laboratory parameters include: alkalinity, bicarbonate, calcium, carbonate, chloride, magnesium, nitrate+nitrite, phosphorus, sodium, sulfate, hardness, total suspended solids, and BTEX. According to SCCD (2008), surface water samples at all sample sites for the period of record have not exceeded any applicable surface water quality standards. All BTEX results have been below laboratory detection limits.

3.0 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 study (Section 3.1). Subsequent steps identify information inputs (Section 3.2) and measurement performance criteria (Sections 3.3 through 3.6). Data collection methods, definitions of the boundaries of the study (specific data collecting points within or adjacent to the PAPA), and the analytic approach (sample type/frequency) are designed to satisfy study goals and objectives and are presented in Section 4. Specific procedures for ensuring data quality assurance and quality control are explained in Section 5.

3.1 STUDY GOALS AND OBJECTIVES

Geomatrix (2008b) identified gaps in the understanding of the hydrogeologic system present in the PAPA. The purpose of this study is to fill those data gaps. Objectives of this study are:

- Develop potentiometric surface maps for each HSU.
- Determine the gain-loss characteristics of the New Fork River.
- Describe the interconnection between the New Fork River and portions of the Green River and the groundwater system.
- Determine hydraulic properties for each HSU.
- Generate surface water and groundwater hydrographs.
- Characterize Mesa and Antelope Springs.
- Investigate the hydraulic connection between each HSU.
- Revise the hydrogeologic conceptual model.

3.2 INFORMATION INPUTS

Various field and analytical data are required to meet the objectives stated above. For this Plan of Study, the following general field and laboratory activities are proposed with respect to filling hydrogeologic data gaps for the PAPA:

- Measure depth to water in existing and new wells.
- Measure flow in streams, rivers, and springs.
- Install new study wells and piezometers.
- Survey locations and elevations of new study wells, piezometers, and stream/river gaging sites.

- Conduct aquifer tests in study wells.
- Install pressure transducers and data-loggers in selected new study wells and at some surface water study sites.
- Measure field parameters in surface water and groundwater samples (pH, electrical conductivity, temperature).
- Collect surface water samples for laboratory analysis of inorganic constituents (common ions) to evaluate interconnection of surface water with groundwater.
- Collect groundwater samples for laboratory analysis of (1) inorganic (common ions) to help evaluate hydraulic connection between HSUs and with surface water, and (2) petroleum constituents (TPH-DRO, TPH-GRO, and BTEX) to assess potential impacts from natural gas exploration and production activities at PAPA.

Typical data parameters and uses to support project decisions are summarized in the following list:

Media	Typical Data Parameters	Data Uses
Surface Water	Flow; annual hydrograph; field and laboratory water quality parameters.	Constituent concentrations; chemical source areas; water pathways; water movement; seasonal flow variation; interconnection with groundwater; water balance; and comparison to surface water quality standards (DEQ).
Groundwater	Depth to groundwater, spatial and temporal variation; flux; hydraulic properties of hydrostratigraphic units; annual hydrograph; field and analytical water quality parameters.	Hydraulic properties of hydrostratigraphic units; constituent concentrations; recharge/discharge areas; regional flow systems; connectivity to surface water and other water-bearing units; water balance; seasonal water level fluctuations; horizontal and vertical gradients; potential effects from gas production activities in the PAPA; and comparison to groundwater quality standards (drinking water standards and livestock standards from DEQ and EPA).

3.3 MEASUREMENT PERFORMANCE CRITERIA

Measurement performance criteria are established for each field and laboratory measurement 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 project are presented in **Table 3**. Requirements for laboratory analytical data precision, accuracy, and completeness are provided in the following sections.

3.4 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 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.

3.5 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 80–120 percent and 75–125 percent, 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).

3.6 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.

4.0 APPROACH

This section describes eight specific tasks that will be completed to fill identified hydrogeologic data gaps for the PAPA. The tasks include both surface water and groundwater studies in and near the PAPA. The focus of surface water studies is along the New Fork River, with some monitoring included on the Green River and primary tributaries to the New Fork River in the project area (Duck Creek, Pine Creek, Pole Creek, Boulder Creek, and East Fork River). Groundwater studies will target areas along the New Fork River and the Anticline within PAPA.

Standard operating procedures (SOPs) for field activities are compiled in **Appendix C**, and standard field forms are in **Appendix D**.

4.1 TASK 1 – ESTABLISH CONTEMPORANEOUS WATER ELEVATION DATA

Depth to water will be measured in those existing PAPA wells that are determined to be "credible" based on procedures described in the "Credible Well Identification" Plan of Study (Geomatrix 2009b) for the PAPA. The water level measurements will be obtained within a short time-frame (e.g., several concurrent days). Water elevations of the New Fork River also will be measured at several locations in the PAPA at the same time. Using the new water level measurements, along with updated survey data for well locations and elevations, new potentiometric surface maps will be prepared for each HSU. The potentiometric maps will be used to confirm direction of horizontal groundwater flow within each HSU, and vertical flow between HSUs.

The field portion of this task will be conducted in mid-April 2009, and the new potentiometric maps will be prepared in June 2009.

4.2 TASK 2 – DETERMINE GAIN-LOSS CHARACTERISTICS OF NEW FORK RIVER

A gain-loss synoptic survey of flow along the main channel of New Fork River, including major tributaries, will be conducted during low flow conditions in late fall (October 2009). Current and former USGS gaging stations for the New Fork River, Green River, East Fork River, Duck Creek, Pine Creek, Pole Creek, and Boulder Creek are shown on **Figure 3**. Only three of the stations (New Fork River at Big Piney – 09205000; Green River at Warren Bridge near Daniel – 09188500; and Green River at La Barge – 09209400) are currently operated by the USGS. **Table 2** lists mean monthly flow rates for all of the current and former USGS gaging stations.

Other stations on the New Fork River have been used by the SCCD as part of its monitoring program in the PAPA. These seven SCCD stations (**Figure 3**) extend along the New Fork River from Pinedale down to near its confluence with the Green River.

Figure 3 shows locations of river and stream sites that will be used for this synoptic study to measure flow for evaluating gain-loss characteristics of the New Fork River. The sites have been selected because they are relatively easy to access from roads and bridges. The New Fork River synoptic stations include the seven SCCD "secondary" study sites, along with the following five "primary" study sites shown on **Figure 3** (from upstream to downstream):

- Highway 191 bridge one mile west of Pinedale;
- 4 miles south of Pinedale at county road bridge;
- Near town of Boulder and Highway 191;
- Highway 351 bridge; and
- Near confluence with Green River at USGS gaging station 09205000.

In addition, flow will be measured at five "primary" tributary streams to the New Fork River: Duck Creek, Pine Creek, Pole Creek, Boulder Creek, and East Fork River. These stations are also located where there is relatively easy access (**Figure 3**). Two "primary" study sites on the Green River also will be measured for flow: (1) near mouth at Highway 351 bridge; and (2) below confluence with New Fork River at USGS gaging station (**Figure 3**).

October is selected as the time to conduct the synoptic flow survey because it is during the low base-flow period when there are minimal affects from irrigation, evapotranspiration, and precipitation. If flow is observed being diverted to or from irrigation ditches along the New Fork River during the synoptic survey, additional flow measurements will be made in the ditches. Flow of any other observed point sources to the river (e.g., springs) will also be measured. Flow measurement methods are described below.

Electrical conductivity (EC), pH, and temperature will be measured in water samples from each synoptic site in the field at the time of flow measurement. Water samples collected from the "primary" stations located on the main East Fork River channel (**Figure 3**) will be analyzed in the laboratory for parameters listed in **Table 4**. These water quality samples also will be collected in October 2009. Surface water sample collection and analysis methods are described below.

The location and water surface elevation of each synoptic flow site will be recorded using a GPS unit, Synoptic site locations will be posted on a common base map of the PAPA. Photographs of each synoptic flow site will also be taken at the time of measurement.

Flow Measurement

Stream flow at designated study stations shown on **Figure 3** will be measured in October 2009 using a current meter (pygmy, electromagnetic, and/or equivalent-type). Where gaging is not possible due to low flows, surface water discharge will be measured or estimated using one of

the following methods: portable flume, area-velocity, or discharge into container of known volume.

Stream velocity varies vertically at each point in a stream. Techniques have been developed for measuring average velocity where stream depth is less than 2.5 feet; in this case, the flow meter is placed at six-tenths of total water depth. Where stream depth is greater than 2.5 feet, the velocity is measured at two-tenths and eight-tenths of total depth, with the two values averaged to determine the single value of stream velocity.

Width will be measured by extending a tape measure across the stream at a right-angle to the main channel. Starting at the edge of one bank, flow measurements will be made at regular intervals across the stream such that a minimum of 10 points is measured, if feasible. A top-setting wading rod will be used to measure stream depths and to set the velocity meter to the appropriate measurement depths. Velocity measurements and depth/distance measurements are used to calculate the total volume of water flowing through each cross-sectional area, the sum of which is the total stream discharge at that location. Stream flow calculations and weather conditions will be recorded on an individual form for each monitoring site. Any unusual stream channel conditions will be noted on the form.

A portable flume may be used to measure flow when low discharge and/or channel geometry preclude use of a flow meter. Water is routed through the leveled flume and water height recorded to the nearest 0.01 foot in the flume. The flume dimensions and water leakage estimate, if any, will be recorded on an individual form for each measurement site. Discharge is calculated using the data and an equation specific for the flume size.

Another method applicable where discharge is low uses a calibrated collection container and stopwatch. Unless a location can be found where a bucket can be placed under a water drop, flow will be routed through a plastic pipe and timed to fill a container of known volume. A minimum of three measurements will be made at each location, with total discharge being the average of the measurements. Any leakage that does not enter the container will be estimated and recorded.

Pressure transducers and data-loggers will be installed at two the "primary" surface water monitoring stations located on the New Fork River: (1) four miles south of Pinedale at county road bridge; and (2) Highway 351 bridge. These instruments will be placed into slotted PVC or steel pipe that will be attached to permanent objects in or along the edge of the river/stream channel, if possible (e.g., bridge support, culvert, large rock, etc.). If such permanent objects are not available at a station, a steel post will be driven or dug into the subsurface, with the transducer pipe attached to the post. Each pipe will have a locking cap on the top to prevent unwanted access to the transducer. Location of each transducer pipe will be established using a GPS unit. Each transducer will be set to record the river/stream water level every two hours. This information will be downloaded to a computer and used to graph daily, weekly, and

monthly variations in water stage. The transducers and data-loggers will be installed when field work begins in approximately July 2009 and continue to record data through at least October 2009 so that high and low flow conditions can be monitored.

Surface Water Quality Sampling and Analysis

This section describes methods used to collect surface water samples. Some parameters will be analyzed in the field immediately after collection, whereas, other parameters will be analyzed by a laboratory after proper collection, preservation, storage, and shipment.

On a river/stream course with more than one study station that will be sampled in one or more consecutive days, water quality sampling will begin at the farthest downstream station to avoid physical disturbance in one area influencing a downstream station. Samples will be collected upstream of any roads, bridges, or other crossings. Sampling will be conducted in a safe manner and will be conducted at the designated location identified by a marked stake for each monitoring event. If flow rate is being measured at the site, the water quality samples will be collected before flow measurement.

Sampling equipment will consist of laboratory-supplied sample bottles, preservatives, field measurement probes, clean sample bucket, peristaltic pump and disposable tubing (used for filtration), disposable filters, sampling forms, camera, and latex gloves. All probes and the sample bucket will be rinsed with deionized or distilled water between samples. New pump tubing and filter will be used for each sample site. New latex gloves will be worn when collecting, filtering, and preserving samples at each site. Sample bottles will be provided by the laboratory and will be rinsed prior to filling with the sample water.

Sampling personnel will face upstream while sampling to prevent contamination by disturbed sediment. Surface water samples will be collected directly from each water source using the grab-technique, where each sample container is submerged into the portion of the stream or spring with the largest flow volume and/or velocity (usually mid-channel). Each container will be filled completely by moving the container slowly down and up the water column in a manner that prevents disturbance to bottom sediment. If the sample bottle requires preservative to be added by the sampler, the bottle will be filled with a small space retained to allow for adding the preservative.

For water samples that require filtration, a clean plastic bucket or large sample bottle will be filled directly from the water source in a manner that prevents disturbance to bottom sediment. A peristaltic pump and tubing will be used to withdraw water from the temporary container, through an in-line 0.45-micron pore size disposable filter, and into the appropriate sample containers for laboratory analysis.

All instruments will be maintained and calibrated in accordance with manufacturer's instructions. Standard solutions for pH probe calibration will include buffers with pH of 4 and 7. The specific conductivity standard will be appropriate for the conductivity range typically observed at the sampling locations. Calibration of field instruments will be performed at least twice per day during sampling activities. Equipment maintenance, probe replacement, battery replacement, irregular readings, or calibration problems encountered using the probes will be recorded on field forms.

Field parameters including pH, EC, and temperature will be measured by directly placing probes in the stream or collecting water in an extra container and placing probes in the container. Results of field measurements will be recorded immediately on the field form.

Field sampling forms will include date/time and a description of weather conditions. If anything is observed at the sample station that suggests there may be a change in water quality or flow (e.g., precipitates, staining, new flow channels, or land disturbance in the area), it will be recorded on the sample form.

Sample bottles and preservatives are transported from the laboratory in clean hard-cased coolers. These coolers are then used to store and transport the samples collected in the field. Coolers that contain collected water samples will have sufficient freezer packs and/or ice intended to maintain a temperature of 1-4° C inside each cooler. Additional ice or freezer packs are replaced in each cooler in the evening and prior to shipping to the laboratory.

Four bottles are used for sample collection at surface water sampling stations (**Table 4**):

- One 250-milliliter (ml) plastic bottle of filtered, unpreserved sample for analysis of anions (chloride, fluoride, sulfate, alkalinity);
- One 250-ml plastic bottle of filtered sample, preserved with nitric acid, for analysis of cations (calcium, magnesium, potassium, sodium);
- One 250-ml plastic bottle of unfiltered, unpreserved sample for analysis of general parameters (EC, pH, and total dissolved solids); and
- One 1000-ml plastic bottle of unfiltered, unpreserved sample for analysis of total suspended solids.

Adhesive sample container labels provided by the laboratory will be applied to dry bottles before sampling. Immediately before sample collection, the labels will be filled-out with a permanent-marking pen for site name, sample date, sample station number, added preservative, and requested analysis.

Chain-of-custody forms will be completed for a set of samples in each cooler as appropriate. Each form will be completed with the following information: list of samples collected using identification number, date/time of sample collection, type of sample (surface water), number of containers per sample site, person(s) collecting samples, company name, address, phone number, contact person, date/time and method of shipment, and any special requirements for handling, analysis, data reporting, and quality control.

One copy of the completed chain-of-custody form will be retained with the project file, and the original and other copies will be submitted to the laboratory. The completed chain-of-custody form will be sealed in a plastic bag and placed inside the cooler, which will then be sealed with tape and labeled with the laboratory address. Prior to sealing the cooler, sufficient ice packs and/or ice cubes in sealed plastic bags will be placed in each cooler and are intended to maintain a temperature of 1-4°C during shipment.

Samples will be transported to the laboratory (target transport time of 48 hours or less) to assure that cool temperatures are maintained inside the coolers prior to receipt by the laboratory. The laboratory will be notified by phone or email when to expect the samples. Finally, the laboratory will return a copy of the chain-of-custody that indicates receipt date/time, laboratory identification numbers, and condition of the sample sets.

Table 4 is a list of laboratory analytical parameters that will be analyzed for each surface water sample. The table indicates the laboratory analytical method and target reporting limit for each parameter. Also included in **Table 4** are the sample requirements for preservation method, holding time, and container material and size. Laboratory analytical methods are from the most recent edition of the American Public Health Association's "*Standard Methods for the Examination of Water and Wastewater*" (APHA 1992). The laboratory used for this project must meet specific quality control requirements (see Section 6).

Data Evaluation

All flow and water quality data collected for the Green River, New Fork River, and its tributaries will be compiled and evaluated to determine gain-loss conditions. Additional study stations may be needed for flow measurement on the Green River if available data are insufficient to determine its gain-loss characteristics. The synoptic flow measurement data will be presented graphically showing gains and losses in flow from upstream to downstream study sites. Similar graphs will be presented for the water quality field parameters (pH, EC, and temperature) and laboratory parameters listed in **Table 4**. Common ion concentrations also will be plotted using Piper and/or Stiff diagrams to assess areas of differing water quality characteristics. The combination of water quantity and quality data will be incorporated into the analysis for Task 3 (Evaluate Surface Water – Groundwater Interconnection) described below.

4.3 TASK 3 – EVALUATE SURFACE WATER – GROUNDWATER INTERCONNECTION

This task consists of installing groundwater study wells and piezometers along the New Fork River and Green River to assist with the evaluation of surface water – groundwater interconnection in PAPA. Groundwater levels in the various HSUs, including river alluvium, will be used to determine direction of groundwater flow (horizontal and vertical) along the rivers. Water samples also will be collected from the study wells and analyzed for chemical characteristics. This water level and quality information will be used in conjunction with surface water quantity and quality data obtained under Task 2 above to characterize surface water – groundwater interconnection in PAPA.

Five locations along the New Fork River and two along the Green River have been selected to install river study wells and piezometers. These locations are described in **Table 5** and shown with the "**X-**" designation on **Figure 4**:

- New Fork River near Highway 191 bridge one mile west of Pinedale (X-1)
- New Fork River four miles south of Pinedale and near Highway 191 (X-2)
- New Fork River near town of Boulder and Highway 191 (X-3)
- New Fork River below East Fork River confluence (X-4)
- New Fork River above Green River confluence (X-5)
- Green River above confluence with New Fork River (X-6)
- Green River along west side of PAPA (X-7)

Each of these river corridor sites would consist of up to three study wells and a transect of new piezometers. **Table 5** identifies the proposed number and estimated depths of wells and piezometers at each of the seven locations. The study wells would be completed in the River Alluvium HSU and to one or two depths in the Regional Wasatch HSU at each transect site along the stream and rivers (**Figure 4**). Approximately four to six piezometers would be installed at each site along a transect across the river or stream valley bottom in the River Alluvium HSU. A schematic of typical study well/piezometer completions along the river is shown on **Figure 5**.

Study Well and Piezometer Construction

The study wells will be installed using a rotary drill rig, and the piezometers installed using a direct-push-type rig. It is assumed that the Operators will assist with obtaining the necessary permissions to access all sites for well and piezometer construction and periodic monitoring activities. It is anticipated that the cluster wells will be completed to the following approximate depths:

- River Alluvium = 20 to 80 feet
- Regional Wasatch Formation = 100 to 200 feet
- Regional Wasatch Formation = 200 to 450 feet

Study wells completed in River Alluvium will extend to the contact between alluvium (sand and gravel) and bedrock (Wasatch Formation). Wells completed in the Regional Wasatch Formation will be screened in individual zones of sandstone. The piezometers will be completed into the saturated zone in the River Alluvium. The expected period of drilling and well/piezometer completion is July through mid-September 2009.

Study well completion will follow requirements specified in Wyoming Quality Rules and Regulations (WQR&R) Chapter 11, Part G – Well Construction. These rules include specific recommendations for the design, construction, and installation of monitoring wells by the DEQ. A schematic of typical well construction for the well cluster is shown on **Figure 6**. Specific well construction methods will include the following:

- Drill holes for study wells will be advanced using conventional air rotary, reverse-circulation, or equivalent drilling methods. Circulation will be maintained using air, unless ground conditions require injection of water or drilling fluids.
- Borehole diameter (8-inch) will be at least four inches larger than the well casing diameter (4-inch).
- Factory screen casing (0.02-inch opening) will be used for the perforated section of the well.
- For water table wells (unconfined aquifers), the screened interval will extend approximately two feet above the highest expected groundwater level.
- Filter pack material placed in the annulus around the screened section will be designed to be compatible with the perforation size and the geologic materials encountered within the perforated interval.
- The filter pack of coarse-grained certified clean sand will be placed around the screened section, extending one to two feet above the top of the screen.
- A minimum 2-ft thickness of bentonite or bentonite grout will be placed on top of the filter pack to serve as the annular seal. If bentonite chips are used, they will be <½-inch in diameter, and sufficiently hydrated with clean water to insure a proper seal.
- The annular space above the bentonite seal will consist of neat cement grout, sand-cement grout, bentonite, or concrete to within one foot of the surface. This material will be pumped into the annulus from the bottom to the top using a tremie pipe.
- 4-inch diameter Schedule 80 flush-threaded PVC pipe will be used for the well casing; it will meet requirements of ASTM F 480 "Standard Specifications for Thermoplastic

Water Well Casing Pipe and Couplings made in Standard Dimension Ratios (SDR)" (ASTM 1996).

- Top and bottom PVC well caps will be installed to prevent sediment and surface water from entering the well.
- A protective steel casing will be cemented into place with the upper one foot of annular space completed in cement, forming a cement cap sloping away from the well. A locking lid will be placed on the well head.
- Wells will be clearly labeled on the outside with the identification number.

The piezometers will consist of 1- or 2-inch diameter Schedule 40 PVC pipe that is placed in the direct-push borehole. The bottom five to 10 feet of pipe will be factory-slotted screen. The annular space will be filled with coarse-grained sand to within one foot of ground surface. The remaining annulus will be filled with cement, with a locking protective steel casing placed into the cement.

Observations of geologic materials encountered during drilling activities will be recorded by a field geologist on a standard lithologic and well completion form (**Appendix D**). Information recorded will include: lithology, drilling method, drilling rate and conditions, depth to saturation and/or saturated intervals, saturated or unsaturated fractures zones, estimated water yield, fluids injected, well materials, screen type and interval, annulus materials and depth, and surface completion.

After completion, each study well will be developed to improve the hydraulic connection between the well and saturated interval. Development is intended to remove any residual drill cuttings and drilling additives. Development techniques may include surge blocks, air-lifting, pumping, and/or bailing. Development will continue until removed water is relatively clear and free of sediment. Measurements or observations of well yield and water turbidity will be made periodically during the well development process and recorded on a well development form (**Appendix D**). Piezometers will be developed using a bailer.

Pressure transducers and temperature probes will be installed in selected study wells to record long-term measurements of hydraulic head and water temperature. It is expected that the transducers will be installed at four of the study well cluster sites (two at New Fork River, one at Green River, and one at Boulder Creek). The transducers will be set to record water levels every six hours to help evaluate groundwater fluctuations over the monitoring period (approximately July through December 2009). For study wells and piezometers without transducers, depth to water will be measured using an electric well probe on a monthly basis for the same monitoring period. The adjacent river surface elevation also will be measured on a monthly basis at each transect location, using a temporary benchmark established at each site.

All project study wells and piezometers will be secured to prevent unauthorized access, clearly marked with flagging, labeled with ID numbers, and surveyed for location and elevation using GPS equipment. Disturbed areas will be properly reclaimed after well completion. Designated depth to water measuring points will be established and clearly marked at each well and piezometer. Data obtained during study well/piezometer construction will be entered into a project-specific well inventory database.

Groundwater Quality Sampling and Analysis

This section describes methods used to collect groundwater quality samples. All samples will be analyzed in the field immediately after collection for field water quality parameters. Samples for laboratory analysis will be preserved after collection in accordance with analytical methods listed in **Table 6**. Samples will be shipped under chain-of-custody to the laboratory for analysis. The groundwater samples will be collected in August - September 2009. Sampling procedures generally will follow these guidance documents:

- HydroGeo, Inc., 2004. Groundwater Monitoring Protocol Manual, Pinedale Anticline Project. October 2004.
- ASTM Standard D4448-01, 1985. Standard Guide for Sampling Groundwater Monitoring Wells.

Sampling equipment will consist of laboratory-supplied sample containers and preservatives, field parameter measurement instruments, de-ionized or distilled water, clean sample bucket, peristaltic pump and tubing, filters, disposable polyethylene bailers, submersible pumps and hose, generator, sampling forms, and latex gloves.

All probes and the sample bucket, if used, will be decontaminated by rinsing with deionized or distilled water between samples. If non-disposable parts of pumping equipment are used that come into contact with groundwater, these parts will be washed with mild soapy water, followed by a rinse with deionized or distilled water between samples. New latex gloves will be worn when collecting samples, filtering, and preserving samples at each study well site.

New sample bottles will be supplied by the laboratory and will be rinsed with the sample water prior to filling with sample water. Preservatives also will be supplied by the laboratory.

A submersible pump or peristaltic pump (if water levels are less than 15 feet below ground surface) will be used to purge study wells prior to sample collection if well yield is sufficient. If formation yield is low or access prevents use of a pump, a new disposable bailer will be used for purging and sampling.

Field parameters including pH, EC, and temperature will be measured during well purging. Typically, samples will be collected after two to three casing volumes have been removed or

field parameters stabilize (±5 percent) for three subsequent measurements. If three casing volumes cannot be purged and field parameters do not stabilize due to low formation permeability, then samples will be collected from the first or second casing volume and this information will be noted on the sampling form. All data collected and observations made during sampling will be recorded on the well sampling form.

After purging, sample bottles will be filled directly from the pump discharge or bailer. If the sample bottle requires preservative to be added by the sampler, the bottle will be filled with a small space retained to allow for adding the preservative.

For water samples that require filtration, a 0.45-micron pore size disposable filter will be used in-line for the pump discharge or attached to the bailer to allow direct filling of the sample bottle for dissolved constituents. If water is collected in a clean bucket, a peristaltic pump and in-line filter can be used to obtain the required sample for dissolved metals.

All instruments will be maintained and calibrated in accordance with manufacturer's instructions. Standard solutions for pH probe calibration will include buffers with pH of 4 and 7. The specific conductivity standard will be appropriate for the conductivity range typically observed at the sampling locations. Instrument calibration will be conducted at least twice per day. Equipment maintenance, probe replacement, battery replacement, irregular readings, or calibration problems encountered using the probes will be recorded on field sampling forms.

For the field parameters of pH, EC, and temperature, the individual probes or multi-probe electronic meter will be placed directly into the water in a bucket immediately after collection from the source, with results recorded on the field sampling form. Another option is to use a flow-through cell that is connected in the pump discharge line. Field sampling forms will record various data including date/time, sampling personnel, field parameter measurements, instrument calibration records, and a description of weather conditions.

Sample bottles and preservatives will be transported from the laboratory in clean, hard-cased coolers. These coolers are then used to store and transport the filled sample bottles in the field. Coolers that contain the collected water samples will have sufficient freezer packs and/or ice to maintain a temperature of 1-4°C inside each cooler. Additional ice or freezer packs are replaced in each cooler in the evening and prior to shipping to the laboratory.

The following bottles are generally used for groundwater sample collection at study wells (**Table 6**):

- One 250-milliliter (ml) plastic bottle of filtered, unpreserved sample for analysis of anions (chloride, fluoride, sulfate, alkalinity);

- One 250-ml plastic bottle of filtered sample, preserved with nitric acid, for analysis of cations (calcium, magnesium, potassium, sodium);

- One 250-ml plastic bottle of unfiltered, unpreserved sample for analysis of general parameters (EC, pH, and total dissolved solids);

- Two 40-ml VOA vials for analysis of volatile organic compounds, preserved with hydrochloric acid (by the laboratory), and no head-space or bubbles;

- Two 40-ml VOA vials for analysis of total petroleum hydrocarbons – gasoline range organics, preserved with hydrochloric acid (by the laboratory), and no head-space or bubbles; and

- One 1000-ml amber glass bottle for analysis of total petroleum hydrocarbons – diesel range organics, preserved with hydrochloric acid (by the laboratory).

Adhesive sample container labels provided by the laboratory will be applied to dry bottles before sampling. Immediately before sample collection, the labels will be filled-out with a permanent marking pen with site name, sample date, sampler's initials, well number, added preservative, and requested analysis.

Chain-of-custody forms will be completed for a set of samples in each cooler as appropriate. Each form will be completed with the following information: list of samples collected using well identification number, date/time of sample collection, type of sample (groundwater), number of containers per sample site, person(s) collecting samples, company name, address, phone number, contact person, date/time and method of shipment, and any special requirements for handling, analysis, data reporting, and quality control.

One copy of the completed chain-of-custody form will be retained with the project file, and the original and other copies will be submitted to the laboratory. The completed chain-of-custody form will be sealed in a plastic bag and taped to inside lid of the cooler. The cooler will then be sealed with tape and labeled with the laboratory address. Prior to sealing the cooler, sufficient ice packs and/or ice cubes in sealed plastic bags will be placed in each cooler to maintain a temperature of 1-4°C during shipment.

Samples will be transported to the laboratory (target transport time of 48 hours or less) to assure that cool temperatures are maintained inside the coolers prior to receipt by the laboratory. The laboratory will be notified by phone or email when to expect the samples. Finally, the laboratory will return a copy of the chain-of-custody that indicates receipt date/time, laboratory identification numbers, and condition of the sample set.

Table 6 is a list of parameters that will be analyzed by the laboratory for each groundwater sample. The table indicates the laboratory analytical method and target reporting limit for each parameter. **Table 6** includes sample requirements for preservation method, holding time, and container material and size. Laboratory analytical methods are from the most recent edition of the APHA "*Standard Methods for the Examination of Water and Wastewater*" (APHA et al. 1992). The laboratory used for this project must meet specific quality control requirements (see Section 6).

Data Analysis

Water level elevations measured in all study wells and piezometers will be compared to elevations of the nearest point of the river for each time period of measurements. These data will be used to determine if hydraulic gradients are toward or away from the rivers and streams. Hydrogeologic cross-sections that include the elevation of the water table in wells and piezometers and surface water in streams will be prepared. The water level data will be evaluated in October 2009 in conjunction with gain-loss surveys conducted under Task 2.

Surface water quality data (e.g., pH, EC, temperature, and common ions) obtained during study sampling events (Task 2) will be compiled into a database and graphed by distance along the New Fork River channel, including data from tributaries and the Green River. Similar chemical characteristics from study wells completed near the river (Task 3) will also be plotted and compared to the surface water data. Common ion data also will be plotted (e.g., Piper and/or Stiff diagrams) to assess areas of differing water quality characteristics. These quality data will be used in conjunction with the water level and gain-loss survey information to evaluate surface water – groundwater interconnection.

4.4 TASK 4 – DETERMINE HYDRAULIC PROPERTIES FOR EACH HYDROSTRATIGRAPHIC UNIT

In addition to the proposed river corridor cluster wells described under Task 3, study wells will be completed in areas determined to have data gaps in the PAPA project area with respect to groundwater characteristics and aquifer sensitivity. Each of the study wells will be completed in one of the following HSUs: Mesa Gravel (where present); Shallow Wasatch Formation; and Regional Wasatch Formation.

Up to 30 study wells are expected to be completed in key target areas throughout the PAPA project area (along the anticline and in areas determined to be vulnerable to impacts from gas production activities or other sources). Some additional study wells will be completed as "background" wells in other areas of the PAPA.

Table 5 describes and **Figure 4** shows locations of the following nine target areas for completing study wells:

- Four target areas along the general anticline axis within the PAPA. It is expected that three or four wells would be completed in separate HSUs as a cluster in each of these areas. One of these target areas is located in a direction suspected to be upgradient from the Mesa Spring. Target areas on the Mesa would have four study wells completed in the Mesa Gravel HSU, Shallow Wasatch HSU, and two depths in the Regional Wasatch HSU. Target areas not on the Mesa would have three study wells completed in the Shallow Wasatch HSU and two depths in the Regional Wasatch HSU. Typical layout of these study wells in cross-section is shown on **Figure 5**.
- One target area in the Sand Springs Draw area which was specified as a highly sensitive aquifer area with respect to potential impacts to groundwater. Three study wells would be completed in this area in the Shallow Wasatch HSU and two depths in the Regional Wasatch HSU.
- One target area west of the main axis of the anticline area on the north side of the New Fork River. Three study wells would be completed in this area in the Shallow Wasatch HSU and two depths in the Regional Wasatch HSU. These wells would serve to monitor groundwater in a downgradient direction from where many of the production wells are located.
- Three target areas along the north and east sides of the PAPA for monitoring "background" conditions for groundwater. One area is in the northwest corner of the PAPA near where the Green River flows into the project area. Another target area is located near the confluence of the New Fork and East Fork rivers where the area was specified as a highly sensitive aquifer area. The third target area for background conditions is located in the southeast portion of PAPA near Antelope Spring.

Final locations, numbers, and depths of study wells described above will be determined after completion of the Credible Well Survey (described in a separate Plan of Study) and an evaluation of land access and obtaining landowner permission in these areas.

Study Well Construction

Study wells completed in the nine target areas shown on **Figure 4** will be installed using a rotary drill rig. It is assumed that the Operators will assist with obtaining the necessary permissions to access all sites for well construction and periodic monitoring activities. It is anticipated that the study wells will be completed in the following HSUs to the specified approximate depths:

- Mesa Gravel = 10 to 35 feet
- Shallow Wasatch Formation = 100 to 150 feet
- Regional Wasatch Formation = 250 to 350 feet
- Regional Wasatch Formation = 450 to 800 feet

Wells completed in Mesa Gravel will extend to the contact between the terrace gravel and underlying bedrock (Shallow Wasatch HSU). Wells completed in the Shallow and Regional Wasatch Formation HSU will be screened in individual zones of sandstone. The expected period of drilling and well completion is July through mid-September 2009.

Well completion will follow requirements specified in Wyoming Quality Rules and Regulations (WQR&R 2009) Chapter 11, Part G – Well Construction. These rules include specific recommendations for the design, construction, and installation of monitoring wells by DEQ/WQD. A schematic of typical well construction for the target area study wells is shown on **Figure 6**. Specific well construction methods will be the same as those described under Task 3 above. Well locations and elevations will be surveyed.

Pressure transducers and data-loggers will be installed in selected study wells to record long-term groundwater levels. It is expected that the transducers will be installed in about 12 study wells that represent the different HSUs across the PAPA. The transducers will be set to record water levels every six hours to help evaluate groundwater fluctuations over the monitoring period (approximately July through December 2009). For study wells without transducers, depth to water measurements would be conducted on a monthly basis.

Aquifer Testing

This section describes procedures to be used to conduct and analyze aquifer tests of study wells completed as part of this task. The actual number and type of aquifer tests performed will be determined after preliminary well yield information is obtained during well completion and development. Only selected wells that adequately represent the various HSUs throughout the PAPA will be subject to aquifer pumping tests. The aquifer testing would likely occur in August-September 2009.

Constant-discharge pumping tests will be performed in selected wells that have sufficient yield to allow pumping for a continuous rate of at least several gallons per minute (gal/min) for a minimum of eight hours. A submersible pump of appropriate size and pumping capacity will be placed in the well at least 10 feet beneath the water surface. Typically, a step-drawdown test will be conducted first to select the appropriate pumping rate (i.e., pump at gradually increasing rates for short time periods while monitoring drawdown).

At the onset of the pumping test and prior to installing the pump, the static water level in the pumping well and in any nearby observation wells will be measured. The pump apparatus will include a check valve, wiring, control box, discharge hose or piping, valve, flow meter, and generator. The water will be discharged at a sufficient distance from the well such that the water will not recharge the aquifer within the zone of influence during the test. If necessary, a discharge permit will be acquired from the DEQ. Water levels will be measured periodically

during the test for the pumping well and any nearby observation wells using a pressure-transducer and data logger.

The pumping rate will be selected to allow the water level to decline substantially in the well during the test, but not too rapidly that measurements cannot be obtained over a minimum period of eight hours. Some wells may be pumped for a greater period of time (e.g., 24 to 48 hours) in order to evaluate longer-term water yield and potential boundary conditions. After the pumping period is terminated, water levels in the pumping well and in any nearby observation wells will continue to be measured during recovery for several hours.

For wells that do not yield sufficient water for pumping, a slug test can be performed to estimate aquifer permeability. After measuring the initial static water level, a solid slug device would be lowered in a well several feet below the water table, which will immediately raise the water level. A pressure transducer and data-logger are used in the well to measure the rate of water level change.

Aquifer test results from pumping and slug tests will be analyzed using standard curve-matching and/or straight-line techniques. Specific analytical methods used to evaluate the test data will depend on the type of test, hydrogeologic conditions at the well site, and results of the aquifer test.

Groundwater Sampling and Analysis

All study wells will be sampled once in 2009 following completion. For wells that are subject to aquifer pumping tests, the samples will be collected during those tests in June-July 2009. Other wells will be sampled using a submersible pump, bailer, or bladder pump. Methods used to collect groundwater quality samples will be the same as those described under Task 3 above. All samples will be analyzed in the field immediately after collection for field water quality parameters (pH, EC, and temperature). Samples for laboratory analysis will be preserved after collection in accordance with analytical methods listed in **Table 6**. Samples will be shipped under chain-of-custody to the laboratory for analysis.

Data Analysis

Well completion logs for all study wells will be prepared and compiled. Hydrogeologic cross-sections using some of these wells, along with other existing wells, will be prepared to delineate HSUs across the PAPA.

Results of all aquifer testing will be compiled and evaluated to determine hydraulic properties (e.g., hydraulic conductivity, transmissivity, and storativity) of the individual HSUs. Boundary conditions, if evident from the test data, will be characterized. Existing information available to characterize hydraulic properties of the Fort Union Formation will be compiled; this

information will be compared to data determined for the other HSUs. Aquifer test results will be used to evaluate: discharge to springs and surface water; groundwater flow directions and velocities for each HSU; groundwater interaction among the HSUs; and vulnerability to surface releases of petroleum constituents.

Groundwater quality data obtained from study wells will be compiled into a database and grouped by HSU. Results will be compared to groundwater data from the river corridor wells to evaluate similarities and differences. The common ions data also will be plotted (e.g., Piper and/or Stiff diagrams) to assess areas of differing water quality characteristics.

4.5 TASK 5 – ESTABLISH DATA COLLECTION SYSTEM NEEDED TO GENERATE HYDROGRAPHS

For Tasks 2, 3, and 4 described above, a total of approximately 24 pressure transducers will be installed in study wells to monitor hydraulic head, and two transducers will be installed at locations along the New Fork River to monitor river stage. It is also possible that some existing credible/suitable production wells will be selected for monthly water level monitoring and/or installation of transducers, including artesian wells located near the New Fork River in the central part of PAPA.

A database will be prepared for all groundwater and surface water level data from which hydrographs will be developed. These hydrographs for study wells and stream gaging sites will be used to evaluate: seasonal variations versus long-term trends; changes in artesian pressures in the Regional Wasatch Formation HSU; differences and similarities between HSU groundwater levels and surface water elevations; and seasonal effects on groundwater flow directions and patterns.

4.6 TASK 6 – CHARACTERIZE MESA, ANTELOPE, AND PARADISE SPRINGS

For Mesa, Antelope, and Paradise springs (**Figure 3**), flow rate will be measured on a monthly basis. These sites will be examined to determine if a transducer and data-logger can be installed to reliably measure water level stage. This could occur if there is a location near the spring discharge point where the flow is confined to a narrow channel and the water depth is sufficient to all measurement with a transducer. If not, flow will be measured monthly using a portable flume or calibrated container with stop-watch.

Water quality samples from each of the spring sites will be collected for field parameters (pH, EC, and temperature) and inorganic constituents listed in **Table 4**. The samples will be collected twice in 2009: July and October. Sampling and analytical procedures will be similar to those described under Task 2 above.

All flow and water quality data collected from the springs will be compiled and evaluated to assist with the analysis of surface water – groundwater interconnection. The water quality data will be compared to nearby groundwater quality data, especially study wells completed on the Mesa, to assess possible source water for the springs. Common ion concentrations will be plotted using Piper and/or Stiff diagrams to assess overall water quality characteristics. Samples from the springs and some nearby wells also may be analyzed for stable isotopes (deuterium and oxygen-18) and radioisotopes (carbon-14, chorine-36, and/or tritium) to evaluate water source origin and age.

4.7 TASK 7 – INVESTIGATE HYDRAULIC CONNECTION BETWEEN EACH HYDROSTRATIGRAPHIC UNIT

The groundwater level data and hydrographs developed under Task 5 above will be used to investigate the hydraulic connection between each HSU. Vertical hydraulic gradients between different HSUs will be determined for well clusters that are completed along the rivers and along the axis of the anticline in the PAPA; these results will be shown graphically on project area maps. Hydrographs will be evaluated to assess similarities between the various HSUs.

Aquifer test data from Task 4 will be evaluated from the well clusters (i.e., study wells completed in different HSUs at single sites) to determine response in all monitored HSUs during each pumping test. When pumping from one HSU, responses in nearby well(s) that are completed in one or more other HSUs indicate that there is hydraulic connection between the units. Conversely, if no response is observed in nearby observation well(s), the HSU at that location probably is not hydraulically connected to other HSUs. The drawdown data measured in the pumping well and observation well(s), if any, can be evaluated using graphical methods to determine the type of connection.

Groundwater quality data from the study wells at PAPA will be evaluated to determine if differences can be discerned between the various HSUs. Statistical and graphical methods will be used to assist with this evaluation. Statistics can be used to group chemical concentrations of constituents separately for each HSU (e.g., mean, median, minimum, maximum, standard deviation). These results can be displayed graphically as well as summarized numerically. Other graphical methods, such as graphs, Stiff diagrams, and/or Piper plots will be used to determine if ion concentrations and types are different between the HSUs. The goal is to establish differences in water quality, if any, between the HSUs that would imply poor connection.

Finally, available hydraulic head and water quality data from injection wells completed in the Fort Union Formation will be added to the evaluation discussed above to evaluate the potential for hydraulic connection between the Fort Union Formation and the Regional Wasatch Formation and other HSUs at PAPA.

4.8 TASK 8 – REVISE HYDROGEOLOGIC CONCEPTUAL MODEL

Information obtained from Tasks 1 through 7 above will be used to refine the current hydrogeologic conceptual model (Geomatrix 2008b), including the following:

- Potentiometric surface for each HSU.
- Gain-loss characteristics of New Fork River.
- Surface water and groundwater interconnection.
- Hydraulic properties of HSUs.
- Characteristics of Mesa, Antelope, and Paradise springs.
- Temporal trends in groundwater and surface water quality.
- Temporal changes in groundwater levels and river stage/flow.
- Groundwater flow direction (horizontal and vertical) within and between HSUs.
- Relationships between domestic, stock, and Operator wells.

Geomatrix will review additional available information and data related to the hydrogeologic setting in the PAPA. Included in this effort will be an interview with Sublette County Planning and Zoning Office staff to obtain information germane to refining the hydrogeologic conceptual model of the PAPA. This could include information related to surface water, groundwater flow, wetlands, flood plain locations, and depth to Wasatch and Fort Union aquifers.

The conceptual model report will be complete with a discussion of the information listed above, as well as the hydrogeologic framework from which the initial conceptual model was developed. In order to ensure the utility of the numerical data with respect to GIS applications, all of the numerical data including all hydrologic and hydrogeologic data obtained from the surface water stations, study wells, and piezometers will be incorporated in the project database where the data are linked to their respective geospatial components. Geospatial analysis will be our decision support system for describing, explaining and predicting spatial relationships, patterns and phenomena of operator wells and groundwater interaction/flow within the PAPA. Additionally, geospatial analysis will be used to visualize, interpret and present both analytical data and geographic data that exist in the Project's GIS data model.

Our analysis techniques include but are not limited to hydrogeologic modeling, trend analysis, data classification, statistical analysis, raster math and feature dataset overlays. Map presentation includes but is not limited to GIS feature datasets, raster datasets and analytical data accompanied by pie charts, bar charts, schematics, diagrams, and graphs. Graphics will include figures showing potentiometric surfaces, hydrographs, study well locations, surface water study sites, hydrogeologic cross-sections, water quality graphs and plots, and gain-loss sections of flow for the New Fork River. The following information will be appended to the report: well completion and lithologic logs for study wells and piezometers; aquifer test data; stream/river flow measurements; water quality data (field and laboratory); GPS/survey data; and photographs.

The revised hydrogeologic conceptual model of the PAPA will be used to develop the draft final Groundwater/Aquifer Pollution Prevention, Mitigation and Monitoring Plan (see Geomatrix 2008a). In particular, selection of appropriate locations for long-term monitoring stations will be based on the revised model and the BDE's monitoring objectives. These monitoring locations will also be based on findings from the low level petroleum hydrocarbon investigation (see Geomatrix 2008a).

5.0 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 monitoring data for water resources, 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 3).

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.

5.1 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.

Quality control checks of field sampling procedures and laboratory analyses are performed using one or more of the following samples:

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 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 Trip Blank Sample: A field trip blank sample can be one of two types: (a) sample bottles are filled with deionized water and inserted into the normal set of water samples for analysis by the laboratory; or (b) sample bottles are filled with deionized water and the preservatives that are normally used with the natural water samples. Trip blank sample bottles are labeled in a way that does not reveal their status to the laboratory.

Field Equipment Blank Sample: A field equipment blank sample consists of deionized water run through decontaminated equipment to detect any residual contamination that may be remaining

on sampling equipment. The water is collected in one or more of the normal sample bottles and submitted for laboratory analysis. The field equipment blank sample bottles are labeled in a way 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.

Decontamination in the field is minimized by using disposable equipment and drawing samples directly from the water 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. The following pieces of equipment require decontamination: field water quality meters and probes; containers used for transferring samples (e.g. buckets); and non-disposable pumps, hose, pump tubing, or discharge line (tubing associated with the peristaltic pump is replaced for each sample). 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.

5.2 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

The 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. Both internal and external quality control programs are required to ensure production of analytical data of known quality and validity, and to provide water quality for inter-laboratory comparisons. 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 redigested 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 control for 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.

5.3 DATABASE AND REPORTING

Laboratories report analytical data in paper copy 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.

5.4 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). 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 1-4°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 <u>control samples</u> and <u>matrix spikes</u> are reviewed to verify that they are within acceptable limits (80–120% for laboratory control samples; 75–125% 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 of 20 percent. 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., stream flow, depth to water, pH, turbidity, 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.

In reporting the water resources monitoring program 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.

6.0 SCHEDULE

A master schedule for all PAPA-related environmental activities to be completed in 2009 is included in the "Project Administration Plan" (Geomatrix 2009c). The following tentative schedule is developed for the eight general tasks described in Section 4 for this Plan of Study:

Task 1 – Establish Contemporaneous Water Elevation Data

The field portion of this task (measure water levels in existing credible wells in the PAPA, and update surveys for well location and elevation, if necessary) will be conducted in mid-April 2009. Elevations of the New Fork River at several locations throughout the PAPA will also be measured at the same time. The new potentiometric maps for each HSU will be prepared in June 2009.

Task 2 – Determine Gain-Loss Characteristics of New Fork River

A gain-loss synoptic survey of flow along the main channel of New Fork River, including major tributaries, will be conducted during low flow conditions in early October 2009. Water quality samples also will be collected at the same time. The water quantity and quality data will be compiled by early November 2009.

Task 3 – Evaluate Surface Water – Groundwater Interconnection

The expected period of drilling and study well/piezometer completion is July to mid-September 2009 for the seven river transect locations. Transducers and temperature probes will be installed in selected wells in August 2009. Groundwater samples will be collected in September 2009. Water levels will be measured in all new study wells and piezometers and adjacent river stage on a monthly basis from July/September through December 2009. All of the water level, temperature, and water quality data will be compiled and evaluated by December 2009; this information will be used to assess surface water – groundwater interconnection in the PAPA.

Task 4 – Determine Hydraulic Properties for each Hydrostratigraphic Unit

The expected period of drilling and study well completion is July to mid-September 2009 for the approximately 30 new study wells. Transducers will be installed in selected wells in August/September 2009. Aquifer testing and groundwater sampling will occur in August-September 2009. Water levels will be measured in all new study wells on a monthly basis from June through December 2009. All of the water level, aquifer testing, and water quality data will be compiled and evaluated by December 2009. This information will be used to characterize the different HSUs at PAPA.

Task 5 – Establish Data Collection System Needed to Generate Hydrographs

A database will be prepared for all groundwater and surface water level data from which hydrographs will be developed by the end of December 2009. These hydrographs for new study wells and stream gaging sites will be used to characterize the hydrogeologic system at PAPA, including seasonal variations and differences and similarities between HSU groundwater levels and surface water elevations.

Task 6 – Characterize Mesa, Antelope, and Paradise Springs

Flow rate will be measured at the three spring sites on a monthly basis from July through October 2009. If deemed suitable, a pressure transducer and data-logger will be installed at one or more of the sites in July 2009. Water quality samples from each of the spring sites will be collected in July and October 2009. All flow and water quality data collected from the springs will be compiled and evaluated in November 2009 to assist with the analysis of surface water – groundwater interconnection.

Task 7 – Investigate Hydraulic Connection between each Hydrostratigraphic Unit

Hydrographs, vertical hydraulic gradients, and aquifer test results will be evaluated between different HSUs for well clusters to determine the hydraulic connection between the HSUs. Groundwater quality data from the new study wells at PAPA will be evaluated to determine if differences can be discerned between the various HSUs. These activities will be completed by December 2009.

Task 8 – Revise Hydrogeologic Conceptual Model

Information obtained from Tasks 1 through 7 above will be used to refine the current hydrogeologic conceptual model (Geomatrix 2008). The new conceptual model report will be prepared in November 2009-January 2010.

7.0 PERSONNEL

The following key personnel from Geomatrix will complete the eight tasks described in this Plan of Study for hydrogeologic data gaps:

- Doug Rogness (Helena) & K. Bill Clark (Missoula) – project study and task managers
- Steve Wright (Helena) & Adam Perine (Missoula) – field task managers
- Tom Hakonson & Carrie Hatch (Pinedale); Adam Johnson & Willy Welzenbach (Missoula) – field staff
- Kevin Van Hook (Houston) – Quality Assurance and Quality Control project officer

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.

8.0 REFERENCES

American Public Health Association, American Water Works Association, and Water Environment Federation (APHA et al.), 1992 (or most recent version). Standard Methods for the Examination of Waters and Wastewaters, 18th Edition. Washington D.C.

American Society for Testing and Materials (ASTM), 1996. Annual Book of ASTM Standards. Philadelphia, PA.

ASTM Standard D4448-01, 1985. Standard Guide for Sampling Groundwater Monitoring Wells.

Code of Federal Regulations (CFR), 1993. CFR 40 Part 136, Appendix B, pp 554-555. U.S. Government, Washington D.C.

Geomatrix, Inc. (Geomatrix or AMEC Geomatrix), 2008a. Final Interim Groundwater/Aquifer Pollution Prevention, Mitigation, and Monitoring Plan. 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, Shell Rocky Mountain Production, Questar Market Resources, and Ultra Resources, Inc. December.

Geomatrix, 2008b. Final Hydrogeologic Conceptual Model, Pinedale Anticline Project Area, Sublette County, Wyoming. March.

Geomatrix, 2009a. Draft Plan of Study for the Monitoring Program Augmentation. Interim Plan, PAPA ROD, Pinedale Anticline Oil and Gas Exploration and Development Project, Sublette County, Wyoming.

Geomatrix, 2009b. Draft Plan of Study for Credible Well Identification. Interim Plan, PAPA ROD, Pinedale Anticline Oil and Gas Exploration and Development Project, Sublette County, Wyoming.

Geomatrix, 2009c. Draft Project Administration Plan. Interim Groundwater/Aquifer Pollution Prevention, Mitigation and Monitoring Plan, Pinedale Anticline Oil and Gas Exploration and Development Project, Sublette County, Wyoming.

HydroGeo, Inc., 2004. Groundwater Monitoring Protocol Manual, Pinedale Anticline Project. October 2004.

Martin, L. J., 1996. Geohydrology of Tertiary Rocks in the Green River Structural Basin in Wyoming, Utah, and Colorado. U.S. Geological Survey (USGS) Water Resources Investigation Report 92-4164.

Sublette County Conservation District (SCCD), 2008. Summary of Pinedale Chemical and Field Data 2000-2008. September 10, 2008.

U.S. Department of Interior, Bureau of Land Management (BLM), 2008. Record of Decision for the Supplemental Environmental Impact Statement for the Pinedale Anticline Oil and Gas Exploration and Development Project, Sublette County, Wyoming. September 12.

U.S. Environmental Protection Agency (EPA), 2006. Data Quality Assessment: Statistical Methods for Practitioners. EPA QA/G-9S. EPA/240/B-06/003. February 2006.

EPA, 2004a. Draft Final, EPA Contract Laboratory Program National Functional Guidelines for Inorganic Data Review. OSWER 9240.1-45, EPA 540-R-04-004. July 2004.

EPA, 2004b. Draft, EPA Contract Laboratory Program National Functional Guidelines for Superfund Organic Methods Data Review. OSWER 9240.1-44, EPA 540-R-04-001. June 2004.

EPA, 2002. Guidance on Environmental Data Verification and Data Validation. EPA QA/G-8. EPA/240/R-02/004. November 2002.

U.S. Geological Survey (USGS), 2009. USGS Surface-Water Monthly Statistics for Wyoming. http://waterdata.usgs.gov/wy/nwis.

Western Regional Climate Center, 2007. Climate Summary for Pinedale, Wyoming. Accessed online at: http://www.wrcc.dri.edu/summary/Climsmwy.html.

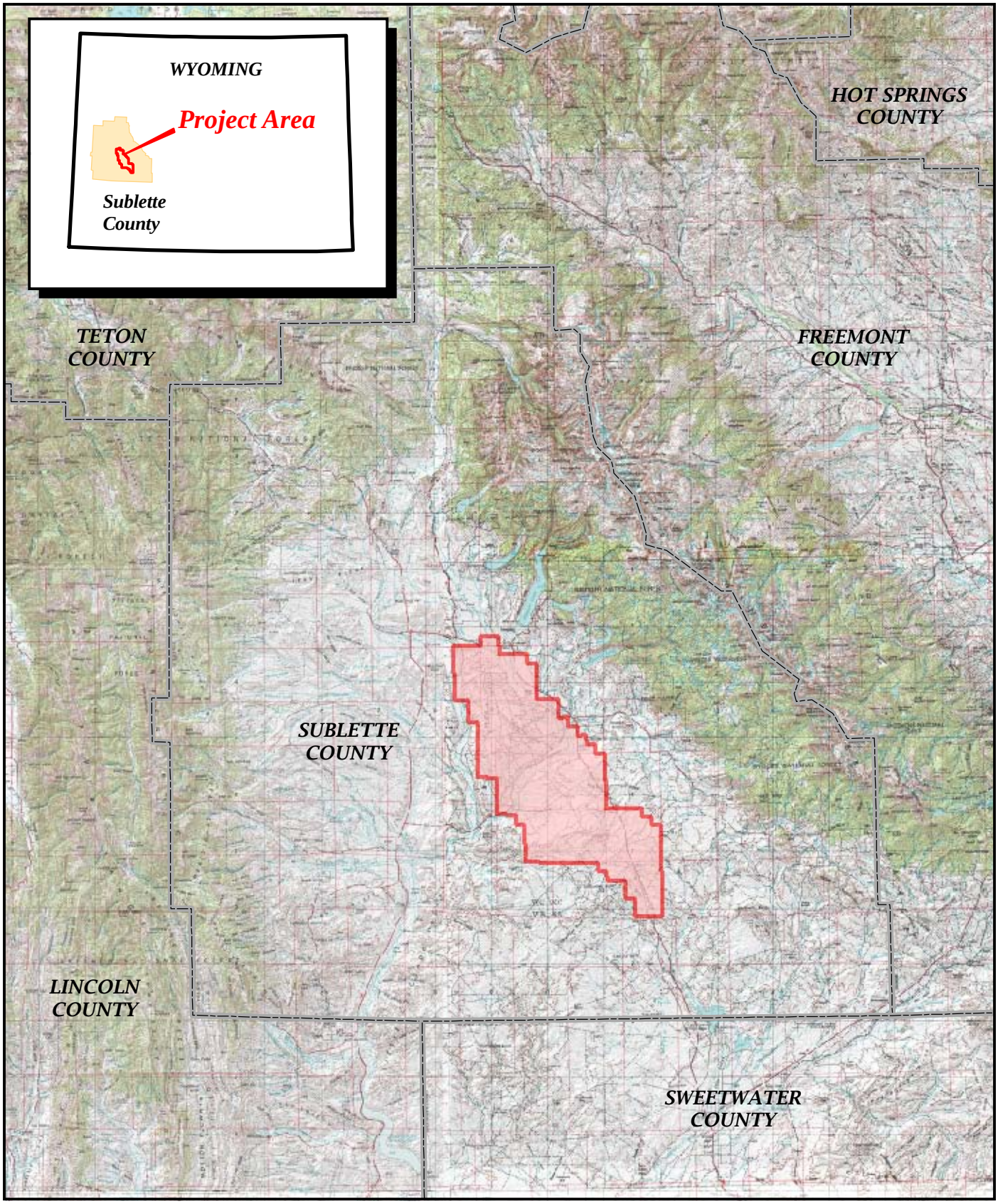
Wyoming Climate Atlas, 2004. Wyoming State Climate Office, University of Wyoming. Accessed online at: http://www.wrds.uwyo.edu/sco/climate/wyoclimate.html.

Wyoming Department of Environmental Quality (DEQ), 2006. Letter from J.F. Wagner to Shell Rock Mountain Production, Pinedale, Wyoming. October 27.

Wyoming Quality Rules and Regulations (WQR&R), 2009. Chapter 11, Part G – Well Construction.

APPENDIX A

FIGURES



H:\13655 Pinedale Anticline\5000 GIS\Loc.mxd

Source: 250K WYGISC, BLM

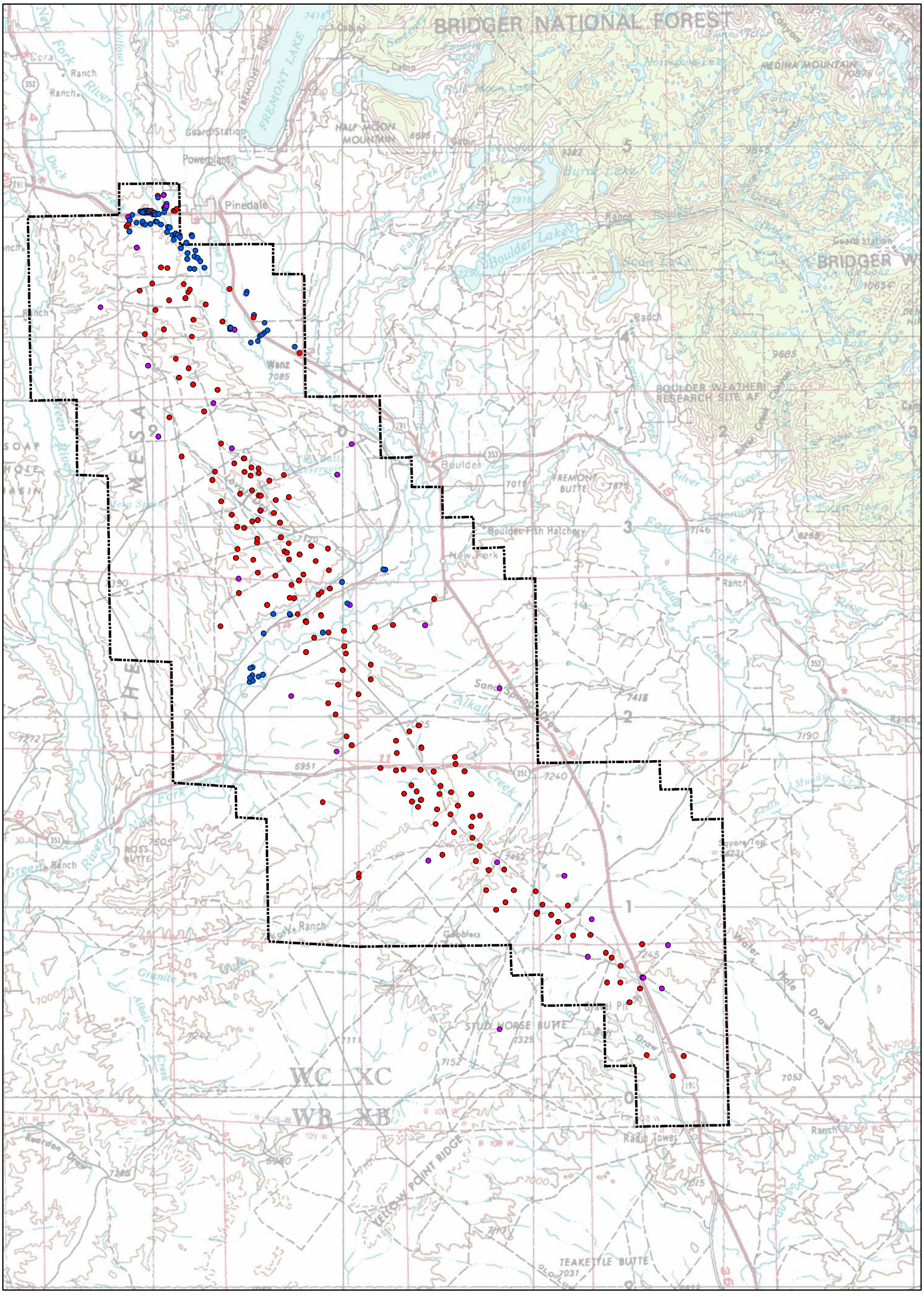
N

0 15
Miles

Project Area

AMEC Geomatrix

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



Source: 100K WYGISC, BLM

Miles
0 1.5 3

AMEC Geomatrix

Note: Wells shown are those that have coordinate information.

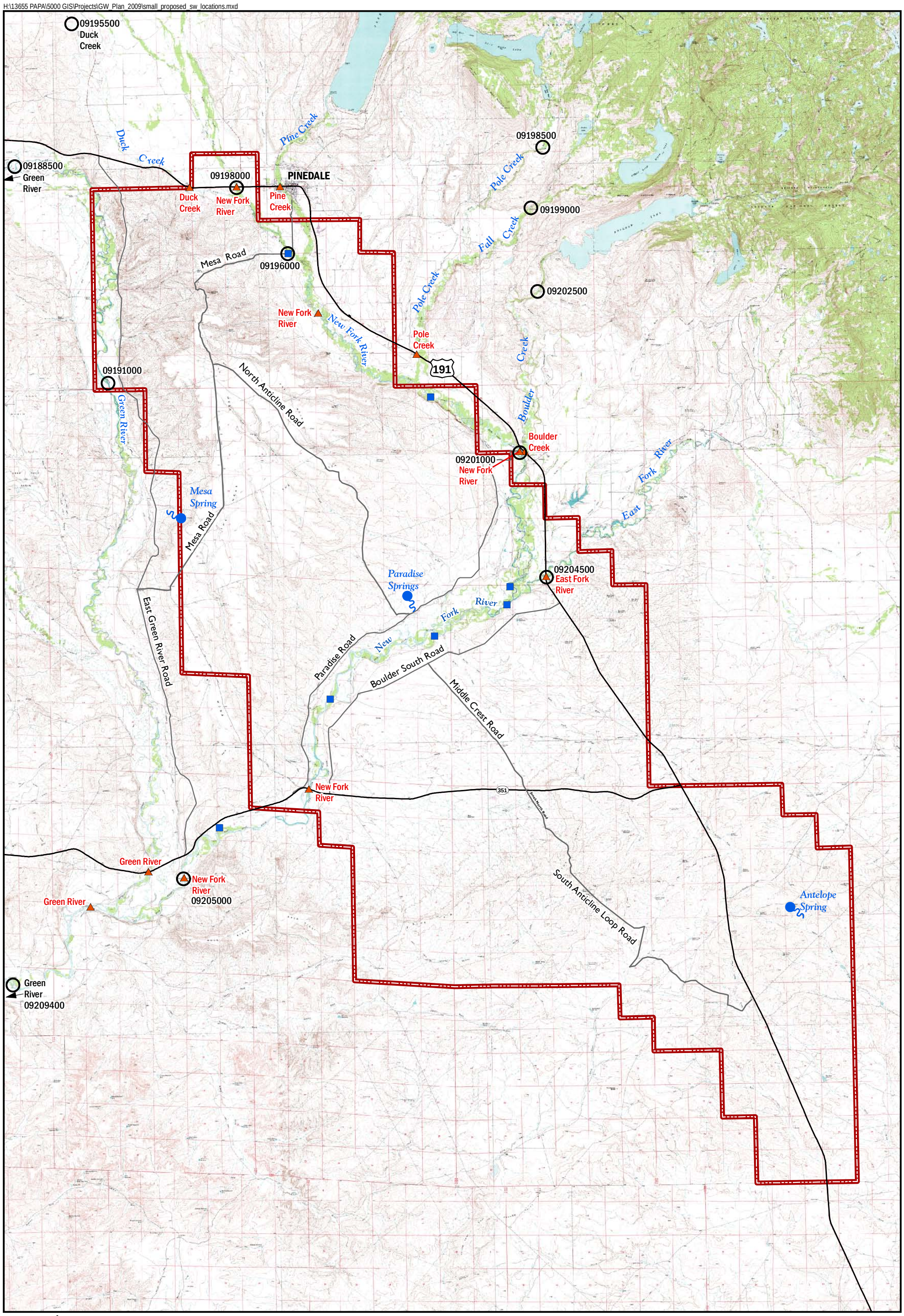
Project Area

Well Type

- Domestic Well
- Industrial Well
- Stock Well

Existing Wells Monitored by SCCD
Hydrogeologic Data Gaps Plan of Study
Pinedale Anticline Project Area
Sublette County, Wyoming
FIGURE 2

H:\13655 PAPA\5000 GIS\Projects\GW_Plan_2009\small_proposed_sw_locations.mxd



N

0 3
Miles

AMEC Geomatrix

Proposed Surface Water Study Locations ("Primary")

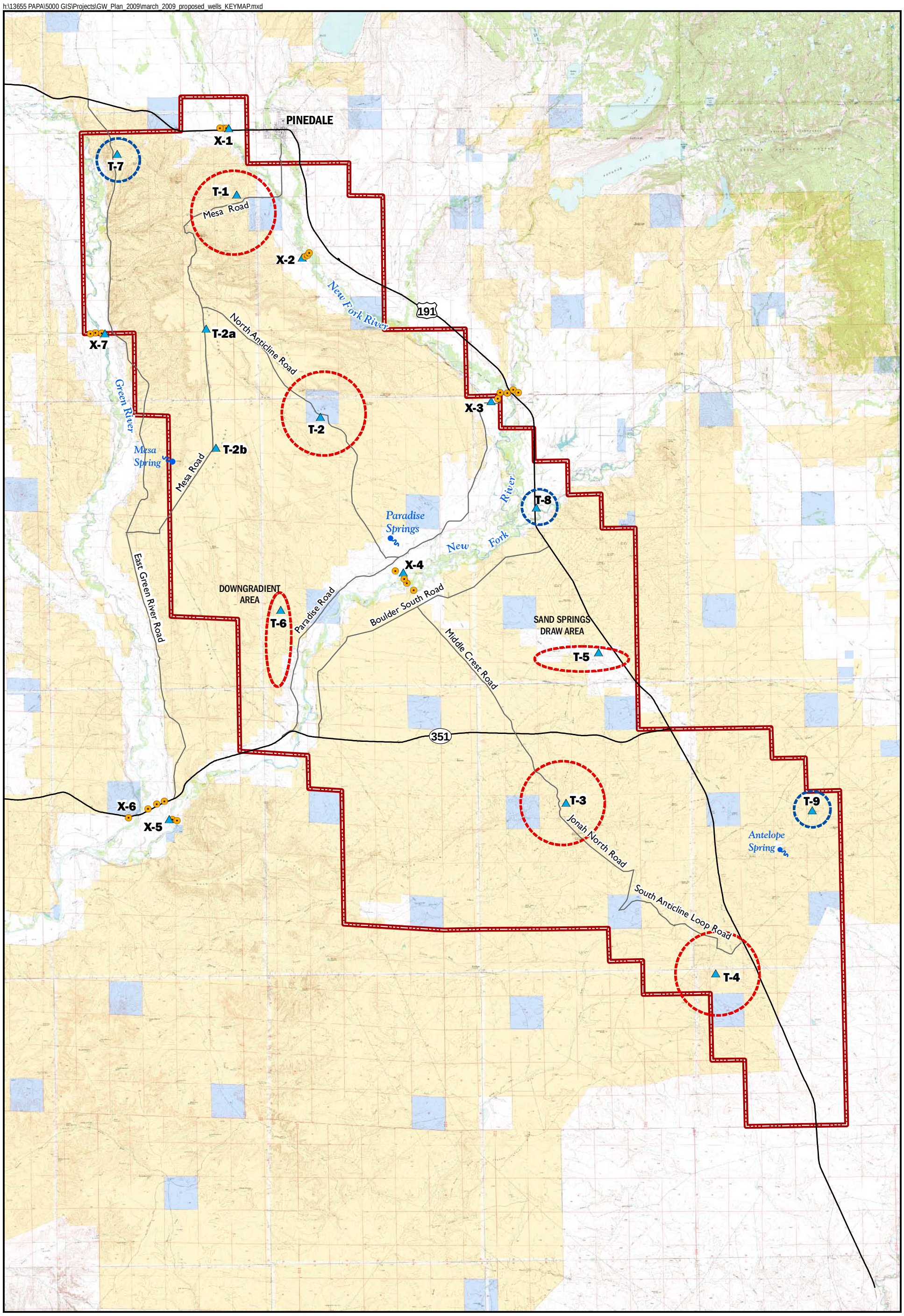
Existing Surface Water Study Locations ("Secondary")

Pinedale Anticline Project Area

Note: Circled locations are current or former U.S. Geological Survey gaging stations, with station number.

Proposed Surface Water Study Locations
Pinedale Anticline Project Area
Sublette County, Wyoming
FIGURE 3

h:\13655 PAPA\5000 GIS\Projects\GW_Plan_2009\march_2009_proposed_wells_KEYMAP.mxd



N

0 Miles 3

AMEC Geomatrix

Area of Study Wells Along Anticline or High Aquifer Sensitivity

Area of Background Study Wells

T-1 Study Area Designation

Pinedale Anticline Project Area

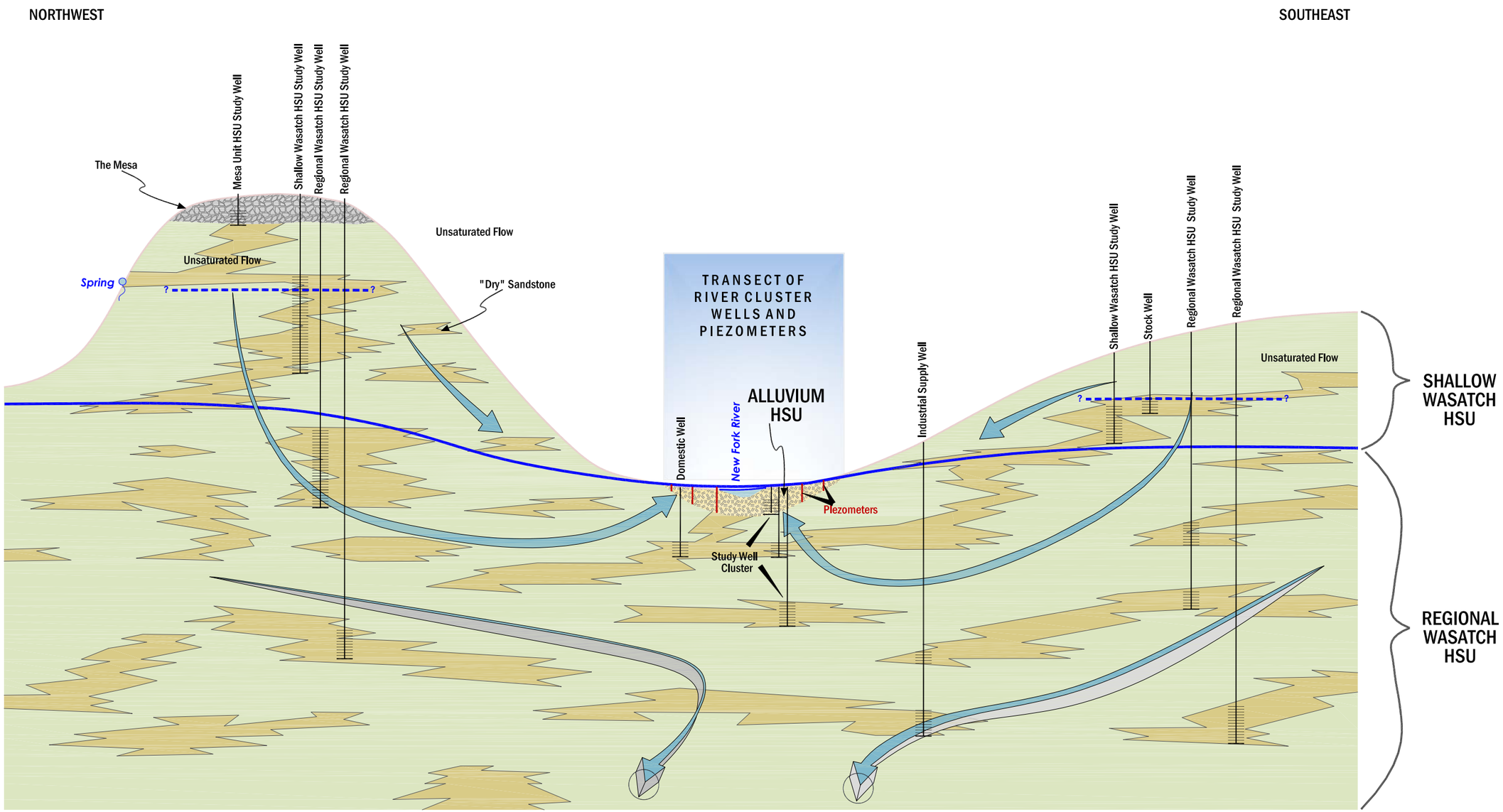
Bureau of Land Management

State

Proposed Well Cluster

Proposed Piezometer

Proposed Study Well and Piezometer Locations
Pinedale Anticline Project Area
Sublette County, Wyoming
FIGURE 4



H:\13655 PAPA\Cadpro\ConceptualDesign.dwg

Not To Scale

Geologic Units
- Gravel
- Sand & Gravel
- Sandstone
- Shale, Mudstone

Stock Well

Well and Perforated Zone

Shallow Wasatch HSU Potentiometric Surface

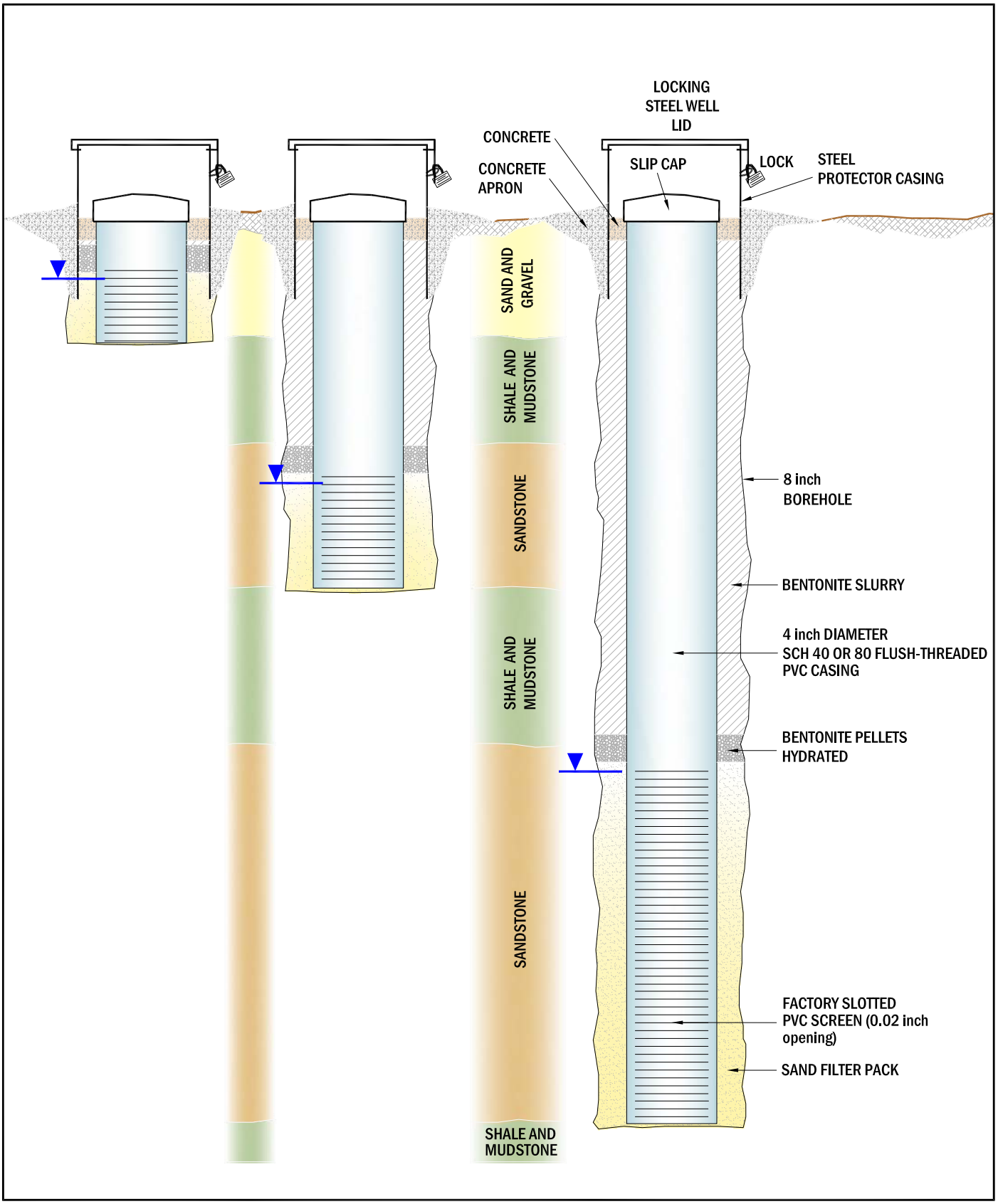
Regional Wasatch HSU Potentiometric Surface

Note: HSU = Hydrostratigraphic Unit

Regional Wasatch Flow Path
Groundwater flow to the Southwest, out of paper

AMEC Geomatrix 13655

Study Well Conceptual Diagram
Hydrostratigraphic Units
Pinedale Anticline Project Area
Sublette County, Wyoming
FIGURE 5



H:\13655 PAPA\Cadpro\well_cluster_schematic.dwg

Not To Scale

AMEC Geomatrix

13655

Cluster Study Well Completion Schematic
Pinedale Anticline Project Area
Sublette County, Wyoming
FIGURE 6

APPENDIX B

TABLES

TABLE 1
Summary of Monthly Climate Data for Pinedale, Wyoming (1948 – 2007)
Interim Plan for PAPA ROD

Measured Parameter	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
Average Total Precipitation (inches)	0.6	0.5	0.6	0.9	1.6	1.2	1	1	1.1	0.8	0.7	0.7	10.82
Average Total Snowfall (inches)	12	9.5	8.2	6	2.4	0.3	0	0	0.7	2.6	9	11	61
Average Snow Depth (inches)	8	9	6	1	0	0	0	0	0	0	2	5	3

Source: Western Regional Climate Center 2007.

TABLE 2
Mean Monthly Stream Discharge at USGS Gaging Stations
Interim Plan for PAPA ROD

USGS Gaging Stn.	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Period of Record
Duck Creek at Cora (09195500)	6.2	5.9	6.2	6.1	5.5	5.9	7.3	7.0	7.6	8.3	7.9	6.7	1938 – 1941
New Fork River near Pinedale (09196000)	23	24	44	93	63	203	176	46	31	48	40	31	1938 – 1944
Pine Creek at Pinedale (09198000)	26	25	26	33	152	611	455	135	56	35	29	28	1904 – 1954
Pole Creek below Half Moon Lake (09198500)	17	17	16	33	260	540	262	71	29	26	20	18	1938 – 1971
Pole Creek at Fayette (Fall Ck) (09199000)	10	10	15	39	288	648	339	125	115	24	12	10	1904 – 1906
New Fork River near Boulder (09201000)	106	108	121	243	578	1580	1010	337	175	167	148	119	1914 – 1969
Boulder Creek near Boulder (09202500)	22	23	24	38	316	1060	355	39	19	22	24	22	1903 – 1932
East Fork River at New Fork (09204500)	40	41	48	83	447	941	188	64	54	58	51	44	1904 – 1932
New Fork River near Big Piney (09205000)	200	209	273	426	1150	2870	1560	558	365	368	319	238	1954 – 2008
Green River at Warren Bridge near Daniel (09188500)	109	109	125	288	1010	1760	1240	523	297	198	145	123	1931 – 2008
Green River near La Barge (09209400)	454	482	719	1350	2750	5400	3230	1360	837	796	717	518	1963 – 2008

Note: Flow rates are in cubic feet per second (ft^3/sec). USGS = U.S. Geological Survey.
New Fork River stations are shaded.
Source: USGS 2009

TABLE 3
Precision, Accuracy, and Completeness Goals
Interim Plan for PAPA ROD

Measurement Parameter	Precision	Accuracy	Completeness
Well and Surface Water Locations[1] (UTM, NAD 83, 12North)	Survey-Grade GPS Instruments	Survey-Grade GPS Instruments	95%
Well and Surface Water Elevations[1] (NAVGD 1988)	Survey-Grade GPS Instruments	Survey-Grade GPS Instruments	95%
Water Level Measurements (electric probes, hand tapes, staff gages)	± 10%	0.01 foot	90%
Water Level Measurements (pressure transducers)	± 10% (check periodically with electric probe)	0.001 foot	90%
Surface Water Flow Measurements (current meters)	± 20% (check periodically with bucket & watch in small confined channels)	0.01-0.1 ft^3/sec (depends on total flow)	90%
Aquifer Test Discharge (in-line flow meter, flume, or calibrated container and watch)	± 10%	0.001-0.01 ft^3/sec (depends on total flow)	100%
Spring Discharge (flume or calibrated container and watch)	± 10%	0.001-0.01 ft^3/sec (depends on total flow)	90%
Field Water Quality Parameters (pH, temperature, specific conductance)	± 20% (compare to lab data)	Variable (depends on parameter)	90%
Laboratory Analysis (inorganic common ions)	±20% RPD [2]	80 – 120% [3] 75 – 125% [3]	95% [4]
Laboratory Analysis (petroleum hydrocarbon compounds)	±20% RPD [2]	80 – 120% [3] 75 – 125% [3]	95% [4]

Note:
[1] Plan of Study for Monitoring Program Augmentation (Geomatrix 2009a)
[2] Refer to Section 3.4; RPD = relative percent difference.
[3] Refer to Section 3.5
[4] Refer to Section 3.6

TABLE 4
Surface Water Quality Parameters for Laboratory Analysis
Interim Plan for PAPA ROD

Parameter	Analytical Method[1]	Laboratory Reporting Limit[2]	Preservation Method	Holding Time	Container Type & Size[3]
Calcium	200.7	0.5 mg/l	Nitric acid & Cool 4°C	6 months	P – 250 ml (dissolved using 0.45 micron filter)
Magnesium		0.5 mg/l			
Potassium		1.0 mg/l			
Sodium		1.0 mg/l			
Chloride	300.0	1.0 mg/l	Cool 4°C	28 days	P – 250 ml (dissolved using 0.45 micron filter)
Fluoride		0.1 mg/l			
Sulfate		5.0 mg/l			
Alkalinity, total	2320B	1.0 mg/l			
Sodium Adsorption Ratio	20b	0.2 unitless		Calculation	Calculation
Electrical Conductivity	2510B	10 µmhos/cm		28 days	P – 250 ml (unfiltered)
pH	4500-H+-B	0.1 – 13.5 s.u.		24 hours	
Total Dissolved Solids	2540C	20 mg/l		7 days	
Total Suspended Solids	2540D	1 mg/l		7 days	P – 1000 ml (unfiltered)

Note:

[1] Analytical methods are U.S. Environmental Protection Agency specified methods.

[2] Laboratory reporting limits (method detection limit or practical quantitation limit), at a minimum. mg/l = milligrams per liter; µmhos/cm = micromhos per centimeter; s.u. = standard units.

[3] P = plastic; ml = milliliters.

TABLE 5
PROPOSED STUDY WELL AND PIEZOMETER LOCATIONS
Hydrogeologic Data Gaps Study – Interim Plan for PAPA ROD

Drilling Locations	Map Coordinates (Northing / Easting)	Legal Location	Land Owner & Permittee	Nearby Water Supply Well, including Depth & Screened Interval	Planned New Study Wells	Notes
Anticline Axis Target Areas						
T-1	4743512.760 590898.836	SE¼ Sec 8, T33N, R109W	BLM – ULTRA Drill Pad	Sherlock Federal 15-8; AMI-016; GS=7200; TD=670; Perf=290-670; DTW=80.	1 Mesa gravel well (30 ft); 2 bedrock wells (150 & 650 ft)	Access drill pad along Mesa Road from Pinedale; Ultra Drill Pad where water supply well is plugged and abandoned.
T-2	4732746.524 595049.292	SW¼ Sec 16, T32N, R109W	State Section – QUESTAR Pad	Mesa 15-16; AMI-119; GS=7470; TD=1000; Perf=700-1000; DTW=428.	1 Mesa gravel well (30 ft): 2 bedrock wells (250 & 800 ft)	Access drill pad long North Anticline Road in State Section.
T-2a	4737059.267 589429.713	SE¼ Sec 31, T33N, R109W	BLM – QUESTAR permittee	No nearby wells	1 Mesa gravel well (30 ft)	Along Mesa Road approximately ½-mile south of intersection with North Anticline Road.
T-2b	4731326.942 589891.270	SW¼ Sec 24, T32N, R110W	BLM – SHELL permittee	No nearby wells	1 Mesa gravel well (30 ft)	Along Mesa Road approximately 1 mile east of Mesa Spring.
T-3	4714223.549 606753.518	SW¼ Sec 15, T30N, R108W	BLM – ULTRA Drill Pad	Warbonnet 7-15D; AMI-237; GS=7400; TD=750; Perf=590-750; DTW=393	2 bedrock wells (300-400 ft & 750 ft)	Access drill pad along Middle Crest Road approx. 2 miles south of Highway 351.
T-4	4706007.902 613956.328	NW¼ Sec 9, T29N, R107W	BLM – YATES Drill Pad	Highway #7; AMI-182; GS=7300; TD=610; Perf=490-610; DTW=291	2 bedrock wells (250 & 600 ft)	Access drill pad along South Anticline Loop Road approx. ½-mile south of South Anticline Road and 1 mile west of Highway 191.
Sand Springs Draw Area						
T-5	4721473.563 608317.828	SE¼ Sec 23, T31N, R108W	Quarter Circle Five (Leslie Schwabacher) ULTRA permittee	Stock Well; ASO-50; GS=7120; TD=unknown	1 bedrock well (600 ft)	Near existing stock well sampled by SCCD approx. ½-mile west of Highway 191 in Sand Springs Draw. Access site on existing two-track road.
Downgradient Target Area						
T-6	4723518.565 593017.805	SW¼ Sec 17, T31N, R109W	BLM- ULTRA permittee	No nearby wells; GS=7000; downgradient area	2 bedrock wells (200 & 500 ft)	Approx. ½-mile west of Paradise Road; access from Paradise Road at State Section 16, or south from The Mesa Road starting near the intersection of Paradise Road and Highway 351. Access site on existing two-track road.
Background Target Areas						
T-7	4745477.180 585150.765	SW¼ Sec 2, T33N, R110W	BLM – Permittee unknown QUESTAR has nearest leased land	No nearby wells; GS=7300; upgradient area near Green River	2 bedrock wells (200 & 500 ft)	Approx. ¼-mile east of East Green River Road. Access site on existing two-track road.
T-8	4728457.917 605321.991	NW¼ Sec 34, T32N, R108W	Circle Nine Ranch (Phelps Swift Jr.) Permittee unknown ULTRA has nearest leased land	No nearby wells; GS=6930; upgradient area near East Fork River	1 alluvial well (50 ft); 1 bedrock well (250 ft)	Along east side of Highway 191 at turn-out just north of East Fork River bridge.
T-9	4713854.778 618603.049	SW¼ Sec 13, T30N, R107W	BLM – YATES permittee	Stock well (USGS) Square Top Well #1; GS=7300; TD=250; DTW=65.	1 bedrock well (800 ft)	East of Highway 191, then east along Speedway Road, and then access stock well site on existing two-track road.
New Fork River Sections						
X-1	4746708.969 590095.466 & 4746699.307 590278.057	SW¼ Sec 32, T34N, R109W	Donald Whitaker – SHELL permittee	Crosswinds #1; AMI-047; GS=7150; TD=90; DTW=5.	2 piezometers	Piezometers along North side of Highway 191 bridge; west side of New Fork River.
	4746705.301 590394.919 & 4746710.405 590513.738				1 piezometer; 1 alluvial well (40 ft); 1 bedrock well (200 ft)	Well cluster and piezometer along North side of Highway 191 bridge; east side of New Fork River.

Drilling Locations	Map Coordinates (Northing / Easting)	Legal Location	Land Owner & Permittee	Nearby Water Supply Well, including Depth & Screened Interval	Planned New Study Wells	Notes
X-2	4740481.983 594054.192 & 4740516.756 594195.114	SE¼ Sec 22, T33N, R109W	Mocroft family partnership – QUESTAR has nearest leased land	Mocroft alluvial well; AS016; TD 35 ft; GS=7080	1 piezometer; 1 alluvial well (40 ft); 1 bedrock well (200 ft)	Well cluster and piezometer along private road and bridge crossing river; west side of New Fork River. Existing Mocroft alluvial well (AS016)in this area.
	4740595.255 594314.153 & 4740709.551 594387.906			No neaby wells; GS=7080	2 piezometers	Piezometers along private road and bridge crossing river; east side of New Fork River.
X-3 (Boulder Creek & New Fork River)	4734101.054 604207.961	SE¼-SW¼ Sec 9, T32N, R108W	Swift Revocable Trust – Sara Swift (outside PAPA boundary) – SHELL has nearest leased land	GS=6970	1 or 2 piezometers	Piezometer(s) on west side of lower Boulder Creek; access land from old Highway 191 bridge; go under current highway bridge.
	4733973.249 604448.534			GS=6970	1 or 2 piezometers	Piezometer(s) on east side of lower Boulder Creek; access land from old Highway 191 bridge; go under current highway bridge.
	4733940.268 603917.469 & 4733973.242 603576.457	SW¼ Sec 9, T32N, R108W		GS=6965	2 piezometers	Piezometers along Paradise Road just west of Highway 191; sites are along north side of Paradise Road on west side of New Fork River.
	No drilling here	NW¼ Sec 16, T32N, R108W	Lazy River Ranch – Permittee unknown	None	None	Need to cross this land to get to Sec 9 Boulder Creek piezometers; no drilling on this section.
	4733666.365 603472.948 & 4733559.751 603140.420	NE¼ Sec 17, T32N, R108W	Circle Nine Ranch (Phelps Swift) – Anshutz permittee. SHELL has nearest leased land	No nearby wells; GS=6970	1 piezometer; 1 alluvial well (40 ft); 1 bedrock well (200 ft)	Well cluster and piezometer along north side of Paradise Road, west side of New Fork River.
X-4	4724460.505 599414.528	SW¼ Sec. 12, T31N, R109W	BLM – ULTRA permittee	Riverside 13-12; GS=6920; TD=450; Perf=250-450; artesian.	1 piezometer	Piezometer on south side of New Fork River; access from Boulder South Road. Avoid buried pipelines.
	4724795.262 599086.614			Vible 1-11D; GS=6900; TD=460; Perf=300-440; artesian.	1 piezometer	Piezometer on north side of New Fork River; access from Paradise Road. Avoid buried pipelines.
	4725001.639 598965.346	SE¼ Sec 11, T31N, R109W	BLM – ULTRA permittee	Vible 1-11D; GS=6900; TD=460; Perf=300-440; artesian.	1 piezometer	Piezometer on north side of New Fork River; access from Paradise Road. Avoid buried pipelines.
	4725379.156 598535.082	NE¼ Sec 11, T31N, R109W	John & Amy Scott – SHELL permittee	Vible 1-11D; GS=6900; TD=460; Perf=300-440; artesian.	1 piezometer	Piezometer on north side of New Fork River; access from Paradise Road. Avoid buried pipelines.
	4725316.416 598912.292				1 alluvial well (40 ft); 2 bedrock wells (200 & 450 ft)	Well cluster on north side of New Fork River on drill pad. Avoid buried pipelines. This Shell drill pad is very active – may be difficult to work around other structures and activities.
X-5	4713450.544 587655.250 & 4713426.033 587804.435	NE¼ Sec 22, T30N, R110W	Anne & Peter Olson (outside PAPA boundary) – SHELL has nearby leased land	No nearby wells; GS=6805	1 piezometer; 1 alluvial well (40 ft); 1 bedrock well (200 ft)	Well cluster and piezometer along County road on west side of New Fork River/bridge at USGS gaging site.
	4713369.516 588020.610	NW¼ Sec 23, T30N, R110W	Wyoming 3 Bar (outside PAPA boundary) – SHELL has nearby leased land	No nearby wells; GS=6805	1 or 2 piezometers	Piezometer(s) along County Road on east side of New Fork River/bridge at USGS gaging site.

Drilling Locations	Map Coordinates (Northing / Easting)	Legal Location	Land Owner & Permittee	Nearby Water Supply Well, including Depth & Screened Interval	Planned New Study Wells	Notes
Green River Sections						
X-6	4714306.309 587412.779	SW¼ Sec 15, T30N, R110W	Wesley & William Miller (outside PAPA boundary) – SHELL has nearby leased land	No nearby wells; GS=6815	1 piezometer	Piezometer along north side of Highway 351 on east side of Green River.
	4714163.681 587049.076 & 4713934.773 586627.636	SE¼ Sec 15, T30N, R110W			2 piezometers	Piezometers along north side of Highway 351 on east side of Green River.
	4713497.369 585685.529	NE¼ Sec 21, T30N, R110W	Milford & Jeannie Lockwood (outside PAPA boundary) – SHELL has nearby leased land	No nearby wells; GS=6810	1 piezometer	Piezometer along south side of Highway 351 on west side of Green River.
X-7	4736840.851 584551.588 & 4736834.339 584395.969	SW¼ Sec 4, T32N, R110W	Sommers Ranch Partnership – ULTRA permittee ?	No nearby wells; GS=6940	1 piezometer; 1 alluvial well (50 ft); 1 bedrock well (200 ft)	Well cluster and piezometer along private road and bridge that is public access to fishing/boat site; east side of Green River; stay on south side of road.
	4736837.871 584093.502 & 4736809.950 583845.343	SE¼ Sec 5, T32N, R110W		No nearby wells; GS=6940	2 piezometers	Piezometers along private road and bridge that is public access to fishing/boat site; west side of Green River; stay on south side of road.

Note: Map coordinates are UTM, Zone 12N, NAD 83. Many of the locations are based on map points, rather than field points, and therefore represent approximate drill sites. Target depth elevation for new deep study wells = 6500-6600 ft.
T = Target location; X = River valley cross section location; GS = Ground surface elevation, feet (approximate); TD = Total depth, feet; DTW = Depth to water, feet; Perf = Perforated interval.

TABLE 6
Groundwater Quality Parameters for Laboratory Analysis
Interim Plan for PAPA ROD

Parameter[1]	Analytical Method[2]	Laboratory Reporting Limit[3]	Preservation Method	Holding Time	Container Type & Size[4]
Inorganic Constituents					
Calcium	200.7	0.5 mg/l	Nitric acid & Cool 4°C	6 months	P – 250 ml (dissolved using 0.45 micron filter)
Magnesium		0.5 mg/l			
Potassium		1.0 mg/l			
Sodium		1.0 mg/l			
Chloride	300.0	1.0 mg/l	Cool 4°C	28 days	P – 250 ml (dissolved using 0.45 micron filter)
Fluoride		0.1 mg/l			
Sulfate		5.0 mg/l			
Alkalinity, total	2320B	1.0 mg/l			
Sodium Adsorption Ratio	20b	0.2 unitless		Calculation	Calculation
Electrical Conductivity	2510B	10 µmhos/cm		28 days	P – 250 ml (unfiltered)
pH	4500-H+-B	0.1 – 13.5 s.u.		24 hours	
Total Dissolved Solids	2540C	20 mg/l		7 days	
Volatile Organic Compounds					
Benzene	5030B / 8021B	0.5 µg/l	Hydrochloric acid & Cool 4°C	14 days	2 VOA vials – 40 ml
Toluene		0.5 µg/l			
Ethylbenzene		0.5 µg/l			
Total Xylenes		1.5 µg/l			
Petroleum Hydrocarbons					
TPH-DRO	5030B / 8015B	1.0 mg/l	Hydrochloric acid & Cool 4°C	14 days	Amber glass – 1000 ml
TPH-GRO		0.2 mg/l			2 VOA vials – 40 ml

Note:

[1] TPH = total petroleum hydrocarbons; DRO = diesel range organics; GRO = gasoline range organics.

[2] Analytical methods generally are U.S. Environmental Protection Agency (EPA) specified methods.

[3] Laboratory reporting limits (method detection limit or practical quantitation limit), at a minimum. mg/l = milligrams per liter; µmhos/cm = micromhos per centimeter; s.u. = standard units; µg/l = micrograms per liter.

[4] Container type is abbreviated as: P = plastic; VOA vials = glass; ml = milliliters.

APPENDIX C

STANDARD OPERATING PROCEDURES

SOP	TITLE
1	AMEC Geomatrix Field Forms
2	Equipment Decontamination
3	Monitoring Well Construction
4	Monitoring Well Development
5	Field Measurement of Ground Water Level
6	Field Measurement of Electric or Specific Conductance (EC/SC)
7	Field Measurement of pH
8	Field Measurement of Dissolved Oxygen
9	Field Measurement of Redox Potential
10	Field Sample Filtration
11	Groundwater Sampling
12	Surface Water Sampling
13	Stream Flow Sampling: Wading Technique
14	Quality Control Samples
15	Sample Documentation
16	Sample Packaging and Shipping
17	Field Measurement of Volatile Organic Compounds Headspace
18	Sample Chain-of-Custody Procedures
19	GPS Surveying
20	Groundwater Sampling in Well with Potential Explosive Gas Levels
21	Management of Investigation-Derived Waste
22	Surveying

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. No general rules can specify the extent of information that must be entered on the field form. However, 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.
- Preservative added to samples.
- 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 nondedicated 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. Change gloves between every sample. 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

MONITORING WELL CONSTRUCTION

SOP-3

1. Arrive on-site with the appropriate drilling equipment and materials for site conditions. The driller shall properly decontaminate all drilling equipment and materials prior to arrival on-site. Decontamination usually includes steam or hot water cleaning methods.

2. Drilling muds or drilling solutions of any kind are not to be used during drilling activities in conjunction with monitoring well construction. Acceptable drilling techniques include air-rotary, cable tool, and hollow-stem auger. If unconsolidated material is encountered, it may be necessary to drive steel casing during drilling to maintain borehole integrity. It is suggested threaded steel casing be used in lieu of welding joints together to minimize this source of potential well contamination. Hydraulic jacks or the drill rig can be used to pull back the steel casing following emplacement of plastic casing.

3. A detailed lithologic log shall be completed during drilling activities. Water bearing characteristics of the formations should also be denoted on the log. In addition, details of monitoring well construction should also be described on the well log including total depth, perforated interval, sizes and types of construction materials, etc.

4. Hollow-stem augers can be used to advance exploratory bore holes in many situations. Appropriate decontamination of the auger flights between bore holes is required. Soil samples are collected using a standard 1.4 inch inside diameter split spoon sampler and a 140 pound drive hammer. The number of blows necessary to obtain an 18 inch length of sample is recorded on the boring log. The split spoon sampler is decontaminated between sample intervals.

   Single or multi-completion monitoring wells can be constructed in individual boreholes. Install factory slotted well screen and blank PVC (or stainless steel or PTFE for organics) well casing into the borehole. Where appropriate, begin pulling temporary steel casing out of borehole. Emplace chemically-inert silica sand above and below any perforated sections and install a betonite plug above the sand. Backfill remaining well annulus with a bentonite slurry or with grout to the surface. Monitoring well development is presented in SOP-4.

5. Place locking protective well cover over well casing(s) after outer steel casing has been removed from the borehole (if necessary). Place bentonite plug below bottom of well cover; grout cover in place and lock with high quality lock.

6. Many states now require certification and licensing for monitoring well drillers. Verify the driller is licensed in the State (if requiremed) prior to beginning field work.

7. Safety equipment required on-site of the drill rig is mandatory. Personal protective equipment includes (at a minimum): hard hat, safety glasses, steel toed boots, gloves, first aid kit, and site safety plan-with routes to hospitals known by all personnel on-site.

STANDARD OPERATING PROCEDURE

MONITORING WELL DEVELOPMENT

SOP-4

1. Visually inspect all well development equipment for damage and repair as necessary.

2. Decontaminate all stingers, air hoses, surge blocks by scrubbing with brush and Liquinox solution, and rinsing with dilute nitric acid solution followed by a triple deionized water rinse. If sampling for organics, replace the nitric acid rinse with 10% methanol (see SOP-2).

3. If using compressed air method for well development, verify the compressor utilized does not produce air laden with hydraulic fluid for lubricating purposes. This may affect the integrity of the monitoring well for producing viable water quality data.

4. Develop well by using surging techniques (surge block or bailer) followed by well evacuation. Repeat this procedure until evacuated water is visibly clean and essentially sand-free. Evacuated water may be disposed of on-site, unless other handling requirements or specified in the project work plan.

5. If specified in the project work plan during the evacuation process, collect water samples for field determinations of temperature, specific conductivity, and pH. Continue developing well until field parameters stabilize to within ±5% on three consecutive measurements.

6. Report field observations and volume of water removed on standard form.

STANDARD OPERATING PROCEDURE

FIELD MEASUREMENT OF GROUNDWATER LEVEL

SOP-5

1. Calibrate the water level meter to a steel tape prior to each sampling event. Note any corrections to water level meter measurements on field forms.

2. Verify the water level meter is operating correctly prior to leaving for the field by placing probe in water to test the buzzer and light. Repair as necessary. Make certain the mater and extra batteries are in the carrying case.

3. Measure all wells (monitoring and domestic) from the top of the well casing in the north quadrant or from a designated measuring point, as appropriate. Measure and record the distance from the measuring point to ground level. Make sure the measuring point is labeled on the well, so future measurements can be made from the same location.

4. Measure the depth to water from the measuring point to the nearest hundredth of a foot. Record measurements on the appropriate field forms. Also record the presence/absence of free product on the field forms.

5. Decontaminate the water level meter between each measurement following the procedures in SOP-2.

6. If free product is known or suspected to be present in a well, an oil-water level indicator should be used to measure the depth to water and the thickness of free product in the well.

STANDARD OPERATING PROCEDURE

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

SOP-6

INSTRUMENT CALIBRATION

1. The meter shall be calibrated prior to each sampling event following the manufacturer's recommendations. If the instrument is a multi-parameter meter, follow the instructions for measurement of electric or specific conductance from the manual.

2. Prior to conducting field measurements, verify the meter automatically corrects for temperature variations. If the meter does not, apply the appropriate temperature correction to the field measurements.

FIELD PROCEDURE

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

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

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

4. Immerse the probe in sample and move it around to displace any air bubbles. The probe should not touch the sides of the beaker. Record the conductivity reading taking note of the scale of the reading, microseimens/centimeter (µs/cm), micromhos/centimeter (µmhos/cm), or milliseimens/centimeter (ms/cm). If the reading is being taken in-situ or using a flow-through cell, wait until the reading stabilizes and record it on the sample field form.

7. Remove the probe from sample and rinse it with deionized water. Store the probe following the manufacturer's recommendations.

STANDARD OPERATING PROCEDURE

FIELD MEASUREMENT OF pH

SOP-7

INSTRUMENT CALIBRATION

1. The meter shall be calibrated prior to each field day following the manufacturer's recommendations. The two point standard method should be used for calibration. If instrument is a multi-parameter meter, follow the instructions for measurement of pH from the manual.

2. The calibration of the pH meter should be checked periodically throughout the field day, especially when air temperatures change more than 5 degrees. To check the calibration, place the probe in 7.0 pH buffer solution. If the measured value differs from the expected value by more than 0.1 pH units, recalibrate the meter according to the manufacturer's instructions.

FIELD PROCEDURES

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

3. Rinse the pH electrode with deionized water.

4. Check the meter using a 7.0 pH buffer. Re-calibrate the meter if the reading is not within 0.1 pH standard units (s.u.).

5. Fill the beaker with sample water.

6. Immerse the probe in the sample and agitate it to provide thorough mixing. Continue to agitate until the reading has stabilized. Read the pH to the nearest 0.1 s.u. If the reading is being taken in-situ or using a flow-through cell, wait until the reading stabilizes and record it.

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

8. Rinse probe with deionized water and store according to the manufacturer's instructions.

STANDARD OPERATING PROCEDURE

FIELD MEASUREMENT OF DISSOLVED OXYGEN

SOP-8

1. Rinse the probe and cable with deionized water.

2. Prepare the probe and dissolved oxygen (DO) meter or multi-parameter meter in accordance with the manufacturer's instructions. Verify the probe contains sufficient electrolyte and the oxygen sensor membrane is in good repair.

3. Calibrate the probe and meter using the fresh water-air calibration method. Correct the calibration value for temperature and altitude and adjust the meter accordingly.

4. When possible, place probe the directly into the stream or well to be measured. If not possible, place the probe into beaker filled with sample. Manually raise and lower probe through the sample about 1 foot/second. Allow sufficient time for the probe to stabilize to sample temperature and dissolved oxygen concentration.

5. Record the dissolved oxygen value on the appropriate field forms.

STANDARD OPERATING PROCEDURE

FIELD MEASUREMENT OF REDOX POTENTIAL (Eh)

SOP-9

1. Calibrate the Eh or multi-parameter meter in accordance with the manufacturer's instructions prior to each sampling event.

2. Decontaminate a sample beaker in accordance with SOP-2.

3. Rinse the Eh electrode with deionized water and then with sample water prior to inserting it into the sample beaker.

4. Obtain a sample of water using a method which minimizes agitation of the sample. The more the sample is exposed to oxygen, the more likely it is that erroneous data will be obtained. If possible, obtain an in situ measurement of Eh.

5. If extractive methods are used to obtain water samples, fill the sample beaker with sample water which has been recently evacuated from the well and, again, minimize agitation.

6. Immerse the Eh electrode in the sample and allow several minutes for the probe to equilibrate with the water.

7. Obtain a reading to the nearest ten millivolts.

8. Record the reading on standardized field forms or in the field book. Note any problems such as erratic or drifting readings.

9. Rinse the probe with deionized water and store it according to manufacturer's instructions.

STANDARD OPERATING PROCEDURE

FIELD SAMPLE FILTRATION

SOP-10

1. Filtration equipment will include disposable 0.45 micron filters.

2. To avoid the need for decontamination, use disposable tubing with a peristaltic pump or disposable bailers and a hand-vacuum pump.

3. Fill pre-preserved, laboratory supplied sample containers with filtered sample and cap. Invert sample container several times to insure complete sample-preservative mixing.

4. Place sample container into cooler; package and ship accordance with SOP-15.

5. If extremely turbid sample water is obtained, pre-filter the sample using 3.0 or 5.0 micron filter paper followed by 0.45 micron filtration.

6. Decontaminate, if necessary, all equipment in accordance with SOP-2 following use.

STANDARD OPERATING PROCEDURE

GROUNDWATER SAMPLING

SOP-11

EQUIPMENT:

Five gallon bucket graduated in gallons	pH meter/thermometer
Coolers and ice	Specific conductance meter
Sample bottles	Bailer(s)
Preservatives	Bailer rope or Teflon reel
Filter apparatus	Field sampling forms
Decontamination equipment & fluids	Indelible marker
Water level meter	Stop watch
Purge/sampling pump(s)	Generator
Discharge hose	Fuel

All sampling equipment shall be inspected for damage and repaired if necessary, prior to arriving on-site.

GENERAL PROCEDURE – PURGING

Purging must be performed on all wells prior to sample collection. If required by the project workplan, the stability of pH, specific conductivity, and temperature will be evaluated. A minimum of three casing volumes shall be purged from the well prior to sample collection. The volume of water present in each well shall be computed using the length of water column and monitoring well inside diameter. The total volume of water in the well (gallons) can be approximated using the following formula (depth and water level measurements in feet; borehole diameter in inches):

$$(1/25)\ (\text{Total Depth - Measured Water Level})\ (\text{Casing Diameter})^2 = \text{gallons}$$

Several general methods are used for well purging. Well purging may be achieved using bailers, bladder pumps and submersible pumps. The specific pumping method shall be chosen based on depth to groundwater, diameter of well, existing well configuration and contaminant(s) of concern. Specific conductance, pH, temperature, and purge volume values will be entered on the Field Sampling Forms. If sampling for hydrocarbon compounds, wells shall be checked for the presence of free product prior to purging and sampling.

Field parameters will be measured periodically during well purging at a minimum of once per casing volume purged. The well is ready for sampling when either or both of the following conditions are met: 1) measured field parameters stabilize within plus or minus five percent over three successive readings or, 2) three to five casing volumes have been evacuated from the well.

If the recovery of a low-yield well exceeds two hours after purging, the sample shall be extracted as soon as sufficient volume is available in the well. At no time will a monitoring well be pumped dry if the recharge rate causes formation water to cascade down the well casing causing an accelerated loss of volatiles and change in pH.

COLLECTING WATER QUALITY SAMPLES

1. Generally, wells shall be sampled from the least contaminated to the most contaminated, if known. Open well and measure water level (SOP-5).

2. Decontaminate sampling equipment following the procedures outlined in SOP-2.

3. Label each sample container with project number, sample location, well owner, date, military time, sampler's initials, preservative, and analysis required.

4. Don clean latex or nitrile gloves immediately prior to obtaining the sample.

5. Sampling Monitoring Wells
    a. Obtain the sample from the well using a disposable polyethylene bailer, a decontaminated stainless steel or Teflon bailer, or pump tubing, as appropriate. When using a bailer, take care to minimize degassing or contamination of the sample by submerging and withdrawing the bailer slowly to avoid splashing. Do not place the bailer on the ground.

6. Sample Domestic Wells
    a. Turn-on household fixture (preferably an outside faucet without a hose connected) that is on the well-side of any household water conditioning device.
    b. Using the above equation, calculate the volume of water to be evacuated. Measure the discharge rate from the faucet in a graduated 5 gallon bucket, or other suitable container, to compute the rate of discharge. Calculate the time needed to evacuate the predicted volume from the well. Record all measurements and calculations on the field forms.
    c. Samples should be collected directly from hydrant or faucet and prior to entry of the water through any water conditioning devices. Do not collect samples through rubber hoses. Aerators or screens (if present) should be removed from faucets prior to sample collection.

7. If sampling for dissolved metals, field filter sample according to SOP-10.

8. Transfer sample water directly into sample bottles, maintaining a slow linear flow with as little aeration as possible. Samples will be preserved as described in the table below.

Parameter	Number	Container	Preservation	Maximum Holding Time Extraction/ Analysis
VOCs	2	40 ml glass	4°C & HCL	14 days to analysis
SVOCs	1	1 liter glass	4°C	7 days/40days from extraction to analysis
Metals	1	500 ml HDPE	4°C & HNO_3	6 months to analysis,, Hg 28 days to analysis
Nutrients	1	500 ml HDPE	4°C & H_2SO_4	Varies – contact laboratory for additional information
Common Ions	1	1 liter HDPE	4°C	7 days/40 days from extraction to analysis

9. For volatile analyses add preservative to sample vial and fill vials at the rate of 100 milliliters per minute (24 seconds for 40 milliliter vial) or less. Fill each sample vial completely so the water forms a convex meniscus at the top to ensure no air space exists in the vial after it has been capped. After filling, immediately cap, invert, and gently tap the vial to check for trapped air. If air bubbles are present, un-cap vial, add more sample water and repeat procedure. If air bubbles are still present, discard the vial.

10. Complete the necessary shipping and handling paperwork, and record all pertinent information on Field Sampling Form in accordance with SOP-1.

STANDARD OPERATING PROCEDURE

SURFACE WATER SAMPLING

SOP-12

GRAB SAMPLING

1. Locate sampling point if feasible at the interval in the steam which exhibits the largest volume of flow and/or highest velocity. More than one interval may be sampled.

2. Submerge pre-labeled sample bottle at sampling point such that mouth of bottle is under water surface 2 to 3 inches, if possible. If sampling inorganics, allow bottle to fill partially; rinse bottle by shaking and discharge this water away from sample site. Repeat this procedure three times. Do not rinse sample bottles for organics analysis.

3. Collect sample, add preservative (if necessary), and cap. If water is too shallow to fill directly to sample bottles use a decontaminated container to collect sample water. Transfer water from composting container into pre-labeled sampling bottles.

4. Fill out appropriate field form(s) documenting sample location, time, and other pertinent information prior to leaving sampling site.

SURFACE SAMPLING

1. This sampling procedure is to be used when sampling for organic constituents that float on top of water (e.g., oil and grease).

2. Decontaminate sampling container in accordance with SOP-2. The sampling container should be a wide mouth jar.

3. Submerge the sampling container in such a manner that leaves the mouth of the container half-way out of the water. Wait for the container to fill.

4. Transfer directly into sampling bottles.

5. Fill out appropriate field form(s) documenting sampling location, time, and other pertinent information prior to leaving the sampling site.

STANDARD OPERATING PROCEDURE

STREAMFLOW MEASUREMENT; WADING TECHNIQUE

SOP-13

1. Check and calibrate flow meter per manufacturer's recommendations.

2. Attach flow meter to top setting wading rod.

3. Anchor surveyor's tape tautly across the stream perpendicular to the direction of stream flow and attach on either side of the stream. Provide at least one foot of clearance between the water surface and surveyor's tape.

4. Divide the stream cross-section into an appropriate number of sections with approximately equal flow in each section. Concentrate measurements in areas of most flow. A very small stream may have only a few sections; a river should have 20 to 30 sections.

5. Person wading in stream calls out to data recorder on shore the location of the first measuring point with respect to the surveyor's tape. Person in stream measures water depth at that vertical, using top setting wading rod, to the nearest half tenth of a foot. Laminar flow depths may be read at a smaller increment, hundredths of a foot, if reasonable.

6. If the water is more than 2.5 feet deep, measurements should be made at 20 and 80 percent of the water column height. For water columns less than 2.5 feet deep, a single measurement of velocity at 40 percent of the water column height will suffice. Person wading adjusts height of flow meter on the top setting wading rod.

7. Person wading stands downstream of the surveyor's tape, facing upstream, holding the wading rod vertical in the water with the flow meter facing directly into the current. Person should not stand directly behind the meter but either to the left or right so as not to influence velocity readings.

8. Person wading notes mean velocity reading on flow meter and calls out to data recorder.

9. Repeat procedure at each vertical.

10. Data recorder reduces data on-site and records other appropriate information on the field form.

11. Stream flow measurement data are reduced using the attached form. Further information can be found in: Rantz et al, 1982. Measurement and Computation of Stream Flow: Volume 1- Measurement of Stage and Discharge, Volume 2- Computation of Discharge. U.S. Geological Survey Water-Supply Paper 2175.

Geomatrix Consultants
Surface Water Discharge Measurement/Sample Notes

Sta. No. _____

Site Name: _____

Date _____ Time _____

Field Crew _____

Discharge Summary

Total Discharge (cfs) _____ Type of Meter _____

Width _____ Method _____

Area _____

Average Velocity _____

Sample Summary

Samples Collected: _____

Sample Method: EWI _____ EDI _____ Grab _____

Sample Time: _____

Bottle List

_____
_____
_____
_____

Site Information

Wading _____ ft. above/below gage

Measurement Rating: Excellent _____ Good _____ Fair _____ Poor _____

Flow (describe) _____

Cross Section (describe) _____

Weather _____

STANDARD OPERATING PROCEDURE

QUALITY CONTROL SAMPLES

SOP-14

Quality Control (QC) samples are submitted along with natural samples to provide supporting laboratory data to validate laboratory results. QC samples are submitted blind with the exception of matrix spikes and trip blanks, 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
FB	Field Blank	Deionized water collected in sample bottle; used to detect contamination introduced during the sampling process.
RB	Rinseate Blank	Deionized water run through or over decontaminated equipment; used to verify the effectiveness of equipment decontamination procedures
MS/MSD	Matrix Spike/ Matrix Spike Duplicate	Certified materials of known concentration; used to assess laboratory precision and accuracy
TB	Trip Blank	Inert material (deionized water or diatomaceous earth) included in sample cooler; sent by the lab, the sample is used to detect any contamination or cross-contamination during handling and transportation.

In general, selected QC samples will be inserted into the sample train within a group of twenty samples. QC samples will be prepared in the field with the exception of trip blanks and matrix spike/matrix spike duplicate samples. Trip blanks will be supplied by the laboratory and will accompany each sample cooler containing samples for analysis of volatile organic compounds. Matrix spike and matrix spike duplicates will be generated by submitting three duplicate samples from the same sample to the laboratory. The laboratory will then spike two of the three samples with known concentrations of select target compounds. After the laboratory has spiked the matrix spike and matrix spike

duplicate samples, they are subject to the same laboratory procedures and analyses as all other samples collected during the investigation.

QC sample collection frequencies are presented in the table below. Each field crew leader will be responsible for all QC samples prepared by that crew.

QC Sample	Purpose	Collection Frequency
Field Duplicate	Measure analytical precision.	1 per every 20 samples
Matrix Spike/Matrix Spike Duplicate	Measure analytical accuracy.	1 per every 20 samples
Equipment rinse blanks	Evaluate effectiveness of equipment decontamination and sample handling procedures.	1 per sampling event per media
Field Blank	Assess possible cross-contamination of samples due to ambient conditions during sample collection.	1 per sampling event
Trip Blanks	Evaluate sample preservation, packing, shipping, and storage.	1 per cooler containing samples with volatile constituents

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

STANDARD OPERATING PROCEDURE

SAMPLE DOCUMENTATION

SOP -15

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 indelible ink for each sample generated include:

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

STANDARD OPERATING PROCEDURE

SAMPLE PACKAGE AND SHIPPING

SOP-16

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 (inside sealed Ziploc bags) and/or frozen blue ice (appropriate for the season) to maintain a temperature of 4°C or less inside the cooler. Ensure 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. 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 consist of a chain-of-custody form, which documents the samples included in the shipment and specifies 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.

4. Close and seal the cooler using strapping tape.

5. Place completed sample custody seals on the cooler such that the seals will be broken when the cooler is opened. Secure the custody seals on the cooler with clear 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.

STANDARD OPERATING PROCEDURE

FIELD SCREENING OF VOLATILE ORGANIC COMPOUNDS HEADSPACE

SOP-17

1. If using a photoionization detector (PID), ensure the instrument is equipped with the appropriate lamp for the compound(s) of interest (refer to table below).

2. Calibrate the instrument prior to each field day following the manufacturer's instructions. Document the calibration on the appropriate field form or in the project field book.

3. Obtain a soil sample from the interval of interest, place it in a new ziploc bag, and seal the bag. Shake the bag to thoroughly mix the sample with the air in the headspace.

4. Allow the sample to come to room temperature (approximately 70 - 80° F) by placing it in a warm location (not in direct sunlight). In the winter, it may be necessary to place the sample bag under a vehicle heater vent.

5. Insert the probe through the ziploc bag and record the maximum reading.

6. Moisture and dust will affect the PID reading. Use a filter to prevent them from contacting the PID lamp.

PID Lamp Selection

Lamp	Description	Typical Compounds Detected
9.8 eV	Most selective lamp	Benzene, aromatic compounds, amines
10.6 eV	Standard PID lamp	All compounds detected by 9.8 eV lamp and chlorinated compounds, including vinyl chloride, DCE, TCE, PCE, and chlorobenzene
11.7 eV	Detects broadest range of analytes	All compounds detected by 10.6 eV lamp, used to detect methylene chloride, carbon tetrachloride, chloroform, 1,1,1-trichloroethane

STANDARD OPERATING PROCEDURE

SAMPLE CHAIN-OF-CUSTODY

SOP-18

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

GLOBAL POSITIONING SYSTEM OPERATIONS

SOP-19

INSTRUMENTATION PREPARATION

Prepare GPS unit in accordance with manufacturers recommendations. Batteries should be fully charged.

DATA COLLECTION

1. Field personnel should be familiar with operation of GPS unit. An SOP on unit operation should be available in the GPS case.

2. Project manager should discuss mapping needs and anticipated feature and attribute information to be collected in the field with field team leaders.

3. Site feature labeling and attribute information should be documented for clarity by the project manager. It is very important that data labels are coded correctly in the field to avoid confusion in post processing of field data.

4. A data dictionary is preferable for ensuring complete feature and attribute data collection. The data dictionary is compiled and loaded onto GPS unit prior to going to the field.

5. Field personnel should record information about GPS data collection each day in field books along with other field data. Information to include is GPS file names, adjustments to GPS settings which would effect accuracy of data, additional features collected which were not anticipated and how those features were labeled, and any other problems encountered during data collection.

6. GPS files should be closed at end of the day. Files left open on the unit are vulnerable to corruption and loss of data.

7. Most GPS units should be able to hold a week's worth of data collection. If a longer time period is anticipated or large amounts of data are collected in a few days it is recommended that a laptop computer is taken in the field with the appropriate software loaded so data downloads can be done at the end of the day. Once again, field personnel should be familiar with this process if necessary.

8. GPS units should be turned over to appropriate office personnel for download and post processing after returning from the field.

POST PROCESSING DATA

Typically GPS units are turned over to office personnel who are familiar with GPS and GIS practices for post processing of data. After data are downloaded and exported a map and/or spreadsheet should be given to field personnel for verification of data collected.

STANDARD OPERATING PROCEDURE

COLLECTING VAPOR AND WATER SAMPLES WHEN COMBUSTIBLE GAS CONCENTRATIONS IN WATER WELL CASING EXCEED LOWER EXPLOSIVE LIMIT

Pinedale Anticline Production Area, Sublette County, Wyoming

SOP-20

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

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 bailer cord

3. Disposable PE bailer

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

MANAGEMENT OF INVESTIGATION-DERIVED WASTE

SOP-21

This SOP describes the management of investigation-derived waste. The project specific Sampling and Analysis Plan should be referenced for additions or deletions to the methods noted below.

FIELD EQUIPMENT

- DOT approved 55-gallon drums
- Drum wrench
- Drum labels

SOIL

Material excavated from a test pit will be placed back in the test pit in the reverse order that it was excavated so that topsoil material is returned to the top of the pit. When backfilling is complete the area will be cleaned up to its original condition.

Drill cuttings from soil borings or monitoring well installation will be monitored during drilling for staining and odor and will also be field screened for VOCs with a PID (refer to SOP 16). Based on the PID screening, cuttings with organic vapor concentrations greater than 100 ppm will be containerized in labeled 55-gallon drums (or roll-off containers if large volumes of cuttings are anticipated) pending further characterization. Alternatively, project personnel may elect to containerize all drill cuttings based on the presence of known contamination and contaminant concentrations. Containerized soil will be disposed of in accordance with state and federal regulations based on of soil analytical results.

Soil that does not appear to be contaminated based on observations by field personnel and PID screening will be spread on the ground near the point of origin.

GROUNDWATER

Groundwater purged from a well during development or sampling will initially be discharged to a rate bucket to allow the flow rate to be measured. Groundwater that has a sheen or contains free product will be containerized in an appropriately labeled 55-gallon drum or tank pending receipt of analytical characterization results. The containerized water will be disposed of in accordance with state and federal regulations based on the analytical results. Groundwater that does not have a sheen or contain free product will be discharged to the ground surface

STANDARD OPERATING PROCEDURE

FIELD SURVEYING – LEVEL SURVEY

SOP-22

1. Make sure instrument is in good working order prior to heading to the field. Become familiar with BM, TBM, BS, HI, FS, and IS. See below.

2. Set up tripod in a manner that will assure it is stable, (i.e., the instrument will be unwavering when you attach it to the tripod). Attach and level the instrument.

3. Set up and backsight (BS) to a permanent benchmark (BM), or establish a temporary benchmark (TBM) within the study area. An arbitrary elevation (e.g., 1000 feet) may be assigned to the TBM.

4. Add the BS rod reading to the BM or TBM elevation to calculate the height of instrument (HI) (i.e., elevation of BM + BS = HI).

5. Shoot intermediate foresight (IS)I; take rod readings at any other point where elevation may be required (i.e., monitoring wells, piezometers, etc.). IS elevations are calculated by subtracting IS rod reading from HI (i.e., HI – IS = elevation).

6. Shoot foresight (FS) rod reading at designated turning point (TP). Subtract FS from HI to determine elevation of TP (i.e., HI – FS = elevation of TP).

7. Set up tripod and level again while rod man remains at TP. Shoot BS to TP and calculate new HI, allowing continuation of level traverse.

8. Two methods may be acceptable to verify accuracy of the level survey:

    1) Arithmetic check: since all BS are added, all FS are subtracted, when the sum of BS is added to the original elevation and the sum of FS is subtracted from that total, the remainder should be the same as the final elevation calculated (original elevation + $\sum$BS - $\sum$FS = new elevation).

    2) Closure: shoot a final FS to the BM or TBM established at the beginning of the survey. Subtract the FS from the HI to redetermine the elevation of the BM or TBM. This elevation should be within the degree of accuracy established for the survey.

Note: Rod readings on turf, ground, and other uneven surfaces are usually taken to the closest 0.1 foot; rod readings taken on concrete, steel, asphalt, and so on are usually taken to the closest 0.01 foot.

(BM) *Benchmark* A permanent point of known elevation.
(TBM) *Temporary benchmark* A semipermanent point of known elevation.
(TP) *Turning point* A point temporarily used to transfer an elevation.
(BS) *Backsight* A rod reading taken on a point of known elevation in order to establish the elevation of the instrument line of sight.
(HI) *Height of instrument* The elevation of the line of sight through the level.
(FS) *Foresight* A rod reading taken on a turning point, benchmark, or temporary benchmark in order to determine its elevation.
(IS) *Intermediate foresight* Rod reading taken at any other point where the elevation may be required.

EXAMPLE OF CLOSED CIRCUIT LEVEL SURVEY

Monitoring Well Elevations
May 10, 1993
Jerry's Mart, Helena, MT
B. Bucher, S. Staley.
Clear, Windy, 46°F

STA	B.S.	H.I.	F.S.	ELEV	DESCRIPTION
TBM	2.75	102.75		100.00	Nail in power pole
MW-1			4.60	98.15	TOP P.V.C.
MW-2			6.12	96.63	TOP P.V.C.
T.P.	4.39	96.33	10.51	92.24	
MW-3			9.02	87.61	TOP P.V.C.
T.P.	8.68	103.38	1.93	94.70	
TBM			3.41	99.97	Nail in power pole
		15.82 / 15.85 MISCLOSURE -0.03'			

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

FIELD PREPARATION CHECKLIST

PROJECT NAME: PROJECT #:

		FIELD PREPARATION AND FOLLOW-UP
		Telephone Calls
		Client/Site Contact:
		Regulatory Agency:
		USA Contact:
		Private Utility Locator:
		Other:
		Additional Numbers or Notes
		Geomatrix:
		Rick Morrow:
		Francis Sefwi:
		Paul Dawson:
		Driver:
		Hospital/Clinic:
		SGS Lab:
		Other:
		Site Walk Information
		Mark borings/excavations
		Obtain utility maps or plans
		Access Issues:
		keys or keypad security code #
		time constraints on work (hours/days)
		limited by power lines, structures, soft ground
		Water or electrical source at site
		Traffic control requirements
		Other:
		Documents to Prepare
		Geomatrix work plan
		Geomatrix Health and Safety Plan
		Subcontractor cost estimates
		Subcontractor work order
		Other:
		Permits
		County Drilling Permit
		Encroachment Permit
		Grading Permit
		Other:
		Analytical Laboratory
		Lab:
		Laboratory Service Request
		Bottle order: sample containers & (circle)
		duplicate or split samples
		trip, atmospheric, or temperature blanks
		equipment, pump, or rinsate samples
		cleaning water
		Sample courier or shipment (airbill label, insurance)
		Other:

		FIELD EQUIPMENT AND REFERENCES
		Equipment
		Geomatrix equipment order
		Water Level Indicator
		Measuring Tape
		Pump
		Tubing
		Hose
		Transducer
		Lap Top Computer
		Personal Protective Equipment
		See health and safety on back
		Hard hat and steel toed boots (leather/rubber)
		Rain gear
		Safety glasses and vest
		Ear protection
		Drinking water
		Sun screen
		Other:
		Additional Personal Items
		Cellular phone
		Camera (digital, disposable)
		Clipboard
		Calculator
		Clock or wrist watch
		Tape measure
		Scale and protractor
		Satellite phone
		Spray water bottle
		Other:
		References and Forms
		H & S Plan, permits, subcontractor WO
		Previous field documents (reports, etc)
		Site location map and site plan
		Work plan or sampling plan
		Telephone contact list
		Unified soil classification tables
		Munsell color charts
		Geomatrix forms (circle): daily field records;
		boring, well, or trench logs;
		development records; well construction
		summary, water-level monitoring, chain-or-
		custody, sample control log, drum inventory
		Other:

FIELD PREPARATION CHECKLIST

PROJECT NAME: PROJECT #:

		Waste Generated				Follow-Up Tasks
		Soil (soil bin, drums, stockpiled on plastic)				Surveyor
		Water (drums, Baker™ tank)				DWR Forms for well installations
		Sample for disposal				Other:
		Coordinate storage location at site and disposal				

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

WELL LITHOLOGIC AND COMPLETION LOG

JOB NO: _____ **WELL NO:** _____

PROJECT: _____ COUNTY: _____ LOGGED BY: _____

LEGAL LOCATION: _____ TRACT _____ DESCRIPTIVE LOCATION: _____

DATE STARTED: _____ DATE COMPLETED: _____ DRILLING CO/ DRILLER: _____

DRILLING METHOD: air rotary/casing hammer BOREHOLE DIAM (IN): _____ DRILL FLUIDS USED: _____

TOTAL DEPTH DRILLED: _____ TOTAL DEPTH CASED: _____ INTERVAL PERFORATED FROM OR SCREENED (FT:) _____ DIAMETER: _____ CASING TYPE: steel

METHOD OF PERFORATION:

_____	Open Hole
_____	Open Bottom
_____	Saw Slotted
_____	Factory ___ (size)
_____	Other: torch cut 1/4" x 4"; 5 rows

DURING WELL CONSTRUCTION WAS/WERE:

	YES	NO
Well Developed		
Well Pumped		
Water Samples Collected		
Material Samples Collected		

ANNULAR COMPLETION CHARACTERISTICS

WELL PROTECTOR: LENGTH: _____ DIAM: _____

LOCK NO: _____

SURFACE SEAL TYPE: _____

BACKFILL MATERIAL: _____ FROM: TO:

HOLE PLUG: _____ FROM: TO:

FILTER PACK TYPE: _____ FROM: TO:

STATIC WATER LEVEL: _____ DATE: _____

MEASURING POINT DESCRIPTION/ ELEVATION: _____

MEASURING POINT RELATIVE TO GROUND SURFACE (+/-)

REMARKS: _____

INTERVAL(FT) below ground surface	LITHOLOGIC DESCRIPTION USCS NAME (USCS symbol): color, moist, % by weight, plasticity, consistency, structure, cementation, geology	REMARKS

amec

WELL LITHOLOGIC AND COMPLETION LOG

WELL NO:

INTERVAL(FT) below ground surface	**LITHOLOGIC DESCRIPTION USCS NAME (USCS symbol): color, moist, % by weight, plasticity, consistency, structure, cementation, geology**	**REMARKS**

FIELD WELL CONSTRUCTION SUMMARY

Geomatrix

Well ID: _____ **Project Name:** _____

Project/Task No.: _____ **Location:** _____

Geomatrix Personnel: _____

DRILLING SUMMARY

Drilling Contractor: _____ Driller: _____

Drilling Method: _____ Drill Rig: _____

Drilling Fluid: _____ Drill Bit(s): _____

BORING AND WELL CASING DEPTH MEASUREMENTS

Pilot Boring: Depth Interval BGS _____ Diameter _____ Depth Interval BGS _____ Diameter _____

Reamed Boring: Depth Interval BGS _____ Diameter _____ Depth Interval BGS _____ Diameter _____

Total Depth BGS of Well Casing: _____ Depth of Perforated Interval BGS: _____

Total Depth of Well Below TOC: _____ Depth of Perforated Interval Below TOC: _____

WELL DESIGN Geologic Log ☐ Geophysical Log ☐ Sieve Analysis ☐

Codes: B = Bentonite Seal, C = Casing, CC = Conductor Casing, CL = Centralizer, EC = End Cap, F = Filter, G = Grout, N = Native Fill, S = Screen, TS = Transition Seal

Casing/Screen			Annular Materials		
Feet	– BGS	Code	Feet	– BGS	Code
	–			–	
	–			–	
	–			–	
	–			–	
	–			–	
	–			–	
	–			–	
	–			–	
	–			–	
	–			–	
	–			–	

Filter Material: _____

Seal (B/TS): _____

Grout: _____

Native Material:

Surface Finish:

Centralizers:

Other: _____

CONSTRUCTION TIME LOG

Task	Start Date	Start Time	Finish Date	Finish Time
Drilling				
Conductor				
Casing				
Geophys.				
Casing				
Filter				
Seal (B/TS)				
Grout				
Other				

Well Casing: _____

C1

C2

Well Screen: _____

S1

S2

Conductor Casing: CC1 _____

CC2

Project No. **Figure No.**

Geomatrix

FIELD WELL CONSTRUCTION SUMMARY
WELL CASING INSTALLATION

Well ID: _____ Project/Task No.: _____

I. Section Measurements: (to 0.01 of a foot)

Well casing sections (A)

_____ _____ _____ _____ _____ _____ _____ _____

_____ _____ _____ _____ _____ _____ _____ _____

_____ _____ _____ _____ _____ _____ _____ _____

Total = _____ (1)

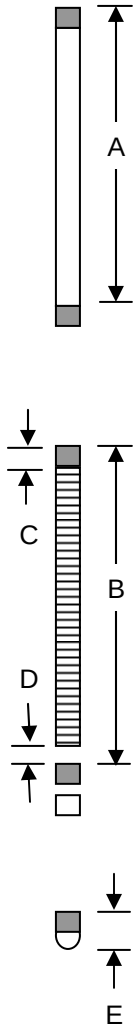
Well screen sections (B)

_____ _____ _____ _____ _____ Total = _____ (2)

Length from top of screen section to top perforation (C) = _____ (3)

Length from bottom of screen section to bottom perforation (D) = _____ (4)

Length of bottom endcap + tailpipe (measured inside of cap) (E) = _____ (5)



II. Total Measurements Referenced to GS: (to 0.01 of a foot)

Total length of well casing (1+2+5) = _____ (6)

Total length of perforated interval (2-3-4) = _____ (7)

Temporary height/depth of top of casing AGS (+) / BGS (–)

(1) Desired depth to top of screen interval _____ (8a) (1+3-8a) = _____ (9a)

or (2) Desired depth to bottom of screen interval _____ (8b) (1+3+7-8b) = _____ (9b)

Actual height/depth of top of casing after installation (to 0.01 of a foot) = _____ (9c)

Total depth of well (BGS) (to 0.10 of a foot) (6-9c) = _____ (10)

Depth of perforated interval (BGS) (to 0.10 of a foot) Bottom (10-5-4) = _____ (11)

Top (11-7) = _____

III. Surface Completion: (to 0.10 of a foot)

Top of casing adjustments: Casing removed (–) / added (+)

_____ _____ _____ _____ Total = _____ (12)

Final TOC: AGS (+) / BGS (–) (9c-12) = _____ (13)

Total Depth of Well below TOC (to 0.10 of a foot) (6-12) = _____ (14)

Depth of Perforated Interval below (TOC) (to 0.10 of a foot) Bottom (14-5-4) = _____ (15)

Top (15-7) = _____

Note: All measurements of well casing and screen sections to be to the nearest 0.01 ft. All final measurements referenced to ground surface and top of casing are to be to the nearest 0.10 ft.

GS = ground surface AGS = above ground surface BGS = below ground surface TOC = top of casing

Geomatrix

SURFACE COMPLETION DETAILS FOR WELLS

Well ID: _____ Project/Task No.: _____

Surface Flush Mount Completion (to 0.10 of a foot)

Well Box Manufacturer: _____ Model No. _____

Well Box: Diameter: _____ Length _____ Bolt Type: Diameter _____ (fractions of an inch, e.g., 5/8) # Bolts: _____

Well Vault: Dimensions: Length _____ x Width _____ x Height _____

Bolt Type: Diameter _____ (fractions of an inch, e.g., 5/8) # Bolts: _____

Notes:

Above Grade Surface Completion (to 0.10 of a foot)

Steel Protective Cover: Length _____ Diameter or Width _____ (circle one) Height AGS _____ Depth BGS _____

Cap Type (check one): Locking Hinged _____ Locking Slip Cap _____

Annular Space (check appropriate): Mortar Collar _____ Sand _____ Other _____ Drainage Hole _____ Height AGS _____

Concrete Pad Dimensions: Length _____ x Width _____ x Thickness _____

Steel Protective Bollards: # of _____ Length _____ Diameter or Width _____ (circle one) Height AGS _____ Depth BGS _____

Radial Distance of Steel Protective Bollard from Well _____

AGS = above ground surface

BGS = below ground surface

Notes:

FIELD WELL CONSTRUCTION SUMMARY NOTES

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)				

AQUIFER TEST - FLOW RATE MEASUREMENT FORM

Project Name: _____
Project Phase: _____
Pumped Well: _____

Date	Time	Flow Rate	Totalizer Reading	Date	Time	Flow Rate	Totalizer Reading	Comments:

AQUIFER TEST - WATER LEVEL MEASUREMENT FORM

Project Name: _____
Project Phase: _____
Pumped Well: _____

Date	Time	Depth to Water (ft)	Measured By:	Date	Time	Depth to Water (ft)	Measured By:

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

ORP CALIBRATION STANDARD UNITS

TEMP(c)	Ag/AgCl (mv)
-5	270.0
0	263.5
5	257.0
10	250.5
15	244.0
20	237.5
25	231.0
30	224.5
35	218.0
40	211.5
45	205.0
50	198.5

Geomatrix

Surface Water Discharge Measurement/Sample Notes

Sta. No. _____

Site Name: _____

Date: _____ Time: _____

Field Crew: _____

Discharge Summary

Total Discharge (cfs) _____ Type of Meter _____

Width (ft) _____ Method _____

Area _____

Average Velocity _____

Sample Summary

Samples Collected: _____

Sample Method: EWI _____ Grab _____

Sample Time: _____

Bottle List _____ _____

_____ _____

_____ _____

_____ _____

Site Information

Wading _____ feet above/below gage

Measurement Rating: Excellent ____ Good____ Fair____ Poor ____

Flow (describe) _____

Cross Section (describe) _____

Weather _____

Remarks _____

Field Parameters

pH (s.u.) _____

Specific Conductivity (μmhos/cm) _____

Temperature (C^0) _____

Dissolved Oxygen (mg/l) _____

ORP _____

Turbidity (NTU) _____

Color (CU) _____

Gage Information

Staff Gage Reading _____ Crest Stage Gage Reading _____

Field Equipment Calibration

pH - 4.0 _____

pH - 7.0 _____

pH - 10.0 _____

Specific Conductivity (μmhos/cm) _____ Standard Used _____

Dissolved Oxygen (%) _____ mm/HG _____

ORP _____ (mmv) Standard Temperature _____ (C^0)

Turbidity (NTU) _____ Standard Used _____

Notes

_____

_____

_____

_____

_____

_____

Dist from initial point (ft)	Width (ft)	Depth (ft)	Observation Depth (ft)	Velocity (ft/sec)	Area (ft^2)	Discharge (ft^3/sec)

APPENDIX E

HEALTH AND SAFETY PLAN

SITE SPECIFIC HEALTH AND SAFETY PLAN

Approvals		
	Initials	Date
Prepared By		
Approved By		

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

AMEC Geomatrix

Date:

Project Name:

Project Number:

Site Location:
PAPA, Sublette County, Wyoming

Scope of Work for Day:

Lead By:

Name (printed)	Signature

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

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**
	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.