REMEDIAL DESIGN
LOCKWOOD SOLVENT GROUNDWATER PLUME SUPERFUND SITE
BEALL SOURCE AREA OPERABLE UNIT 1
YELLOWSTONE COUNTY, MONTANA
WA122-RDRD-08AK

July 11, 2012

Aquifer Testing Program of the Beall Source Area
Revision 2

1.0 INTRODUCTION 1
2.0 OBJECTIVE 1
3.0 DATA SUMMARY 1
3.1 Hydraulic Characteristics 1
3.2 Local Geology 2
3.3 Hydrology 2
3.4 Groundwater Contamination 2
4.0 SITE ACCESS 2
5.0 INVESTIGATION AND TESTING 3
5.1 Borehole Drilling and Well Installation 3
5.1.1 Utility Clearance 3
5.1.2 Exclusion Zone 4
5.1.3 Borehole Logging 4
5.1.4 Aquifer Test Wells Locations 4
5.1.5 Monitoring Well Construction 4
5.2 Groundwater Sampling and Initial Depth Measurements 5
5.3 Step Drawdown Testing 5
5.4 Constant Rate Aquifer Testing 7
5.5 Schedule 9
5.6 Equipment Decontamination 9
5.7 Investigation-Derived Waste Management 9
6.0 REPORTING 10
7.0 REFERENCES 10

FIGURES

Figure 1	Site Layout
Figure 2	Conceptual Well Designs

APPENDICES

Appendix A	Equipment and Materials List
Appendix B	Standard Operating Procedures
Appendix C	Well Completion Details

LIST OF ACRONYMS

bgs	below ground surface
CRT	constant rate aquifer test
EPA	U.S. Environmental Protection Agency
gpm	gallons per minute
ISB	in-situ bioremediation
PWT	Pacific Western Technologies

Prepared by: Catherine LeCours Date: July 11, 2012

Catherine LeCours
Project Manager, PWT

Approved by: Roger Hoogerheide Date: July 12, 2012

Roger Hoogerheide
Remedial Project Manager, US EPA

Document Revision Log

Revision	Date	Primary Changes
0	April 19 2012	Draft to EPA
1	June 8, 2012	Draft Final to EPA incorporating comments on the draft
2	July 11, 2012	Final to EPA incorporating comments on the draft final

1.0 INTRODUCTION

Under Remedial Action Contract No. EP-W-06-006, the U.S. Environmental Protection Agency (EPA) Region 8 has requested Pacific Western Technologies, Ltd. (PWT) provide remedial design support for the Lockwood Solvent Groundwater Plume Site. The remedial design focuses on the Beall Source Area within Operable Unit 1. PWT is tasked to complete a remedial design that supports the successful construction of the remedies for chlorinated solvent-contaminated soil and groundwater that meet the objectives and performance criteria selected in the Record of Decision. Based on the initial evaluation of the Remedial Investigation and Feasibility Study work performed in 2003 to support the Record of Decision, PWT has concluded that additional data need to be collected to ensure that the selected remedies for soil and groundwater are viable and effective in meeting remedial objectives. Existing soil and groundwater data for parameters such as intrinsic permeability and hydraulic conductivity suggest that In-Situ Bioremediation (ISB) may not be ideal given the current understanding of subsurface site conditions.

Thus, an aquifer testing program, consisting of step drawdown and constant rate aquifer test (CRT), is planned to provide data on the hydraulic characteristics of the uppermost hydrostratigraphic unit at the Beall Source Area. For the effective implementation of in-situ technologies, such as ISB, it is important that the aquifer properties are well defined. An aquifer test will provide results that are more representative of aquifer characteristics than those predicted by slug or bailer tests. If the aquifer test results support the feasibility of ISB, the aquifer parameters established during the aquifer tests will then be used to estimate the injection rates of emulsified oil substrate and the sizing of pumps and piping network for the pilot- and full-scale ISB system. The data collected during the aquifer test program will also be used to support the Beall Operable Unit portion of the Controlled Groundwater Use Area petition.

2.0 OBJECTIVE

The objective of the CRT portion of the aquifer testing program is to collect the data necessary to estimate the hydraulic properties of the aquifer, including the transmissivity, hydraulic conductivity, storage coefficient, and specific yield. Estimates of groundwater velocity and radius of influence can be made from these properties. These hydraulic parameters, in conjunction with the concentrations of contaminants in the groundwater, will be used for the development of the ISB system.

3.0 DATA SUMMARY

3.1 Hydraulic Characteristics

PWT has evaluated the data that was collected to estimate aquifer properties during the 2003 Remedial Investigation work. Although a number of both slug and pumping aquifer tests are cited in the Remedial Investigation Report, the hydraulic characteristics gleaned from these tests have a significant amount of uncertainty associated with their application to the Beall Source Area for the following reasons:

- There is a three order-of-magnitude difference between the hydraulic conductivity values cited in the Remedial Investigation of the constant rate (aquifer pumping) and slug tests.

- The CRTs were conducted in a coarser geologic unit, consisting of gravel, cobbles and boulders close to the modern-day Yellowstone River, while the slug tests were conducted in an older, finer-grained terrace deposit located in the Beall Source Area. Therefore, the CRTs are not representative of the aquifer at the Beall Source Area testing location. Figure 1 illustrates the

Beall Source Area and associated west plume and identifies the wells in the vicinity of Beall on which slug tests were conducted in 2003.

- The values obtained from slug tests (hydraulic conductivities between 0.17 and 0.63 ft/day or 1.97 $x10^{-06}$ and 7.29 $x10^{-06}$ ft/sec) (TTEMI 2003) are characteristic of silt and clay, but there is a significant amount of sand and gravel in the deposits below the Beall Source Area according to the lithologic logs from the site. Therefore, the slug test results may not be indicative of the aquifer at the current testing location.

For these reasons, PWT proposes to conduct an aquifer test at the Beall Source Area to obtain better estimates of the hydraulic parameters that can be used for remedial design.

3.2 Local Geology

The geology of the Beall Source Area consists of a fluvial terrace deposit consisting of a silty gravel/sand unit at the base, grading upwards to silt. The unconsolidated uppermost hydrostratigraphic unit is saturated at a depth of approximately 45 feet below ground surface (bgs), and has a lower contact with siltstone/sandstone bedrock at an approximate depth of 70 feet bgs, providing a saturated thickness of approximately 25 feet.

3.3 Hydrology

The Yellowstone River is approximately 2,000 linear feet to the north from the Beall Source Area. The Beall Source Area is located on an upper terrace bench with respect to the Yellowstone River. No potential influence is expected from the Yellowstone River on the groundwater gradient during the aquifer testing program.

3.4 Groundwater Contamination

The solvent plume emanating from the Beall Source Area is assumed to be approximately 350-feet wide as it leaves the Beall property. There are 16 groundwater monitoring wells in the immediate vicinity of the Beall Source Area extending to the leading edge of the western plume. Fifteen of these are completed in the unconsolidated uppermost hydrostratigraphic unit with one being completed in the bedrock layer. Generally, these wells have been sampled semi-annually at minimum since 2003. Data indicates the plume is stable without significant changes in concentrations or migration over the period of sampling. Monitoring Well 219 was installed during the remedial investigation and is completed through the bedrock layer at a total depth of 103 feet below ground surface. Trichloroethene has not been detected in MW219 since 2006 with only random and very minimal detections prior to 2006.

4.0 SITE ACCESS

The EPA has secured access for the Beall property. All activities associated with this aquifer test program are located on the Beall property.

5.0 INVESTIGATION AND TESTING

The following technical assumptions were used as a basis for estimating the scope of the aquifer test:

- The groundwater flow modeling report (TTEMI 2003, Appendix E) was used to provide the basis for estimating the extracted water volume. Values of hydraulic conductivity (20 ft/day), hydraulic gradient (0.006 ft/ft), and cross sectional area (8750 square feet) (width of plume 350 feet and saturated thickness 25 feet) were used in a Darcy flow equation to estimate the flow rate (5.5 gallons per minute (gpm)) through the uppermost hydrostratigraphic unit in the Beall Source Area.

- The estimate of the flow rate attainable in the saturated zone is approximately 5.5 gallons per minute (gpm). A safety factor of 2 was applied to the 5.5 gpm, yielding a maximum flow rate of 11.0 gpm. This factor of safety was used in order to overestimate the total volume of groundwater that may be generated by the aquifer test. This volume of groundwater that may be generated (step tests plus CRT) is estimated to be approximately 51,000 gallons.

Appendix A contains a list of equipment and materials necessary to execute the following field activities.

5.1 Borehole Drilling and Well Installation

The drilling of the boreholes and the installation of a new four inch pumping well and a new two inch observation well will be carried out by the Drilling Contractor. Installation and completion of the two wells will be performed in accordance with the Monitoring Well Construction Standards, Subchapter 8, Section 36.21 (Board of Water Well Contractors) of the Administrative Rules of Montana. Boreholes will be drilled by using hollow-stem augers. Well permits are not required by the State of Montana for monitoring wells.

5.1.1 Utility Clearance

The potential for accidental damage to underground and overhead utilities is always present during drilling and excavation activities. When utility hits occur, there can be negative impacts to residents or businesses due to service interruptions, in addition to the serious safety risk to site personnel. Before any drilling operations are undertaken, proposed boring locations will have been located, numbered, and identified using stakes or marking paint on paved surfaces. Utilities, including natural gas, telecommunications, water and sewer, electrical, fiber optics and cable, will be located and clearly marked. The site manager and drilling subcontractor will also inspect the area for overhead utility hazards. The procedure is detailed in SOP PWT/ES.101, Utility Clearance, found in Appendix B. Utility clearance activities will be documented in the field logbook by the site manager or drill rig geologist. The documentation will include sign-off of the utility locator service, personnel present for locate, the final project-site representative approval (if requested), and any current and historical maps used in locating utilities (or references to location of maps for future reference).

If the presence of utilities impacts the locations of any of the proposed wells, the PWT Project Manager and Project Engineer will be notified to evaluate and determine a new location for the new monitoring wells.

5.1.2 Exclusion Zone

After borehole locations have been cleared and obstructions removed, an exclusion zone will be established for each well to be installed according to the project Health and Safety Plan, and the drill rig will be set up.

5.1.3 Borehole Logging

The newly installed wells will not need to be continuously logged given the known lithology from historical sampling events. The cuttings from the borings will be containerized according to SOP PWT/GW.105, Investigation Derived Waste Management.

5.1.4 Aquifer Test Wells Locations

Figure 1 illustrates the approximate locations of the newly drilled pumping and observation wells and identifies existing monitoring wells that will be used as observation wells for the aquifer test. The pumping well will be placed in a location that will take into consideration the relatively low hydraulic conductivities that were estimated from previous slug tests in the Beall Source Area, between 0.17 and 0.63 ft/day or 1.97 $x10^{-06}$ and 7.29 $x10^{-06}$ ft/sec (TTEMI 2003), available data from the Remedial Design Supplemental Sampling Program (PWT 2012), and the saturated zone of 25 feet thick on average. These factors necessitate a careful consideration of the distance between the pumping well and the observation wells in the CRT. If the distance between the wells is too large with a low hydraulic conductivity ($< 10^{-03}$ cm/sec), the CRT may not perform well and a small or no drawdown may be noted in the observation wells. For this reason, the pumping well is proposed to be installed approximately 15 feet and 30 feet from two observation wells.

The observation wells will consist of four existing and one newly installed wells. The pumping well (MW221) will be approximately 15 feet from the newly installed observation well (MW220) and 30 feet from MW200. In addition, existing monitoring wells MW012, MW201, MW204, MW205, and MW206 have been identified as observation wells for the aquifer tests.

5.1.5 Monitoring Well Construction

The procedure for the installation of the wells can be found in Appendix C: Well Completion Details. The wells will be installed pursuant to SOP PWT/GW.103, Monitoring Well and Piezometer Installation with specific details shown on Figure 2. The pumping well, once installed, may be used to serve several functions. First, it will act as the pumping well for the aquifer test, including both the step drawdown test and the CRT. Second, based on field observations of the soil lithology and aquifer characteristics, it also may be used as an injection well for the ISB pilot test to inject a suitable electron donor such as emulsified oil substrate into the contaminated source area. The new observation well may also be utilized for the ISB pilot test program and possibly as a performance monitoring well during remedial action.

The pumping well shall screen the entire thickness of the saturated zone, from an approximate depth of 42 feet bgs to the bedrock at approximately 66 feet bgs, exact depths will be field verified. This screened interval will meet the needs of both the aquifer test as well as the potential injection needs of the ISB pilot test. The screen slot size will be selected appropriately to facilitate the ISB injection needs while taking into account the field observations, including grain size to ensure that the screen openings are not too large. The pumping well will and have a five-foot sump, extending into the upper, weathered bedrock, to house a pressure transducer and data loggers such that it will not be disturbed by the pump.

Well drilling and completion will not require disinfection of equipment, materials, or supplies since this borehole drilling will result in monitoring wells, not domestic water supply wells. Furthermore, PWT does not want to alter the chemistry of the groundwater in the Beall Source Area by the introduction of disinfection chemicals, including chlorine.

5.2 Groundwater Sampling and Initial Depth Measurements

After the installation and development of the new wells, all wells identified to be measured during the aquifer test will be sampled for volatile organic compounds (EPA Method 524.2) pursuant to PWT's Supplemental Sampling Program QAPP (PWT 2012). The same wells will be sampled at the conclusion of the CRT.

Also prior to the start of any pumping and after development, the depth to groundwater and total depth will be recorded manually for the pumping well and each observation well identified for the CRT. The measurements will be collected and recorded pursuant to SOP PWT/GW.102, Water Level Measurements in Wells and Piezometers, found in Appendix B.

5.3 Step Drawdown Testing

The step drawdown test will be used to test the performance of the pumping well, including the maximum yield, specific capacity, well loss coefficient, and well efficiency. To ensure that a functioning pumping well has been installed and to determine its capacity and maximum sustainable pump rate, an eight hour step drawdown pump-test shall be performed within two days after well development, using SOP PWT/GW.106, Well Development, found in Appendix B. Field parameters will be measured following procedures detailed in SOP PWT/GW.108, Field Parameter Measurement, found in Appendix B. The step drawdown test will consist of continuously pumping the well at progressively increasing fractions of the proposed discharge and recording drawdown in the pumping well.

After the new wells are drilled, a temporary pump will be installed in the pumping well for the step drawdown test. The pumping well will be at "normal' static level prior to the test. Water level measurements will be conducted 24, 16, 12, 3, 2, and 1 hour prior to initiating pumping. Within the hour immediately preceding pumping, water level measurements will be taken at 20-minute intervals to establish any short term trend in water levels changes that may be occurring. Barometric measurements of atmospheric pressure (inches of mercury) will also be made concurrently with the manual water level measurements. The barometric measurements will allow appropriate corrections to be applied to the drawdown data. The step drawdown test may take up to or more than eight hours to complete, and the water levels will be allowed to return to static levels before the start of the CRT.

PWT shall furnish accessories necessary to accurately measure the flow from the pump up to twice the rate desired for the well. A mechanical flow meter with an indicator and a totalizer register shall be used. Standard procedures (e.g., flow meter manufacturers, State of Washington internet search, USEPA Region 4 Operating Procedure for Wastewater Flow Measurement) suggest a minimum distance of ten pipe diameters straight pipe upstream and five pipe diameters of straight pipe downstream of the flow meter and totalizer is necessary to ensure accurate readings. PWT will consider any manufacturer's specific suggested modifications to this standard. The mechanical flow meter shall be calibrated prior to use and at the termination of the project per the manufacturer's instructions. All results shall be summarized and submitted to the PWT Project Manager and Project Engineer for approval. The rate of pumping shall be maintained within +/- 10 percent of the designated pumping rate and depth to water level measurements accurate within 0.01 feet.

The submersible pump, or equivalent type, used during testing shall be located at the bottom of the saturated zone screened interval. The estimated maximum flow rate for the pumping well is 11.0 gpm. Based on the aquifer response, this maximum flow rate may be adjusted in the field. Pumping shall commence at a constant rate equal to 0.5 times the estimated maximum flow rate for the pumping well and shall continue for two hours. Water levels in the pumping well shall be measured using transducers and data loggers (with manual measurement backup at one half the frequencies for the data logger noted below). The water level in the pumping well will be recorded during each step, at a minimum, every minute for the first 10 minutes, every five minutes for 10 to 30 minutes, and every 10 minutes for 30 to 120 minutes. Immediately following this step (Step 1), three additional steps shall be conducted at flow rates of 0.75 (Step 2), 1.0 (Step 3), and 1.25 (Step 4) (in that order) times the maximum flow rate, if the well has sufficient capacity to produce at those rates for the required time (120 minutes each Step). The water level in the pumping well shall be recorded as prescribed for Step 1 for Steps 2 and greater. If the water level drops to less than five feet above the pump intake at a pumping rate prior to the two hours, subsequent steps at higher rates need not be attempted. However, the flow rate shall be reduced until the water level in the pumping well stabilizes to at least five feet above the pump intake and the test continued for the remainder of the two hours.

The field team will calculate the formation and well loss coefficients (per the equations below) with real-time data from the step drawdown test. If the maximum design flow rate has been reached before all of the steps have been executed, the test will continue for at least two additional steps to confirm the calculations. Alternatively, if the maximum design flow rate has not been reached by the end of Step 4 as described above, the test will continue for at least two steps beyond the point at which the calculations show the maximum design rate has been reached.

This data shall be tabulated in the following format:

	Q_w (pumping rate)	**s_w (drawdown at pumping well)**	**s_w / Q_w**
Step 1	-	-	-
Step 2	-	-	-
Step 3	-	-	-
Step 4	-	-	-

This data can be used to derive the formation loss coefficient, β, and the well loss coefficient, α, by using the following equation (Chin 2006):

$$\frac{Sw}{Qw} = \beta + \alpha \times Qw$$

Where Sw = drawdown at pumping well
Qw = pumping rate from pumping well
β = formation loss coefficient
α = well loss coefficient

The formation loss coefficient and the well loss coefficient are able to be solved for simultaneously. The well loss coefficient shall then be compared with the following table to characterize the well condition:

Well Loss Coefficients, α	Well Condition
<1800	Properly designed and developed
1800 – 3600	Mild deterioration or clogging
3600 – 14400	Sever deterioration or clogging
>14400	Difficult to restore well to original capacity

(Chin 2006)

The PWT Project Manager and Project Engineer shall be contacted at the completion of the step drawdown test to calculate and confirm the well performance criteria. If the well does not meet the performance criteria, the PWT Project Manager and Project Engineer shall contact the EPA RPM for further direction. If the well does meet the performance criteria, the CRT shall commence.

This step drawdown test will establish an optimum pumping rate for testing the hydraulic properties of the aquifer through the CRT. An expected drawdown distance can be determined with a given pumping rate, by using the following equation (Chin 2006):

$$Sw = \beta \times Qw + \alpha \times (Qw^2)$$

From this drawdown value, the specific capacity, Qw/Sw, can be calculated and compared with previously tabulated values to establish how productive the well is at the given pumping rate. From these calculations, an optimum pumping rate for the CRT can be established.

5.4 Constant Rate Aquifer Testing

Before the CRT begins, sufficient time (estimated time of 24 hours) must pass to allow the pumping well to recover fully from the step drawdown test. PWT will measure the water level of the pumping well and observation wells and will consider the wells to be recovered when the water levels reach 95 percent of the measured water level prior to the start of the step drawdown test. PWT will not begin the CRT until the wells have recovered. PWT will utilize a pump able to operate in a continuous mode (i.e., a Grundfos Redi Flo pump) for the CRT. Since the saturated thickness of the upper hydrostratigraphic unit is 25 feet, at a maximum, there is relatively little available drawdown, which could limit the duration of the test.

The proposed test site is a chlorinated solvent (trichloroethene) source area and the pumping well will be placed within the source area to minimize the potential for pulling contaminated water away from the source area. Pursuant to Section 5.2, contaminant concentrations in each well used during the aquifer test will be measured immediately before and after pumping. These results, when compared to historical and future data, will further PWT's understanding of contaminant flow and overall impact of the aquifer test, if any, to the groundwater plume. In addition, the contaminant concentration data will be used to evaluate disposal options for the extracted water. This issue is discussed further in Section 5.7, Investigation-Derived Waste Management.

Wells MW012, MW200, MW201, MW205, MW220, and MW221 will be equipped with automatic data loggers to provide a seamless and accurate record of drawdown, within the pumping well and in the adjacent water-bearing unit. The data loggers will be programmed to record the depth to water level measurement every minute for the duration of the test. Manual measurements of the depth to groundwater with concurrent barometric pressure readings will be collected from all of the CRT wells every thirty minutes for the first 6 hours of the test, morning, mid-day, and evening for the duration of the test, and again every thirty minutes for 6 hours at the completion of the CRT during well recovery for comparison to the operation of the dataloggers. The frequency of manual recordings may be modified (either increased or decreased) in the field based on aquifer response, field observations, and equipment performance.

Well Identification	Distance to MW221 (feet)	Transducer Recording Frequency (minutes)[1]	Manual Recording Frequency[2]
MW012	166	1	30 min/12 hours/30 min
MW200	30	1	30 min/12 hours/30 min
MW201	56	1	30 min/12 hours/30 min
MW204	298	None installed	30 min/12 hours/30 min
MW205	212	1	30 min/12 hours/30 min
MW206	233	None installed	30 min/12 hours/30 min
MW220	15	1	30 min/12 hours/30 min
MW221	N/A	1	30 min/12 hours/30 min

1 – The data logging transducers will run continuously beginning one hour prior to the pump starting until the well reaches complete recovery.
2 – Manual recording will occur every 30 minutes after the pump initially starts for up to 6 hours, every 12 hours during the test, and again every 30 minutes after the pump is turned off until well reaches complete recovery.

The transmissivity will be hand calculated from the field data, using the Theim equation shown below (Chin 2006):

$$T = \frac{Qw}{2\pi(s'1 - s'2)} * \ln\frac{r2}{r1}$$

Where:

$$s'1 = s1 - \frac{s1^2}{H}$$

and

$$s'2 = s2 - \frac{s2^2}{H}$$

Where T = transmissivity in an unconfined aquifer
Qw = pumping rate from pumping well
s1 = drawdown from observation well 1
s2 = drawdown from observation well 2
r1 = distance between pumping well and observation well 1
r2 = distance between pumping well and observation well 2
H = saturated thickness in the absence of pumping

The following table summarizes the resulting decision-making tools and identifies the hydraulic parameters that can be determined directly from the pumping tests or pumping test measurement component. This table also shows that some of the parameters may be determined in more than one manner.

Table 1: Data provided by Drawdown Measurements and Pumping Test

Step Drawdown Test	**Constant Rate Test**	**Recovery Data (optional)**	**Observation Well Data**
Well Efficiency, Pumping Rate, Well Loss Coefficient, Specific Capacity, Maximum Yield	Transmissivity, Hydraulic Conductivity, Specific Yield	Transmissivity, Storage Coefficient	Storage Coefficient

5.5 Schedule

The aquifer test program is tentatively scheduled to begin in August 2012. Drilling and well development is estimated to take three days, the step drawdown test up to one day, and the CRT up to three days.

5.6 Equipment Decontamination

Field decontamination is anticipated for the hollow stem auger drill rig. Prior to commencement of drilling operations, in between borings, and before leaving the site, all equipment and tools will be cleaned using a high-pressure steam cleaner or other method provided by the Drilling Contractor. Additionally, rods and other non-dedicated equipment coming in direct contact with subsurface materials will be decontaminated between each drilling location. The Drilling Contractor is responsible for containerizing decontamination water and for cleaning the decontamination area after use. If alternate decontamination procedures are implemented by the Drilling Contractor, then these procedures shall be presented to PWT for review and acceptance, and shall be in accordance with accepted industry practices.

Equipment will be inspected for evidence of fuel oil or hydraulic system leaks consistent with SOP PWT/ES.103, Personnel and Equipment Decontamination, found in Appendix B. If lubricants are required for downhole equipment, only pure vegetable oil will be used.

Aquifer testing equipment will be decontaminated prior to use or disposable equipment will be used. After use, the equipment will either be properly disposed or decontaminated. If field decontamination is required, it will be conducted and documented in accordance with procedures described in SOP PWT/ES.103, Personnel and Equipment Decontamination, found in Appendix B.

5.7 Investigation-Derived Waste Management

Drilling wells typically results in the generation of investigation-derived waste. Potentially contaminated soil, groundwater, and used personal protective equipment will all be produced in the course of the aquifer testing program. Soil will generally be containerized, labeled, and stored at a secure location onsite until disposed of properly pursuant to PWT's Supplemental Sampling Program QAPP (PWT 2012). Used personal protective equipment will be disposed of in accordance with SOP PWT/GW.105, Investigation Derived Waste Management, found in Appendix B.

PWT is coordinating with the City of Billings' pretreatment program to determine the appropriate disposal for the extracted groundwater. Pursuant to an email request dated March 12, 2012 from the City of Billings pretreatment program, PWT collected samples for semi-volatile organic compounds and metals from MW201 on May 1, 2012, which are in addition to those analyses identified in PWT's Supplemental Sampling Program QAPP (PWT 2012). The analytical results were provided to the City of Billings who will then make the determination of the appropriate disposal procedure. The City of Billings will provide written documentation to PWT, including instruction for the disposal procedure, prior to PWT's start of the extraction of groundwater. PWT will provide the documentation to the EPA and proceed only after EPA approval of the disposal procedure. PWT will include the City's instructions and a detailed disposal procedure as an addendum to this work plan.

Potential disposal procedures may include:

- Direct discharge to the publically-owned treatment works.
- Storage of extracted groundwater in 21,000-gallon Baker storage tanks. Three tanks may be required based on current volume estimates. This water will then be analyzed (for volatile organic

chemicals, semi-volatile organic chemicals, and metals) from the Baker storage tanks. The analytical results will be provided to the City of Billings for evaluation and disposal determination.

- If the City of Billings determines that the stored extracted groundwater requires treatment prior to disposal, PWT will treat the water by filtration using 55 gallon drums with granular activated carbon. PWT will then coordinate with the City of Billings for final approval for disposal. If this process is deemed the appropriate disposal procedure, PWT will include as an addendum to this work plan a more detailed description for EPA approval of this treatment, testing and disposal method.

6.0 REPORTING

An aquifer test report will be prepared that summarizes the results of the test and includes recommendations. The aquifer test report will also include a discussion of the extracted groundwater disposal procedure. The hydraulic characteristics, including hydraulic conductivity and transmissivity, that are estimated as a result of this aquifer testing program will be used for the feasibility evaluation and potential development of the ISB system. This report will be used to support the remedial design and development and the Controlled Groundwater Use Area, and will be submitted to the EPA within 30 days after the aquifer test is completed.

7.0 REFERENCES

Chin, David A. (Chin). 2006. *Water Resources Engineering*. 2nd ed. Pearson Education, Inc. 2006.

Tetra Tech EM Inc. (TTEMI). 2003. *Remedial Investigation Report, Lockwood Solvent Groundwater Plume Site*. June.

Pacific Western Technologies, Ltd. (PWT). 2012. *Remedial Design, Supplemental Sampling Program Quality Assurance Project Plan, Lockwood Solvent Groundwater Plume Site Beall Source Area Operable Unit 1*. March.

FIGURES

Figure 1

Site Layout

Aquifer Test Work Plan
Beall Source Area Operable Unit 1
Lockwood Solvent Groundwater Plume Site

July 2012

- **2003 Slug Test**
- **Existing Monitoring Well**
- **Existing Monitoring Well/ Aquifer Test Observation Well**
- **New 4" Monitoring Well/ Aquifer Test Pumping Well**
- **New 2" Monitoring Well/ Aquifer Test Observation Well**
- **Beall West Plume**
- **Site Boundary**
- **Culvert**
- **Drainage ditch**

Note: Areas Approximate

N W E S

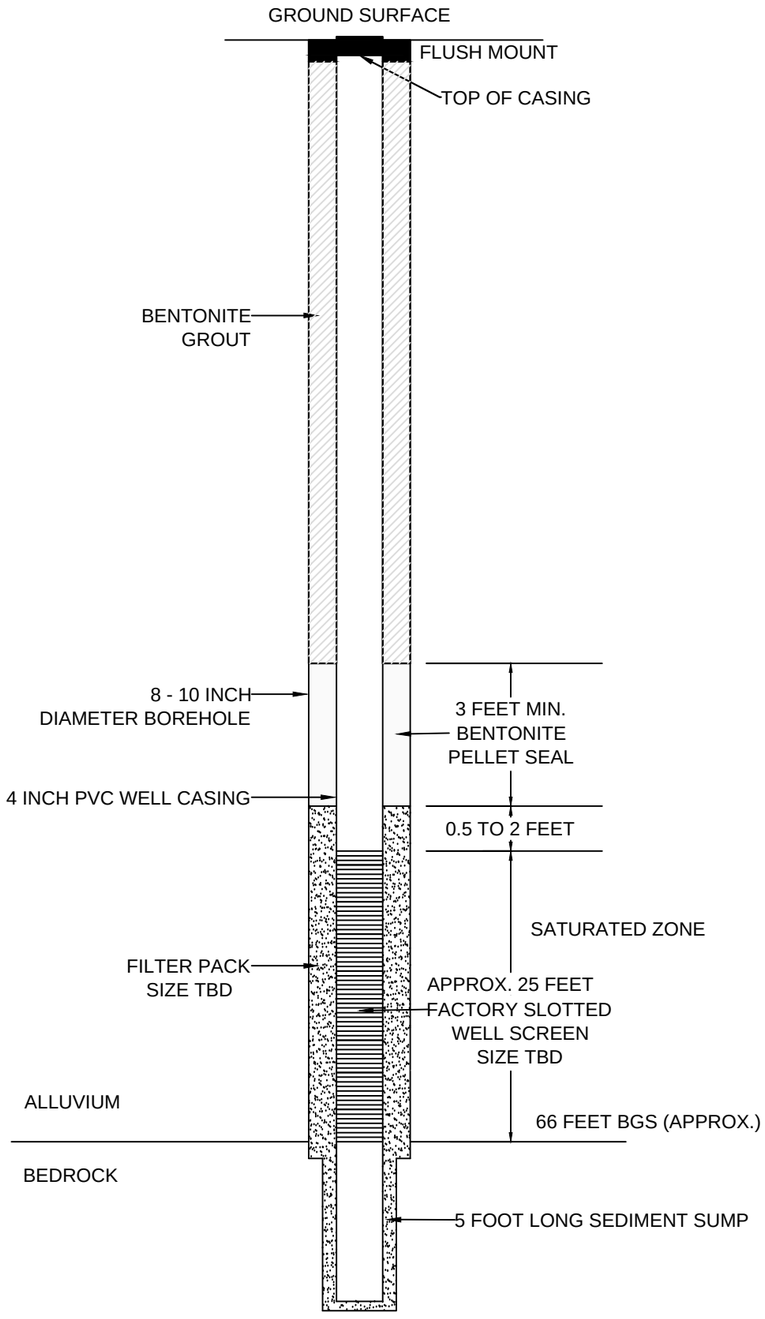
0 100 200 400 Feet

State Plane Coordinate System
Montana - NAD 83

Aerial Photograhy Provided by Bing Maps
NAIP 2009

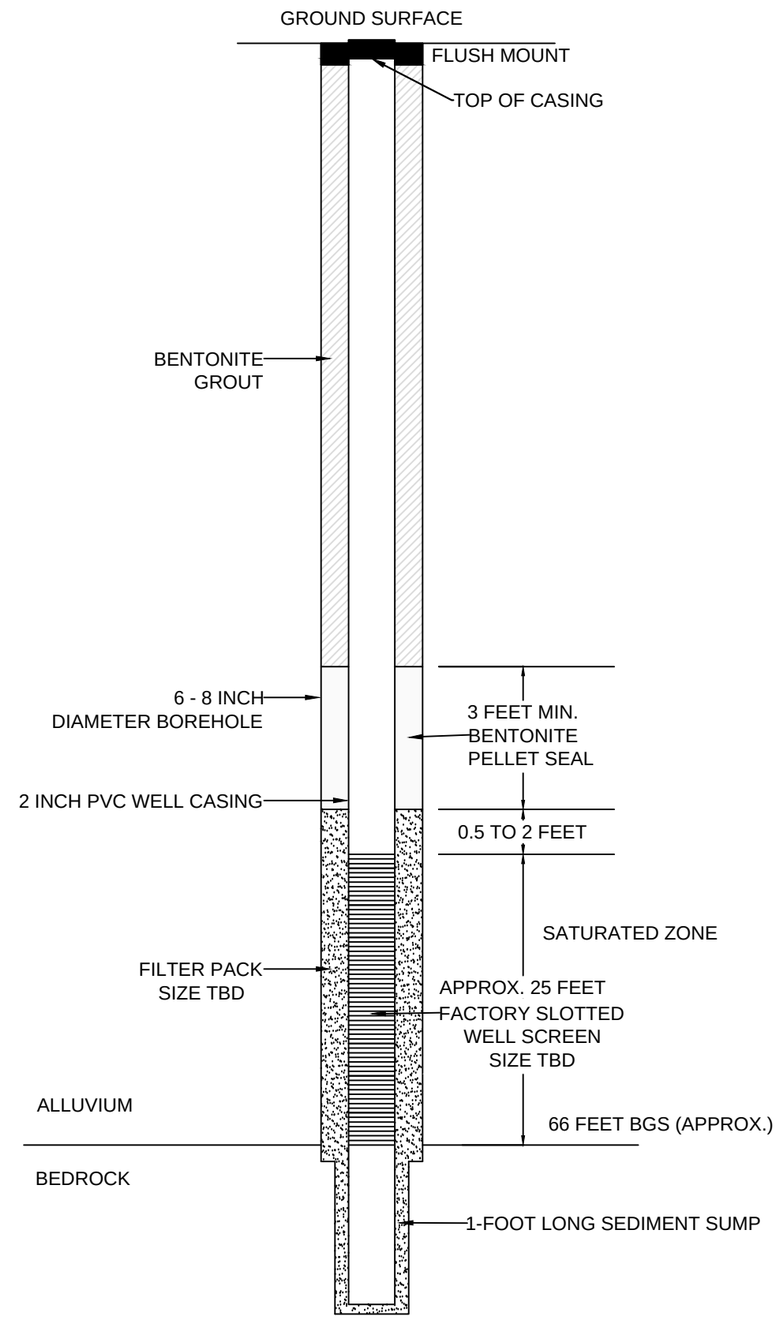
PACIFIC WESTERN TECHNOLOGIES, LTD.

Path: K:\GIS Library\122_LockwoodRD\CORA 122.007.004\Figure_1_sitelayout_aquifertest_071112.mxd



1 NEW 4 INCH PUMPING WELL SCHEMATIC

NOT TO SCALE



2 NEW 2 INCH OBSERVATION WELL SCHEMATIC

NOT TO SCALE

Notes:

1. NEW PUMPING WELL WILL BE A 4 INCH MONITORING WELL INSTALLED TO 71 FEET IN DEPTH TO INCLUDE A FIVE FOOT SUMP. SCREENED INTERVAL WILL BE APPROXIMATELY 20 TO 25 FEET IN LENGTH. BOREHOLE WILL BE 8 TO 10 INCHES IN DIAMETER.

2. NEW OBSERVATION WELL WILL BE A 2 INCH MONITORING WELL INSTALLED TO 67 FEET IN DEPTH TO INCLUDE A ONE FOOT SUMP. SCREENED INTERVAL WILL BE APPROXIMATELY 20 TO 25 FEET IN LENGTH. BOREHOLE WILL BE 6 TO 8 INCHES IN DIAMETER.

3. FILTER PACK AND SLOT SIZE WILL BE DETERMINED IN CONSULTATION WITH THE DRILLING SUBCONTRACTOR.

NOT TO SCALE

Lockwood Solvent Groundwater Plume Site
Beall Source Area OU1
Aquifer Test Work Plan
FIgure 2
CONCEPTUAL WELL DESIGNS

Drawn: GRH	Date: APRIL 17, 2012
Revised: GRH Rev.2	Rev. Date: JUNE 8, 2012
Checked: CDL	Approval: SHS

PACIFIC WESTERN TECHNOLOGIES, LTD.

Drawing:

File location:

APPENDIX A
EQUIPMENT AND MATERIALS LIST

- Drill rig equipped for drilling with hollow-stem augers
- Silica sand filter pack
- Granular bentonite
- Rig mounted mud/grout pump
- Tank for mixing bentonite grout
- Sand bailer
- 1 inch to 2 inch ID tremie pipe, with hose
- 2 inch ID PVC casing (1.5 to 2 foot lengths; for use as protective casing)
- Locking “J” caps for 2 inch ID protective casings
- Flush-mount assemblies (if required)
- Locks for well lids
- Grundfos Redi Flo pump, or equivalent, operating in continuous mode, for use in the step drawdown test and the CRT
- Onsite generator to power the pump (if an onsite power connection is not available)
- Drums for containment of cuttings
- Field book with black waterproof pens
- Boring log forms
- Tape measure
- Stainless steel knife, screwdriver, rock hammer
- Decontamination equipment and supplies (e.g., wash/rinse tubs, brushes, Alconox, plastic sheeting, paper towels, sponges, baby wipes, garden-type water sprayers, large plastic bags, potable water, distilled water and/or deionized water)
- Electronic water level meter
- Multi-parameter flow-through cell for measurement of field parameters (e.g., Horiba)
- Spare batteries (appropriate sizes for all field equipment using batteries)
- Photoionization detector and personal protective equipment as required by the Site-Specific Health and Safety Plan
- Mechanical flow meter with an indicator and a totalizer register
- Six pressure transducers and data loggers
- barometer
- Stop watch or other time recording device as backup to data loggers
- Sampling equipment and supplies (nitrile gloves, disposable tubing for the flow through cell, sample containers, coolers, ice, zip-top bags, sample field forms, shipping forms, sample labels)

APPENDIX B
STANDARD OPERATING PROCEDURES

Utility Clearance (PWT/ES.101)

Personnel and Equipment Decontamination (PWT/ES.103)

Well and Borehole Abandonment (PWT/ES.104)

Water Level Measurements in Wells and Piezometers (PWT/GW.102)

Monitoring Well and Piezometer Installation (PWT/GW.103)

Investigation Derived Waste Management (PWT/GW.105)

Well Development (PWT/GW.106)

Field Parameter Measurement (PWT/GW.108)

Borehole Logging (PWT/SS.101)

TABLE OF CONTENTS

Section Page No.

TABLE OF CONTENTS i

1.0 PURPOSE 1

2.0 RESPONSIBLE PERSONNEL 1

3.0 PROCEDURES 1

4.0 DOCUMENTATION 1

REVISION LOG		
Revision Number	Description	Date
1.0	Original SOP	July 2011
2.0	Revise for Montana Operations	March 2012

1.0 PURPOSE

This Standard Operating Procedure (SOP) provides technical guidance and procedures for utility clearances at project sites. This SOP serves as a supplement to site-wide and investigation area specific workplans and the site-specific Quality Assurance Project Plan (QAPP) and may be used in conjunction with other SOPs.

2.0 RESPONSIBLE PERSONNEL

The contractor project manager has the overall responsibility for implementing this SOP. The project manager will be responsible for assigning staff to implement this SOP and for ensuring that the procedures are followed by all personnel. The contractor site manager is responsible for ensuring that the appropriate utility clearances have been performed prior to any intrusive field activities. All utility clearances will comply with applicable portions of the project-specific health and safety plan (HASP).

3.0 PROCEDURES

Locations selected for intrusive field activities (e.g. borehole drilling, trenching) will be cleared of utilities before field activities begin. Before intrusive field activities can be performed. Each location will be cleared for the following utilities; natural gas, telecommunications, water and sewer, electrical, fiber optics and cable. At some locations additional utilities that may require clearance include petroleum service lines, irrigation lines, and building foundations. Notification for a utility clearance should be scheduled at least 1 week in advance.

It is the responsibility of the contractor to contact utility organizations directly for utility clearance.

Some utility companies guarantee that they will be present at the scheduled meet time. Other utility companies may call to reschedule at a different time or day or reschedule the day of the scheduled utility meet. If possible the utility clearance should be done a few days prior to intrusive work to allow enough time for utilities companies to clear their lines.

The utility companies will identify their utilities with spray paint on the ground. They also may leave a map at the location with their lines identified.

In addition to the contractor, each subcontractor performing the actual intrusive work is required to attend the utility clearance, to pose any necessary questions. The subcontractors should request the same meet time that the primary contractor has set up. A representative from each of the subcontractors is required to be present at the utility meet.

4.0 DOCUMENTATION

Utility clearance activities will be documented in the field logbook by the site manager or rig geologist. The documentation will include the utility locator service sign-off, personnel present for the locate, the final project-site representative approval (if requested), and any current and historical maps used in locating utilities (or references to locations of maps for future reference).

PWT STANDARD OPERATING PROCEDURE

TABLE OF CONTENTS

Section ..... Page No.

TABLE OF CONTENTS i

1.0 PURPOSE AND SCOPE 1

2.0 PERSONNEL QUALIFICATIONS 1

3.0 MATERIALS AND EQUIPMENT 1

4.0 PROCEDURES 1

4.1 Decontamination 1

4.1.1 Location of Decontamination Activities 1

4.1.2 Personnel Decontamination 2

4.1.3 Small Sampling Equipment Decontamination 2

4.1.4 Decontamination of Submersible Pumps 3

4.1.5 Heavy Equipment Decontamination 3

4.1.6 Decontamination Sediment and Fluids 4

4.2 EQUIPMENT RINSATE SAMPLING 4

5.0 DECONTAMINATION DOCUMENTATION 4

REVISION LOG		
Revision Number	Description	Date
1.0	Original SOP	July 2011
2.0	Revise for Montana Operations	March 2012

1.0 PURPOSE AND SCOPE

This Standard Operating Procedure (SOP) provides technical guidance and methods that will be used to conduct decontamination of personnel and investigation equipment during environmental investigations. This SOP serves as a supplement to site-wide and investigation area specific workplans and the site-specific Quality Assurance Project Plan (QAPP) and may be used in conjunction with other SOPs.

2.0 PERSONNEL QUALIFICATIONS

Personnel overseeing and performing decontamination activities will have knowledge and experience in the equipment and methods proposed, or will work under the direct field supervision of knowledgeable and experienced personnel. Personnel will also be qualified to perform this work in accordance with the project-specific health and safety plan (HASP).

3.0 MATERIALS AND EQUIPMENT

The following materials and equipment may be needed for personnel and equipment decontamination:

- Monitoring equipment and personal protective equipment (PPE) as outlined in the HASP.
- Decontamination equipment and supplies (e.g., wash/rinse tubs, nitrile disposable gloves, brushes, Alconox, plastic sheeting, paper towels, sponges, baby wipes, garden-type water sprayers, large plastic bags, potable water, distilled water and/or deionized water [laboratory-grade])
- High pressure washer/steamer
- Four-foot long capped PVC casing for decontamination of submersible pumps
- Drums or other approved water-tight containers for containing decontamination sediment and fluids
- Materials necessary to construct an investigation site-specific decontamination facility, if required (e.g., heavy plastic sheeting, berming materials, sump pump, water tanks, roll-off bins)

4.0 PROCEDURES

This procedure describes the method for physically removing contaminants. It applies to chemical and radioactive decontamination of personnel and equipment used in field investigations. All equipment must be decontaminated before use at the project site, prior to sample collection, and before being removed from the project site. Decontamination of personnel, sampling equipment (e.g., soil sampling equipment and submersible pumps) and heavy equipment (e.g., hollow stem auger rigs, backhoes) is required to ensure the health and safety of personnel, reduce the potential for sample cross-contamination, and reduce the potential for contamination to enter or leave the project site on personnel or equipment.

4.1 Decontamination

4.1.1 Location of Decontamination Activities

Decontamination activities may take place either in the exclusion zone of the investigation site or at a decontamination facility designed to contain larger volumes of potentially contaminated fluids and materials, or at a combination of the two. Decontamination activities conducted in the exclusion zone will be limited to washing of personnel and small sampling equipment using wash tubs or wipes. Scraping of PPE and large equipment to remove adhered clumps of soil will also be performed in the exclusion zone.

Decontamination of heavy equipment or equipment requiring high-pressure washing will be performed at a decontamination facility designed to contain large volumes of washing fluids. The decontamination facility may consist of an investigation area-specific temporary facility constructed near the investigation

site, or a decontamination facility central to the project site that may be used for multiple investigations. If a central decontamination facility is used, sufficient decontamination of equipment will be performed in the exclusion zone prior to moving to the central facility to reduce the potential for deposition of contaminated materials on roadways between the investigation area and decontamination facility.

Decontamination facilities will be constructed to limit the potential for contact of potentially contaminated materials (decontamination sediment and fluids) with environmental media (i.e., soil or water) in the decontamination area. This will be accomplished by performing decontamination activities in lined and bermed areas, and by containing decontamination sediment and fluids as they are generated.

4.1.2 Personnel Decontamination

The following steps will be used to perform personnel decontamination:

- Soil adhering to boots, apparel and equipment will be scraped off at the sampling or excavation site.
- Boots and outer apparel that will not be damaged by water will be washed with Alconox low-sudsing detergent and potable water and scrubbed with a bristle brush or similar utensil (if possible). Apparel will be rinsed with potable water.
- Coveralls removed (if used).
- Hard hat and other safety equipment removed and washed with Alconox and rinsed with potable water.
- Gloves and respirator (if used) removed.
- Personnel shall wash hands, face, and forearms before eating/drinking.
- Following decontamination, apparel will be placed in a clean area, on clean plastic sheeting to prevent contact with contaminated soil. If the apparel is not used immediately, the equipment will be stored in plastic sheeting or heavy duty trash bags.
- Disposable PPE will be handled in accordance with Section 4.1.1 of PWT's Investigation Derived Waste Management SOP.

4.1.3 Small Sampling Equipment Decontamination

Small sampling equipment consists of split spoons, sample bowls, scoops, hand augers, filtering devices, non-dedicated pumps, water level meters, and other such small equipment used in the exclusion zone or the immediate vicinity of the sample collection location. Small sampling equipment is designed to be decontaminated at the sampling location using small wash tubs. Decontamination of small sampling equipment does not require high-pressure washing or steam cleaning, or result in production of large volumes of decontamination sediment or fluids.

The following steps will be used to decontaminate small sampling equipment:

- To reduce personal exposure, personnel will dress in suitable PPE in accordance with the HASP.
- Soil adhering to equipment will be scraped off at the sampling site and containerized.
- Equipment that will not be damaged by water will be placed in a wash tub containing Alconox or equivalent detergent and potable water and scrubbed with a brush. Equipment will then be rinsed initially with potable tap water and then with distilled water.
- Equipment that cannot be submerged in water (e.g., air monitoring devices, electronic devices) will be carefully wiped clean using a sponge and detergent water or baby wipes.

- Wash and potable rinse water should be replaced frequently. Decontamination sediment and water will be handled as investigation derived waste (IDW) (see Section 4.1.6).
- Disposable sampling equipment will be handled in accordance with PWT's Investigation Derived Waste Management SOP.

Following decontamination, equipment will be placed in a clean area or on clean plastic sheeting. If the equipment is not used immediately, the equipment will be covered or wrapped in plastic sheeting or trash bags.

4.1.4 Decontamination of Submersible Pumps

Submersible pumps used to conduct groundwater sampling will be decontaminated before being placed in the well. A decontaminated four-foot length of polyvinyl chloride (PVC) capped on one end will be utilized for this procedure. The following steps will be used to decontaminate submersible pumps:

- To reduce personal exposure, personnel will dress in suitable PPE in accordance with the HASP.
- Scrub the outside of the pump with a solution of Alconox or equivalent detergent and potable water and then rinse with potable water and distilled water.
- Fill the PVC tube with Alconox/potable water solution.
- Pump the solution through the submersible pump by lowering the intake tube of the pump to the bottom of the PVC tube. Be careful not to uncover the intake of the pump to prevent damage to the pump.
- Rinse the inside of the PVC tube with potable water to remove detergent and then fill the PVC tube with potable water.
- Pump the potable water through the pump.
- Repeat the rinse procedure with distilled water.
- Decontamination sediment and water will be handled as IDW (see Section 4.1.6 below).

Following decontamination, the pump will be wrapped in plastic sheeting or trash bags and placed in a clean area.

4.1.5 Heavy Equipment Decontamination

Heavy equipment used within the exclusion zone and/or for intrusive activities (e.g., drill rigs and associated heavy drilling and sampling equipment, backhoes, sampling-related vehicles) will be decontaminated upon arrival at the project site, between investigation locations (i.e., between boreholes and test pits), and prior to leaving the project site. The following steps will be used to decontaminate heavy equipment:

- To reduce personal exposure, personnel will dress in suitable PPE in accordance with the HASP.
- Prior to use at the project site and between investigation locations (i.e., between boreholes, test pits), the portion of the equipment directly exposed to potential contamination (e.g., augers, drill rods, backhoe bucket) will be decontaminated by pressure washing the equipment at the decontamination facility.
- Drill rigs and vehicles will not require pressure washing between investigation locations unless they have become substantially dirty as a result of drilling or investigation activities.
- Prior to leaving the project site, the portions of the heavy equipment potentially exposed to contamination will be pressure washed using potable water at the decontamination facility.

Special attention will be given to removing any soil or other site-related foreign materials on the equipment.

- Decontamination sediment and water will be handled as IDW as described in Section 4.1.6 below.

4.1.6 Decontamination Sediment and Fluids

Sediment and fluids from decontamination activities will be initially contained and stored in approved water-tight containers at the sampling site or decontamination facility. Each container will be labeled with its contents and the date using a paint pen, or permanent marker. As soon as practical, decontamination sediment and fluids will be transferred from the sampling site to a designated IDW management area. Handling of IDW is addressed by PWT's Investigation Derived Waste Management SOP.

4.2 Equipment Rinsate Sampling

Equipment rinsate blank samples may be collected to verify the effectiveness of the decontamination procedures. Equipment rinsate blank sampling is usually performed for small sampling equipment, rather than heavy equipment. The frequency of rinsate blank sample collection, as well as the analysis methods, will be specified in the investigation-specific FSP. In general, the rinsate blank sample collection procedure will consist of rinsing decontaminated equipment with laboratory-grade deionized water and collecting the rinsate water in sample bottles provided by the analytical laboratory. Special attention will be given to rinsing the portions of the equipment exposed to environmental samples or potential contamination. Rinsate samples will be handled in the same manner as environmental and other quality assurance/quality control (QA/QC) samples in accordance with PWT's Sample Handling SOP. Rinsate sample collection will be documented in the same manner as environmental and other QA/QC samples.

5.0 DECONTAMINATION DOCUMENTATION

Field personnel will be responsible for documenting proper sampling and heavy equipment decontamination. The purpose of documentation is to demonstrate in the written field record that decontamination was performed in accordance with this SOP. Decontamination activities will be documented at least each day they are performed. The documentation will be recorded in a logbook or on appropriate project forms (i.e., boring log, sample field data sheets). The information recorded concerning decontamination will include:

- Date and times of decontamination
- Location of decontamination activities (i.e., sample site, central decontamination facility)
- Decontamination personnel and materials
- Decontamination steps/observations
- Other applicable information

TABLE OF CONTENTS

Section Page No.

TABLE OF CONTENTS i

List of Attachments i

1.0 PURPOSE 1

2.0 PERSONNEL QUALIFICATIONS 1

3.0 MATERIALS AND EQUIPMENT 1

4.0 PROCEDURES 1

4.1 Borehole Abandonment 1

4.2 Monitoring Well and Piezometer 2

5.0 DOCUMENTATION 2

ATTACHMENT A 4

WELL/BOREHOLE ABANDONMENT FORM 4

List of Attachments

Attachment A Borehole Abandonment Form

REVISION LOG		
Revision Number	Description	Date
1.0	Original SOP	July 2011
2.0	Revise for Montana Operations	March 2012

1.0 PURPOSE

This Standard Operating Procedure (SOP) provides technical guidance and methods that will be used to seal and abandon wells and boreholes. This SOP serves as a supplement to site-wide and investigation area specific workplans and the site-specific QAPP. This SOP may be used in conjunction with other SOPs.

2.0 PERSONNEL QUALIFICATIONS

Personnel overseeing and performing a well/borehole abandonment will have knowledge and experience in working with drill rigs and sealing and abandoning environmental boreholes. Personnel will also be qualified to perform this work in accordance with the project-specific health and safety plan (HASP).

3.0 MATERIALS AND EQUIPMENT

The following materials and equipment may be needed for well/borehole abandonment:

- Personal protective equipment (PPE) as outlined in the HASP
- Drill rig equipped with a hoist (for removal of well/piezometer casing and screen)
- Grout mixing and pumping equipment
- Grouting materials and equipment (potable water, bentonite powder, bentonite chips, cement for grouting [portland type II or IV], large tank for mixing grout, trash pump for mixing grout, plastic or steel tremie pipe)
- Well/Borehole Abandonment Form

Other materials and equipment may be needed based on field conditions.

4.0 PROCEDURES

Abandonment is the procedure by which a borehole is permanently sealed in place, or a monitoring well or piezometer is sealed in place or removed. The objective of abandonment is to eliminate the potential vertical pathway to the subsurface associated with boreholes or unneeded wells. Abandonment will be performed at the project site for the following:

- Following drilling and sampling of investigation wells/boreholes.
- To remove wells or piezometers no longer needed.

4.1 Borehole Abandonment

Investigation wells and boreholes drilled for collection of subsurface material samples will be abandoned immediately following sampling and/or data collection. Prior to any intrusive drilling associated with abandonment, utility clearance will have been accomplished according to the PWT Utility Clearance SOP.

The following steps will be performed to abandon a well or borehole:

- All wells/boreholes to be abandoned will be grouted with a cement/bentonite grout.
- Grout will be injected into the borehole using a tremie pipe as the hollow-stem augers are pulled. Measurements will be taken of the grout level during the process to verify that the grout level does not fall below the bottom of the augers, thus ensuring a continuous seal is injected into the borehole.
- The cement-bentonite grout mixture will consist of the following in accordance with in accordance with state specific well abandonment regulations. The amount of bentonite shall not

exceed 8% bentonite per dry weight of cement. The volume of water used is limited to 0.75 gallons per 94 pound sack of cement for each 1% of bentonite added.

- During grouting, water present in the well/borehole will be displaced up the well/borehole. Displaced water cannot be discharged to the ground surface. Displaced water will be pumped from the well/borehole as grouting progresses and contained in drums or other approved water-tight containers for handling as investigation derived waste (IDW). IDW management is addressed in the PWT Investigation Derived Waste Management SOP.
- Twenty-four hours after grouting, the well/borehole will be checked for grout settlement and will be topped off to the ground surface with grout, if necessary.
- Any excess grout will be placed in drums for disposal in accordance with the PWT Investigation Derived Waste Management SOP.

4.2 Monitoring Well and Piezometer

Monitoring wells or piezometers that are no longer needed may be abandoned at the client's request. The preferred method of abandonment is to remove the surface completion (i.e., protective casing, bollards, and surface seal), pull or drill out the well or piezometer casing and screen, drill out the annular seal and filter pack material, and seal the well/borehole.

In some cases it may not be feasible to remove the well casing. Wells that are not pulled or drilled out, will be sealed by injecting grout under pressure into the well casing. Well casings may be split prior to grouting.

Typically, the following steps will be performed to abandon a well or piezometer:

1. Remove the surface completion and surface seal.
2. Attempt to pull the well casing and screen using the rig hoist.
3. If the casing and screen cannot be pulled, attempt to drill out the casing and screen with the drill rig.
4. Once the casing and screen are removed, use the drill rig to drill out all annular seal and filter pack material.
5. Seal the well/borehole as described in Section 4.1.

If the well or piezometer cannot be pulled or drilled out, the well or piezometer will be sealed in place by injecting grout under pressure into the well casing. The PVC well casing may be split using a down-hole casing splitter prior to grouting.

All well/piezometer casing and annular materials will be handled as IDW. IDW management is addressed in the PWT Investigation Derived Waste Management SOP.

5.0 DOCUMENTATION

This rig geologist or other responsible person will document all borehole or well/piezometer abandonment procedures on the Well/Borehole Abandonment Form (Attachment A) and in the field logbook.

The following information will be documented:

- Borehole or well/piezometer designation
- Investigation contractor and personnel names
- Abandonment subcontractor and personnel names

- Dates of abandonment
- Measured diameters and depths of wells/boreholes and wells/piezometers prior to initiating abandonment activities
- Detailed record of abandonment procedures
- Volume of water produced and contained during abandonment
- Grout composition and quantity used
- Casing reused or left in place
- IDW generated

ATTACHMENT A
WELL/BOREHOLE ABANDONMENT FORM

Pacific Western Technologies Well/Borehole Abandonment Form

Well/Borehole Designation _____

Project Information

Project Name: _____

Investigation Contractor: _____ Rig Geologist: _____

Abandonment Contractor and Personnel: _____

Rig Type: _____ Tremie and Pumping Equipment _____

Well/Borehole Information

Circle one: Borehole Well

Borehole Dia. (in) _____ Borehole Depth (ft bgs) _____

Casing/Screen Material: _____ Surface Completion: _____

Depth to Water (ft) _____ from (circle) TOC (PVC) Ground Surface

Abandonment Information

Date and Time of Abandonment: _____

Borehole Abandonment:

Volume of Water Displaced and Contained _____

Grout Composition _____

Volume of Grout Placed (ft^3 or gal): _____

Well Abandonment: Casing and annular material removed? (circle) YES or NO

Describe well and annular materials removed and/or left in place (type, length, dia., condition):

_____

Volume of Water Displaced and Contained _____

Grout Composition _____

Volume of Grout Placed (ft^3 or gal): _____

IDW Generated: _____

Chronological Record of Activities (and comments)

_____

Rig Geologist's Name and Signature: _____

PWT STANDARD OPERATING PROCEDURE

WATER LEVEL MEASUREMENTS IN WELLS AND PIEZOMETERS

Procedure No. PWT/GW.102
Revision 1
Date effective: 3/31/07

APPROVED: _____ _____ Page 1 of 16
PWT Project Manager Date

TABLE OF CONTENTS

Section Page No.

1.0 PURPOSE....3
2.0 SCOPE....3
3.0 REQUIREMENTS....3

3.1 Personnel Qualifications....3
3.2 Equipment....3

4.0 INSTRUCTIONS....4
4.1 Surveying the Measuring Point....4
4.2 Using an Organic Vapor Monitor....5
4.3 Instruments and Associated Water Level Measurement Techniques....5

4.3.1 Electronic Water Level Sounder....5
4.3.2 Measuring Water Levels in Well Points....6
4.3.3 Immiscible Layers and Use of an Interface Probe....6
4.3.4 Graduated Steel Tape....8

4.4 Down-Hole Water-Level Pressure Transducer....8

4.4.1 Preparation....8
4.4.2 Installation....9
4.4.3 Operation....10

4.5 Decontamination....11

5.0 QUALITY ASSURANCE / QUALITY CONTROL....11
6.0 RECORDS....11
7.0 REFERENCES....13
7.1 Source References....13
7.2 Internal References....14

FORM PWT/GW.102A....15
FORM PWT/GW.102B....16

1.0 PURPOSE

This document contains guidelines for measuring water levels in wells and piezometers. Water level data can be obtained from wells and piezometers, or from surface water manifestations of the groundwater systems such as springs, lakes, and streams.

2.0 SCOPE

This document applies to all PWT personnel and subcontractors conducting groundwater-related work on the Vasquez/I70 Phase II RI/FS project. This document, which constitutes a Standard Operating Procedure (SOP), describes various acceptable methods for measuring water levels in wells and piezometers that will meet regulatory guidelines of accuracy.

3.0 REQUIREMENTS

The following sections identify the personnel qualifications and equipment for measuring water levels in wells and piezometers.

3.1 Personnel Qualifications

Personnel performing water level measurement procedures are required to have completed the initial 40-hour OSHA classroom training that meets the Department of Labor requirements 29 CFR 1910.120(e)(3)(i), and must maintain a current training status by completing the appropriate annual 8-hour OSHA refresher courses. Personnel must also have read and signed the appropriate Health and Safety Plan(s). Prior to engaging in water level measurement activities, personnel must have a complete understanding of the procedures described within this SOP and, if necessary, will be given specific training regarding these procedures by other personnel experienced in the methods described within this SOP.

Only qualified personnel will be allowed to perform these procedures. Required qualifications vary depending on the activity to be performed. The subcontractor's project manager will document personnel qualifications related to this procedure in the subcontractor's project QA files.

3.2 Equipment

The following is a list of basic equipment typically required when measuring water levels. Additional equipment may be required in less typical applications, and will be specified in the project-specific work plan or other appropriate document.

- Groundwater Level Measurements/Calculations forms (Form PWT/GW.102A)
- Electronic water level sounder
- Manometer and appropriate polyethylene or polytetrafluoroethylene (PTFE, e.g., Teflon™) tubing
- Interface probe (If required)
- Graduated steel tape and carpenter’s chalk (if required)
- Decontamination equipment and supplies
- Health and safety equipment and supplies (organic vapor monitor and personal protective equipment)

In most water level measuring activities, an electronic water level sounder is preferred. However, some small-diameter well points exist which require the use of a manometer, and some wells may contain immiscible layers that will require an interface probe and/or graduated steel tape and chalk. Some wells may contain down-hole pressure

transducers that will require additional equipment such as a portable computer, diskettes, and the manufacturer's instructions for downloading data, and form PWT/GW.102B.

4.0 INSTRUCTIONS

Field measurements typically include depth to standing water and the total depth of the well. Water level measurements will be recorded to the nearest 0.01 foot as specified by the RCRA Groundwater Monitoring Technical Enforcement Guidance Document.

Each well will have a permanent, easily identified measuring point (MP) from which the water level measurement will be made. For the purpose of this SOP, the MP is defined as a surveyed point notched into the northern edge of the inner polyvinyl chloride (PVC) or stainless steel casing. If an MP is not established in a well, the water level will be measured from the northern edge of the inner casing, and the point marked by notching with a file. The addition of the permanent MP will be noted on form PWT/GW.102A.

In addition, the following conditions must be considered in order to obtain acceptably accurate groundwater level measurements:

- Water levels in wells and piezometers will be allowed to stabilize for a minimum of 24 hours following installation or development before the water level is measured. Water levels require varying time periods to reach static conditions in new wells; therefore, the date and time of well construction, and the date, time, and reading of the initial water level measurement will be noted.

- Water levels should be measured before initiating purging and sampling activities.

- At some locations multiple sampling events may occasionally occur over a few days. For wells that recharge slowly the water level measured at such a well may not reflect static water conditions. In order to prevent a misinterpretation of static water levels in these cases, the date of the last sampling or well purging event will be documented in the water level measurement database.

- Static water levels will usually be measured with electronic sounders. If the well or piezometer is too small in diameter to accept an electronic sounder, a manometer and appropriately sized tubing will be used. If non-aqueous phase liquids (NAPLs) are potentially present, an interface probe will be used. In some cases, a graduated steel tape and carpenter's chalk may be preferable to an interface probe.

- Water level measurements that show the water level to be within the well sump will be considered technically dry for purposes of recording water level information.

4. 1 Surveying the Measuring Point

Each well must have a permanent, easily identified, notched MP on the north edge of the inner PVC well casing. The elevation of the MP should preferably be established by a licensed surveyor, and should be referenced to an established benchmark. However, depending upon the purpose and location of some wells, the coordinates of the wells and the elevations of their respective MP's may be established by use of Global Positioning System (GPS) technology. In this case the elevation will be established to the nearest foot. For consistency, water level measurements must be referenced to the same datum or elevation. The MP is surveyed with reference to the land surface datum (LSD), and all water levels and total depth measurements are converted to elevations expressed as mean sea level (MSL).

A reference point (RP) for water level measurements is an additional datum elevation established from a permanent benchmark and surveyed by a licensed surveyor. The RP is usually located on the top of the outer steel casing of a well and is used as a backup to the MP. If the MP is disturbed or destroyed, the RP will be used to establish a new MP.

4.2 Using an Organic Vapor Monitor

Prior to measuring the water level in any well or piezometer, a photoionization detector (PID) or accepted substitute will be used to measure the levels of organic vapors in background, well bore, and breathing zone air where defined by the project Health and Safety Plan. Operation of the PID shall be in accordance with the manufacturer's instructions.

- The background air will be monitored in the vicinity of the well and working area before the well cap is removed. The effects of any potential sources of organic vapors, such as operating generators, vehicles, or the like will be minimized as much as is practicable (e.g. a vehicle will be turned off or parked downwind from where activities are taking place). The presence of potential sources of organic vapors that are beyond the control of water level measurement personnel will be noted on form PWT/GW.102A. The level of organic vapors in background air will be recorded on form PWT/GW.102A.

- The well cap (s) will be removed and the tip of the PID placed within the opening of the inner well casing to measure the level of organic vapors within the well bore. The results of this measurement will be recorded on form PWT/GW.102A.

- Finally, the level of organic vapors in the breathing zone will be measured and recorded on form PRO.105A.

4.3 Instruments and Associated Water Level Measurement Techniques

Water level measurement instruments are used to determine the water level in boreholes, wells, piezometers, and some accessible subsurface structures. Measurements may be made with a number of different devices and procedures. Outside power sources are not generally required to operate most instruments. However some will require that batteries be replaced or recharged periodically.

The following subsections describe the use of electronic water level sounders; the use of a manometer to measure water levels in small diameter well points; the use of an interface probe in the determination of immiscible layers; and the use of a graduated steel tape to measure water levels and total depths of wells.

Electronic water level sounders are the preferred water level measuring instruments. Typically, a steel tape will only be used for measuring the total depth of a well when LNAPLs are present. Using a steel tape under these conditions will help ensure that the interface probe and other electronic water level measuring devices do not become grossly contaminated, and thereby helps to prevent cross-contamination.

4.3.1 *Electric Water Level Sounder*

Typically, an electronic water level sounder marked to 0.01-foot intervals will be used to measure groundwater levels and total depths of wells. Before lowering the electronic sounder probe into the well, the circuitry shall be checked by pressing the test button, if the unit is so equipped, or by dipping the probe in clean water. If the unit is working properly, the results of either test should be an audible tone. The probe will be lowered slowly into the well, minimizing wall contact, until contact with the water surface is indicated. The individual measuring the water level shall perform at least two measurements that agree within 0.01 foot. If the two measurements do not agree within 0.01 foot, this individual shall continue to measure until two consecutive readings agree within 0.01 foot. If

difficulties or inconsistencies persist, a second person shall repeat this process. Measurement shall continue until the values obtained by the two individuals agree within 0.05 foot. An average of the reproducible readings shall be used to determine the water level. Record and average the two reading that agree within 0.05 foot on form PWT/GW.102A, The difficulties or inconsistencies also will be recorded on form PWT/GW.102A, as they may indicate the presence of NAPLs, damage to the water level sounder, or other problems with the well.

Electronic sounders are recommended for measuring the depth to water in wells that are being pumped because sounders generally do not require removal from the well for each reading. However, if oil is present in the well, if water is cascading into the well, or if the water surface is turbulent, measuring water level with an electronic sounder may be difficult. Oil not only insulates the contacts of the probe, but it will also give an erroneous reading if there is a considerable thickness of oil. As noted previously and discussed in Subsection 4.3.4, if LNAPL is present a steel tape shall be utilized for measuring the total depth to the bottom of the well.

4.3.2 *Measuring Water Levels in Well Points*

A manometer may be required to measure the water level in well points because well points are often of too small a diameter to accept the probe and tape of a water level sounder. Before using a manometer, check the unit to be sure it is in working order. The manometer should be able to read 0.1 inches of water. Measure water levels as follows:

- Attach an appropriate length of appropriately sized polyethylene or PTFE (Teflon™) tubing to the manometer.
- Using the adjustment know, zero the display reading.
- Insert the tubing into the well point tubing while watching the manometer. When a change in the manometer reading is observed, mark a point on the inserted tube.
- Withdraw the inserted tubing and measure its length (to the nearest 0.01-foot) from the down-hole end to the marked point. Be sure not to stretch the tubing during this measurement.
- Record the required information on form PWT/GW.102A.

4.3.3 *Immiscible Layers and Use of an Interface Probe*

The NPS co-located well drilling and sampling project does not have the potential for the presence of immiscible organic compounds. However, because there may be locations that have observable immiscible layers in the ground water, procedures have been established to detect the presence of these compounds and to sample them when present.

The first step is to determine whether there is a positive response on the PID when its tip is positioned in the well bore. If the response is positive, the next step is to determine the presence and thickness of any NAPLs by use of an interface probe. In areas where the potential exists for NAPLs, an interface probe will be used to measure water levels. If groundwater samples are to be collected, the interface probe will be used in each well prior to each sampling event.

- The manufacturer's instructions shall be followed when using the interface probe. The probe shall be sufficiently precise to measure water and NAPL levels to the nearest 0.01 foot.
- The accuracy of repeated measurements must agree within 0.05 foot, and shall be measured from the MP on the inner well casing.

- The probe will be lowered very slowly so as to minimize disturbance of any layers of NAPL that may be present, and to limit penetration of any NAPL layers so as to ease decontamination of the probe. When lowering the probe, care will be taken to minimize rubbing of the tape against the well casing.

- Typically, the interface probe will produce different sounds to distinguish between aqueous and non-aqueous organic layers. Depth to aqueous or non-aqueous phases will be recorded to the nearest 0.01 foot, measured from the MP on the inner well casing.

If LNAPLs are not present, the interface probe may be used to determine the presence and thickness of DNAPL layers and the total depth of the well.

- The interface probe will be slowly raised and lowered to pinpoint the depth that the appropriate indicator tone is reproducibly obtained. This will be done slowly and with care so as to minimize disruption of any NAPL layers.

- Measurements from three consecutive readings will be taken by two individuals and must not differ more than ± 0.05 foot or three more readings must be taken.

- An average of the reproducible readings will be used to determine the water or NAPL level. The results of all readings will be recorded on form PWT/GW.102A.

Once the level has been determined and recorded, the probe will be carefully retrieved to ensure minimal rubbing of the tape against the inside well casing. The probe and tape will be decontaminated between use at each well following procedures given in SOP PWT/GW.101, Groundwater Sampling.

Due to the difficulty in decontaminating the interface probe after it has passed through a non-aqueous organic phase, if LNAPLs are present the interface probe will not be used to check for DNAPLs or to measure the total depth of the well. Instead, fluid will be collected to check for DNAPL, and a graduated steel tape and carpenter's chalk will be used to measure the total depth as described in Section 4.3.4.

Wells containing LNAPLs shall be checked for the presence of DNAPLs by very slowly lowering a purge pump or pump tubing to the bottom of the well and collecting the first purge water from the bottom of the well in a one liter colorless glass container. The container will be initially checked with an organic vapor analyzer (OVA) for compared background readings. The liquid shall be allowed to stand for 15 minutes and visually observed for the presence of separate phases. If no DNAPLs have separated out of the solution after 15 minutes, the well shall be presumed free of DNAPLs.

If either LNAPLs or DNAPLs are detected, the well will be sampled for these phases as described in SOP PWT/GW.101, Groundwater Sampling if requested by the project specific work plan.

4.3.4 *Graduated Steel Tape*

The use of graduated steel tapes will normally be limited to determination of the total well depth of wells containing LNAPLs. A slender, stainless steel weight will be attached to the end of the tape to create tautness and to permit a feel for obstructions and for the bottom of the well. The weight will be attached using wire, rivets, or other method that does not have the potential for contributing contaminants to the well. The tape will be lowered to the bottom of the well, and the total depth will be read off the tape at the MP on the inner well casing.

The graduated steel tape method is considered accurate for measuring the water level in nonflowing wells (National Handbook of Recommended Methods for Water-Data Acquisition, 1977, pp. 2-8), but will not be used for this purpose except in unusual circumstances as instructed by the subcontractor's project manager. If used to measure the water level, available well construction and prior water level data should be consulted first. After determining what length of tape may be submerged in the water within the well, use the carpenter's chalk to coat the tape from its down-hole end to a point a few feet above what would be a high water level for that well. The coated end shall be lowered down the well, taking care to minimize contact with condensation on the interior surfaces of the well, until the end is resting on the bottom of the well. The total depth (relative to the MP) shall then be recorded and the tape shall be withdrawn, again minimizing contact with the walls of the well. The water level is marked by a water line in the chalk. The water level below MP is calculated by subtracting the wetted length of tape from the total depth measured with the tape.

Before and after each well measurement, that part of the tape measure that extends down the well will be decontaminated. Decontamination procedures are discussed in Subsection 4.5 of this SOP.

4.4 Down-Hole Water Level Pressure Transducer

Water levels may be measured on a continuous basis through the use of a probe that is installed below the water level in a well. The probe contains a pressure transducer attached to a network of cables and tubing. The transducer measures pressure changes that result from changes in the volume of water (the head) above the probe. The cables and tubing may perform such functions as positioning the probe at the desired depth, relaying transducer data to a data logger, and venting the probe so that fluctuations in barometric pressure are not recorded as changes in the water level. Because water level is derived from pressure changes detected by the transducer, only vented water level pressure transducer probes will be used.

The data logger may be a separate, stand-alone unit that may be placed on the ground next to the well. It may also be contained within the probe, and feature a data transfer (downloading) cable that extends from the probe to the top of the well casing; or it may be stationed within the top of the well casing. Accumulated data are periodically downloaded from the data logger onto a portable computer.

4.4.1 *Preparation*

If the down-hole water level pressure transducer probe is to be installed in a well for long-term water level monitoring, it may be advantageous to assemble the components to fit the individual well to be studied. Custom fitting will typically be performed by the manufacturer, but at times may be performed by PWT or subcontractor personnel. In most cases this requires cutting the assorted cables and tubing to lengths that, when assembled, allow the probe to be suspended at a depth below the lowest anticipated water level or at the bottom of the well. Personnel performing these activities will be careful not to twist, kink, or otherwise damage cables and tubing.

A variety of diaphragms, with associated pressure ranges, are typically available for the pressure transducer. A diaphragm with a low-pressure rating allows the unit to be used in shallow-water settings, and higher-pressure ratings allow the unit to be used in deeper-water settings. Using the wrong diaphragm may result in poor resolution or faulty data.

The manufacturer's instructions shall be followed during all assembly and modification activities. If the unit is being modified by the manufacturer to fit a particular well, care will be taken to ensure that all depth and head (water column within the well) information reported to the manufacturer are correct.

Prior to installing a probe in a well, (1) the desiccant in the unit (if applicable) will be checked to ensure that it is fresh; (2) All communications between the probe, data logger, and downloading computer will be checked to

ensure that they are functioning properly; (3) The data logger shall be programmed to collect and store the required data at the desired frequency and in the proper storage location; and (4) the unit's internal clock and calendar will be set.

The power source for the data logger and the amount of available memory on the logger will be checked to ensure they are adequate. The probe, cables and tubing, connectors and other down-hole components will be decontaminated according to this SOP or, if these instructions are not appropriate, the manufacturer's instructions. Be sure not to twist, kink, or otherwise damage the components, and keep dry any connectors or other parts that would be damaged if they were to get wet.

Immediately before the probe is installed, The water level in the well will be measured and recorded using other equipment, such as an electronic water level sounder. The transducer will be zeroed, if appropriate. The manufacturer's instructions will be followed to ensure all pre-installation tasks have been performed.

4.4.2 Installation

Proper installation of the down-hole pressure transducer probe and the data logger is crucial. A secure and well-known probe placement, together with proper connections to and programming of the data logger, are critical to ensuring high-quality water level data are collected and stored.

The depth at which the probe will be positioned will be determined to within 0.01 foot. (If possible this measurement will be made to within 0.01 foot. However due to stretching of the cables and tubing, this may not be feasible.) When the unit is ready to be installed, the data logger will be activated and the probe will be lowered slowly down the well. The probe will not be allowed to "free fall" as this may damage the transducer and/or strain gauge. When the probe is positioned, a reading will be taken from the probe and recorded on the data logger. The probe's position will gradually stabilize as the cables straighten and stretch from its weight. As the probe's position stabilizes, so will the water level equilibrate to account for the volume of water displaced by the probe. It is recommended that the data logger be programmed to record depths over this stabilization period (generally about an hour, but the manufacturer's instructions should be checked, and up to several hours or more for water level equilibration, depending on the hydrologic setting of the well screen). The frequency at which measurements are made may need to be adjusted to adequately characterize this period, then reset to the frequency desired for long-term measurements. For example, if the water level in the well is to be measured once every hour, the frequency should be adjusted to once every five minutes or so until the probe position and water level have stabilized, then reset to once each hour. However, if instructed by the PWT Field Manager, collection of these stabilization data may be omitted.

4.4.3 Operation

Unless requested by the PWT Field Manager, measurement of the total depth of a well will not be made in wells equipped with a down-hole water level probe at the same frequency as it is in wells lacking this equipment. To do so will generally require removal of the unit, which is impractical and time consuming, and can result in damage to the equipment.

The data logger has a finite amount of memory storage space. Data will not be allowed to be overwritten or otherwise lost (e.g., due to delay in downloading data or battery failure). Downloading the logger will occur on a regular schedule that allows plenty of extra time for unforeseen problems (such as weather delays) without a loss of data. Unless the logger is recording measurements every five minutes or less, it should not be necessary to halt data collection during downloading. The communication cable will be plugged into the computer and the data downloaded according to the manufacturer's instructions. After the data have been downloaded to the computer and

downloading has been verified, the data on the logger will be erased and the unit returned to use. This activity will be performed quickly, efficiently, and carefully, so as to ensure that all new data were downloaded and no non-downloaded data are recorded on the data logger and then erased.

The condition of the unit (batteries, desiccant, etc.) will be checked each time the unit is downloaded. If the manufacturer's instructions recommend a more frequent check, these recommendations will be followed. If requested by the PWT or subcontractor Field Manager as an additional check, the water level may be measured using other equipment such as an electric sounder (see Subsection 4.3.1) each time this unit is downloaded. If so, the down-hole probe will be minimally disturbed during this procedure. If it is necessary to partially withdraw the unit in order to make the measurement (for example, if the data logger is installed within and blocks access through the well casing), this will be done carefully and efficiently, without instructing the unit to pause in its data collection and without kinking the cables and tubing or otherwise damaging or contaminating the withdrawn portion. (Note that even partial withdrawal of the unit will cause the water level to drop somewhat relative to its position prior to this withdrawal.) The withdrawn components will not be allowed to contact potentially contaminated media and will be sheltered from windblown dust and debris; if they do contact these media or become dirty, they will be decontaminated according to this SOP, and the manufactures instructions. Components will be restored to their proper place as quickly and carefully as practicable. A chronological log of these activities and their results will be maintained within the comments section of the Groundwater Level Data from Down-Hole Pressure Transducer form (Form PWT/GW.102B).

If groundwater sampling is to be performed on a well equipped with a down-hole water level probe, provisions must be made in advance for storing the probe, cables, tubing, data logger, and associated components during these activities. Depending on the duration of the sampling activities (single or multiple days), the size of the unit, and the quantity of cables and tubing, it may be desirable to store the submersible components in a clean, covered tub filled with deionized or distilled water, and the remaining components in a clean plastic bag adjoining the tub. (The manufacturer's instructions will first be consulted to ensure the unit is compatible with the water to be used, as some pieces of equipment are sensitive to deionized water.) Alternatively, the unit may be placed on clean plastic sheeting. If the well dewaters and takes more than one day to complete sampling, the probe and its associated down-hole components will be safely stored in a clean enclosure such, as one or more large, heavy-duty plastic bags until sampling has concluded, and will be decontaminated before reinstalled in the well.

Regardless of the method of temporary storage, the components will not be allowed to contact potentially contaminated media and will be sheltered from windblown dust and debris. Data collection from the probe will be halted. Withdrawal of the unit from the well will proceed slowly and carefully, and in accordance with the manufacturer's instructions. All components of the down-hole probe assembly will be visually inspected as they are withdrawn. Any necessary cleaning or repairs (for example, removing accumulated sediments from the probe) will be performed following the manufacturer's instructions and/or this SOP. The well will then be sampled as per SOP PWT/GW.101, Groundwater Sampling. After sampling has concluded and the down hole probe reinstalled, data collection will be reactivated.

General maintenance will be performed as recommended by the manufacturer. Routine maintenance may include replacing the desiccant, cleaning the filter at the pressure transducer, clearing the ports at the pressure transducer, replacing the batteries, recalibrating the probe, and general cleaning and checking of components and connections. Depending on the unit, many of these tasks may only be performed by the manufacturer. If necessary, the unit will be removed from the well, decontaminated, and returned to the manufacturer for service.

Computer connectors will be handled carefully and used properly. Some probes have specially-designed connector caps or storage that adequately addresses potential moisture problems. If this is not the case with the connector being used, it will be kept dry by storing it in a plastic bag within the wellhead. If condensation is a problem, a packet of desiccant may be kept in the bag, unless the manufacture's instructions specify other alternatives.

4.5 Decontamination

Methods used to prevent cross contamination include scheduling activities to proceed from locations with potentially lesser to those with potentially greater levels of contamination, and thorough decontamination of all materials contacted by potentially contaminated media. Water level measurement equipment and the personnel who use them are decontaminated for the dual purposes of minimizing cross-contamination and providing a safe and healthy working environment.

Equipment should be constructed of stainless steel, PTFE, or other inert materials that have been approved by PWT. Equipment will be decontaminated before and after use at each well.
If freshly decontaminated equipment is kept clean during transport to the next well by being stored in a clean plastic bag, clean plastic wrap, or clean equipment storage case, the need for repeated decontamination prior to using the equipment at that next well may be eliminated. In such cases the equipment need only be decontaminated immediately following use at each well. Procedures for decontamination are set forth in the site-specific health and safety plan and this SOP.

5.0 QUALITY ASSURANCE / QUALITY CONTROL

The frequency of measurements and the accuracy desired in measuring changes in water levels depends on the objectives established in the Work Plan or the Sampling and Analysis Plan for a given project. All appropriate data will be recorded on a Groundwater Level Measurements/Calculations form (Form PWT/GW.102A) or Groundwater Level Data from Down-Hole Pressure Transducer form (Form PWT/GW.102B) before leaving the well site.

Electronic water level sounders will be calibrated quarterly by following the manufacturer's instructions or by suspending the sounder and measuring it against a calibrated steel tape if no other calibration instructions are supplied. Down-hole water level probes will be calibrated by the methods and frequency recommended by the manufacturer and the results documented on a log sheet kept on file in the groundwater monitoring field office.

6.0 RECORDS

A permanent record of the implementation of this SOP will be kept by documenting field observations and data in waterproof ink on a Groundwater Level Measurements/Calculations form (Form PWT/GW.102A). If the well is equipped with a down-hole water level probe, the appropriate observations and data will be recorded on a Groundwater Level Data from Down-Hole Pressure Transducer form (Form PWT/GW.102B).

When measuring with tools other than a down-hole pressure transducer, the following information should be recorded for each observation-well site:

- The PWT Project Number and well number
- The date and time of the water level measurements
- The names of personnel performing the measurements
- The equipment manufacturer, model, and serial number
- Results of PID monitoring
- Depth to water and total depth of well, both relative to MP
- The perceived condition of the bottom of the well (soft vs. hard)
- Comments on any unusual conditions that may relate to these data, as appropriate
- The name of the QC reviewer and the date of the QC review.

Individual measurements are entered onto the Groundwater Level Measurements/Calculations form (Form PWT/GW.102A) as the measurements are performed. The information is recorded as follows:

1. Record well number in the first column.

2. Measure and record the depth to water from the measuring point in the second column (WD). The measurement will be taken twice, or more if measurements are difficult to obtain. Measurements from the two readings must agree within 0.01 foot. If the measurements do not agree within 0.01 foot, a second individual may attempt the measurement. Continue to measure until the reason for the lack of agreement is determined or until two consecutive readings are shown to agree within 0.01 foot, or 0.05 foot if the measurements are made by two individuals. An average of the reproducible readings will be utilized for the determination of the water level.

3. Measure the total depth of the well from the MP and record this value in column three (MTD). The measurement will be taken twice. Measurements from the two readings must agree within 0.01 foot. If the two measurements do not agree within 0.01 foot, continue to measure until the reason for the lack of agreement is determined or until two consecutive readings are shown to agree within 0.01 foot (0.05 foot if made by two individuals). An average of the reproducible readings will be utilized for the determination of the total depth.

4. In some devices the length of the probe end may not have been taken into consideration when the measuring tape was marked. In this case the length of the probe end will need to be added to the measured total depth in order to determine the total depth of the well from the MP. Record the length of the probe end in column four (Probe end).

5. Determine the total depth of the well from the measuring point by adding the length of the probe end to the measured total depth from the MP and record this value in column four (TD). Total depths of wells may be measured monthly, quarterly, or as instructed by the PWT Field Manager.

6. In the blank marked “Chk’d by”, record the initials of the individual who checks the calculation performed in Step 5.

7. In the “Comments” section, note any significant features or activities near the well that could affect the water level, PID readings, or other data recorded on form PWT/GW.102A.

In wells equipped with down-hole pressure transducers, form PWT/GW.102B shall be used. The following information shall be recorded for each observation-well site:

- The PWT Project Number and well number
- The names of personnel downloading the data and performing associated activities
- The equipment manufacturer, model, and serial number
- Results of PID monitoring
- The date and time of the first and last water level measurements recorded on the data logger
- The number of records downloaded and the frequency of measurement
- The depth of the probe
- Water level and probe datum, if other than MP
- Battery condition
- The identity of the diskette(s) on which downloaded data were stored
- Whether the water level was checked using other means, and if so, the results of this measurement
- Comments on any unusual conditions that may relate to these data, as appropriate

- The name of the QC reviewer and the date of the QC review

Water level data downloaded from wells equipped with down-hole pressure transducers and data loggers will be archived electronically in their original form without conversion or other data manipulation. If conversion is necessary to render the data useable, converted data shall be archived separately and an explanation of the conversions shall be included. Data diskettes (original and converted forms) will be transmitted to the RMRS project manager on the same schedule as data from wells without down-hole probes unless this individual requests otherwise. Copies of the data diskettes will also be stored by the subcontractor. Summary hydrographs will also be provided to the PWT project manager, and will display water level depth and topographic elevation versus time. Hard copies of the data shall not be provided unless the PWT Field Manager requests them.

7.0 REFERENCES

7.1 Source References

The following references were reviewed before this procedure was written:

Freeze, R. Allen, and John A. Cherry, 1977, *Groundwater*, Prentice-Hall, Inc., Englewood Cliffs, NJ

U.S. Department of Energy (DOE), August 1987, *The Environmental Survey Manual*, Volumes 1-4, DOE/EH-0053.

U.S. Department of Interior, Water Resources Division , 1977, *National Handbook of Recommended Methods for Water-data Acquisition*.

U.S. Environmental Protection Agency (EPA), September 1986, *RCRA Groundwater Monitoring Technical Enforcement Guidance Document*, OSWER-9950.1.

U.S. Environmental Protection Agency, December 1987, *A Compendium of Superfund Field Operations Methods*, EPA/540/P-87/001.

U.S. Environmental Protection Agency (EPA), October 1988, *Guidance for Conducting Remedial Investigations and Feasibility Studies Under CERCLA, Interim Final.*

U.S. Environmental Protection Agency (EPA), May 1989, *RCRA Facility Investigation Guidance, Interim Final.*

7.2 Internal References

Related SOPs cross-referenced by this SOP are as follows:

- SOP PWT/GW.101, Groundwater Sampling

FORM PWT/GW.102A
GROUND WATER LEVELS
MEASUREMENTS / CALCULATIONS

EQUIPMENT MANUFACTURER:

PROJECT NO.: MODEL:

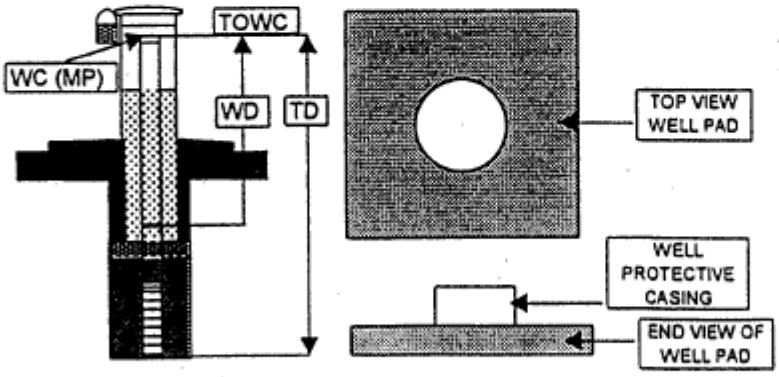
DATE: SERIAL NO.:

PERSONEL: (1) CALIBRATION: DATE PASSED: DATE DUE:

(2) QC REVIEW: NAME DATE:

☐ Quarterly
☐ Monthly
☐ Special

WELL NO.			Comments:		MINI RAE *
	WD	MTD	Background	Headspace	Well Bore
MEASUREMENT 1					
MEASUREMENT 2					
TIME:					
	AVERAGE WD	AVERAGE MTD	PROBE END	TD	CHK'D BY



COMMENTS:

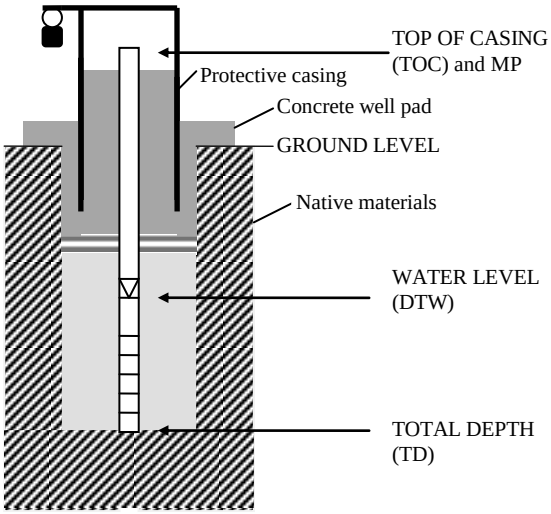
SIGNATURE: DATE:

FOOTNOTES:
TOWC=TOP OF WELL CASING
WD = DEPTH OF WATER FROM MP
MTD = MEASURED TOTAL DEPTH FROM MP
PROBE END = LENGTH BEYOND MEASURING POINT OF PROBE
TD = DEPTH OF BOTTOM OF WELL FROM MP

NOTES:
ALL MEASUREMENTS ARE MADE IN FEET RELATIVE TO MARK POINT (MP) = N. SIDE OF TOWC.
QC REVIEW BY SUPERVISOR IS A CHECK OF REASONABLENESS
MEASUREMENTS 1 AND 2 MUST BE WITHIN 0 05 FT

Form PWT/GW.102B
Groundwater Levels
DATA FROM DOWN-HOLE PRESSURE TRANSDUCER

WELL NO. _____				
DOWNLOAD DETAILS	DATE / TIME OF FIRST RECORD _____	DATE / TIME OF LAST RECORD _____	NO. OF RECORDS DOWNLOADED _____	PID equipment _____ _____ Background _____
EQUIPMENT / PROGRAM STATUS	PROBE DEPTH _____	BATTERY CONDITION _____	MEASUREMENT FREQUENCY _____	Breathing zone _____ Well bore _____ DISKETTE _____
WATER LEVEL DATUM (IF OTHER THAN MP)* _____	WATER LEVEL CHECKED? [Y] / [N]	IF Y: Equipment used (mfr./serial): _____ _____	IF Y, DTW = _____ TIME = _____	Did water level check require partial withdrawal of down-hole tools? [Y] / [N]



COMMENTS and CHRONOLOGICAL RECORD OF ACTIVITIES

_____
_____
_____
_____
_____
_____
_____
_____
_____
_____
_____
_____
_____
_____

NAME / SIGNATURE: _____ DATE: _____

TOC = top of well casing
MP = measuring point (on north side of TOC)
DTW = depth to water (from MP)
TD = total depth (from MP)

NOTE:
*Unless otherwise indicated, all measurements are made in feet relative to measuring point (MP), which is located on the north side of TOC.

PWT STANDARD OPERATING PROCEDURE

MONITORING WELL AND PIEZOMETER INSTALLATION

Procedure No. PWT/GW.103
Revision 0
Date effective:03/31/07
Page 1 of 38

APPROVED: _____ _____
PWT Project Manager Date

USE CATEGORY 2
TABLE OF CONTENTS

1.0 PURPOSE 3
2.0 SCOPE 3
3.0 REQUIREMENTS 3

3.1 Personnel Qualifications 4
3.2 Equipment and Materials 4

4.0 ADMINISTRATIVE DOCUMENTATION PRECEDING WELL INSTALLATION 7

5.0 INSTRUCTIONS 7

5.1 GENERAL REQUIREMENTS 7
5.2 WELL DESIGN CONSIDERATIONS 9
5.3 WELL INSTALLATION USING A DRILL RIG 10
5.3.1 Hollow-Stem Auger Boreholes Drilled for UHSU Wells 10
5.3.2 Alluvial Piezometer and Monitoring Well Installation 11
5.3.3 Bedrock Piezometer and Monitoring Well Installation 15
5.3.4 Well Materials 17
5.3.4.1 Well Casings 17
5.3.4.2 Well Screens and Sediment Sumps 18
5.3.4.3 Filter Pack 18
5.3.4.4 Bentonite Seal 19
5.3.4.5 Bentonite Grout 19
5.4 WELL INSTALLATION USING PUSH-TYPE EQUIPMENT 20
5.4.1 Well Installation Using Macro-Core or Dual Wall Equipment 21
5.4.2 Installation of Pre-Packed Well Screens Using Dual Wall Equipment 23
5.4.3 Well Point Installation 24
5.4.4 Aseptic Surface Protection for Wells Installed Using Push-Type Equipment 25
5.5 MONITORING WELL FEATURES AT GROUND SURFACE 26
5.5.1 Above-Ground Surface Protection for Wells Installed with a Drill Rig 27
5.5.2 Above-Ground Surface Protection for Wells Installed with Push-Type Equipment 29
5.5.3 Flush-Mount Surface Protection 31

6.0 POST-INSTALLATION DOCUMENTATION 36

7.0 REFERENCES 37
7.1 Source References 37

7.2 Internal References 37

LIST OF FIGURES

PWT/GW.103-1 ALLUVIAL MONITORING WELL INSTALLED WITH A DRILL RIG 12
PWT/GW.103-2 BEDROCK MONITORING WELL INSTALLED WITH A DRILL RIG 16
PWT/GW.103-3 ABOVE-GROUND WELL PROTECTION AT DRILL RIG WELLS 28
PWT/GW.103-4 ABOVE-GROUND WELL PROTECTION AT PUSHED WELLS 30
PWT/GW.103-5 FLUSH-MOUNT SUFACE PROTECTION 32

1.0 PURPOSE

This standard operating procedure (SOP) describes the equipment and procedures to be used for installing monitoring wells and piezometers using hollow-stem auger, rotary drilling or rock coring, or push type (also termed probing, using Geoprobe® or equivalent) sampling equipment. In general, hollow-stem auger drilling will be the preferred technique for installing monitoring wells requiring 2 inch or larger inside diameter (ID) well casing into the alluvium and/or alluvium/bedrock interval. In this SOP the terms "alluvium" and "alluvial" are often used to refer to any/all unconsolidated surficial deposits, whether truly consisting of alluvium or not. Wells installed in confined bedrock aquifers will normally require rotary drilling or rock coring equipment. Small diameter wells and piezometers (well casing having an ID of one inch or less) typically can be installed using push type sampling equipment, although this equipment's ability to penetrate cobbly alluvium is often limited to a depth of 30 feet or less.

This SOP also describes requirements for administrative documentation of new monitoring wells and piezometers, and lists the related field procedures that will be used. This SOP contains the forms for documenting well construction and describes the field procedures and materials that will be used to install monitoring wells and piezometers in order to attain acceptable standards of precision, accuracy, representativeness, comparability, and completeness.

2.0 SCOPE

This SOP, applies to all PWT personnel and subcontractors conducting borehole drilling, probing/pushing, and/or well installation operations and related work on remedial investigation projects. (The term "well" in this SOP typically includes other groundwater monitoring installations such as piezometers and well points. The terms "probe" and "push" are used interchangeably to refer to the act of forming a borehole using push-type equipment.) The procedures described herein will be followed whenever drilling, probing, and well installation operations or associated activities are being performed, unless alternative procedures are required and described in an approved work plan under which the activities are being performed.

3.0 REQUIREMENTS

PWT or subcontractor personnel overseeing the installation of monitoring wells and piezometers will be geologists, geotechnical engineers, or field technicians with experience and training related to borehole drilling and/or probing (as appropriate) and monitoring well and piezometer installation. All drilling/probing and well installations are to be performed by a reputable firm with proven borehole drilling or push type sampling experience and well installation expertise. These activities shall be performed in accordance with approved work control documents (work plan, sampling and analysis plan, etc.), approved health and safety plans, and/or other controlling documents as applicable.

3.1 Personnel Qualifications

Personnel performing these procedures are required to have completed the initial 40-hour OSHA classroom training that meets Department of Labor Regulation 29 CFR 1910.120(e)(3)(i), and must maintain a current training status by completing the appropriate 8-hour OSHA refresher courses. Personnel will also maintain a current OSHA medical evaluation (i.e., approved annual physical) and will complete any other PWT-required training that may be necessary to perform the work.

Prior to conducting borehole and monitoring well and piezometer installation operations and other related work, personnel are required to have a complete understanding of the procedures described within this and other pertinent SOPs. Personnel will receive specific training regarding these procedures as necessary (such as on-the-job training in well installation and associated activities).

3.2 Equipment and Materials

The procedures and equipment required for drilling and sampling boreholes for the installation of monitoring wells or piezometers (using either a hollow stem auger drill rig or a rotary drilling and/or core drilling rig) are documented in SOP PWT/GW.114, Drilling and Sampling Using Hollow-Stem Auger and Rotary Drilling and Rock Coring Techniques.

The procedures and equipment required for probing and sampling boreholes using push type sampling equipment (Geoprobe® or equivalent) are documented in SOP PWT/GW.124, Push Subsurface Soil Sampling. Because this technique is generally restricted to the shallow alluvium, there is typically no need for installing isolation casing except where required in areas of contaminated surface soils.

Additional equipment and materials typically required for installing monitoring wells or piezometers include, but are not limited to:

For Installations Using a Drill Rig

- Groundwater Monitoring Well and Piezometer Report (Figures PWT/GW.103-1, PWT/GW.103-2, and PWT/GW.103-3)
- Rig mounted mud/grout pump
- Tank for mixing bentonite grout
- Sand bailer
- 1 inch to 2 inch ID tremie pipe, with hose
- 10-20 silica sand filter pack
- Bentonite pellets (not time-release variety)
- High-solids, reduced-pH bentonite grout
- Flush-threaded 2 inch ID PVC well casing
- Flush-threaded 2 inch ID PVC well screen with 0.020 inch factory machined slots
- Flush-threaded 2 inch ID PVC well sumps (2 foot lengths)
- Flush-threaded 2 inch ID PVC casing caps (sump bottom caps)
- 2 inch PVC slip caps (for top of well casing)
- 5 foot lengths of 6 inch ID steel protective casing
- Locking caps for protective casings
- Flush-mount assemblies (if required instead of 5 foot steel protective casing and locking cap)
- Locking 2 inch "J" caps (if required; typically for flush-mount wells)
- Locks
- 12 to 16 inch ID steel casing (in lengths as specified in approved work plan) for aseptic location (if required)
- 6-foot lengths of 3 inch outside diameter (OD) steel pipe (if required; to guard wells in traffic areas)
- Ready-mix cement or concrete
- Concrete forms for well pads
- Rolls or sheets of heavy plastic
- Distilled or deionized water

For Installations Using Push-Type Equipment

- Groundwater Monitoring Well and Piezometer Report (Figure PWT/GW103-4)
- 16-40 silica sand filter pack
- Granular bentonite
- Flush-threaded 3/4 inch ID clean PVC well casing with slip caps for top of casing; appropriate for Geoprobe® macro or dual wall system
- Flush threaded 3/4 inch ID PVC well screen with threaded bottom caps (appropriate for Geoprobe® macro

or dual wall system)

- Pre-packed well screen with PVC well casing (if specified in approved work plan – typically used only with Geoprobe® dual wall system)
- 2 inch ID PVC casing (1.5 to 2 foot lengths; for use as protective casing)
- Locking "J" caps for 2 inch ID protective casings
- Flush-mount assemblies (if required)
- Locks
- Ready-mix cement or concrete
- Roll or sheets of heavy plastic
- Deionized or distilled water

Tools and supplies required to operate the drilling or probing equipment and perform well installations are also necessary, as are the appropriate health and safety, decontamination, waste handling, etc. equipment.

All downhole equipment and supplies shall be clean and free of contamination. Well construction materials (e.g., PVC) should be new, factory-decontaminated, and received from the factory in plastic sleeves or other protective packaging that prevents the contents from being contaminated. If not factory cleaned, or not new or not received from the factory in adequately protective packaging, these materials shall be steam cleaned. In addition, materials shall be free of stenciling, stickers, and other residues. If steam cleaning does not result in materials that are visibly clean and free of residual potential contamination, these materials shall be replaced. Filter pack, bentonite, grout, and cement/concrete shall be new and shall be received in unopened packages. Any materials or supplies suspected of being potentially contaminated will not be used and must be replaced. Tools shall be decontaminated in advance of well installation activities in accordance with the appropriate decontamination procedures.

This SOP describes the major points of well installation and addresses some actions that may be taken to ensure the well's integrity (e.g., aseptic protection). However, other actions should be taken to further protect the borehole and well components, such as replacing soiled gloves before handling clean downhole tooling or well components, and preventing these items from becoming soiled or dusty. The purpose of the well – typically, to enable representative samples of groundwater to be collected for analysis – should be kept in mind at all times, with potentials for cross-contamination of the borehole, downhole tooling, and well components minimized or removed. The well installation crew should perform all activities with suitable equipment and materials and in such a way as to ensure that the well's purpose can be met.

4.0 ADMINISTRATIVE DOCUMENTATION PRECEEDING WELL INSTALLATION

For any well or piezometer that is expected to remain in service for a period of one year or longer, the PWT Field Manager or designee will submit the required well permit application to the State Engineers Office.

5.0 INSTRUCTIONS

5.1 General Requirements

Boreholes for wells will be drilled using a drill rig or probed using push type sampling equipment (probe truck) capable of completing the well to the depth specified in the project work plan. Subcontracted equipment will be inspected before it is allowed onsite, and any repairs that may be needed, especially those posing a potential health and safety hazard or involving fluid systems having a contamination potential (e.g., hydraulics, fuel, oil, coolant, etc.) must be completed prior to the equipment being allowed onsite. All drilling/probing equipment, including the drill rig or probe truck, water tanks, and all downhole equipment, will be in excellent operating condition and will be decontaminated prior to beginning the project.

Downhole equipment will be decontaminated between boreholes. Drill rigs will be decontaminated when moving between drilling projects and before leaving the project, and may be decontaminated more frequently if it becomes necessary (e.g., due to muddy conditions, or due to equipment failures, such as ruptured hydraulic lines or grease seals, that present a potential for contaminating the ground surface and/or borehole). Drill rig equipment failures posing a potential health and safety hazard or having the potential to cause contamination shall be repaired immediately, in accordance with the manufacturer's instructions, prior to resuming drilling activities; this may require the drill rig to be taken to a shop for repairs. Probe trucks, due to their inherently cleaner operations, will not be required to be decontaminated between project areas unless one of the areas is known to contain surface soil contamination. Otherwise, the frequency with which this equipment will be decontaminated shall be determined by the Field Manager in consultation with the driller. However, in all cases, whether using drill rig or probe truck, if the equipment becomes excessively soiled and/or exhibits a potential for contaminating the ground surface or borehole, it shall be decontaminated prior to resuming operation.

Before drilling or probing, proposed borings/wells will have been located, numbered, and identified using stakes or pin flags or other suitable markers (such as spray paint on paved surfaces). These locations will be evaluated and cleared for buried metal objects and utilities.

Groundwater monitoring wells and piezometers installed using a drill rig will be constructed in boreholes drilled and sampled according to PWT/GW.114, Drilling and Sampling Using Hollow-Stem Auger and Rotary Drilling and Rock Coring Techniques. Small diameter monitoring wells and piezometers installed by push type sampling equipment will be constructed in boreholes probed and sampled according to PWT/GW.124, Push Subsurface Soil Sampling. Boreholes will be advanced from the ground surface to a predetermined target depth given in the project work plan. Borehole core and/or cuttings for either type installation will be logged following SOP PWT/GW.104, Borehole Logging.

Approved project-specific work plans shall take precedence over these SOPs. For example, the approved work plan may require abbreviated logging detail or alternative drilling equipment or well designs. In such cases, the work plan shall clearly state any alternative requirements that are to be followed.

The distinction between wells and piezometers is based on the intended use. Wells are used for obtaining samples of groundwater while piezometers are primarily intended only for water level measurements, although they may occasionally be used for water sampling purposes. If different types of piezometers are required (e.g., isolated electronic or pneumatic piezometers), they will be addressed in a project-specific work plan. To assure the environmental integrity of each well, downhole drilling/probing and sampling equipment and materials will be decontaminated prior to use, and protected from the ground surface with clear plastic sheeting or placed on clean racks or other suitable equipment.

5.2 Well Design Considerations

Personnel installing monitoring wells need to be cognizant of the many factors influencing the screened intervals selected for wells. Several examples shall serve to illustrate how these factors can control the well design.

Piezometers should have screens of sufficient length, situated at the appropriate depth, to monitor groundwater levels in the geologic interval of interest without the water table dropping below the screened interval.

Wells constructed in materials having a slow recharge potential should have sufficient screen area to allow maximum yield. However, long screened intervals should generally be avoided if there is a need to characterize discrete zones of contamination.

Wells proposed to monitor groundwater in alluvium (or other shallow, unconsolidated surface deposits) are typically installed in boreholes advanced only a couple of feet into the relatively impermeable bedrock. However, if the bedrock

immediately beneath the surficial deposits consists of sandstone, this design may need to be adjusted because in such cases the sandstone and the surficial deposits together form the water-bearing zone. Frequently, unless the sandstone unit is thick the boreholes for these wells will be advanced through the sandstone unit and into the impermeable unit beneath, with the well screened from the base of the sandstone to a point within the overlying alluvium/surficial deposits. The approved work plan should clearly discuss anticipated conditions and provide for any adjustments in design that might result. The project manager shall be consulted and will determine what, if any, adjustments should be made.

If a well is to be installed in an area of suspected surface contamination, then the procedures for aseptic surface installations should be developed. If a well is to be installed in a confined aquifer within the bedrock, then it will be necessary to install surface casing to isolate the bedrock aquifer from any aquifers within the alluvium or the weathered interval of the upper bedrock. This will normally apply only to wells installed by a drill rig. The procedure for installing an isolation casing is described in Subsection 4.4 of SOP PWT/GW.114. Wells installed by push type methods and incorporating aseptic surface features will follow the procedures in Subsection 7.1 of SOP PWT/GW.124 and Subsection 5.4.4 of this SOP.

5.3 Well Installation Using a Drill Rig

Because hollow-stem auger drill rigs are most commonly used to install alluvial wells, this SOP focuses on that equipment. If another type of drill rig is used, the approved work plan should describe any deviations to this SOP that might be required. The General Requirements subsection and the general well construction specifications presented in this SOP will still apply unless the work plan specifies otherwise.

5.3.1 *Hollow-Stem Auger Boreholes Drilled for alluvial Wells*

Boreholes drilled using hollow-stem augers and which are intended for alluvial well installation will be augered as little as possible into claystone bedrock since the claystone cuttings may tend to smear along the side of the borehole in the alluvium. Therefore, after the augers have been advanced to the bedrock contact, an appropriately sized drive sampler will be driven 2 feet into the claystone bedrock to provide lithologic information and a pilot hole for the sediment sump. The sampler should be no more than 1 inch greater in diameter than the OD of the sump casing and should result in a pilot hole that will accommodate the sediment sump. If the desired total depth (TD) has been reached, the well casing may then be set with the sump in the pilot hole. If the TD has not been reached, then the pilot hole should be reamed with the augers (while attempting to minimize claystone smearing along the borehole walls), and another drive sample pilot hole driven. Where claystone smearing is not a problem, the borehole may be augered to the well TD. The

sediment sump will be a 2-foot-long piece of blank casing (including a flush-threaded cap) installed immediately beneath the screen. It will be of the same material as the well screen and casing (as specified in the project specific work plan). It should be noted that the depth of penetration into claystone bedrock, using hollow stem augers, may be restricted by the density and other physical properties of the bedrock, or by the specific requirements of the project work plan.

If a center bit is used instead of a continuous hollow-stem core or split-spoon sampler and the target TD is in the uppermost bedrock, drive samples should be taken periodically to determine whether the alluvial/bedrock contact has been reached. If it has not, drilling will resume. If auger behavior (monitored by the drill rig operator) indicates the presence of sand, the center bit will be removed slowly to prevent the possibility of sand entering the bottom auger. In the event flowing sand is encountered, potable or fire hydrant water may be added to the inside of the augers to equalize the hydrostatic pressure of the formation water. Alternatively, the center bit may be lowered and the augers raised until they are back in correct alignment. The center bit should not be forced deeper into the sand, as this may damage the tools or cause them to bind. A record of the intervals drilled using a center bit will be noted on the applicable log sheets, and the amount of water placed in the well (if applicable) will be recorded so it can be taken into account during well development.

A minimum 2-inch annulus is required between the well casing and borehole wall. Therefore, for wells installed inside augers, the OD of the augers should be a minimum of 4 inches with respect to the OD of the casing. Similarly, a minimum 2-inch annulus will be provided around well screens and casings when wells are constructed in open portions of boreholes. In open-hole installations (wells constructed in uncased boreholes) greater than 40 feet deep, the use of stainless steel casing centralizers will be required to ensure the 2-inch annulus is maintained. Centralizers should be provided above and below the well screen, but not within the filter pack or bentonite seal. (If the sump is installed in a pilot hole, the lower centralizer may not be necessary.) Depending on the well depth and diameter, centralizers may also be required at 20-foot intervals along the well casing to provide a 2-inch grout annulus.

During drilling, the cuttings and formation water from the boring will be placed in environmental materials or drums if required, and management as investigative derived waste (IDW).

Single-cased wells will typically be installed in the alluvium. Double casing may be required for bedrock wells installed in areas of potentially contaminated alluvial groundwater. If required, isolation casing will be installed through the alluvium according to the procedures in Subsection 4.3 of SOP PWT/GW.114, Drilling and Sampling Using Hollow-Stem Auger and Rotary Drilling and Rock Coring Techniques.

5.3.2 *Alluvial Piezometer and Monitoring Well Installation*

Figure PWT/GW.103-1 shows a schematic diagram of the lower portion of an alluvial well completion. If muddy water is present in the borehole when preparing to install the well, it may be necessary to remove the formation water and fine grained sediment using a sand bailer or pump until the water is relatively clear and free of sediments. This activity will be performed at the discretion of the project manager. If granular soils do not flow into the bottom auger, raising the augers 1 to 2 feet above the bottom of the hole can help with the removal of muddy water from outside of the augers. This will not work if the hole caves or fills with flowing sand or sediment.

The borehole depth will be measured to the nearest 0.1-foot with a decontaminated, weighted tape. The well assembly components, consisting of the sump, bottom cap, well screen, and well casing, will be individually measured to the nearest 0.01 foot, then summed to determine the total well assembly length. Measurements in inches will not be used. (Threaded male portions of these components, which will not contribute to total length but instead be contained within the adjacent component, shall not be part of these measurements.) Results of these measurements shall be recorded in the rig geologist's notebook. The total well assembly length may then be rounded to the nearest 0.1 foot. The well components may then be assembled, either in total (if not overly long and unwieldy) or in sections (if the entire well assembly would be too long to safely and easily handle).

Before placing the well assembly into the borehole, excessive void space between the bottom of the borehole and the depth at which the bottom of the sediment sump is to be positioned will be backfilled. This may occur naturally by raising the augers slightly and rotating them so that native materials (from the deep portion of the borehole) fill the bottom of the hole. If this approach is selected, care shall be taken to avoid smearing the screened interval with clays and to prevent shallow/surface soils from entering the hole; cuttings brought to surface shall not be used as backfill. The native materials will be packed to remove void space by tamping with a clean center bit or other appropriate tooling. Alternatively, the hole may be backfilled with commercially available bentonite pellets (<u>not</u> of the time release variety). Backfilling will proceed carefully to ensure the bentonite pellets end up where they are supposed to, and do not adhere to borehole walls or auger surfaces and potentially foul the borehole interval that is to be screened by the well. A tremie pipe should be used to place the bentonite, but if the tremie extends below the water level in the borehole the bentonite pellets must be added extremely slowly to prevent the tremie from clogging.

Once the well assembly is in place, it may be cut as necessary to remove excess length ("stick-up"). (If stainless steel components are used, this cut should be made prior to lowering the well assembly into the borehole.) This cut may be preliminary (with the final cut, to the designed level of the top of casing, postponed until after the well is installed) or final, although in some cases the well may shift positions slightly and a new "final" cut may be

warranted before the well is considered complete. In any case, the cut shall be made as straight and smooth as possible, and shall be perpendicular to the long axis of the well assembly so as to provide a uniform and horizontal top of casing once the well is installed. Prior to adding filter pack, the well shall be capped; this cap should be taped on for added security.

Filter pack (10-20 silica sand unless the approved job-specific work plan specifies otherwise) will then be added to the borehole slowly. If there is water in the borehole, extra care and time shall be taken to ensure the sand is being allowed to settle to the bottom. Sand should be added to the zone below the water level by tremie. In open-hole completions, tremie pipe should be used for filter pack placement to prevent sand from adhering to the borehole walls in intervals that are to be sealed with bentonite or bentonite grout, as this sand may provide a pathway for fluids not intended to be monitored by the well. The filter pack will be added in small (approximately 1 to 2-foot) increments so that the sand level is always at or slightly above the bottom of the augers. Depth measurements of the top of the filter material will be taken continuously as the filter pack is placed. The final depth to the top of the filter pack will be approximately 2 feet, but in no case less than 0.5 foot, above the top of the well screen. The top of the filter pack will be directly measured by a tape measure, which will be raised and lowered vigorously and otherwise used in such a way as to prevent it from becoming embedded in the filter pack and help prevent bridging. Even so, the weight on the tape measure will be stainless steel in the event that it accidentally becomes embedded in the filter pack.

If bridging of the filter material occurs in the well annulus or tremie pipe during placement, the bridged material will be broken loose mechanically by shaking the augers and/or well assembly. Bridged material in the annulus may also be broken loose by probing with a 1-inch-diameter tremie pipe or other decontaminated rigid tool. If these methods are unsuccessful, deionized or distilled water may be pumped through the tremie pipe or other clean tubing to dislodge the bridged material. A record of the amount of water placed in the well will be kept so that it can be taken into account during well development. The volume of filter material placed will also be recorded.

A 3 foot minimum bentonite pellet seal (before hydration) will be installed immediately above the filter pack. (Approved granular bentonite may be used in place of bentonite pellets if the work plan or project manager so directs.) If the bentonite pellet seal will be placed below the water table, the bentonite pellets will be added slowly to reduce the chances for bridging of the pellets. A tremie pipe may be used for this, but due to the difficulties involved this is not a requirement. If the bentonite seal is placed above the water level in the borehole, the pellets may be allowed to free-fall into the borehole. Regardless of the method used to install the bentonite pellets, they shall not be allowed to bridge. (If bridging occurs, the same methods as described above for filter pack shall be used to remove the bridge.) If the well is being installed within the augers, the augers will be raised approximately 1 foot above the filter pack prior to adding the

bentonite pellets (less if the base of the augers is in very loose, collapsing material; it may be slightly more if the material is competent and is unlikely to collapse onto the top of the sand pack). The top of the bentonite seal should never be above the base of the augers.

Once at its designed thickness, the bentonite pellet seal will be hydrated by slowly pouring 5 gallons of distilled or deionized water into the borehole along the outside of the well assembly, so that the well acts to guide the water to the seal rather than have the water scour the borehole walls. This step shall be performed after the base of the augers are raised approximately 1 foot above the top of the bentonite seal. However, if the bentonite seal is at or below the level of groundwater in the borehole, no distilled or deionized water will be added. The completed bentonite seal will be allowed to hydrate for a minimum of 30 minutes before proceeding with the grouting operation.

Bentonite grout backfill will be placed from the top of the bentonite seal to within 1 to 2 feet of the ground surface. The grout mixture will conform to the specifications outlined in Subsection 5.3.4.5, Bentonite Grout. The grout will be tremied into the well annulus at a low pressure so as to avoid damaging the bentonite seal or borehole walls. The volume of grout placed will be recorded. After 24 to 72 hours of settling, the bentonite grout will be checked and, if it has settled to more than 3 feet below ground surface, additional bentonite grout will be added to bring the level to within 1 to 2 feet of the ground surface. The added grout will be allowed to set for an additional 24 to 72 hours.

Alternatively, where alluvial wells are to be installed in such a way as to place the top of the filter pack within 10 feet of the surface, the bentonite pellet seal may be extended to 1.5 to 3 feet below the surface and hydrated. In such cases, no bentonite grout is needed.

A protective steel casing will then be installed (Subsection 5.5.1) to guard the above-ground portion of the well. The steel casing will be embedded in ready-mix cement or concrete. The cement will occupy the upper 1.5 to 3 feet of the well annulus to anchor the protective casing. This may require removing some of the bentonite grout from the upper 1.5 to 3 feet of the well annulus. If the upper grout surface is dehydrated, it will either be removed or rehydrated by adding a small amount of distilled or deionized water and waiting approximately 30 minutes before installing the casing.

Alternatively, the well may be installed with flush-mount surface protection (Subsection 5.5.3). This is often necessary in areas of high traffic. If flush-mount protection is to be installed, the well casing must be cut off below ground surface and a locking J-cap used to provide well security (unless the flush-mount can be locked). Where flush-mounts are installed, the top of the bentonite grout (or seal, if the well is shallow enough to allow omission of the grout) will be removed to a depth of approximately 1.5 feet and the sides of the borehole will be cleaned of bentonite and enlarged to accept the flush-mount assembly and sufficient concrete to form a structurally stable flush-mount installation. A small

amount (0.2 to 0.5 foot) of filter pack sand is then poured in the bottom of this excavation to allow the flush-mount to drain any water that may otherwise collect in it (regardless of claims as to the unit's waterproof construction). Concrete will then be placed in the annulus between the flush-mount skirt and the enlarged borehole, with the smoothed, finished surface flush or slightly raised above ground surface. If in an area subject to snowplow or other scraping equipment, the flush-mount installation should be at or slightly below the level of the ground surface for protection, even though this will cause ponding of surface waters at (and often within) the flush-mount. This configuration should be avoided if possible.

Refer to Section 5.5 for a detailed discussion of well protection requirements.

5.3.3 *Bedrock Piezometer and Monitoring Well Installation*

Figure PWT.103-2 shows a schematic diagram of the lower portion of a bedrock well completion. Bedrock piezometers and monitoring well installations will be similar to alluvial well installations except that a surface casing (isolation casing) through the alluvium may be required to guard against potential cross-contamination of aquifers by contaminated groundwater and/or soils. If required, the surface casing will extend from the ground surface to at least 3 feet below the alluvial/bedrock contact, or deeper in areas with shallow confined sandstone bedrock. (The project-specific work plan will state whether isolation casing is required, and the depth to which it is to be installed. If for some reason this information is not specified in the project-specific work plan, isolation casing will be installed at the direction of the project manager and on an as-needed basis. Surface isolation casing is not a Site-wide requirement for bedrock wells and piezometers.) This casing will be installed according to SOP PWT/GW.114, Drilling and Sampling using Hollow-Stem Auger and Rotary Drilling and Rock Coring Techniques.

If rotary drilling methods (see SOP PWT/GW.114) are required, well installation procedures will be similar to those for alluvial wells except that the well may be completed in an open hole. If longer than 60 feet (or at the rig geologist's discretion for shorter wells), the well string will be suspended approximately 0.2 foot above the bottom of the borehole prior to installing the filter pack. This will reduce bending of the well assembly and minimize the potential for collapse of the casing due to the weight of fluid in the annulus. Stainless steel centralizers will be placed at 20-foot-maximum spacing for wells deeper than 40 feet and which are completed in open holes; this 20-foot spacing will exclude the area of the well screen and bentonite seal, which shall be free of centralizers. Typically, one centralizer will be positioned at the bottom of the well on the sediment sump, the next above the bentonite seal, and then at 20-foot intervals to the surface.

Where wells cannot be completed in an open hole because of borehole instability or other problems and/or the well

cannot be completed within augers, the well may be installed through casing. This casing will be a diameter sufficient to provide a 2 inch annulus around the well casing and will consist of clean (decontaminated) PVC or steel. The casing will be advanced to the selected depth either using no additional fluids or by circulating potable water or water obtained from a fire-hydrant down through the casing. After reaching the selected depth, a sand bailer or pump should be used to remove any accumulated sediments until the borehole is empty of fluids or until fluids are relatively clear and free of sediment. The well assembly will then be advanced through the casing to the designated depth and the annulus between the casing and the well assembly will be used to tremie well materials. The well will be installed as per alluvial wells installed through augers, except that the casing will be used instead of augers.

5.3.4 *Well Materials*

5.3.4.1 Well Casings

Well casings will consist of new, threaded, flush-joint schedule 40 or schedule 80 poly-vinyl chloride (PVC) unless another type of casing (e.g., stainless steel) is required by the project-specific work plan. Unless installed as a flush-mount, the well casing will extend from the top of the well screen to approximately 2 feet above ground surface. The tops of all well casings will be fitted with slip-on or threaded PVC caps that can be easily removed by hand. All joints within the casing string will be threaded. Heat-welded joints, solvents, and/or gaskets will not be used. If recommended by the manufacturer, inert, non-degrading O-rings may be used between joints or polytetra fluoroethylene (PTFE) tape can be wrapped around the joint threads to improve the seal. All well casings will be free of foreign material and if not provided in wrapped, factory-cleaned condition will be steam cleaned with approved water before use. Clean casings will be stored flat (so as to prevent them from adopting a permanent bend) in plastic sleeves prior to use. Casing with stickers or stamped or stenciled nomenclature will <u>not</u> be used.

5.3.4.2 Well Screens and Sediment Sumps

Well screens will consist of new, threaded, flush-joint schedule 40 or schedule 80 PVC pipe with 0.020-inch factory-machined slots, unless another slot size is required by a project-specific work plan. All well screens will have an ID equal to or greater than that of the well casing. The wall thickness of PVC screen will be the same as that of the well casing. Unless otherwise stated in the project-specific work plan or directed by the project manager, wells will have a 2-foot-deep sediment sump with a flush-threaded PVC bottom cap attached beneath the screen. Well screens and sumps will be free of foreign material and if not provided in wrapped, factory-cleaned condition will be steam-cleaned with approved water before use. Clean screen and sumps will be stored flat in plastic sleeves prior to use. Well screen and sediment sumps with stickers or stamped or stenciled nomenclature will <u>not</u> be used.

5.3.4.3 Filter Pack

The filter pack material will be chemically inert, rounded, silica sand of appropriate size for the well screen and host environment. Grain size analyses of the unconsolidated formations underlying the Denver area have indicated a 10-20 gradation is appropriate and will be used unless the project-specific work plan requires otherwise. The filter pack will extend approximately 2 feet above the top of the screen unless otherwise specified. Where the thickness of the alluvium is insufficient to allow this, the top of the filter pack may extend as little as 0.5 foot above the top of the screen. The final depth to the top of the filter pack will be measured directly by using a weighted tape measure and not by using volumetric calculation methods. The volume placed will be recorded.

5.3.4.4 Bentonite Seal

A bentonite seal will be installed above the filter pack. The seal will consist of a layer of commercially available bentonite pellets (not of the time release variety) that is a minimum of 3 feet thick when measured immediately after placement, without allowance for swelling. Approved granular bentonite may be used in place of bentonite pellets if the work plan or project manager so directs. The volume placed will be recorded.

5.3.4.5 Bentonite Grout

The annular space between the well casing and the borehole will be grouted from the top of the (hydrated) bentonite seal to 1 to 2 feet below ground surface. The grout will consist of high-solids reduced-pH bentonite grout (American Colloid Pure Gold™ or approved equivalent) mixed in a powered mechanical grout mixer according to the grout manufacturer's recommendations. The grout may be mixed by hand for intervals less than 5 feet thick. The grout will contain at least 30 percent solids by weight and have a minimum density of 9.9 pounds per gallon after mixing. The density will be checked with a mud balance and recorded in the rig geologist’s logbook.

Grout will be placed outside of the monitoring well casing using a tremie pipe that should be positioned just above the top of the bentonite seal. The grout will be pumped through the pipe at a low rate to minimize disturbance of the bentonite seal and borehole walls. If groundwater is present in the borehole above the top of the seal, grout will be pumped into the borehole until undiluted grout flows from the annular space at the ground surface. If no groundwater is present above the top of the seal, grout will be pumped to 1 to 1.5 feet below ground surface. The tremie pipe will then be removed and more grout added if necessary to compensate for settling, with the final grout level at 1 to 2 feet below surface. The site will be checked for grout settlement prior to installing surface protection and more grout added if necessary to compensate for additional settling. The total volume placed will be recorded.

When excessive grout loss into landfilled or other highly porous materials occurs, grouting will be stopped and bentonite chips or pellets will be added to the annular space to seal off the area losing grout. (However, if there is good reason to believe grout loss may be attributed to the presence of buried utilities or other structures, such as tunnels or vaults, the project manager shall be contacted immediately and shall determine the proper approach.) A minimum of two feet of pellets or chips will be added, then grouting will resume as above. If grout loss continues or if grout is again lost further uphole, grouting will again be stopped and additional bentonite pellets or chips will be added until grout loss is stopped.

Unless grout loss is anticipated, only enough grout to fill the hole should be mixed. Required grout volume should be carefully calculated, with a reasonable amount added to account for borehole irregularities. Excess grout may be diluted with additional potable or fire hydrant water so as to be usable for the next well installation. Otherwise, it must be handled as waste or, if the volume is small and the project manager so instructs, the excess grout may be similarly diluted and then sprayed over a thinly or non-vegetated area. In this event, care shall be taken to provide adequate dilution and dispersal so as to avoid harming vegetation or coating the ground surface.

5.4 Well Installation Using Push-Type Equipment

Alluvial well boreholes formed using push-type equipment are limited by the depth they can attain and the materials they can penetrate, as well as the casing and borehole diameter requirements of the well. Geologic conditions in the area of interest, and the depth of interest, must be considered when determining whether this methodology is appropriate. In most areas, geologic conditions typically limit the depth of penetration using this type of equipment to around 30 feet. Boreholes that are formed using push-type equipment shall be bored in accordance with PWT/GW.124, Direct Push Subsurface Soil Sampling.

Where push-type equipment is used, it may be necessary to case off surficial materials to minimize their entry into the borehole as the borehole is probed. This is especially important where surficial materials may be contaminated and where the well is being installed in an asphalt-paved area, as these surficial materials can fall into the hole and artificially skew sample results. Using dual-wall probing equipment (see PWT/GW.124, Push Subsurface Soil Sampling) can help to minimize the amount of surface soils entering the borehole, but if the tools are withdrawn to install the well these soils are apt to collapse into the borehole. Surface soils may be prevented from entering the borehole using aseptic installation methods (see Subsection 5.4.4) or similar temporary techniques.

Various types of wells may be installed in probed boreholes. The most common are 3/4 inch to 1 inch ID PVC wells. However, manufacturers of push-type equipment have produced several varieties of groundwater monitoring

systems (e.g., pre-packed well screens, screen points, etc.) that may be installed directly into the probed boreholes through push tooling. The installation of one such system, the pre-packed well screen, is described in this SOP (see Subsection 5.4.2). However, other systems may be used; the main requirement is that the system be installed in accordance with the manufacturer's instructions and in a manner consistent with the requirements of this SOP.

5.4.1 *Well Installation Using Macro-Core or Dual Wall Equipment*

Wells may be installed in boreholes probed using Geoprobe® Macro-Core® Sampler or a Dual Wall Soil Sampler (or equivalent equipment). The borehole will be pushed to the appropriate depth, and core logged, in accordance with the pertinent SOPs (PWT/GW.124, Push Subsurface Soil Sampling; and PWT/GW.104, Borehole Logging, respectively) and/or as specified in the project work plan. Typically, wells installed in pushed boreholes will be of 3/4 inch to 1 inch ID, with short threaded bottom end-caps (as opposed to a 2 foot sump) and an annulus significantly less than 2 inches. The end cap shall be considered the sediment sump, unless a longer and more formal sump is required by the approved job-specific work plan, and the well shall be centered within the borehole as well as possible.

In some cases, it is acceptable (e.g., when core is not required) or necessary (e.g., when attempting to break through a cobble) to use a solid point to push the borehole, instead of using a core barrel to push the borehole and collect core. When using a solid point because core is not required, the same process will be used as when the borehole is being drilled using hollow-stem augers with a center bit. That is, as the depth of the pushed borehole approaches the depth at which the bedrock contact is anticipated, the solid point should periodically be replaced by a core barrel and core collected to confirm the depth of the bedrock contact. If the depth of the contact is already well known, this may not be necessary.

Wells installed in pushed boreholes may be installed open-hole and centralizers need not be used. However, care shall be taken when installing these wells so as to minimize or prevent the problems most common to wells installed in pushed boreholes:

- Borehole collapse, wherein TD is reached and the push tooling withdrawn, but the hole partially collapses such that the required TD can't be reached with the well assembly and the tooling must be used to clear out the hole and/or the well design must be adjusted for the reduced depth. This can result in a poorly-constructed and/or improperly-screened well. Often the solution is to simply ensure that the well components are assembled and ready to place in the borehole immediately upon the (rapid) withdrawal of the push tooling. However, if this is a recurring problem, the project manager shall be contacted for instructions. Substantial adjustments to well design must also be approved by the project manager.

- Poorly centered well (wherein the well assembly is not centered in the borehole). This may be due to inattention on the part of the installation crew, well materials containing a slight bend (as may be caused by PVC well materials being stored or transported with inadequate protection from flexing, such that they adopt a permanent bend), the hole walls not being straight (typically due to cobbles or partial caving along the borehole), and/or the well assembly being forced deeper in the hole to recover lost depth and bending as a result. The consequence can be a poorly-constructed well that produces abundant silts and clays and can potentially prevent sampler access. To prevent this, well materials will be stored and transported flat, the well assembly will be carefully lowered and centered in the hole, and the well assembly will not be unnecessarily forced to achieve greater depth. In addition, once the assembly is in place, filter pack sand should be added as quickly and efficiently as possible, taking care to both minimize the time in which borehole caving can occur yet still ensure the sand does not bridge in the borehole.

The specific project requirements shall be considered when determining the acceptability of any well exhibiting problems such as these, and the project manager shall be consulted to determine whether such a well must be replaced.

Wells constructed in boreholes having an annulus smaller than 2 inches (e.g., pushed boreholes) follow the same requirements as those described in Subsection 5.3.2, with several exceptions that are discussed herein.

When measuring the borehole depth, spatial limitations may make it more feasible to use a steel tape measure instead of a weighted tape measure, especially after the well assembly has been placed in the hole. Addition of filter pack and other well materials shall be performed so as to minimize the risk of bridging. However, the small annulus in these wells prohibits all but the smallest of tremie pipes; therefore, tremies are typically not used. While adding these well materials, the steel tape or other small-diameter rigid tool (such as extension rods designed for use with a Geoprobe® piston assembly, for example) should be continuously raised and lowered in the borehole to keep it clear. Bridged material will be broken up using the same tool, taking care to prevent the tool from being damaged or embedded in the borehole.

Well components shall conform to the requirements listed in Subsection 5.3.4.1 through 5.3.4.3 above, with the previously noted exceptions of component size and other minor exceptions. Unless flush-mount surface protection is planned, the well casing, when placed in the borehole, will extend from the top of the well screen to approximately 0.5 to 1 foot above ground surface. Shorter sediment sumps may be installed in these smaller wells; it is acceptable to omit a formal sump and simply use a threaded bottom cap, unless the project-specific work plan requires otherwise.

The filter pack material will conform to the requirements listed in Subsection 5.3.4.3 above, and will extend across the screened interval to 0.5 to 2 feet above the top of the screen.

The requirements listed in Subsections 5.3.4.4 and 5.3.4.5 for bentonite seal and grout do not apply. Instead, granular bentonite will be added to the annulus following completion of the filter pack. Granular bentonite will be added slowly and a steel measuring tape, extension rods, or other small-diameter rigid tool will be used to prevent bridging of the bentonite and assist its packing. This is especially critical in boreholes containing water above the top of the filter pack, where bridging is likely and therefore the rate at which the granular bentonite is added must be very slow and anti-bridging efforts must be constant.

These small-annulus wells may be completed either as flush-mounts or with a protective casing of steel or, if small-diameter (less than 2 inch ID), of PVC. Surface protection is discussed in Section 5.5.

5.4.2 *Installation of Pre-packed Well Screens Using the Dual Wall Equipment*

Pre-packed well screens are installed using the Geoprobe® Dual Wall Soil Sampler (or equivalent). Using this method requires either that the well be installed at a predetermined depth, omitting core sampling as the downhole tools are advanced in depth; or by using an expendable cutting shoe, wherein core may be recovered while the hole is being driven and the pre-packed screen installed after the expendable shoe is disengaged at the bottom of the hole.

To set a pre-packed well screen, or coupled pre-packed screens, at a predetermined depth, an expendable drive point with a snap-lock connector assembly is attached to the lead drive rod of the outer drive rods (2.125 inch OD) of the dual wall sampler. The inner drive rods are not used during this procedure. A drive cap is threaded to the top of the drive rod, and the rod is pushed or hammered to a depth that will allow the removal of the drive cap and the addition of the next drive rod. The drive cap is threaded into the added rod, and the assembly driven or hammered to depth to allow for the removal of the drive cap and the addition of another drive rod. This procedure is repeated until the desired TD is reached.

The well assembly will then be prepared for installation. It will consist of factory-cleaned or decontaminated pre-packed well screen(s) and PVC casing which are threaded together as a unit. If necessary, as instructed by the manufacturer, inert non-degrading O-rings provided by the manufacture may be used at each threaded joint. A slip cap will be placed at the top of the casing string, and should be taped on to ensure it remains attached to the casing. The assembly will be lowered through the inside of the probe rods until the lower pre-packed screen locks into place in the

snap-lock connector attached to the expendable drive point.

The well assembly will then be held in place by hand as the drive rods are slowly raised using the rod grip assembly (mounted on the back of the hydraulic drive assembly). When the expendable drive point has disengaged from the drive rods, filter pack (as described in Subsection 5.3.4.3) may be added around the pre-packed well screen(s) through the drive rods as they are slowly removed. It is critical that bridging of filter pack be avoided, because this can damage the tooling and destroy the well components. After the filter pack has been added to a predetermined depth, or to 0.5 to 2 feet above the top of the screen if not otherwise specified, granular bentonite may be added as the rods are removed. If the well is in competent material, the filter pack and bentonite may be added after the drive rods are removed. A steel tape will be used to determine the depth of the filter pack and granular bentonite as each is being added to the well bore, and to prevent bridging. Care should be taken not to embed the tape in either material while it is being added to the hole. The well will be completed at the surface according to the procedures in Section 5.5 of this SOP.

To set pre-packed well screen(s) using an expendable cutting shoe instead of expendable drive point, the procedures for sampling using the Dual Wall Soil Sampler in SOP PWT/GW.124 should be followed, except that an expendable cutting shoe and adapter will be substituted for the standard cutting shoe. When the hole TD has been reached, the expendable cutting shoe can be disengaged after the inner drive rod assembly and sample tube has been removed. The pre-packed well assembly will be inserted and the well completed as discussed in the paragraphs above.

5.4.3 *Well Point Installation*

Well points are similar to wells and piezometers installed using push-type equipment except in their purpose and materials. Their purpose is typically restricted to providing water level data, although small-volume samples may be collected if necessary. (This is generally discouraged, since well point construction materials may not be as inert as is required for monitoring wells; however, on occasion well points may provide useful screening-level data.) Well points are typically constructed in smaller-diameter boreholes and of flexible tubing that is hand-perforated along one end, with that end acting as the screened interval.

Push-type equipment (Geoprobe® or equivalent) and standard drive rods (1 or 1.25 inches in diameter) equipped with an expendable point adapter and expendable point will be used to push to the desired TD. When TD is reached, the hand-perforated end of the tubing (Polyethylene or Teflon), with a threaded stud attached to the leading end, will be fed down through the probe rods until it is threaded into the expendable drive point. The perforated section of the tubing will typically range between 1 and 5 feet, with this length based upon the anticipated

magnitude of water level fluctuations.

The probe rods will then be withdrawn from the hole, leaving the expendable point and tubing in place. Unless specified otherwise in the work plan, 10-20 silica sand filter pack will be added to the borehole to a point approximately 0.5 foot above the top of the screen, while maintaining slight tension on the tubing to keep it straight and centered in the hole. A granular bentonite seal of at least 0.5 foot in thickness will be installed above the filter pack to approximately 0.3 foot below ground surface.

Surface protection on well points will be minimal, typically consisting of an approximately eight-inch long, one-inch diameter PVC casing with threaded or slip cap. This casing will be embedded at least 4 inches into the ground, after which additional granular bentonite will be added to just above ground surface. It is not necessary to lock well points.

The well point will then be marked with a stake, pin flag, or other suitable marker. In areas of traffic, a steel post or steel fence post should be installed adjacent to the protective casing to act as a more visible marker and traffic barrier.

5.4.4 *Aseptic Surface Protection for Wells and Piezometers Installed using Push-Type Equipment*

Where surface soils are or may be contaminated, wells and piezometers should be installed aseptically so as to prevent this contamination from entering the hole and thereby causing cross-contamination and potential artificial contamination of samples. While the following text describes the major points of aseptic installation, other actions may be taken to further protect the borehole, such as replacing soiled gloves before handling clean downhole tooling or well components, preventing soils from being knocked into the hole, preventing potential sources of contamination from entering the hole, etc.

Aseptic installations using push-type equipment are typically much simpler than those for wells installed using a drill rig (as described in SOP PWT/GW.114). In all cases, if the project-specific work plan describes the aseptic design to be used, it shall take precedence over the aseptic design presented herein.

Materials needed to perform aseptic installations using push-type equipment are only loosely defined because the well design and surficial protection can affect material selection. Typically, all that is required is a 2 to 4 foot length of schedule 40 or schedule 80 PVC of a diameter sufficient to allow passage of the core sampler and probe rods. The length depends on the anticipated vertical extent of contamination, and the ID depends on the size of the probe

tools. For example, if the dual wall system is used (2.125 inch OD) and if only the uppermost 0.5 to 1 foot are potentially contaminated, a 2 foot long section of 4 inch ID schedule 40 PVC should be sufficient.

Once the probing location has been selected, cleared, and the probing equipment is available, aseptic preparations may begin. The push-type equipment may be used to start the excavation (this is especially helpful in paved areas), in which case an area just large enough to contain the aseptic surface casing (and flush-mount, if applicable) will be probed to a depth several inches shallower than what is eventually required. Hand tools, such as narrow spades and a post-hole digger, will then be used to clean out the hole so as to remove shallower, potentially contaminated soils from the hole. Only then will the hand tools be used to finish the excavation. The soil will be carefully removed so as to prevent shallower soils from entering the hole. Once the hole is of the appropriate depth and diameter to accept the aseptic casing, any remaining loose soils will be removed and the aseptic casing will be placed in the hole. In the example above, using a 2 foot length of 4 inch ID schedule 40 PVC as the aseptic casing, this hole would be slightly less than 2 feet deep (so as to leave a short amount of PVC projecting above ground surface) and approximately 4.5 to 5.5 inches in diameter (large enough to accept the PVC, but small enough to prevent it from wobbling about).

A small amount (1 inch or so) of granulated bentonite is then poured in the annulus around the outside of the aseptic casing. This bentonite is then saturated to form a seal so as to prevent soils from entering the hole by bypassing the outside of the aseptic casing. (If the casing is wobbly, it may be braced with additional bentonite.) Once this seal is firmly in place, probing may begin, with probe tools threaded and the borehole advanced through the center of the aseptic casing. If probing is discontinued for any reason (e.g., end of the day), the opening of the aseptic casing will be sealed with clean sheet plastic to prevent foreign materials from entering the borehole.

After the well or piezometer is installed, the aseptic casing may be removed and its excavation filled with granulated bentonite. If the well is to be a flush-mount installation, the excavation for the flush-mount assembly may be made at this time or as part of the aseptic excavation. (If the well will be a flush-mount, the aseptic casing may be cut as appropriate to fit within the flush-mount, and a locking cap of the appropriate size may be attached to it such that the aseptic casing forms the lockable casing. Alternatively, the aseptic casing may be thoroughly decontaminated for reuse on another location and replaced with a lockable protective casing as described in Section 5.5.)

5.5 Monitoring Well and Piezometer Features at Ground Surface

Once installed, the well or piezometer must be protected and in almost all cases locked. This subsection describes

the various forms of protection, and will be considered to apply to any type of groundwater monitoring device (well, piezometer, etc.) although in many cases only the term “well” is used. The type of protection required should be set forth within the project-specific work plan. If it is not, this topic should be discussed between the rig geologist and the project manager before drilling or probing activities begin.

In all cases, the first step should be to ensure that the top of the well casing is smooth and cut flat (perpendicular to the long axis of the well). A small notch should then be filed or cut into the north edge of this casing to serve as the measuring point (MP), which will be the reference point for all subsequent measurements of water level and well depth. Once this task is complete, the selected surface protection may be installed.

5.5.1 *Above-Ground Surface Protection for Wells Installed with a Drill Rig*

Figure PWT/GW.103-3 shows a schematic diagram of typical above-ground well protection on wells and piezometers installed in larger-diameter boreholes (i.e., 6 inches or larger, with an annulus of 2 inches or more). This is generally limited to boreholes drilled using a drill rig rather than those probed using push-type equipment, since the latter forms a borehole in the 2 to 3 inch diameter range.

A 5-foot-long protective steel casing with a locking steel or aluminum cap will be installed over the monitoring well casing as shown in Figure PWT/GW.103-3. (Hinged steel caps should be avoided because they tend to rust and may break.) This protective casing should be installed between 24 and 72 hours after initial grout placement, except when temperatures are below freezing. A shorter length protective steel casing (no less than 3-foot long) may be used where a longer casing would breach the bentonite seal. The protective casing will have a minimum 8-inch ID for 4-inch wells and a minimum 5-inch ID for 2-inch wells. The bottom of the 5-foot-long protective casing will be embedded 2 to 3 feet below the ground surface in concrete or cement. (If a shorter steel casing is required, it will be embedded a minimum of one foot below the surface.) If there is some doubt as to the well’s integrity, prior to installing the protective casing the well may be checked for alignment by lowering a 3-foot long, 1 3/4-inch OD bailer down the entire depth of the well. If the bailer hangs up, the project manager will decide whether or not the well needs to be reconstructed.

At the same time the protective steel casing is cemented in place, an external, approximately 3-foot square, cement or concrete well pad will be poured around the protective casing at the ground surface. The well designation will be inscribed in the concrete before it sets. The pad will be graded to slope away from the casing in all directions, and should be at least 5 inches thick.

The annulus between the well casing and the steel protective casing will be filled with nonshrink cement or concrete to approximately 1 foot above the ground surface. A 1/4-inch-diameter weep hole will be drilled in the protective casing just above the cement or concrete surface to allow for drainage.

When daytime temperatures are consistently below freezing, it is not feasible to excavate the uppermost 1.5 to 3 feet of grout in order to install the surface well features since the grout is often frozen and difficult to remove. In addition, poured concrete may freeze before it cures causing cracking and necessitating replacement to ensure a competent surface seal. In these instances, the PVC well casing will be securely capped until warmer weather allows the setting of surface features. Wells installed during freezing weather will not be permitted to stand without surface features for more than two months.

5.5.2 *Above-Ground Surface Protection for Wells Installed with Push-Type Equipment*

Figure PWT/GW.103-4 shows above-ground protection and surface features of wells, piezometers, and well points installed using push-type equipment and having an annulus of less than 2 inches. Because of the smaller size of these wells and their often temporary purpose, it is generally not reasonable or necessary to install the same above-ground steel protection and concrete pad required for larger, more permanent monitoring wells.

These smaller wells and piezometers will typically use schedule 40 or schedule 80 PVC casing in place of the larger wells' steel protective casing. The PVC will be approximately 1.5 feet to 3 feet long, depending on how high above the ground the well extends. The PVC should be of a diameter small enough to fit within the borehole yet sufficiently large to allow access to the well cap within. (For example, a 0.75-inch ID well installed in a borehole pushed with 2.125-inch OD tools typically employs a 2 inch ID protective casing.)

The PVC will be embedded below ground surface at least 0.6 foot for stability, and more if feasible. This will require that the top of the granulated bentonite added during well installation be at or below this depth, as it can be very difficult to force the PVC to depth through the bentonite, and such attempts may damage or destroy the PVC and, potentially, the well. The depth to which the PVC is pushed will be recorded, as will its diameter, its above-ground height, and that of the well casing within.

The top end of the PVC protective casing will be cut smooth and flat so as to accept a locking J-cap or other lockable cap. This casing should extend above the well casing with just enough extra space above the well to fit the well cap and the internal components of the locking cap. If too much space is left at the top, measurements of water level and TD (which are relative to the MP on the top of the casing), and removal and replacement of the well cap,

can be exceedingly difficult since the protective casing is typically too small to allow a hand to enter. To assist removal of the well cap, a Teflon-lined stainless-steel cable may be formed into a loop and threaded through small holes drilled in the well cap (drilled just large enough to accept this cable). (Other methods may be used as an alternative to the stainless-steel loop, so long as the materials are inert and the well cap is not pierced with holes so large as to defeat the cap's purpose.)

Granular bentonite will then be added to the borehole both within and outside the protective casing. Outside the casing, it will fill the hole and form a mound around the base of the casing; it will then be saturated with distilled or deionized water. Inside the protective casing, in the annulus between the well casing and protective casing, granular bentonite will be added to a level that is above that on the outside yet is far enough below the top of the well casing to eliminate the possibility that it may swell with moisture and enter the well. It need not be hydrated. The protective casing need not be drilled with a weep hole. However, if the well is screened in confined water-bearing materials (which is unlikely for this type of well), a weep hole may be necessary and will be installed if instructed by the project manager.

The well designation will be written with a permanent marker or paint pen on the protective casing and, if possible, on the locking cap. In areas of high vegetation, flagging and/or a tall metal stake may be required to aid subsequent location of the well. In areas of high traffic, these smaller wells should be installed with flush-mount well protection instead of above-ground protection. If this is not feasible, one or more tall metal stakes should be installed next to the well for protection and better visibility.

It should be noted that flush-mount wells installed with push-type equipment typically require a lockable casing to be installed within the flush-mount assembly, but completely below ground-surface. In such cases, the same methods for installation of protective PVC casing will be used and adjusted as appropriate for this application. (See next subsection for additional information.)

Where the purpose of the well or piezometer is temporary, full completion as described in this SOP may not be necessary. The project manager shall make this determination and it will be documented in the project-specific work plan or other controlling document as well as in the rig geologist's logbook.

5.5.3 *Flush-Mount Surface Protection*

In areas of high traffic, it may be necessary to install flush-mount surface protection (Figure PWT/GW.103-5) on monitoring wells rather than above-ground protective casings. Flush-mount protection is appropriate for wells

installed with traditional drilling methods (e.g., hollow-stem augers) as well as push-type methods (e.g., Geoprobe®). The advantage of using a flush-mount is that the well does not present an obstruction. However, flush-mounts have several disadvantages that must be considered. These disadvantages must be addressed through the use of careful installation techniques.

The main disadvantages to flush-mount surface protections are:

- the well is more difficult to locate since it is a less-noticeable landmark;
- there is a tendency for flush-mounts to collect loose dirt, potentially fouling the seal of the manhole as well as rendering the flush-mount even less visible;
- there is a tendency for flush-mounts to collect surface water if recessed or be damaged if raised above the adjacent ground surface;
- if located in areas of heavy traffic and subject to being repeatedly run over or parked on by vehicles, the flush mount may break, requiring administratively and physically difficult replacement;
- only a small amount of space is available in the most commonly used flush-mounts (6 inches to 8 inches in diameter) to accommodate the well cap and lock;
- the flush-mount itself cannot be locked.

Prior to installing a flush-mount, the project manager and/or rig geologist will determine the best final height of the unit and, together with the well installation crew, devise plans for addressing the other problems listed above as much as is feasible.

Flush-mount casings consist of a cap (the “manhole”); a rim in which the manhole sits; and a skirt, which extends downward from the rim into the ground (typically 8 inches to 1 foot). Only pre-manufactured flush-mount assemblies will be used. Flush-mounts will be of a diameter sufficient to contain the well casing, a lockable cap (e.g., J-cap), and lock, with enough spare room to allow sampling personnel easy access to the well cap and lock by hand. In some cases, e.g., where dedicated pumps will be installed, additional room within the flush-mount may be required to allow room for the surface components of the pump system. The manhole of the flush-mount will be designed so as to be watertight and will be secured to the rim with bolts. (A flexible gasket will typically be present in the rim to make the sealed assembly watertight.) The assembly will be rugged enough to provide protection even if installed in an area of heavy vehicular traffic. However, if possible the well should be placed so as to minimize direct vehicular contact (e.g., in the middle of a traffic lane instead of in the tire tracks). Flush-mount assemblies that are not designed to be watertight, or that do not employ manholes that can be secured with bolts, will not be used. Threaded manholes designed to be screwed into the rim will not be used as the threads are easily fouled with dust and dirt. (Even “watertight” assemblies are typically not watertight, but the extra protection and water resistance afforded by this construction is nonetheless helpful.)

Flush-mount casings will typically be installed “flush” with the ground surface. However, in some instances it may be preferable to install the unit so that it is raised somewhat above ground surface, as in low-lying areas (to prevent surface water from ponding at the wellhead) or areas where the well would otherwise be difficult to locate due to poor visibility (for example, in bare earth and/or vegetated locations, where the well cover may be obscured by loose dirt or vegetation). If the area is landscaped and mown, the flush-mount should not extend much, if any, above ground surface or it may present a hazard to groundskeepers. If the well is in a heavily trafficked area, it will most likely need to be installed flush with or very slightly lower than the adjacent topography so as to be safe from vehicles such as snow plows or other heavy equipment. In any case, it may be helpful to paint the manhole a fluorescent color to aid its location, especially in unpaved areas.

When installed at wells drilled with conventional drilling methods (such as hollow-stem augers), the flush-mount unit will generally be installed within the existing borehole. In some cases, especially where the well is installed using methods that yield a smaller-diameter borehole (as in push-type probing methods) or where a well is being converted from an above-ground surface protection to flush-mount surface protection, it may be necessary to enlarge the borehole at the surface to accommodate the flush-mount. This may be done in advance of drilling or probing activities, or after the well is installed. Performing this in advance helps decrease the amount of surface materials falling into the borehole, and the well does not form an obstruction that must be carefully avoided; however, if probe or auger tip refusal is encountered and the borehole must be offset, this step must be repeated. The time at which the borehole is enlarged (pre- or post-probing) will be left to the project manager or designee to decide. If performed after the well is installed, borehole enlargement shall be performed very carefully so as to avoid damaging the well.

If borehole enlargement is required, push equipment (e.g., Geoprobe®) may be used to break up surficial soils and/or pavement to the proper size and depth. Hand tools will be used to finish the enlargement. Soils and other materials that are removed will be handled in accordance with the appropriate work plan and/or Standard Operating Procedure. Tools will be decontaminated before use and between locations.

The following steps describe the typical installation requirements, which are to take place after the annulus between the well and the borehole has been filled with grout or granulated bentonite.

1. Ensure there is sufficient space between the top of the well casing and eventual position of the manhole on the flush-mount assembly. If necessary, cut off additional well casing and notch the north side. Record the length of any casing that is removed so that the well construction diagram will be correct. (If the well is to be

equipped with a dedicated pump, the top of the well casing and the inside surface of the manhole should be separated by approximately 6 inches; if it will not be so equipped, the separation can be less.)

2. Using an indelible marker, write the well location code on the top of the well cap.
3. Cap the well securely to prevent soils from entering the well and lock the cap. (Locking J-caps are appropriate for this; if the well was installed using push-type equipment, it may be necessary to prepare the same type of lockable protective casing as is described above in Subsection 5.5.2, but at a below ground-surface level.)
4. Excavate and/or enlarge the borehole as necessary to accommodate the flush-mount assembly and sufficient concrete to provide a structurally sound installation. If the borehole was drilled with a drill rig and contains bentonite grout up to the bottom of the flush-mount excavation, remove the top 0.2 to 0.5 foot of grout and clean the sides of the borehole to allow better drainage.
5. With the manhole removed, lower the flush-mount assembly into the borehole, centering the well in the assembly.
6. Adjust the elevation of the flush-mount as necessary using borehole materials (soils and/or rocks).
7. Once the level is correct, place a small amount (0.2 to 0.5 foot) of filter pack sand around the well (if installed with drill rig) or protective casing (if installed with push-type equipment) (Figure PWT/GW.103-5). This allows the assembly to drain in the event that water enters it. Be sure the top of the sand is several inches below the top of the well.
8. Attach the manhole to the rim.
9. Mix an appropriate quantity of quick-setting concrete.
10. Place the concrete in the annulus between the flush-mount skirt and the borehole, tamping and poking the concrete in so as to remove bubbles and voids within the concrete. Concrete may also be placed around the inside bottom edge of the skirt (without preventing drainage) for additional structural stability. (See inset, Figure PWT/GW.103-5.)
11. If necessary, push the flush-mount deeper into the borehole, being careful not to damage it.
12. Finish the surface of the concrete to form a smooth seam between the surrounding surface and the top of the flush-mount. Do not allow the rim of the flush-mount to jut above the level of the concrete.
13. Place traffic cones around the flush-mount to protect it while the concrete cures. If temperatures are low or precipitation is likely, it may be necessary to cover the flush-mount with sheet plastic to assist the curing process and protect the concrete.

The flush-mount assembly will be marked with the well location code, using an engraver or set of stamps, either in advance of installation or after the concrete has cured. If the metal is too hard to etch legibly, mark the concrete (AFTER it has completely cured) using a paint pen. In some cases it may be necessary to attach a numbered metal plate to the manhole using an indoor/outdoor epoxy-type adhesive; if this is the case, it should be done in advance

so that the manhole may be thoroughly cleaned and its temperature controlled to assist the curing of the adhesive. In addition, the adhesive must not be subject to darkening or clouding from exposure to sunlight. Unless instructed otherwise by the project manager, the well location code will not be inscribed in the wet concrete as this tends to significantly weaken feathered concrete aprons such as those placed around flush-mounts. Once the location code has been added, remove any traffic cones and plastic used to protect the flush-mount while it cured, make sure the manhole is securely tightened to the rim, and reopen the area to normal traffic.

6.0 POST-INSTALLATION DOCUMENTATION

The installation of monitoring wells and piezometers will be documented in the rig geologist's logbook and on geologic, drilling/probing, and groundwater monitoring well and piezometer report forms. The rig geologist's logbook shall provide a detailed and chronological description of events, including but not limited to field personnel, weather, drilling equipment, drilling and associated activities, sampling and associated activities, well installation and associated activities, geologic information, borehole and well component measurements (e.g., TD = 23.0 feet; screens = 10.02' & 5.00' long), well component types (e.g., screen = 0.020-slot, schedule 40 PVC), quantities of well materials (e.g., number of 50-lb. bags of filter pack) used, visitors to the drill site, and any other observations that may be pertinent.

Drilling, probing, geologic, and sampling information will be documented in accordance with SOP PWT/GW.104, Borehole Logging. Drilling/ probing and well/piezometer/well point construction information will be recorded on blank copies of Figures PWT/GW.103-1, PWT/GW.103-2, PWT/GW.103-3, PWT/GW.103-4, and PWT/GW.103-5). Location references will use the State Plane Coordinate System and elevations will be in feet above mean sea level (USGS datum). All depth and height measurements will be from ground surface.

Flush-mount installations differ from above-ground installations in that the skirt is considered to be the protective casing. For wells installed with push-type equipment (e.g., Geoprobe®), the skirt is the protective casing and the lockable PVC casing is considered the secondary casing. For wells installed aseptically (as described for a drill rig in SOP PWT/GW.114), the well may have surface casing, protective casing, and aseptic casing (which would be listed as the secondary casing). If a third casing is installed (e.g., for wells installed aseptically and which also incorporate surface isolation casing), the additional casing(s) will be described on well completion forms with explanations added to the diagrams, if necessary.

7.0 REFERENCES

7.1 Source References

The following is a list of references reviewed prior to the writing of this procedure:

A Compendium of Superfund Field Operations Methods. EPA/540/P-87/001. December 1987.

Guidance for Conducting Remedial Investigations and Feasibility Studies Under CERCLA. Interim Final. EPA/540/G-89/004 October 1988.

RCRA Facility Investigation Guidance. Interim Final. May 1989.

RCRA Groundwater Monitoring Technical Enforcement Guidance Document. EPA, OSWER-9950.1, Washington D.C., September 1986.

State Board of Examiners of Water Well Construction and Pump Installation Contractors, 2CCR 402-2. State of Colorado, Office of the State Engineer, Denver, Colorado, Revised Effective August 1, 1996.

7.2 Internal References

Related SOPs cross-referenced by this SOP are as follows:

- PWT/GW.104, Borehole Logging
- PWT/GW.114, Drilling and Sampling Using Hollow-Stem Auger and Rotary Drilling and Rock Coring Techniques
- PWT/GW.124, Direct Push Subsurface Soil Sampling

FIGURE PWT/GW.103-1 ALLUVIAL MONITORING WELL INSTALLED WITH A DRILL RIG
Note: Drawing is not to scale.

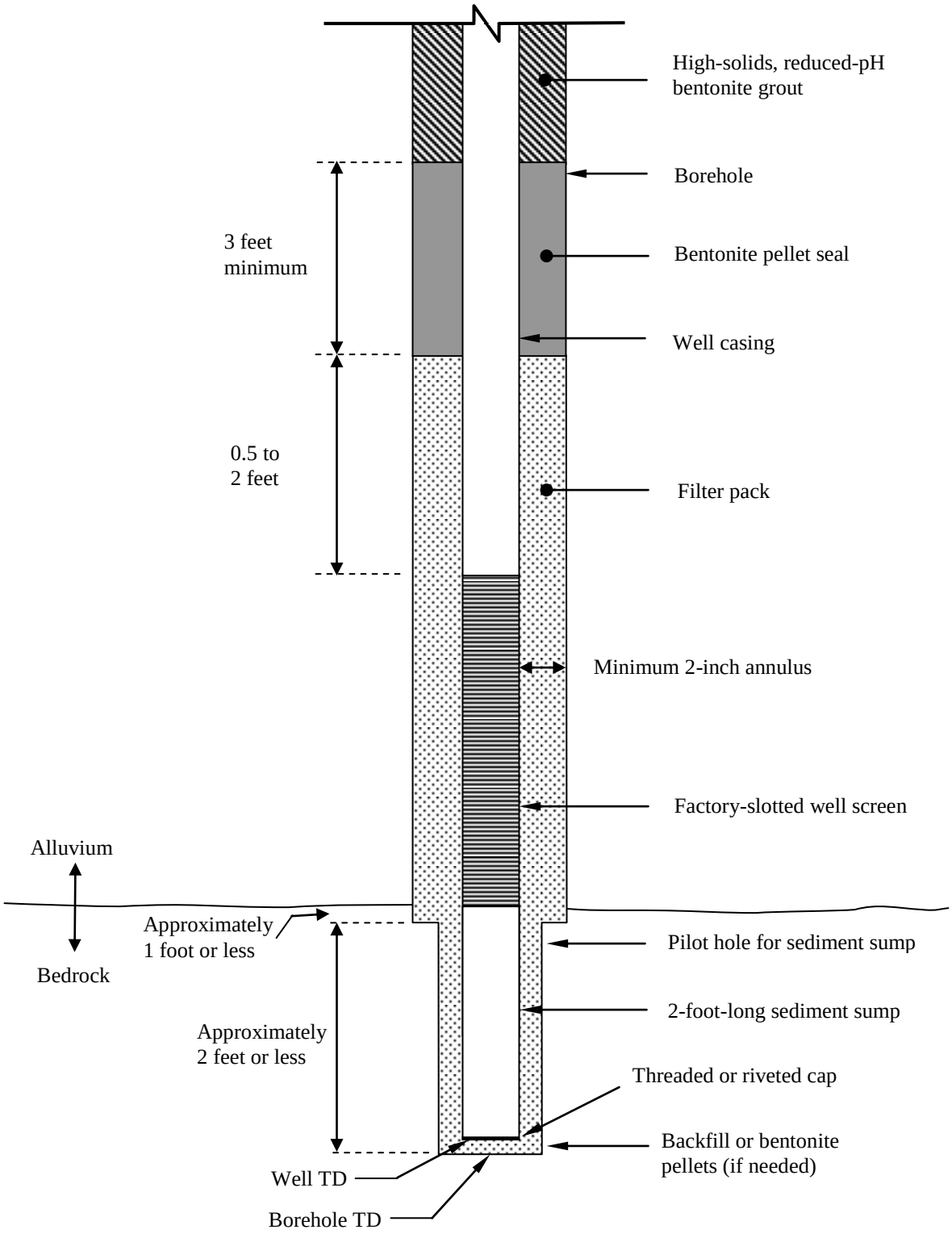


FIGURE PWT/GW.103-2 BEDROCK MONITORING WELL INSTALLED WITH A DRILL RIG
Note: Drawing is not to scale.

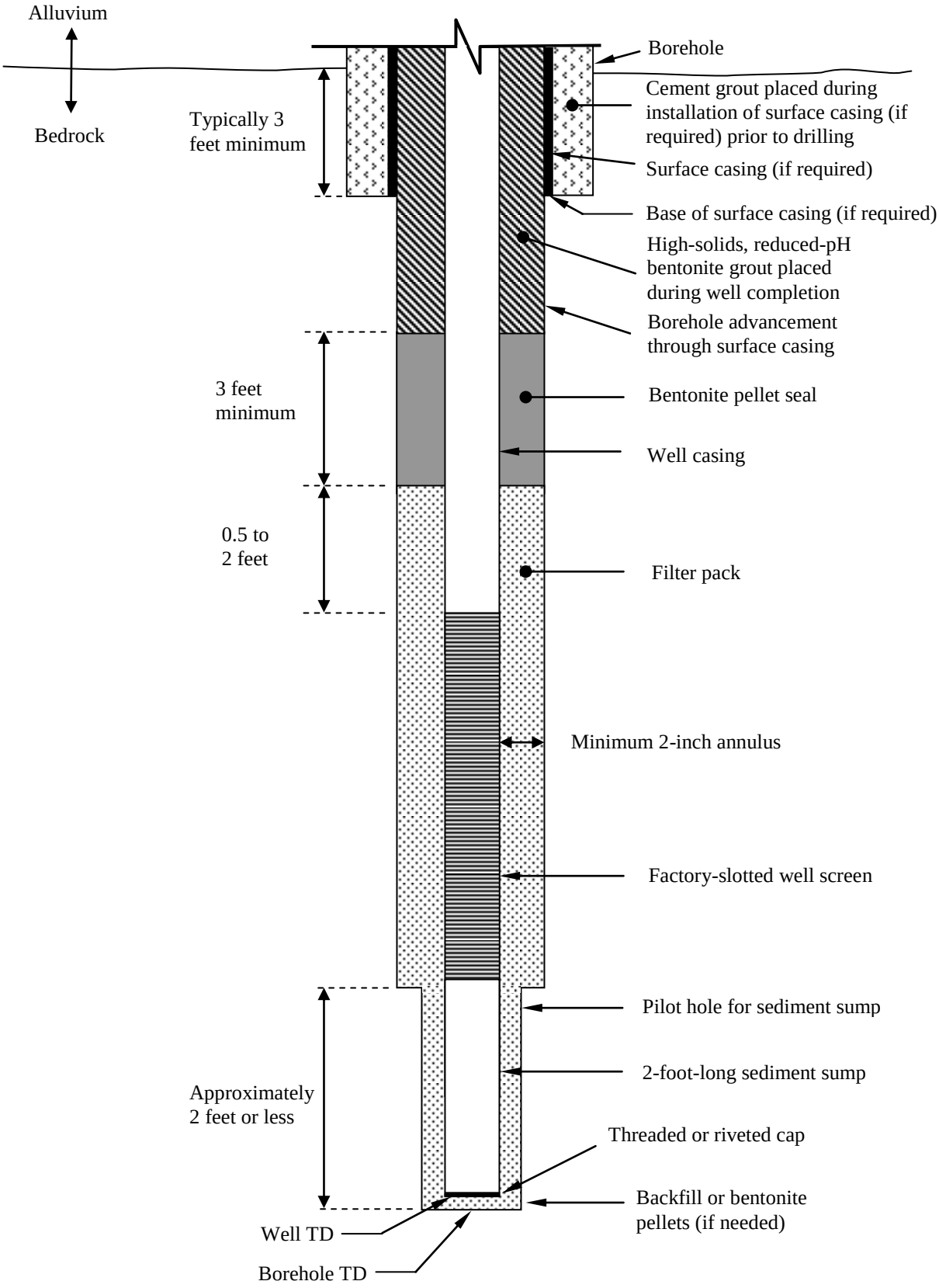


FIGURE PWT.103-3 ABOVE-GROUND WELL PROTECTION AT DRILL RIG WELLS
Note: Drawing not to scale.

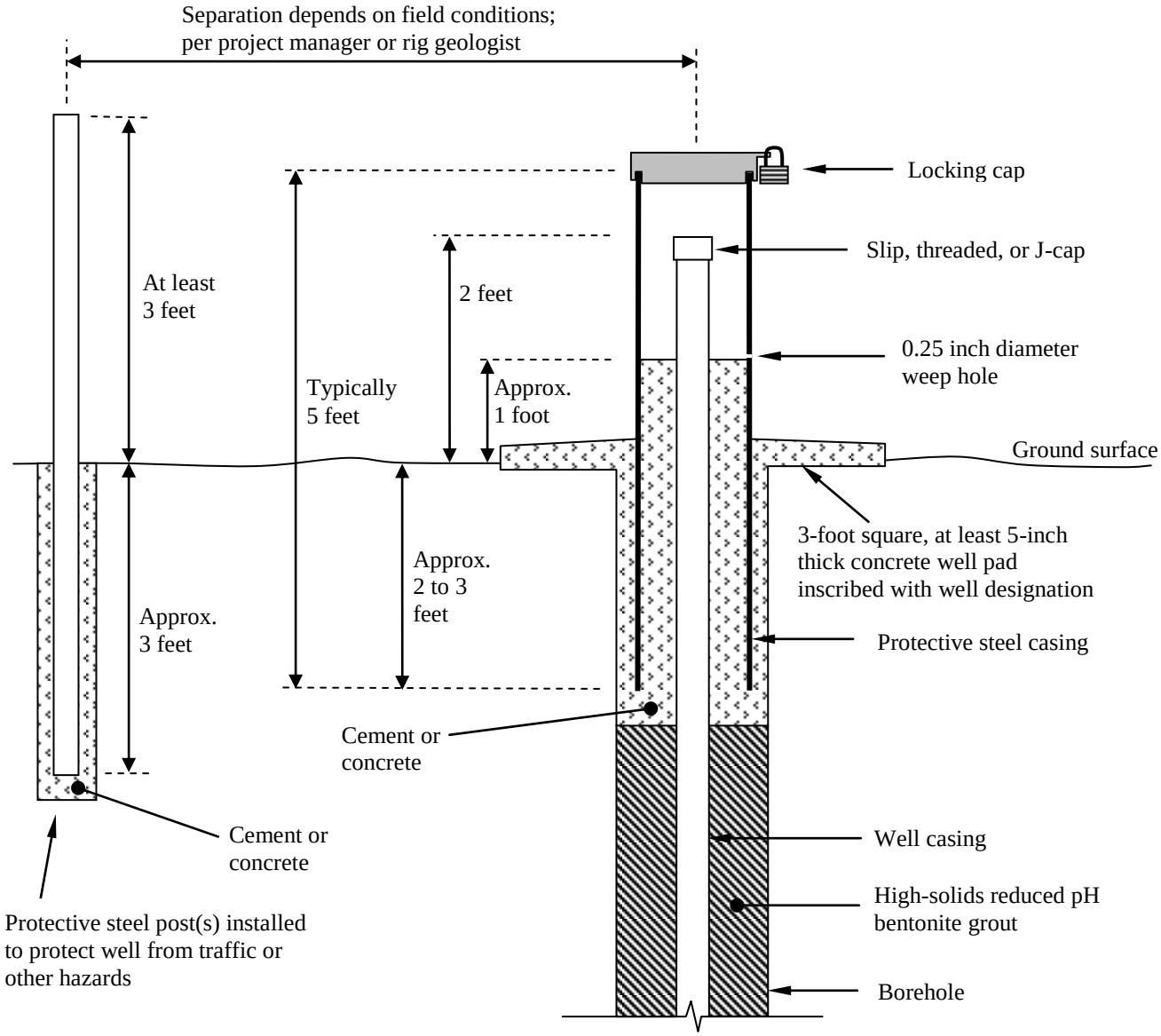


FIGURE PWT/GW.103-4 ABOVE-GROUND WELL PROTECTION FOR PUSHED BOREHOLES

Notes: Drawing not to scale.
As an example, a 0.75-inch ID PVC well is shown in a 2.125-inch borehole. (Other construction materials and/or borehole sizes may require other well component dimensions. However, dimensions given for filter pack and above-ground height/below-ground depth of protective casing are requirements.)

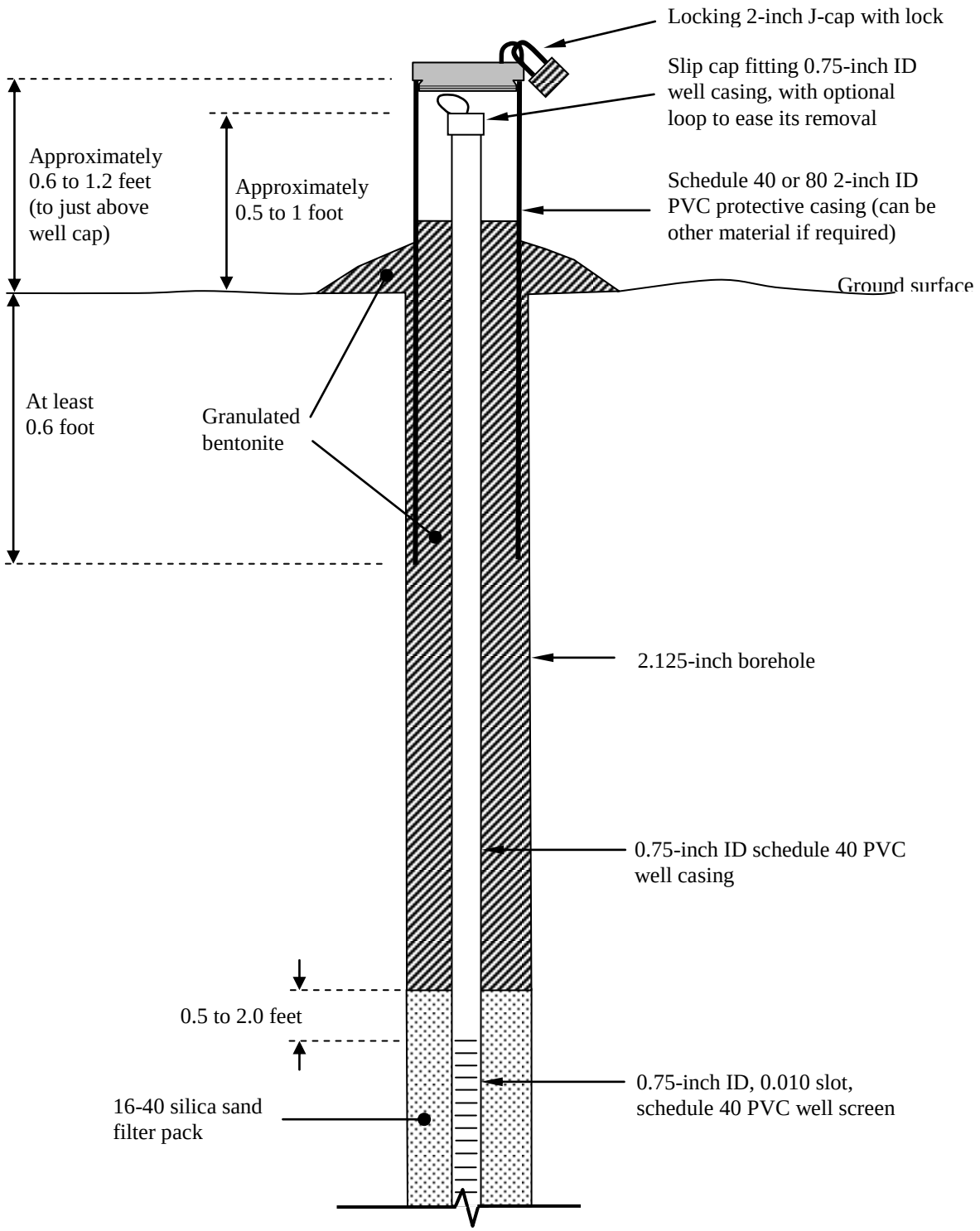
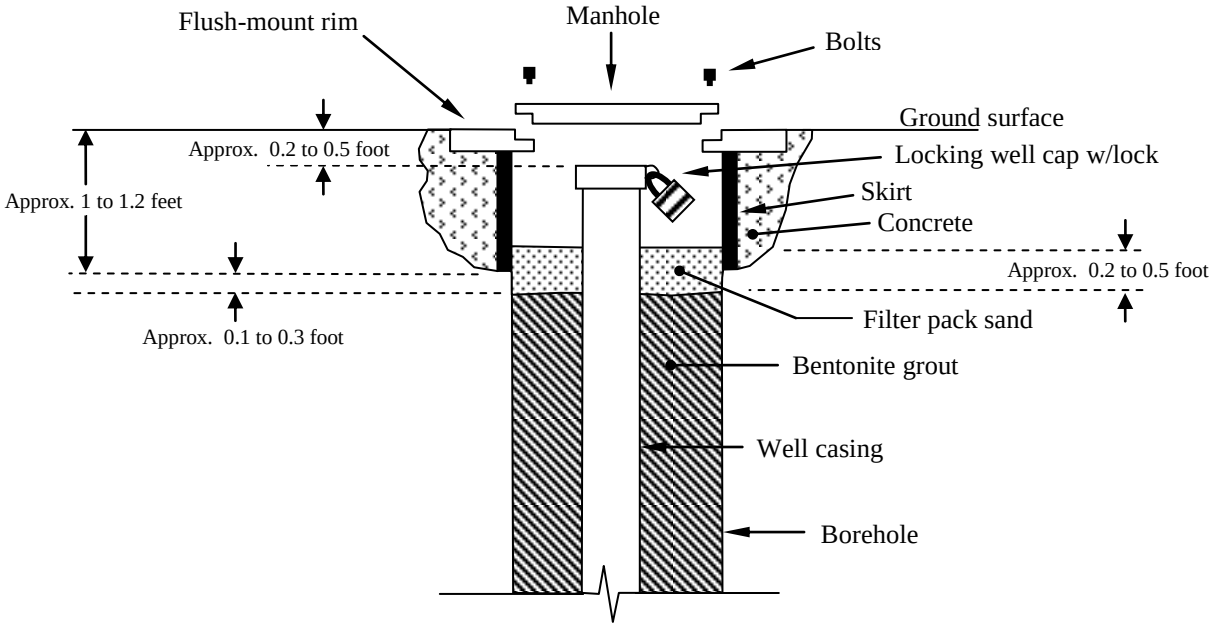


FIGURE PWT/GW.103-5 FLUSH-MOUNT SURFACE PROTECTION
NOTES: Drawing is not to scale.

Depths shown are based on an 8-inch diameter by 12-inch deep flush-mount assembly. These dimensions may need to be adjusted to fit the available materials and the conditions encountered, and/or the project requirements. (For example, if the well is to be installed with a dedicated pump, it may require additional room between the well cap and the manhole. Refer to project work plans for specific requirements.)

If the manhole can be locked, the locking J-cap on the well (or protective casing, if the well is small-diameter as would be installed with push-type equipment, as shown in the inset) may be omitted.

A concrete ring around the inside of the skirt may be poured for added structural stability (as illustrated in the inset); however, this ring must not be installed so as to prevent drainage provided by the sand.



AT RIGHT:
Example flush-mount installation for wells installed with push-type equipment

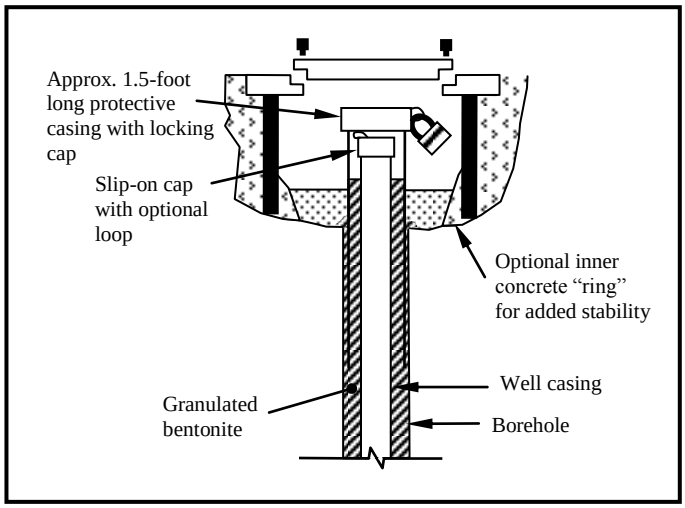


TABLE OF CONTENTS

Section Page No.

TABLE OF CONTENTS i
List of Attachments i
1.0 PURPOSE 1
2.0 PERSONNEL QUALIFICATIONS 1
3.0 MATERIALS AND EQUIPMENT 1
4.0 PROCEDURES 1
4.1 Non Liquid IDW 2
4.1.1 Soil IDW 2
4.1.2 Excavated Soil from Trenches 3
4.1.3 Construction Debris and Landfill Material 4
4.1.4 PPE and Disposable Investigation Equipment 4
4.2 Liquid IDW 4
5.0 DOCUMENTATION 5

List of Attachments

Attachment A Waste Inventory Tracking Form

Attachment B Maximum Concentration of Contaminants for the Toxicity Characteristic

REVISION LOG		
Revision Number	Description	Date
0.0	SOP No. GW.105	1/23/2012
1.0	Revised for Montana Operations	3/1/12

1.0 PURPOSE

This Standard Operating Procedure (SOP) provides technical guidance and methods that will be used for the handling, management, and disposal of investigation derived waste (IDW) encountered or generated during environmental activities supporting CERCLA Remedial Investigations (RI) or RCRA Remedial Facility Investigations (RFI). This SOP serves as a supplement to the investigation area-specific work plans and QAPPs, and is intended to be used with other activity-specific SOPs. IDW management personnel are also referred to *Management of Investigation-Derived Wastes During Site Inspections* (EPA 1991), *Guide to Management of Investigation-Derived Wastes* (EPA 1992) and applicable state and RCRA requirements.

2.0 PERSONNEL QUALIFICATIONS

Personnel overseeing the handling and disposal of IDW will have IDW management knowledge and experience, or will work under the direct field supervision of knowledgeable and experienced personnel. Personnel will perform this work in accordance with the project-specific health and safety plan (HASP).

3.0 MATERIALS AND EQUIPMENT

The following materials and equipment may be needed for IDW management:

- Personal protective equipment (PPE) as outlined in the HASP
- Decontamination equipment and supplies (e.g., wash/rinse tubs, brushes, alconox, plastic sheeting, paper towels, sponges, baby wipes, garden-type water sprayers, large plastic bags (minimum 0.85 mil), potable water, distilled water and/or deionized water)
- Department of Transportation (DOT)-rated 55-gallon drums or other approved containers for containing soil cuttings, decontamination water, and formation water
- Drum/bung wrench and drum funnel
- Heavy equipment forklift or vehicle with drum grappler
- Laboratory-supplied sample containers
- Photoionization detector (PID) or flame ionization detector (FID)
- Wood pallets
- Non-porous (e.g., stainless steel) shovels
- Hazardous Waste Labels
- Soil roll-off bins with liners and covers (if warranted)
- Polyethylene tank (if warranted)
- Waterproof and permanent marking pens

4.0 PROCEDURES

RI or RFI field activities may generate IDW that poses a risk to human health and the environment. It is anticipated that both non-liquid and liquid IDW will be generated or encountered during RI/RFI field activities.

Non-liquid IDW may include:

- Drill cuttings from soil borings
- Sludges (from soil borings in the saturated zone and from development water)
- Excavated soil from trenches
- Construction debris (e.g., concrete and asphalt)
- Buried landfill materials (e.g., burned wood, desks, and metal objects)
- PPE
- Disposable investigation equipment (i.e., bailers, twine, discarded sample bottles, preservative containers, paper towels, aluminum foil)
- Empty drums

Liquid IDW may include:

- Well development water
- Purge water (from monitor wells)
- Well abandonment water
- Decontamination water

Before initiating any field activity that will generate IDW, field personnel must determine if the activity is located within the area potentially containing F-listed waste. Saturated soil and water IDW generated from investigation activities conducted within a defined solvent plume area also potentially contain F-listed waste. Therefore, the saturated soil and water IDW generated from these areas may need to be segregated from other IDW and characterized and disposed of separately.

4.1 Non Liquid IDW

4.1.1 Soil IDW

- Soil cuttings generated during drilling and soil sampling will be placed into DOT-rated 55-gallon drums, or appropriately sized containers at the point of generation.
- Mixing of the cuttings from several borings or sampling locations is permissible in order to fill the drums. The splitting of cuttings from one boring into several drums should be avoided.
- When drums are full, or daily activities are completed, the drum lids and rings will be fastened. Full drums will be transported to a designated IDW accumulation area on a regular basis to avoid accumulation of drums at investigation sites for extended periods of time. Alternative temporary IDW accumulation areas can be used as specified in the investigation-specific work plan.

- If large volumes of soil IDW will be generated, soil IDW will be transferred from the drums into roll-off bins (lined and covered) located within the designated IDW accumulation area.
- If only a small volume of soil IDW will be generated, DOT-rated 55-gallon drums can be used for the temporary storage of soil IDW pending analysis. Drums will be stored on pallets at the designated IDW accumulation area. Drums from individual sites will be segregated from each other as much as possible. The drums will be sealed and labeled with permanent markings (using paint pens or drum labels) with the following information:
    1. Source: the boring(s), well, or site identification number
    2. Matrix (e.g., soil, water)
    3. Sample interval (e.g., 0–20 ft or well screen depth) (multiple drums of development or purge water will be numbered consecutively as they are filled)
    4. Fill date
    5. Drum identification number
    6. Contractor
    7. The EPA or PWT designee point of contact with phone number
    8. "Contents Pending Analysis"

Soil IDW in drums will typically be characterized and disposed of based on the characterization of associated investigation sample results (if collected and analyzed).

If no associated investigation sample results exist, a composite soil sample will be collected from the soil IDW drums by collecting a drive or hand auger sample from each of the drums associated with a specific field activity. The sample material from all of the drums will be composited into a single sample that will be used to characterized and dispose of the soil IDW.

4.1.2 Excavated Soil from Trenches

Most trenching operations will generate substantial volumes of excavated soil.

Large volumes of excavated soil IDW will be placed directly into roll-off bins (lined and covered) at the excavation site. This procedure will minimize concerns resulting from stock piling the soil IDW, such as wind dispersion and contamination of the ground surface.

- Small volumes of excavated soil can be placed in drums at the excavation site. Drums will be labeled and stored as described in Section 4.1.1.
- Soil IDW in drums will be sampled (if warranted), characterized, and disposed of as described in Section 4.1.1 above.

Soil IDW placed on the ground surface prior to placement into drums or roll-off bins, must be placed on plastic sheeting covering the ground surface. The soil IDW must be transferred to drums or roll-off bins before completion of the days activities.

4.1.3 Construction Debris and Landfill Material

- Small pieces of construction debris or landfill materials, that do not, and have not, contained controlled substances may be placed in the soil IDW roll-off bins or drums. For example, small amounts of wood, concrete, rebar, and paper do not require segregation from the soil IDW.
- Large volumes of the materials listed above, and large objects, such as desks or large metal objects, will be segregated separately from the soil IDW.
  - If the associated soil IDW is characterized as nonhazardous, these materials can be disposed of as nonhazardous solid waste.
  - If the associated soil IDW is characterized as hazardous, potential surface contamination will be removed from the large objects with nonporous surfaces (e.g., metal desks) by brushing off, or using small amounts of water to scrub off, gross potential contamination. After decontamination, these objects can be disposed of as nonhazardous solid waste.
  - If the associated soil IDW is characterized as hazardous, large objects with porous surfaces may require disposal as hazardous waste. Consult the IDW disposal contractor.
- Containers that may contain or potentially contained controlled substances (e.g., paint cans, drums) will be segregated from the materials described above and placed in appropriately sized containers.
  - Consult the IDW disposal contractor for the appropriate disposal requirements for these materials.

4.1.4 PPE and Disposable Investigation Equipment

- PPE and disposable investigation equipment will be segregated separately and placed in dedicated heavy duty (minimum 0.85 mil) plastic bags or containers (e.g., drums).
- Potentially contaminated PPE or disposable investigation equipment will be decontaminated prior to placement in the plastic bags or containers, if warranted.
- Decontamination procedures consist of brushing off, or using small amounts of water to scrub off, gross potential contamination.
- PPE and disposable investigation equipment that have been decontaminated, if warranted, are considered refuse and do not require characterization prior to disposal as nonhazardous solid waste.

4.2 Liquid IDW

- Well development, purge, abandonment, and decontamination water will be contained in DOT-rated drums, or appropriately sized water-tight containers, at the point of generation. When drums are full, or daily activities are completed, the drum lids and rings will be fastened, and the drums will be transported to the designated temporary IDW accumulation area as described

in Section 4.2 of Attachment B. Alternative temporary IDW accumulation areas can be used as specified in the activity-specific work plan.

- If large volumes of water will be generated, the water will be transferred into an appropriately sized polyethylene tank. The liquid IDW in the polyethylene tank will be characterized based on the analytical results of the well or wells sampled, or from a representative grab sample collected from the tank. The sample will be collected using a colliwasa, disposable point source bailer, or bomb sampler for discrete interval sampling within the polyethylene tank.
- After analytical data for the liquid IDW1 are obtained from the laboratory, the data will be directly compared to the hazardous waste concentrations presented in Table 1 i***n*** 40 CFR §261.24 (Appendix A). The liquid IDW1 will then be removed, and treated and disposed of by a certified hazardous waste contractor in accordance with the applicable waste characterization (Section 5.0).
- If only a small volume of water IDW will be generated, DOT-rated 55-gallon drums can be used for the temporary storage of water IDW pending analysis. Water IDW drums will be labeled and stored as described in Section 1.1.1, Soil IDW above.
- Water IDW in drums will be characterized and disposed of based on the characterization of associated investigation sample results (if collected and analyzed).
- If no associated investigation sample results exist, a composite water sample will be collected from each of the water IDW drums associated with a specific field activity. The sample will be used to characterize and dispose of the water IDW.
- The list of chemicals to be analyzed for is the same as the list for soil characterization (Appendix A).

5.0 DOCUMENTATION

Project staff are responsible for thoroughly documenting IDW handling and disposal activities. IDW personnel will be responsible for documenting the collection, transportation, labeling (if applicable), and staging or disposition of IDW. The documentation will be recorded with waterproof ink on a Waste Inventory Tracking Form (Attachment A) or in the sampler's field notebook with consecutively numbered pages. The information entered concerning IDW should include the following:

- Project Name
- RI/RFI contractor and personnel
- Site location
- Type of activities
- Date waste generated
- Boring, well, or site number(s)
- Matrix
- Type of container(s) and identification number(s)

- Estimated volume
- Disposition of contents (roll-off/location, tank/location, temporary staging area)
- Waste characterization
- Comments (field evidence of contamination [e.g., PID reading, odors])

ATTACHMENT A
WASTE INVENTORY TRACKING FORM

WASTE INVENTORY TRACKING FORM

Project Name: _____

RI/RFI Contractor and Personnel:_____

Site Location: _____

Type of Activities:_____

Date Waste Generated	Borehole, Well, or Site #	Matrix	Type of Container (Plus ID#, if applicable)	Estimated Volume	Disposition of Contents	Waste Characterization	Comments (Field Evidence of Contamination [e.g., PID reading, odors])

Signature:_____

APPENDIX A

Maximum Concentration of Contaminants for the Toxicity Characteristic

APPENDIX B

Maximum Concentration of Contaminants for the Toxicity Characteristic

EPA Hazardous Waste Number	Contaminant	Regulator Level (mg/L)
D004	Arsenic	5.0
D005	Barium	100.0
D018	Benzene	0.5
D006	Cadmium	1.0
D019	Carbon tetrachloride	0.5
D020	Chlordane	0.03
D021	Chlorobenzene	100.0
D022	Chloroform	6.0
D007	Chromium	5.0
D023	o-Cresol	(1) 200.0
D024	m-Cresol	(1) 200.0
D025	p-Cresol	(1) 200.0
D026	Cresol	(1) 200.0
D016	2,4-D	10.0
D027	1,4-Dichlorobenzene	7.5
D028	1,2-Dichloroethane	0.5
D029	1,1-Dichloroethylene	0.7
D030	2,4-Dinitrotoluene	0.13
D012	Endrin	0.02
D031	Heptachlor (and its epoxide)	0.008
D032	Hexachlorobenzene	0.13
D033	Hexachlorobutadiene	0.5
D034	Hexachloroethane	3.0
D008	Lead	5.0
D013	Lindane	0.4
D009	Mercury	0.2
D014	Methoxychlor	10.0
D035	Methyl ethyl ketone	200.0
D036	Nitrobenzene	2.0
D037	Pentachlorophenol	100.0
D038	Pyridine	5.0
D010	Selenium	1.0
D011	Silver	5.0
D039	Tetrachloroethylene	0.7
D015	Toxaphene	0.5
D040	Trichloroethylene	0.5
D041	2,4,5-Trichlorophenol	400.0
D042	2,4,6-Trichlorophenol	2.0
D017	2,4,5-TP (Silvex)	1.0
D043	Vinyl chloride	0.2

Notes:
(1)If o-, m-, and p- Cresol concentrations cannot be differentiated, the total cresol (DO26) concentration is used. The regulatory level of total cresol is 200 mg/L.
Source: 40 CFR 261.24 and WHWRR, Chapter 2, Section 3 (e)(ii).

PWT STANDARD OPERATING PROCEDURE

WELL DEVELOPMENT

Procedure No. PWT/GW.106
Revision 1
Date effective: 03/02/12

APPROVED: /s/ _____ _____ Page 1 of 8
PWT Project Manager Date

TABLE OF CONTENTS

Section No. Page

1.0 PURPOSE 2
2.0 SCOPE 2
3.0 REQUIREMENTS 2
3.1 Personnel Qualifications 2
3.2 Equipment 2
4.0 DEVELOPMENT PROCEDURES 3
4.1 Low Energy Development Methods 3
4.1.1 Low Energy Well Development Instructions 5
4.2 High Energy Development Methods 6
4.3 Disposition of Purge and Development Water 8
5.0 DOCUMENTATION 8
6.0 REFERENCES 9
6.1 SOURCE REFERENCES 9
6.2 INTERNAL REFERENCES 10

FORM PRO.106A

REVISION LOG		
Revision Number	Description	Date
0.0	Original SOP	March 2007
1.0	Revise for Montana Operations	March 2012

1.0 PURPOSE

This document contains guidelines for the development of new wells and piezometers installed by PWT as part of ongoing field investigation projects. These procedures also apply to the redevelopment of pre-existing wells or piezometers by removing sediment or other built-up material. The objective of a completed well development activity is to provide groundwater inflow that is as physically and chemically representative as possible of the aquifer that is open to the well or piezometer.

2.0 SCOPE

This document applies to all PWT personnel and subcontractors conducting groundwater-related work on remedial investigation projects. This document, which constitutes a Standard Operating Procedure (SOP), describes acceptable methods for the development or re-development of wells and piezometers installed by PWT.

3.0 REQUIREMENTS

The following sections identify the personnel qualifications and equipment for the development of wells and piezometers.

3.1 Personnel Qualifications

Personnel performing these procedures are required to have completed the initial 40-hour OSHA classroom training that meets Department of Labor Regulation 29 CFR 1910.120(e)(3)(i), and must maintain a current training status by completing the appropriate 8-hour OSHA refresher courses. Personnel must also have read and signed the appropriate Health and Safety Plan(s).

Prior to engaging in well or piezometer activities, personnel are required to have a complete understanding of the procedures described within this and other related SOPs and receive specific training regarding these procedures if necessary.

3.2 Equipment

The following is a list of basic equipment typically required when developing wells or piezometers. Additional equipment may be required in less typical applications, and will be specified in the project-specific work plan or other appropriate document.

- Watch
- Graduated purge water container
- Stainless steel or Teflon® bailer
- Mechanical reel equipped with a stainless steel Teflon® coated cable
- Inertial or peristaltic pump
- Positive air displacement pump
- Surge Block
- Water parameter test equipment
- Wash/Rinse tubs
- Clear plastic sheeting or vinyl sheeting which may be decontaminated
- Liquinox detergent
- Containers for development water
- Electronic water level sounder (see SOP PWT/GW.102, Water Level Measurements in Wells and Piezometers)
- Distilled or deionized water

- Field book and/or field forms
- Health and safety equipment and supplies
- Organic vapor detector (OVD, FID or PID) if necessary
- Calculator
- Black water proof pens

4.0 DEVELOPMENT PROCEDURES

Monitoring well development is the process by which the well drilling fluids and mobile particulates are removed from within and adjacent to the newly installed wells and piezometers. This process can also be used to remove sediment or other built-up material from an older well. The objective of a completed well development activity is to provide groundwater inflow that is as physically and chemically representative as possible of the aquifer that is open to the piezometer or well.

4.1 Low Energy Development Methods

Low energy well development methods are typically applicable to newly installed wells or for pre-existing monitoring wells that have been routinely sampled using standard purging and sampling methods because the sediment in the well is fine grained and has not compacted to the point where suspension and removal is problematical. For new wells or piezometers, perform the development as soon as practical after installation, but no sooner than 48 hours after grouting and pad installation is completed. The equipment of choice for well development is an inertial pump or bottom discharge/filling bailer. Small diameter wells will be developed using either a small diameter Teflon® or stainless steel bailer, or a peristaltic pump. If sediment in the well is not easily removed by low energy methods, high-energy methods such as surge blocks or overpumping may be necessary. See Section 4.1.2 for procedures for development using high energy methods.

New wells that are installed in areas known to be contaminated with organics (e.g., volatile organic compounds), or which cause a positive reading on the OVD, will be checked for the presence of immiscible layers prior to well development. The method for detecting these layers in monitoring wells is discussed in SOP PWT/GW.102, Water Level Measurements in Wells and Piezometers. If an immiscible layer of 5 mm or greater has been detected in a newly installed well, well development procedures will not continue until the PWT Field Team Leader has been notified. In the case where an immiscible layer is not identified, a water level measurement will be taken according to SOP PWT/GW.102, Water Level Measurements in Wells and Piezometers, and well development activities will continue. The water level measurement along with the total depth measurement will be used to determine the volume of water in the well casing. Well casing calculations are presented in Subsection 4.1.1 of this SOP.

For wells where the fines are thought to be interstitial to the sand pack, formation water and fines will be evacuated by slowly lowering and raising the inertial pump or bailer intake throughout the water column of the screen. The inertial pump may be placed inside a decontaminated 1-inch diameter PVC pipe if the pump intake cannot be lowered to the bottom of the well. The PVC pipe will prevent the inertial pump intake from bending prior to reaching the desired depth. PWT personnel will determine whether an inertial pump will be dedicated to a specific well based on verified organic vapor detector (OVD) readings obtained during the drilling of the well. OVD readings are described in the owner's manual for the particular equipment used. If a bailer is used for well development, it will be used with a mechanical reel equipped with a stainless steel Teflon® coated cable or nylon rope. For wells where the fines have collected at the bottom of the well, fines will be evacuated by slowly lowering and raising the inertial pump or bailer intake near the fines to collect the sediment. This action will cause some of the water to be displaced and will help to stir up and suspend the sediment particles. Development equipment will be protected from the ground surface with clear plastic sheeting. Development

equipment, including bailers and pumps, will be decontaminated before well development begins and between well sites.

For small diameter piezometers the formation water and fines will be evacuated by slowly lowering and raising the peristaltic pump intake tubing or bailer throughout the water column. If a peristaltic pump is used, it will be fitted with chemically inert silicon or equivalent type tubing for the intake and discharge lines. If a bailer is used for well development, it will be used with a mechanical reel equipped with a stainless steel Teflon® coated cable or with nylon rope. For wells where the fines have collected at the bottom of the well, fines will be evacuated by slowly lowering and raising the inertial pump or bailer intake near the fines to collect the sediment. This action will cause some of the water to be displaced and will help to stir up and suspend the sediment particles. Development equipment will be protected from the ground surface with clear plastic sheeting. Development equipment, including bailers and pumps, will be decontaminated before well development begins and between well sites. Decontamination and rinse water will be disposed of in either a satellite container or in the purge water storage container in the groundwater sampling vehicle.

Decontamination and development water will be handled according to the procedures outlined in Subsection 4.3 of this SOP.

4.1.1 Low Energy Well Development Instructions

Development shall proceed in the manner described herein and continue until the following are met:

- Removal of a minimum of five well casing volumes. Typical well casing volume calculations include:

  a. 0.75-inch inside diameter well:
  87 milliliters/ft x____(linear ft. of water) = ml of water

  b. 2-inch inside diameter well:
  0.16 gal/ft x ___(linear ft of water) = gallons of water

  c. 4-inch inside diameter well:
  0.64 gal/ft x ___ (linear ft of water) = gallons of water

Graduated containers will be used to measure the amount of water removed.

1. If the initial water measurement (WLM) indicates water is at a depth below the bottom of the screened interval, the well is considered "technically dry" for development purposes. Most wells are installed with a sump that may be up to 2 feet deep. Piezometers that are less than 2 inches in diameter will have sumps that vary in length. If a well is dry or technically dry, it is recommended (but optional) that monthly water level measurements be taken for one year to check seasonal changes in the water table. A well can be developed following a WLM which indicates the well is not dry (water covering all or a portion of the screened interval).

2. When a monitoring well or piezometer has an initial water column that covers only a portion of the screened interval, but does not dewater prior to evacuating the five minimum volumes, well development can proceed if the recharge rate in the well will allow for evacuating the total volume needed within a reasonable timeframe not to exceed one week. Otherwise, the Field Team Leader should be contacted for additional instructions.

3. All wells that measure technically dry may indicate that water is below the screened interval and has collected in the sump. These wells should be bailed dry to remove well construction water and to insure that the first monthly WLM will more accurately reflect any groundwater recharge.

- A well or piezometer is considered successfully developed when consistent measurements of pH, temperature, specific conductance, and turbidity are recorded for the final three consecutive casing volumes evacuated from the well. Consecutive readings are temperatures within 1°C; pH readings within 0.2 units; consecutive conductivity readings within 10 percent of each other; and formazine turbidity units (FTU) within 10 percent of each other. The requirement for temperature stabilization may be waived in cases where the reason for instability is related to limitations associated with the purging technique, such as limited volume of purge water combined with ambient air and purge equipment temperature extremes. It is expected that this condition could exist at wells having less than 2000 ml in storage. This variance must be documented with a full explanation on the Well Development/Redevelopment Log (Form PWT/GW.106A).

- If water was used during drilling, the total fluid added will be recorded, and two times the fluid lost in the borehole during drilling will be recovered in addition to the five well casing volumes. Additional purging will be required if, after removing the required volume, the field parameters have not stabilized. In this case, well development will continue until field parameter stabilization is achieved.

- The sediment in the well should be completely removed from the screened interval and removed from the well sump to the extent practicable. The well will be checked for the accumulation of additional sediment one-week after initial development. If sediment has collected in the screened interval or significant additional sediment has accumulated in the well sump, re-development will be performed using the same procedures.

4.2 High Energy Development Methods

In wells where the sediment accumulation cannot be removed by low energy methods, high energy development methods may be necessary. The equipment and procedures used for high energy well development are included in Section 3.2. The methods that will be employed for high energy well development are mechanical surging, bailing and/or overpumping. Once the majority of the sediment is removed from the well using these methods, the low energy methods will be employed to fully develop the well.

Mechanical surging is the process of forcing water to flow into and out of a screen by operating a plunger up and down in the casing similar to a piston in a cylinder. The tool normally used is called a surge block or surge plunger. The concern associated with using a surge block is that it can force fine grained sediment back into the formation. Therefore, this method is most applicable for removing coarser grained materials in the well after the fines have been removed by other methods.
Before starting to surge, the wells should be pumped or bailed to make sure that water will flow in through the screen. The surge block should be lowered until it is 10 to 15 feet beneath the static water level but above the wells screen. The water column in the well casing will effectively transmit the action of the block to the screen section. The initial surging motion should be relatively gentle allowing any material that is blocking the screen to break up and go into suspension. As water begins to move easily in and out of the screen, the surging tool is lowered in steps to just above the screen. In a well with a particularly long screen, it may be necessary to operate the surge block in the screen to concentrate its action at particular levels. Surging should continue for several minutes then the block should be slowly pulled from the well while maintaining the same surging motion. Sediment can be removed using a bailer or by using a bottom filling positive air displacement pump. Piston or drive type pumps such as Grundfos Rediflow pumps should be avoided because they can be damaged by pumping sand sized particles. Surging should be continued until little or no sand sized particles are being drawn into the well. At this point, well development can be conducted using methods in Section 4.1.

Overpumping is another method for removing sediment from the water bearing formation and involves pumping at a higher rate than the well will be pumped during sampling. The general concept is that any well that can be pumped sand free at a high discharge rate can be pumped sand free at a lower discharge rate. The difference between low energy pumping and overpumping as it applies to this procedure is that consideration must be given to using a pump capable of achieving higher flow rates than pumps that may be used for sample collection. Also, if sand sized materials are to be removed from the well a pump that is capable of pumping sand sized particles must be used. A bottom- filling positive air displacement pump such as the Geotech Reclaimer, which is used for product recovery may be preferable to piston or drive type pumps such as Grundfos Rediflow pumps which are damaged by pumping sand sized materials. The pump should be operated starting at the top of the screen and then lowered sequentially to insure that fines are not just removed from the top of the screened interval. Overpumping should be performed for a few minutes at varying depth intervals and checked for sand materials using a bailer. Once the overpumping activity has been performed well development can be conducted using methods in Section 4.1. Concerns that should be considered when using overpumping are that fines are only being pushed in one direction, which may compact finer sediments around the borehole or clog the screen. Overpumping will also tend to generate more development water for disposal.

4.3 DISPOSITION OF PURGE AND DEVELOPMENT WATER

All water removed from a well during development procedures will be collected either in a satellite container or drum, or a purge water collection container in the groundwater sampling vehicle. When the collection container is filled, or near capacity, it will be transferred to an appropriate treatment facility or to a contracted service company for disposal. Arrangements must be made with the facility manager or company prior to developing the wells. PWT SOP GW_105 Investigation Derived Waste Management should be referred to for investigation derived waste disposal.

5.0 DOCUMENTATION

The following well development information will be recorded on the Well Development and Sampling Form (Form PWT.106A) for newly installed wells, or redevelopment of pre-existing wells.

- Well or piezometer I.D. and location survey coordinates
- Date(s) and time of well development
- Well designation
- Static water level from measuring point
- Total depth from measuring point
- Calculated well casing volume
- Quantity of water lost during drilling (if applicable)
- Quantity of water added during development
- Depth from top of well casing to top of sediment inside well, before and after development
- Development method
- Field measurements of pH, specific conductance (SC), turbidity, and temperature, taken at full casing volumes, or more frequently if desired
- Physical description of removed water throughout development (color and odor)
- Quantity of water removed (incremental and total values)

6.0 REFERENCES

6.1 SOURCE REFERENCES

The following is a list of references reviewed prior to the writing of this procedure:

Driscoll, F.G. 1986. Groundwater and Wells, Second Edition. Johnson Division.

EPA. 1987., A Compendium of Superfund Field Operations Methods. EPA/540/P-87/001. December 1987.

EPA. 1988. Guidance for Conducting Remedial Investigations and Feasibility Studies Under CERCLA. Interim Final. October.

EPA. 1989. RCRA Facility Investigation Guidance. Interim Final. May.

EPA. 1986 RCRA Groundwater Monitoring Technical Enforcement Guidance Document. OSWER-9950.1.September.

6.2 INTERNAL REFERENCES

Related SOPs cross-referenced by this SOP are as follows:

- SOP PWT/GW.103, Monitoring Well and Piezometer Installation
- SOP PWT/GW102, Water Level Measurements in Wells and Piezometers
- SOP PWT/GW105, Investigation Derived Waste Management
- SOP PWT/GW.108, Measurement of Groundwater Field Parameters

PWT DEVELOPMENT/REDEVELOPMENT LOG FORM PWT/GW.106A

LOCATION CODE: _____

SAMPLE TEAM MEMBERS: _____, _____,

Development Method – Type Used: Li Bailer (Li Teflon or Li SS) Li Peristaltic Pump Li Other

DEVELOPMENT VOLUMES AND FIELD WATER QUALITY MEASUREMENTS

Date (MM/DD/YY)	Time (24 Hour)	Volume Purged (☐ GAL or ☐ ML)	Temp (°C)	Specific Cond. (☐ mS/cm or ☐ µS/cm)	pH (SU)	Turbidity (☐ FTU or ☐ NTU)	Water Description (Color, Odor)

ALKALINITY DETERMINATION

pH Offscale, ☐ YES or ☐ NO pH Offscale Reading = _____Checked by (initials)

if YES -- At_____ pH, Total Alkalinity =_____ x 10 = _____ ppm

if NO---- At _____ pH, Total Alkalinity (full range)= _____ppm

Completed By: (Print Name) _____ Signature:_____Date: _____
Checked By: (Print Name)_____ Signature: _____Date:

TABLE OF CONTENTS

Section Page No.

TABLE OF CONTENTS i

1.0 PURPOSE AND SCOPE 1

3.0 MATERIALS AND EQUIPMENT 1

4.0 PROCEDURES 1

4.1 In-Flow Multi-Parameter System 2

4.2 pH 2

4.2.1 pH Meter Calibration Procedure 2

4.2.2 pH Measurement Procedure 3

4.3 Conductivity 3

4.3.1 Conductivity Meter Calibration Procedure 3

4.3.2 Conductivity Measurement Procedure 4

4.4 Dissolved Oxygen 4

4.5 Eh 5

4.6 Turbidity 5

4.7 Temperature 6

5.0 DOCUMENTATION 6

REVISION LOG		
Revision Number	Description	Date
1.0	Original SOP	July 2011
2.0	Revise for Montana Operations	March 2012

1.0 PURPOSE AND SCOPE

This Standard Operating Procedure (SOP) provides technical guidance and methods that will be used to measure field parameters in water during environmental investigations. Field parameters will be measured during monitoring well development, purging and sampling, and during surface water sampling. This SOP serves as a supplement to site-wide and investigation area specific workplans and the site-specific Quality Assurance Project Plan (QAPP) and is intended to be used in conjunction with other SOPs.

2.0 PERSONNEL QUALIFICATIONS

Personnel performing field parameter measurement activities will have knowledge and experience in the equipment and methods proposed, or will work under the direct field supervision of knowledgeable and experienced personnel. Personnel will also be qualified to perform this work in accordance with the project-specific health and safety plan (HASP).

3.0 MATERIALS AND EQUIPMENT

In addition to the equipment cited in the PWT Groundwater Sampling SOP GW.101, and the PWT Surface Water Sampling SOP SW.101, the following materials and equipment may be necessary for measurement of field parameters.

- Portable pH meter and pH 4, 7, and 10 buffer solutions
- Spare pH probe or electrolyte cartridge, as applicable
- pH electrode storage solution
- Conductivity meter and calibration solutions that bracket the expected range of measurements
- Portable dissolved oxygen kit and low and high range dissolved oxygen AccuVac ampuls (or equivalent)
- Portable Eh tester electrode
- Portable turbidity meter
- In-flow multi-measurement meter
- TygonTM or silicone tubing
- Peristaltic pump, bladder pump, or other appropriate pump
- 12-volt battery
- Extra batteries for all instruments
- Beakers of assorted sizes
- Deionized or distilled water
- Wash bottle
- Kimwipes® or equivalent.

4.0 PROCEDURES

Several of the field parameters are physically or chemically unstable and may be tested using either an in-flow multi-measurement system or a field test kit or instrument immediately after sample collection.

Examples of unstable parameters include pH, temperature, Eh, and dissolved oxygen. Although the conductivity of a substance is relatively stable, it is recommended that this characteristic be measured in the field. Most instruments measuring conductivity require temperature compensation; therefore, the temperature of the samples should be measured at the time the conductivity is measured. The specific field parameters to be measured will be specified in the site-specific QAPP.

An unfiltered water grab sample (if not using an in-flow multi-measurement system) will be collected for measuring field parameters. Field parameter measurements should be obtained immediately after sample collection. The same grab sample can be used to measure all field parameters, but should not be used for laboratory analysis.

Field parameters commonly measured are as follows:

1. Dissolved oxygen
2. Oxidation/reduction potential (ORP)/Eh
3. pH
4. Specific conductivity
5. Turbidity
6. Temperature
7. Time

4.1 In-Flow Multi-Parameter System

The in-flow multi-parameter monitoring system or similar multi-parameter instruments, may be used for measuring pH, temperature, conductivity, ORP/Eh, and dissolved oxygen. The instrument operation and maintenance manual shall be followed when operating or calibrating the instrument.

4 . 2 p H

Determine the pH from a water sample as soon as possible after collecting it, or use an in-flow multi-measurement system. Determine the pH by the electrometric method. The electrometric method is the preferred method because of its greater accuracy and ease of measurement. Either a glass electrode and a reference electrode, or a combination electrode, which combines the glass membrane electrode and the reference electrode, will be used. The procedures described in this section are generic; they were generally written for HACH EC10 and EC20 (or equivalent) pH meters.

4.2.1 pH Meter Calibration Procedure

The pH meter shall automatically compensate for temperature and be capable of calibration with a two-point (using two buffers) slope adjustment method. The meter shall have a precision of at least 0.05 pH units.

Before collecting samples, calibrate the pH meter in accordance with the manufacturer's instructions using standard buffer solutions. Field sampling personnel will record all pH measurement data, including calibration dates and times, readings, the meter number, and sample temperatures on either surface water or ground water field data sheets or in the field logbook.

Calibrate the pH meter daily prior to field activities. Verify the pH calibration using a pH 7 buffer solution before each sampling location, and recalibrate as necessary. Thoroughly document all calibrations and verification pH readings and temperature, in the field logbook and on field data sheets.

Sampling personnel will calibrate the pH meter as follows:

1. Before immersing the probe(s) into the buffer solution or sample, rinse the probe with deionized or distilled water.
2. Calibrate the meter with two buffer solutions (two-point slope adjustment). One of the buffer solutions used for the slope adjustment should approximate the anticipated pH of the sample, and the other buffer should always have a pH of 7. Ensure that the buffer solutions are at the same temperature and are as close as practical to the temperature of the water to be measured.
3. Record the results of the calibration.
4. Decontaminate the pH meter and associated equipment in accordance with the PWT Decontamination of Personnel and Equipment SOP ES.103.

4.2.2 pH Measurement Procedure

Field sampling personnel will measure pH as follows:

1. If the pH is measured in a container, rinse the sample container with deionized or distilled water and then rinse it three times with the sample water prior to measurement. If using an in-flow multi-measurement system, measurements are continuously displayed.
2. Rinse the pH probe with deionized or distilled water. Be sure to protect the fragile glass bulb at the end of the probe from damage.
3. Immerse the electrode in the water, allow the pH reading to stabilize, and monitor the drift of the instrument. Do not immerse the electrode above the top of the pH probe.
4. When the pH reading stabilizes (i.e., the meter beeps), record the temperature to the nearest 0.1°C and the pH reading to the nearest 0.01 unit.
5. Between measurements, store the electrode in pH electrode storage solution or equivalent solution, if possible, or put a cotton swab soaked in electrode solution in the protective cap of the electrode.
6. Decontaminate pH meter/in-flow multi-measurement system and associated equipment in accordance with the PWT SOP GW.101, Groundwater Sampling.

4.3 Conductivity

Electrical conductivity, or specific conductance, is the ability of water to conduct an electric current and depends on the concentration of ions in solution. The relationship between conductivity and the concentration of dissolved solids is approximately linear for most natural waters. Changes in this relationship indicate changes in the proportions of different salts and, therefore, changes in the sources of dissolved substances that enter the water body.

For measuring conductivity in the field, the meter shall have an automatic temperature compensator and shall display conductivity directly in units of microsiemens per centimeter (µS/cm) for samples with a conductivity less than 2,000 µS/cm, or in millisiemens per centimeter (mS/cm) for samples with a conductivity greater than 2.00 mS/cm, corrected to a temperature of 25°C.

4.3.1 Conductivity Meter Calibration Procedure

Before collecting samples, calibrate the conductivity meter using calibration solutions in accordance with the manufacturer's instructions. Sampling personnel will record all conductivity measurement data,

including calibration dates, readings, the meter number, and sample temperatures on a field data sheet or in a field logbook.

Reagent-grade potassium chloride (KCl) or other equivalent solutions are universally used as reference solutions to calibrate conductivity equipment. The reference solutions are also used to check the accuracy of the meter. The conductivity of the reference solutions that are used to calibrate the meter should bracket the expected range of the conductivity of the water samples. Commercially prepared calibration standards are available from laboratory suppliers at many standard concentrations.

Field sampling personnel will calibrate the conductivity meter as follows:

1. Calibrate the meter according to the manufacturer's instructions.
2. Prepare or obtain standard reference solutions of a known value at a known temperature. Adjust the meter or the calibration solution to the correct temperature.
3. Adjust the meter to read the reference conductivity.
4. Rinse the probe with deionized or distilled water.
5. Re-immerse the probe in the reference solution and read the measured value to validate the corrected conductivity.
6. Record the results of the calibration.
7. Decontaminate conductivity meter/in-flow multi-measurement system and associated equipment in accordance with the PWT SOP GW.101, Groundwater Sampling.

Check the calibration of the conductivity meter against a known standard prior to sampling at each location and recalibrate as necessary.

4.3.2 Conductivity Measurement Procedure

Measure conductivity immediately after a field parameter grab sample is collected. Record conductivity readings to the nearest 1 µS/cm (for samples with conductivities less than 2,000 µS/cm) or 0.01 mS/cm (for samples with conductivities greater than 2.00 mS/cm).

Field sampling personnel will measure conductivity as follows:

1. Rinse the probe with deionized or distilled water. If using an in-flow multi-measurement system, measurements are continuously displayed.
2. Insert the probe into the sample and agitate the probe vertically.
3. Allow the reading to stabilize before recording measurements.
4. Record the conductivity and temperature of the sample.
5. During normal use, rinse the probe thoroughly with deionized or distilled water between measurements to minimize the buildup of interfering substances on the probe element.
6. Decontaminate conductivity meter/ in-flow multi-measurement system and associated equipment in accordance with the PWT SOP GW.101, Groundwater Sampling.

4.4 Dissolved Oxygen

The dissolved oxygen (DO) concentration may be measured with an in-flow multi-measurement system at the time of parameter sample collection or using an in situ probe.

This method for DO measurement is appropriate for qualitative assessment only (e.g., assessing field stabilization). It is not appropriate as a quantitative measure of DO for assessing natural attenuation.

The DO meter is factory calibrated; the factory calibration shall be confirmed before the DO meter is sent to the field. Each day before collecting samples and as applicable for the instrument, the in-flow DO probe shall be calibrated according to the manufacturers suggested procedures for altitude. The in situ DO probe, which may be used for parameter measurements of surface water, will be calibrated daily before sample collection in accordance with manufacturer's instructions.

Inflow DO concentrations are continuously displayed with the multi-measurement system. All DO measurements should be recorded along with temperature readings.

4 . 5 E h

Eh may be measured in the field at selected locations for some projects at the time of water sample collection. Either an in situ probe or inflow multi-measurement water will be used for Eh measurement.

The Eh meter shall be calibrated prior to being sent to the field. Check the calibration of the Eh meter against a known standard daily, and recalibrate as necessary. Additionally, an Eh sensitivity verification will be completed each day before collection of samples. Sensitivity verification will be demonstrated by a reduction in Eh with an increase in pH. Consult the manufacturer's instruction manual for proper use.

Field sampling personnel will measure Eh as follows:

1. At the start of each day, measure the Eh and temperature of the standard solution and record results in the field logbook.
2. Remove the Eh electrode cap and turn on the meter
3. Dip the electrode 1/2 to 1 inch into the sample and stir once. The electrode should stabilize within 2 to 5 minutes. When stable, take a reading and record it on the sample data sheet. Any instability will be noted and recorded on the sample data sheet.
4. Decontaminate the Eh meter probe and associated equipment in accordance with the PWT SOP GW.101, Groundwater Sampling.

4.6 Turbidity

The turbidity will be measured at the time of sample collection. A colorimeter (HACH DR700 or equivalent) and ampules (AccuVac) containing the appropriate reagents or a portable turbidity meter will be used for field determination of turbidity in the parameter samples.

The turbidity meter is factory calibrated and requires no field calibration. The factory calibration shall be checked before the turbidity meter is sent to the field. Additionally, the calibration of the turbidity meter will be checked daily before collection of samples against a known formazin standard. The instrument will be recalibrated as necessary based on the daily check. Refer to the manufacturer's instruction manual for proper use.

The turbidity test measures an optical property of the water sample that results from the scattering and absorbing of light by the particulate matter present. The amount of turbidity registered is dependent on such variables as the size, shape, and refractive properties of the particles. This procedure is commonly calibrated using formazin turbidity standards, and the readings are in terms of nephelometric turbidity units (NTUs).

4.7 Temperature

Temperature measurements will be made with a high quality mercury-filled thermometer or in-flow multi-measurement system having an analog or digital readout device. This thermometer is to have been standardized by comparison with a thermometer calibrated against a National Institute of Standards and Technology (NIST) calibrated thermometer. All temperature-measuring devices will be scaled to indicate degrees Celsius and marked as appropriate to meet data quality objectives. Glass thermometers will be transported in a protective case to prevent breakage.

Temperature measurements made for the purpose of providing adjustment factors for other field parameters will be conducted simultaneously with those related measurements. Volumes and methods of collection will be determined by the procedural requirements of the primary field measurement taken.

Field sampling personnel will measure temperature as follows:

1. Inspect the thermometer daily before each field trip to ensure that there are neither cracks in the glass nor air spaces or bubbles in the mercury.
2. Allow the thermometer or in-flow multi-measurement system enough time to equilibrate to outside temperature when removed from a field vehicle.
3. Insert the thermometer into the parameter sample. Swirl the thermometer if the medium is calm and take the temperature reading when the reading stabilizes. If using an in-flow multi-measurement system, readings will be continuously displayed.
4. Record the temperature reading in the field logbook to the nearest ±0.5ºC.
5. Decontaminate the thermometer/in-flow multi-measurement system and associated equipment in accordance with the PWT SOP GW.101, Groundwater Sampling.

5.0 DOCUMENTATION

Field sampling personnel will document field parameter instrument calibration procedures and measurements in the field logbook and appropriate field data sheets. Information to be documented includes calibration checks, verifications, calibrations, factory calibration records, and field parameter measurements.

Standard Operating Procedure
For
BOREHOLE LOGGING

Prepared by:

PACIFIC WESTERN TECHNOLOGIES, LTD.

July 2011

Revision 1.0

SOP BOREHOLE LOGGING

1.0 PURPOSE AND SCOPE 1
2.0 PERSONNEL QUALIFICATIONS 1
3.0 MATERIALS AND EQUIPMENT 1
4.0 PROCEDURES 1
4.1 BORING LOG 2
4.2 FIELD LOGBOOK 3

List of Tables

Table 1 Log Descriptors for Unconsolidated Soil
Table 2 Log Descriptors for Consolidated Rock

List of Attachments

Attachment A Boring Log Form

REVISION LOG		
Revision Number	Description	Date
1.0	Original SOP	July 2011

SOP BOREHOLE LOGGING

1.0 PURPOSE AND SCOPE

This Standard Operating Procedure (SOP) provides technical guidance and methods that will be used to log boreholes drilled in unconsolidated and weathered bedrock during environmental investigations. This SOP serves as a supplement to site-wide and investigation area specific work plans and the site-specific Quality Assurance Project Plan (QAPP) and is intended to be used in conjunction with other SOPs.

2.0 PERSONNEL QUALIFICATIONS

Personnel responsible for logging boreholes in unconsolidated and consolidated geologic material will be appropriately trained individuals with a minimum of a bachelor's degree in geology or a related field and have applicable field experience. Other qualified personnel may include geotechnical engineers or field technicians with an appropriate amount of applicable field experience or on-the-job training under the supervision of another qualified person. Personnel will also be qualified to perform this work in accordance with the project-specific health and safety plan (HASP).

3.0 MATERIALS AND EQUIPMENT

The following materials and equipment may be needed for borehole logging:

- Boring log forms (Attachment A)
- Bound field notebook
- Waterproof pens
- Hand lens (10x magnification or higher)
- Latex or nitrile gloves and other required PPE
- Tape measure
- Stainless steel knife, screwdriver, rock hammer
- Decontamination equipment and supplies (e.g., wash/rinse tubs, brushes, Alconox, plastic sheeting, paper towels, sponges, baby wipes, garden-type water sprayers, large plastic bags, potable water, distilled water and/or deionized water)
- Electronic water level meter
- Appropriate field monitoring instruments (e.g., photoionization detector [PID], flame ionization detector [FID], combustible gas indicator [CGI]), as required by the HASP
- Reference tables listing ASTM and/or USCS codes and descriptions
- Munsel color chart

Other materials and equipment may be needed based on field conditions.

4.0 PROCEDURES

4.1 BORING LOG

The boring log is the primary record of observations of physical conditions encountered during borehole drilling. The primary purpose of the boring log is to document all pertinent information that may be necessary for someone other than the rig geologist to understand and interpret the geologic and hydrogeologic conditions observed during drilling. At some sites, a critical issue is the contact between the unconsolidated material and the weathered bedrock, which may be readily apparent based on textural or color indications, or may be difficult to discern, requiring determination based on mineralogical properties. The boring log must provide sufficient textural, color, and mineralogical information so that someone other than the rig geologist can understand the basis for identification of those items, conditions or locations which are critical to the specific investigation or project.

Each borehole will be drilled and sampled in accordance with an appropriate Drilling and Sampling SOP. The rig geologist will be responsible for preparing detailed, complete, and accurate boring logs in the field using the boring log form (Attachment A) as drilling progresses. The preparation of legible and complete boring logs during drilling is necessary so that the borehole and geologic conditions are properly documented.

At a minimum, the following information will be documented on the boring log:

- Project name / Investigation name
- Supervising contractor name
- Boring identification number
- Start date and time
- End date and time
- Rig geologist name
- Drilling subcontractor and personnel
- Drill rig type
- Drilling method
- Bit diameter (and borehole diameter, if different)
- Auger external and internal diameter
- Sampling method
- Total depth of borehole recorded to the nearest 0.1 feet
- Ground surface elevation (recorded on log following surveying)
- Surveyed horizontal coordinates (recorded on log following surveying). If surveyed horizontal coordinates are not available at the time of drilling, location sketches referencing measured distances to prominent surface features (e.g., building corners, existing wells, fence corners) shall be recorded in the geologist's field log book.
- Sample depths or intervals recorded to the nearest 0.1 feet
- Blow counts

- Sample recovery
- USCS or USDA classification for unconsolidated materials
- Rock type classification for consolidated materials
- Graphic representation of material
- Detailed lithologic description. For unconsolidated materials the description should address the parameters listed in Table 1, including compaction/consistency, water content, color, texture (grain sizes, sorting, and shapes) and plasticity, major and minor constituents (e.g., gravel, sand silt, clay), and major mineralogy (as identifiable from the sample). For rock materials the description should address the parameters listed in Table 2, including weathering classification, color, texture, hardness, rock type and major mineralogy, and presence and orientation of fractures, staining, and bedding.
- Stratigraphic/lithologic changes. Where distinct lithologic changes are directly observed, they will be identified on the boring log by a solid horizontal line. Gradational transitions and changes identified indirectly from cuttings or methods other than direct observation and measurement will be identified by a horizontal dashed line.
- Detailed description of basis for identification of top of weathered bedrock and top of unweathered bedrock.
- Depth at which water is first encountered, the depth of water at the completion of drilling, and the static depth to water (if possible). Static water level data will include time allowed for levels to stabilize. The absence of water in borings will also be indicated.
- Borehole field meter readings (e.g., PID, FID, CGI, radioactivity meter)
- Other drilling, sampling, and borehole observations as appropriate (e.g., resistant layers, typical or unusual odors or other indications of potential contamination)

4.2 FIELD LOGBOOK

In addition to the boring log, the geologist will also maintain a bound field logbook. The purpose of the field logbook is to document a semi-narrative record of the field conditions, activities, and events relevant to the field program on a daily basis. The field logbook constitutes the daily written record of the field activities, while the boring log constitutes the written record of the borehole conditions. The following information shall be recorded daily in the bound field logbook if approved field forms are not used:

- Arrival time at site
- Names and affiliations of personnel working at the drilling location
- Equipment used at the drilling location (drill rig, field screening equipment)
- Names of visitors to the drilling location
- Health and safety and field procedure briefings and attendees
- Weather conditions

- Chronological record of drilling and sampling activities documenting times and drilling subcontractor rates and material quantities
- Significant events, such as equipment breakdown, health and safety problems, drill crew standby
- Location and sample station number (including sketches showing measurements from prominent surface features (e.g., building corners, existing wells, fence corners)
- Sample documentation, disposition, and cross references to sampling forms and chain-of-custody records
- Decontamination activities
- Investigation Derived Waste handling activities
- Field screening instrument calibration information and measurements
- Other health and safety observations or concerns
- Significant deviations from the QAPP or SOPs
- Other applicable information
- Departure time from site

Table 1
LOG DESCRIPTORS FOR UNCONSOLIDATED SOIL

Parameter	Example
Depositional environment and formation, (if named and if known).	Alluvium; Piney Creek
Unified Soil Classification System and designation.	Clayey sand (SC), sandy clay (CL)
Secondary components and estimated quantities either by percentages or by descriptive percentage ranges (note: terms used to indicate ranges should be described on the log or in a general legend).	Sand: fine, with trace of med. trace gravel
Color. May use Munsel color chart.	Gray, brown, yellowish, 5YR 3/2, 5YR 4/4
Consistency (cohesive soil). Use relative term.	Very soft, soft, medium, stiff, very stiff, hard
Density (non-cohesive soil). Use relative term.	Loose, medium, dense, very dense
Moisture content. Use relative term. Do not express as a percentage unless a value has been measured.	Dry, damp, moist, wet, saturated
Texture/fabric/bedding	No apparent bedding, thinly bedded
Grain angularity	Rounded, subangular
Sorting (sands)	Poorly sorted, well graded
Grain or fragment size	Coarse, very fine
Mineralogical indicators	Quartz, feldspar grains
Note "fill", "top of natural ground", "top of weathered bedrock", and “top of unweathered bedrock” where appropriate	

Table 2
LOG DESCRIPTORS FOR CONSOLIDATED ROCK

Parameter	Example
Formation name (if known)	Denver Formation
Rock type	Sandstone, shale, siltstone
Modifier denoting variety	Shaly, calcareous, siliceous, argillaceous, sandy, micaceous
Hardness	Very soft, soft, moderately hard, hard, very hard
Color	Medium brown, bluish-gray
Bedding	Parting band, thin bedded, medium bedded, thick bedded, massive, structureless, interbedded (Note: provide thickness range of each in legend)
Texture	Poorly cemented, well cemented, fine, coarse
Degree of weathering	Unweathered, intensely weathered
Degree of fracturing, fracture staining or filling	Highly fractured, limonite staining in fractures, MnO staining, calcite or zeolite fracture filling
Fracture orientation	Inclined 30º, horizontal
Structure and Orientation	Dipping beds at 10º
Mineralogical indicators	Andesite, volcanic grains, mafic minerals
Moisture content	Dry, damp, moist, wet, saturated

ATTACHMENT A

BORING LOG FORM

SOIL BOREHOLE LOG

SITE NAME AND LOCATION:	DRILLING METHOD:	BORING NO.	
		SHEET ____ OF ____	
	SAMPLING METHOD		
		DRILLING	
		START	FINSH
NORTHING:	COMMENTS	TIME	TIME
EASTING: ELEVATION:		DATE	DATE
DRILL RIG	SURFACE CONDITIONS		
ANGLE BEARING			
SAMPLE HAMMER			

DEPTH IN FEET (ELEVATION)	Blow/ 6 in on sampler	RECOVERY	SYMBOL	SAMPLE NUMBER AND DESCRIPTION OF MATERIAL	SAMPLER TYPE	REMARKS
1						
2						
3						
4						
5						
6						
7						
8						
9						
10						
11						
12						
13						

DRILLING CONTRACTOR: _____ DRILLER NAME: _____

LOGGED BY: _____ CHECKED BY: _____

PROJECT NUMBER: _____ PROJECT NAME: _____

APPENDIX C
WELL COMPLETION DETAILS

Installation and completion of two monitoring wells (one four inch diameter pumping well and one two inch diameter observation well) will be performed in accordance with SOP PWT/GW.103, Monitoring Well and Piezometer Installation, and the Monitoring Well Construction Standards, Subchapter 8, Section 36.21 (Board of Water Well Contractors) of the Administrative Rules of Montana. Figure 2 illustrates well construction diagrams for both the pumping and observation well.

The drilling of the boreholes for the installation of the wells will be conducted using hollow-stem augers and necessary sampling equipment. The borings for both wells will be advanced to the depth of bedrock, at approximately 66 feet bgs. The pumping well boring will be advanced an additional five feet into bedrock and the observation well boring will be advanced an additional one foot into bedrock. A minimum 2-inch annulus is required between the well screen and borehole wall. Therefore, the outer diameter of the augers for the pumping well should be eight to ten inches and six to eight inches for the observation well.

The pumping well and observation well casing will be constructed of either four inch or two inch diameter new, threaded, flush-joint schedule 80 poly-vinyl chloride (PVC). If recommended by the manufacturer, inert, non-degrading O-rings may be used between joints or polytetrafluoroethylene (PTFE) tape can be wrapped around the joint threads to improve the seal. All well casings will be free of foreign material. Clean casings will be stored flat (so as to prevent them from adopting a permanent bend) in plastic sleeves prior to use. Casing with stickers or stamped or stenciled nomenclature will not be used. The pumping well will have a five-foot sump with flush threaded PVC bottom cap, extending into the upper, weathered bedrock, to house a pressure transducer and data loggers such that it will not be disturbed by the pump. The observation well will have a one foot sediment sump extending into bedrock. Both wells shall be screened over the entire thickness of the saturated zone. The saturated zone is estimated to be approximately 25 feet thick, so the well will be screened with a 25 foot screen from an approximate depth of 42 feet below ground surface (bgs) to the bedrock at approximately 66 feet bgs, exact depths will be field verified.

Well screens will consist of new, threaded, flush-joint schedule 80 PVC pipe with factory-machined slots. The pumping well screen will be sized to meet the needs of both an aquifer test extraction and in-situ bioremediation injection needs. All well screens will have an inner diameter equal to the well casing. The wall thickness of PVC screen will be the same as that of the well casing. Well screens will be free of foreign material. Clean screen and sumps will be stored flat in plastic sleeves prior to use. Well screen and sediment sumps with stickers or stamped or stenciled nomenclature will not be used.

The use of stainless steel casing centralizers may be required to ensure the two inch (minimum) annulus is maintained. If required, centralizers should be provided above and below the well screen, but not within the filter pack or bentonite seal. Depending on the well depth and diameter, centralizers may also be required at 20-foot intervals along the well casing to provide a two inch grout annulus. The well installation subcontractor will determine the need for the centralizers.

Once the well assembly is placed into the borehole, it may be cut as necessary to remove excess length. The cut shall be made as straight and smooth as possible, and shall be perpendicular to the long axis of the well assembly so as to provide a uniform and horizontal top of casing once the well is installed. Prior to adding filter pack, the well shall be capped; this cap should be taped on for added security.

The filter pack will be chemically inert, rounded, silica sand of appropriate size for the well screen and host environment. In addition, the filter pack for the pumping well will be appropriate to meet the possible needs of groundwater extraction and substrate injection. If there is water in the borehole, extra care and time shall be taken to ensure the sand is being allowed to settle to the bottom. Sand should be added to the zone below the water level by tremie pipe. The filter pack will be added in small

(approximately 1- to 2-foot) increments so that the sand level is always at or slightly above the bottom of the augers. Depth measurements of the top of the filter material will be taken continuously as the filter pack is placed. The final depth to the top of the filter pack will be approximately 2 feet above the top of the bottom well screen which extends from the top of the saturated zone down to bedrock. The top of the filter pack will be directly measured by a tape measure, which will be raised and lowered vigorously and otherwise used in such a way as to prevent it from becoming embedded in the filter pack and help prevent bridging.

A three foot (approximately) bentonite pellet seal (before hydration) will be installed immediately above the filter pack. Approved granular bentonite may be used in place of bentonite pellets if the project manager so directs. The bentonite seal will be placed above the water level in the borehole, so the pellets may be allowed to free-fall into the borehole. Regardless of the method used to install the bentonite pellets, they shall not be allowed to bridge. If the well is being installed within the augers, the augers should be raised approximately 1 foot above the filter pack prior to adding the bentonite pellets (less if the base of the augers is in very loose, collapsing material; it may be slightly more if the material is competent and is unlikely to collapse onto the top of the sand pack). The top of the bentonite seal should never be above the base of the augers.

Once the designed thickness is achieved, the bentonite pellet seal will be hydrated by slowly pouring potable water into the borehole along the outside of the well assembly, so that the well acts to guide the water to the seal rather than have the water scour the borehole walls. This step shall be performed after the base of the augers are raised approximately one foot above the top of the bentonite seal. The completed bentonite seal will be allowed to hydrate for a minimum of 30 minutes before proceeding with the next filter pack operation. The volume of hydration water to be used will be determined during well installation.

The annular space between the well casing and the borehole will be grouted from the top of the (hydrated) bentonite seal to two feet below the ground surface. The grout will consist of high-solids reduced-pH bentonite grout (American Colloid Pure Gold™ or approved equivalent) mixed in a powered mechanical grout mixer according to the grout manufacturer's recommendations. The grout may be mixed by hand for intervals less than five feet thick. The grout will contain at least 30 percent solids by weight and have a minimum density of 9.9 pounds per gallon after mixing. The density will be checked with a mud balance and recorded in the rig geologist’s logbook.

Grout will be placed outside of the well casing using a tremie pipe that should be positioned just above the top of the bentonite seal. The grout will be pumped through the pipe at a low rate to minimize disturbance of the bentonite seal and borehole walls.

The tops of all well casings will be fitted with slip-on or threaded PVC caps that can be easily removed by hand. The wells are proposed in a heavily trafficked area and will need to be installed flush with or very slightly lower than the adjacent topography so as to be safe from vehicles such as snow plows or other heavy equipment. Because the surface completion of the well will utilize a flush mount, a locking slip-on well cap will be used. Flush-mount protective casings will typically be installed “flush” with the ground surface and will have cover that is attached with recessed bolts. It may be helpful to paint the manhole a fluorescent color to aid its location. The well number should be etched onto the surface flush mount with a metal scribe.