**ENVIRONMENTAL
RESTORATION
PROGRAM**

**Hydraulic Testing Plan for the Bear Creek
Valley Treatability Study,
Oak Ridge Y-12 Plant,
Oak Ridge, Tennessee**

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LOCKHEED MARTIN ENERGY SYSTEMS, INC.
FOR THE UNITED STATES
DEPARTMENT OF ENERGY

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**Hydraulic Testing Plan for the Bear Creek
Valley Treatability Study,
Oak Ridge Y-12 Plant,
Oak Ridge, Tennessee**

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PREFACE

The *Hydraulic Testing Plan for the Bear Creek Valley Treatability Study, Oak Ridge Y-12 Plant, Oak Ridge, Tennessee* (Y/ER-292) describes the location and installation of the trench and NT-1 wells, the locations and purpose of the monitoring wells, and the procedures for performing the pumping tests of the trench and NT-1 wells to evaluate hydraulic impacts of pumping these locations. This project supports the Bear Creek Valley Feasibility Study. This work was performed under Work Breakdown Structure 1.1.02.41.10.34.20 (Activity Data Sheet 2302, "Bear Creek Valley Operable Unit").

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ABBREVIATIONS

BCV	Bear Creek Valley
bgs	below ground surface
LMES	Lockheed Martin Energy Systems, Inc.
NT-1	North Tributary-1
ORNL	Oak Ridge National Laboratory
PVC	polyvinyl chloride
SAIC	Science Applications International Corporation
Trench	Treatability Study Trench

1. INTRODUCTION

The Bear Creek Valley (BCV) Treatability Study is intended to provide site-specific data defining potential treatability technologies applicable to contaminated groundwater and surface water. The ultimate goal of this effort is to install a treatment system that will remove uranium, technetium, nitrate, and several metals from groundwater before it reaches Bear Creek. This project directly supports the BCV Feasibility Study.

Part of the Treatability Study, Phase II Hydraulic Performance Testing, will produce hydraulic and treatment performance data required to design a long-term treatment system. This effort consists of the installation and testing of two groundwater collection systems: a trench in the vicinity of GW-835 and an angled pumping well adjacent to NT-1. Pumping tests and evaluations of gradients under ambient conditions will provide data for full-scale design of treatment systems. In addition to hydraulic performance, in situ treatment will be evaluated in a section of the trench filled with reactive media. Groundwater flow and treatment chemistry data will be obtained from monitoring wells installed in the reactive media section of the trench. The in situ treatment work is not part of this test plan.

This Hydraulic Testing Plan describes the location and installation of the trench and NT-1 wells, the locations and purpose of the monitoring wells, and the procedures for the pumping tests of the trench and NT-1 wells.

2. TREATABILITY STUDY FACILITIES

2.1 HYDRAULIC TEST TRENCH

A narrow trench will be installed parallel to Bear Creek in the area shown in Fig. 1. The location of the trench was selected to facilitate hydraulic testing of an interception trench to determine the applicability of in situ treatment for remediation of contaminated sites in BCV. The trench will be installed across the pre-1940s location of Bear Creek. Well data indicates that the old stream bed is a preferential flow path for local groundwater. The trench will be filled with relatively high conductivity backfill, creating a new preferential flow path along the trench. In addition, a section of the trench will be filled with iron filings treatment media to evaluate the hydraulic and treatment performance of an in situ installation.

The trench will be constructed as follows. An initial bench approximately 30 ft wide, 4 ft deep, and 225 ft long will be excavated in relatively uncontaminated surface soil. Approximately half of the clean, excavated soil will be disposed of in an on-site ravine west of the trench location, and the remaining soil will be stockpiled for refilling the excavated bench. The bench will serve as a location for stockpiling and, eventually, disposing of potentially contaminated soils from the trench excavation. A trench 2 ft wide, 225 ft long, and approximately 22 ft deep (excavated to the top of bedrock) will be excavated along the length of the bench. Material excavated from the trench will be placed on the bench south of the trench. Backfill material, coarse silica sand and iron filings, will be placed in the trench to the bottom of the bench. The backfilled trench will be covered with a geotextile to prevent cover soil from migrating into the backfill from above. The soil excavated from the trench will then be spread

across the bench along with stockpiled soil that was originally excavated from the bench. Finally, the gravel surface will be replaced and the site restored to its initial contours.

A vertical extraction well with 6-in. polyvinyl chloride (PVC) casing and well screen will be installed at the west end of the trench. The extraction well will serve as a dewatering sump during construction and later as the extraction well for trench pump testing. Additional monitoring wells will be installed in the trench backfill and surrounding the trench. The monitoring wells will be used to provide water level data to assess the hydraulic performance of the trench under both active and passive (pumped and ambient) modes of operation. Water from trench dewatering during construction and pump testing will be filtered and discharged overland to Bear Creek.

Thirteen new monitoring wells (TMW-01 through TMW-13) and seven existing wells will be used for evaluating the hydraulic performance of the Treatability Study Trench (Trench) under ambient and pumping operating conditions. The locations of the wells have been selected to provide the maximum utility of data collected, given the number of wells allowed and the effective area of the tests to be performed. All shallow monitoring wells will be installed through the use of a hollow-stem auger drilling method to the top of bedrock. The bedrock wells (>40 ft total depth) are to be installed through the use of an air rotary drilling method.

2.2 NT-1 SITE

A well, PTW-01, will be installed adjacent to the North Tributary-1 (NT-1) immediately south of where NT-1 crosses Bear Creek Road and west of Tank Farm 4 (see Fig.1). PTW-01 will be installed at a 45° angle from horizontal to a depth of 110 ft below ground surface (bgs). Total drilling distance for PTW-01 will reach approximately 155 ft bearing parallel to the Oak Ridge Y-12 Plant grid north. Well screen length will be 140 ft. A cross-section of the PTW-01 design is shown in Fig. 2. Monitoring wells PTMW-01 and PTMW-02 will be installed near well PTW-01 at depths of 65 ft bgs and 50 ft bgs, respectively. The intent is to locate the screened sections of the PTW-01, PTMW-01, and PTMW-02 wells within the southward dipping beds of shale bedrock identified during the Remedial Investigation and the Treatability Study Phase 1 Investigation as significant contaminant pathways to NT-1 seeps.

In addition to the wells, four surface water locations will be sampled for field parameters. The seepage of contaminated groundwater into the NT-1 creek is the focus of this NT-1 Site testing. This surface water testing will help directly measure the potential reduction of contaminant concentrations in NT-1. A relationship will be established between the conductivity measurements and nitrate concentrations. In this manner, the change in nitrate concentrations can be inferred from quick and inexpensive field conductivity measurements. This relationship will be determined in conjunction with the fixed-base laboratory measurements that are being conducted under other parts of the BCV Treatability Study.

Following installation and development of these three wells, a stepped pumping test will be performed at PTW-01 to evaluate production capacities of the well and the hydraulics of the surrounding fractured bedrock. A constant rate pumping test will then be conducted to determine the impacts of pumping on surrounding wells and NT-1.

Fig. 1. BCV feasibility study vicinity map.

Fig. 2. NT-1 angled well schematic.

3. HYDRAULIC TESTING

A pumping test involves continuously pumping water from a well and observing water level changes within the pumping well and a series of observation piezometers. The water level data is recorded with transducers, automated data recorders, and field logs of manual measurements. The duration of the test is dependent upon the hydraulic properties of the porous media and the pumping rate(s) used during the test. A typical schematic of the pumping well and instrumentation is shown in Fig. 3. For the angled well, the details of the depths and orientations would be different.

A total of four pumping tests will be performed as part of the BCV Treatability Study for the Trench and NT-1 sites to approximate production capabilities of the Trench and NT-1 inclined well. One stepped pumping test will be performed at both the Trench and the NT-1 Site. The constant rate pumping tests will be conducted for as long as possible, up to 2 weeks. Capturing at least one significant rainfall event during the long-term tests is desirable. These tests will assist in understanding the local flow fields under pumping conditions. In addition to these pumping tests, an ambient flow condition test will be conducted at the Trench site.

These pumping tests are intended to provide information on the capability of the underlying formation to produce groundwater during pumping conditions within the Trench and NT-1 inclined wells. Additional information regarding specific aquifer characteristics (e.g., hydraulic conductivity, transmissivity) will also be estimated as part of this work.

The hydraulic testing in support of the BCV Treatability Study will consist of the following four phases.

1. The first phase will consist of background data collection for both tests at the Trench and NT-1 sites. The goal of this phase of data collection will be to monitor meteorological conditions, groundwater level fluctuations, and seasonal groundwater level trends over the entire period of testing (i.e., approximately 3 months).
2. The second phase will include intensive data collection in and around the Trench (following the Trench installation) while the Trench is operating under nonpumping conditions. The goal of the second phase of data collection will be to monitor groundwater level fluctuations over a period of 3–5 weeks (schedule permitting), with a minimum of two storm events occurring during that time period.
3. The third phase will include intensive data collection during the stepped drawdown test and the long-term constant rate pumping test at the NT-1 Pumping Well (PTW-01).
4. The fourth phase will include intensive data collection during the stepped drawdown test and the long-term constant rate pumping test at the Trench Extraction Well (EW-01).

To sufficiently evaluate the hydrologic and hydrogeologic system at the NT-1 and Trench sites during the BCV Treatability Study, two types of data are needed. The first type, hydraulic data, is the major focus of this study. Water levels and climatological data will be collected to largely fill this data need. The second type of data needed are water quality parameters as they represent bodies of water and groundwater tracers. This data need will be filled through the collection of field parameters consisting of temperature, conductivity, pH, and dissolved oxygen. For each of the testing sites, the specific needs of hydraulic data and field parameter sampling will be discussed. Lists of piezometers or wells to be used for collection of water level data and field parameters are detailed in the following

Fig. 3. Typical pumping well instrumentation and configuration.

paragraphs. It should be noted that the piezometers and wells listed may be changed based on ongoing evaluations by Lockheed Martin Energy Systems, Inc. (LMES); ENTECH, Inc.; and Science Applications International Corporation (SAIC). However, piezometers and wells listed will not change without issuance of a field change order and written approval by the LMES Project Manager.

3.1 BACKGROUND AND CLIMATOLOGICAL DATA

Background groundwater levels, precipitation data, and barometric pressure data will be collected during the entire period of the investigation, not to be less than 3 months. Groundwater levels will be collected from the list of wells in Table 1. Precipitation and barometric pressure data will also be collected by a data logger located at the well GW-101 location. The Well GW-101 location should provide the background groundwater level data that is not affected by the hydraulic testing. This data will be used to assist in the interpretation of the pumping data and hydraulic analysis. The data will also assist in the understanding of how the behavior of these three parameters affect the local groundwater regime. The list of wells may be changed based on ongoing evaluations by LMES, ENTECH, and SAIC. Wells on this list will not change without approval by the LMES Project Manager and issuance of an addendum to the Hydraulic Testing Plan in letter format.

**Table 1. List of wells to be recorded
for background water levels**

Well ID	Water level measurement type	Frequency
GW-101	Data logger	15 min ^a
GW-815	Manual	Weekly
GW-814	Manual	Weekly
GW-813	Manual	Weekly
GW-122	Manual	Weekly
GW-123	Manual	Weekly
GW-616	Manual	Weekly
GW-127	Manual	Weekly
GW-100	Manual	Weekly
GW-236	Manual	Weekly
GW-309	Manual	Weekly
GW-244	Manual	Weekly
GW-245	Manual	Weekly
GW-246	Manual	Weekly

^aField parameters will be collected on a weekly basis.

To obtain the maximum amount of useful data during this short-duration project, the continuous data collection program will begin as soon as possible for those wells that will be logged at the NT-1 and Trench sites. Water levels in 16 wells (GW-101, TMW-01 through TMW-05, GMW-835, GMW-836, PTW-01, PTMW-01, PTMW-02, GW-834, GW-100, GW-345, GW-346, and GW-526) at the NT-1 and Trench sites will be continuously recorded starting as soon as possible. Continuous monitoring of TMW-06 through TMW-13 will begin following Trench construction. Each well will be equipped with a Druck pressure transducer (or equivalent) that will be connected to either a Well Sentinel or Hermit Data Logger. Each pressure transducer will be programmed to record depth to water from the top of the PVC casing. Water levels will be scanned and recorded at least every 15 min to a 0.01 ft accuracy. Data retrieval for this background data will occur at least every week.

3.2 NT-1 TESTING

This testing will consist of a stepped drawdown test and a constant rate pumping test. The following sections outline the test plan. A detailed layout of the NT-1 Site is presented in Fig. 4. The pumping wells and monitoring wells are shown. A vertical section showing all the wells collapsed onto a single section is presented in Fig. 5. This figure shows the orientation of the wells, their screened intervals, and the Nolichucky's dip.

3.2.1 Monitoring Schedule

Water level data will be continuously recorded at the pumping well (PTW-01), seven monitoring well locations, and the P-2 seep during the step test and the constant rate pumping test. In addition to the continuous data collection, manual measurement will be conducted for a series of wells. Table 2 lists all of the wells to be monitored and their measurement frequency. During the testing, the continuously logged data will be downloaded as needed, often several times a day during the start of the test.

Table 2 also shows the field parameter testing schedule to be measured during the testing. In addition to the P-2 seep, four other surface water sites will be sampled for field parameters. These sites will be field located at the beginning of the program. The stream sites are intended to pick up the upstream to downstream increase or decrease in nitrates in NT-1. The seep sites will be based on site-specific flow conditions. These sites will be flagged and described in the field logs. The field parameter sampling sites that will be automatically recorded will be conducted using down hole continuous loggers. Field parameters will include temperature, pH, conductivity, and dissolved oxygen.

Table 2. Schedule of wells and surface water sites to be measured during the NT-1 testing

Matrix	Well ID	Measurement type	Water level frequency	Field parameter
GW	PTW-01	Data logger	5 min ^a	5 min ^a
GW	PTMW-01	Data logger	5 min	5 min
GW	PTMW-02	Data logger	5 min	5 min
GW	GW-834	Data logger	5 min	5 min
GW	GW-100	Data logger	5 min	NS ^b
GW	GW-345	Data logger	5 min	NS
GW	GW-346	Data logger	5 min	NS
GW	GW-526	Data logger	5 min	NS
GW	TPB-01	Manual	Hourly	NS
GW	TPB-04	Manual	Hourly	NS
GW	TPB-05	Manual	Hourly	NS
SW	P-2 Seep in NT-1	Data logger	5 min	5 min
SW	2 TBD NT-1 Seeps	Manual	NS	Daily ^a
SW	2 TBD NT-1 Stream Points	Manual	NS	Daily ^a

^aThis rate will vary during the initial stages of the pumping tests.

^bNot sampled.

Fig. 4. NT-1 site pumping and monitoring well layout.

Fig. 5. North-south cross section through the NT-1 site.

These recordings are necessary for several reasons. The data will be used to identify fluctuations in groundwater levels during the three phases of testing. The continuous recordings will provide additional pumping test groundwater level data at varying distances away from the pumping test sites for analysis and quantification of aquifer parameters. Lastly, the continuous water level recordings may provide information for refinements of the conceptual hydrogeologic model.

3.2.2 Stepped Pumping Test Methodology

An 8-h stepped pumping test will be conducted to determine the ability of the underlying bedrock to produce water. The pumping rates will be held constant for 30 min, with water levels being measured continuously within the pumping well and surrounding monitoring wells. On the basis of historical evidence of the hydraulic characteristics of the bedrock in Bear Creek (SAIC 1997), it is anticipated that PTW-01 will not produce any significant flow rate of water. A sustainable pumping rate of around 1.5 gal/min is anticipated. Therefore, stepped tests will consist of the pumping rates and durations as summarized in Table 3. The equipment for the pump test will be set up as shown Fig. 3. The purged water will be discharged to a water filtration swale constructed on-site to remove suspended solids and then discharged to Bear Creek.

Table 3. NT-1 step test pumping schedule

Elapsed time (h)	Pump rate (gal/min)	Incremental volume (gal)	Total volume (gal)
0.5	0.25	8	8
1	0.5	15	23
1.5	0.75	23	46
2	1	30	76
2.5	1.25	38	114
3	1.5	45	159
3.5	1.75	53	212
4	2	60	272
4.5	2.25	68	340
5	2.5	75	415
5.5	2.75	83	498
6	3	90	588
6.5	3.5	105	693
7	4	120	813
7.5	4.5	135	948
8	5	150	1098

If the test is conducted in this manner, a total of 1098 gal of water will be generated. If during this progressive test the aquifer cannot sustain a particular pumping rate, the previous pumping rate (i.e., the maximum sustainable 30-min pumping rate) will be used through the duration of the 8-h test. If this rate cannot be sustained because of excessive drawdown or dewatering, the pumping rate will be lowered in an attempt to obtain a sustainable pumping rate.

3.2.3 Constant Rate Pumping Test

A 7-day constant rate pumping test will be conducted at the PTW-01 Extraction Well following the completion and analysis of the stepped pumping test. The step test analysis will provide a pumping

rate for PTW-01 that may be sustained over long periods of time (>7 days). The wells listed in Table 2 will also be used for this phase of the pumping test. For a 24-h period before and immediately after this test, these wells will also be monitored.

Once the test begins, the water level in PTW-01 will be recorded at logarithmic time intervals starting with 1.0 sec as the initial time step up to a 5-min time step. Once the 5-min time step is reached, data will be recorded at this interval for the remainder of the test. Flow rate and water quality field parameters (i.e., temperature, pH, conductivity, dissolved oxygen) will also be recorded on a 5-min interval.

3.3 TRENCH TESTING

This testing will consist of a stepped drawdown test, a constant rate pumping test, and an ambient flow condition test with the Trench installed. A detailed layout of the Trench site is shown in Fig. 6. The Trench is shown along with the Trench wells and the deep and shallow wells. Figures 7 and 8 are cross sections showing how the wellscreen intervals relate to the Trench and bedrock dip. The following sections outline the test plan.

3.3.1 Monitoring Schedule

At the Trench site, water level data will be continuously recorded at Pumping Well EW-01 and 12 monitoring well locations during the step test and the constant rate pumping test. Ten new push probes will also be installed after the Trench is installed to assess the shallow flow patterns. These piezometers will only be referred to here in very general terms. They will be installed by Oak Ridge National Laboratory (ORNL) personnel at locations that will be mutually agreed upon by the project geologist and the ORNL research team. In addition to the continuous data collection, manual measurements will be conducted for a series of wells. A list of all the wells to be monitored and their measurement frequency is presented in Table 4. During the testing, the continuously logged data will be downloaded as needed, often several times a day during the start of the test.

Table 4 also shows the field parameter testing schedule to be measured during the testing. In addition to the wells and push probes, four surface water sites will be sampled for field parameters. These sites will be field located at the beginning of the program. The stream sites are intended to pick up the upstream to downstream conditions in Bear Creek. The seep sites will be based on site-specific flow conditions. These sites will be flagged and described in the field logs. The field parameter sampling sites that will be automatically recorded will be conducted using down hole continuous loggers.

These data are necessary for several reasons. The data will be used to identify fluctuations in groundwater levels during the three phases of testing. The continuous recordings will provide additional pumping test groundwater level data at varying distances away from the pumping test sites for analysis and quantification of aquifer parameters. Lastly, the continuous water level recordings may provide information for refinements of the conceptual hydrogeologic model.

3.3.2 Trench Ambient Flow Test

The purpose of this portion of the test is to identify the ambient shallow groundwater flow patterns after the Trench is installed. The flow conditions before construction will be determined from existing push probes and monitoring wells. Then, with the new data after the Trench is installed, the impact on the local flow system can be determined, and the water fluxes through the Trench can be estimated.

Fig. 6. Trench site layout.

Fig. 7. Trench site cross section B-B'.

Fig. 8. Trench site cross section C-C'.

Table 4. Schedule of wells to be measured for the trench testing

Matrix	Well ID	Measurement type	Water level frequency	Field parameter frequency
GW	EW-01	Data logger	5 min ^a	5 min ^a
GW	TMW-01	Data logger	5 min	NS ^b
GW	TMW-02	Data logger	5 min	5 min
GW	TMW-03	Data logger	5 min	5 min
GW	TMW-04	Data logger	5 min	5 min
GW	TMW-05	Data logger	5 min	NS
GW	TMW-06	Data logger	5 min ^a	NS
GW	TMW-07	Data logger	5 min ^a	NS
GW	TMW-11	Data logger	5 min ^a	5 min
GW	TMW-12	Data logger	5 min ^a	NS
GW	TMW-13	Data logger	5 min ^a	NS
GW	GW-835	Data logger	5 min	NS
GW	GW-836	Data logger	5 min	NS
GW	10 new push probes	Data logger	5 min ^c	NS
GW	TPB-06	Manual	.5 h ^a	NS
GW	TPB-07	Manual	.5 h ^a	NS
GW	TPB-08	Manual	.5 h	NS
GW	TPB-16	Manual	.5 h	NS
GW	TPB-29	Manual	.5 h	NS
GW	GW-122	Manual	1 h ^d	NS
GW	GW-123	Manual	1 h ^d	NS
GW	GW-813	Manual	1 h ^d	NS
GW	GW-814	Manual	1 h ^d	NS
GW	GW-815	Manual	1 h ^d	NS
GW	GW-616	Manual	1 h ^d	NS
SW	2 TBD Seeps in BCV	Manual	NS	Daily
SW	2 SW in Bear Creek (NPDES location and BCK 12.41)	Manual	NS	Daily

NPDES = National Pollutant Discharge Elimination System; BCK = Bear Creek kilometer.

^aThis rate will vary during the initial stages of the pumping tests.

^bNot sampled.

^cLocations to be determined after the Trench is installed.

^dOnly measured during constant rate test.

The wells and push probes listed in Table 4 will be used for the ambient test. The frequency of manual measurements will be reduced to daily for most piezometers.

As stated earlier, this part of the Trench testing will begin as soon as the Trench is constructed. During the initial time of the ambient test, the effects of installation will likely be picked up by the monitoring. Also, these data will likely be useful in developing an understanding of the shallow flow system.

Through the use of these data, a simple flow net can be used to gain a quick understanding of the change in flow patterns. More detailed numerical analysis of these results, in combination with the pumping test analysis, may also be useful.

3.3.3 Stepped Pumping Test Methodology

The 98-h stepped pumping tests will be conducted to determine the ability of the underlying bedrock and the saturated overburden. On the basis of a pumping test performed at GMW-835 on November 12, 1996, and the characteristics of the site geology, it is anticipated that the pumping wells will only produce enough water to sustain low pumping rates [less than 1.5 gal/min (SAIC, 1997)]. For this reason, the pump will be capable of sustaining pumping rates ranging from 1 gal/min up to 10 gal/min. Currently, the stepped pumping test is intended to last 98 h. Table 5 contains the pumping schedule for this test. The equipment for the pump test will be set up as shown in Fig. 3. The purged water will be discharged to a water filtration swale constructed on-site to remove suspended solids and then discharged to Bear Creek.

Table 5. Trench step test pumping schedule

Elapsed time (h)	Pump rate (gal/min)	Incremental volume (gal)	Total volume (gal)
25	10	15000	15000
49	5	7200	22200
74	2.5	3750	25950
98	1	1440	27390

The Trench Extraction Well EW-01 will be the location of the pumping test (see Fig. 6). All new Trench monitoring wells as well as existing push probes (TPB-06, TPB-07, TPB-08, TPB-16, TPB-29, and wells GMW-835 and GMW-836) will be used as observation points during this test. This test will provide information regarding the performance capabilities of the Trench and result in a recommended pumping rate for Trench operation. In addition, this test will provide a picture of how the shallow saturated groundwater system responds under pumped conditions.

If the test is conducted in this manner, a total of 27,390 gal of water will be generated. If during this decreasing test the aquifer cannot sustain a particular pumping rate, the next pumping rate will be used for the remaining time increment. The volume of water in the Trench is estimated to be 16,000 gal. This test is designed to initially remove the Trench storage water, then begin to test the Trench/aquifer system hydraulics.

3.3.4 Constant Rate Pumping Test

To estimate the long-term production viability of the Trench, a 7-day constant rate pumping test will be conducted at the Trench extraction well following the completion and analysis of stepped

pumping tests. Following this analysis, a pumping rate that may be sustained within the Trench over long periods of time (>7 days) will be selected. The wells listed in Table 4 will also be used for this phase of the pumping test. For a 24-h period before and immediately after this test, these wells will also be monitored.

Once the test begins, the water level in ETW-01 will be recorded at logarithmic time intervals starting with 1.0 sec as the initial time step up to a 5-min time step. Once the 5-min time step is reached, data will be recorded at this interval for the remainder of the test. Flow rate and water quality field parameters (i.e. temperature, pH, conductivity, dissolved oxygen) will also be recorded on a 5-min interval.

4. ANALYSIS AND REPORTING

4.1 PUMP TEST ANALYSIS

Before processing the data collected during the pumping tests, the data must be reviewed for possible corrections. Necessary corrections may include antecedent trends, rhythmic fluctuations, and barometric effects.

The pumping test data sets will be analyzed by using either a type curve or straight line method of analysis. The actual method of analysis (e.g., Theis, Neuman, Cooper & Jacob) cannot be determined at this time. Because of the potentially complex nature of the bedrock conductivity structure and overburden/bedrock interaction, a numerical model approach will be useful in analyzing and estimating the aquifer parameters. Initially an analytical solution will be determined by using the appropriate program and methodology. Next, using these preliminary results, ENTECH will work with SAIC to refine the existing three-dimensional numerical model using the test data results. Refinement of the parameters and sensitivity testing will be conducted.

4.2 REPORTING

A summary report of preliminary results of all the aquifer tests (including pump test analyses and time series plots of the data) will be generated for formal documentation of those activities. Field parameter sampling will be summarized tabularly, using time series plots. The report will include diskettes of all collected data, descriptions of the analytical methods used for the analyses, and computational results.

5. UNDERLYING ASSUMPTIONS

The successful completion of the pumping tests is dependent upon the following underlying assumptions.

- Purge water from the pumping test can be fed via gravity flow into the water filtration swale.

- The NT-1 and Trench pumping tests can be successfully completed at a sustained pumping rate that approaches or exceeds 1.5 gal/min. Extraction System: The on-site extraction system will be installed as indicated in Fig. 3.
- Water level measurements during the actual test measurements will be made through the use of pressure transducers programmed to electronically log data at predetermined intervals. The pumping well and each of the nearby observation wells will be equipped with logging equipment.
- Discharge from the pumping well will be regulated by the use of a restricting valve. A flow rate and totalizer meter will be used to quantify flow.
- Duration of the test has been based on existing information and reasonable assumptions. The pumping tests will be designed to accommodate a 168-h test. It is possible that excessive drawdown in the well could prohibit a test of this duration. Should a problem arise with the actual test before the predetermined duration, a decision to continue at a lower flow rate or terminate the test will be at the discretion of the Site Geologist.

6. REFERENCES

Science Applications International Corporation. April, 1997. *Field Characterization Report on Phase I of the Bear Creek Valley Treatability Study*, Y/ER-286, prepared for Lockheed Martin Energy Systems, Inc., Oak Ridge Y-12 Plant, Oak Ridge, Tennessee.

APPENDIX
STANDARD OPERATING PROCEDURES

LIST OF STANDARD OPERATING PROCEDURES

1. SINGLE WELL PUMP TEST
2. WELL DEVELOPMENT AND PURGING
3. FIELD EQUIPMENT DECONTAMINATION
4. GROUNDWATER SAMPLING WITH BAILERS
5. SPECIFIC CONDUCTIVITY AND TOTAL DISSOLVED SOLIDS METER CALIBRATION AND MEASUREMENT
6. STEPPED DRAWDOWN PUMPING TEST
7. TEMPERATURE MEASUREMENT
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9. SURFACE WATER SAMPLING
10. PRESSURE TRANSDUCER DEPLOYMENT AND TROUBLESHOOTING
11. PRESSURE TRANSDUCER ONE POINT CALIBRATION CHECK
12. PRESSURE TRANSDUCER FIVE POINT CALIBRATION
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15. pH PROBE CALIBRATION pH MEASUREMENT: ELECTROMETRIC TECHNIQUE

STANDARD OPERATING PROCEDURES SINGLE WELL PUMP TEST

1. OBJECTIVE

The objective is to define the procedure for pump testing an existing groundwater monitoring well to define transmissivity in the vicinity of the well. This procedure refers specifically to the use of a Grundfos Redi-Flo® pump and an In-Situ® transducer and data logger but may be modified for use with other systems.

2. BACKGROUND

Pump tests are performed to better estimate transmissivity of the area in the vicinity of the well tested so as to enhance the certainty of predictions of aquifer transmissivity characteristics.

It is imperative that set-up personnel be well acquainted with the transducer and data logger being used to prevent damage or loss of data caused by improper set-up and maintenance. Care must be taken not to over-pressure the transducer; 2.2 ft of water is equivalent to approximately 1 pound per square inch. See the pressure transducer specification sheet for pressure ratings. Use the ratings and well hydrologic data to determine the appropriate depth for transducer placement.

3. EQUIPMENT

- Pressure transducer
- Data logger
- Electronic water level indicator
- Pump, pump controller, power supply and discharge hose
- Portable tank to contain groundwater

4. PROCEDURE

4.1 Hardware Setup

1. Hardwire the transducer to the chosen data logger according to the manufactures guidelines.
 - 1.1 Secure the transducer cable at well casing (e.g., through hubble connector in well casing or with tape).
 - 1.2 Secure transducer cable to logger.
2. Ensure that there is a thin coating of silicone grease on the pressure transducer membrane if the transducer type requires it.
3. Record the transducer serial number and secure the transducer at the desired depth with a nondamaging device (e.g., rubber grip). Appropriate depth will be a factor of transducer rating and the expected fluctuations in water level.
4. Set data logging device in accordance with the manufacturers instructions.

5. Install pump, discharge tubing, and flow monitoring equipment.
6. Start data logger.
7. Manually measure water level to verify logger performance.
8. Start pump at desired flow rate and conduct test for specified time period.
9. Stop test.
10. Remove equipment from well and decontaminate.
11. Secure well.
12. Download data according to logger manufacture's instructions.

5. LIMITATIONS

Pressure transducers are particularly susceptible to interferences caused by water entering the vent tube and the interstitial spaces of the wiring cable. Effects of water in the vent tube or cable can range from daily fluctuations in output accuracy to complete sensor failure. The open end of the vent tube must be protected from moisture and particles. The open end of the cable must be protected from moisture. See the operating instructions for specific recommendations.

6. REFERENCES

In-Situ® Logger and pressure transducer operations manual

Grundfos Redi-Flo® operations manual

STANDARD OPERATING PROCEDURES WELL DEVELOPMENT AND PURGING

1. OBJECTIVE

The objective is to define the procedural requirements for well development and purging.

2. BACKGROUND

Monitoring wells are developed to remove fines and well-bore formation damage produced during drilling and to grade the sand in the filter pack. This should improve well recharge rates and reduce the turbidity of the recharge water. Wells should not be developed for 24 hours after completion when a cement bentonite grout is used to seal the annular space. However, wells may be developed before grouting if conditions warrant.

Wells are purged immediately before groundwater sampling to remove stagnant water and to provide a sample representative of groundwater conditions. Wells should be sample within 3 hours (optimum) to 24 hours after purging (maximum).

3. EQUIPMENT

- Pump, bailer, etc.
- Power source (e.g., generator), if required.
- Water level meter.
- Temperature, conductivity and pH meters.
- Personnel protective equipment as specified in the site specific Sampling and Analysis Plan (SAP).
- Decontamination supplies, if required on-site.
- Disposal drums, if required.

4. PROCEDURES

4.1 Well Development

1. Don protective clothing and equipment as specified in the site-specific SAP. Prepare a work area by covering the ground at the well head with plastic sheeting.
2. Open and check the condition of the wellhead, including the condition of the surveyed reference mark, if any. If necessary, check for vapors by using vapor analyzing equipment.
3. Determine the depth to static water level and depth to bottom of the casing.
4. Prepare the necessary equipment for developing the well. A number of techniques can be used to develop a well. Some of the more common methods are bailing, over pumping, backwashing, mechanical surging, surge and pump, and high-velocity jetting. All of these procedures are acceptable; however, final approval of the development method rests with the appropriateness of a specific method to the site and to the project guidelines.

5. For screened intervals longer than 10 ft, develop the well in 2- to 3-ft intervals from bottom to top. This will ensure proper packing and sorting in the filter pack. Note: it is good practice to develop all screened and filter packed wells in stages.
6. Continue well development until produced water is clear and free of suspended solids or has reached an acceptable minimum of turbidity as determined by the appropriate project personnel. Record pertinent data in the field logbook and on appropriate well development forms. Successful well development may be indicated by stabilization of pH, conductivity/total dissolved solids, and temperature at the discretion of appropriate project personnel.
7. Remove the pump assembly or bailers from the well, decontaminate all appropriate equipment, and clear up the site. Lock the well cover before leaving. Dispose of produced water as required by the project work plan.

4.2 Volumetric Method of Well Purging

1. Don protective clothing and equipment as specified in the site-specific health and safety plan. Prepare a work area by covering the ground at the wellhead with plastic sheeting.
2. Open the well cover and check the condition of the wellhead, including the condition of the surveyed reference mark, if any. If necessary, check for vapors by using vapor analyzing equipment.
3. Determine the depth to static water level and depth to bottom of well. Calculate the well volume (volume of water within the well casing) by using the following formula (or equivalent):

$$V = \pi r^2 \times h \times 7.48 = \text{fluid volume in gallons}$$

where:

$\pi = 3.14$,

r = radius of well casing in feet,

h = height of the static water column within the well,

7.48 = conversion from ft^3 to gallons.

Record these data and calculations in the field logbook or appropriate data sheet.

4. Prepare the pump or bailer, and lower it into the casing to the appropriate depth.
5. Remove 3–5 well volumes or the number of well volumes specified in the project SAP. In low-recharge aquifers, the well will commonly pump or bail to dryness. If this is the case, there is no need to continue with purging operations. Record all activities in the field logbook and appropriate forms.
6. Remove the pump assembly or bailer from the well; decontaminate used equipment. Dispose of produced water as required by the project work plan.

4.3 Indicator Parameter Method of Well Purging

1. Don protective clothing and equipment as specified in the site-specific health and safety plan. Prepare a work area by covering the ground at the wellhead with plastic sheeting.

2. Open the well cover and check the condition of the wellhead, including the condition of the surveyed reference mark, if any. If necessary, check for vapors by using vapor analyzing equipment.
3. Determine the depth to static water level and depth to bottom of well. Calculate the well volume (volume of water within the well casing) by using the following formula (or equivalent):

$$V = \pi r^2 \times h \times 7.48 = \text{fluid volume in gallons}$$

where:

$\pi = 3.14$,

r = radius of well casing in feet,

h = height of the static water column within the well,

7.48 = conversion from ft^3 to gallons.

Record these data and calculations in the field logbook or appropriate data sheet.

4. Install probes. Three probe configurations are available. In situ measurements are made with the probe(s) of the indicator meters in the water near but not on the well bottom. A flow-through system may also be used for indicator parameter measurement. Alternatively, set up surface probe(s) at the discharge orifice of the pump or bailer. Allow subsurface probe(s) to equilibrate according to manufacturer's specifications. Record the equilibrated readings in the field logbook together with the time.
5. Assemble the pump or bailer, and lower into the casing.
6. Begin pumping or bailing the well. Record indicator parameter reading at predetermined intervals. Maintain a record of the approximate volumes of water produced. Remove a minim of one well volume of water during the purge.
7. Continue pumping or bailing until indicator parameter readings remain stable within $\pm 10\%$ for three consecutive recording intervals. In low-recharge aquifers the well may pump or bail to dryness before indicator parameters stabilize. In this case, there is no need to continue purging. Record pertinent data (e.g., water volume) in the field logbook or appropriate data sheet.
8. Remove the pump assembly or bailer from the well; decontaminate used equipment. Dispose of produced water as required by the project work plan.

5. LIMITATIONS

Natural conditions such as slow recharge caused by soils or fast recharge caused by fracture flow may influence the effectiveness of well development.

Where flammable product is expected or known to exist on or in groundwater, use only intrinsically safe electrical devices and place portable power sources 50 ft or more from the well head and disposal drums.

6. REFERENCES

Driscoll, F.G., Groundwater and Wells, 2nd Edition, St. Paul, Minnesota, Johnson Division, 1986.

U.S. Environmental Protection Agency, 1986. Engineering Support Branch Standard Operating Procedures and Quality Assurance Manual, Region IV. Athens, GA.

STANDARD OPERATING PROCEDURES FIELD EQUIPMENT DECONTAMINATION

1. PURPOSE

The purpose of this procedure is to describe the procedures required for decontamination of field equipment.

2. BACKGROUND

Decontamination of field equipment is necessary to ensure the quality of samples by preventing cross-contamination. Further, decontamination reduces health hazards and prevents the spread of contaminants off-site.

3. RESPONSIBILITIES

Site Manager: The Site Manager is responsible for ensuring that field personnel are trained in the use of this procedure and that decontamination is conducted in accordance with this procedure.

4. REQUIRED EQUIPMENT

4.1 Nonsampling Equipment

Nonsampling Equipment includes rigs, backhoes, augers, drill pipe, Geoprobe, Rig, bits, casing, and screen.

- High-pressure pump with metered soap dispenser or steam-spray unit
- 2- to 5-gal manual-pump sprayer (pump sprayer material must be compatible with the solution used)
- Stiff-bristle brushes
- Gloves, goggles, steel-toed boots, and other protective clothing as specified in the site-specific health and safety plan

4.2 Down Hole and Sampling Equipment

Small Equipment includes split spoons, Geoprobe spoons and rods, bailers, bowls, dredges, kemmer or wheaton water samplers, filtration equipment, and other small items.

- 5-gal plastic buckets and/or troughs
- Laboratory-grade detergent (phosphate free)
- Stiff-bristle brushes

- Nalgene or Teflon sprayers or wash bottles or 2- to 5-gal manual-pump sprayer (pump sprayer material must be compatible with the solution used)
- Plastic sheeting
- Disposable wipes or rags
- Distilled water [American Society for Testing and Materials (ASTM) Type II or better]
- Appropriate decontamination solutions (pesticide grade or better)
- Gloves, goggles, and other protective clothing as specified in the site-specific health and safety plan

4.3 Pumps and Pump Assemblies

- 55-gal drums
- Plastic sheeting
- 5-gal or larger containers of distilled water (ASTM Type II or better) and other required decontamination solutions
- Disposable wipes or rags
- Gloves, goggles, and other protective clothing as specified in the site-specific health and safety plan

5. PROCEDURES

5.1 Nonsampling Equipment Decontamination

Equipment includes drilling rig, Geoprobe rig and backhoe, etc.

1. Set up a decontamination pad that is large enough to fully contain the equipment to be cleaned. Use one or more layers of heavy plastic sheeting to cover the ground surface.
2. With rig in place, spray areas (rear of rig or backhoe) exposed to possibly contaminated soil with steam or high-pressure sprayer. Be sure to spray down all surfaces, including the undercarriage. It is also good practice to clean motor, hydraulic lifts, oil fill, and fuel tank areas before use to avoid introducing contaminants to the work site.
3. If soapy water is used for the washdown step, rinse the equipment with potable (tap) water.
4. Record equipment type and serial number, date, time, and method of decontamination in the appropriate logbook.

5.2 Down Hole Equipment Decontamination

Down hole equipment includes hollow-stem augers, drill pipe, Geoprobe rods, casing, and screen. The following steps must be followed when decontaminating this equipment:

1. Set up a centralized decontamination area, if possible. The area should be set up to contain contaminated rinse waters and to minimize the spread of airborne spray.
2. Set up a "clean" area upwind of the decontamination area to receive cleaned equipment for air drying. At a minimum, clean plastic sheeting must be used to cover the ground, tables, or other surfaces on which decontaminated equipment is to be placed.
3. Put on gloves, boots, goggles, and any other protective equipment as specified in the site-specific health and safety plan.
4. Place object to be cleaned on metal or plastic-covered wooden sawhorses or other supports.
5. Using the high-pressure sprayer (or steam unit), spray the contaminated equipment. Aim downward to avoid spraying outside the decontamination area. Be sure to spray inside corners and gaps especially well. Use a brush, if necessary, to dislodge soil.
6. If using soapy water, rinse the equipment using clean, clear tap water. If using steam, the rinse step is not necessary to dislodge dirt.
7. Remove the equipment from the decontamination area and place in the clean area to air-dry.
8. Record the equipment number (if assigned) or type, date, and time of decontamination in the appropriate logbook.
9. Record the decontamination reference procedure, equipment number, or description together with the date and time of decontamination in the appropriate logbook.
10. After decontamination activities are completed, collect all contaminated waters, used solvents and acids, plastic sheeting, disposable gloves, boots, and clothing in separate containers or receptacles. All receptacles containing contaminated items must be properly labeled for disposal. Liquids and solids must be contained in separate containers.

5.3 Sampling Equipment Decontamination

Sampling equipment includes split spoons, Geoprobe spoons and rods, spatulas, and composting bowls that directly contact samples. The following steps must be followed when decontaminating this equipment:

1. Set up a decontamination line on plastic sheeting. The decontamination line should progress from "dirty" to "clean" and end with an area for drying of decontaminated equipment. At a minimum, clean plastic sheeting must be used to cover the ground, tables, or other surfaces on which decontaminated equipment is to be placed.
2. Wash the item thoroughly in a 5-gal bucket of soapy water. Use a stiff-bristle brush to dislodge any clinging soil. Disassemble any item that might trap contaminants internally before washing. Do not reassemble until decontamination is complete.

3. Rinse the item in clear tap water. Rinse water should be replaced as needed, generally when cloudy.
4. Repeat Step 3 in a separate bucket (optional).
5. Using hand sprayer, wash bottles, or manual pump sprayer, rinse the item with ASTM Type II water.
6. After drying, wrap the cleaned item in aluminum foil for storage, shiny side out.
7. Record the decontamination protocol and equipment number or description together with the date and time of decontamination in the appropriate logbook.
8. After decontamination activities are completed, collect all contaminated waters, used solvents, plastic sheeting, disposable gloves, boots, and clothing. Place contaminated items in properly labeled drums for disposal. Liquids and solids must be contained separately.

5.4 Pump Decontamination

1. Set up decontamination area and separate "clean" storage area using plastic sheeting to cover the ground, tables, and other porous surfaces. Set up three drums in a triangle. The two drums at the base of the triangle will be used to contain dilute (nonfoaming) soapy water and potable water. The drum at the apex will receive wastewater. Place 5-gal cans of distilled water adjacent to the waste drum on the same side as the potable water drum.
2. Pump should be set up in the same configuration as for sampling. Submerge pump intake (or pump, if submersible) and all down hole wetted parts (tubing, piping, foot valve) in soapy water of the first drum. Place the discharge outlet in the waste drum above the level of wastewater. Pump soapy water through the pump assembly until it discharges to the waste drum.
3. Move pump assembly to the potable water drum while leaving discharge outlet in the waste drum. All down hole wetted parts must be immersed in the potable water rinse. Pump potable water through the pump assembly until it runs clear.
4. Move the pump intake to the distilled water can. Pump distilled water through the pump assembly. Usually, three pump-and-line assembly volumes will be required.
5. Decontaminate the discharge outlet by hand following the steps outlined in Sect. 5.3.
6. Remove the decontaminated pump assembly to the "clean" area, and allow to air dry. Intake and outlet orifices should be covered with aluminum foil to prevent the entry of airborne contaminants and particles.
7. Record the equipment type and identification, date, time, and method of decontamination in the appropriate logbook.

5.5 Waste Disposal

1. All wash water, rinse water, and decontamination solutions that have come in contact with contaminated equipment are to be handled, packaged, labeled, marked, stored, and disposed of as hazardous waste unless other arrangements are approved in advance.

2. Small quantities of used decontamination solutions are to be generated; it may be best to segregate each type of waste in separate containers. This may permit the disposal of wash water and rinse water in a sanitary sewage treatment plant rather than as a hazardous waste. If an industrial wastewater treatment plant is available, the disposal of acid solution and methanol-water solutions may be permitted.
3. Unless required, plastic sheeting and disposable protective clothing may be treated as a solid nonhazardous waste.

6. REFERENCES

- U.S. Environmental Protection Agency, Region IV, 1986, Engineering Support Branch Standard Operation Procedures and Quality Assurance Manual.
- U.S. Environmental Protection Agency, 1987, A Compendium of Superfund Field Operations Methods, EPA/540/P-87/0 0.01.

STANDARD OPERATING PROCEDURE GROUNDWATER SAMPLING WITH BAILERS

1. PURPOSE

The purpose is to define requirements for the collection of groundwater samples with bailers.

2. BACKGROUND

Methods used for the collection of groundwater samples include bailing and a variety of pumping techniques. Bailers are hollow cylinders with unidirectional (open up) check valves at the bottom end. Some bailers may also be closed or valved at the upper end. Bailers used in environmental applications are typically constructed of stainless steel or Teflon. For the best results, the sequence of sampling is from least to most contaminated wells. Bailers generally provide poor quality, nonreproducible results. Generally ENTECH restricts their use to shallow well development, floating-sinking product investigations, and samples collection for screening purposes.

3. EQUIPMENT

Bailing equipment includes the following:

- Bailer;
- Bailer emptying device;
- Clean rope or wire line;
- Appropriate sample containers with labels and preservatives, as required;
- Water-level measuring device;
- Plastic sheeting;
- Personnel protective clothing and equipment, if required by the site-specific Sampling and Analysis Plan (SAP); and
- Latex gloves.

4. PROCEDURE

1. Don protective clothing and equipment as specified in the site-specific health and safety plan
2. Cover the ground surface around the wellhead with plastic sheeting.
3. Open the well and note the condition of the casing and cap. If required, check for vapors by using vapor analyzing equipment. Determine the static water level and depth to well bottom. Record this information in the field log book or on the water sampling form.

4. Purge the well of 3 well volumes, if not already accomplished. Allow the water level to recover to a depth at least sufficient for the submergence of the bailer without contacting the well bottom.
5. Securely attach a decontaminated bailer to the appropriate type of line. The other end of the line should also be secured to prevent loss of equipment down the borehole.
6. Arrange the sample containers in the order of use. When applicable, collect samples for analytes in this order:
 - Floating or sinking compounds,
 - Volatile organic compounds (VOC)¹,
 - Purgeable organic carbon (POC)¹,
 - Purgeable organic halogens (POX)¹,
 - Total organic halogens (TOX)¹,
 - Total organic carbon (TOC)¹,
 - Extractable organics¹,
 - Other unpreserved analytes¹,
 - Total metals¹,
 - Dissolved metals¹,
 - Phenols¹,
 - Cyanide¹,
 - Other preserved analytes¹, and
 - Radionuclides¹.

¹Bailers generally unsuitable for collection of these analytes.

7. Lower the bailer into the well. The bailer should enter the water slowly to minimize aeration, particularly when samples are being collected.
8. Retrieve the filled bailer to the surface. Do not allow the line to contact the ground. The first bailer of water should be used as a bailer rinse and discarded.
9. Collect additional bailers full of water.
10. Collect any required VOA samples by using the bailer emptying device to gently transfer water to the sample bottle. The sample bottle should be tilted when filling to minimize aeration. Check the filled vial for bubbles.
11. Unless otherwise specified, do not rinse sample containers before sample collection.
12. Fill the remaining sample containers. If sample filtration is required, it should be done as soon as possible. Add preservative (if needed), cap, seal, and properly label all containers. Place the filled containers in the cooler(s) immediately.
13. Collect a sample for measurement of final pH, conductivity, and temperature of the well water if required by the project.
14. Document all samples collected.
15. Decontaminate sampling equipment, if required.

16. Clean up the area and place disposable materials (plastic sheeting, gloves, Tyvek) in the designated receptacle. Close and lock the well cover.

5. LIMITATIONS

Aeration of sample water caused by bailer immersion can reduce the integrity of sample aliquots that are to be analyzed for VOC. Bailers are generally considered to provide the least representative groundwater samples of all available sample collection devices.

6. REFERENCES

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

RCRA Guidance, 1992.

U.S. Environmental Protection Agency, December 1984. Characterization of Hazardous Waste Sites
- A Methods Manual: Available Sampling Methods. EPA/600/4-84-076. Washington D.C.

**STANDARD OPERATING PROCEDURE
SPECIFIC CONDUCTIVITY AND TOTAL DISSOLVED SOLIDS METER CALIBRATION
AND MEASUREMENT**

1. OBJECTIVE

The objective is to define the requirements for producing credible specific conductivity (SC) and Total Dissolved Solids (TDS) data.

2. BACKGROUND

The SC and/or TDS of a sample is measured with a self-contained electrode-type sensor calibrated at two different concentrations. This method is applicable to ground, surface, and saline waters, as well as domestic and industrial waste.

3. EQUIPMENT

- Self-contained electrode-type conductivity meter.
- Commercially available conductivity standards.
- Optional: 30 ppm NaCl and 500 ppm NaCl for TDS; Null standard (air) and 1400 μ mhos/cm (0.01M) KCl for SC.
- Reagent grade water.

4. PROCEDURES**4.1 Calibration**

1. Visually inspect the probe.
2. Dip the probe into a standard, allow time for equilibration and adjust the probe output so that the output is within 5% of the standard (adjust to zero if a null standard is used).
3. Thoroughly rinse the probe with reagent grade water between standards.
4. Continue alternating the probe between the two chosen standards until the output remains stable within 5% of the standard.

4.2 SC Or TDS Measurement

1. Visually inspect the conductivity probe.
2. Immerse the electrodes in situ when possible. If not possible, take a grab sample in a clean container.

3. Allow time for equilibration and record the output.
4. Thoroughly rinse the probe with reagent grade water after each use and before storage.

5. LIMITATIONS

Cole Parmer 1491-50 TDS meter output times 10 equals the actual TDS value. Most SC sensors are temperature compensated to 25°C. For those that are not, temperature corrections must be made and results reported at 25°C.

6. REFERENCES

Clesceri, Lenore S., et al. 1989. Standard Methods for the Examination of Water and Wastewater, 17th ed. Washington, D.C.

Hydrolab Corporation, 1987. Performance Manual for Field Water-Quality Instrumentation.

U.S. Environmental Protection Agency. March, 1983. Methods for Chemical Analysis of Water and Wastes. EPA/600/4-79-020. Washington, D.C.

STANDARD OPERATING PROCEDURE STEPPED DRAWDOWN PUMPING TEST

1. OBJECTIVE

Step drawdown tests are performed to relate aquifer characteristics such as T, K, boundary conditions, and other general aquifer properties and to determine the maximum cone of depression with the appropriate pumping rate that yields the least amount of wastewater.

2. BACKGROUND

The required data to be collected or reasonable assumptions established before conducting the test include:

- well construction details;
- geologic characteristics of the subsurface;
- type of aquifer material and any confining beds;
- thickness and lateral extent of aquifer; and
- any known boundary conditions.

3. EQUIPMENT

- Pump that can deliver the correct flow rate for the aquifer material being tested.
- Water level measuring device (i.e., E-tape or transducer and data logger).
- Device for measuring discharge from the well (i.e., flowmeter, bucket and stop watch, or piezotube).
- Analysis tool (i.e., AQTESLOV[®] or other comparable utility for analysis).
- If necessary, containment for wastewater; otherwise, tubing long enough to discharge water outside the well's influence.
- Laptop computer with spreadsheet.
- Data collection forms and field logbook.
- Power supply and power cords for pumps.
- Decontamination supplies (see Decontamination Standard Operating Procedure).
- Groundwater containers of the volume required for the test with some reserve capacity, a fill port, and cleanout port.
- Toolbox and hand tools.
- Tape for holding downhole equipment in place.

- Notes and manufacturers' operating instructions on pumps and related material.
 - Acceptable Pumps
 1. Peristaltic pump with variable speed for very low flows when water levels are within 25 ft of surface (including drawdown).
 2. Submersible pumps with flow capabilities overlapping the higher flows of the peristaltic pump.
- Discharge tubing—on a reel; review well depths for amount needed.

4. PROCEDURES

- Prime pump with appropriate water (i.e., well water, distilled water, ASTM Type II, or tap water).
- If data logger is being used, set the data logger to the appropriate settings (e.g., logarithmic scale, top of casing, feet/meters, header and file names).
- Make sure the data logger and transducer have compatible settings.
- Set pump in well to the appropriate level, a few feet below maximum drawdown.
- Reset total flowmeter and check flow gauges.
- Turn on pump and data logger, let run for a minimal amount of time, then check the amount of drawdown. If drawdown is excessive compared with the total height of the available water column, stop the test, let the system re-equilibrate, and restart at a lower pumping rate.
- At set times, increase pumping rate. Repeat this until well goes dry or until the appropriate drawdown is reached.
- Data to be collected:
 - discharge rate from well,
 - time and total discharge, and
 - drawdown in well.

NOTE: Measurements should be confirmed with an E-tape.

- After approximately 45 min, depending on the test, check the drawdown curve against the Cooper Jacobs straight-line method, accounting for wellbore storage to see if the test has run long enough to consider the cone of depression in equilibrium. If not, continue the test until such time as the cone of depression is in equilibrium.

5. LIMITATIONS

- Peristaltic pumps are useable only for lift distances less than approximately 25 ft.
- Grundfos pumps may be used at flows less than 0.5 gal/min; but at low flows in some environments, the pump will slowly become locked up with sediment, thus halting the test. Grundfos 2-in. pump is not recommended for flows below 0.3 gal/min.

- Some flowmeters are unreliable under 0.6 gal/min.

6. REFERENCES

Kruseman, GP, and de Ridder, NA, 1991. *Analysis and Evaluation of Pumping Test Data*, ILRA Publication 47, Netherlands.

Driscoll, FG, 1989. *Groundwater and Wells*, H.M. Smyth Company, Inc., St. Paul, MN.

STANDARD OPERATING PROCEDURE TEMPERATURE MEASUREMENT

1. OBJECTIVE

The objective of this procedure is to define the requirements for producing credible temperature measurement data.

2. PROCEDURES

1. Measure temperature of target media in situ or collect aliquot and measure immediately. Swirl the probe in the media.
2. Record the measurement when the output changes not more than $\pm 0.1^{\circ}\text{C}$ per minute.
3. Report results to nearest 0.5°C or better.

3. LIMITATIONS

Ambient conditions may affect the temperature of a sample aliquot not tested in situ.

4. REFERENCES

- Clesceri, Lenore S., et al. 1989. Standard Methods for the Examination of Water and Wastewater, 17th ed. Washington, D.C.
- U.S. Environmental Protection Agency, March 1983. Methods for Chemical Analysis of Water and Wastes. EPA/600/4-79-020, Method 170.1.
- U.S. Environmental Protection Agency, 1986. Engineering Support Branch Standard Operating Procedures and Quality Assurance Manual. Region IV, Athens, GA.

STANDARD OPERATING PROCEDURE WATER LEVEL MEASUREMENT

1. PURPOSE

The purpose of this procedure is to outline the methods used in measuring the static water level in monitoring wells and piezometers.

The purpose of the water level measurement is to establish the potentiometric surface at the well location. Information obtained from water level measurements will be used to define the potentiometric surface over a given area.

2. SCOPE

The scope of services includes obtaining a water level measurement from monitoring wells and piezometers.

3. EQUIPMENT

Sampling equipment includes the following items:

- electronic measuring device, such as an M-Scope;
- well key;
- latex gloves; and
- water level record sheet.

4. PROCEDURE

A. Battery Check

- turn on the switch and press the battery test button;
- an alarm will sound and/or a light will illuminate if the battery is good; and
- if the alarm does not sound and/or the light does not illuminate, replace the battery and test again.

B. Water Level Measurement

- unlock and open well;
- don latex gloves;
- record in the logbook or field sheet date, time, and any other well-specific pertinent information;

- locate reference mark at top of well inner casing. If none is noted, use the North side of the inner casing;
- lower the probe into the well, making sure the cord and the probe do not scrape the sides of the well casing;
- when the audible alarm sounds and/or the light illuminates, stop lowering the probe;
- pull up on the cord until alarm no longer sounds and/or light no longer illuminates;
- lower probe again slowly. Stop at the instant the alarm sounds and/or the light illuminates;
- hold the tape at the reference mark (or the North side of the well casing) and note the measurement to the nearest 0.01 ft;
- repeat Steps 6 through 8 two to three times for consistency. Measurement should remain constant. Record the measurement in the Synoptic Water Level Event log; and
- rinse tip of probe with ASTM Type II water.

WELL PURGING/SAMPLING FORM

Page _____ of _____
 Project _____
 Well Number _____

Floaters/Sinkers _____
 Photoionization Reading _____
 Stick-Up (ft)/Casing Type _____
 Static Water Level Before Purging (ft) _____
 Total Depth (ft) _____
 Height of Water Column (ft) _____
 Inside Diameter of Well (in.) _____
 Well Volume ($V = 0.163 r^2 h$) (gal) _____

Well Purging Notes:

Purging Date _____
 Purging Time From _____ to _____
 Purging Method _____
 Purged By _____

Time	Volume	pH	SC	Temp (°)	eH (mV)	DO (mg/L)	Turbidity & Color

Sample Collection:

	Time	pH	SC	Temp (°)	eH (mV)	DO	Turbidity & Color
Units							
Initial							
Final							

Date/Time Sampled _____
 Method _____
 Sampled By _____

STANDARD OPERATING PROCEDURES SURFACE WATER SAMPLING

1. OBJECTIVE

The objective of this procedure is to define requirements for collection of surface water grab samples.

2. BACKGROUND

Surface water is defined as water that flows over or rests on the land and is open to the atmosphere. This includes ditches, streams, springs, rivers, lakes, pools, ponds, basins, or any other impoundment that fits the definition of surface water.

3. EQUIPMENT

This list is intended to provide examples of equipment only:

- personnel protective equipment (PPE);
- rubber boots and/or rubberized waders;
- decontamination equipment and supplies;
- stainless steel dippers or other suitable sample collection device;
- temperature, conductivity, and pH meters, if required; and
- weighted volatile organic compound (VOC) sampler.

4. PROCEDURE

4.1 Preparation

1. Don PPE as specified in the project-specific Sampling and Analysis Plan.
2. Prepare sampling site by laying out plastic sheeting on the ground and on any tables or sample preparation areas.
3. Record in the log book and other appropriate forms initial pH, temperature, and conductivity of the medium to be sampled, if necessary.

4.2 Shallow Surface Water Sample Collection

4.2.1 Volatile organics

1. Slowly submerge a weighted VOC sampler or an individual volatile organic analysis (VOA) vial completely into the water and fill. Do not disturb bottom sediments. If an individual vial is used, the open end of the vial should be pointed upstream in undisturbed gently flowing water, if possible.

2. Tip vial slightly while filling until nearly filled. Then straighten vial to vertical for final filling, allowing room for preservatives, use cap to dip final fill volume required, add any required preservatives.
3. Seal the VOA vial with a cap containing a Teflon septum. Be sure to dislodge air bubbles from the cap before sealing the vial.
4. Turn the vial upside down and check for air bubbles. Tap the bottom of the VOA vials to dislodge any bubbles that may have formed around the cap or sides. Discard and resample if bubbles are present.
5. Rinse the outside of the sample vial with water and wipe dry, if necessary.
6. Place sample container(s) in zip-top or other plastic bags, if required, and immediately place in a sample cooler. Check for completed sample label at this time.
7. Document all samples in the field logbook and other appropriate forms.

4.2.2 Nonvolatile and inorganic compounds

1. Use the appropriate flask, dipper, pail, pond sampler, or sample container to collect samples. If wading is required, approach the sample site from downstream and do not enter the actual sample area. Use extension handles to reach into the sample site, when necessary.
2. Immerse collection device into the water and fill. Do not disturb underlying sediments, if possible.
3. Decant sample into the required sample containers. Filter and preserve aliquots as necessary.
4. Seal sample containers, rinse outer surfaces with water and wipe dry, when necessary.
5. Place sample container(s) in zip-top or other plastic bags, if required, and place in a sample cooler.
6. Document all samples in the field logbook and other appropriate forms, chain of custody, seals, etc.

5. LIMITATIONS

Sampling with a dipper or other transfer device should be avoided when aeration must be minimized or where significant material may be lost as a result of adhesion to the transfer container. In these cases, fill sample bottle directly from surface water source.

6. REFERENCES

Cheremisinoff, Paul N., Bruce T. Mangamiello, 1987. Environmental Field Sampling Manual. North Brook, IL.

Department of Energy, July 1990. Standard Operating Procedures for Site Characterization. DOE/HWP-100. Oak Ridge, TN.

U.S. Environmental Protection Agency, December 1984. Characterization of Hazardous Waste Sites--A Methods Manual: Available Sampling Methods. EPA/600/4-84-076. Washington, D.C.

U.S. Environmental Protection Agency, 1986. Engineering Support Branch Standard Operating Procedures and Quality Assurance Manual. Region IV, Athens, GA.

STANDARD OPERATING PROCEDURES

PRESSURE TRANSDUCER DEPLOYMENT AND TROUBLESHOOTING

1. OBJECTIVE

The objective is to define the procedure for deploying a pressure transducer in preparation of collecting water level data. Trouble-shooting procedures are included. This procedure refers specifically to the union of a Druck pressure transducer and an Omnidata Easy Logger but may be modified for use with other systems.

2. BACKGROUND

Depth measurement with a strain gauge-type pressure transducer ordinarily requires conversion of an output in millivolts to a reading in feet of water. Pressure transducers may be deployed in open waters or in water wells. If deployed in open water, it is advisable that they be placed in a stilling well to prevent damage by shock and vibrations.

It is imperative that set-up personnel be well acquainted with the transducer and data logger being used to prevent damage or loss of data as a result of improper set-up and maintenance. Care must be taken not to over-pressure the transducer; 2.2 ft of water is equivalent to approximately 1 pound per square inch. See the pressure transducer specification sheet for pressure ratings. Use the ratings and well hydrologic data to determine the appropriate depth for transducer placement.

3. EQUIPMENT

- Pressure transducer.
- Data logger.
- Electronic water level indicator.
- Power surge protectors.
- Desiccant.
- Output terminal.
- Field box and connectors.

4. PROCEDURE

4.1 Hardware Setup

1. Hardwire the transducer to the chosen data logger according to the following guidelines.
 - 1.1 Secure the transducer cable at well casing (e.g., through hubble connector in well casing).
 - 1.2 Secure transducer cable through field box (e.g., hubble connector through premachined holes).
 - 1.3 Attach transducer wires to Zapnots or equivalent surge protector on the bus terminal strip and wire the Zapnots to the Easy Logger.

Transducer wiring:

Red wire through power line Zapnot to variable excitation.
White wire through power line Zapnot to analog ground.
Yellow wire through signal line Zapnot to channel positive.

Blue wire through signal line Zapnot to channel negative.

Mesh wire to ground at signal line Zapnot.

1.4 Secure the supplied copper ground wire to the bus terminal strip and to an appropriate grounding source outside the field box.

2. Insure that there is a thin coating of silicone grease on the pressure transducer membrane if the transducer type requires it.
3. Record the transducer serial number and secure the transducer at the desired depth with a nondamaging device (e.g., rubber grip). Appropriate depth will be a factor of transducer rating and the expected fluctuations in water level.
4. Verify that all holes in the field enclosure are sealed or have a breather plug (e.g., 5 micron Teflon filter available from Druck).
5. Insert the transducer vent tube into a dryer tube (desiccant), and place an open container of desiccant in the field enclosure. Replace these as necessary to maintain a dry environment.

NOTE: Particles of desiccant must not enter the vent tube.

6. Verify the power supply to the logger. The power supply may range from 9 to 30 Volts DC. An independent 12 VDC supply may be wired to the Easy Logger as follows:
 Positive wire to "BATT +."
 Negative wire to "D GROUND."
7. Verify that the lithium battery (disk type battery) inside the logger is in place.
8. Verify that a data storage pack (DSP) is in place and of sufficient capacity for project requirements.

4.2 Software Setup

1. Enter data collection parameters:

NOTE: Never perform OPTION 52, clear system, except in extreme cases as a step towards correcting a malfunctioning system.

2. Configure the data logger output value (OPT 12) as appropriate using the values for "C" and "K" determined during calibration.

Option	Description
10	Site Name
11	Operator name or initials
12	Set sensors (See Table 1)
13	Set wiring (See Table 2)
14	Scan interval (minutes)
15	Set reports (See Table 3)
20	Time
25	Variable excitation (e.g., 100)

Table 1. Easy Logger Option 12, examples

Sensor (name)	Full scale range	Sensor formula
Serial No.	100 mVDC	$-(V * C) + K$

V = sensor output (mV); C = sensor response slope from calibration; K = zero offset.

Table 2. Easy Logger Option 13, examples

Channel number	Sensor (name)	Channel name
(From Easy Logger terminal strip)	(From Option 12)	(e.g., Well No.)

Table 3. Easy Logger Option 15, examples

Report Number - 1 <enter>, unless otherwise specified.	
Start when? <enter>	
Stop when? <enter>	
Report interval - (minutes) <enter>	
C1	
Heading	"Random name"
Heading	"Random name"
Units	(e.g., ft)
Source	"Channel name" from Option 13
Type	(e.g., avg)
Decimal	(e.g., "2" for 0.00)

4.3 Sensor Response Verification

4.3.1 Quick response

1. Set logger to test sensors (OPT 30).
2. Raise/lower the submerged transducer a discrete distance through the water column.
3. Monitor the logger output to verify correlation between the magnitude of the transducer movement and the logger output change.
4. If the logger output does not change in direct proportion to the distance moved by the transducer, verify that the transducer is submerged and review the set up procedure, if necessary.

4.3.2 Long-term Response

Process the data and produce graphical output suitable for validation of long-term system response within 2 weeks for system deployment.

5. LIMITATIONS

Pressure transducers are particularly susceptible to interferences caused by water entering the vent tube and the interstitial spaces of the wiring cable. Effects of water in the vent tube or cable can range from daily fluctuations in output accuracy to complete sensor failure. The open end of the vent tube must be protected from moisture and particles. The open end of the cable must be protected from moisture. See the operating instructions for specific recommendations.

6. TROUBLESHOOTING

When unexplained steps or "spikes" appear in Omnidata Easy Logger output, a faulty system condition may exist. Sections 6.1 through 6.3 may be used to diagnose or correct this problem.

6.1 Analog Chip Check

1. Remove terminal strips from logger face.
2. With the hand terminal turned on. Press <ctrl> 020.
3. Check sum? **Yes**
4. The resulting value indicates that all chips inside the logger are functioning if the value equals:
 7329 for software version 2.01
 138 for software version 2.03
 (If the value does not equal this number, then refer to Omnidata International, Inc. for assistance.)
5. <down arrow>
6. Test analog? **Yes**
7. The resulting value should be around 3000 after about 3 seconds or ten "flickers." Refer to Omnidata International, Inc. for assistance if the display does not stabilize or the value is too high (usually around 4000) or too low (usually around 1500).
8. The analog chip check indicates proper hardware conditions if the correct values are output in Steps 4 and 7.

6.2 Hard Reset

Performance of a "hard reset" will clear the entire system and may return the system software to acceptable operating conditions. During a hard reset, all set up information is lost. Never perform this operation except as the final attempt to correct a system error. Section 6.3 includes the steps necessary for returning the setup information to the system by cloning a used DSP.

The following situations might cause a system failure that would require a hard reset:

- Removing the hand terminal from the logger face before turning the terminal off. (An extremely discharged logger battery may simulate this action.)
- Changing a DSP during a scan.

- Allowing a full DSP to remain on the logger during logging.
- 1. Verify hardware conditions by performing an analog chip check (Sect. 6.1).
- 2. Slip paper between lithium batter and contact (inside logger case).
- 3. Remove external power source.
- 4. Wait at least 3 minutes for the system to discharge.
- 5. Remove the slip of paper that was inserted in Step 2.
- 6. Replace the external power supply.
- 7. Turn on hand terminal. A successful hand reset is indicated when the system time and date must be reset.

6.3 Cloning a DSP

1. Obtain the DSP that contains the desired setup information.
2. With the hand terminal connected, clear the system (OPT 52).
3. Turn the hand terminal back on.
4. With the DSP in place, enter Option 53 to clone the DSP.
5. Locate the file containing the desired setup parameters and enter that file.
6. View the logger setup specifications to verify the accuracy of the cloned parameters.

6.4 Transducer Brakeout at 120°F

Transducer brakeout at a low temperature may be necessary to remove humidity from the vent tube. This may be indicated by diurnal fluctuations in sensor response.

The brakeout period should extend for several days, and the temperature should not exceed 120°F. Higher temperatures may damage the sensor components.

NOTE: This procedure may not be sufficient to correct problems caused by water in the vent tube. Refer to Druck, Inc. for further assistance.

7. REFERENCES

Craig, Paul M., et al., 1989. Tumulus Environmental Monitoring Plan: Operational Phase. Environmental Consulting Engineers, Inc., for Martin Marietta Energy Systems, Inc., Oak Ridge, TN.

Eposito, Richard, November, 1990. Correspondence. Druck, Inc.

Hydrolab Corporation, 1987. Performance Manual for Field Water-Quality Instrumentation.

STANDARD OPERATING PROCEDURES
PRESSURE TRANSDUCER ONE POINT CALIBRATION CHECK

1. OBJECTIVE

The objective of this procedure is to define requirements for verifying pressure transducer accuracy at one point in a monitoring well or other similar application.

2. BACKGROUND

Because of the possibility of electronic circuit drift and other influences that may impair the ability of a pressure transducer to record accurate depth measurement, a one point check should be performed at regular intervals on the monitoring system. This procedure is performed in situ.

3. EQUIPMENT

- Pressure transducer.
- Data logger (e.g., Easy Logger, Datapod II).
- Electronic water level indicator.
- Chronograph.
- Output terminal.

4. PROCEDURE

NOTE: Record all activities on a Transducer Calibration Worksheet or similar form.

4.1 Method 1—One Minute Data Logging Calibration

1. Program the data logger to scan and report at 1-minute intervals.
2. Synchronize chronograph with time on data logger.
3. Manually check the water level from Top of Casing (TOC) at each well by using the electronic water level indicator. Record the level to nearest 0.01 ft and time of measurement.

NOTE: If TOC is not identified on the well casing, specify the TOC for future reference.

4. Record the corresponding water levels from the data logger output at the times noted in Step 3 (OPT 40).
5. Calculate delta Depth to Water (DTW) according to

$$\text{tape DTW} - \text{logger DTW} = \text{delta DTW}.$$

6. If delta DTW is within project specific tolerances, no adjustment is necessary. If delta DTW is not within tolerances, correct the offset (K) in the logger equation by delta DTW (OPT 12). Routine limits for delta DTW are ± 0.03 ft.

7. Return the logger to its prescribed scan and report intervals, and record the time that logging will resume.

4.2 Method 2—Real Time Output Calibration

NOTE: The apparent sensor output will fluctuate, so only experienced operators should use this method.

1. Measure depth to water with electronic water level meter and record (tape DTW).
2. Enter Option 30 on Easy Logger hand terminal and immediately record the output value (logger DTW).
3. Calculate delta DTW according to:

$$\text{tape DTW} - \text{logger DTW} = \text{delta DTW}.$$

4. If delta DTW is within project specific tolerances, no adjustment is necessary. If delta DTW is not within tolerances, then correct the offset (K) in the logger equation by delta DTW (OPT 12). Routine limits for delta DTW are ± 0.03 ft.

4.3 Calculations

1. To determine the slope (C) and offset (K) of the transducer, perform a linear regression using mV for the V values and pressure (feet of H₂O or PSIG) for the D values in the following equation:

$$D = V \times C + K$$

where:

- D = feet of water or PSIG,
- V = sensor output (mV),
- C = slope (ft/mV),
- K = offset (ft).

NOTE: R^2 less than 0.998 may indicate a faulty transducer.

2. In the field, use the following equation to calculate depth to water values as D. $\langle R \rangle K$ is modified as necessary during one point calibrations performed in the field to represent the true groundwater level.

$$D = -(V \times C) + K$$

5. LIMITATIONS

1 psig = approximately 2.2 ft of H₂O, do not overpressure the transducer. Pressure ratings are included on the transducer specification sheet.

Offset and C must be determined separately for each transducer.

6. REFERENCES

Craig, Paul M., et al., 1989. Tumulus Environmental Monitoring Plan: Operational Phase. Environmental Consulting Engineers, Inc. for Martin Marietta Energy Systems, Inc., Oak Ridge, TN.

Druck. Operator's Manual DPI 601.

Hydrolab Corporation, 1987. Performance Manual for Field Water Quality Instrumentation.

STANDARD OPERATING PROCEDURES
PRESSURE TRANSDUCER FIVE POINT CALIBRATION

1. OBJECTIVE

The objective of this procedure is to define the requirements for calibrating a pressure transducer in the laboratory over the range expected in the field.

2. BACKGROUND

Pressure transducers are calibrated to verify the linear relationship between applied pressure (feet of water or pounds per square inch gauge) and sensor output (millivolts). Known amounts of pressure are applied in series to the transducer with a pressure cell (e.g., Druck DPI 601). Alternatively, the calibration may be performed by lowering a transducer into a water-filled pipe to appropriate increments. A linear equation is then solved for the pressure vs sensor output data to provide a response factor for each transducer.

3. EQUIPMENT

- Pressure Transducer.
- Data Logger (e.g., Easy Logger, Datapod II).
- Pressure cell (e.g., Druck DPI 601).
- Output terminal.
- Instrument calibration worksheet.

4. PROCEDURE

4.1 Setup

This procedure is specifically written for use with a Druck DPI 601 and Omnidata Easy Logger. It may be modified for use with any acceptable pressure cell.

1. Connect the pressure transducer wiring to the Easy Logger.
 - Blue wire to Channel negative.
 - Yellow wire to Channel positive.
 - White wire to Analog ground.
 - Red wire to Variable excitation.
2. Press the on button and the 20 PSI gauge button DPI 601.
3. Remove black protective cap from transducer (don't touch exposed strain gage; you may damage the transducer). Screw adapter fitting onto transducer and attach to DPI 601. Be sure to open vent valve before attaching this fitting!
4. Screw volume adjuster knob to left fully.

5. Change formula in Easy Logger (OPT 12) to V (this will give an output in mV). Take note of original formula for future reference, if necessary.
6. Close DPI 601 vent and adjust the zero trim on display.
7. Turn volume adjuster knob right to provide each required pressure setting.

4.2 Real Time Calibration

NOTE: Apparent sensor output may fluctuate.

1. Apply pressure to the transducer at approximately five points that are representative of the range of normal field operations.
2. At each pressure point, allow the pressure to stabilize for 5 to 10 seconds, go to Option 30, and then record the pressure and the sensor output. Escape out of Option 30 after each reading so sensor is not continually powered up.

NOTE: If readings are not "stable" to the hundredths place, check for system leaks. A leak is indicated by falling pressure.

4.3 Calculations

1. To determine the slope (C) and offset (K) of the transducer, perform a linear regression using mV for the V values and pressure (feet of H₂O or PSIG) for the D values in the following equation:

$$D = V \times C + K$$

where:

D	=	feet of water or PSIG,
V	=	sensor output (mV),
C	=	slope (ft/mV),
K	=	offset (ft).

NOTE: R² less than 0.998 may indicate a faulty transducer.

2. In the field, use the following equation to calculate depth to water values as D.<R>K is modified as necessary during one point calibrations performed in the field to represent the true groundwater level.

$$D = -(V \times C) + K$$

5. LIMITATIONS

1 psig = approximately 2.2 ft of H₂O, do not overpressure the transducer. Pressure ratings are included on the transducer specification sheet.

Offset and C must be determined separately for each transducer.

6. REFERENCES

Craig, Paul M., et al., 1989. Tumulus Environmental Monitoring Plan: Operational Phase. Environmental Consulting Engineers, Inc. for Martin Marietta Energy Systems, Inc., Oak Ridge, TN.

Druck. Operator's Manual DPI 601.

Hydrolab Corporation, 1987. Performance Manual for Field Water Quality Instrumentation.

STANDARD OPERATING PROCEDURES TIPPING BUCKET RAIN GAGE

1. OBJECTIVE

The objective is to define the procedures for the set up, calibration, and use of a tipping bucket rain gage. This procedure refers specifically to a Weathertronics Rain Gage, Model #6011-A but may be modified for use with other systems.

2. BACKGROUND

Precipitation enters the small funnel inside the instrument and is directed to one of two tipping buckets. When one bucket fills, its weight tips the next bucket into position, and empties the first. At the same time, a 100 millisecond momentary contact closure occurs. This closure increments an event accumulating devices. The water is drained out the bottom of the instrument. Each tip of the bucket represents 0.01 inches (0.25 mm) of rainfall. If it is desired, a tank can be designed to catch the water draining out of the instrument for further evaluation.

3. EQUIPMENT

- Rain gage and anchor pad.
- Data logger and accessories.
- Calibration check equipment.

4. PROCEDURE

4.1 Operation

1. This instrument is thoroughly tested and fully calibrated at the factory and is ready for installation.
2. Two prime considerations must be evaluated when locating an installation site for this rain gage. The gage must be mounted level, and the gage must be adequately protected from high winds. Errors of more than 5% can occur if not protected from the wind as a result of rainfall blowing over the lip of the orifice.
3. Consider the height of surrounding obstacles, including vegetation. Install the rain gage at a distance away from the obstacles that is two to four times the obstacle's height. Although the obstacle makes an ideal wind shield, it may block the normal rainfall path into the gage or rainfall may blow off the obstacle and into the gage.
4. A recommended method of mounting the gage is to pour a small (12-in. square) concrete pad at the site with three anchor bolts set for the hole pattern of the mounting feet. If strong winds do exist, a wind screen is recommended. Mount the wind screen as described in its manual.
5. Remove the three bolts attaching the outer housing of the rain gage to the tipping bucket mechanism.

6. Using the bulls-eye level on the tipping bucket mechanism, level and securely mount the gage.
7. Connect a two conductor cable between the two terminal posts on the gage and the event accumulating device.
8. Be sure to remove any packing material and the bucket retaining clips from the instrument.
9. Verify correct calibration before reinstalling the outer housing, if necessary.

4.2 Calibration

1. The instrument was calibrated before leaving the factory and should not require any further calibration unless maintenance is performed on the instrument. If manufacturer's calibration equipment is used, refer to the manual for the specific precipitation gage calibrator used.
2. For model 6011-A, 8.683 milliliters of water is equivalent to 0.01 in. of rainfall, and 8.493 milliliters of water is equivalent to 0.25 mm of rainfall.
3. To calibrate the tipping bucket rain gage, remove the outer cover by first removing the three screws at the base. **BE SURE THE GAGE IS LEVEL**, using the built-in bulls-eye level as an indicator.
4. Devise a source of water with a uniform flow rate of approximately 400 milliliters per hour. Direct this flow onto the wall of the small funnel.
5. Set up a counting device to count the number of tips of the bucket assembly. An event recorder or a solenoid counter may be used, or a manual counting system can be employed.
6. After the gage has tipped several times and the buckets are wet, collect the water in two containers, one under each drain tube. Carefully insert the collection containers between tips and allow at least 10 tips of each bucket (20 counts on the recorder). Remove the containers, between tips, after an even number of tips. Measure the amount of water in each container either by weight or volume. Divide each quantity by the number of tips of each bucket. The value should be within 0.5% of the value listed in Sect. 4.2.2.
7. Adjustments may be made to the stops located under the buckets. Raising the stop of the bucket will reduce the catch for that bucket and, consequently, lowering the stop will increase the catch. **NOTE:** The stop for a bucket is located under the opposite bucket. Make only small corrections at a time (1/4 turn per test). Repeat the calibration procedure until the gage is within specifications.
8. The above procedure is for a rate of 0.5 in./hour. The gage may be calibrated at other rates of interest.
9. After calibration, note date and place of calibration and reinstall the outer cover and three screws. Be sure the cover is lined up.
10. If the gage has been removed from a field location for calibration, be sure the gage is installed and leveled properly.
11. To check for calibration in the field, make sure the buckets are empty and add the amount of water specified in Sect. 4.2.2. If the buckets tip too soon or do not tip at all, the instrument

requires a laboratory calibration as previously described. A standard 10 milliliters pipet or a Qualimetrics Model 60103 Calibration Bottle can be used as a field test device. Refer to the manual for the specific precipitation gage calibrator used.

12. For maximum sensitivity, remove both the outer cover and the small funnel. Direct the water to the center of the bucket partition when the buckets are at midpoint. The errors introduced by surface wetting and droplet formation at the funnel tip are eliminated by using this method of calibration. Take care to avoid water flow onto the tops of the buckets. For most users, the small funnel can remain in place for calibration with negligible errors.

4.3 Maintenance

Maintenance is limited to cleaning debris out of the orifice and periodically oiling the pivot points with a light silicon oil.

5. REFERENCES

QUALIMETRICS, Inc., 1986. *Manual for Precipitation Gage Calibrator Model 60103*. Manual Number 60103-001, Sacramento, CA.

WeatherMeasure WEATHERtronics, 1984. *Manual for Tipping Bucket Rain Gage Model 6011-A, 6011-B*. Division of QUALIMETRICS, Inc., Manual Number 6011-A01, Sacramento, CA.

STANDARD OPERATING PROCEDURES GROUNDWATER SAMPLING WITH PERISTALTIC PUMPS

1. OBJECTIVE

The objective of this procedure is to define the requirements for the collection of groundwater samples with a peristaltic pump.

2. BACKGROUND

Methods used for the collection of groundwater samples include bailing and a variety of pumping techniques. Certain pump types, when constructed of appropriate materials for project needs, can be used to perform sampling more quickly, with greater reproducibility and accuracy. The parameters of interest may be affected by the selection of a sampling pump. Peristaltic pumps use suction to collect the sample and, therefore, are generally not applicable if the depth to water is more than 28 ft. Careful consideration should be given to the selection of the sampling tubing.

3. EQUIPMENT

- Peristaltic pump.
- Power source.
- In line filters (if application).
- Appropriate sample containers with labels and preservatives, as required.
- Water-level meter.
- Temperature, conductivity, pH, dissolved oxygen, and organic vapor meters, if required.
- Plastic sheeting.
- Personnel protective clothing and equipment, if required by the site-specific health and safety plan.
- Latex gloves.

4. PROCEDURE

1. Don protective clothing and equipments as specified in the site-specific health and safety plan.
2. Cover the ground surface around the wellhead with plastic sheeting.
3. Open the well and note the condition of the casing and cap. If required, check for vapors by using vapor analyzing equipment. Determine the static water level and depth to well bottom. Record this information in the field log book or appropriate forms.
4. Purge the well according to P2T guidelines. Sampling should be performed within 24 hours of the completion of the well purging process. Otherwise sample as soon as well recharge is sufficient for sample collections.
5. Arrange the sample containers in the order of use. When applicable, collect samples for analytes in this order:
 - Volatile organic compounds (VOC) – not recommended.

- Purgeable organic carbon (POC) – not recommended.
 - Purgeable organic halogens (POX) – not recommended.
 - Total organic halogens (TEX) – not recommended.
 - Total organic carbon (TOC) – not recommended.
 - Extractable organics.
 - Other unpreserved analytes.
 - Total Metals.
 - Phenols.
 - Cyanide.
 - Other preserved analytes.
 - Radionuclides.
6. Lower the tubing into the well to the appropriate depth. The pump should enter the water slowly to minimize aeration and disturbance, particularly when volatile organic analysis (VOA) and semivolatile organic analysis (SVOA) samples are being collected.
 7. Begin pumping. Initial pumping rate should be specified in the Sampling and Analysis Plan based on well geometry and groundwater flow rate. The first pump volume of water should be used as a pump rinse and be discarded. After the rinse, obtain pH, conductivity, and temperature measurements of the groundwater.
 8. Collect any required VOA samples. The recommended flow for collection of VOA samples is approximately 100 mL/min. The VOA sample vials should be tilted when filling to minimize aeration. Check the filled vial for bubbles.
 9. Pump water into the remaining sample containers. Unless otherwise specified, do not rinse sample containers before sample collection. If sample filtration is required, connect in-line filter to the pump at the appropriate time. Add preservative, (if needed), cap, seal, and properly label all containers. Place the filled containers in the coolers(s) immediately.
 10. Record the final pH, conductivity, and temperature for the groundwater.
 11. Document all samples collected in log book and other appropriate forms.
 12. Decontaminate sampling equipment, if required.
 13. Clean up the area and place disposable materials (plastic sheeting, gloves, Tyvek) in the designated receptacle. Close and lock the well cover.

5. LIMITATIONS

Peristaltic pumps are not suitable for sampling volatile organic compounds and have limited depth capabilities (e.g., 25 ft or less).

6. REFERENCES

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

U.S. Department of Energy, July 1990. Standard Operating Procedures for Site Characterizations. DOE/HWP-100. Oak Ridge, TN.

U.S. Environmental Protection Agency, RCRA, 1992.

U.S. Environmental Protection Agency, December 1984. Characterization of Hazardous Waste Sites – A Methods Manual: Available Sampling Methods. EPA/600/4-84-076. Washington, D.C.

**STANDARD OPERATING PROCEDURES
pH PROBE CALIBRATION pH MEASUREMENT:
ELECTROMETRIC TECHNIQUE**

1. OBJECTIVE

The objective of this procedure is to define the requirements for producing credible pH measurement data.

2. BACKGROUND

The pH of a sample is determined electrometrically by using either a glass electrode in combination with a reference potential or a combination electrode. The measuring device is calibrated by using a series of standard solutions of known pH. This method is applicable to ground, surface, and saline waters, as well as domestic and industrial wastes.

3. EQUIPMENT

- Glass electrode with reference potential or combination electrode.
- Secondary standard buffer solutions (e.g., pH 4, pH 7, pH 10) purchased from commercial vendors.
- Reagent grade water.

4. PROCEDURE

4.1 Calibration

Note: Minimum frequency for calibration is at the beginning and end of each field excursion.

1. Visually inspect the pH probe. Correct any obvious deficiencies or obtain an acceptable probe.
2. Place the probe in a buffer solution. Begin with the pH 7 solution then alternate with one other pH solution.
3. After the probe output has stabilized (± 0.1 pH units/minute), adjust the probe until the output is within ± 0.1 pH units of the buffer solution.
4. Thoroughly rinse the probe electrodes with reagent grade water between buffers.
5. Make adjustments and alternate the probe between the chosen buffer solutions (they should bracket the expected sample pH range) until the output remains stable within ± 0.1 pH units of the buffer solution of interest.
6. Record the results.

4.2 pH Measurement

1. Visually inspect the pH probe and allow equilibration to ambient temperature.
2. If the sample temperature differs by more than 2°C from the buffer solution, the measured pH values must be corrected. Some instruments are equipped with automatic or manual compensators that electronically adjust for temperature differences. Refer to the manufacturer's instructions.
3. Thoroughly rinse the electrodes with reagent grade water before measuring the pH of samples.
4. Immerse the electrode in situ when possible. If not possible, take a grab sample in a clean beaker or equivalent. Allow the meter to reach equilibrium (± 0.1 pH units/min).
5. Record sample pH to nearest 0.1 pH unit. If the pH meter does not automatically compensate for sample temperature, record the sample temperature for pH temperature compensation.
6. Thoroughly rinse the electrodes with reagent grade water after each use.

5. LIMITATIONS

Stability requirements have been met when the pH output fluctuates no more than 0.1 pH units/min. Low ionic strength fluids ($<100 \mu\text{S/cm}$) generally take longer to stabilize.

Coatings of oily material, particulate matter, or other substances that can impair electrode response should be removed by a gentle wiping with a laboratory tissue followed by a reagent grade water rinse.

Temperature effects on the electrometric measurement of pH are controlled by using instruments having temperature compensation or by calibrating the electrode meter system at the temperature of the samples. In addition, manual calculations may be made to correct the pH results to the temperature of the sample when necessary.

6. REFERENCES

- Clesceri, Lenore S., et al., 1989. Standard Methods for the Examination of Water and Wastewater, 17th ed. Washington, D.C.
- Hydrolab Corporation, 1987. Performance Manual for Field Water-Quality Instrumentation.
- U.S. Environmental Protection Agency, 1986. Engineering Support Branch Standard Operating Procedures and Quality Assurance Manual. Region IV. Athens, GA.
- U.S. Environmental Protection Agency, March 1983. Methods for Chemical Analysis of Water and Wastes. EPA/600/4-79-020. Washington, D.C.
- U.S. Environmental Protection Agency, November 1986. Test Methods for Evaluating Solid Waste. 3rd Ed. Washington, D.C.

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