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March 12, 2008

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Dear Dr. McLaughlin:

In accordance with the U.S. Army's request, Science Applications International Corporation (SAIC) is submitting six hard copies and 1 electronic copy on compact disk-read only memory (CD-ROM) of the *Field Sampling Plan (FSP) Addendum 6 – Depleted Uranium Impact Area Site Characterization: Water Chemistry Sampling for Ground-Water Age Estimates and Comparison of Flowmeter-Based and Water-Level-Based Directions of Ground-Water Flow in a Karst Hydrogeologic Framework*. This document was written by Mr. Paul Buszka (U.S. Geological Survey, Indiana Water Science Center). Please contact Mr. Paul Cloud at (410) 436-2381, e-mail address: [paul.d.cloud@us.army.mil](mailto:paul.d.cloud@us.army.mil) or Mr. Paul Buszka at (317) 290-3333, extension 179, e-mail address: [pmbuszka@usgs.gov](mailto:pmbuszka@usgs.gov) if you have any questions.

Sincerely,

A handwritten signature in black ink that reads "Joseph N. Skibinski".

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SAIC Central Records Project File (transmittal memo only)



## **FIELD SAMPLING PLAN ADDENDUM 6**

**Depleted Uranium Impact Area Site Characterization:  
Water Chemistry Sampling for Ground-Water  
Age Estimates and Comparison of Flowmeter-Based and  
Water-Level-Based Directions of Ground-Water Flow in  
a Karst Hydrogeologic Framework  
Jefferson Proving Ground, Madison, Indiana**

**FINAL**

*Prepared for:*

**U.S. Department of Army  
Installation Support Management Activity  
5183 Blackhawk Road  
Aberdeen Proving Ground, Maryland 21010-5424**

**and**

**U.S. Army Corps of Engineers  
Louisville District  
600 Dr. Martin Luther King, Jr. Place  
Louisville, Kentucky 40202-2230**

*Submitted by:*

**U.S. Geological Survey  
USGS Indiana Water Science Center  
5957 Lakeside Boulevard  
Indianapolis, Indiana 46278-1996**

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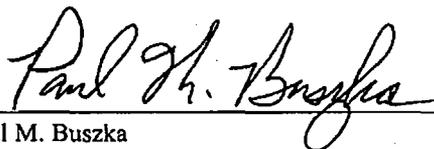
**March 2008**

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**Ground-Water Flow in a Karst Hydrogeologic Framework**  
**Jefferson Proving Ground, Madison, Indiana**

March 2008

**Final**



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Paul M. Buszka  
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Telephone

3/7/08

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Date

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## LIST OF ACRONYMS AND ABBREVIATIONS

ATP	Advanced Technology Products
CBFM	Colloidal Borescope Flowmeter
CCD	Charge Coupled Device
CD	Compact Disc
CFC	Chlorofluorocarbon
CSM	Conceptual Site Model
DO	Dissolved Oxygen
DU	Depleted Uranium
FID	Flame Ionization Detector
FS-A	Field Supervisor (Age Dating Activity)
FS-B	Field Supervisor (Borehole Flowmeter Activity)
FSP	Field Sampling Plan
GC/MS	Gas Chromatography/Mass Spectrometry
HASP	Health and Safety Plan
HDPE	High-Density Polyethylene
HPFM	Heat Pulse Flowmeter
HPT	Health Physics Technician
I.D.	Identification
ID	Inside Diameter
IDW	Investigation-Derived Waste
JPG	Jefferson Proving Ground
LED	Light Emitting Diode
mS/m	Millisiemens per Meter
NAD 83	North American Vertical Datum of 1983
NAD 88	North American Vertical Datum of 1988
NRC	Nuclear Regulatory Commission
OD	Outside Diameter
PC	Project Chief
POC	Point of Contact
psi	Pounds per Square Inch
PVC	Polyvinyl Chloride
QA	Quality Assurance
RPD	Relative Percent Difference
SAIC	Science Applications International Corporation
SHSO	Site Health and Safety Officer
TU	Tritium Unit
USACE	U.S. Army Corps of Engineers
USGS	U.S. Geological Survey
UXO	Unexploded Ordnance
WBS	Work Breakdown Structure

## CONVERSION FACTORS

Multiply	By	To obtain
<b>Length</b>		
inch (in.)	2.54	centimeter (cm)
inch (in.)	25.4	millimeter (mm)
foot (ft)	0.3048	meter (m)
mile (mi)	1.609	kilometer (km)
<b>Area</b>		
acre	0.004047	square kilometer (km <sup>2</sup> )
square mile (mi <sup>2</sup> )	2.590	square kilometer (km <sup>2</sup> )
<b>Volume</b>		
ounce, fluid (fl. oz)	0.02957	liter (L)
ounce, fluid (fl. oz)	29.57	milliliter (mL)
<b>Pressure</b>		
atmosphere, standard (atm)	101.3	kilopascal (kPa)
bar	100	kilopascal (kPa)
<b>Radioactivity</b>		
picocurie per liter (pCi/L)	0.037	becquerel per liter (Bq/L)
picocurie per liter (pCi/L)	0.3125	Tritium unit (TU)
centimeter (cm)	0.3937	inch (in.)
millimeter (mm)	0.03937	inch (in.)
meter (m)	3.281	foot (ft)
kilometer (km)	0.6214	mile (mi)
<b>Area</b>		
square meter (m <sup>2</sup> )	0.0002471	acre
hectare (ha)	2.471	acre
square kilometer (km <sup>2</sup> )	247.1	acre
<b>Mass</b>		
picogram (pg)	3.527 x 10 <sup>-11</sup>	ounce, avoirdupois (oz)
microgram (mg)	3.527 x 10 <sup>-8</sup>	ounce, avoirdupois (oz)
milligram (mg)	3.527 x 10 <sup>-5</sup>	ounce, avoirdupois (oz)
gram (g)	0.03527	ounce, avoirdupois (oz)
<b>Volume</b>		
liter (L)	33.82	ounce, fluid (fl. oz)
Milliliter (mL)	0.03382	ounce, fluid (fl. oz)
<b>Pressure</b>		
kilopascal (kPa)	0.009869	atmosphere, standard (atm)
kilopascal (kPa)	0.01	bar
<b>Radioactivity</b>		
becquerel per liter (Bq/L)	27.027	picocurie per liter (pCi/L)
Tritium unit (TU)	3.2	picocurie per liter (pCi/L)

Temperature in degrees Celsius (°C) may be converted to degrees Fahrenheit (°F) as follows: °F=(1.8×°C)+32

Vertical coordinate information is referenced to the insert datum name (and abbreviation) here (for instance, "North American Vertical Datum of 1988 [NAVD 88]").

Horizontal coordinate information is referenced to the insert datum name (and abbreviation) here (for instance, "North American Datum of 1983 [NAD 83]").

Altitude, as used in this report, refers to distance above the vertical datum.

## 1. INTRODUCTION

This Field Sampling Plan (FSP) documents and describes specific activities and details of the Jefferson Proving Ground (JPG) Depleted Uranium (DU) Impact Area ground-water sampling program to collect data to estimate ground-water ages that were not addressed in the original FSP (SAIC 2005a) or have been modified from the information presented in the original FSP. The age-dating task involves the collection of ground-water samples from approximately 20 wells drilled and installed by Science Applications International Corporation (SAIC) in support of the JPG site characterization program. This FSP also documents and describes specific activities and details of data analyses related to borehole flowmeter and related field measurements to be made by the U.S. Geological Survey (USGS). These measurements are intended to assist in defining aspects of the hydrogeologic framework of the JPG DU Impact Area that were not addressed in the original FSP (SAIC 2005a) or have been modified from the information presented in the original FSP. The flowmeter task involves borehole geophysical logging, flowmeter logging, and water level measurements in wells drilled and installed by SAIC in 2007 in support of the JPG site characterization program.

### 1.1 INTRODUCTION TO THE GROUND-WATER AGE-DATING TASK

Ground-water samples will be collected from approximately 17 to 20 observation wells and analyzed by USGS for their concentrations of several dissolved gases and age-dating constituents (chlorofluorocarbon compounds, tritium, and helium-3). The dissolved gas data will be used to estimate the recharge temperature of water; that estimate is needed to estimate the age of ground-water samples since their infiltration below the water table. Section 2 provides the updated project organization and responsibilities. Additional details concerning the scope and objectives of the age-dating sampling, including the plan for wells to be sampled, are presented in Section 3. Section 4 provides information on field sample collection procedures, including measurements of field-determined water chemistry properties. Section 5 provides details about analytical methods and laboratory sources of water analyses. Section 6 provides information about analysis of quality assurance (QA) data from sequential duplicate analyses of all laboratory-determined constituents and equipment blanks of chlorofluorocarbon compound analyses. Section 7 discusses data use and interpretation. The Appendix provides supporting documentation for sample collection and laboratory log-in procedures.

### 1.2 INTRODUCTION TO THE FLOWMETER MEASUREMENT TASK

This FSP also describes and references the methods to be used to collect and analyze hydrogeologic, geophysical, and borehole flowmeter data. For established methods, this report provides brief descriptions of procedures used to collect and process data. For recent methods, such as the borehole flowmeter measurements, a more detailed description is included. The purpose for this documentation is to ensure that consistent methods are used throughout the data collection period and that the methods conform to USGS or other established policies, where possible.

Borehole geophysical logs, borehole camera observations, horizontal flowmeter measurements, and water levels will be measured in approximately 20 SAIC observation wells. The geophysical log and borehole camera data will be used in conjunction with well log information compiled by SAIC. Dissolved gas data will be used to estimate the recharge temperature of water; that estimate is needed to estimate the age of ground-water samples since their infiltration below the water table. Additional details concerning the hydrogeologic setting, scope, objectives, and schedule of the field measurements are presented in Section 8. Section 9 provides basic information about field measurement procedures for purposes of understanding the planned approach. Section 10 provides an overview of how interpretations of the results are currently envisioned.

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## 2. PROJECT ORGANIZATION AND RESPONSIBILITIES

USGS personnel will comply with those policies and procedures specified in this FSP Addendum, FSP Addendum 4 (SAIC 2007), FSP Addendum 5 (SAIC 2008), the original project Health and Safety Plan (HASP) (SAIC 2005b), and other related project documents that relate to the field sample collection and data analysis activities and health and safety.

The following describes the roles and responsibilities of the USGS personnel, summarized in Figure 2-1, who will be collecting and analyzing ground-water samples and collecting associated field data:

- **Paul M. Buszka – USGS Project Chief and Data Manager**—The USGS Project Chief (PC) is responsible for ensuring that tasks and other requirements in the contract are executed on time and according to the procedures in the system, as defined for the project and in the FSP and other applicable project-related documents; assessing the quality of participant work; submitting accurate and timely deliverables to the Army Project Officer; and coordinating attendance at conference calls, training, meetings, and related project activities with the Army. The PC is responsible for preparation of the USGS report to the Army, including interpretation of the analytical results from the age-dating samples in the context of the site hydrogeologic framework. The PC also is responsible for ensuring adequate training and supervision of all activities involved in generating field data. The PC supervises data management for the study, which includes such responsibilities as ensuring that results are placed in the USGS National Water Information System database; ensuring the quality of the data; transferring the data to the Army; and providing the point of contact (POC) for the Army to resolve issues related to the data.
- **David C. Lampe – USGS Hydrologist and Field Supervisor (Borehole Flowmeter Activity)**—The USGS Field Supervisor (Borehole Flowmeter Activity) (FS-B) is responsible for the acquisition of field data measurements in a timely manner that meet the project objectives. The FS-B is responsible for coordinating and working with the SAIC Hydrogeology and Multimedia Sampling and Analysis Lead, Field Manager, and Site Health and Safety Officer (SHSO) and their representatives when collecting hydrologic, geophysical, borehole camera, and borehole flowmeter data. The FS-B also is responsible for collection of hydrologic, geophysical, borehole camera, and borehole flowmeter data. The FS-B is also responsible for verifying that this FSP Addendum is followed by USGS when collecting field data and that the project is producing data of known and acceptable quality. The FS-B evaluates and ensures whether the PC has provided adequate field training. The FS-B is responsible for all activities involved in generating the above field data, corrective action taken, as well as facilitating internal audits. The FS-B oversees data management for the study, which includes such responsibilities as receiving field results from staff, placing those results in the appropriate USGS database data archive, and preparing final logs. The FS-B also notifies the USGS PC of particular circumstances that may adversely affect the quality of data.
- **David A. Cohen – USGS Hydrologist and Field Supervisor/Database Manager (Age-Dating Activity)**—The USGS Field Supervisor (Age-Dating Activity) (FS-A) is responsible for the acquisition of field data measurements and water samples in a timely manner that meet the project objectives. The FS-A is responsible for coordinating and working with the SAIC Hydrogeology and Multimedia Sampling and Analysis Lead, Field Manager, and SHSO and their representatives when collecting hydrologic and field property data and samples for dissolved gas and age-dating. The FS-A also is responsible for verifying that the FSP is followed by USGS when collecting field data and that the project is producing data of known and acceptable quality. The FS-A oversees field data collection and data management for the age-dating study, which includes such responsibilities as preparing field equipment and forms,

compiling field data and laboratory submission records, ensuring proper disposition and transport of the samples to the laboratory, and placing those results from field and laboratory data collection in the appropriate USGS data archive. In addition, Mr. Cohen manages the USGS, National Water Information System, Ground-Water Site Inventory database for the USGS Indiana Water Science Center, where hydrologic data from the project are stored. The FS also notifies the USGS PC of particular circumstances that may adversely affect the quality of data.

- **Amanda Ulberg and Scott Lowe – USGS Field and Technical Assistants**—These hydrologists (Ms. Ulberg and Mr. Lowe) will provide sampling and other field assistance during the data collection and provide insights during the interpretation of the analytical results.
- **E. Randall Bayless – USGS Indiana Water Science Center, Ground-Water Specialist**—Dr. Bayless provides technical advice regarding interpretation of hydrologic and ground-water age-dating information. Dr. Bayless also may assist the PC with interpretation of age-dating information and compilation of the USGS report to the Army.

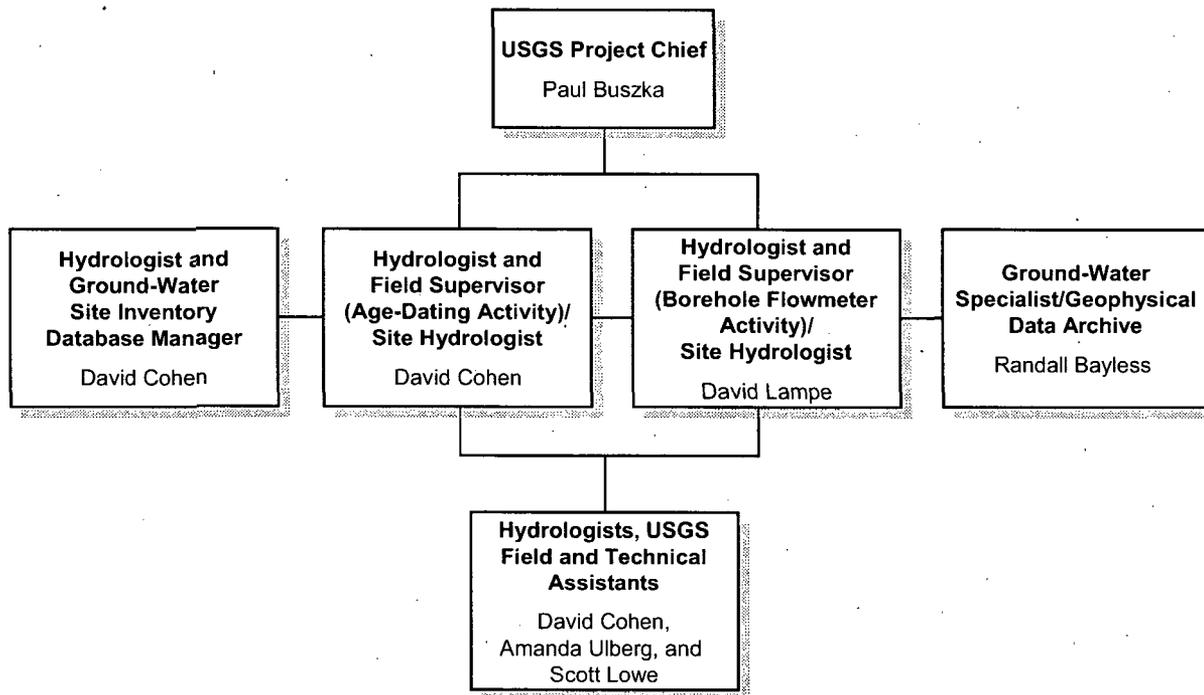


Figure 2-1. USGS Project Organization

### 3. OBJECTIVES AND SCOPE OF THE AGE-DATING SAMPLING

The Army has petitioned the Nuclear Regulatory Commission (NRC) to decommission the DU Impact area (Figure 3-1). As part of this effort, the Army and its contractor, SAIC, are actively investigating the hydrogeologic framework north of the firing line. The Army and SAIC have implemented surface-water discharge and springflow monitoring at gaged sites located within and at the upgradient and downgradient boundaries of the DU Impact Area. Additional observation wells have been installed in unconsolidated overburden and in shallow and relatively deeper zones within carbonate bedrock underlying the area. The wells were installed to provide information to further refine the conceptual site model (CSM) and to provide locations for sampling ground water and monitoring ground-water levels in these zones.

#### 3.1 DESCRIPTION OF PROBLEM

Estimates of the residence time of ground water that is sampled from observation wells are critical to planned interpretation of ground-water monitoring data and geochemical modeling of potential DU constituent transport. Current hydrogeologic studies at JPG are targeted to define characteristics important to potential DU transport away from the DU Impact Area. Ground-water age-dates can help identify which wells in the carbonate aquifer and unconsolidated overburden produce water whose recharge dates are from during and after DU munitions firing. The planned geochemical simulations of DU and daughter product fate and transport require an understanding of the residence time of ground water relative to the firing of DU munitions. As an example, assume a ground-water sample from the DU firing area did not contain the DU-related elements in detectable concentrations. If a water sample from that well also had an estimated age of ground-water recharge that was from the period of DU munitions firing, the age-date could imply the relative lack of transport of DU constituents into ground water at that location. Conversely, ground-water samples that predate the DU munitions firing could help define parts of the hydrogeologic system that would be less susceptible to contamination.

The objective of this work is to collect and analyze ground-water samples to estimate the residence time of each sample since it infiltrated below the water table. Several types of water samples will be collected from observation wells in and around the DU Impact Area, including the following constituents, to assist in the estimation of ground-water ages (Table 3-1).

#### 3.2 WELLS TO BE SAMPLED

Wells to be sampled during this effort will be selected from those installed in 2007 by SAIC to evaluate the hydrogeologic framework of the DU Impact area (Figure 3-2). Detailed information about these well locations is already available and will be the subject of geophysical and camera logging by USGS. These wells also were designed to be sampled for ground-water quality. In addition, the wells are accessible by previously cleared roads and are at sites that have been examined and cleared of DU munitions and unexploded ordnance (UXO).

Several criteria will be used to indicate the suitability of wells to sample for dissolved gases and age-dating constituents:

1. If water levels have not recovered in a well since post-installation pumping and development, very low or no-flow conditions are likely. No age-dating sampling will be conducted from that type of well.
2. If ground-water levels have recovered since post-installation pumping and development, sampling of water representative of the aquifer appears possible. Dissolved gas and age-dating samples will be collected from that type of well.

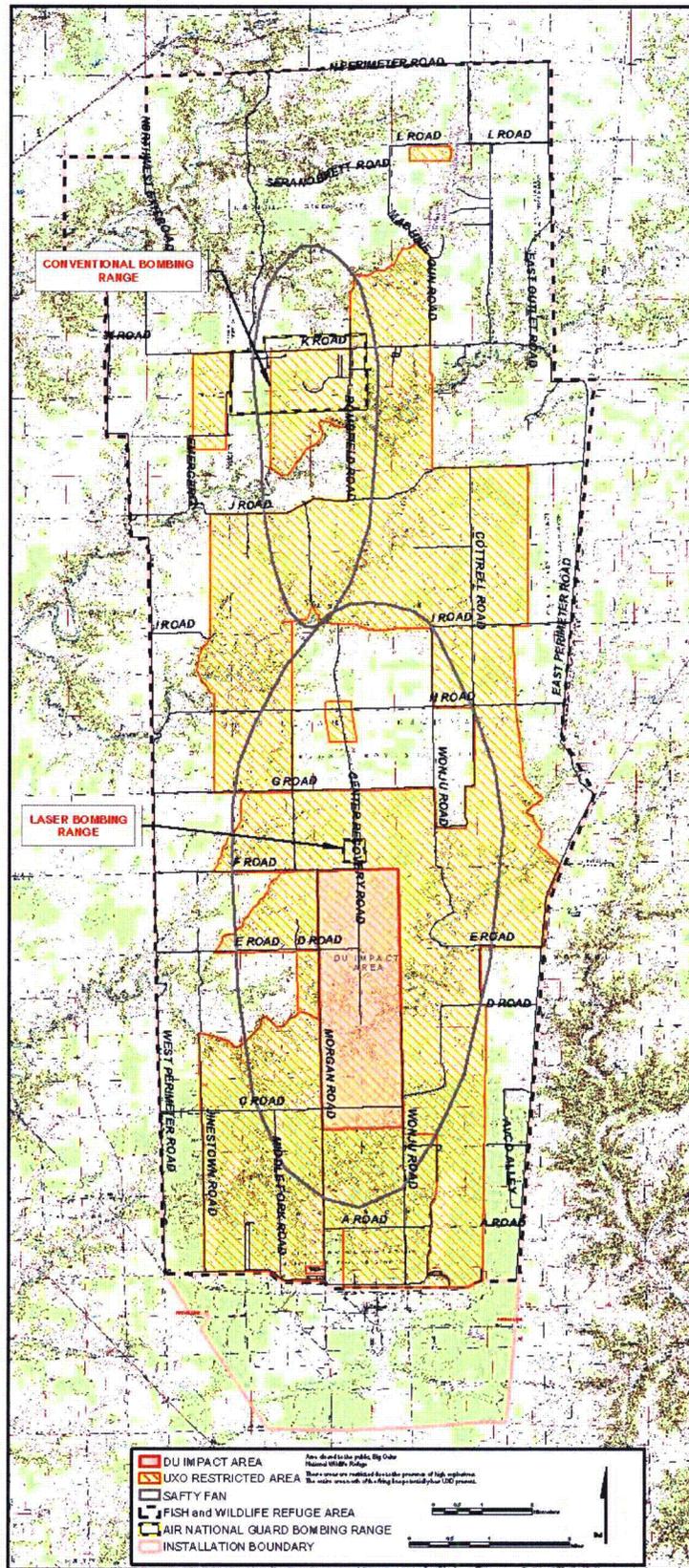


Figure 3-1. Jefferson Proving Ground, Madison, Indiana

**Table 3-1. Constituents to Be Analyzed in Water Samples from Wells  
Jefferson Proving Ground, Madison, Indiana.**

Sample Type	Sample Container	Analysis Source	Purpose
Field properties (pH, conductivity, temperature, dissolved oxygen)	Probe measured values	Field data, SAIC	Evaluate sampling conditions; evaluate stability of general water chemistry in ground water to be sampled
Dissolved major gases: nitrogen (N <sub>2</sub> ), carbon dioxide (CO <sub>2</sub> ), oxygen (O <sub>2</sub> ), methane (CH <sub>4</sub> ), argon (Ar)	Septum vial, collected under water in beaker	USGS Dissolved Gas Laboratory, Reston, VA (same address as USGS CFC Laboratory)	Evaluate feasibility of CFC dating and average recharge temperature for CFC-based age-dating estimate
Dissolved helium (He)	Septum vial, collected under water in beaker	USGS CFC Laboratory, Reston, VA	Evaluate excess He concentration to decide about submitting tritium-helium analyses
Chlorofluorocarbon compounds (Freon-11, Freon-12, Freon-113)	Glass bottle	USGS CFC Laboratory, Reston, VA	Age-dating constituent (post 1930s recharge dates through present)
Tritium (reporting limit to about 2 pCi/L)	Glass bottle, taped cap	USGS Tritium Laboratory, Menlo Park, CA	Relative age date (either pre- or post-1952 recharge) and for refined tritium/helium-3 age-date
Helium-3, neon	3-foot sealed copper tubing	USGS CFC Laboratory, Reston, VA and Lamont-Doherty Earth Observatory	Refined age-date for modern to post-1952 recharge. Collected but not submitted if excess helium present

USGS CFC Laboratory (<http://water.usgs.gov/lab/>) contacts:

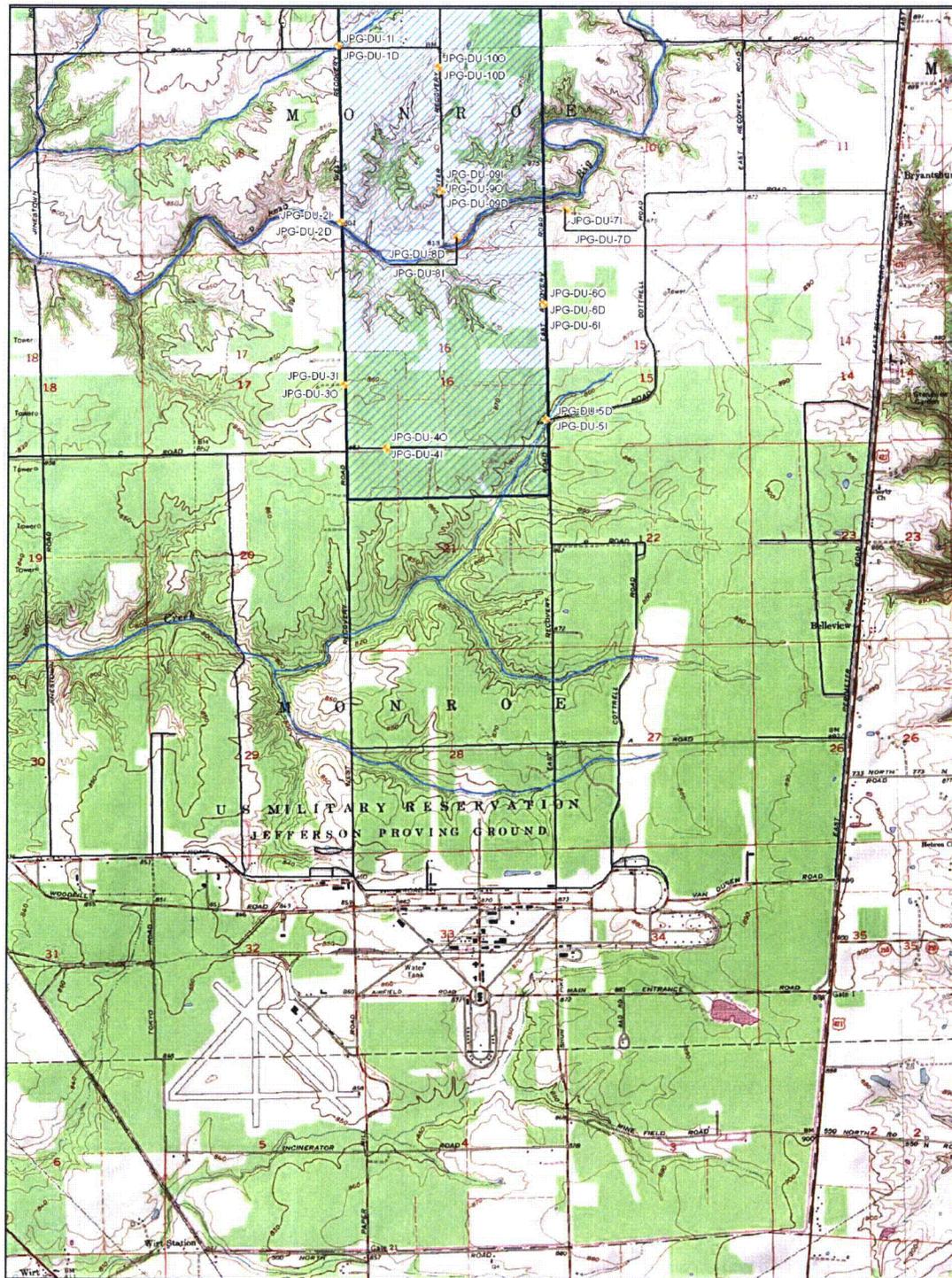
Julian Wayland  
Eurybiades Busenberg  
CFC Laboratory  
US Geological Survey  
432 National Center  
12201 Sunrise Valley Drive  
Reston, VA 20192

USGS Tritium Laboratory contacts:

Robert Michel (650-329-4547)  
U.S. Geological Survey  
345 Middlefield Rd  
MS 434  
Menlo Park, CA 94025

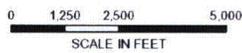
USGS Tritium-Helium dating contacts:

Julian Wayland (703-648-5847) and Dr. Peter Schlosser  
Lamont-Doherty Earth Observatory  
Geochemistry Bldg  
RM 74  
Route 9W  
Palisades, NY 10964



- Legend**
- DU Well
  - Streams
  - Roads
  - DU Impact Area

NOTE: Base map from the USGS 7.5 min. Chitty Falls and San Jacinto Quadrangle



Jefferson Proving Ground  
Madison, Indiana

2007 Installed Well Locations

Drawn	AQM	Checked	Approved	Figure No.
Don		3/7/08		<b>3-2</b>
IR # 01-1633-04-8527-710				



3. If ground-water levels have been observed to vary in periodic measurements, sampling of water representative of the aquifer and relatively young age-dates are possible. Dissolved gas and age-dating samples will be collected from that type of well.

Twenty-three SAIC wells are available for dissolved gas and age-dating sampling. Fewer wells may be deemed to be suitable for age-dating sampling, based on the above criteria and hydrologic observations.

### 3.3 DECISION STATEMENT

If ground-water ages predate the use of the DU Impact Area for testing of DU projectiles, the date can be used to evaluate the likelihood of whether ground-water recharge from the time scale of DU munitions firing has or would reach the sampled interval of aquifer. Similarly, if estimated ground-water age-dates are from the period of DU range firing or later, or represent a mixture of ages that include water contemporaneous with or after DU Impact Area operation, that information can be used to evaluate the feasibility of DU transport into ground water.

### 3.4 RESOURCES, COORDINATION WITH SAIC, AND SCHEDULE

The resources to conduct this investigation have been provided to USGS by the Army under U.S. Army Corps of Engineers (USACE) Military Interdepartmental Procurement Request. Field investigation activities will be conducted by USGS jointly with SAIC during one of their scheduled quarterly ground-water sampling events (April or July 2008). USGS will provide the necessary technical expertise and resources to the age-dating investigation, based on the attached project based on the technical requirements and schedule. In addition, SAIC, through its activities outlined in FSP Addendum 5 (SAIC 2008) and preceding activities and associated HASPs, provides the necessary technical expertise and resources to support field activities and site information needs of this project, based on the technical requirements and schedule in FSP Addendum 5.

The overall project schedule of activities is summarized in Table 3-2. As project priorities are established and/or adjusted by the Army in coordination with NRC, they may adjust the project schedule to meet these priorities.

**Table 3-2. Planned Project Milestones  
Jefferson Proving Ground, Madison, Indiana**

Deliverable/Activity	Date
FSP Addendum 5 (SAIC)	January 2008
FSP Addendum 6 (USGS)	March 2008
Ground-Water, Surface-Water, and Sediment Sampling (SAIC)	April, July, and October 2008 and January 2009
USGS Ground-Water Sampling for Age-Dating, co-collected with SAIC (USGS)	April or July 2008
Transmittal letter with preliminary results of dissolved gas and tritium analyses and decisions about which samples were submitted for age-dating (USGS)	Four months after conclusion of sampling (August or November 2008)
Draft USGS-series report prepared for technical review by SAIC and Army staff. (Estimated review time of 1 month)	Provided by USGS to reviewers within 10 weeks after completion of the last age-dating analysis (November 2008 or January 2009; see schedule note about tritium-helium dating)
Final USGS-series report will be prepared for release to NRC/public	Planned for April 2009 or June 2009

Schedule note about tritium/helium-3 dating: Samples for tritium/helium-3 determinations for age-dating may be submitted for analysis if dissolved helium reveals that no artificial excess of helium is apparent in ground water. Helium-3 determinations will require about 6 to 9 months of additional analysis time, following the decision to analyze the samples. The report contents and a revised schedule will be discussed and developed with the Army and SAIC if the decision to analyze the tritium-helium samples would be made.

This FSP Addendum assumes that USGS will work under and meet the requirements specified in the Army/SAIC HASP. USGS field activities will be coordinated with the Army and SAIC. USGS staff will be accompanied by Army or SAIC staff when traveling to and from well sites and when working at individual well sites. USGS work will be restricted to travel to and from well sites on established roads and work at existing wells within the established safe work area. The Army/SAIC will provide oversight by a UXO technician and site-specific training to enable USGS staff to avoid UXO.

#### 4. GROUND-WATER SAMPLE COLLECTION FOR DISSOLVED GASES AND AGE-DATING CONSTITUENTS

This section summarizes the ground-water sampling for dissolved gases and age-dating constituents to be conducted by USGS, in cooperation with SAIC, at JPG starting in the spring or summer of 2008. Hydrologic data, including water-level measurements that will be taken before and during sampling, will be collected by SAIC; this activity is described in Section 5.1 of the FSP Addendum 5 (SAIC 2008). The procedures to be used to produce ground water for sampling are described in Section 5.2 of the FSP Addendum 5 (SAIC 2008).

In general, the wells to be sampled for this effort will be those that produce sufficient water to be sampled under the "well yield matched purge sampling technique" described in Section 5.2.1 of the FSP Addendum 5 (SAIC 2008). As part of this technique, the field water-quality properties specific conductance, temperature, pH, dissolved oxygen (DO), and turbidity will be measured by SAIC to evaluate when representative ground water for sampling is being produced. The water-level and water-quality property data will be provided at each site to USGS to be recorded on field forms and laboratory submission documents for water samples.

Sections 4.1 through 4.5 of this FSP describe the procedures and supplies used to collect dissolved gas and age-dating samples. Ground-water samples will be co-collected by USGS, using sampling equipment supplied and operated by SAIC, with special fittings and tubing to be supplied by USGS. The sampling methods will have been designed to collect samples from each well that are representative of water from the aquifer adjacent to each well screen. This section describes those elements of the sampling that relate specifically to the collection of dissolved gas and age-dating samples.

Ground-water samples to be collected are likely to contain concentrations of dissolved gases that differ substantially from atmospheric concentrations. Procedures outlined herein have been selected to minimize sample contact with the atmosphere and minimize the effect of pressure changes from the source of the sample to the point of field measurement or sample processing (USGS 2006).

Samples from monitoring wells will be collected with a portable, low-capacity Grundfos or equivalent submersible pump. Pre-sampling well development, pumping, and measurement of field properties will be conducted by SAIC before sample collection, using procedures outlined in the FSP Addendum 5 (SAIC 2008). USGS will supply a discharge adaptor fitting that SAIC will use to split flow from the pump into two flows at the pump head (shown in Figure 4-1). The discharge adaptor fitting for the Grundfos Pump has a ½-in. outside diameter (OD) pipe thread, which is located at the base where the fitting joins the pump. The SAIC flow will discharge to tubing and be collected using procedures outlined in the FSP Addendum 5 (SAIC 2008). The USGS flow will be routed directly into nylon tube and pumped to the collection point at land surface. A specification for an approved source of this tubing is Advanced Technology Products (ATP) Nylon 12; ¼ in. OD; ATP product number N14BNA; inside diameter (ID) approximately 0.18 in. Both the SAIC tube and USGS tube will be routed to land surface. The remainder of this discussion relates to the sampling and collection of the USGS dissolved gas and age-dating samples, in the order they are to be collected.

Wells that meet criteria 2 but do not have a sufficient yield that enables purging with stabilization of the water level will be evaluated for sampling by a "Low-Yield Well Sampling" method, as described in Section 2.2.2 of the FSP Addendum 5 (SAIC 2008). USGS will consult with SAIC to determine the likelihood that water-level recovery rates are sufficient to produce sufficient volume to allow sample collection without entraining atmospheric gas into the water sample. At a minimum, USGS will collect a water sample from these wells for possible tritium analysis through the USGS Isotope Tracers Project Laboratory, as described in Section 4.1.

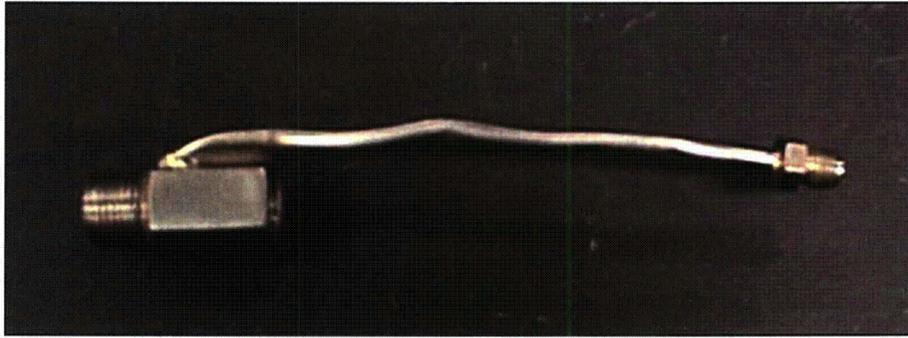


Figure 4-1. Photograph of Discharge Adaptor Fitting for Grundfos Pump

#### 4.1 TRITIUM IN WATER SAMPLING PROCEDURE

Unfiltered samples of ground water will be collected and submitted for tritium analysis. Water samples and sequential duplicates will be collected at each sampled well. Water will be sampled directly from the discharge end of the nylon tubing into a pre-cleaned, 1-liter polyethylene bottle. The bottles will be sealed with a polyseal cap, with the cap taped in place using a strip of standard electrical tape. No equipment rinsate blanks will be collected as no additional contribution of tritium from sampling equipment is anticipated.

#### 4.2 DISSOLVED GAS IN WATER SAMPLING PROCEDURE

The following method is reproduced from the USGS Reston Chlorofluorocarbon Laboratory website (<http://water.usgs.gov/lab/dissolved-gas/sampling/>). Pre-weighed 150-mL serum bottles and stoppers are provided for sample collection by this laboratory.

Serum bottle sampling procedure

1. Insert a needle into the rubber stopper until the tip slightly exits through the stopper, as demonstrated in Steps 1 through 5 of Figure 4-2.
2. Fill a 1- or 2-liter beaker with well water.
3. Place the water discharge tube at the bottom of the 150 mL sample bottle. After it is filled, place the bottle in the water filled beaker. The water should be flowing into the bottle when it is put in the beaker. **Do not filter the sample, use raw, unfiltered sample.**
4. Make sure that no bubbles are adhering to the sides of the bottle. Insert the stopper in the bottle while the bottle is submerged in the water. Make sure that you push the stopper all the way down. **Sequential duplicates are collected for all samples.**
5. Remove the needle from the stopper while the bottle is still submerged in the water. **Properly dispose of all needles or return the used needles with the samples.**
6. Record the (a) sample name, (b) water temperature, and (c) estimated recharge altitude on the label attached to the foam sleeve.
7. Keep samples cool or about the temperature of the ground water. This will keep the stoppers from popping up as the sample warms up. Store sample bottles upside down.
8. Ship samples with ice in cooler overnight express to the USGS Dissolved Gas Laboratory. Dissolved gas samples should not be shipped on Fridays to avoid warming in transit.

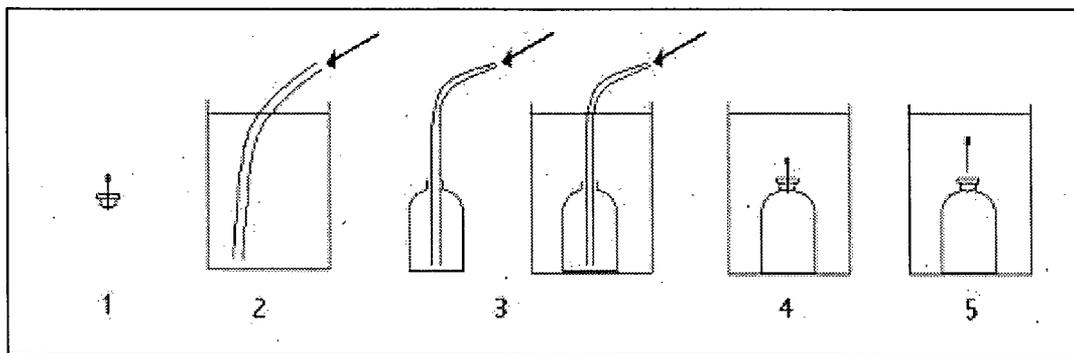


Figure 4-2. Dissolved Gas Sampling Illustrations

#### 4.3 HELIUM SAMPLING PROCEDURE FOR GROUND WATER

The following method is reproduced from the USGS Reston Chlorofluorocarbon Laboratory website (<http://water.usgs.gov/lab/dissolved-gas/sampling/>). The water samples for Helium gas (He) analysis are collected in 150-mL septum bottles that are filled without headspace in the field using procedures identical to those used to collect other dissolved gases. The samples are stored on ice in the field, and in a refrigerator at 4°C in the laboratory prior to analysis, to minimize expansion and possible sample loss, and to lower rate of biological activity in the sample prior to analysis.

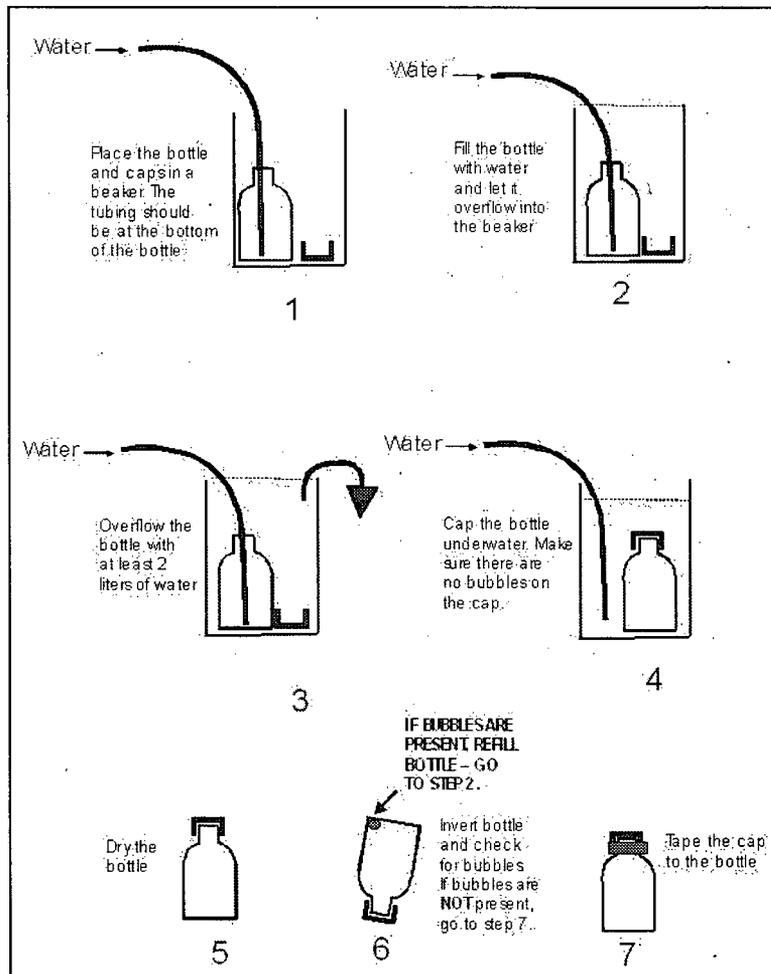
#### 4.4 CHLOROFLUOROCARBON COMPOUND SAMPLING PROCEDURE FOR GROUND WATER

This section describes the sampling procedure for collection of chlorofluorocarbon (CFC) compound samples in glass bottles capped with a special foil-lined cap, as described below. The following method is reproduced from the USGS Reston Chlorofluorocarbon Laboratory website (<http://water.usgs.gov/lab/chlorofluorocarbons/sampling/bottles/>).

Bottles used for CFC sample collection are 125-mL (4 oz) boston round clear glass with separate bottle caps with aluminum foil liners. Any caps with a scratched, dented, or altered foil liner will be discarded.

The bottles and caps will be thoroughly rinsed with the ground water. The bottles are filled underwater in a beaker and capped underwater. Refrigeration-grade copper tubing is required. The filling procedure is carried out within a 2- to 4-liter beaker. A plastic beaker is fine. Collect five bottles per well or spring. The procedure is described below and in the accompanying illustration:

1. After the well has been purged, place the bottle in the beaker and then insert the end of the copper tubing from its connection to the nylon tubing from the pump all the way into the **bottom** of the bottle. Always use fresh water from the well being sampled to fill the bucket or container in which the sample bottle is submerged for sample collection.
2. Fill the bottle as demonstrated in Steps 1 through 7 of Figure 4-3 with well water until it overflows. Place the discharge end of the copper sample line all the way to the bottom of the sample bottle and fill from the bottom up, displacing the water already in the bottle.
3. Continue to overflow the bottle until the beaker overflows. Allow at least 2 liters of water to flow through and overflow the bottle and flow out of the beaker before capping the bottle. Be sure to measure the 2 liters of overflow volume; one way to do this is to place the sample bottle in an empty 2-liter beaker, then allow the sample bottle to fill and overflow until the beaker itself fills and overflows.



**Figure 4-3. Chlorofluorocarbon Sampling Illustrations**

4. Select a bottle cap, submerge the cap in the bucket or beaker with the foil liner facing up, and tap it under water to dislodge air bubbles. Remove the copper tube from the bottle and **tightly cap the bottle underwater** without allowing the water in the bottle to come in contact with air. Make sure that all the air bubbles are displaced from the cap before sealing the sample bottle. Flushing the bottle with more water is far better than with less water.
5. Remove the capped bottle from the beaker, dry the bottle and **re-tighten** the cap. The tighter the cap the better. Invert the bottle and look for air bubbles. A small pea-sized bubble may occur due to degassing, but there should not be any bubbles of significant size.
6. Invert the bottle, tap it, and check it for air bubbles. If there are bubbles, repeat the procedures from steps 2 through 5 above. If it is necessary to refill the bottle, you must use a **new** cap.
7. If there are no bubbles present, tape the cap **securely** to the bottle with **electrical tape**. Using masking tape will cause a large bubble to form during shipping as shown in Figure 4-4, Sample C. Tightly wrap the cap with at least three revolutions of electrical tape in a clockwise direction (in the same direction as the threads) looking down from the bottle top. Loose tape will result in an improper seal and cause an air leak, as shown in Figure 4-4, Sample B. Do not forget to label each bottle with the well name, date, and time of sampling and the sequence number of each bottle as it was collected, one through five, in the order of collection. The clockwise wrap in the same direction as the threads forces the cap on tighter. This will prevent

the cap from working loose during shipping and also helps prevent the cap liner from drying out.

8. Store bottles upside down until shipment. A tiny bubble will form in samples sealed properly, as seen in Figure 4-4, Sample A. This is normal, as shown in the illustration. Ship them each day, overnight to the USGS Reston Chlorofluorocarbon Laboratory; holding times for the CFC and gas samples are limited and the samples need to get into the sample processing queue immediately. Do not ice these samples for storage and shipping.

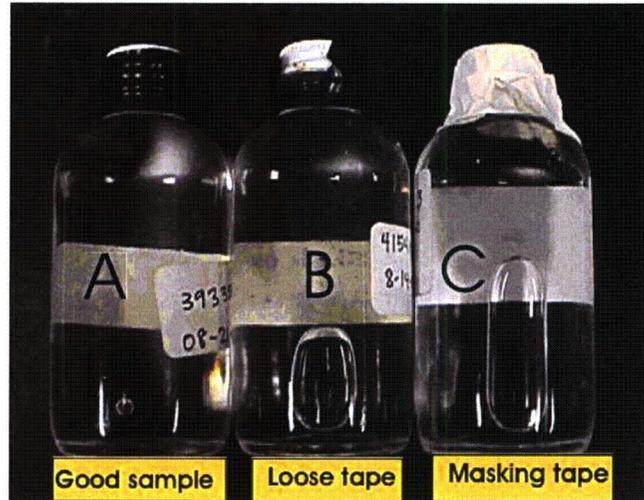


Figure 4-4. Examples of Properly and Improperly Sealed Bottles

#### 4.5 TRITIUM/HELIUM-3 SAMPLING PROCEDURE FOR GROUND WATER

Proper collection of a water sample for  $^3\text{H}/^3\text{He}$  age determination requires:

1. Filling a special copper sample tube, in duplicate, that is used for helium and neon analyses, and determination of the  $^3\text{H}/^4\text{He}$  isotope ratio ( $\delta^3\text{He}$ ) of dissolved helium.
2. Filling two 500cc bottles, which are used for tritium determination by helium in-growth.

Safety-coated 500cc glass bottles with polycone seals are recommended for the tritium sample, though high-density polyethylene (HDPE) bottles with polycone seals may be substituted. The water samples for helium and neon determinations are collected in special pinch-off copper tubes ( $3/8$ -in. diameter, 30-in. length, containing approximately 40 mL of water, and fitted with stainless steel pinch-off clamps at each end). Both the tritium and helium samples should be collected in duplicate. The duplicate water sample for tritium determination (duplicate 500-mL bottle) will be retained at the project office, but both copper tubes should be submitted to the laboratory for each sample. The duplicate water sample for tritium determination is collected using the procedure in Section 4.1.

The copper tube for He and Ne determinations can normally be flushed and filled within 5 minutes. Remove and discard the plastic caps that cover the ends of the copper tube, taking care not to scratch or bend or otherwise damage the ends of the copper tube. Damage to the ends of the copper tube may prevent proper attachment of the sample tube to the vacuum extraction line for sample preparation at the contract laboratory. The copper tube, which is fixed in an aluminum channel holding the stainless steel pinch-off clamps, is connected to a closed path from the well or pump. The connection to the well or pump can be of almost any material including plastic, rubber, or metal tubing, providing that all connections are airtight and will not come loose when back pressure is applied during closing of the copper tubes. Clear plastic tubing (Tygon) is preferred because one can visually observe whether air

bubbles are present in the water line. It is recommended that connections be secured with stainless steel hose clamps, again being careful not to damage the end of the copper tube. The length of the path from the well or pump discharge should not exceed approximately 5 ft to minimize the possibility of gas separation from the water sample prior to sealing the copper tube.

Any trapped air or formation of gas bubbles in the helium water sample will produce erroneous results. Back pressure is normally applied to the discharge end of the copper tube during flushing. The project office will need to obtain a small valve and suitable compression type fittings to attach the valve to the discharge end of the copper tube. Figures 4-5 and 4-6 show diagrams of the copper tube and back-pressure valve assemblies, respectively. The symbols for “no bubbles” show areas where clear plastic tubing can be inserted to observe inflow to the copper tube (Figure 4-5) and discharge from the copper tube (Figure 4-6) before the back pressure valve to check for bubble formation. Both water flow and back pressure on the sample should be increased if gas bubble formation is observed in either clear plastic tubing. The valve should not be closed completely during filling because a steady flow of water must be maintained through the copper tube during sealing.

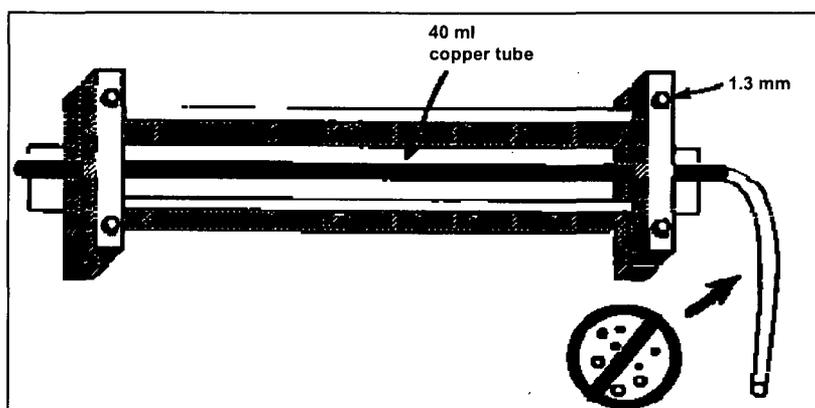


Figure 4-5. Inflow to the Copper Tube

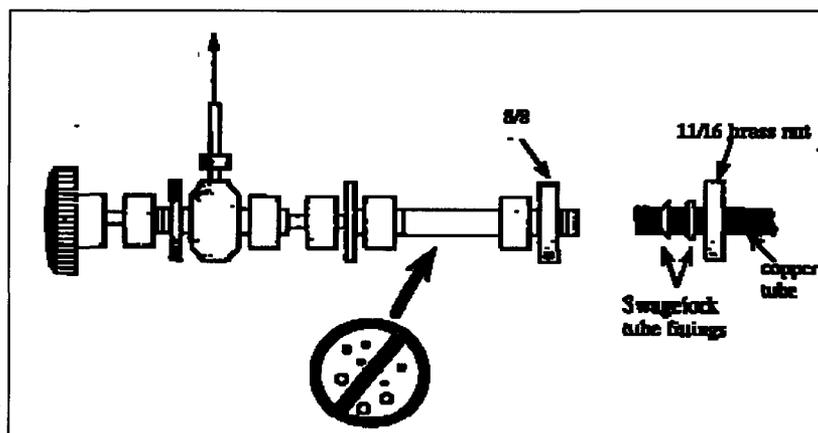


Figure 4-6. Discharge from the Copper Tube

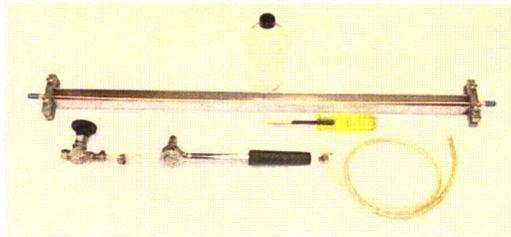
Suitable parts to make the back pressure valve assembly are:

- Whitey valve SS-1RS6, 3/8-in. stainless steel valve
- Swagelok 3/8-inch Nylon ferrules set, NY-600 sets (10 each).

These items are available through the Swagelok Companies or their suppliers. An over-pressure of approximately 1 atmosphere, 14 pounds per square inch (psi), is normally sufficient to prevent gas bubble

formation in the ground-water sample. However, in general, to prevent gas bubble formation, the back-pressure applied must exceed the internal pressure of the dissolved gases in the water sample. Both ends of the aluminum channel have clamps to hold a piece of copper tube. They may rattle loose during shipment. These clamps should be finger-tightened to hold the copper tube firmly on center in the aluminum channel (Figure 4-5).

Figures 4-7 through 4-10 show photographs of the equipment used to take the noble gas and tritium sample. Figure 4-7 shows the copper tube in an aluminum channel with stainless steel pinch-off clamps, a 1/4-in. copper tube used to connect to the pump, and back-

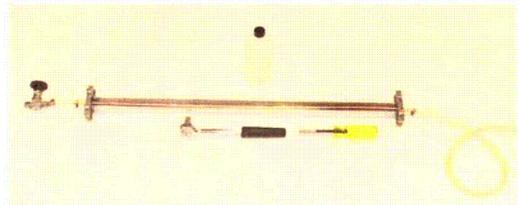


**Figure 4-7. Copper Tube in Aluminum Channel**

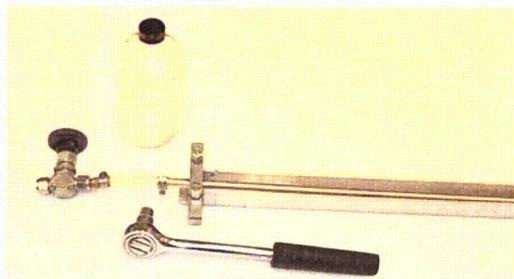
pressure valve. Figure 4-8 shows the parts of Figure 4-7 connected for sampling and a 500-mL safety coated glass bottle with polycone seal for collection of a tritium sample. Note that in this case, clear plastic tubing was not inserted at the inflow and outflow ends of the copper tube and, thus, in this case, there is no opportunity to check if gas bubbles are forming inside the tubing. Figure 4-9 shows the back-pressure valve connected to the end of the copper tube. Figure 4-10 shows the ends of properly sealed copper tubes

(note the centering of the tubes in the pinch-off clamps).

To flush the tube, open the pressure valve completely. Keep the pressure in the system as high as possible (it is safe up to 10 bars). Hold the copper sampler vertically (pressure valve UP) with one hand and the ratchet wrench and socket with the other hand. Allow the water to run at least 1 minute through the system to flush the sample tube with bubble-free water. Watch the polyvinyl chloride (PVC)



**Figure 4-8. Parts Connected for Sampling**

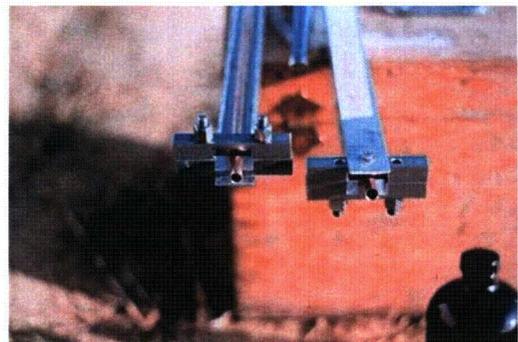


**Figure 4-9. Back-Pressure Valve Connected**

tubing and the plexiglass tube near the valve (Figure 4-6) for bubbles. Bubbles do preferentially form near fittings. If bubbles are present, squeeze the tube or knock against the tube to get rid of the bubbles. The sampler also may try to increase the pressure further by reducing the flow through the copper tube by partially closing the pressure valve. During flushing, bang the side of the aluminum channel with the ratchet handle to remove trapped air bubbles from the copper tube. Watch again the plexiglass tube between the valve and the sample container for bubbles (Figure 4-6). If formation of bubbles cannot be avoided, take the sample

anyway, and mark the sample container accordingly.

A socket wrench with 13-mm (note metric bolt) socket is used to turn the bolts that close the pinch-off clamps. Prior to turning the bolts, the entire line from the well through the copper tube should be tapped forcibly to dislodge any gas bubbles that may be in the line or copper tube. During the tapping process, the copper tube should be turned and held at an approximate 45-degree angle with discharge pointing up, to ensure that gas bubbles, if present, will be completely flushed. This tapping procedure normally requires approximately 1 minute to complete. Once satisfied that water flowing through the copper tube is free of any gas bubbles, the socket wrench is used to close



**Figure 4-10. Properly Sealed Copper Tubes and Tritium Bottle**

the bolts on the pinch-off clamps, beginning with the bolts at the discharge end. Before turning the bolts, be sure to position the copper tube in the approximate center of the pinch-off clamp. There are two bolts on each clamp. Turn the bolts in successive order (back and forth approximately four times until firmly closed) so that the blades of the pinch-off clamp close approximately evenly. The pinch-off clamps are machined to leave about a 1-mm space when the bolts are turned all the way down; however, care should be taken not to over tighten and strip the threads on the bolts. After tightening the discharge end bolts, tighten the upstream bolts in the same manner, again centering the copper tube between the blade. When done, double check to ensure that all bolts are tight. The sample is then complete and the copper tube can be disconnected from the well or pump.

Remove the back-pressure valve from the discharge end of the copper tube. Precautions should be taken not to scratch or otherwise damage the ends of the copper tubes. If waters are corrosive, such as seawater or other saline or acidic waters, the ends of the copper tubes should be washed with dilute water to prevent corrosion, which might prevent obtaining a proper seal when extracting the noble gases. Care should be taken not to further bend the ends of the sealed copper tubes because they can easily break off. If the tubes were received with plastic caps protecting the ends, do not replace the caps after filling.

USGS personnel will be responsible for proper collection of water samples, including: (1) care in avoiding possible damage to ends of sample tubes, which might preclude proper connection to laboratory high-vacuum extraction lines, and (2) exclusion of gas bubbles during sample collection. The laboratory will report samples that could not be extracted or analyzed because of improperly sealed sample containers and/or damaged sample containers. Improperly collected samples, such as samples containing gas bubbles, are usually not detected until the analysis of noble gases is made.

#### **4.6 FIELD DOCUMENTATION AND SAMPLE SUBMISSION**

USGS field notes will be collected on field ground-water sampling forms included in the Appendix. Additional information will be recorded in a field logbook should it be needed to document additional aspects of ground-water sampling. The field logbook will be with the USGS staff responsible for sampling or in the USGS project file when not being used during field work. The laboratory submission form for samples also is included in the Appendix.

Tritium samples, including up to three sequential duplicates from three different wells, will be shipped unchilled to the USGS Isotope Tracers Project Laboratory and logged in through the laboratory submission form for samples included in the Appendix. These samples will be sent directly to:

U.S. Geological Survey  
USGS Isotope Tracers Project Laboratory  
Attn: Bob Michel, MS 434  
345 Middlefield Road  
Menlo Park, CA 94025

Telephone: 650-329-4547  
E-mail: [rlmichel@usgs.gov](mailto:rlmichel@usgs.gov)

***Dissolved Gas and CFC Samples***—When the samples have been collected and are ready to be analyzed, the project office must download and complete the Sample Submission Form (an Excel spreadsheet, available at <http://water.usgs.gov/usgs/lab/shared/submission.html>). The completed submittal spreadsheet is returned by e-mail attachment to [jwayland@usgs.gov](mailto:jwayland@usgs.gov) with a cc to [cfc@usgs.gov](mailto:cfc@usgs.gov). Sample identifier tracking numbers will be assigned by the USGS Reston Chlorofluorocarbon Laboratory and returned to the project office via e-mail, and/or as stick-on labels. It is the responsibility of the project office to properly identify each sample with the sample identification (I.D.) tracking number. The project office then ships the samples to the USGS Reston Chlorofluorocarbon Laboratory and notifies the laboratory (via

e-mail to [jwayland@usgs.gov](mailto:jwayland@usgs.gov) with a cc to [cfc@usgs.gov](mailto:cfc@usgs.gov)) of date of shipment. The project office will be notified of any samples damaged in shipment.

Dissolved-Gas Sample Shipping Address

Peggy Widman  
U.S. Geological Survey Dissolved Gas Laboratory  
MS 432  
12201 Sunrise Valley Dr.  
Reston, VA 20192  
Telephone: 703-648-5347  
E-mail: [pkwidman@usgs.gov](mailto:pkwidman@usgs.gov)

Chlorofluorocarbon Sample Shipping Address

Peggy Widman  
U.S. Geological Survey CFC Laboratory  
MS 432  
12201 Sunrise Valley Dr.  
Reston, VA 20192  
Telephone: 703-648-5347  
E-mail: [pkwidman@usgs.gov](mailto:pkwidman@usgs.gov)

***Tritium-Helium-3 Samples***—When the samples have been collected and are ready to be analyzed, the project office completes the same Sample Submission Form as referenced under “Dissolved gas and CFC samples.” The completed submittal spreadsheet is returned by e-mail attachment to [jwayland@usgs.gov](mailto:jwayland@usgs.gov) with a cc to [cfc@usgs.gov](mailto:cfc@usgs.gov). Sample I.D. tracking numbers will be assigned by the USGS Reston Chlorofluorocarbon Laboratory and returned to the project office via e-mail, and/or as stick-on labels. It is the responsibility of the project office to properly identify each sample with the sample I.D. tracking number.

The project office then ships the samples to Lamont-Doherty Earth Observatory and notifies the USGS Reston Chlorofluorocarbon Laboratory (via e-mail to [jwayland@usgs.gov](mailto:jwayland@usgs.gov) with a cc to [cfc@usgs.gov](mailto:cfc@usgs.gov)) of date of shipment. Lamont-Doherty Earth Observatory will notify the USGS Reston Chlorofluorocarbon Laboratory when samples are received and condition of samples upon receipt. Precautions need to be taken to ensure that samples shipped in winter months do not freeze during shipping. The project office will be notified of any samples damaged in shipment. Note: NWQL ASR forms are no longer used to request analytical services for  $^3\text{H}/^3\text{He}$  dating (use submittal spreadsheet as described above). The sample tube(s) and water samples for tritium-helium-3 are shipped to:

Dr. Peter Schlosser  
Lamont-Doherty Earth Observatory  
Geochemistry Bldg, RM 74  
Route 9W  
Palisades, NY 10964

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## 5. ANALYTICAL METHODS USED FOR DISSOLVED GAS AND AGE-DATING ANALYSES

The analytical methods to be used for the dissolved gas and age-dating analyses are summarized in Table 5-1. Details of the methods can be found at the referenced sources or websites.

**Table 5-1. Analytical Methods for Ground-Water Samples to be Collected for Dissolved Gas and Age-Dating Analyses  
Jefferson Proving Ground, Madison, Indiana**

Constituent or Property Name	Reporting Unit	Reporting Limit	Source of Analysis	Analytical Method Description
<b><i>Dissolved Gases</i></b>				
Dissolved gases, unfiltered (oxygen, nitrogen, argon, carbon dioxide, methane)	milligram per liter	—	USGS Dissolved Gas Laboratory, Reston, VA	GS/MS, thermal conductivity detector (oxygen, nitrogen, argon) and FID (carbon dioxide and methane) <a href="http://water.usgs.gov/lab/dissolved-gas/lab/analytical_procedures/">http://water.usgs.gov/lab/dissolved-gas/lab/analytical_procedures/</a>
Dissolved helium	milligram per liter	—	USGS Dissolved Gas Laboratory, Reston, VA	Thermal conductivity detector; Sugisaki et al. (1982); and <a href="http://water.usgs.gov/lab/dissolved-gas/lab/helium.html">http://water.usgs.gov/lab/dissolved-gas/lab/helium.html</a>
Chlorofluorocarbon compounds: CFC-12, CFC-11, and CFC-113	picograms per liter	0.5-1.0 pg/L	USGS Chlorofluoro-carbon Laboratory, Reston, VA	<a href="http://water.usgs.gov/lab/chlorofluorocarbons/lab/analytical_procedures/">http://water.usgs.gov/lab/chlorofluorocarbons/lab/analytical_procedures/</a>
<b><i>Isotopes</i></b>				
Tritium, unfiltered	TU or picocurie per liter	About 0.8 TU	USGS Isotope Tracers Project Laboratory, Menlo Park, CA	Electrolytic enrichment, liquid scintillation method, R-1174-76 (USGS TWRI Book 5, Chapter A5)
Tritium/Helium-3 age dating, unfiltered (includes tritium, helium-3, helium-4 and neon determinations)	—	—	Dr. Peter Schlosser Lamont-Doherty Earth Observatory Geochemistry Bldg, RM 74 Route 9W Palisades, NY 10964	Schlosser et al. (1988); Schlosser et al. (1989); also see 3H/3He Dating Background at <a href="http://water.usgs.gov/lab/3h3he/background/">http://water.usgs.gov/lab/3h3he/background/</a> ; tritium, helium-3, helium-4 are measured by in-growth method with isotope mass spectrometry

- = not available or not known
- FID = flame ionization detector
- GC = gas chromatography
- MS = mass spectroscopy
- pg/L = picogram per liter
- TU = tritium unit
- USEPA = U.S. Environmental Protection Agency

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## 6. QUALITY ASSURANCE SAMPLING AND ANALYSES

Field QA components will include collection of QA samples and data to evaluate the reproducibility of the sampling (sequential duplicates, all sample types) and to identify problems with cleaning of sampling equipment (equipment blanks; CFC samples only).

Sequential duplicates will be used to evaluate the reproducibility of the sampling and analysis. A sequential duplicate is a sample collected in immediate succession to the water sample from the same source, using the same equipment and methods. Sequential duplicates will be submitted to the same analytical laboratories with water samples for identical analyses. The difference between analyses from a water sample and its sequential duplicate will be evaluated, using the relative percent difference (RPD) statistic. The RPD is the absolute value of the difference of the two concentrations of a single constituent divided by the average of the sum of the concentrations, expressed as a percent. An RPD comparison will be made only when constituent concentrations are detected in the water sample, the sequential duplicate, or both. The RPDs will be computed for the paired water sample and sequential duplicate as:

$$RPD = |(SD-WS)/((SD+WS)/2)| \times 100$$

where:

- RPD = is the relative percent difference
- SD = is the concentration in the sequential duplicate
- WS = is the concentration in the water sample.

The RPD statistic describes the difference in concentrations between two samples that are identical in their handling and analysis and that should be identical in composition. If the RPD of an analysis is within 25 percent, the water quality sample result meets the precision objectives of this study. If the RPD is greater than 25 percent, the water quality sample result will be reported, but the concentration for that analysis will be flagged with the letter "Q" in data tables to indicate that the concentration is an estimate.

Equipment blanks will be collected and analyzed for CFC analyses to determine whether CFCs are being contributed to water samples by the sampling procedure or by residue from previous samples. Equipment blanks will be prepared by pumping reagent-grade organic-free water through the sampling apparatus after the decontamination protocol outlined in Section 5 of the FSP Addendum 5 (SAIC 2008) is complete. The reagent-grade organic-free water is anticipated to have smaller concentrations of CFCs and will be used to prepare equipment blanks.

Concentrations of constituents in equipment blanks will be compared with analytical results from water samples to assess whether sample collection interferences may be present. The results will be grouped in the following categories:

- **No Equipment Interference**—Constituent was not detected in the equipment blank(s) or not detected in a corresponding ground-water sample.
- **No Apparent Equipment Interference**—Constituent concentration in the equipment blank was more than 10 times the largest concentration detected in the reagent-grade organic-free water.
- **Potential Interference**—Constituent concentration in one or more water samples was within 10 times the largest concentration detected in the equipment blank(s).

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## 7. INTERPRETATION OF GROUND-WATER AGE ESTIMATES

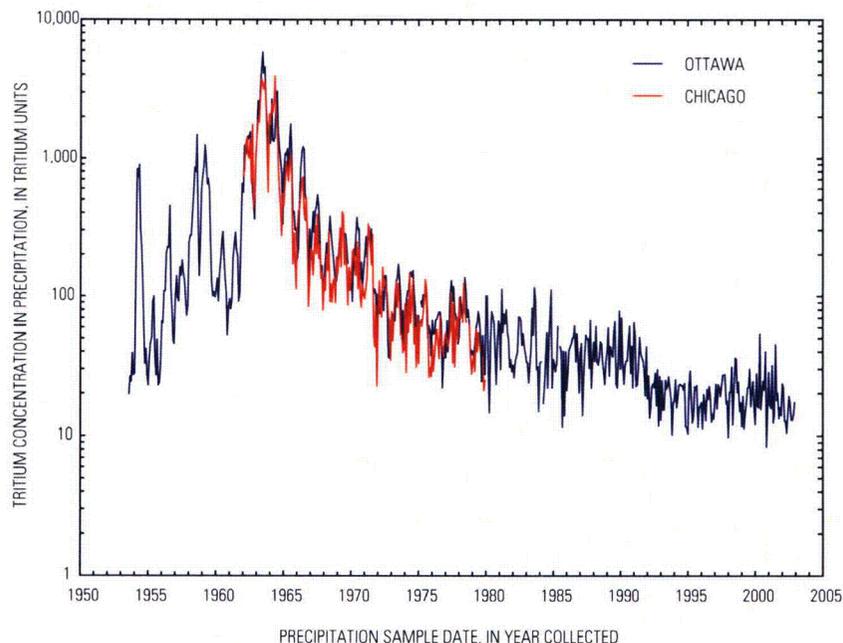
Ground-water age estimates may be computed for this study using three data sources: tritium concentrations, concentrations of CFC compounds, and tritium-helium-3 dating. The methods to be used to estimate ground-water ages are summarized below.

### 7.1 QUALITATIVE GROUND-WATER AGE ESTIMATES USING TRITIUM CONCENTRATIONS.

Tritium concentrations will be used to distinguish between aquifer recharge that (younger ground water) postdated 1952 and aquifer recharge that predated 1952 (older ground water). For example, recharge to ground water in the deeper parts of the bedrock aquifer may have longer flow paths and relatively older ages than ground water in unconsolidated sediments and in the upper parts of the bedrock aquifer. Tritium concentrations can be used to qualitatively classify ground-water residence times for continental regions, using the following data ranges, as modified from Clark and Fritz (1997, p. 185).

1. Less than about 0.8 tritium units (TUs)—Water represents ground water recharged before 1952 (submodern).
2. 0.8 to about 4 TU—Water represents mixture of submodern and recent (post-1952 recharge).
3. About 4 TU to about 15 TU—Water represents substantially modern recharge (post-1972). Smaller tritium concentrations in this range indicate more mixing with older ground water. Concentration of about 15 TU indicate that there was little or no mixing with older ground water.
4. Greater than about 30 TU—Water contains a significant proportion of synthetic tritium from post-1952 to about 1970 recharge.

Tritium concentrations in ground water will be compared with a record of decay-corrected tritium concentrations in precipitation from a long-term station at Ottawa, Canada (IAEA 2006) (Figure 7-1), to evaluate similarities and infer a likely range of ground-water age, expressed as the time of recharge.



**Figure 7-1. Average Monthly Tritium Concentration in Precipitation in Samples Collected from Ottawa, Canada, 1953-2002, and from Chicago, Illinois, 1962-1979**

## 7.2 GROUND-WATER AGE ESTIMATES USING CHLOROFLUOROCARBON COMPOUND CONCENTRATIONS AND DISSOLVED GAS CONCENTRATIONS

Ground-water age is defined as an estimated number of years since infiltrating water reached the water table and recharged the aquifer. Ground-water age estimates are apparent ages and can be based on interpretations of measured concentrations of CFCs in ground water and processes affecting the CFCs from entry into the aquifer with recharge until they are sampled. The following description of ground-water age-dating methods and their interpretation are paraphrased from Plummer and Busenberg (1999) and Rowe, Dunkle-Shapiro, and Schlosser (1999).

CFCs are stable, synthetic, halogenated alkanes that were developed in the early 1930s as refrigerants. Production of CFC-12 began in 1931, followed by CFC-11 in 1936. Many other CFC compounds, most notably CFC-113, have been produced since. Precipitation that recharged the aquifer within the past 50 years is assumed to have contained CFCs. The concentrations of the CFCs in the atmosphere and in recharge have changed through the passage of time; these changes can be used to indirectly estimate ground-water age.

To compute the age of a ground-water sample, concentrations of each CFC compound in a water sample are divided by the appropriate Henry's Law constant. This result gives the partial pressure of the compound in air from the unsaturated or "vadose" zone above the water table when water infiltrated below the water table and became isolated from the atmosphere. The solubility ( $C$ ) of a CFC compound ( $D$ ) relates to the equilibriums between gas and water phases, as described by Henry's Law:

$$C_D = K_{D(T,S)} \times P_D$$

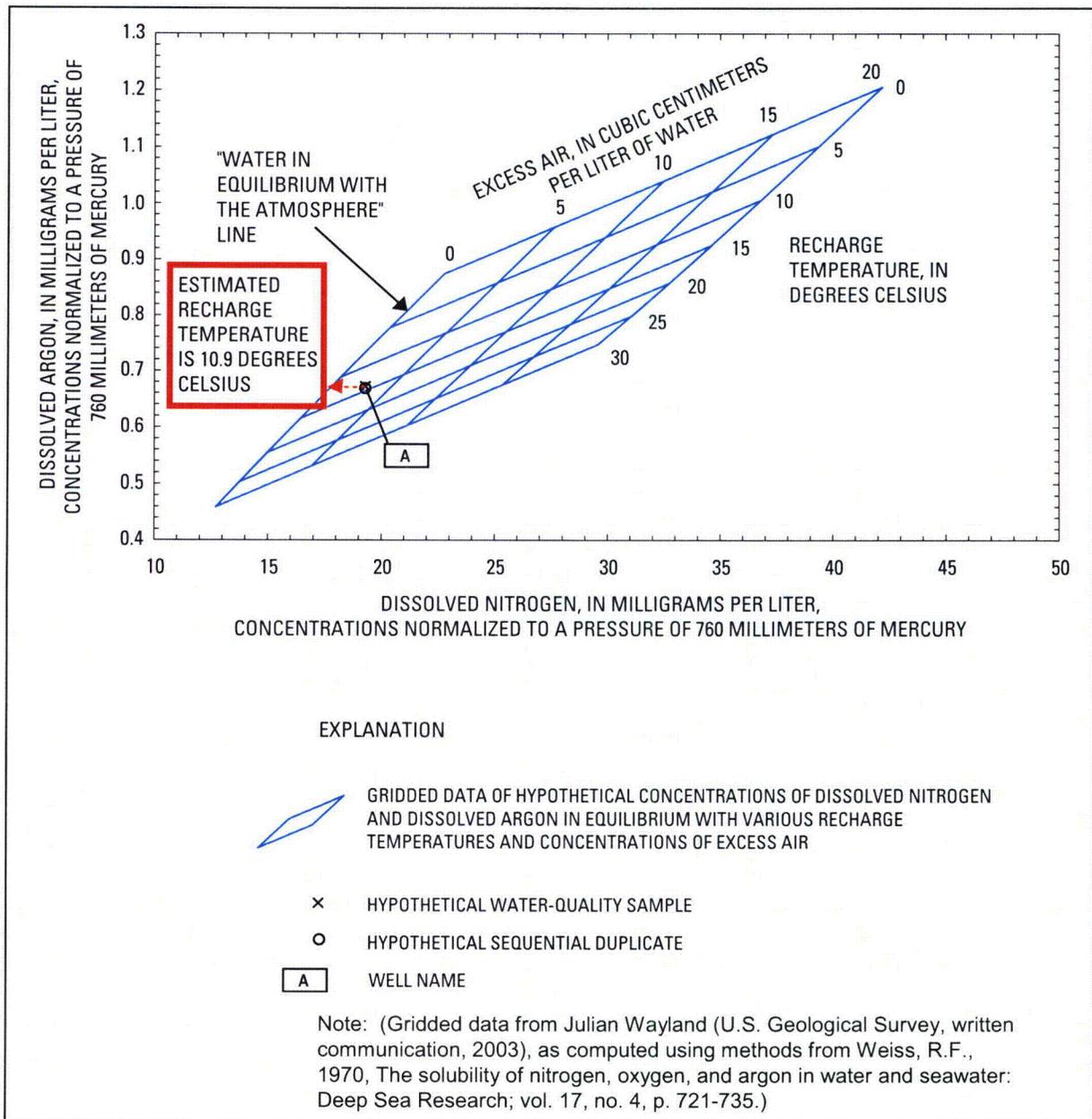
where:

$K$  = the Henry's law constant for the dating compound at a defined average recharge temperature ( $T$ ) and salinity ( $S$ ) and

$P$  = the partial pressure, under atmospheric conditions (Schwarzenbach, Gschwend, and Imboden 1993), of the respective CFC compound.

The solubility of dissolved gases (such as CFCs, argon, and nitrogen) depends on the average recharge temperature of the ground-water sample. For this study, two average recharge-temperature estimates may be computed to estimate ground-water age: (1) the average recharge temperature derived from dissolved-gas measurements, and (2) a fixed recharge temperature equal to the average annual air temperature for Madison, Indiana (MRCC 2008). The latter method may be used because typical recharge temperatures for modern ground water can be generally close to the average annual air temperature (within about 1 to 2°C; Rowe, Dunkle-Shapiro, and Schlosser 1999, p. 35).

Recharge temperatures are typically estimated with the ratio of DO to argon gas in water samples (Rowe, Dunkle-Shapiro, and Schlosser 1999). The concentrations of nitrogen and argon in water infiltrating below the water table may be expected to be in equilibrium with the atmosphere at the prevailing surface pressure and temperature (Heaton and Vogel 1981). Nitrogen and argon concentrations are typically normalized, using an assumed recharge altitude to a pressure of 760 mm of mercury, to limit altitude effects on comparison of gas solubility. Nitrogen and argon concentrations in ground water also may be corrected for the amount of "excess air" introduced into ground water when infiltrating ground water entraps air in bubbles that ultimately are carried below the water table and incorporated into the dissolved gas content of ground water (Heaton and Vogel 1981). Excess air refers to the volume of dissolved gas present in a liter of ground water in excess of that predicted by an equilibrium of infiltrating water with the atmosphere. Recharge temperatures then were estimated by comparing the normalized concentrations of nitrogen and argon gas with a plot of nitrogen-argon solubilities in water at 760 mm of mercury with excess air contents ranging from 0 to 20 cm<sup>3</sup>/kg of water (as described by Heaton and Vogel 1981), using gas-solubility data from Weiss (1970) (Figure 7-2).



**Figure 7-2. Recharge Temperature Grid with Hypothetical Concentrations of Dissolved Nitrogen and Dissolved Argon at Various Recharge Temperatures and Concentrations of Excess Air in Water Samples**

Excess nitrogen in a water sample can affect the CFC-based estimate of ground-water age. Excess nitrogen can originate from biogeochemical processes in an aquifer, such as denitrification. Denitrification produces more nitrogen gas than would be dissolved if the water were in equilibrium with soil gas at the time of recharge. Excess nitrogen in a sample must be subtracted from the amount of excess air to account for the overestimate of excess air in that sample so that a proper estimate of the amount of each CFC in recharge to ground water can be computed.

The calculated partial pressures of CFCs in each water sample, corrected for the amount of excess air in the sample, are then compared with the reconstructed record of atmospheric concentrations of each CFC compound throughout the period of record (Figure 7-3) to infer the age of each water sample (Rowe,

Dunkle-Shapiro, and Schlosser 1999). Interpretations of ground-water age depend on the assumption that CFC concentrations in infiltrating water are in equilibrium with gases in the soil and that those CFC concentrations are equal to those in the atmosphere (Rowe, Dunkle-Shapiro, and Schlosser 1999). This assumption is generally reasonable when the depth to ground water is shallow.

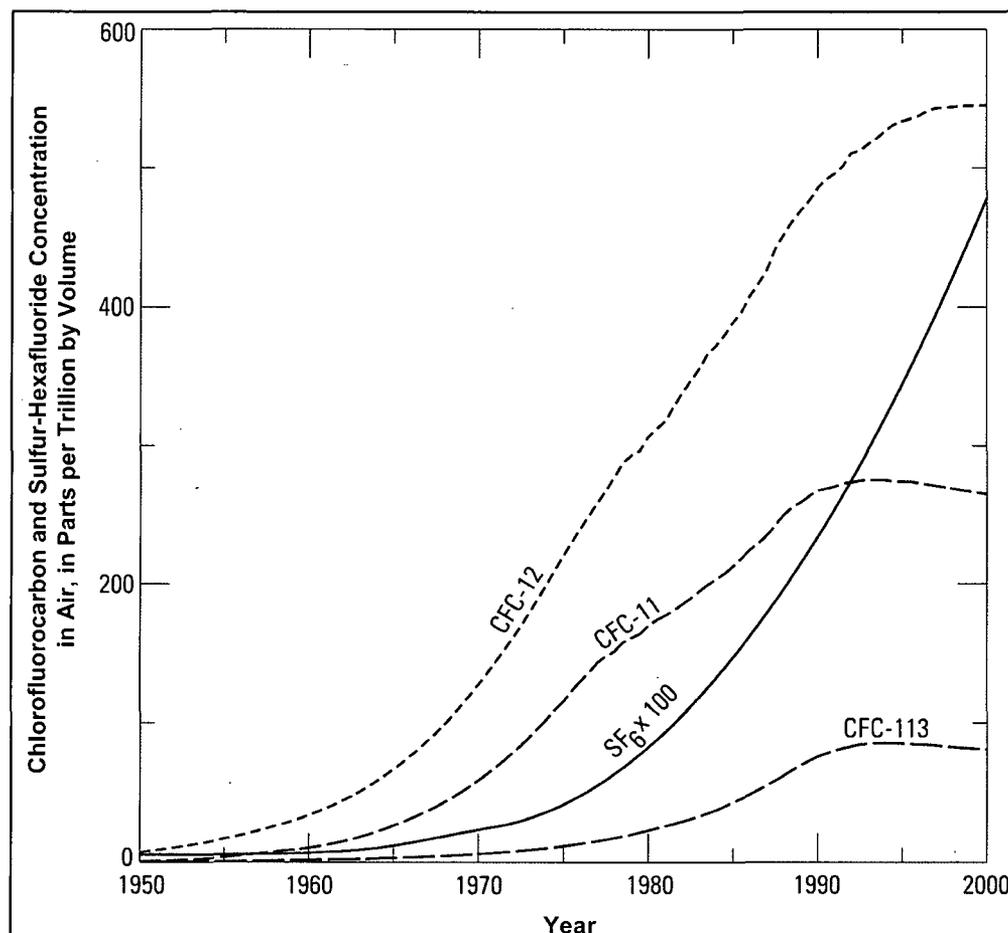


Figure 7-3. Atmospheric Concentrations of Dichlorodifluoromethane (CFC-12), Trichlorofluoromethane (CFC-11), Trichlorotrifluoromethane (CFC-113), and Sulfur Hexafluoride (SF<sub>6</sub>) for Air in North America

### 7.3 GROUND-WATER AGE ESTIMATES USING TRITIUM/HELIUM-3

The following discussion is from Nelms et al. (2003). The <sup>3</sup>H/<sup>3</sup>He method is based on the radioactive decay of <sup>3</sup>H to <sup>3</sup>He such that the helium isotope mass balance is used to determine the amount of tritiogenic <sup>3</sup>He (<sup>3</sup>He *trit*) derived from <sup>3</sup>H (Schlosser et al. 1988 and 1989). If the <sup>3</sup>He *trit* is confined in the aquifer, apparent <sup>3</sup>H/<sup>3</sup>He ages of the water samples (τ) can be calculated from the following formula (Schlosser et al. 1988 and 1989):

$$\tau = T_{1/2} / \ln 2 \times [1 + (^3\text{He } \textit{trit} / ^3\text{H})] \quad (1)$$

where:

$T_{1/2}$  = the half-life of tritium.

Neon (Ne) concentrations are used to correct  $^3\text{He}$  *trit* for samples that contain terrigenic helium ( $^4\text{He}$ ) from crustal and mantle sources such as crystalline rocks. More detail concerning interpretations of ground-water age estimates using tritium/helium-3 is found in Schlosser et al. (1988 and 1989).

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## **8: OBJECTIVES AND SCOPE OF THE FLOWMETER MEASUREMENTS**

The Army and its contractor, SAIC, are actively investigating the hydrogeologic framework north of the firing line. The Army and SAIC have implemented surface-water discharge and springflow monitoring at gaged sites near and downgradient from the DU Impact Area. Additional observation wells have been installed in unconsolidated overburden, and in shallow and relatively deeper zones within carbonate bedrock underlying the area. The wells were installed to provide information to further refine the CSM and to provide locations for sampling ground water and monitoring ground-water levels in these zones.

### **8.1 DESCRIPTION OF PROBLEM**

Local flow directions measured with flowmeters have been shown to vary from regional directions computed from water-level measurements (Vroblesky, Petkewich, and Casey 2001; AquaVISION 1999). This is especially true in karst settings. For example, ground-water velocities computed using water-level data and hydraulic properties averaged over the entire screened (or aquifer) thickness can be much slower than actual flow rates through thin but highly permeable strata and features. Therefore, the transport of contaminants of concern can be faster than rates estimated using water-level data only; the former is measurable with flowmeters. Flowmeter measurements of ground-water flow rates and directions also can be affected by the location of well screens relative to preferential ground-water flow paths in an aquifer. Flowmeter measurements can supplement water-level data based interpretations of flow direction and velocity and assist in interpreting local flow characteristics and ground-water quality.

As part of Work Breakdown Structure (WBS) 2.2.5 of planned field work (SAIC 2004), the Army has requested USGS to measure ground-water flow directions using ground-water flowmeter technology and compare those measurements to conventionally interpreted flow directions. USGS previously used several borehole flowmeter measurement techniques in wells south of the firing line at JPG (Wilson et al. 2001) and has since been testing horizontal flowmeters in a laboratory setting to evaluate their performance (Bayless, Mandell, and Pedler 2005). Measurements of borehole geophysical parameters (natural gamma and electromagnetic-induction logging) and borehole camera logs are planned to provide supporting information with available well log information to refine and target flowmeter measurement intervals.

This work is directed to characterize whether ground-water flow directions in the DU Impact Area at JPG may locally differ from those that would be predicted from mapping of water-table or potentiometric surfaces using ground-water altitudes measured at wells. Measurements of ground-water levels, natural gamma radiation and electromagnetic-induction borehole-geophysical logs, camera logs, and horizontal flowmeter measurements will be taken in approximately 20 wells installed by SAIC in May-June and November-December 2007 (the SAIC wells). Well logs and well construction diagrams for the wells installed by SAIC in May-June and November-December 2007 will provide information about hydrogeology and the construction and location of well screens relative to fractured and dissolution modified intervals in the carbonate aquifer.

### **8.2 HYDROGEOLOGIC SETTING**

Background hydrogeologic information for the study area will be obtained predominantly from previous studies and ongoing studies of site hydrogeology by SAIC and others. The following information about site geology was compiled from Greeman (1981) and Sheldon (1997).

Limestone and dolomite in Jennings County and JPG can be grouped into upper and lower sequences (Greeman 1981, p. 10-11). Discontinuous Silurian shale, as thick as 12 ft, separates the upper and lower sequences in some areas. The upper sequence and the shale have been eroded from the entire proving ground. The lower limestone-dolomite sequence is of Silurian age and 50 to 60 ft thick, except

where erosion has thinned or removed it. A fine-grained, thick-bedded dolomite unit, containing numerous chert nodules, forms a resistant protective cover for the lower sequence. In outcrop, the lower sequence forms a low relief plain that underlies the proving ground. Beneath the lower limestone-dolomite sequence are thin, interbedded, argillaceous limestone and shale beds of Ordovician age that crop out along several stream channels on the east side of this area. Karst features, including caves, sinks and closed depressions, have been identified in and around the DU Impact Area adjacent to Big Creek (Sheldon 1997).

### **8.3 OBSERVATION WELLS TO BE CONSIDERED FOR FLOWMETER MEASUREMENTS BY THIS STUDY**

A total of 23 observation wells were installed by SAIC during the period May through December 2007 at sites where fracture trace analysis and surface electromagnetic imaging techniques had indicated the potential presence of subsurface voids capable of transmitting ground water (Figure 3-1). Three types of wells were installed by SAIC at 10 sites. Several wells were completed in an unconsolidated overburden above the carbonate bedrock (unconsolidated overburden observation wells). Observation wells also were installed at 10 sites in the top portion of bedrock with shallow fractured and dissolution modified intervals in the carbonate bedrock (shallow bedrock observation wells). Additional wells were installed at the eight sites with well screens deeper within the carbonate bedrock where indications suggested that permeability was present to support a functional monitoring well (deep bedrock observation wells).

Well screens used for the observation wells were a Schedule 40 dual wall (U-pack) design, as described in FSP Addendum 4 (SAIC 2007). These well screens were selected to limit the infiltration of fine (silt and clay sized) particles into observation wells and to aid in the proper placement of well screen and filter pack in areas where difficult drilling conditions exist as are expected during the well installation task. Prior well installations at JPG with single wall well screens had substantial infiltration of fine sediment particles into the well bore. The velocity of ground-water flow through the U-pack well screen may be restricted by the sand pack between the inner and outer well screens, relative to a hypothetical, open fracture or dissolution modified void. In addition, measurements of other hydrogeologic properties through U-pack well screens, such as by aquifer or slug tests, may differ from formation values (Bartlett et al. 2004, p. 38). Ground-water flow velocity directions and magnitudes reported by this study therefore will be referred to as "relative ground-water flow velocity."

Several criteria will be used to indicate the suitability of wells to sustain measurable flow rates for borehole flowmeter measurements and to select a suitable flowmeter tool for those measurements.

1. If water levels have not recovered in a well since post-installation pumping and development, very low or no-flow conditions are likely. In that case, no flowmeter measurements will be taken in that well.
2. If ground-water levels have been observed to vary in periodic measurements, measurable flows through the well screen are likely and flowmeter measurements will be taken.
3. If the borehole-camera log of a well indicates very clear water, sufficient visible colloids may not be present to enable a flow measurement using a colloidal borescope flowmeter (AquaVISION Colloidal Borescope System). In that case, a secondary, heat pulse based tool, the K-V Associates Model 200 GeoFlo<sup>®</sup> Ground-water Flowmeter (the heat pulse flowmeter [HPFM]) will be used for flow measurements.

Twenty-three SAIC wells are available, but fewer wells may be deemed to be suitable for these measurements, based on the above criteria and hydrologic observations.

## 8.4 DECISION STATEMENT

If flowmeter based ground-water flow directions differ substantially from flow directions inferred from mapping of water-table or potentiometric surfaces, the information would indicate that heterogeneities in carbonate aquifer permeability may create locally different pathways for transport of potential contaminants. Similarity in flowmeter-based ground-water flow directions and flow directions inferred from mapping of water-table or potentiometric surfaces reduces the likelihood of different flowpaths affecting transport of potential contaminants in ground water. Changes in flowmeter-based flow directions between high and lower water level conditions at selected wells would indicate whether local flow directions vary with hydrologic conditions. That information can be used to evaluate the feasibility of transport pathways for potential contaminants in ground water.

## 8.5 RESOURCES, COORDINATION WITH SAIC, AND SCHEDULE

The resources to conduct this investigation have been provided to USGS by the Army under a USACE Military Interdepartmental Procurement Request. Field investigation activities will be conducted by USGS jointly with SAIC. USGS will provide the necessary technical expertise and resources to the flowmeter investigation, based on the project technical requirements and schedule. In addition, SAIC, through its activities outlined in the FSP Addendum 5 and preceding activities and associated HASPs, will provide the necessary technical expertise and resources to support the field activities and site information needs of this project, based on their technical requirements and schedule in the FSP Addendum 5.

The overall project schedule of activities is summarized in Table 8-1. As project priorities are established and/or adjusted by the Army in coordination with NRC, they may adjust the project schedule to meet these priorities.

**Table 8-1. Planned Project Milestones for Flowmeter Study and Related Items  
Jefferson Proving Ground, Madison, Indiana**

Deliverable/Activity	Date
FSP Addendum 5 (SAIC)	January 2008 (complete)
FSP Addendum 6 (USGS)	March 2008
Ground-Water, Surface-Water, and Sediment Sampling (SAIC)	April, July, and October 2008 and January 2009 (included for reference only)
USGS borehole geophysics measurements with SAIC health and safety support (USGS)	To be determined; April 2008 or earlier
Transmittal letter with preliminary results of borehole geophysical logging and decisions about which wells and intervals are suitable for flowmeter logging (USGS)	One month after post processing of logs complete (May 2008)
Laboratory calibration of heat-pulse flowmeter for anticipated carbonate and unconsolidated aquifer correction factors	April-May 2008
USGS borehole flowmeter measurements with SAIC health and safety support	May 2008 (relatively wet conditions) and August 2008 (relatively dry conditions)
Transmittal letter with preliminary results of borehole geophysical logging and decisions about which wells and intervals are suitable for flowmeter logging (USGS)	One month after conclusion of second set of flowmeter logs (planned September 2008)
Draft USGS-series report prepared for technical review by SAIC and Army staff. (Estimated review time: 6 weeks)	Provided by the USGS to reviewers within 12 weeks after completion of the last flowmeter measurements (December 2009)
Final USGS-series report will be prepared for release to NRC (public release later)	Planned for May 2009

This FSP assumes that USGS will work under and meet the requirements specified in the Army/SAIC HASP. USGS field activities will be coordinated with the Army and SAIC. USGS staff will be accompanied by Army or SAIC staff when traveling to and from well sites and when working at individual well sites. USGS work will be restricted to travel to and from well sites on established roads and work at existing wells within the established safe work area. The Army/SAIC will provide oversight by a UXO technician and site-specific training to enable USGS staff to avoid UXO.

Amplified details of several of these work tasks are outlined below.

1. Laboratory calibration of HPFM flowmeter for anticipated carbonate and unconsolidated aquifer correction factors (1 week). The purpose of the laboratory testing is to derive a multiplier value to convert in-well bore flow estimates to relative ground-water flow estimates.
2. In May 2008 after the SAIC wells have been developed, USGS will access wells for initial flowmeter measurements (est. 20 working days). In addition, USGS will measure water levels in the SAIC wells at the beginning of each week of flowmeter measurements and after significant hydrologic events (at the discretion of the USGS FS). Those readings will be used to compute water-level elevation using measuring point/land surface altitude data supplied by SAIC).
3. In August 2008 (relatively dry conditions), a second set of measurements will be taken from three to five of the SAIC wells to evaluate changes in flow directions.
4. In September 2008, flowmeter and water-level data will be recorded, and preliminary flow directions will be transmitted to the Army/SAIC.
5. In December 2008, a draft USGS report comparing flowmeter-based directions with hydraulic-head based directions in high and low water-level conditions will be prepared and delivered to the Army/SAIC and USGS.
6. USGS/Army/SAIC will conduct technical reviews and USGS will conduct editorial and policy reviews, with USGS approval under this work plan anticipated by April 2009 (12 to 16 weeks).
7. Final formatting and release of the USGS report to the Army will be conducted by the USGS Enterprise Publishing Network by the end of May 2009.

## 9. HYDROGEOLOGIC, GEOPHYSICAL AND FLOWMETER MEASUREMENTS

This section summarizes the measurements to be made by USGS in connection with the flowmeter measurements of ground-water flow direction, in cooperation with SAIC, at JPG starting in the spring of 2008. Hydrologic data, including water-level measurements that will be taken before and during sampling, also will be collected by SAIC; that activity is described in Section 5.1 of the FSP Addendum 5 (SAIC 2008).

Sections 4.1 through 4.3 of this FSP describes the procedures and general supplies to be used to measure ground-water levels, complete borehole geophysical logs and camera logs, and conduct borehole flowmeter logging.

### 9.1 GROUND-WATER-LEVEL MEASUREMENTS

Ground-water-level measurements will be made in the SAIC observation wells before geophysical measurements are made and at additional times selected by the USGS site hydrologist. During the period when flowmeter measurements are made, synoptic water-level measurements will be made in all SAIC wells used for flowmeter measurements at the beginning and end of each week and after significant hydrologic events. These will be used to establish whether flow conditions in the aquifer have changed during the period of measurement.

Water levels will be measured using a modified version of USGS procedure GWPD 4 (Water-Level Measurement Using an Electric Tape ([http://water.usgs.gov/usgs/ogw/tech\\_proc/GWPD.4.pdf](http://water.usgs.gov/usgs/ogw/tech_proc/GWPD.4.pdf), accessed January 8, 2008). Land surface datum and measuring point altitudes will be obtained from survey data compiled by SAIC. The measuring tape (a Solinst model electrical tape) will be rinsed before and after measurements using a deionized water rinse to eliminate the possibility of cross-contamination between wells; no bleach will be used.

Water-level data and basic observation well data will be entered into the USGS National Water Information System database. A description of these data that will be entered can be found at (Martin and Cohen 1994, p. 8-9)

### 9.2 BOREHOLE GEOPHYSICAL LOGGING

Borehole geophysical methods will be used to make a log of measurements along the axis of observation wells completed in boreholes drilled for this study. Geophysical logs have several attributes that benefit classification of aquifer characteristics (Paillet and Crowder 1996, p. 884-886):

1. Geophysical logs are a continuous series of measurements with depth, each made in the same way with the same equipment.
2. There is little opportunity for misplaced or missing data.
3. Characteristics of the undisturbed geologic formation around the borehole are measured.
4. More than one geophysical property can be measured independently from a well or borehole and the relation between the properties can be analyzed to reveal aquifer or geologic characteristics.

Three types of borehole geophysical logs will be made in selected wells at the 10 SAIC well sites. These logs include natural-gamma radiation and electromagnetic-induction borehole-geophysical logs, and borehole camera logs. Borehole logs of electromagnetic-induction-resistivity and natural-gamma radiation will be made to provide information about geologic formation characteristics outside the immediate borehole to supplement data from geologic cores collected by SAIC during drilling. Natural-gamma radiation and electromagnetic-induction borehole-geophysical logs will be measured in the well at each SAIC site with the greatest depth. Borehole camera logs will be collected to document well screen

intervals and construction characteristics relative to planned intervals for flowmeter logging in all wells at each SAIC well site.

### **9.2.1 Natural-Gamma Radiation Logging**

A natural-gamma log provides a record of the total gamma radiation detected in a borehole or well casing that is within a selected energy range (Keys 1990). The natural gamma probe uses a sodium iodide crystal that emits a pulse of light when struck by a gamma ray. The pulse of light is amplified by a photomultiplier tube that outputs a current pulse. The winch cable transmits the current pulses from the probe to the logging controller. A laptop computer and logging software records the counts per second of gamma radiation for each 0.1 ft of depth (Mt. Sopris 1996).

Gamma radiation is emitted by naturally occurring, gamma-emitting daughter products of the uranium- and thorium-decay series and from the decay of potassium-40. Fine grained detrital sediments that contain a relatively large proportion of clay, such as shale, tend to emit more gamma radiation than limestone (Keys 1990). Uranium and thorium are concentrated in clay by the processes of adsorption and ion exchange and potassium is abundant in some feldspar and mica that decompose to clay (Keys 1990). The natural gamma log cannot distinguish between gamma radiation from natural and artificial sources.

Typically, 90 percent of the gamma radiation detected by a natural gamma log probably originates from within 6 to 12 in. of the borehole wall (Keys 1989). The volume of material contributing to the measured signal may be considered approximately spherical, with no distinct boundary at the outer surface. A natural gamma log can be used above and below the water table and maintains a consistent log form between the two conditions (Bleuer 2004).

Natural gamma logs will be run in the deepest well at each site installed by SAIC in 2007. Standard Methods will be used in all measurements made (Keys 1990). Logging will be conducted using a Mount Sopris Instruments model 2PGA-1000 Natural Gamma, Spontaneous Potential, Single Point Resistance multifunction tool attached by wireline to a MGX drawworks and processed using personal computer-based Logshell software. Logging will be conducted at an approximate time speed of 10 ft/min; digital gamma radiation data will be acquired and stored in ASCII files. The top of the cable head makeup will be placed at land surface and the software will be given a setting of zero ft. During post processing, the length of the top of the cable head makeup to the probe sensor, and the height of the top of casing above land surface will be used to correct the log data to depth below land surface. Preliminary logging will be conducted as the tool is lowered downhole until the tool contacts the bottom of the well; uphole logging then will be done from the bottom of the well to land surface. The uphole log is the log of record unless otherwise noted.

### **9.2.2 Electromagnetic-Induction Logging**

An electromagnetic induction borehole log measures the ability of the aquifer materials and ground water in the vicinity of a well to conduct electricity. The electromagnetic conductivity measured by the tool relates to the concentration of dissolved solids in ground water and the content of conductive geologic materials, such as clay or shale, in the aquifer material (Keys 1990, p. 66). In carbonate rock, the electromagnetic conductivity within a fractured or dissolution modified zone is in general higher than the electromagnetic conductivity of the host rock (Ernstson and Kirsch 2006), whether in water-filled or dry fracture zones. Clay mineral filling in a fractured or dissolution modified zone also can increase electromagnetic conductivity values and may reduce the hydraulic conductivity of the pore space. It is therefore important to measure natural gamma counts in boreholes to indicate whether a large electromagnetic conductivity value indicates open or clay-filled porosity.

Operating principles for the electromagnetic-induction log were described by McNeill (1986). An alternating current is sent through the transmitter coil in the electromagnetic-induction probe, which

creates a primary magnetic field that is transmitted into the surrounding geologic formation. The primary magnetic field induces loops of eddy currents that induce a secondary magnetic field, both of which induce current voltage in a receiver coil in the probe. A second receiver coil in the probe helps to focus the primary magnetic field.

Borehole logs of electromagnetic conductivity will be made by lowering and raising a Mt. Sopris Instrument Co., Inc., Model 2PIA-1000 poly-induction probe (also known as a Geonics Limited EM-39 slimline induction tool) into and out of each logged well at about 10 ft/min with a logging controller and cable winch. A laptop computer and logging software will record the electromagnetic conductivity in millisiemens per meter (mS/m) for each 0.1 ft of depth (Mt. Sopris 1996). The probe measures the electromagnetic conductivity at a radial distance ranging 20 to 100 cm (approximately 8 to 39 in.) from the vertical axis of the well. The probe is most sensitive at a radial distance of 30 cm (approximately 1 ft). The measurements are not affected appreciably by water in the well or by plastic well casing (McNeill, Bosnar, and Snelgrove 1990). Each day, the conductivity probe will be equilibrated to the ambient downhole temperature in the well casing and calibrated according to the manufacturer's instructions before each use. The uphole log is the log of record unless otherwise noted.

### **9.2.3 Borehole Camera Logging**

A borehole camera log will be made on each well to inspect the condition of well casing and screen and the orientation of slotted sections on the well screen of each observation well. This inspection is needed to:

1. Verify well construction details
2. Identify obstructions that could interfere with geophysical and flowmeter logging
3. Identify the orientation of the slotted sections of well screen for interpretation relative to flowmeter measurements
4. Identify visible colloids that could be used to measure flows.

Each well will be camera logged using a Geovision Jr. color borehole camera. Data will be saved to an Apple iMac laptop computer running a version of iMovie software. The data will be saved to DVD-read only format media.

### **9.2.4 Post-Processing of Borehole Geophysical Data**

Digital records from the natural gamma and electromagnetic induction logs will be checked for proper referencing to land surface. Electromagnetic induction log data will be inspected for overscale values; those will be compared with borehole camera measurements and well logs to indicate the location of metallic screws near the top of the U-pack screens. Those electromagnetic conductivity data will be censored and removed from the analysis. Digital data from the same depth in a well will be cross plotted to reveal depths where relatively lower values of natural gamma counts and relatively higher values of electromagnetic conductivity coincide. That pattern may indicate open or water-filled fractures or voids in bedrock. Those data also will be compared with geologic logs compiled during drilling to indicate the presence or absence of open fractures or dissolution features.

## **9.3 BOREHOLE FLOWMETER LOGGING**

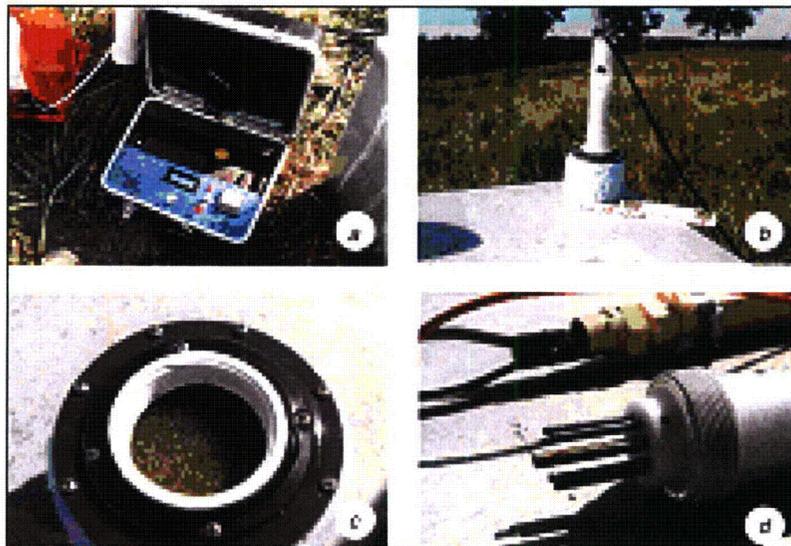
The initial USGS plan for flowmeter logging of observation wells is to make flowmeter measurements in 20 proposed wells at 10 nested sites around the DU Impact Area. A total of 23 wells have been installed by SAIC as part of the current project. The primary flowmeter to be used for groundwater flow velocity and orientation measurements in these wells is the AquaVISION Colloidal Borescope System ([http://www.aquavisionenv.com/files/colloidal\\_borescope\\_flyer.pdf](http://www.aquavisionenv.com/files/colloidal_borescope_flyer.pdf)). A secondary tool, the K-V

Associates Model 200 GeoFlo® Groundwater Flowmeter (now Kerfoot Technologies, <http://www.kva-equipment.com/product.php?26,0,300605p,ker299637,,Index>), will be used in wells that lack sufficient optically visible colloids for colloidal borescope flowmeter measurements.

The AquaVISION colloidal borescope flowmeter (CBFM) is used to evaluate horizontal ground-water flow direction and velocity (Bayless, Mandell, and Pedler 2005). The CBFM employs a charge coupled device (CCD)-based camera, magnetometer, light emitting diode (LED) light source, and a fixed focal point magnifying lens mechanism to track optically visible colloid-sized particles. Naturally occurring colloids move advectively with the native ground-water flow system. By recording the output of the CCD and using particle-tracking computer software (AquaLite, v.1.0), the compass direction and advective velocity of horizontal ground-water flow in a well can be evaluated. An illustration and product sheet that describes the components and attributes of the CBFM can be assessed at [http://www.aquavisionenv.com/files/colloidal\\_borescope\\_flyer.pdf](http://www.aquavisionenv.com/files/colloidal_borescope_flyer.pdf).

The KVA HPFM uses ground-water transport of an emitted heat pulse to compute horizontal ground-water flow rates and directions (Bayless, Mandell, and Pedler 2005). The heat pulse is released from an emitting device that is surrounded by four high-resolution thermistors. Sequential measurements in the network of thermistors track the heat pulse as it leaves the borehole with flowing ground water. An integrated packer system isolates the tested aquifer interval and reduces nonlaminar flow created by the open borehole.

The KVA HPFM, as shown in Figure 9-1, is composed of a controller box or computer (a) connector rods and a probe (b). The packer system (c) uses glass beads to minimize borehole acceleration of ground water relative to the aquifer. A thermistor system (d) is embedded in the packer during deployment.



**Figure 9-1. KVA Heat-Pulse Flowmeter**

Wells installed for this project were to have well screens that were 10 ft in length. Preliminary plans are to measure flow at a maximum of five locations within each well screen, typically at 2-ft intervals, extending from 1 to 9 ft below the top of the screen. These measurement locations will change, based on the indications of large voids in the geologic formation outside the well screen from geophysical or drilling evidence.

### **9.3.1 Colloidal Borescope Measurements of Ground-Water Flow**

The following is the description and procedure for CBFM measurements, as reproduced from Wilson et al. (2001, p. 13-16). The colloidal borescope uses a CCD video camera to view optically visible colloids in the ground water. The borescope is lowered into a well by a winch; a depth encoder on the winch records the depth of the borescope.

The colloidal borescope consists of a charged couple device camera, a flux-gate magnetometer, an optical magnification lens, an illumination source, and stainless-steel housing. The housing is approximately 24 in. long and has a diameter of 1.7 in. During operation, as optically visible colloids in the ground water pass beneath the camera lens, a light-emitting-diode backlighting source illuminates the colloids, similar to a conventional microscope with a lighted stage. An electronic image of the colloids flowing past the view of the camera is magnified 140 times and transmitted to the surface. A video-frame grabber digitizes individual video frames at intervals selected by the operator. Computer software compares two digitized video frames, matches particles from the two images, and assigns pixel addresses to the particles. Only particles that remain in focus across the field of view (indicating horizontal flow) are analyzed. A flux-gate magnetometer (compass) is incorporated into the system to reference flow directions to magnetic north. Using this information, the software computes and records the average particle size, number of particles, speed, and direction. The system is capable of analyzing flow measurements every 4 seconds, resulting in a large data base after only a few minutes of observations. The colloidal borescope is capable of measuring velocities from essentially stagnant, zero-flow conditions to 7,085 ft/d (25 mm/s) (AquaVISION 1999).

This work will emphasize flow measurements for zones that display consistent horizontal laminar flow in a steady direction over a substantial time period. Swirling-flow zones are commonly observed because of adjacent low-permeable sediments, skin effects, vertical-flow gradients, or nearby preferential flow zones that can dominate flow in the observed zone (Kearl 1997).

The following is the general procedure for colloidal borescope measurements.

1. Arrive at well and open casing.
2. Measure initial ground-water level in well.
3. Lower CBFM tool by optical cable and winch system to shallowest measurement depth, wait 5 min for borehole conditions to stabilize.
4. Monitor CBFM data output for sufficient colloids and consistent flow direction and velocity (nonswirling flow) conditions. If flow direction and velocity are consistent, acquire data for 15 to 30 min. If swirling conditions do not abate after 5 additional min, move to next measurement position. If sufficient colloids are not detected, move to next measurement position.
5. Repeat procedure for each measurement depth until all measurements collected.
6. Remove tool from borehole, rinsing probe and cable with deionized water between emergence from well casing and spooling onto cable.
7. Measure final ground-water level.
8. Archive raw data files onto dated CD at end of each work day.

### **9.3.2 Heat-Pulse Flowmeter Measurements of Ground-Water Flow**

The following is the procedure for HPFM measurements, as reproduced from Wilson et al. (2001, p. 9-12). The HPFM is operated by inserting the probe into a borehole at the selected measurement depth. The probe is operated electrically by software running on a personal computer. The flowmeter is attached to lightweight aluminum rods used to move the probe up and down the well and determine depth. The

end of the probe is threaded into a porous shroud or “fuzzy packer” filled with glass beads that surround the heat source and thermistors (Figure 9-1). Once the probe is inserted into a well, ground water saturates the pore space between the glass beads so that the heat source and thermistors are surrounded by ground water and glass beads and are hydraulically connected to the borehole wall or screen by the fuzzy packer. The fuzzy packer is constructed of a section of PVC pipe with many uniformly spaced holes. A screen covers the sides and bottom; plastic polymer pile is attached to the outside of the screen and exterior side walls; uniform-sized glass beads of known porosity and hydraulic conductivity fill the interior. Measurements of ground-water flow are taken in a controlled environment where ground water flows from the external media through the fuzzy packer back to the external media. The top of the fuzzy packer, where the probe is attached, is solid PVC that blocks vertical flow through the probe as long as the fuzzy packer fits snugly against the borehole wall.

When the HPFM is on, each thermistor continuously sends its voltage-based temperature to the software on the laptop computer. The software routes the incoming thermistor information and delivers a machine-unit readout that represents the arithmetic difference between diametrically paired thermistors. Each set of diametrically paired thermistors is positioned during construction of the probe to geometrically subdivide a horizontal plane into equal parts, totaling 360 degrees in a circle (Figure 9-1). Magnetic north at each site is obtained by fitting a compass to the top of the connecting rods that hold the flowmeter probe in place; a particular pair of thermistors on the probe then is referenced to magnetic north. Consequently, each pair of thermistors corresponds to a designated geographic direction.

Following placement of the probe, the water column in the borehole is allowed to reach equilibrium before measurements are made. Equilibrium is determined when changes in the machine-unit readout minimize over time and the water level stabilizes. After equilibrium is achieved, an initial set of machine-unit readings is recorded.

Immediately following, the operator initiates a test through the software; the device creates a single point source heat pulse at the center of the probe inside the fuzzy packer. The heat pulse lasts for a designated time (generally 30 sec), after which the dissipation or convection of the heated water is measured for 3 min. After the initial readings and activation of the heat pulse, the heat spherically dissipates in the water from the heat source through the glass beads in the fuzzy packer. Under the additional force of ground-water flow in the borehole and fuzzy packer, however, spherical heat dissipation is shifted in the direction of ground-water flow. Consequently, the migration of the heat pulse is sensed as a larger increase in temperature by the thermistors in the direction of ground-water flow. The magnitude of heat transfer decreases with the cosine of the angle from the main axis of flow.

For sand-packed screens, hydraulic-conductivity and porosity corrections should be made to adjust HPFM probe readings to flow conditions in the aquifer. A set of controlled flow measurements will be made using the HPFM and the CBFM in a sample of pre-packed well screen used for the SAIC observation wells to develop adjustment factors. Procedures for this testing are described in Kerfoot (1988).

## 10. INTERPRETATION OF BOREHOLE FLOWMETER AND GROUND-WATER LEVEL-BASED FLOW DIRECTIONS

Flowmeter-derived directions of ground-water flow will be compared with directions of flow inferred from water levels measured in wells in the unconsolidated surficial aquifer material and carbonate aquifers. Preliminary plans are to construct two maps, one using water levels measured in the shallow bedrock observation wells (Section 3.3, this FSP) and a second using water levels measured in the deep bedrock observation wells. These plans depend on the amount of water level data available to support this type of interpretation. Water-level mapping will be conducted using methods consistent with those described by Heath (1983), as modified using concepts of karst hydrogeology described in Fetter (2001) and Bayless, Taylor, and Hopkins (1994). Water levels from wells where the water level did not recover after well development will not be used for this mapping.

Where the flowmeter-based ground-water flow directions agree with water level-based maps of water level gradients, they can validate confidence in using those data to define local and regional flow directions. Where flowmeter-based ground-water flow directions differ from water level-based maps of water-level gradients, the differences will be qualitatively evaluated relative to published information about lineament orientations from SAIC and Greeman (1981) and karst features near streams mapped by Sheldon (1997). These differences, although potentially related to local orientation of karst features, can be used to indicate the importance of karst heterogeneities in establishing ground-water flow directions. In both cases, the flowmeter measurements can indicate subsurface drainage patterns that assist in evaluating contributing areas for recharge to the subsurface flow system.

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## 11. INVESTIGATION-DERIVED WASTES

After age-dating samples are collected and daily field work is completed, investigation derived waste (IDW) generated by the sampling will be turned over to the Army for storage and disposal, as defined in Section 9 of the FSP Addendum 5 (SAIC 2008). No radioactive waste is anticipated to be generated under this work scope.

IDW generated during these sampling tasks will consist of decontamination liquids; paper, cardboard, and plastic bagging and containers from sampling materials; Tyvek® coveralls; disposable tubing; and disposable gloves. Ground water from well purging fluids (ground water) and decontamination fluids (if used) generated from equipment decontamination will be disposed of on the ground in the general area from which the materials originated.

Materials and any other wastes, if determined to be radioactive by SAIC, will be turned over to the Army and will be surveyed, packaged, stored, and transported in accordance with applicable regulations, and disposed of as normal solid waste if determined not to be radioactive. Any materials such as disposable gloves, Tyvek®, paper towels, paper and plastic bagging, containers from sampling materials, plastic sheeting, and disposable tubing will be surveyed or placed into plastic garbage bags and later surveyed by the Health Physics Technician (HPT) to determine if they are radioactive, and placed into roll-off containers supplied by the drilling contractor for disposal as normal solid waste if determined to not be radioactive.

If IDW disposal of materials generated by USGS activities is determined to be necessary, the Army will accept custody of those wastes from USGS. The wastes then will be property of the Army and the Army will be responsible to securely store and dispose of the wastes.

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**APPENDIX**

**FIELD DATA RECORD AND LABORATORY SUBMISSION SHEETS  
TO BE USED BY THIS PROJECT**

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U. S. GEOLOGICAL SURVEY GROUND-WATER QUALITY NOTES FIELD ID \_\_\_\_\_

NWIS RECORD NO \_\_\_\_\_

Station No. \_\_\_\_\_ Station Name \_\_\_\_\_ Field ID \_\_\_\_\_  
 Sample Date \_\_\_\_\_ Mean Sample Time (watch) \_\_\_\_\_ Time Datum \_\_\_\_\_ (eg. EST, EDT, UTC)  
 Sample Medium \_\_\_\_\_ Sample Type \_\_\_\_\_ Sample Purpose (71999) \_\_\_\_\_ Purpose of Site Visit (50280) \_\_\_\_\_ QC Samples Collected? Y N  
 Project No. \_\_\_\_\_ Proj Name \_\_\_\_\_ Project No. \_\_\_\_\_ Proj Name \_\_\_\_\_  
 Sampling Team \_\_\_\_\_ Team Lead Signature \_\_\_\_\_ Date \_\_\_\_\_

FIELD MEASUREMENTS

Property	Parm Code	Method Code	Result	Units	Re-mark Code	Value Qualifier	Null Value Qualifier	NWIS Result-Level	Comments
Water Level (see p. 5 for codes and units)									
Flow Rate	00059			gal/min					
Sampling Depth	72890 00003			ft b/w msl ft					
Depth to top of sampling interval	72015			ft b/w lsd					
Depth to bottom of sampling interval	72016			ft b/w lsd					
Temperature, Air	00020	THM04 (thermistor) THM05 (thermometer)		°C					
Temperature, Water	00010	THM01 (thermistor) THM02 (thermometer)		°C					
Specific Conductance	00095	SC001 (contacting sensor)		µS/cm					
Dissolved Oxygen	00300	MEMBR (amperometric) LUMIN (luminescent)		mg/L					
Barometric Pressure	00025			mm Hg					
pH	00400	PROBE (electrode)		units					
ANC, unfiltered, Incremental	00419	TT001		mg/L					
Alkalinity, filtered, Incremental	00365	TT013		mg/L					
Carbonate, filtered, Incremental	00452	TT019		mg/L					
Bicarbonate, filtered, Incremental	00453	TT017		mg/L					
Hydroxide, filtered, Incremental	71834	TT023		mg/L					
Turbidity (see attachment for codes)									
Redox potential (Eh)	53302			mvolts					
Hydrogen sulfide odor detected?	71875	SNIF1 (sniff test, acidified sample) SNIF2 (sniff test, unacidified sample)	#	Yes No	M detect U non-detect				Sample acidified beforehand? yes no
Hydrogen sulfide, unfiltered, measured	99119	ISE01 (electrode) KITE1 (Chemetrics) KITE2 (Hach)		mg/L					
Other									
Other									
Other									

SAMPLING INFORMATION

Parameter	Pcode	Value	Information
Sampling Condition*	72006		Sampler/Pump Type (make/model): _____
Sampling Method*	52305		Pump/Sampler ID: _____
Sampler Type*	84164		Sampler Material: stainless steel pvc teflon other _____
*see p. 8 for values			Tubing Material: teflon plastic tygon copper other _____
			Filter type(s): capsule disc 142mm 25mm GFF membrane

COMPILED BY: \_\_\_\_\_ DATE: \_\_\_\_\_ CHECKED BY: \_\_\_\_\_ DATE: \_\_\_\_\_ LOGGED INTO NWIS BY: \_\_\_\_\_ DATE: \_\_\_\_\_

**SAMPLING CONDITIONS**

Aquifer name \_\_\_\_\_ Depth pump set at: \_\_\_\_\_ ft blw lsd msl mp.

Sampling point description \_\_\_\_\_

GW Color: *brown gray blue green other* \_\_\_\_\_ GW Clarity: *clear turbid muddy other* \_\_\_\_\_

GW Odor: *yes no describe* \_\_\_\_\_

Sample in contact with: atmosphere oxygen nitrogen other \_\_\_\_\_

Weather: *sky-* clear partly cloudy cloudy *precipitation-* none light medium heavy snow sleet rain mist \_\_\_\_\_

*wind-* calm light breeze gusty windy est. wind speed \_\_\_\_\_ mph *temperature-* very cold cool warm hot

Observations:

Sample Comments (for NWIS; 300 characters max.):

**LABORATORY INFORMATION** Sample Set ID \_\_\_\_\_

**SAMPLES COLLECTED:**

Nutrients: \_\_\_WCA \_\_\_FCC \_\_\_FCA Major cations: \_\_\_FA \_\_\_RA Major anions: \_\_\_FU Trace elements: \_\_\_FA \_\_\_RA

Mercury: \_\_\_FAM \_\_\_RAM \_\_\_Wis. Hg Lab Lab pH/SC/ANC: \_\_\_RU

VOC: GCV (\_\_\_ vials) Organics: \_\_\_GCC filtered \_\_\_ unfiltered \_\_\_ C18 \_\_\_ Kansas OGRG Lab

Suspended solids: \_\_\_SUSO Turbidity: \_\_\_TBY

Phenols: \_\_\_PHE Oil&Grease: \_\_\_OAG Methylene Blue Active Substances: \_\_\_MBAS Color: \_\_\_RCB

Carbon: \_\_\_TPCN \_\_\_PIC filter1-vol filtered \_\_\_mL filter2-vol filtered \_\_\_mL filter3-vol filtered \_\_\_mL \_\_\_DOC \_\_\_TOC

Radon: \_\_\_RURCV (Radon sample collection time: \_\_\_\_\_) Stable isotopes: \_\_\_FUS \_\_\_RUS

Radiochemicals: \_\_\_FUR \_\_\_RUR \_\_\_SUR \_\_\_FAR \_\_\_RAR \_\_\_RURCT \_\_\_BOD \_\_\_COD

Other: \_\_\_\_\_ (Lab \_\_\_\_\_) Other: \_\_\_\_\_ (Lab \_\_\_\_\_) Other: \_\_\_\_\_ (Lab \_\_\_\_\_)

Other: \_\_\_\_\_ (Lab \_\_\_\_\_) Other: \_\_\_\_\_ (Lab \_\_\_\_\_) Other: \_\_\_\_\_ (Lab \_\_\_\_\_)

Microbiology: \_\_\_\_\_ (Lab \_\_\_\_\_)

Laboratory Schedules: \_\_\_\_\_

Lab Codes: \_\_\_\_\_ add/delete \_\_\_\_\_ add/delete \_\_\_\_\_ add/delete \_\_\_\_\_ add/delete \_\_\_\_\_ add/delete

Comments: \_\_\_\_\_

Date shipped: \_\_\_\_\_ Lab(s): \_\_\_\_\_

**\*\*Notify the NWQL in advance of shipment of potentially hazardous samples—phone 1-866-ASK-NWQL or email LabLogin@usgs.gov**

Comments:

Calibrated by: \_\_\_\_\_ Location: \_\_\_\_\_  
 Date: \_\_\_\_\_ Time: \_\_\_\_\_

FIELD ID \_\_\_\_\_

**METER CALIBRATIONS/FIELD MEASUREMENTS**

**TEMPERATURE** Meter make/model \_\_\_\_\_ S/N \_\_\_\_\_ Thermistor S/N \_\_\_\_\_ Thermometer ID \_\_\_\_\_

Calibration criteria:  $\pm 1$  percent or  $\pm 0.5$  °C for liquid-filled thermometers  $\pm 0.2$  °C for thermistors

Lab Tested against NIST Thermometer/Thermistor? Y N Date: \_\_\_\_\_  $\pm$  \_\_\_\_\_ °C

Measurement Location: FLOW-THRU CHAMBER SINGLE POINT AT \_\_\_\_\_ ft blw LSD VERTICAL AVG. OF \_\_\_\_\_ POINTS

Field Readings # 1 \_\_\_\_\_ #2 \_\_\_\_\_ #3 \_\_\_\_\_ #4 \_\_\_\_\_ #5 \_\_\_\_\_ MEDIAN: \_\_\_\_\_ °C Method Code \_\_\_\_\_ Remark \_\_\_\_\_ Qualifier \_\_\_\_\_

**pH** Meter make/model \_\_\_\_\_ S/N \_\_\_\_\_ Electrode No. \_\_\_\_\_ Type: GEL LIQUID OTHER \_\_\_\_\_

Sample: FILTERED UNFILTERED FLOW-THRU CHAMBER SINGLE POINT AT \_\_\_\_\_ ft blw LSD VERTICAL AVG. OF \_\_\_\_\_ POINTS

pH Buffer	Buffer Temp	Theoretical pH from table	pH Before Adj.	pH After Adj.	Slope	Millivolts
pH 7						
pH 7						
pH 7						
pH ____						
pH ____						
pH ____						
CHECK pH ____						

Temperature correction factors for buffers applied? Y N

BUFFER LOT pH 7: \_\_\_\_\_  
 NUMBERS: \_\_\_\_\_  
 pH: \_\_\_\_\_  
 CHECK pH: \_\_\_\_\_

BUFFER EXP. pH 7: \_\_\_\_\_  
 DATES: \_\_\_\_\_  
 pH: \_\_\_\_\_  
 CHECK pH: \_\_\_\_\_

Calibration Criteria:  $\pm 0.1$  pH units

Field Readings #1 \_\_\_\_\_ #2 \_\_\_\_\_ #3 \_\_\_\_\_ #4 \_\_\_\_\_ #5 \_\_\_\_\_ MEDIAN: \_\_\_\_\_ units Method Code \_\_\_\_\_ Remark \_\_\_\_\_ Qualifier \_\_\_\_\_

**SPECIFIC CONDUCTANCE** Meter make/model \_\_\_\_\_ S/N \_\_\_\_\_ Sensor Type: Dip Flow-thru Other \_\_\_\_\_

Sample: Flow-thru chamber Single point at \_\_\_\_\_ ft blw lsd Vertical avg. of \_\_\_\_\_ points

Std. Value $\mu$ S/cm	Std. Temp	SC Before Adj.	SC After Adj.	Std Lot No.	Std. type (KCl; NaCl)	Std Exp. Date

Calibration Criteria:  $\pm 5$  % for SC  $\leq 100$   $\mu$ S/cm or 3% for SC  $> 100$   $\mu$ S/cm

AUTO TEMP COMPENSATED METER \_\_\_\_\_

MANUAL TEMP COMPENSATED METER \_\_\_\_\_

CORRECTION FACTOR APPLIED? Y N

CORRECTION FACTOR= \_\_\_\_\_

Field Readings #1 \_\_\_\_\_ #2 \_\_\_\_\_ #3 \_\_\_\_\_ #4 \_\_\_\_\_ #5 \_\_\_\_\_ MEDIAN: \_\_\_\_\_  $\mu$ S/cm Method Code \_\_\_\_\_ Remark \_\_\_\_\_ Qualifier \_\_\_\_\_

**DISSOLVED OXYGEN** Meter make/model \_\_\_\_\_ S/N \_\_\_\_\_

Sensor Type: Amperometric Luminescent Probe No. \_\_\_\_\_

Sample: Flow-thru chamber Single point at \_\_\_\_\_ ft blw lsd Vertical avg. of \_\_\_\_\_ points BOD bottle Stirrer Used? Y N

Water-Saturated Air Air-Saturated Water Air Calibration Chamber in Water Air Calibration Chamber in Air Winkler Titration Other \_\_\_\_\_

Calibration Temp °C	Barometric Pressure mm Hg	DO Table Reading mg/L	Salinity Correction Factor	DO Before Adjustment	DO After Adjustment

Zero DO Check \_\_\_\_\_ mg/L Adj. to \_\_\_\_\_ mg/L Date: \_\_\_\_\_

Zero DO Solution Date \_\_\_\_\_ Thermistor Check? Y N Date \_\_\_\_\_

Membrane Changed? N Y N/A Date: \_\_\_\_\_ Time: \_\_\_\_\_

Barometer Calibrated? N Y Date: \_\_\_\_\_ Time: \_\_\_\_\_

Battery Check: REDLINE \_\_\_\_\_ RANGE \_\_\_\_\_

Calibration Criteria:  $\pm 0.2$  mg/L

Field Readings #1 \_\_\_\_\_ #2 \_\_\_\_\_ #3 \_\_\_\_\_ #4 \_\_\_\_\_ #5 \_\_\_\_\_ MEDIAN: \_\_\_\_\_ mg/L Method Code \_\_\_\_\_ Remark \_\_\_\_\_ Qualifier \_\_\_\_\_

FIELD ID \_\_\_\_\_

**TURBIDITY** Meter make/model \_\_\_\_\_ S/N \_\_\_\_\_ Type: turbidimeter submersible spectrophotometer

Sample: pump discharge line flow-thru chamber single point at \_\_\_\_\_ ft blw LSD MSL MP Sensor ID \_\_\_\_\_

Sample: Collection Time: \_\_\_\_\_ Measurement Time: \_\_\_\_\_ Measurement: In-situ/On-site Vehicle Office lab NWQL Other \_\_\_\_\_

Sample diluted? Y N Vol. of dilution water \_\_\_\_\_ mL Sample volume \_\_\_\_\_ mL

TURBIDITY VALUE =  $A \times (B+C) / C$   
 where:  
**A**= TURBIDITY VALUE IN DILUTED SAMPLE  
**B**= VOLUME OF DILUTION WATER, mL  
**C**= SAMPLE VOLUME, mL

Comments/Calculations:

Calibration Criteria: ± 0.5 TU or ± 5%	Lot Number or Date Prepared	Expiration Date	Concentration (units)	Calibration Temperature °C	Initial instrument reading	Reading after adjustment
Stock Turbidity Standard						
Zero Standard (DIW)						
Standard 1						
Standard 2						
Standard 3						

Field Readings #1 \_\_\_\_\_ #2 \_\_\_\_\_ #3 \_\_\_\_\_ #4 \_\_\_\_\_ #5 \_\_\_\_\_

MEDIAN \_\_\_\_\_ Parameter Code \_\_\_\_\_ FNU NTU NTRU FNMU FNRU FAU FBV AU METHOD CODE \_\_\_\_\_ Remark \_\_\_\_\_ Qualifier \_\_\_\_\_

**WELL and WATER-LEVEL INFORMATION**

WELL _____ SPRING _____ MONITOR _____ SUPPLY _____ OTHER _____ SUPPLY WELL PRIMARY USE: DOMESTIC _____ PUBLIC SUPPLY _____ IRRIGATION _____ OTHER _____ Casing Material: _____ Altitude (land surface) _____ ft abv MSL Measuring Point: _____ ft abv blw LSD MSL Well Depth _____ ft abv blw LSD MSL MP Sampling condition (72006) pumping (8) flowing (4) static (n/a) <small>[see reference list for additional fixed-value codes]</small> Water Level: _____ ft blw LSD (72019) ft blw MP (61055) ft abv MSL (NGVD 1929) (62610) ft abv MSL (NAVD 1988) (62611) [enter the selected code on p. 1.] Water Level Method: steel tape electric tape airline other _____ Comments: _____	<table border="1"> <thead> <tr> <th colspan="4">Depth to Water and Well Depth</th> </tr> <tr> <th></th> <th>1ST</th> <th>2ND</th> <th>3RD (optional)</th> </tr> </thead> <tbody> <tr><td>Time</td><td></td><td></td><td></td></tr> <tr><td>Hold (for DTW)</td><td></td><td></td><td></td></tr> <tr><td>- Cut</td><td></td><td></td><td></td></tr> <tr><td>= DTW from MP [electric tape reading]</td><td></td><td></td><td></td></tr> <tr><td>- Measuring point (MP)</td><td></td><td></td><td></td></tr> <tr><td>= DTW from LSD</td><td></td><td></td><td></td></tr> <tr><td>Hold (for well depth)</td><td></td><td></td><td></td></tr> <tr><td>+ Length of tape leader</td><td></td><td></td><td></td></tr> <tr><td>= Well depth below MP</td><td></td><td></td><td></td></tr> <tr><td>- MP</td><td></td><td></td><td></td></tr> <tr><td>= Well depth below LSD</td><td></td><td></td><td></td></tr> </tbody> </table>	Depth to Water and Well Depth					1ST	2ND	3RD (optional)	Time				Hold (for DTW)				- Cut				= DTW from MP [electric tape reading]				- Measuring point (MP)				= DTW from LSD				Hold (for well depth)				+ Length of tape leader				= Well depth below MP				- MP				= Well depth below LSD			
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**WATER-LEVEL DATA FOR GWSI**

DATE WATER LEVEL MEASURED (C235) \_\_\_\_\_ - \_\_\_\_\_ - \_\_\_\_\_ TIME (C709) \_\_\_\_\_ WATER LEVEL TYPE CODE (C243) **L M S**  
below land surface below meas. pt. sea level

WATER LEVEL (C237/241/242) \_\_\_\_\_ MP SEQUENCE NO. (C248) \_\_\_\_\_  
 (Mandatory if WL type=M)

WATER LEVEL DATUM (C245) \_\_\_\_\_  
 (Mandatory if WL type=S)

<b>NGVD 29</b>	<b>NAVD 88</b>	Other (See GWSI manual for codes)
National Geodetic Vertical Datum of 1929	North American Vertical Datum of 1988	

SITE STATUS FOR WATER LEVEL (C238)

<b>A</b>	<b>B</b>	<b>C</b>	<b>D</b>	<b>E</b>	<b>F</b>	<b>G</b>	<b>H</b>	<b>I</b>	<b>J</b>	<b>M</b>	<b>N</b>	<b>O</b>	<b>P</b>	<b>R</b>	<b>S</b>	<b>T</b>	<b>V</b>	<b>W</b>	<b>X</b>	<b>Z</b>
atmos. pressure	tide stage	ice	dry	recently flowing	flowing	nearly flowing	nearly flowing	injector site	injector site	plugged	measure-ment discontinued	obstruct- tion	pumping	recently pumped	nearly pumped	nearly pumped	foreign sub- stance	well des- troyed	affected by surface water	other

METHOD OF WATER-LEVEL MEASUREMENT (C239)

<b>A</b>	<b>B</b>	<b>C</b>	<b>E</b>	<b>F</b>	<b>G</b>	<b>H</b>	<b>L</b>	<b>M</b>	<b>N</b>	<b>O</b>	<b>R</b>	<b>S</b>	<b>T</b>	<b>V</b>	<b>Z</b>
airline	analog	calibrated	est- mated	trans- ducer	pressure gage	calibrated pres. gage	geophys- ical log	manometer	non-rec. gage	observed	reported	steel tape	electric tape	calibrated elec. tape	other

WATER LEVEL ACCURACY (C276) **0 1 2 9**

SOURCE OF WATER-LEVEL DATA (C244)

<b>A</b>	<b>D</b>	<b>G</b>	<b>L</b>	<b>M</b>	<b>O</b>	<b>R</b>	<b>S</b>	<b>Z</b>
other govt	driller's log	geol- ist	geophys- ical logs	memory	owner	other reported	reporting agency	other

PERSON MAKING MEASUREMENT (C246) \_\_\_\_\_ MEASURING AGENCY (C247) (SOURCE) \_\_\_\_\_ RECORD READY FOR WEB (C858) **Y C P L**  
checked, ready for web display not checked; no web display proprietary; no web display local use only; no web display





**QUALITY-CONTROL INFORMATION**

**PRESERVATIVE LOT NUMBERS**

7.5N HNO<sub>3</sub> \_\_\_\_\_ (METALS&CATIONS)      6N HCl \_\_\_\_\_ (Hg)      4.5N H<sub>2</sub>SO<sub>4</sub> \_\_\_\_\_ (NUTRIENTS&DOC)      Conc. H<sub>2</sub>SO<sub>4</sub> \_\_\_\_\_ (COD, PHENOL, O&G)      NaOH \_\_\_\_\_ (CYANIDE)

OTHER \_\_\_\_\_ 1:1 HCl \_\_\_\_\_ (VOC)      Number of drops of HCL added to lower pH to ≤ 2 \_\_\_\_\_ (NOTE: Maximum number of drops = 5)

**BLANK WATER LOT NUMBERS**

Inorganic (99200) \_\_\_\_\_ 2nd Inorganic (99201) \_\_\_\_\_

Pesticide (99202) \_\_\_\_\_ 2nd Pesticide (99203) \_\_\_\_\_ Spike vials (99104) \_\_\_\_\_

VOC/Pesticide (99204) \_\_\_\_\_ 2nd VOC/Pesticide (99205) \_\_\_\_\_ Surrogate vials \_\_\_\_\_

**FILTER LOT NUMBERS**

capsule \_\_\_\_\_ pore size \_\_\_\_\_ type \_\_\_\_\_

disc \_\_\_\_\_ pore size \_\_\_\_\_ type \_\_\_\_\_

142mm GFF \_\_\_\_\_ pore size \_\_\_\_\_ type \_\_\_\_\_  
(organics)

47mm GFF \_\_\_\_\_ pore size \_\_\_\_\_ type \_\_\_\_\_  
(organics)

25mm GFF \_\_\_\_\_ pore size \_\_\_\_\_ type \_\_\_\_\_  
(organic carbon)

142mm membrane \_\_\_\_\_ pore size \_\_\_\_\_ type \_\_\_\_\_  
(inorganics)

other \_\_\_\_\_ pore size \_\_\_\_\_ type \_\_\_\_\_

**QC SAMPLES**

Starting date for set of samples (99109) (YMMDD) \_\_\_\_\_ Ending date for set of samples (99110) (YMMDD) \_\_\_\_\_

Sample Type	NWIS Record No.	Sample Type	NWIS Record No.	Sample Type	NWIS Record No.
Equip Blank _____	_____	Sequential _____	_____	Trip Blank _____	_____
Field Blank _____	_____	Spike _____	_____	Other _____	_____
Split _____	_____	Concurrent _____	_____	Other _____	_____

NWQL schedules/lab codes (QC Samples) \_\_\_\_\_

Comments \_\_\_\_\_

(Circle appropriate selections)

**99100 Blank-solution type**

10 Inorganic grade (distilled/deionized)

40 Pesticide grade (OK for organics and organic carbon)

50 Volatile-organic grade (OK for VOCs, organics, and organic carbon)

200 Other

**99102 Blank-sample type**

1 Source Solution

30 Trip

60 Filter

70 Preservation

80 Equipment (done in non-field environment)

90 Ambient

100 Field

200 Other

**99103 Spike-solution volume, mL**

<b>99106 Spike-sample type</b>	<b>99107 Spike-solution source</b>
10 Field	10 NWQL
20 Laboratory	

**99101 Source of blank water**

10 NWQL

40 NIST

55 Wisconsin Mercury Lab

140 EMD Chemicals

150 Ricca Chemical Company

200 Other

**99111 QC sample associated with this environmental sample**

1 No associated QA data

10 Blank

30 Replicate Sample

40 Spike sample

100 More than one type of QA sample

200 Other

**99112 Purpose, Topical QC data**

1 Routine QC (non-topical)

10 Topical for high bias (contamination)

20 Topical for low bias (recovery)

100 Topical for variability (field equip)

110 Topical for variability (field collection)

120 Topical for variability (field personnel)

130 Topical for variability (field processing)

140 Topical for variability (shipping&handling)

200 Topical for variability (lab)

900 Other topical QC purpose

**99105 Replicate-sample type**

10 Concurrent      40 Split-Concurrent

20 Sequential      50 Split-Sequential

30 Split      200 Other

A complete set of fixed-value codes can be found online at:  
<http://www.nwis.er.usgs.gov/currentdocs/index.html>

REFERENCE LIST FOR CODES USED ON THIS FORM

**Sample Medium Codes**  
 6 Regular Ground water  
 S Quality-control sample (associated environmental sample -6 (GW))  
 For replicates and spikes  
 Q Artificial

**Value Qualifiers**  
 e see field comment  
 f sample field preparation problem  
 k counts outside the acceptable range

**Null-value Qualifiers**  
 e required equipment not functional or available  
 f sample discarded; improper filter used  
 o insufficient amount of water  
 p sample discarded; improper preservation  
 q sample discarded; holding time exceeded  
 r sample ruined in preparation

**50280 Purpose of site visit**  
 2001 Primary (primary samples should not exist for a site for more than one date per HIP, and the primary sampling date generally has the highest number of NAWQA analytes)  
 2002 Supplemental (to fill in missing schedules not sampled or lost)  
 2003 Temporal characterization (for previously-sampled schedules; includes LIP and seasonal samples)  
 2004 Resample (to verify questionable concentrations in primary sample)  
 2098 Ground-water quality control  
 2099 Other (ground-water related samples with medium code other than "6", such as soil samples or core material)

A complete set of fixed-value codes can be found online at:  
<http://www.nwis.er.usgs.gov/currentdocs/index.html>

**71999 Sample purpose**  
 10 Routine  
 15 NAWQA  
 50 GW Network  
 110 Seepage Study  
 120 Irrigation Effects  
 130 Recharge  
 140 Injection

**Sample Type Code**  
 9 Regular  
 7 Replicate  
 2 Blank  
 1 Spike

**Time Datum Codes**

Time Zone	Std Time Code	UTC Offset (hours)	Daylight Time Code	UTC Offset (hours)
Hawaii-Aleutian	HST	-10	HDT	-9
Alaska	AKST	-9	AKDT	-8
Pacific	PST	-8	PDT	-7
Mountain	MST	-7	MDT	-6
Central	CST	-6	CDT	-5
Eastern	EST	-5	EDT	-4
Atlantic	AST	-4	ADT	-3

**82398 Sampling method**  
 4010 Thief sampler  
 4020 Open-top bailer  
 4025 Double-valve bailer  
 4030 Suction pump  
 4040 Submersible pump  
 4045 Submersible multiple impeller (turbine) pump  
 4050 Squeeze pump  
 4060 Gas reciprocating pump  
 4070 Gas lift  
 4080 Peristaltic pump  
 4090 Jet pump  
 4100 Flowing well  
 4110 Resin trap collector  
 8010 Other

**84164 Sampler type**  
 4010 Thief Sampler  
 4020 Open-top Bailer  
 4025 Double-valve Bailer  
 4030 Suction Pump  
 4035 Submersible Centrifugal Pump  
 4040 Submersible Positive-pressure Pump  
 4041 Submersible Helical Rotor Pump  
 4045 Submersible Gear Pump  
 4050 Bladder Pump  
 4060 Gas Reciprocating Pump  
 4070 Gas Lift  
 4075 Submersible Piston Pump  
 4080 Peristaltic Pump  
 4090 Jet pump  
 4095 Line-Shaft Turbine Pump  
 4100 Flowing Well  
 8010 Other

**72006 Sampling Condition**  
 0.01 The site was dry (no water level is recorded)  
 0.02 The site had been flowing recently  
 0.03 The site was flowing, head could not be measured  
 0.04 A nearby site that taps the Aquifer was flowing  
 0.05 Nearby site tapping same Aquifer had been flowing recently  
 0.06 Injector site  
 0.07 Injector site monitor  
 0.08 Measurement discontinued  
 0.09 Obstruction encountered in well above water surface  
 0.10 The site was being pumped  
 0.11 The site had been pumped recently  
 0.12 Nearby site tapping the same Aquifer was being pumped  
 0.13 Nearby site tapping the Same Aquifer was pumped recently  
 0.14 Foreign substance present on the surface of the water  
 0.16 Water level affected by stage in nearby site  
 0.17 Other conditions affecting the measured water level  
 2 Undesignated  
 4 Flowing  
 6 Flowing on gas lift  
 8 Pumping  
 10 Open hole  
 18 Producing  
 19 Circulating  
 22 Lifting  
 23 Flowing to Pit  
 24 Water Flooding  
 25 Jetting  
 30 Seeping  
 31 Nearby well pumping  
 32 Nearby well taking water  
 33 Well taking water

**Alkalinity/ANC Parameter Codes**  
 39086 Alkalinity, water, filtered, incremental titration, mg/L  
 00418 Alkalinity, water, filtered, fixed endpoint, mg/L  
 29802 Alkalinity, water, filtered, Gran titration, mg/L  
 00419 ANC, water, unfiltered, incremental titration  
 00410 ANC, water, unfiltered, fixed endpoint, mg/L  
 29813 ANC, water, unfiltered, Gran titration, mg/L  
 29804 Bicarbonate, water, filtered, fixed endpoint, mg/L  
 63786 Bicarbonate, water, filtered, Gran, mg/L  
 00453 Bicarbonate, water, filtered, incremental, mg/L  
 00440 Bicarbonate, water, unfiltered, fixed endpoint, mg/L  
 00450 Bicarbonate, water, unfiltered, incremental, mg/L  
 29807 Carbonate, water, filtered, fixed endpoint, mg/L  
 63788 Carbonate, water, filtered, Gran, mg/L  
 00452 Carbonate, water, filtered, incremental, mg/L  
 00445 Carbonate, water, unfiltered, fixed endpoint, mg/L  
 00447 Carbonate, water, unfiltered, incremental, mg/L  
 29810 Hydroxide, water, filtered, fixed endpoint, mg/L  
 71834 Hydroxide, water, filtered, incremental, mg/L  
 71830 Hydroxide, water, unfiltered, fixed endpoint, mg/L  
 71832 Hydroxide, water, unfiltered, incremental, mg/L

**71875 Hydrogen Sulfide Odor**  
 Value  
 # none entered (null)  
 Remark Code Method Code  
 M detect U un-acidified sample  
 U non-detect V acidified sample

00003 Sampling depth, ft  
 78890 Sampling depth, ft blw msl  
 00059 Flow rate, instantaneous, gallons per minute  
 72004 Pump or flow period prior to sampling, minutes

**Water Level**  
 61055 Water level, depth below measuring point, feet  
 62610 Ground-water level above NGVD  
 1929, feet  
 62611 Ground-water level above NAVD  
 1988, feet  
 72019 Depth to water level, feet below land surface

Parameter and method codes for field measurements and turbidity can be found in separate attachments at <http://water.usgs.gov/usqs/owq/Forms.html>

**U.S. GEOLOGICAL SURVEY – NATIONAL WATER QUALITY LABORATORY  
ANALYTICAL SERVICES REQUEST**

**THIS SECTION MANDATORY FOR SAMPLE LOGIN**

NWIS RECORD NUMBER  SAMPLE TRACKING ID	User Code	Project Account	LAB USE ONLY  NWQL LABORATORY ID
STATION ID	2 0 Begin Date (YYYYMMDD)	Begin Time	Medium Code    Sample Type
District Contact Phone Number	End Date (YYYYMMDD)	End Time	District Contact Email

**SITE / SAMPLE / SPECIAL PROJECT INFORMATION (Optional)**

State	County	Geologic Unit Code	Analysis Status*	Analysis Source*	Hydrologic Condition*	Hydrologic Event*	Chain of Custody	Sample Set.
NWQL Proposal Number	NWQL Contact Name	NWQL Contact Email	Program/Project					

Station Name: \_\_\_\_\_ Field ID: \_\_\_\_\_

Comments to NWQL: \_\_\_\_\_

Hazard (please explain): \_\_\_\_\_

**ANALYTICAL WORK REQUESTS: SCHEDULES AND LAB CODES (CIRCLE A=add D=delete)**

SCHED 1: \_\_\_\_\_ SCHED 2: \_\_\_\_\_ SCHED 3: \_\_\_\_\_ SCHED 4: \_\_\_\_\_ SCHED 5: \_\_\_\_\_ SCHED 6: \_\_\_\_\_

Lab Code: _____	A D								
Lab Code: _____	A D								
Lab Code: _____	A D								

**SHIPPING INFORMATION (Please fill in number of containers sent)**

ALF	COD	FA	FCN	IQE	IRM	RA	RU	SUR	TPCN
BGC	CRB	FAM	FU	IQL	MBAS	RAM	RUR	SUSO	UAS
C18	CU	FAR	FUS	IQM	OAG	RAR	RURCT	TBI	WCA
CC	CUR	FCA	GCC	IRE	PHE	RCB	RURCV	TBY	
CHL	DOC	FCC	GCV	IRL	PIC	RCN	RUS	TOC	

NWQL Login Comments: \_\_\_\_\_

Collected by: \_\_\_\_\_ Phone No. \_\_\_\_\_ Date Shipped: \_\_\_\_\_

**FIELD VALUES**

Lab/P Code	Value	Remark	Lab/P Code	Value	Remark	Lab/P Code	Value	Remark
21/00095 Specific Conductance uS/cm @ 25 deg C			51/00400 pH Standard Units			2/39086 Alkalinity - IT mg/L as CaCO3		
/			/			/		

Field Comments: \_\_\_\_\_

\*MANDATORY FOR NWIS

## PLEASE USE BLACK INK ONLY

### INSTRUCTIONS FOR COMPLETING ANALYTICAL SERVICES REQUEST FORM

#### SAMPLE IDENTIFICATION (Mandatory)

- NWIS Record No. - Record number of sample assigned by NWIS database (District)
- User Code - Enter District user code (indicates which office sample data are to be directed)
- Project Acct - Enter 9 character account number
- NWQL Laboratory ID - Leave blank (for Laboratory use only)
- Station ID - Enter downstream order number, 15 digit latitude, longitude and sequence number or unique sample identifier
- Begin Date (YYYYMMDD) - Enter 4 digit number for year, 2 digit number for month, 2 digit number for day sample collection started
- Begin Time - Enter 4 digit military time sample collection started
- Medium Code - Enter sample medium code (see attached table)
- Sample Type - Enter sample type code (see attached table)
- District Contact Phone Number - Enter complete phone number for District contact for sample questions or problems
- End Date (YYYYMMDD) - Enter 4 digit number for year, 2 digit number for month, 2 digit number for day sample collection ended
- End Time - Enter 4 digit military time sample collection ended
- District Contact Email - Enter complete email address for District contact for sample questions or problems

#### SITE / SAMPLE / SPECIAL PROJECT INFORMATION (Optional)

- State - Enter 2 digit FIPS code for State in which station is located
- County - Enter 3 digit FIPS code for county in which station is located
- Geologic Unit Code - Enter geologic unit code for ground-water sample (multiple aquifer identification)
- \*Analysis Status - Enter analysis status code (see attached table)
- \*Analysis Source - Enter analysis source code (see attached table)
- \*Hydrologic Condition - Enter hydrologic condition code (see attached table)
- \*Hydrologic Event - Enter hydrologic event code (see attached table)
- Chain of Custody - Enter Y if sample is chain of custody
- Sample Set - Enter identifier for sample set, and place on all bottles and associated log form, for example: "A", "BB" (max. 2)
- NWQL Proposal Number - Denotes non-routine or custom work assigned by NWQL in negotiated proposal
- NWQL Contact Name - Enter name of NWQL person to be contacted when sample arrives at Lab
- NWQL Contact Email - Enter email of NWQL person to be contacted when sample arrives at Lab
- Program/Project - For example: NAWQA, NASQAN, NPDES, DW - if applicable
- Station Name - Enter local station name
- Field ID - Enter identification assigned by District
- Comments to NWQL - Enter information about sample that NWQL should be aware of (high concentration, etc.)  
**Note:** Samples collected for analysis by Geologic Division MUST have the latitude/longitude provided for login
- Hazard - Describe any known hazard associated with sample (chemical, biological, radiological, etc.)

#### ANALYTICAL WORK REQUESTS: SCHEDULES AND LAB CODES

- Schedule - Enter schedule number(s) for the desired analyses.
- Lab Code - Enter lab code for analyses to be added or deleted. Circle "A" for addition or "D" for deletion. Maximum 15.

#### SHIPPING INFORMATION (Please fill in number of sample types sent)

- NWQL Login Comments - NWQL login personnel comments.
- Collected by: - Enter name of individual that collected/shipped samples
- Phone No. - Enter phone number of individual that collected/shipped samples
- Date Shipped - Enter date samples packed/shipped to NWQL.

#### FIELD VALUES

- Lab/P Code/Value/Remark - Enter values and remarks for sc, pH, alk, if needed, enter P code, value, remark for other field values
- Field Comments - For field use only. Will not be used by NWQL.

\*Mandatory for storage in NWIS

## CODES USED IN WATER-QUALITY PROCESSING SYSTEM

Sample Medium Code	Description
A	Artificial
B	Solids (street sweepings, etc.)
C	Animal tissue
D	Plant tissue
E	Core material
F	Interstitial water
G	Soil
H	Bottom material
J	Sludge
K	Soil moisture
L-P	TAXONOMIC DATA
L	Phytoplanktonic species composition and enumeration
M	Phytoplanktonic species composition
N	Periphytic species composition
O	Benthic invertebrates species composition and enumeration
P	Periphytic diatoms species composition and enumeration
Q	Quality-assurance sample - Artificial
R	Quality-assurance sample - Surface water
S	Quality-assurance sample - Ground water
T	Quality-assurance sample - Wet deposition
U	Quality-assurance sample - Bulk deposition
V	Quality-assurance sample - Suspended sediment
W	Quality-assurance sample - Bottom material
X	Quality-assurance sample - Animal tissue
Y	Quality-assurance sample - Plant tissue
Z	Quality-assurance sample - Interstitial water
1	Suspended sediment
2	Leachate
3	Dry deposition
4	Landfill effluent
5	Elutriation
6	Ground water
7	Wet deposition
8	Bulk deposition
9	Surface water
0	Not determined
\$	Treated water supply
%	Effluent
*	Air
&	Soil gas
{	QC sample for treated water supply
}	QC sample for effluent
[	QC sample for air
]	QC sample for soil gas

Sample Type Code	Description
A	Not determined
B	Other QA
H	Composite (time)
1	Spike
2	Blank
3	Reference
4	Blind
5	Duplicate
6	Reference material
7	Replicate
8	Spike Solution
9	Regular

*Analysis Status Code	
Status Code	Description
A	Not determined
H	Initial entry
1	Retrieved, in review
3	Data in temporary hold status
7	Reviewed, approved for transfer to EPA STORET
9	Proprietary data (Regional Hydrologist approval required)

*Analysis Source Code	
Source Code	Description
A	Not determined
B	Non-USGS field
C	Non-USGS lab only
D	Non-USGS lab and field
F	USGS field and non-USGS field
G	USGS field and non-USGS lab
H	USGS field and non-USGS lab and field
1	USGS lab and non-USGS field
2	USGS lab and non-USGS lab
3	USGS lab and non-USGS lab and field
4	USGS lab and field and non-USGS field
5	USGS lab and field and non-USGS lab
6	USGS lab and field and non-USGS lab and field
7	USGS field only
8	USGS lab only
9	USGS lab and field

*Hydrologic Condition Code	
Condition Code	Description
A	Not determined
4	Stable, low stage
5	Falling stage
6	Stable, high stage
7	Peak stage
8	Rising stage
9	Stable, normal stage
X	Not Applicable

**CODES USED IN WATER-QUALITY PROCESSING SYSTEM  
(Continued)**

*Hydrologic		Remark	
<u>Event Code</u>	<u>Description</u>	<u>Code</u>	<u>Description</u>
A	Spring breakup	Blank	Not Remarked
B	Under ice cover	E	Estimated Value
C	Glacial lake outbreak	<	Actual value is known to be less than value shown
D	Mudflow	>	Actual value is known to be greater than value shown
E	Tidal action	M	Presence of material verified but not quantified
F	Drainage basin affected by fire	N	Presumptive evidence of presence of material
H	Dam break	U	Material specifically analyzed for but not detected
J	Storm		
K	Backwater	A	Average value
1	Drought	V	Value affected by contamination - OWQ 97.8
2	Spill	S	Most probable value
3	Regulated flow		
4	Snowmelt		
5	Earthquake		
6	Hurricane		
7	Flood		
8	Volcanic action		
9	Routine sample		
X	Not applicable		

VALUES FOR PARAMETER CODE 82398

(Sampling Method)

10	Equal Width Increment (EWI)	4010	Thief sample
20	Equal Discharge Increment (EDI)	4020	Open-top bailer
25	Timed sampling interval	4025	Double-valve bailer
30	Single vertical	4030	Suction pump
40	Multiple verticals	4031	Suction lift centrifugal pump
50	Point sample	4032	Suction lift jet pump
55	Composite-multiple point samples	4033	Suction lift peristaltic pump
60	Weighted bottle	4040	Submersible pump
70	Grab sample (dip)	4041	Submersible bladder pump
80	Discharge integrated, equal transit rate (ETR)	4042	Submersible gas reciprocating pump
90	Discharge integrated, centroid	4043	Submersible gas lift pump
100	Van Dorn sampler	4044	Submersible jet pump
110	Sewage sampler	4045	Submersible multiple impeller (turbine) pump
120	Velocity integrated	4046	Submersible helical rotor pump
200	Zooplankton-net	4047	Submersible gear pump
210	Benthic invertebrate-mechanical grab	4048	Submersible gas-displacement pump
220	Benthic invertebrate-mechanical dredge	4050	Squeeze pump
230	Benthic invertebrate-artificial substrate	4060	Gas reciprocating pump
240	Benthic invertebrate-natural substrate	4070	Gas lift
250	Benthic invertebrate-net	4080	Peristaltic pump
260	Phytoplankton-net	4090	Jet pump
270	Phytoplankton-water bottle	4100	Flowing well
280	Periphyton-natural substrate	4110	Resin trap collector
290	Periphyton-artificial substrate	5010	Sediment core
900	Suspended sediment; Pumping; stream sample using a pumping machine	8010	Other
910	Suspended sediment; Single-stage, nozzle at fixed stage, passively filling	8020	Syringe sample
920	Suspended sediment; Box single vertical, depth-integrated, attached to structure	8030	Grab sample at water-supply tap
930	Suspended sediment; Partial depth, depth integrated, part of single vertical		
940	Suspended sediment; Partial width, depth/width integrated, part of cross-section		
1000	(Bedload), Single equal width increment (SEWI)		
1010	(Bedload), Multiple equal width increment (MEWI)		
1020	(Bedload), Unequal width increment (UWI)		

## QUALITY ASSURANCE DATA PARAMETER CODES

99100	Blank, Type of solution	99103	(Continued)
	10 Distilled/deionized water		70 Natural Sample
	20 Standard reference water sample		80 Ocala Lab
	30 Matched matrix		99 Unknown
	40 Organic-free water		100 Chemical Supplier
	50 VOC free water		200 Other
	60 Sterile saline buffered water	99104	Reference Material or Spike Source, Code Number
	70 Sterile buffered water PO <sub>4</sub> /MgCl <sub>2</sub>	99105	Replicate, Type (fixed value)
	200 Other		10 Concurrent
99101	Blank, Source of solution (fixed value)		20 Sequential
	10 National Water Quality Lab		30 Split
	20 U.S. Environmental Protection Agency		40 Split-concurrent
	30 Standard Reference Water Sample (USGS)		50 Split-sequential
	35 Mix of Standard Reference Water Samples		200 Other
	40 NIST (formerly NBS)	99106	Spike, Type (fixed value)
	50 Canadian Inland Waters		10 Field
	60 District Lab		20 Laboratory
	61 Subdistrict #1 Lab		30 Surrogate
	62 Subdistrict #2 Lab		40 Internal Standards
	63 Subdistrict #3 Lab		200 Other
	64 Subdistrict #4 Lab	99107	Spike, Source (fixed value)
	70 Natural Sample		10 National Water Quality Lab
	71 Field Office #1 Lab		20 U.S. Environmental Protection Agency
	72 Field Office #2 Lab		30 Standard Reference Water Sample (USGS)
	73 Field Office #3 Lab		35 Mix of Standard Reference Water Samples
	74 Field Office #4 Lab		40 NIST (formerly NBS)
	80 Ocala Lab		50 Canadian Inland Waters
	99.99 Unknown		60 District Lab
	100 Chemical Supplier		70 Natural Sample
	110 Burdick and Jackson		80 Ocala Lab
	120 J.T. Baker		99.99 Unknown
	200 Other		100 Chemical Supplier
99102	Blank, Type of sample (fixed Value)		110 Supelco
	1 Source Solution		120 Protocol Analytical Supplies, Inc.
	10 Shelf (bold)		200 Other
	20 Refrigerator	99108	Spike Volume
	30 Trip	99109	Starting Date for a Set of Samples (YMMDD)
	40 Sampler	99110	Ending Date for a Set of Samples (YMMDD)
	50 Splitter	99111	Quality Assurance Data Type Associated with Sample (fixed value code)
	60 Filter		1 No Associated QA Data
	70 Preservation		10 Blank
	80 Equipment		20 Blind Sample
	90 Ambient		30 Replicate Sample
	100 Field		40 Spike Sample
	150 Lab Blank		100 More than one type of QA Sample
	200 Other		110 Cross-Section Information Stored
99103	Reference Material; Source (fixed value)		200 Other
	10 National Water Quality Lab		
	20 U.S. Environmental Protection Agency		
	30 Standard Reference Water Sample (USGS)		
	40 NIST (formerly NBS)		
	50 Canadian Inland Waters		
	60 District Lab		

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