PNNL-17512

Drilling, Sampling, and Well-Installation Plan for the IFC Well Field, 300 Area

Bruce Bjornstad
Jake Horner

May 2008

Prepared for the U.S. Department of Energy
under Contract DE-AC05-76RL01830

PACIFIC NORTHWEST NATIONAL LABORATORY
operated by
BATTELLE
for the
UNITED STATES DEPARTMENT OF ENERGY
under Contract DE-AC05-76RL01830

Printed in the United States of America

Available to DOE and DOE contractors from the
Office of Scientific and Technical Information,
P.O. Box 62, Oak Ridge, TN 37831-0062;
ph: (865) 576-8401
fax: (865) 576-5728
email: reports@adonis.osti.gov

Available to the public from the National Technical Information Service,
U.S. Department of Commerce, 5285 Port Royal Rd., Springfield, VA 22161
ph: (800) 553-6847
fax: (703) 605-6900
email: orders@ntis.fedworld.gov
online ordering: http://www.ntis.gov/ordering.htm

This document was printed on recycled paper.
(9/2003)

PNNL-17512

Drilling, Sampling, and Well-Installation Plan for the IFC Well Field, 300 Area

Bruce Bjornstad
Jake Horner

May 2008

Prepared for
the U.S. Department of Energy
under Contract DE-AC05-76RL01830

Pacific Northwest National Laboratory
Richland, Washington 99352

Contents

Figures

Tables

1.0 Introduction

The 300 Area was selected as a location for an Integrated Field-Scale Subsurface Research Challenge (IFC) because it offers excellent opportunities for field research on the influence of mass-transfer processes on uranium in the vadose zone and groundwater. The 300 Area was the location of nuclear fuel fabrication facilities and has more than 100 waste sites. Two of these waste sites—the North and South Process Ponds—received large volumes of process waste from 1943 to 1975 and are thought to represent a significant source of the groundwater uranium plume in the 300 Area. Geophysical surveys and other characterization efforts have led to selection of the South Process Pond for the IFC.

Thirty-five new wells (Table 1.1 and 1.2) will be drilled for a U.S. Department of Energy (DOE)-sponsored IFC located within the footprint of the former 300 Area South Process Pond. Well-injection and tracer experiments will be performed using these wells to investigate multi-scale mass transfer processes associated with a subsurface uranium plume impacting both the vadose zone and groundwater. Twenty–eight wells will be equipped with electrical-resistivity electrodes (ERT) and thermistors to monitor changes in wells during these experiments. Continuous core will be recovered from seven of the wells to provide intact lexan-lined samples for physical and chemical characterization. One deep well drilled to basalt (~180 ft depth) will be used to collect samples for microbiological characterization. Bulk grab samples will be collected from all remaining wells, which will be relatively shallow ($\leq$ 60 ft deep). Wells are identified in Table 1.1, and their locations in the well array are illustrated in Figure 1.1.

Part of the 300 Area IFC will be installation of a network of high-density borings and wells to monitor migration of fluids and contaminants (uranium), both in groundwater and vadose zone (Figures 1.1 and 1.2). The IFC plot is located over an area of suspected contamination at the former 300 Area South Process Pond.

Table 1.1. IFC wells. See Appendix B for details on drilling, sampling, and well completion

	Well ID	Well Name	Function
1	C6184	399-2-7	ERT electrodes
2	C6185	399-2-8	ERT electrodes
3	C6186	399-2-9	ERT electrodes + characterization + primary injection well
4	C6187	399-2-10	ERT electrodes
5	C6188	399-2-11	ERT electrodes
6	C6189	399-2-12	ERT electrodes + characterization
7	C6190	399-2-13	ERT electrodes + characterization
8	C6191	399-2-14	ERT electrodes
9	C6192	399-2-15	ERT electrodes
10	C6193	399-2-16	ERT electrodes
11	C6194	399-2-23	ERT electrodes
12	C6195	399-2-17	ERT electrodes
13	C6196	399-2-18	ERT electrodes
14	C6197	399-2-19	ERT electrodes + characterization
15	C6198	399-2-20	ERT electrodes
16	C6199	399-2-24	ERT electrodes
17	C6200	399-3-25	ERT electrodes + characterization
18	C6201	399-2-21	ERT electrodes
19	C6202	399-2-22	ERT electrodes
20	C6203	399-3-26	ERT electrodes + characterization
21	C6204	399-3-27	ERT electrodes
22	C6205	399-3-28	ERT electrodes
23	C6206	399-3-29	ERT electrodes
24	C6207	399-2-23	ERT electrodes
25	C6208	399-2-24	ERT electrodes + characterization
26	C6209	399-2-25	Deep microbial characterization + gw monitoring
27	C6210	399-2-26	Shallow gw monitoring
28	C6211	399-2-27	Intermediate gw monitoring
29	C6212	399-2-28	Deep gw monitoring + ERT electrodes
30	C6213	399-3-30	Shallow gw monitoring
31	C6214	399-3-31	Intermediate gw monitoring
32	C6215	399-3-32	Deep gw monitoring + ERT electrodes
33	C6216	399-2-29	Shallow gw monitoring
34	C6217	399-2-30	Intermediate gw monitoring
35	C6218	399-2-31	Deep gw monitoring + ERT electrodes

Characterization wells with intact, lexan-lined core

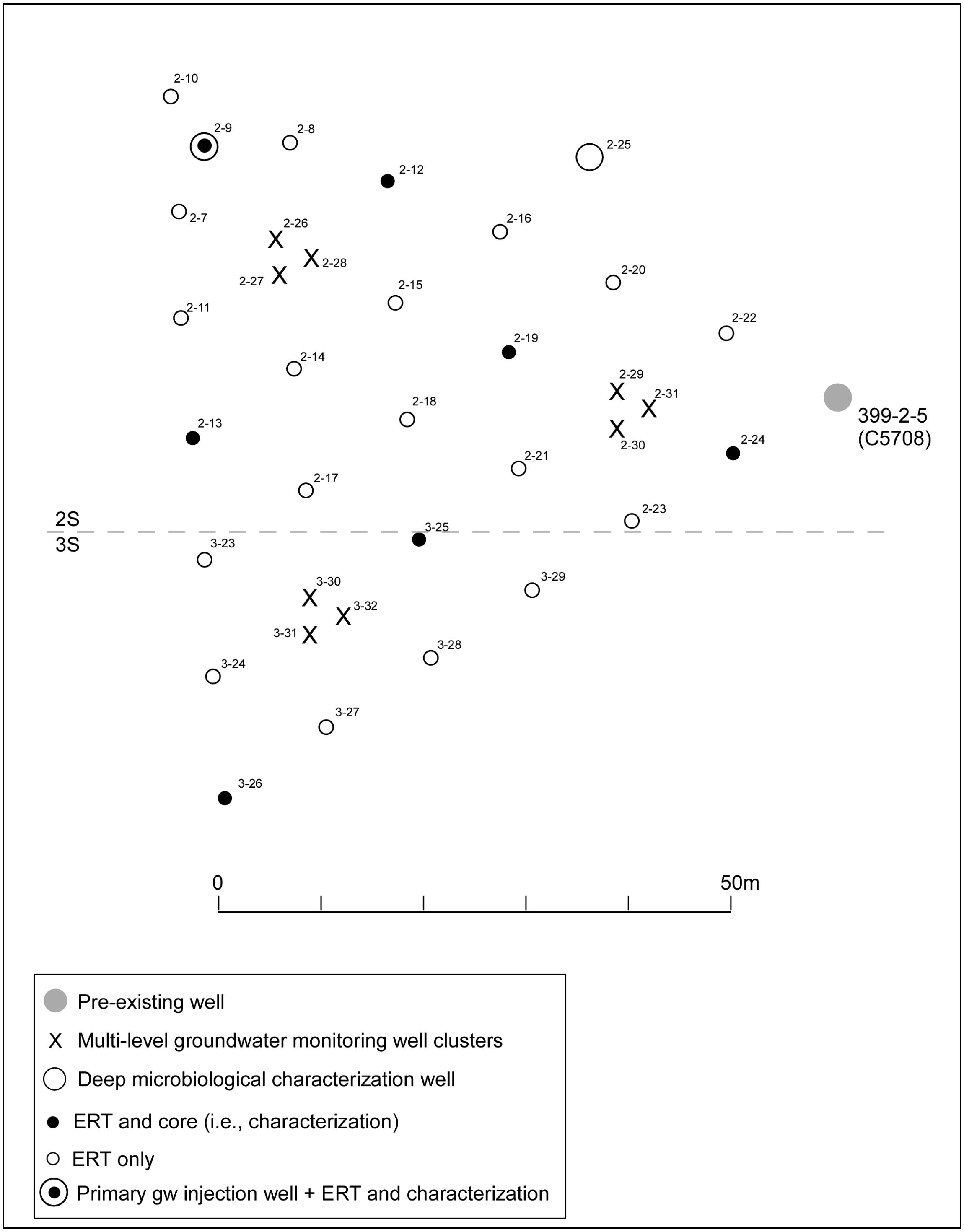

Figure 1.1. Layout of 300 Area IFC well array by well number. All wells include a "399-" prefix.

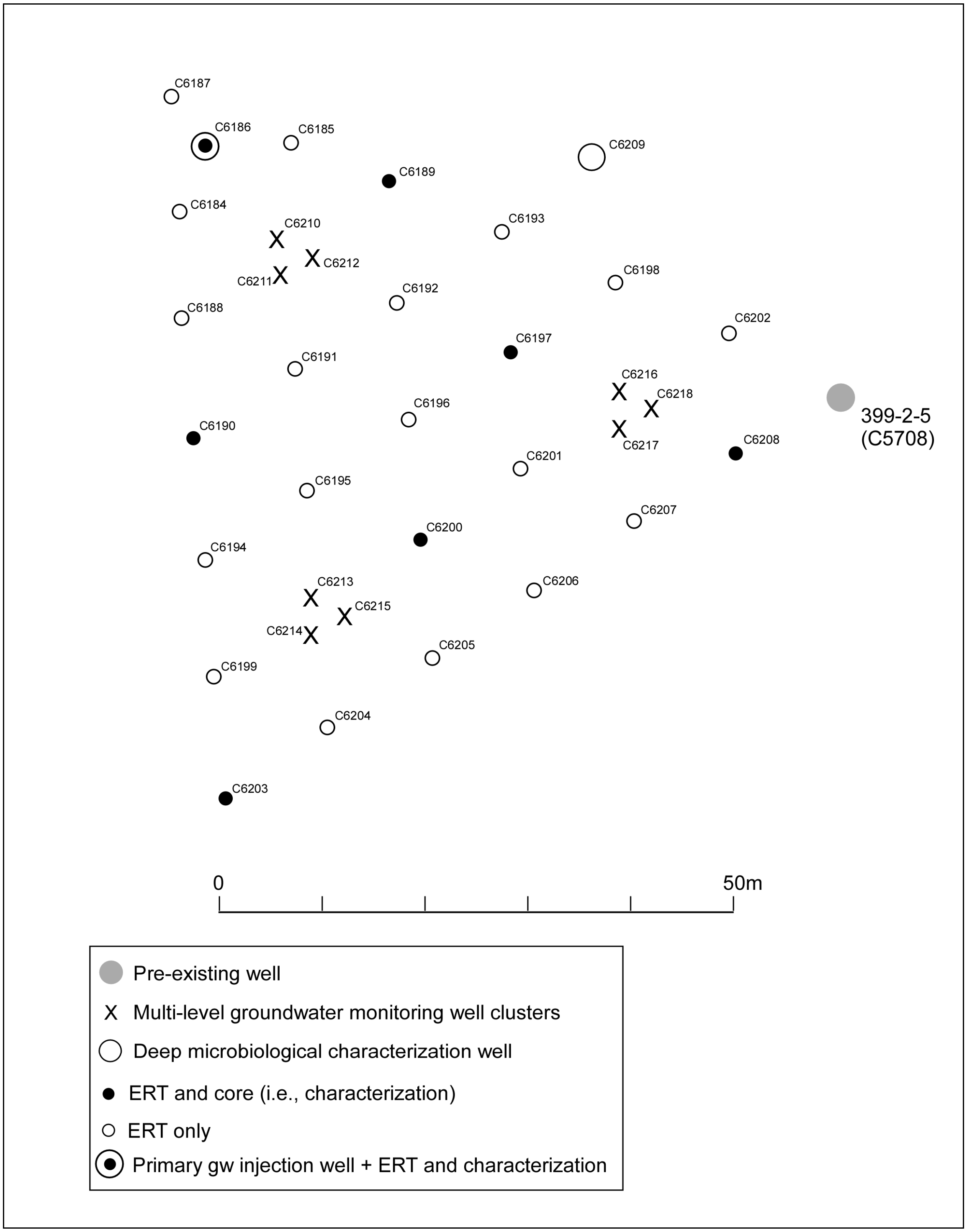

Figure 1.2. Layout of 300 Area IFC well array by well ID

Table 1.2. Drilling, sampling, and well-completion summary for new IFC wells. See Appendix B for more-detailed breakdown for drilling, sampling, and well completion on each well.

Type	# Wells	Total Depth (ft)	Borehole Diameter	Screen	Screen Interval (ft)	Proposed Sampling	Total # samples/well	Total # samples	Comments
ERT/gw monitoring without lexan core collection	20	58	8"	4" PVC	31-56	Bulk grab samples about every 2 ft	~29 grab samples*	~580 grab samples*	Sand pack below 10' depth
ERT/gw monitoring with lexan core collection	7	58	8"	4" PVC	31-56	7 holes continuous, intact core in 1-ft lexan liners within 5-ft long, min. 4-in ID split spoon;	12 split spoons or ~58, 1-ft lexan liners	84 split spoons or ~400, 1-ft lexan liners;	sand pack below 10' depth
3-well cluster (multi-level) gw monitoring	3 clusters	37, 46, 57	8"	4" PVC	30-35, 42-44, 53-55	Bulk grab samples about every 2 ft	~70 grab samples/cluster*	~210 grab samples*	ERT on deep (57 ft) well only (sand pack below 10' depth)
Deep characterization; gw monitoring	1	~180	8"	4" PVC	60-140	~50 ft of core collected in lexan liners, from five intervals (30-35', 50-70 ', 95-100', 122'-132 ft', and 170-180' (or TOB)		50, 1-ft core segments and; up to 65 grab samples* in between core intervals	Continuous 80-ft screen to monitor gw in Ringold Unit E
Total wells	35			*collected at surface by transferring core from thin, flexible plastic sleeves (core bags) into ~2-gal. buckets					

The site hydrogeology is illustrated in Figure 1.3, based on results from nearby well 399-2-5. Because this well is immediately adjacent to the IFC site, it provides a reasonable approximation for the thicknesses and types of strata to be encountered in the new IFC wells. Expected strata include 13 ft of backfill overlying ~20 ft of unsaturated, coarse-grained flood deposits (Hanford formation). Below the water table, lie ~23 ft more of Hanford formation. The contact with the underlying Ringold Formation lies at ~56 ft below ground surface. The top of the fluvial-lacustrine Ringold Formation, consisting of fine sand to silt, forms a local aquitard separating the Hanford formation portion of the unconfined aquifer from the locally semi-confined Ringold Unit E coarse sands and gravels below. About 60 ft of Ringold Unit E overlies a thick (~50 ft) fine-grained Ringold sequence (i.e., Ringold lower mud). Based on a few deep wells located elsewhere in the 300 Area, the top of basalt is estimated at ~180 ft bgs.

The water table, based on hydrographs from nearby wells over the last 10-20 years, ranges from a high elevation of 107.3 m (~25 ft bgs) to a low elevation of 104.3 m (~35 ft bgs). The wide fluctuation in the water table is a direct reflection of changes in seasonal river stage in the adjacent Columbia River. The average low water table in this area is about 33 ft bgs (105 m elev.).

The remainder of this document outlines the plans and procedures for geologic logging; photographic logging; geophysical logging; sample collection; sample identification; sample handling, storage, and inventory; well installation and completion; instrument calibration; and staff responsibilities

Because drilling depths and materials are measured in English units, all geologic-logging, sampling, and well-installation activities also will be recorded in English units (i.e., feet or tenths of feet). Due to the likelihood of introducing conversion errors, it is not practical or wise to record this information using the metric system of measurement. As needed, English units will be converted to metric units later.

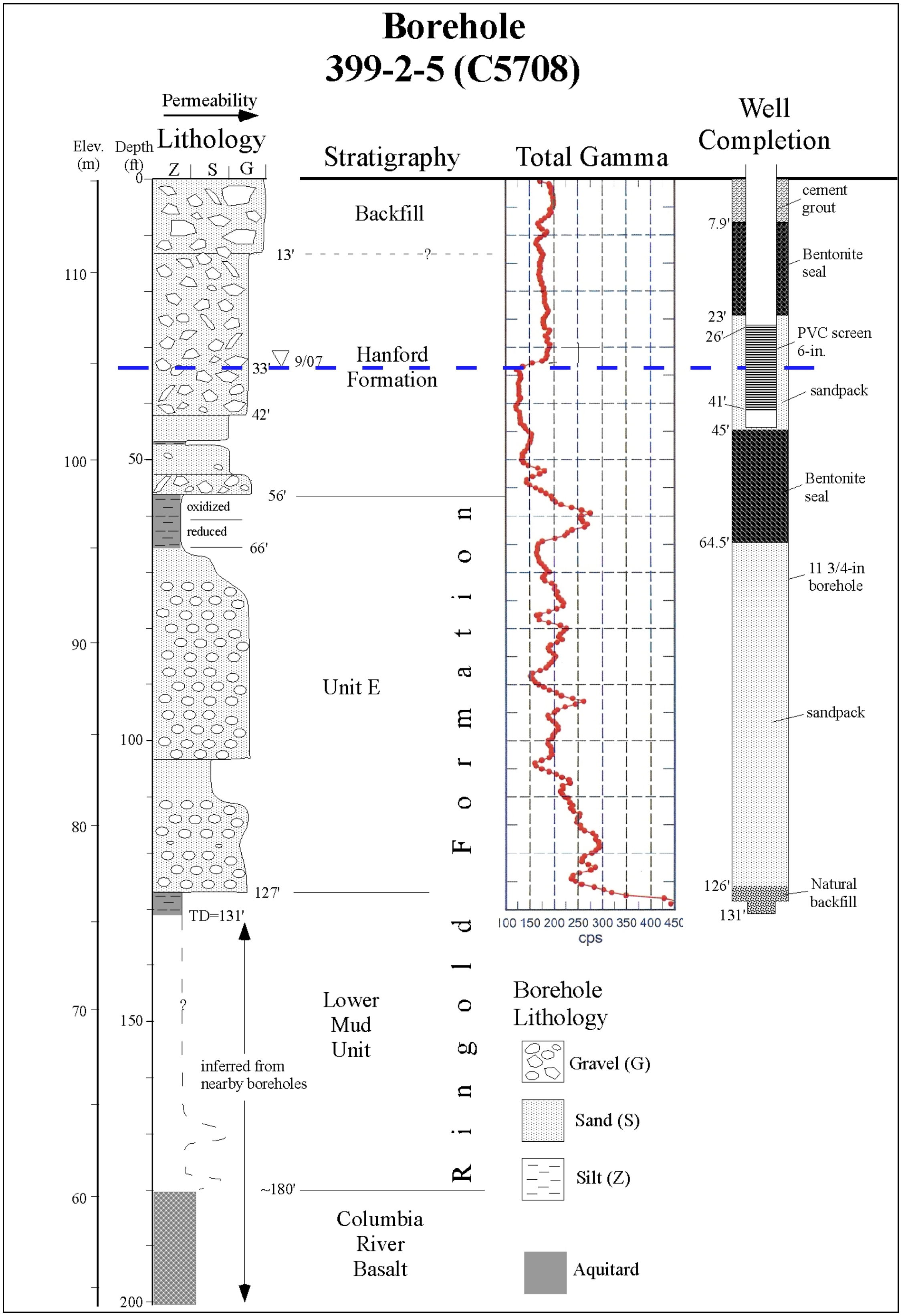

Figure 1.3. IFC site hydrogeology based on well 399-2-5. See Figure 1.1 for location.

2.0 Geologic Log

While drilling, it is important for the well-site geologist to produce a comprehensive, detailed, geologic, and photographic log of the sedimentary materials recovered from each of the 35 IFC boreholes. Information recorded on the Borehole Log (

Figure 2.1) includes the following:

- Depth
- Sample type/sample number
- Moisture condition
- Graphic log
- Lithologic description
  - Sediment class
  - Range in particle size
  - Maximum particle size
  - Mafic content in sand vs gravel fractions
  - Sorting
  - Roundness
  - Color
  - Consolidation
  - Cementation
  - Reaction to hydrochloric acid
  - Structure
  - Fabric
  - Other notable characteristics.

A continuous log of these characteristics will be recorded for each change in lithology.

BOREHOLE LOG			Page ___ of ___ Date:
Well ID:	Well Name:	Location:	
Project:		Reference Measuring Point:	

Depth (Ft.)	Sample		Graphic Log	**Sample Description**	**Comments**
	Type No.	Blows Recovery		Group Name, Grain Size Distribution, Soil Classification, Color, Moisture Content, Sorting, Angularity, Mineralogy, Max Particle Size, Reaction to HCl	Depth of Casing, Drilling Method, Method of Driving Sampling Tool, Sampler Size, Water Level

Reported By:	Reviewed By:
Title:	Title:

Figure 2.1. Geologic log form

3.0 Photographic Log

In addition to a detailed geologic log, the well-site geologist will keep a complete photographic log of the sonic core material retrieved from each of the 35 boreholes. Photographs will be taken with a high-resolution digital camera. This includes a continuous photographic log of core recovered in flexible, thin plastic sleeves (core bags) from each of the 28 non-characterization holes. Before taking the photograph, the well name and the top and bottom depths of the core segment will be written and clearly visible on the plastic sleeve or onto an erasable whiteboard. Each photograph should include a scale for reference.

For the seven characterization wells, where continuous core will be collected downhole in lexan liners, photographs should be taken of each end of the 1-ft lexan liners. These photographs should be taken after the liners are removed from the split spoon and before securing the end caps. In these photos, the core will be taken next to a whiteboard with sample identification as it is photographed. The number will include the well name (minus the 399- prefix), the core sample designation “C,” and the discrete depth of the core end. For example, the photograph of the top end of a core collected from 17-18 ft in borehole 399-2-19 should be labeled 2-19-C17.

In the deep microbial characterization borehole, pictures need only be taken after exposing core collected in thin, flexible, plastic sleeves (core bags) between intervals of lexan-lined core. After opening and exposing the thin plastic lining, each core segment will be labeled with the well name and the top and bottom depths clearly visible on the plastic sleeve or onto an erasable whiteboard before taking the photograph. The lexan-lined core, on the other hand, needs to be covered immediately with sterile end caps upon reaching the surface to minimize microbial contamination. Therefore no photographs will be taken in the field from the lexan-lined core for the deep microbiological characterization borehole.

Photographs should be archived and stored onto a computer hard drive and CD every few days.

4.0 Geophysical Logging

Upon reaching total depth, each hole will be logged by S.M. Stoller Corp. using a spectral-gamma tool from the surface to total depth inside the temporary steel casing, before any well-completion activities. Readings will be collected every 0.5-ft for 200 seconds each. A neutron-moisture log will also be collected for the vadose zone (0-35 ft) in each of the wells before well completion.

5.0 Geologic Sampling

A critical aspect of the IFC research is to provide IFC investigators access to highly valuable samples for analysis. The availability of such samples, their analytical characteristics, and other research results generated on them will be readily traceable and linked through the web interface and associated database.

An intense sampling campaign is planned for all IFC boreholes. Geologic samples will provide material for evaluating the physical, chemical and microbiological characteristics of the sediments and to aid in the development of the conceptual hydrogeologic and geochemical models for the site. A limited number of samples also may be sent offsite to be analyzed by offsite investigators.

5.1 Sample Log

In addition to the Borehole Log, the well-site geologist also will maintain a sample summary log (Figure 5.1) for each well. This form will be used to record the location, type, and ID of each bulk grab and core sample collected during drilling.

5.2 Sample Identification

To minimize confusion and to maximize ease of sample storage and retrieval each discrete geologic sample will consist of a unique sample identification number. This ID number will consist of the abbreviated well name (i.e., well name minus 399- prefix that is common to all the wells), followed by the letter "C" (i.e., core) or "G" (i.e., bulk grab) and depth in feet of the sample interval. For example, a lexan-lined core sample from well 399-2-19 collected from a depth of 50-51 ft would have the sample ID number *2-19-C50-51*. Alternatively, a grab sample collected from 45-49 ft in well 399-3-29; emptied from the sonic core barrel into thin, flexible plastic sleeves (core bag) at the surface; and later transferred to a plastic bucket; would have the sample ID number *3-29-G45-49*. On core samples, this number and the "up" arrow will be written onto two labels (Figure 5.2): one affixed to the side of the lexan liner and another label affixed to the top of the upper end cap. On bucket (grab) samples, the sample ID number will be written onto two permanent labels: one affixed to the side of the bucket and the other on the lid of the bucket.

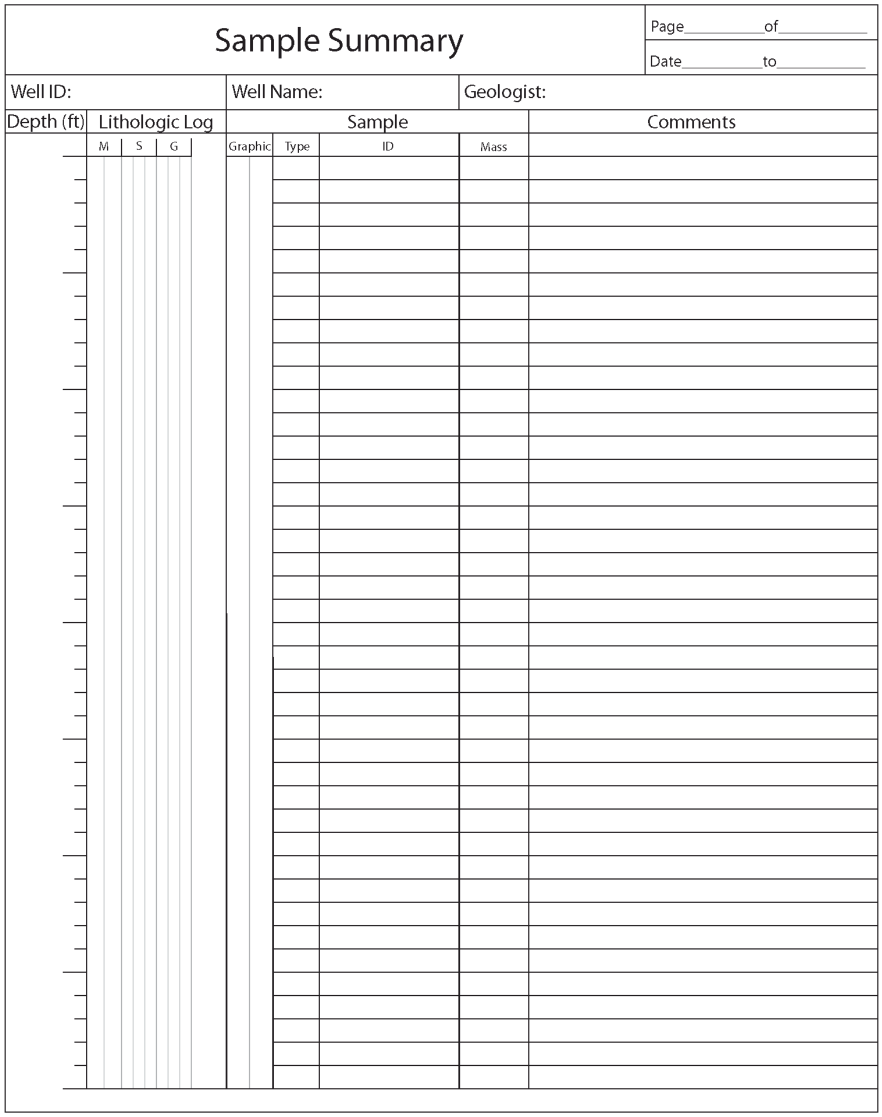
Sample Summary
Page____of____
Date____to____
Well ID: | Well Name: | Geologist:
Depth (ft) | Lithologic Log | Sample | Comments
M | S | G | Graphic | Type | ID | Mass

Figure 5.1. Sample Summary log form.

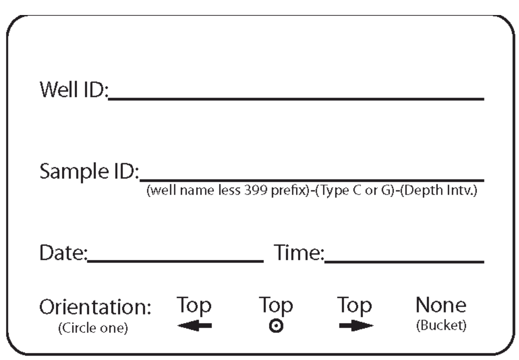
Well ID:____
Sample ID:____
(well name less 399 prefix)-(Type C or G)-(Depth Intv.)
Date:____ Time:____
Orientation: (Circle one) Top Top Top None (Bucket)

Figure 5.2. Example of label used to identify geologic samples. Each sample will have two of these labels: one affixed to the side of the lexan liner and the other on top of the upper end cap.

5.3 Sample Collection

The well-site geologist will collect archive samples for the Hanford Geotechnical Sample Library in glass pint jars and small chip-tray samples at a minimum of every 5 ft or major change in lithology within each borehole.

Characterization samples will be collected as both lexan-lined cores and/or bulk grab samples. Intact, lexan-lined core samples will be distinguished from grab samples by the letters "C" and "G" in the sample identification number. Continuous, capped lexan-lined core samples will be collected from seven of the ERT-instrumented wells (see Table 1.1). As an example, the official sample identification for an intact core sample collected from a 22-23 ft depth in well 399-2-13 would have the number *2-13-C22-23*. The entire core interval (22-23 ft), an "up" arrow, and the date and time of collection also will be written with an indelible marker onto a label affixed to the outside of the liner. Another label with the same identification will be placed over the upper end cap. Having two labels will facilitate storage and retrieval of the samples and maintain positive identification in case one of the labels later detaches.

Any void space that exists on either end of liners will be filled with a ball of bunched-up aluminum foil before securing the end caps. This is to keep the core from disaggregating or mixing any further inside the liner during sample handling and storage. Well name, well ID, date and time of collection, an "up" arrow, and the sample identification number also should be written clearly onto two labels affixed to the lexan liner. One label should go on the surface of the upper end cap and the other along the side of the liner.

For the remaining holes, core samples will be vibrated from the core barrel and emptied into ~2-ft long plastic sleeves (core bags) at the surface. The sleeves will be cut lengthwise to expose the inside core. Sample identification will be written onto the plastic sleeve or a whiteboard. Before disturbing the exposed core, a high-resolution digital image (i.e., photograph) will be obtained of the core in each opened sleeve. After geologic logging, the core will be transferred into a plastic bucket labeled with well name, well ID, sample ID number, and date and time of collection. As an example, the official sample identification for a bulk grab sample transferred from the 35 to 38 ft sleeved interval in well 399-2-16 would have the sample ID number *2-16-G35-38*.

As much as possible, grab samples should consist of a similar lithology or sedimentary unit. Care should be taken not to mix diverse stratigraphic units when collecting grab samples. For example, a sand or silt lens within a predominantly gravelly sequence should be sampled and labeled separately and placed in a separate container from the gravel. This step does not apply to core samples collected in lexan liners, which should not be separated since these can be subsampled later upon core opening.

The following sections document field-sample collection as it relates to the different types of wells.

5.3.1 ERT-instrumented Wells.

The seven ERT-instrumented characterization holes will be cored continuously via the resonant-sonic method to a total depth of ~58 ft. Approximately 4-in (ID) split-spoon samplers will be used to collect sediment core in 4-5 ft long runs; and the core barrel will be lined with precut 1-ft lexan liner sections. Upon retrieval, the ends of each 1-ft core segment will be photographed, capped, and affixed with labels that contain the well name, well ID, depth, date, and an "up" arrow. End caps will be secured with duct tape.

In the 18 remaining ERT-instrumented wells, drill cuttings will be emptied into ~2-ft-long plastic sleeves (core bags) as cuttings are vibrated out of the sonic core barrel. Each bag will be labeled by well number and depth, cut open lengthwise, photographed, and logged in the plastic sleeve. Non-sloughed core material in the plastic sleeves will be transferred to ~2-gallon buckets labeled with the well name, well ID, sample identification number, depth interval, and date and time of collection. Distinctly different lithologies should be separated and placed into separate labeled buckets.

5.3.2 Multi-Level Groundwater Monitoring Wells.

Sonic core from all nine multilevel groundwater monitoring wells will be emptied into flexible plastic sleeves (core bags) from the core barrel at the surface. After cutting the plastic sleeves lengthwise and photographing and logging the core, non-sloughed material in the sleeve will be transferred to a plastic bucket labeled with the well name, well ID, sample identification number, depth interval, type of sample, and date and time of collection. Distinctly different lithologies should be separated and placed into separate labeled buckets.

5.3.3 Deep Microbiology Characterization Well.

A total of 60 ft of lexan-lined, split-spoon core samples will be collected in 5-ft runs from 30-35 ft, 50-70 ft, 95-100 ft, 122-132 ft, and 170 ft to the top of basalt (~180 ft depth). For each of these intervals, the 5-ft sampler will be lined with five precut 1-ft lexan liner sections. Upon retrieval, the ends of each 1-ft core segment will be capped and the liner labeled with well name, well ID, sample identification number, depth interval, date and time of collection, and an "up" arrow.

Between lexan-lined core runs, core samples will be vibrated from the core barrel into flexible plastic sleeves (core bags) at the surface. The plastic sleeves will be cut lengthwise, photographed, and logged. Non-sloughed material of similar lithology in the sleeve will be transferred into plastic buckets labeled with well name, well ID, sample identification number, depth interval, type of sample, and date and time of collection. Samples of distinctly different lithology should be placed in separate, labeled containers.

5.4 Sample Handling, Storage, and Inventory

After labeling and sealing the ends of core liners, or securing lids of bucket grab samples, the samples will be placed into the sample storage trailer located onsite. Samples should be arranged by well number and depth as closely as possible to facilitate retrieval of samples as needed. One-foot-long lexan core samples will be stored upright with the top of the core and ID number written on end cap facing up. This configuration will allow for the most efficient use of space and easy retrieval of sediment core as needed. Grab-sample buckets will be stored and stacked upright by well number, in their natural depth sequence (i.e., shallowest sample on top), with the sample ID number clearly visible on the top of each lid.

Upon collection, all samples will be entered onto chain-of-custody (COC) forms (Figure 5.3) by the NCO samplers. A unique COC number will be entered on each form. The number will consist of the well name and the depth interval for the samples included on the form. Multiple samples from the same well will be entered in sequence onto the COC form. As an example, the COC number on the form that includes samples from 40-58 ft in well 399-2-16 would read 2-16-40-58.

The Sample and Inventory Custodian will enter all samples onto a sample inventory form (Figure 5.4). Data on these forms will be entered into a computerized database (Excel spreadsheet), which will be maintained and updated on a regular basis by the Sample Inventory Custodian. The Sample Inventory Custodian will control the distribution of the samples as they are removed from the storage facility and transferred to other labs or investigators. The Sample Inventory Custodian will note this information on the inventory form.

The IFC Project will maintain a website (http://ifchanford.pnl.gov) that provides access to controlling documentation, geologist logs, photographs, and sample inventory, etc.

Pacific Northwest National Laboratory
IFC Chain of Custody (COC) Form

Chain of Custody No.		Drill Method				Project Point of Contact	Phone Number
Date	Time	Sample Identification #	Type of Sample	Borehole	Depth (ft)	Sampler	Comments
Date	Time	Relinquished by	Date			Time	Received by
Date	Time	Relinquished by	Date			Time	Received by
Date	Time	Relinquished by	Date			Time	Received by

Figure 5.3. Sample Chain-of-Custody Form

IFC Geologic Sample Inventory

Well Name:

Well ID:

Sample Type[1]	Depth Interval (ft bgs)	Sample ID	Date Collected	COC #	Lithology	Mass	Storage Location	Transferred to:	Comments

[1] G = grab, C = core

inventory.form.xls

Figure 5.4. Sample Inventory Form

6.0 Well Installation and Completion

Detailed information on well installation and completion will be summarized onto well summary sheets (Figure 6.1) and the Well Construction Summary Report form. This information will include, but is not limited to the following:

- Drill method
- Borehole diameter
- Total depth
- Casing and well-screen depths
- Type of casing and screen/slot size
- Filter-pack material
- Annular-seal material
- Location of centralizers
- Location of downhole sensors
- Water level
- Surface-completion details.

6.1 ERT-Instrumented Wells

All 28 ERT-instrumented wells will be constructed using a 4-in. PVC screen (with end cap and riser). A 25-ft long, 20-slot, continuous wire-wrap screen will be installed with the bottom of the screen set at the contact with the Ringold Formation (~56 ft depth). Special ERT electrodes, thermistors, and ancillary wiring will be attached to the outside of the PVC during installation (Figure 6.2), so special care will be required lowering the assembly to the bottom of the hole under the supervision of the PNNL cognizant scientist. After the PVC and electronics are in place, 10-20 mesh silica sand will be added to the annular void space as the temporary steel casing is pulled back. Once 10-20 sand has been emplaced and settled via surging to within 2 ft above the top of the screen, 40-140 mesh sand will be placed in the annulus to 10 ft below ground surface.

The distribution of downhole electrodes and other sensors placed in the annulus are shown in Figure 6.3. These include cables and sensors for both thermistors and ERT electrodes. A separate wire will run from each thermistor to the surface. The ERT electrodes, on the other hand will be connected via two wires, one connecting the upper 15 electrodes and another cable connecting the lowermost 15 electrodes. Electrodes, thermistors, and cables will be attached to the outside of the PVC via plastic zip ties.

WELL SUMMARY SHEET		Start Date:	Page ___ of ___
		Finish Date:	
Well ID:		Well Name:	
Location:		Project:	
Prepared By:	Date:	Reviewed By:	Date:
Signature:		Signature:	

CONSTRUCTION DATA		Depth in Feet	GEOLOGIC/HYDROLOGIC DATA	
Description	Diagram		Graphic Log	Lithologic Description

A-6003-643 (03/03)

Figure 6.1. Well Summary Sheet

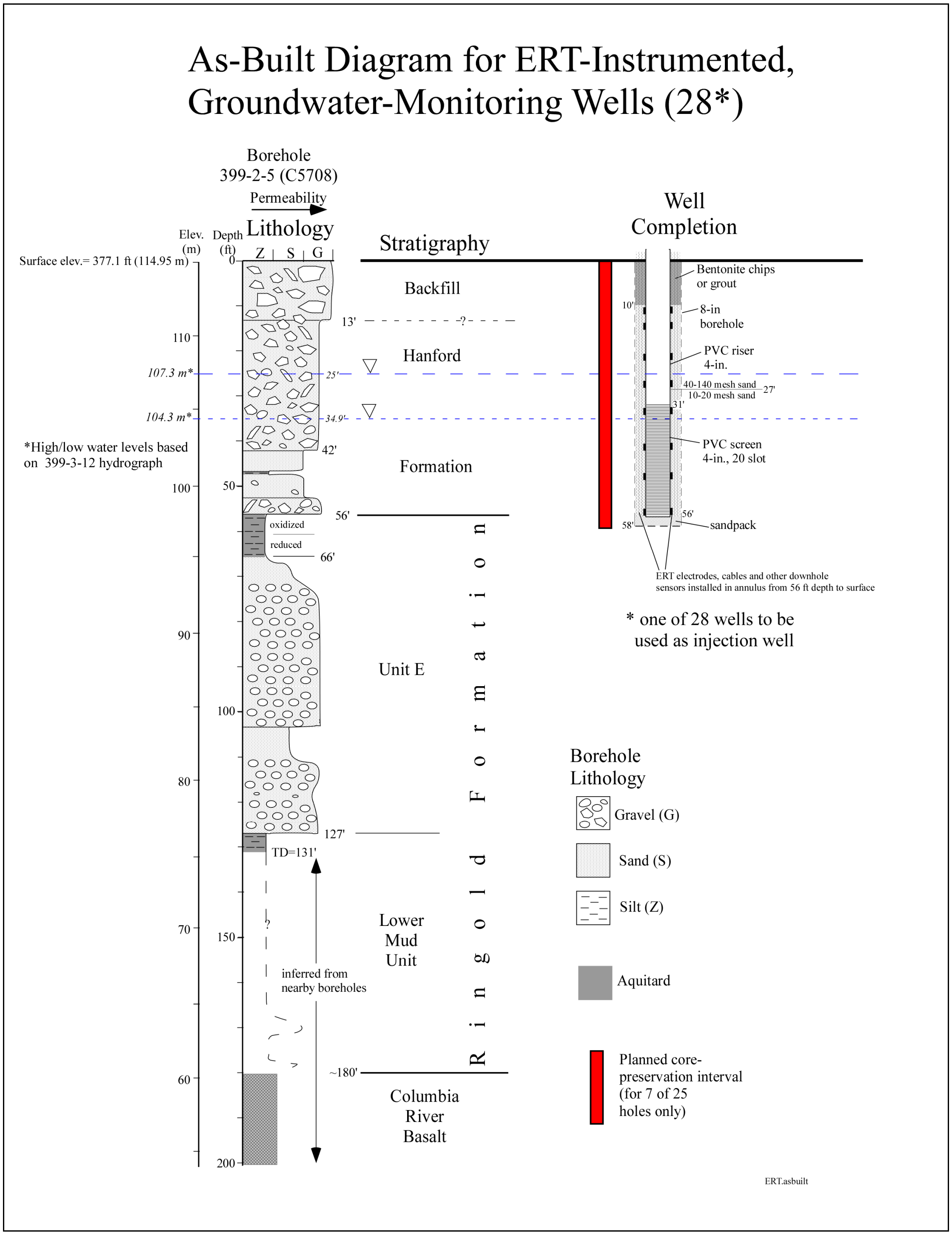

Figure 6.2. Planned well completion at the 28 ERT-instrumented wells

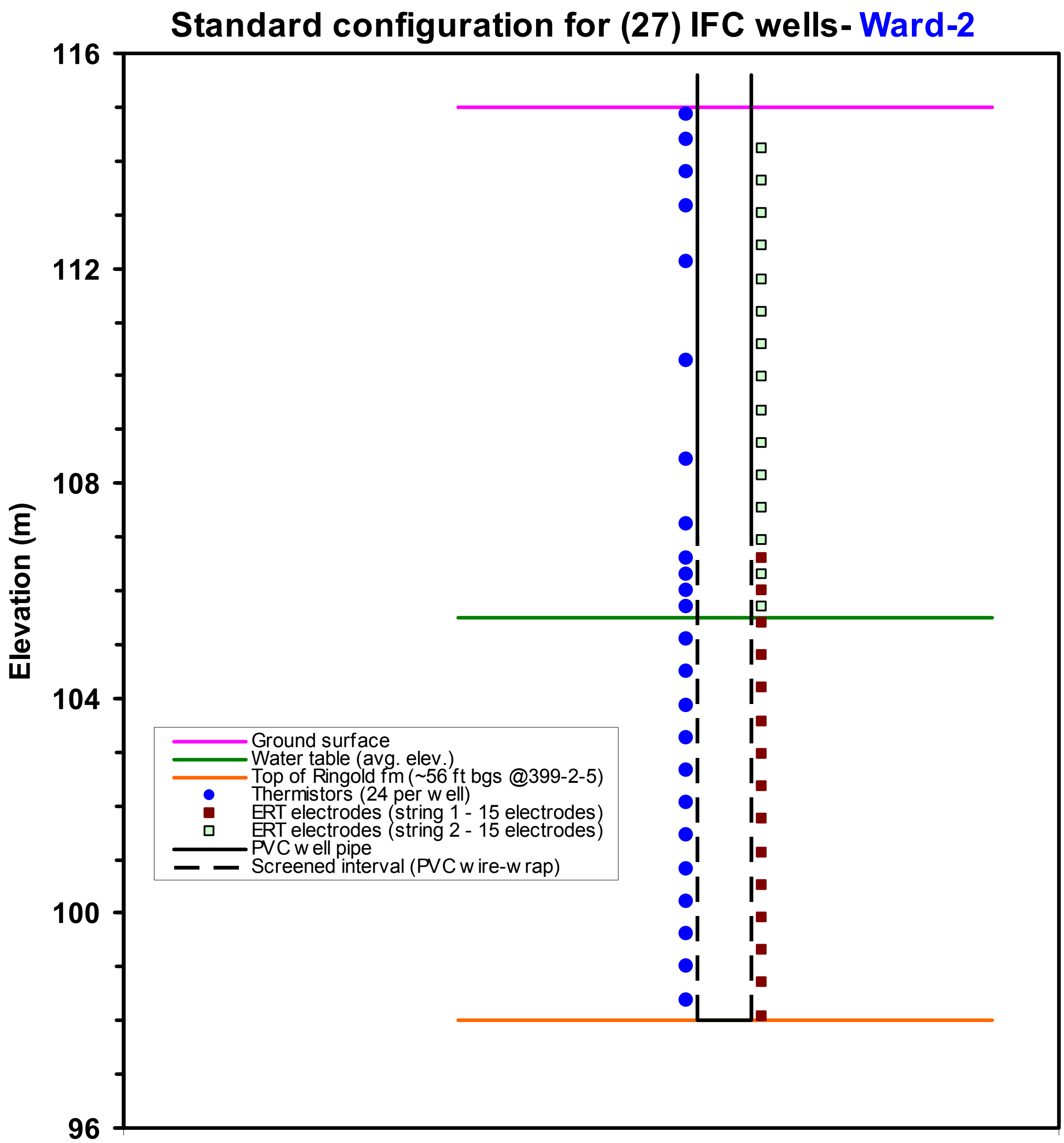

Figure 6.3. Locations of downhole sensors to be placed outside of PVC casing and screen in 28 ERT-instrumented holes

Figure 6.4 shows a photograph of a potted thermistor. Each thermistor is potted in epoxy and housed in a stainless steel tube. A two-conductor cable is attached to the thermistor extends to the surface for connection to monitoring instruments. Thermistors have been pre-assembled in bundles of 24, labeled according to well identification number, and stored on PVC spindles, one for each well, for easy identification and installation (Figure 6.5). During installation, the prelabeled bundle will be unwrapped from the PVC spindle and laid horizontally on the ground adjacent to the well screen. Each bundle will then be attached to the well screen using cable ties (Figure 6.6).

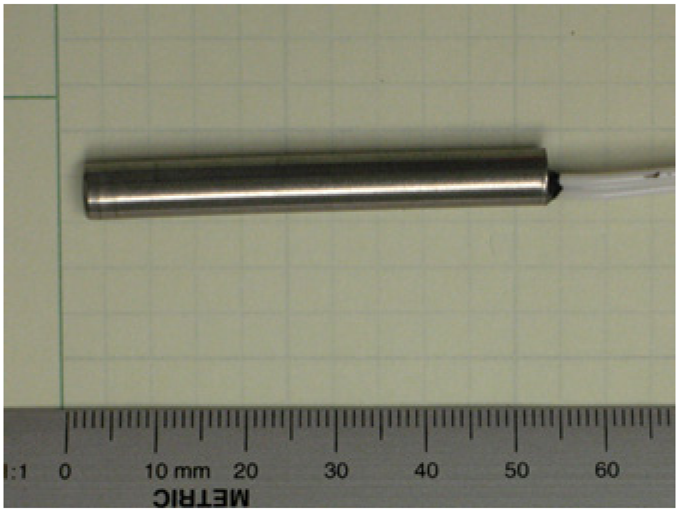

Figure 6.4. Photograph of potted thermistor that will be used for in situ temperature measurements

Figure 6.5. Photograph of preassembled thermistor bundles. Each bundle of 24 thermistors is spooled on a PVC spindle for minimize tangling and simplify installation

The vertical electrode arrays for the ERT measurements consist of a 15-conductor cable with fifteen electrodes per cable. Electrodes are 4 in long and constructed of wire-wound type 316 stainless steel with a single wire connection at 2-ft intervals along the cable (Figure 6.6). Each cable has a unique identifier and is fitted with a circular 15-pin male connector at the proximal end. The cable must be installed with the connector end at the ground surface. Each well will be instrumented with two cables. Cables will be uncoiled next to the appropriate well casing with the connector end towards the surface end of the screen. Cables will be attached to the outside of the screen using cable ties. Figure 6.7 shows a prototype well assembly with an attached thermistor and ERT vertical electrode array attached via cable ties.

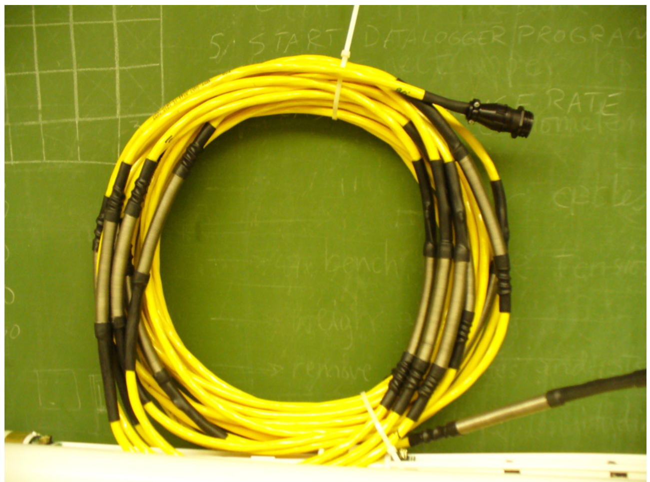

Figure 6.6. Photograph of a coiled vertical electrode array showing the multiconductor cable and the 4-in wire wrapped stainless steel electrodes

Figure 6.7. Photograph of a prototype well assembly showing a thermistor (on the left-hand side) and an ERT electrode (on the right-hand side)

All thermistor and ERT cables will be routed to the ground surface where they will be connected to central connector/data acquisition box at the wellhead.

Surging of the sand pack should be performed between each 5-10 ft casing lift. Surging is especially important to get sand to settle in completely around the ERT electrodes, cables, etc., which will be partially blocking the annular space between permanent and temporary casings. Before adding 40-140 mesh sand to the annulus, it is important to surge the 10-20 mesh sand pack so it is no less than 2 ft above the top of the screen (~27 ft depth) after surging.

A surface seal of cement grout or bentonite will extend from a 10 ft depth to the ground surface. Flush-mount surface completions will consist of a 10-12 in. well vault centered within a concrete pad. The vault will be equipped with a drain to remove any water that may accumulate within the vault.

6.2 Multi-Level Groundwater Monitoring Wells

Three clusters of multi-level groundwater monitoring wells will be installed at the IFC site (Figure 6.8). Three wells each will monitor the shallow, intermediate, and deep levels of the unconfined Hanford formation aquifer.

6.2.1 Deep Monitoring Well.

The well will be constructed using a 4-in diameter, schedule 40 PVC. After this hole is drilled to a depth of about 58 ft, a 2.5-ft-long, 4-in. (ID), 20-slot, PVC screen (actual screen length = 2 ft) will be installed just above the base of the Hanford formation and unconfined aquifer (~53-55 ft). Sand pack will be placed from 2 ft below to 2 ft above the top of the screen. To avoid hydraulic interference with other nearby wells within the cluster, a minimum 5-ft thick bentonite seal will be placed above this primary sand pack. Because this well will be instrumented for ERT and other sensors along the outside of the PVC, a sand pack (40-140 mesh) will be placed above the bentonite seal to 10 ft below ground surface. A surface seal of bentonite chips or grout will extend from a 10-ft depth to the ground surface. Flush-mount surface completions will consist of a 10-12 in. well vault centered within a concrete pad. The vault will be equipped with a drain to remove any water that may accumulate within the vault.

6.2.2 Intermediate Monitoring Well.

The well will be constructed using a 4-in diameter, schedule 40 PVC. After this hole is drilled to about 46 ft, a 2.5-ft-long, 4-in. (ID), 20-slot, PVC screen (actual screen length = 2 ft) will be installed near the middle of the unconfined aquifer (~42-44 ft). Sand pack (10-20 mesh) will be placed from 2 ft below to 2 ft above the top of the screen. A 5-ft bentonite seal will be placed above the sand pack, followed by a continuous seal of bentonite chips or grout to the surface. Flush-mount surface completions will consist of a 10-12 in. well vault centered within a concrete pad. The vault will be equipped with a drain to remove water that may accumulate within the vault.

6.2.3 Shallow Monitoring Well.

The well will be constructed using a 4-in diameter, schedule 40 PVC. After this hole is drilled to about 37 ft, a 5-ft-long, 4-in. (ID), 20-slot, PVC screen (actual screen length = 2 ft) will be installed at the top of the unconfined aquifer (~31-33 ft). Sand pack (10-20 mesh) will be placed from 2 ft below to 2 ft above the top of the screen. The annulus will be sealed to the surface above the sand pack (starting ~28 ft depth). Either bentonite chips or grout can be used for the seal. It is possible that during certain times of year the screen in the shallowest wells in clusters could lie above the water table and be temporarily dry. However, because the source for uranium contamination may lie in this zone of fluctuating water table, it is important to target this zone for groundwater analysis. Flush-mount surface completions will be imbedded into a cement pad equipped with a 10-12 in. vault to collect any surface runoff and to keep surface water from entering the inside of the well.

6.3 Deep Microbiology Characterization Well

After drilling is completed and the borehole has reached a total depth of ~180 ft, the bottom of the hole will be backfilled with bentonite to the base of the well (~140 ft) (Figure 6.9). The well will be constructed using a 4-in diameter, schedule 40 PVC. The well screen will be a 10-slot, continuous wire wrap and 80 ft in length (60-140 ft depth). A sand pack of 20-40 mesh Colorado Silica Sand will be placed from 2 ft below to 2 ft above the top of the screen. Surging of the sand pack will be performed as sand is added. Surging of the sand pack will occur at a minimum of every 20 ft. After final surging of the sand pack, at least 5 ft of bentonite chips followed by chips or grout will be installed above the sand pack to the surface.

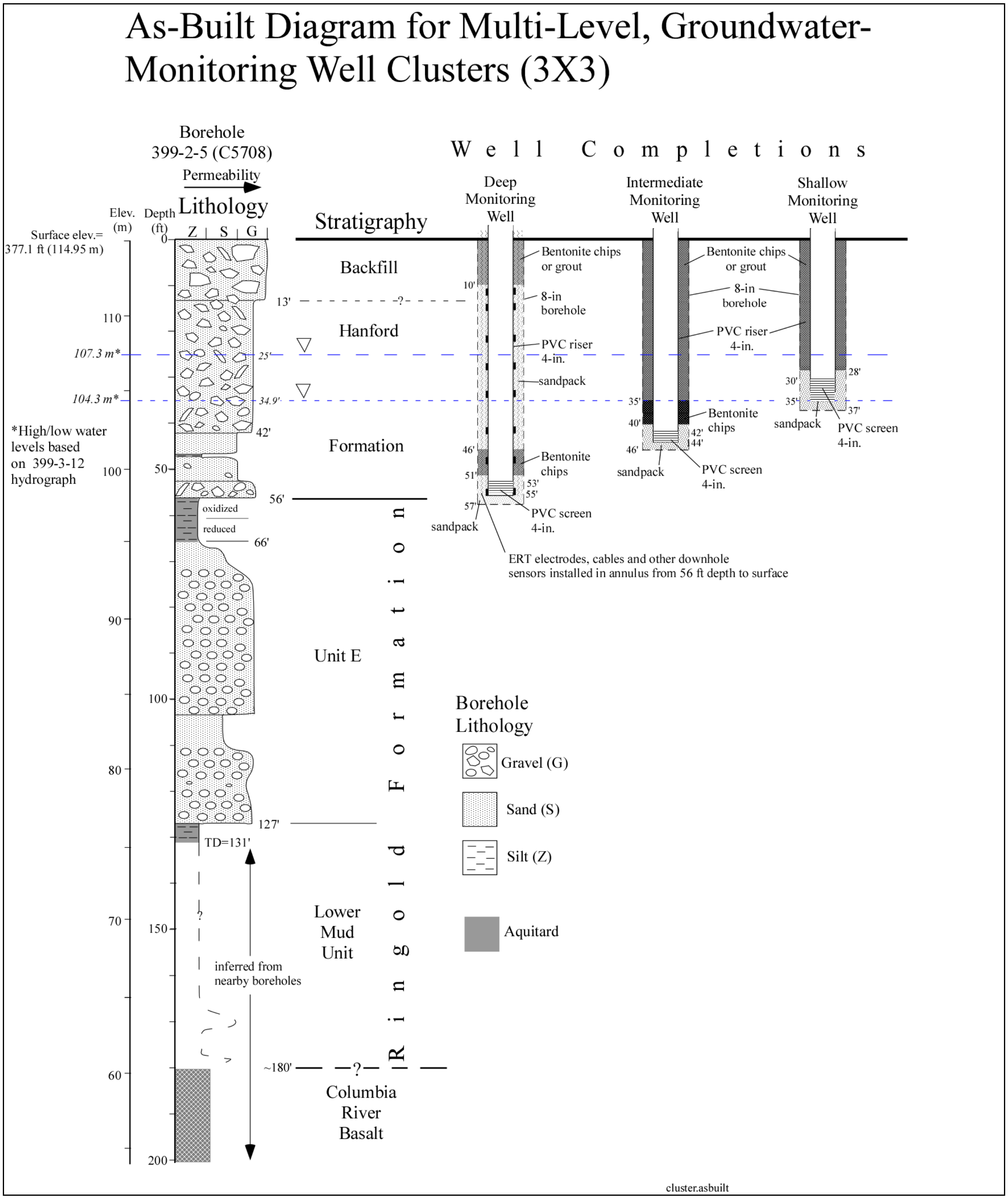

Figure 6.8. Planned well completions for the nine multi-level groundwater monitoring wells

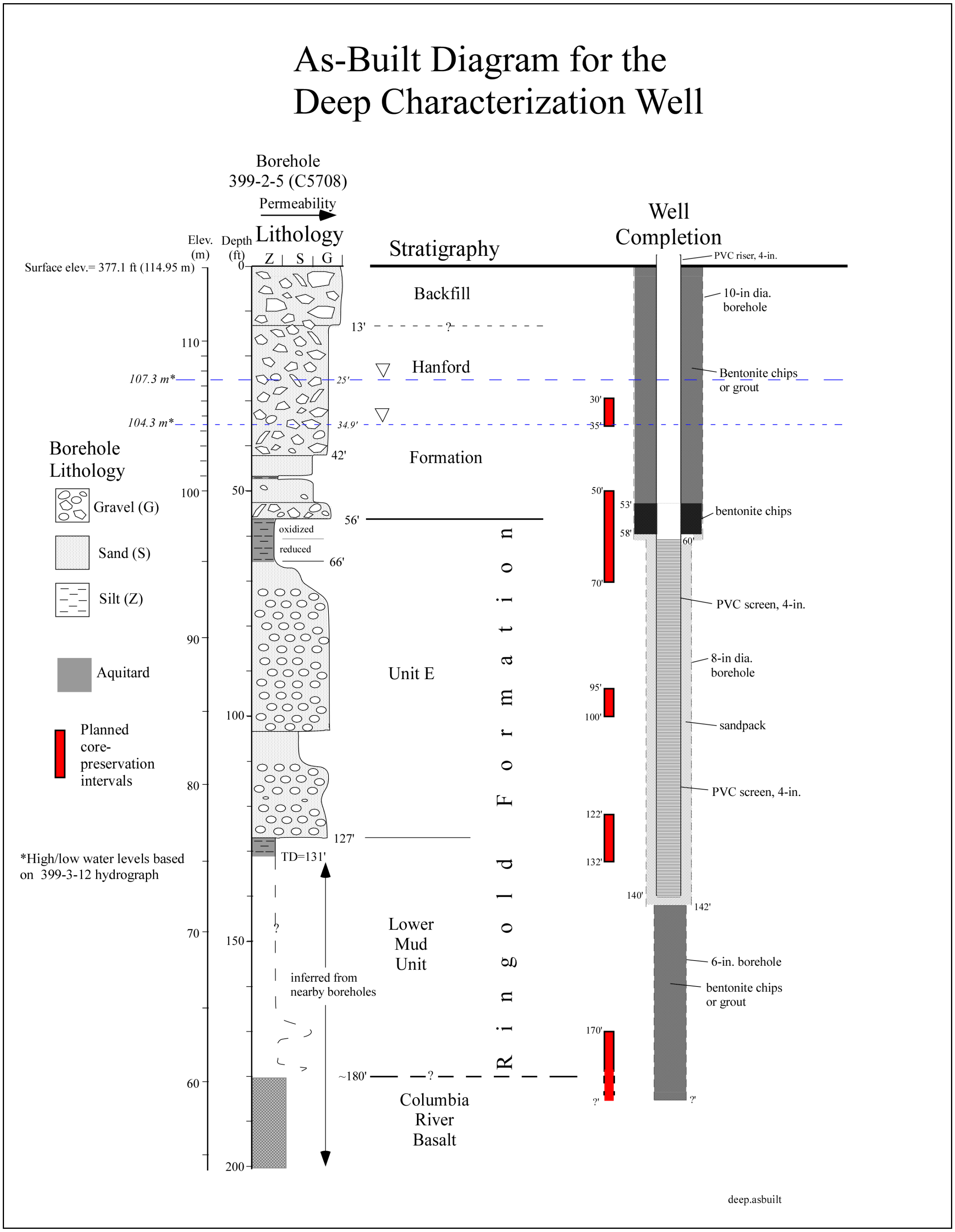

Figure 6.9. Planned well completion for the single, deep microbiology characterization well

7.0 Instrument Calibration

All of the thermistors have been precalibrated in the laboratory. Thermistors were calibrated in batches of 144 by placing them in a water bath, equilibrating to a preset temperature, and recording the water temperature and resistance. Although no further calibration is required, after installation and before borehole completion, the thermistors will be interrogated via the data acquisition system to verify functionality. The ERT electrodes do require calibration. However, before installation and again after installation but before borehole well completion, electrodes will be connected to the data acquisition system and interrogated to verify electrical continuity between electrodes.

8.0 IFC Staff Roles and Responsibilities

A directory of field personnel involved in the IFC project is presented in Appendix B.

8.1 PNNL Personnel

John Zachara, IFC Project Manager

- Manages the 300 Area IFC site and research operations
- Supervises IFC staff and subcontractors
- Interacts with the DOE Environmental Remediation Sciences Division (ERSD) and the DOE Richland Operations Office and their subcontractors, Washington Closure Hanford and Fluor Hanford, to plan and conduct work
- Develops and maintains overall Scientific Research Plan and schedule
- Participates in quarterly conference calls with the ERSD program manager
- Submits quarterly progress reports to the ERSD program manager
- Provides state-of-the-art equipment and knowledgeable staff to perform field experiments at the IFC
- Leads publications of scientific research results from field experiments at the IFC
- Assists ERSD program manager with transfer of knowledge and technology to DOE Environmental Management, primarily the Richland Operations Office, for making progress on remediation of DOE sites

Mark Freshley, IFC Field Site Manager

- Manages the 300 Area IFC site operations, including obtaining applicable permits, preparing and implementing site safety plans, scheduling field activities and operations, and supervising IFC staff and subcontractors in the field
- Co-manages the 300 Area IFC site and research operations
- Supervises IFC staff and subcontractors during field operations
- Establishes and maintains management and operating procedures for the IFC
- Approves work plans for all field activities at the IFC before initiation
- Monitors field operations at the IFC
- Oversees collection, tracking, and documentation of field samples
- Participates in quarterly conference calls with the ERSD program manager
- Contributes to quarterly progress reports to the ERSD program manager
- Provides state-of-the-art equipment and knowledgeable staff to perform field experiments at the IFC
- Distributes groundwater and sediment materials to other IFC participants and ERSD investigators, as requested

Vince Vermeul, Environmental Engineer/Hydrologist

- Primary responsibility for aquifer testing and hydrologic characterization
- Primary responsibility for tracer-injection tests

Andy Ward, Hydrogeophysicist

- Responsible for deriving physical characteristics from downhole geophysical measurements and analyses
- Responsible for installing ERT and other instrumentation in wells

Mark Rockhold, Hydrologist

- Lead author of site characterization plan
- Performs pre- and post-injection hydrologic modeling of the site

Jim McKinley, Geochemist

- Geochemical characterization
- Oversees development of site geochemical model

Bruce Bjornstad, Geologist

- Prepares drilling and sampling specification document for input into the Drilling Statement of Work
- Prepare drilling and geologic sampling plan
- Monitors field operations at the IFC, including geologic logging and sampling
- Oversees collection, tracking, and documentation of field samples
- Monitors well installation and completion
- Manages compilation and integration of geologic data and development of site conceptual geologic model

Jim Fredrickson, Microbiologist

- Responsible for microbiological characterization

Jake Horner, Geologist

- Onsite drilling, sampling and well-completion oversight.
- Assists with installation of downhole instrumentation in wells.
- Checks and verifies quality and consistency of geologic logging and sample labeling.

Ray Clayton, Technician

- Assists with installation of downhole instrumentation in wells

Chris Strickland, Scientist

- Assists with installation of downhole instrumentation in wells

Mike Singleton, Technician

- Calibration of down-hole sensors for the wells

Donny Mendoza, Environmental Engineer

- Acquires and maintains electricity to the site.
- Assists with hydrologic testing

Dean Moore, Sample and Inventory Custodian

- Manages storage, inventory, and distribution of geologic samples
- Maintains sample inventory and tracking of geologic samples

Sonia Enloe, IFC Administrator

- Performs administrative duties for IFC project.

8.2 Non-PNNL Personnel

Roelof Versteeg (Idaho National Engineering and Environmental Laboratory), Database Manager and Geophysicist

- Manages database of IFC-related data and information
- Assists with design of geophysical instrumentation.

Gram, Inc. (contracted to Fluor Hanford, Inc. to provide geologic support)

- Documents day-to-day drilling and sampling activities onsite
- Completes geologic and well-completion log forms, daily activity reports, as-built diagrams
- Collects and maintains a core photographic log.

S.M. Stoller, Inc., Geophysical Logging

- Downhole spectral-gamma logging across full length of IFC holes
- Downhole neutron logging of vadose zone (<35 ft) in all IFC wells.

9.0 References

AGI, 1982, AGI Data Sheets for Geology in the Field, Laboratory, and Office: American Geological Institute, Falls Church, Virginia, 22041.

American Society for Testing and Materials (ASTM), 1984, Standard Practice for Description and Identification of Soils (Visual-Manual Procedure): Procedure D 2488-93, American Society for Testing and Materials, Philadelphia, Pennsylvania, p. 218-228.

Compton, R.T., 1962, Manual of Field Geology: John Wiley & Sons, New York, 378 p.

Folk, R.L., 1968, Petrology of Sedimentary Rocks, Hemphill's, Austin, Texas, 170 p.

Last, G. V., and Liikala, T. L., 1987, A field guide for well-site geologists: cable-tool drilling: PNL-6392, Battelle, Pacific Northwest National Laboratory, Richland, Washington.

Munsell, 1975, Munsell Soil Color Charts: Macbeth, a division of Kollmorgen Co., Baltimore, Maryland, 7 charts.

Tucker, M. E., 1982, The Field Description of Sedimentary Rocks: John Wiley and Sons, New York, 112 p.

Walker, L.D., and L.C. Swanson, 2006, Geologic Logging, Groundwater Remdiation Project Administrative Procedure, GRP-EE-01-7.0, Fluor Hanford Inc., Richland, Washington.

Wentworth, C. K., 1922, "A Grade Scale and Class Terms for Clastic Sediment" in *Journal of Geology*, 30, p. 377-392.

Appendix A

IFC Drilling, Sampling and Well Completion Specifications Summary

Appendix B. IFC Drilling, Sampling, and Well Completion Specifications Summary

					Sampling			Well Completion								
Well ID	Well Name	Function	Total depth (ft)	Temp. Casing Diameter (in.)	Type	Sample Depth Interval (ft bgs)	Approx. # samples[5]	Completed Depth (ft)	PVC diameter (in)	Screen Interval (ft bgs)	Screen Slot size	Bentonite seal (ft bgs)	Minimum # Centralizers[4]	Sump	Surface completion	Comments
C6184	399-2-7	ERT electrodes	58	8	Grab[1]	0-58	30	58	4	31-56	20	0-10	3	none	Flush mount	10-20 sand to 2 ft above screen, then 40-140 sand to surface seal
C6185	399-2-8	ERT electrodes	58	8	Grab[1]	0-58	30	58	4	31-56	20	0-10	3	none	Flush mount	10-20 sand to 2 ft above screen, then 40-140 sand to surface seal
C6186	399-2-9	ERT electrodes + characterization + gw injection	58	8	Intact core[2]	0-58	55	58	4	31-56	20	0-10	3	none	Flush mount	10-20 sand to 2 ft above screen, then 40-140 sand to surface seal
C6187	399-2-10	ERT electrodes	58	8	Grab[1]	0-58	30	58	4	31-56	20	0-10	3	none	Flush mount	10-20 sand to 2 ft above screen, then 40-140 sand to surface seal
C6188	399-2-11	ERT electrodes	58	8	Grab[1]	0-58	30	58	4	31-56	20	0-10	3	none	Flush mount	10-20 sand to 2 ft above screen, then 40-140 sand to surface seal
C6189	399-2-12	ERT electrodes + characterization	58	8	Intact core[2]	0-58	55	58	4	31-56	20	0-10	3	none	Flush mount	10-20 sand to 2 ft above screen, then 40-140 sand to surface seal
C6190	399-2-13	ERT electrodes + characterization	58	8	Intact core[2]	0-58	55	58	4	31-56	20	0-10	3	none	Flush mount	10-20 sand to 2 ft above screen, then 40-140 sand to surface seal
C6191	399-2-14	ERT electrodes	58	8	Grab[1]	0-58	30	58	4	31-56	20	0-10	3	none	Flush mount	10-20 sand to 2 ft above screen, then 40-140 sand to surface seal
C6192	399-2-15	ERT electrodes	58	8	Grab[1]	0-58	30	58	4	31-56	20	0-10	3	none	Flush mount	10-20 sand to 2 ft above screen, then 40-140 sand to surface seal
C6193	399-2-16	ERT electrodes	58	8	Grab[1]	0-58	30	58	4	31-56	20	0-10	3	none	Flush mount	10-20 sand to 2 ft above screen, then 40-140 sand to surface seal
C6194	399-2-23	ERT electrodes	58	8	Grab[1]	0-58	30	58	4	31-56	20	0-10	3	none	Flush mount	10-20 sand to 2 ft above screen, then 40-140 sand to surface seal
C6195	399-2-17	ERT electrodes	58	8	Grab[1]	0-58	30	58	4	31-56	20	0-10	3	none	Flush mount	10-20 sand to 2 ft above screen, then 40-140 sand to surface seal
C6196	399-2-18	ERT electrodes	58	8	Grab[1]	0-58	30	58	4	31-56	20	0-10	3	none	Flush mount	10-20 sand to 2 ft above screen, then 40-140 sand to surface seal
C6197	399-2-19	ERT electrodes + characterization	58	8	Intact core[2]	0-58	55	58	4	31-56	20	0-10	3	none	Flush mount	10-20 sand to 2 ft above screen, then 40-140 sand to surface seal
C6198	399-2-20	ERT electrodes	58	8	Grab[1]	0-58	30	58	4	31-56	20	0-10	3	none	Flush mount	10-20 sand to 2 ft above screen, then 40-140 sand to surface seal
C6199	399-2-24	ERT electrodes	58	8	Grab[1]	0-58	30	58	4	31-56	20	0-10	3	none	Flush mount	10-20 sand to 2 ft above screen, then 40-140 sand to surface seal
C6200	399-3-25	ERT electrodes + characterization	58	8	Intact core[2]	0-58	55	58	4	31-56	20	0-10	3	none	Flush mount	10-20 sand to 2 ft above screen, then 40-140 sand to surface seal
C6201	399-2-21	ERT electrodes	58	8	Grab[1]	0-58	30	58	4	31-56	20	0-10	3	none	Flush mount	10-20 sand to 2 ft above screen, then 40-140 sand to surface seal
C6202	399-2-22	ERT electrodes	58	8	Grab[1]	0-58	30	58	4	31-56	20	0-10	3	none	Flush mount	10-20 sand to 2 ft above screen, then 40-140 sand to surface seal

C6203	399-3-26	ERT electrodes + characterization	58	8	Intact core[2]	0-58	55	58	4	31-56	20	0-10	3	none	Flush mount	10-20 sand to 2 ft above screen, then 40-140 sand to surface seal
C6204	399-3-27	ERT electrodes	58	8	Grab[1]	0-58	30	58	4	31-56	20	0-10	3	none	Flush mount	10-20 sand to 2 ft above screen, then 40-140 sand to surface seal
C6205	399-3-28	ERT electrodes	58	8	Grab[1]	0-58	30	58	4	31-56	20	0-10	3	none	Flush mount	10-20 sand to 2 ft above screen, then 40-140 sand to surface seal
C6206	399-3-29	ERT electrodes	58	8	Grab[1]	0-58	30	58	4	31-56	20	0-10	3	none	Flush mount	10-20 sand to 2 ft above screen, then 40-140 sand to surface seal
C6207	399-2-23	ERT electrodes	58	8	Grab[1]	0-58	30	58	4	31-56	20	0-10	3	none	Flush mount	10-20 sand to 2 ft above screen, then 40-140 sand to surface seal
C6208	399-2-24	ERT electrodes + characterization	58	8	Intact core[2]	0-58	55	58	4	31-56	20	0-10	3	none	Flush mount	10-20 sand to 2 ft above screen, then 40-140 sand to surface seal
C6210	399-2-26	Shallow gw monitoring	37	8	Grab[1]	0-37	18	37	4	30-35	20	0-28	2	2 ft	Flush mount	
C6211	399-2-27	Intermediate gw monitoring	46	8	Grab[1]	0-46	23	46	4	42-44	20	0-40	2	none	Flush mount	
C6212	399-2-28	Deep gw monitoring + ERT electrodes	57	8	Grab[1]	0-57	29	57	4	53-55	20	0-10, 46-51	3	none	Flush mount	
C6213	399-3-30	Shallow gw monitoring	37	8	Grab[1]	0-37	18	37	4	30-35	20	0-28	2	2 ft	Flush mount	
C6214	399-3-31	Intermediate gw monitoring	46	8	Grab[1]	0-46	23	46	4	42-44	20	0-40	2	none	Flush mount	
C6215	399-3-32	Deep gw monitoring + ERT electrodes	57	8	Grab[1]	0-57	29	57	4	53-55	20	0-10, 46-51	3	none	Flush mount	
C6216	399-2-29	Shallow gw monitoring	37	8	Grab[1]	0-37	18	37	4	30-35	20	0-28	2	2 ft	Flush mount	
C6217	399-2-30	Intermediate gw monitoring	46	8	Grab[1]	0-46	23	46	4	42-44	20	0-40	2	none	Flush mount	
C6218	399-2-31	Deep gw monitoring + ERT electrodes	57	8	Grab[1]	0-57	29	57	4	53-55	20	0-10, 46-51	3	none	Flush mount	
C6209	399-2-25	Deep Microbiological Characterization + gw monitoring	0-60 0-142 0- ~180	10 8 6	Grab[1]	0-30, 35-50, 70-95, 100-122, 132-170	45	142	4	60-140	10	0-58, 142-TD	5	none	Standard	20-40 mesh sandpack, telescope temp casing across aquitards
					Intact core[2]	30-35, 50-70, 95-100, 122-132, 170-180?	50									
													101			

[5] Geologic samples	
Grab (plastic bucket)	750
1' intact lexan core	435
Total	1185

[1] Core sample from thin, flexible plastic sleeve transferred to 2-gal. plastic bucket after photographing and logging

[2] Intact core sample collected downhole in 1-ft long, ~4-in dia. lexan liners

[4] Non-metallic

Appendix B

Staff Directory

Hanford IFC Field Team

Name	Affiliation	Role	Office phone (509-)	Cell phone (509-)	Email
Bjornstad, Bruce	PNNL	Geology	371-7223	948-9893	bruce.bjornstad@pnl.gov
Clayton, Ray	PNNL	Technician	371-7251		ray.clayton@pnl.gov
Enloe, Sonia	PNNL	Administrator	371-6363		sonia.enloe@pnl.gov
Fredrickson, Jim	PNNL	Microbiology	376-7063	378-0227	jim.fredrickson@pnl.gov
Freshley, Mark	PNNL	Field Site Manager	372-6094		mark.freshley@pnl.gov
Horner, Jake	PNNL	Geology	371-7237		jake.horner@pnl.gov
Kennedy, Dave	PNNL	Microbiology	376-6711		david.kennedy@pnl.gov
Konopka, Allan	PNNL	Microbiology	376-1557		allan.konopka@pnl.gov
McCain, Rick	Stoller	Geophysical Logging	376-6435		rmccain@stoller.com
McKinley, Jim	PNNL	Geochemistry	371-6386		james.mckinley@pnl.gov
Mendoza, Donny	PNNL	Environmental Engineering	371-7199	430-4754	donald.mendoza@pnl.gov
Mehrer, Jim	Gram	NCO (samplers) contact	376-2868	521-3233	James_D_Mehrer@rl.gov
Moore, Dean	PNNL	Sample and Inventory Custodian	376-4141		damoore@pnl.gov
Pearson, Alan	Stoller	Geophysical Logging			apearson@stoller.com
Rockhold, Mark	PNNL	Hydrological Modeling	375-2516		mark.rockhold@pnl.gov
Singleton, Mike	PNNL	Technician			
Strickland, Chris	PNNL	Scientist	372-6431	303-9957	christopher.strickland@pnl.gov
Vermeul, Vince	PNNL	Environmental Engineering; hydrology	371-7170	438-6545	vince.vermeul@pnl.gov
Ward, Andy	PNNL	Geophysics	372-4417		andy.ward@pnl.gov
Wright, Chris	Fluor	Drilling Contract	373-3994	531-7638	christopher_S_wright@rl.gov
Zachara, John	PNNL	Project Manager, Geochemistry	371-6355		john.zachara@pnl.gov