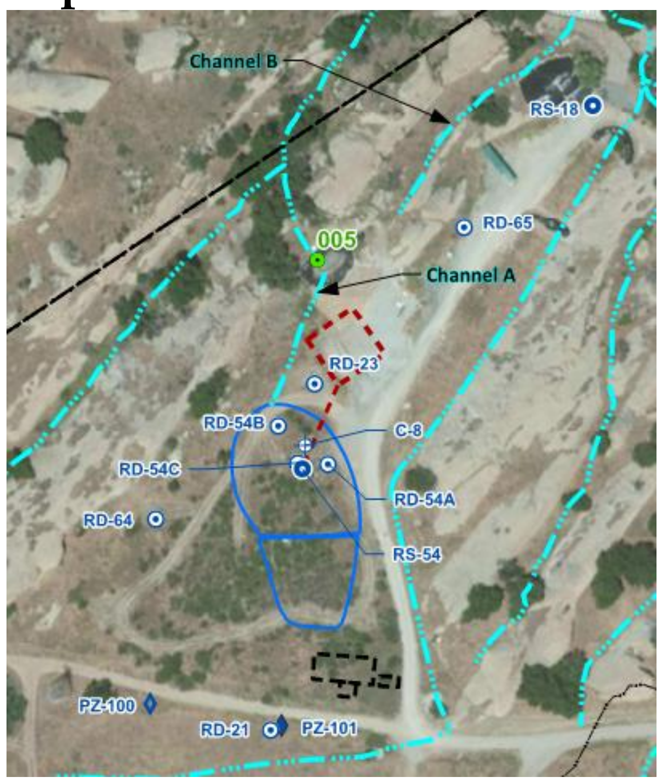
Santa Susana Field Laboratory
Former Sodium Disposal Facility
Groundwater Interim Measures
Implementation Plan
September 2015 DRAFT



Santa Susana Field Laboratory
Ventura County, California

Prepared for:

Department of Energy
4100 Guardian Street, Suite 160
Simi Valley, California 93063

Prepared by:

A Federal Programs Corporation (CDM Smith)

Prepared under:
US Department of Energy, EM Consolidated Business Center
Contract DE-EM0001128
CDM Task Order DE-DT0003515

September 2015

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Department of Energy
Energy Technology Engineering Center
4100 Guardian Street, Suite 160
Simi Valley, CA 93063

November 24, 2015

Cassandra Owens
Los Angeles Regional Water Quality Control Board
320 West 4th Street, Suite 200
Los Angeles, CA 90018

SUBJECT: Department of Energy (DOE) Groundwater Interim Measure (GWIM) Work Plan submittal

Dear Cassandra:

Please find attached, the DOE GWIM Work Plan submittal. This work plan addresses Groundwater Interim Measures for the groundwater impacted location within the Area IV Former Sodium Disposal Facility (FSDF) to be implemented by DOE.

The FSDF has been identified as a source area for trichloroethlyne (TCE) contamination in groundwater. Although DOE has no expectations that an interim measure will eliminate or remediate the source zone contamination, past pumping of groundwater in Area IV has resulted in significant reductions of groundwater contaminants, a desirable outcome of the FSDF GWIM. Per the 2007 Consent Order, DOE is required to submit a work plan for the Implementation of GWIM, and the Implementation Plan serves as the work plan for the FSDF GWIM.

It is important for DOE to communicate its plans to the RWQCB and DTSC on our plans for the DOE GWIM Work Plan for the FSDF. We look forward to you reviewing the plan and providing us your comments to move the implementation forward in the immediate future.

If you have any questions, please give me a call at (805) 416-0992.

Sincerely,

John B. Jones, PMP
Director of DOE/ETEC

cc: Stephie Jennings, DOE
Simon Lipstein, DOE
John Wondolleck, CDM
Samuel Unger, RWQCB
Ray LeClerc, DTSC
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CDM Smith

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Santa Susana Field Laboratory Former Sodium Disposal Facility Groundwater Interim Measures Implementation Plan

September 2015 DRAFT

Approved by:

Project Engineer
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Michael Hoffman, P.G.____________________

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Project Manager
John Wondolleck ____________________

Project No. 128979-94489

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Acronyms

AALs	Archived advisory levels
ATP	Aquifer Test Plan
bgs	below ground surface
BMPs	Best Management Practices
Boeing	Boeing Company
CEQA	California Environmental Quality Act
ClO_4^-	perchlorate
cu ft	cubic feet
DB	Design-Build
DOE	US Department of Energy
DTSC	Department of Toxic Substances Control
ESADA	Empire State Atomic Development Authority
FLUTe	Flexible Liner Underground Technologies
FSDF	Former Sodium Disposal Facility
ft/ft	foot/foot
GAC	granular activated carbon
GETS	Groundwater Extraction Treatment System
GFH®	Evoqua Granular Ferric Hydroxide
gpd	gallons per day
gpm	gallons per minute
GWIM	groundwater interim measure
LARWQCB	Los Angeles Regional Water Quality Control Board
lbs	pounds
MCC	motor control center
MCLs	Maximum Contaminant Levels
msl	mean sea level
NaK	sodium/potassium
NASA	National Aeronautics and Space Administration
NLs	Notification levels
NPDES	National Pollutant Discharge Elimination System
O&M	Operations and Maintenance
PCB's	polychlorinated biphenyls
PFD	Process Flow Diagram
psig	per square inch gas
RALs	regulatory action levels
RFI	RCRA Facility Investigation
ROWD	Report of Waste Discharge
SAP	Sampling and Analysis Plan
SDWA	Safe Drinking Water Act
SMCLs	Secondary Maximum Contaminant Levels
SOW	Scope of Work
SSFL	Santa Susana Field Laboratory
SWPPP	Stormwater Pollution Prevention Plan

TCA	Trichloroethane
TCE	Trichloroethylene
VFD	variable frequency drive
VOC	Volatile organic chemical
WDR	Waste Discharge Requirements
WQOs	Water Quality Objectives

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Section 1

Introduction

CDM Smith Inc. (CDM Smith) has prepared this Implementation Plan for the groundwater interim measure (GWIM) study to be performed at Former Sodium Disposal Facility (FSDF) at the Santa Susana Field Laboratory (SSFL). The scope of this action will include aquifer property testing, extended aquifer pumping, treatment of extracted groundwater, and release of treated water at the FSDF site. This Implementation Plan has been developed based on a request from the U.S. Department of Energy (DOE) to use onsite treatment and discharge of groundwater instead of conveying the water beyond the boundaries of Area IV of the SSFL. This Implementation Plan provides the scope and requirements for the onsite treatment and local release of extracted groundwater.

1.1 Site Location

The SSFL is located 30 miles northwest of downtown Los Angeles in southeastern Ventura County, near the crest of the Simi Hills at the western border of the San Fernando Valley. A former rocket engine test and nuclear research facility, the 2,849-acre field laboratory is currently the focus of a comprehensive environmental investigation and cleanup program, conducted by The Boeing Company (Boeing), the DOE, and the National Aeronautics and Space Administration (NASA), and overseen by the California Department of Toxic Substances Control (DTSC).

The FSDF is located in the western portion of Area IV of the SSFL. Area IV consists of 290 acres owned by Boeing and 90 acres leased by the DOE. DOE and its contractors operated several nuclear reactors and associated fuel facilities and laboratories within this area. This area also includes five surface water discharge outfalls monitored by Boeing in accordance with discharge requirements set by the Los Angeles Regional Water Quality Board (LARWQCB).

Figure 1-1 shows the location of the FSDF within the SSFL, while **Figure 1-2** illustrates the locations of historic features associated with the facility.

Figure 1-3 provides the proposed location of the treatment system and piping. The treatment location was selected because of the availability of a relatively flat gravel area and existing power service.

1.2 Objectives and Rationale

Boeing submitted to the DTSC in July of 2008 the *Work Plan (revision 2) Groundwater Interim Measures* and *Addendum 2 of the Work Plan for Groundwater Interim Measures* in February of 2009. This Work Plan addresses groundwater interim measures for groundwater impacted locations within the SSFL to be implemented by DOE, Boeing, and NASA. Included in the Work Plan was a proposed GWIM action for the FSDF. Following its review of the documents, DTSC issued a public notice and fact sheet describing the GWIMs and conducted a 30-day public comment on the GWIM work plan. In March of 2013 DTSC approved the GWIM Work Plan for implementation.

The scope of the GWIM for the FSDF, as stated in the approved GWIM Work Plan, was to pump groundwater from shallow monitoring well RS-54 and convey the extracted water via pipeline into Area III. The Area IV pipeline would connect to a Boeing extracted-groundwater piping system to the central groundwater extraction treatment system (GETS) located in the central SSFL.

The route of the Area IV segment of the pipeline would cross soil that has been identified to exceed Administrative Order on Consent Look-up Table values indicating a potential need for remediation. Construction of the pipeline would therefore require special measures for the handling and disposal of soil excavated for pipeline placement. In addition, pumping of groundwater and conveying it beyond Area IV would transfer the water from one watershed and release it into another watershed. The FSDF is located in the Meier Canyon watershed with groundwater flow to the north/northwest. The GETS is located in the Bell Canyon watershed, with groundwater flow to the south and then east. The community has raised concerns regarding transfer of water between watersheds. Finally RS-54 is typically dry and likely would not sustain continuous pumping if groundwater levels lower at its location. Candidate replacement pumping wells for RS-54 are needed.

This Implementation Plan for the FSDF GWIM addresses aquifer testing to identify the candidate pumping well(s), technical aspects of onsite treatment and discharge of treated water, and provides greater details regarding GWIM data collection activities. This Implementation Plan does not change the overall objectives of the GWIM program as stated in the GWIM Work Plan approved by DTSC in March 2013.

1.3 Regulatory Environment

Regulatory requirements for the investigation and cleanup of groundwater at SSFL are addressed in the Consent Order for Corrective Action Docket No. P3-07/08-003 (DTSC 2007). Section 3.3 of the Consent Order addresses the requirements for conducting interim measures. The Consent Order states that "interim measures shall include active remedial technologies" to be applied "at source zone(s) to eliminate and/or remediate the contaminant mass flux from the source areas." The FSDF has been identified as a source area for trichloroethlyne (TCE) contamination in groundwater. Although DOE has no expectations that an interim measure will eliminate or remediate the source zone contamination, past pumping of groundwater in Area IV has resulted in significant reductions of groundwater contaminants, a desirable outcome of the FSDF GWIM. Per the Consent Order, DOE is required to submit to DTSC a work plan for the Implementation of GWIM, and this Implementation Plan serves as the work plan for the FSDF GWIM.

Discharge of treated water will require establishment of Waste Discharge Requirements (WDRs) as issued by the LARWQCB.

1.3.1 Department of Toxic Substances Control

DTSC is the lead regulatory agency providing oversight and approval of risk assessment, clean-up levels, and clean-up actions at the SSFL site. Multiple state, federal, and local government agencies also play a role in the cleanup underway at the SSFL site.

1.3.2 Los Angeles Regional Water Quality Control Board

The LARWQCB works in partnership with DTSC providing regulatory support and enforcement for groundwater related issues. Relative to treated water discharges from aquifer testing and treatment activity, LARWQCB will be providing approval for WDR permitting.

1.4 Plan Organization

- Section 1 – Introduces the work plan, presents general purpose and summarizes the scope of work (SOW) key requirements of this work plan. It discusses the regulatory environment and interim measures as required by the consent order.
- Section 2 –presents and summarizes the existing site condition. It provides information pertaining to site background and environmental settings on which the work is to be performed.
- Section 3 –provides rationale, design basis, and methodology pertaining to the aquifer testing. It discusses major elements to achieving the aquifer testing objectives.
- Section 4 –provides rationale and design basis pertaining to the treatment process of extracted groundwater to meet regulatory discharge requirements.
- Section 5-–provides the details of the treatment system. It discusses major design methodology for the equipment.
- Section 6– provides details about the requirements required for permitting the system.
- Section 7– provides the general approach to the implementation of the treatment system. It discusses major elements of the construction and installation elements including a project schedule.
- Section 8– provides references used throughout this work plan.

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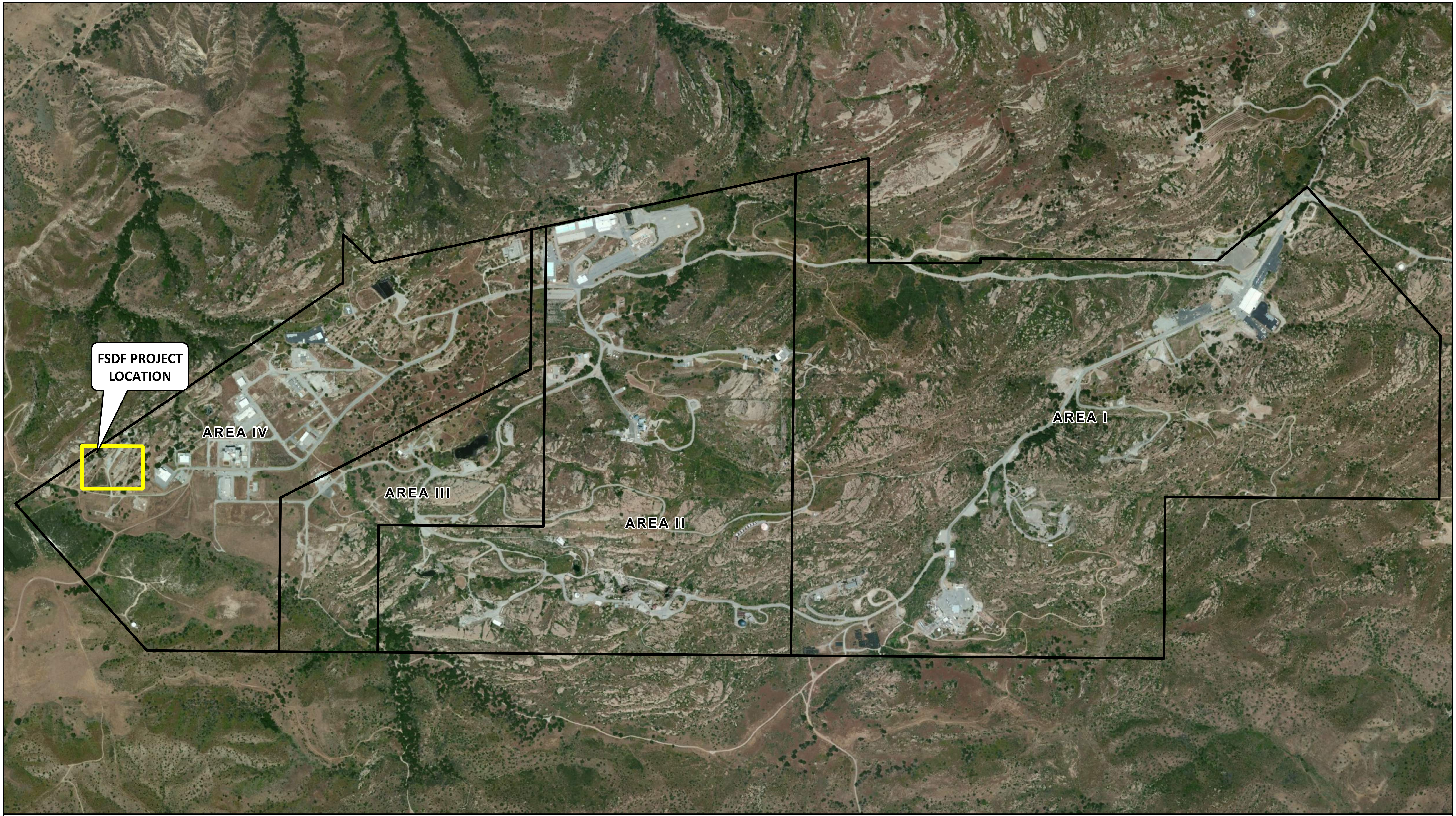

Location of the FSDF within the Santa Susana Field Laboratory

Santa Susana Field Laboratory
Ventura County, California
Figure 1-1

Legend

Site Area Boundary

0 500 1,000 2,000 Feet

Service Layer Credits: Source: Esri, DigitalGlobe, GeoEye, i-cubed, USDA, USGS, AEX, Getmapping, Aerogrid, IGN, IGP, swisstopo, and the GIS User Community.

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Legend
- Drainage
- FSDF Pond
- Concrete Pool

Note: 1978 Aerial provided by Boeing.

Historic FSDF Features

0 27 54 108 Feet

Santa Susana Field Laboratory
Ventura County, California
Figure 1-2

CDM Smith

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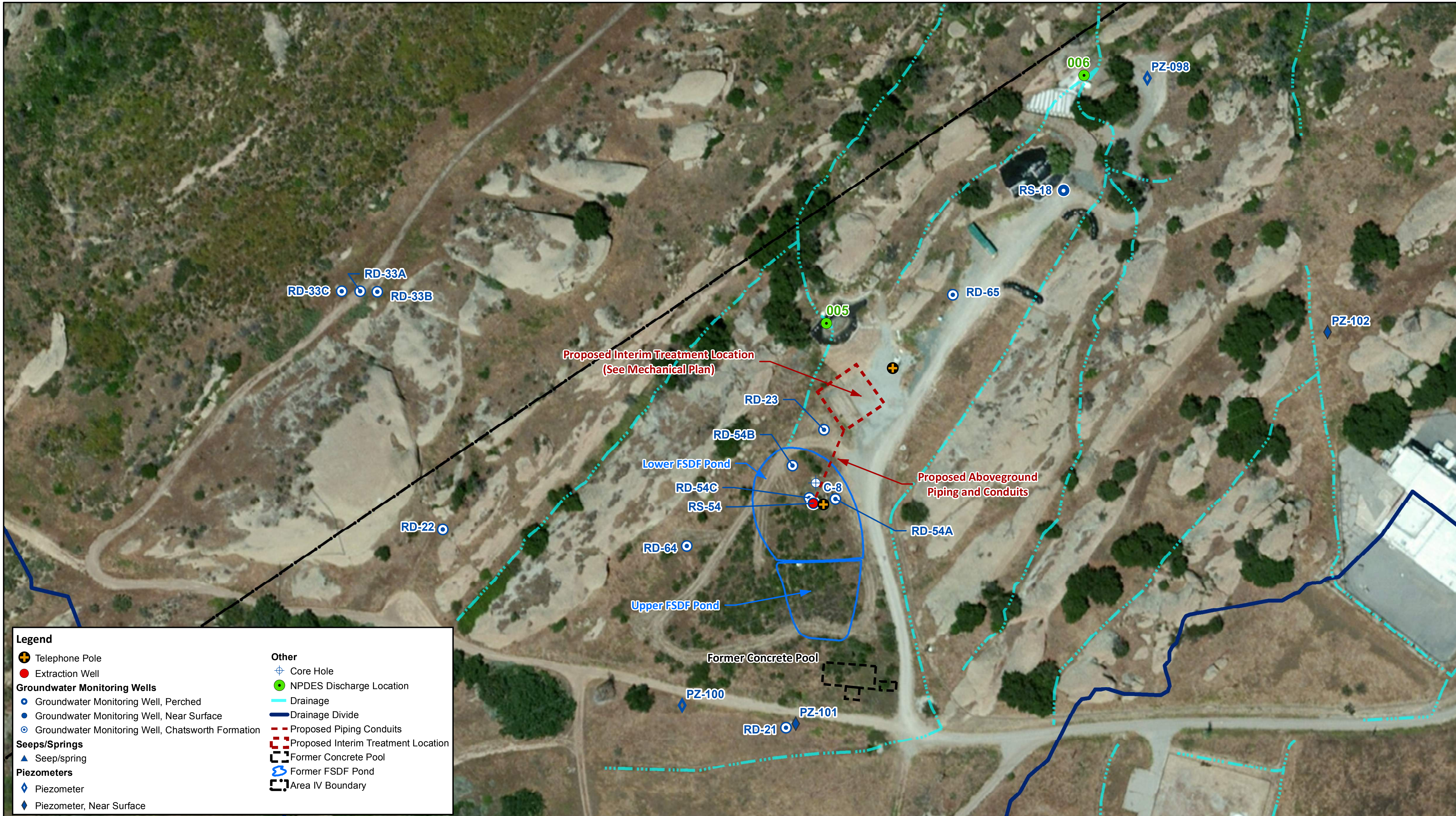

FSDF GWIM Proposed Treatment Location

Santa Susana Field Laboratory
Ventura County, California
Figure 1-3

CDM Smith

Service Layer Credits: Source: Esri, DigitalGlobe, GeoEye, i-cubed, USDA, USGS, AEX, Getmapping, Aerogrid, IGN, IGP, swisstopo, and the GIS User Community.

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Section 2

Environmental Setting

2.1 Historical Information

The FSDF, also known as the Sodium Burn Pit, was used between 1956 and 1978 to clean metallic components and other materials (pipes, valves, tanks, instruments) of alkali metals (sodium and potassium/sodium mixtures) (Rocketdyne Propulsion & Power 2000). Treatment occurred by reacting the alkali metals using either a pressure washer or a placement in a pool of water. The use of the FSDF ceased in 1978 when rules under the Resource Conservation and Recovery Act precluded treatment and disposal in open unlined facilities. In addition to sodium contaminated materials, the FSDF received chemical wastes including chlorinated solvents (i.e., TCE), polychlorinated biphenyls (PCBs), metals such as mercury, and radionuclides (primarily Cesium-137) (Rocketdyne Propulsion & Power 2000). The site was also used for the burning of "Santo-wax," an organic compound used as a heat transfer medium in nuclear reactors.

The FSDF consisted of three facilities; an asphalt and concrete pad used for steam cleaning objects with an adjacent concrete submergence pit (pool) (Figure 1-2). The pit was used for a final reaction of residual sodium with water. To the immediate north was the upper earth-formed pond, with a second lower earth-formed pond at the north edge of the facility. The treatment process consisted of steam cleaning sodium-impacted objects on the pad, and then placing the material in the concrete pit for final reaction with water (MWH 2007). Following treatment the material was either reused or debris (e.g., pipes, machined metal parts, and tubes) placed into one of the earthen ponds, thereby using the ponds for disposal of debris not intended for reuse. As maintenance activity, material that was left in the ponds was periodically removed after the pond was allowed to dry (Boeing 2000). The debris was bulldozed out of the pond and disposed of either locally in the western debris area or removed from the site. The submergence pit next to the steam cleaning pad was connected to a pipe from the Empire State Atomic Development Authority (ESADA) facility (B4814) thus receiving liquid wastes from sodium metal tests conducted in that facility.

The FSDF was operated from 1956 to 1978. Following cessation of use, the FSDF area was subject to removal of surface debris and a series of soil and groundwater investigations. The soil within and adjacent to the ponds was found to be contaminated by PCBs, mercury, Cesium-137, and solvents (MWH 2007). Groundwater was found to be contaminated by TCE,-1,1,1-Trichloroethane (TCA), metals, and perchlorate (ClO_4^-).

The finding of contaminants in groundwater resulted in the FSDF being subject to an initial soil removal action that was planned in 1991, initiated in early 1992, and completed in June 1993. During this first soil removal action, approximately 12,000 cubic yards of soil were removed (ICF Kaiser 1997). Soil was excavated to the bedrock interface and all debris found within the excavation removed.

Soil exhibiting radioactivity above background was managed and disposed of separately from soil that was only chemically contaminated per DOE rules. Soil removal also included two drainages north of the facility also found to be contaminated. Boeing reports that "238 boxes of soil, which weighed approximately 775,000 pounds (lbs) (net), equal to 425 cubic yards" were transported to the Envirocare facility in Tooele County, Utah (Boeing North America 1999).

In 1994, based on soil surveys for radioactivity that found no radiation above background, the FSDF was no longer considered a radioactive material handling area (Boeing North America 1999). Some limited excavations of buried objects occurred in August 1996 within previously non-excavated areas based on the results of a geophysical survey. Soil sampling conducted in 1995 in the vicinity of the FSDF site identified contamination by mercury, TPH, PCBs, and dioxins.

In 1999, DTSC approved the Interim Measure Work Plan describing removal actions for the Upper Pond, the Western Area, and Channels A, B, and C. The circa 2000 removal action focused on removal of elevated dioxins, PCBs, mercury, and perchlorate at these areas. Soil and debris removals at and in the vicinity of the FSDF ponds totaled 14,928 tons (approximately 12,000 cubic yards) (MWH 2007). The materials were disposed at a Class I Landfill (MWH 2007).

Soil from a DTSC-approved Area IV Soil Borrow Area was used to backfill the excavations and infiltration monitoring system was installed. **Figure 2-1** presents the final grading and instrument locations at the FSDF (Shaw Environmental 2011). In December 2000 the site was hydroseeded and oak trees were planted (IT 2002). In 2011 the oak trees were between 10 and 15 feet in height. To measure the downward infiltration of rainwater through the soil overlying the FSDF ponds, two pan lysimeters were installed in 2000 (IT 2002). The first was installed in the area of the Lower Pond and the second to the south of the first. The lysimeters were placed about 1 foot above the bedrock interface. The total soil cover above lysimeter 1 is approximately 7 feet and above lysimeter 2 is about 11 feet. Four piezometers were installed to measure water at the backfilled soil-bedrock interface. The piezometers were advanced from the surface to 4 to 6 inches into the bedrock.

Groundwater monitoring of bedrock water quality was initiated in August 1989 with the installation of RD-21 south of the FSDF ponds and RD-23 north of the FSDF ponds. RD-22 was installed 300 feet west of the FSDF ponds at the same time. Monitoring well cluster RD-54 located in the center of the lower FSDF pond was installed between July and August 1993 and included RD-54C (deepest bedrock well), RD-54A (shallow bedrock well), RD-54B (intermediate depth bedrock well), as well as RS-54 (alluvial, above bedrock well).

In April 1997, pumping of wells RD-21 and RS-54 was initiated. The record on why these wells were pumped is not clear. Pumping rate was less than 2 gallons per minute (gpm) due to low transmissivity. RD-21 was pumped from 1997 until 2002 and typical extraction rates averaged 173 gallons per day (gpd; or 0.12 gpm) (MWH 2006). In 2003, only RS-54 was pumped (Rocketdyne 2004). Groundwater was not extracted from RS-54 during 2004 (Boeing 2005). The pumped groundwater was treated at the GETs with granular activated carbon (GAC), chemically analyzed, and discharged to the surface drainage to Outfall 019.

During 2003 to 2004, a pumping test was performed using RD-54B. The objectives of the pumping test were to determine transmissivity, hydraulic conductivity, storativity, and influence of aquitards on groundwater flow at the FSDF (MWH 2006). A drawdown test was performed and it was determined that the well could not sustain a 2.5-gpm pumping rate. Groundwater was extracted from RD-54B at a constant rate of 173 gpd for 165 days. A total of 28,300 gallons of groundwater was extracted from the well at an average pumping rate of 0.12 gpm.

2.2 Geology, Hydrology, and Hydrogeology

The following descriptions of site geology, hydrology, and hydrogeology were primarily taken from *Group 8 – Western Portion of Area IV RCRA Facility Investigation Report, Santa Susana Field Laboratory, Ventura County, California* (MWH 2007).

2.2.1 Geology

The SSFL is located in southern California's Transverse Ranges, a geomorphic province resulting from north-south compression associated with the San Andreas Fault. As a result, geologic structures such as faults and folds generally trend in an approximate east-west direction at the SSFL. Soils and bedrock in the vicinity of the FSDF are described in this section.

2.2.1.1 Soil

Soils in the area of the FSDF consist of alluvium, primarily comprised of weathered Chatsworth Formation bedrock, colluvium, and fill soils. Native soil (i.e., alluvium and colluvium), which is present primarily in topographic lows and stream drainages, ranges in thickness from less than a foot to approximately 12 feet. Fill materials have also been used at the FSDF. Based on soil boring logs and information collected during site excavation activities, the approximate soil and/or fill thickness ranges from 2 to 12 feet in the FSDF area. Soils are generally thin and are comprised mostly of clay, silt, and sand with trace gravel. Clayey soils are likely due to the presence of the shale and siltstone layers within the Chatsworth formation. Weathered sandstone and siltstone underlie the unconsolidated alluvium and/or fill material. The fill materials overlaying the thin layer of alluvial soil typically range in thickness from less than 1 foot to approximately 25 feet sitewide. Fill materials primarily consist of silty, fine sand, and sandy silt with sandstone gravel and cobbles. The maximum depth of backfill in the area of the former FSDF pond excavation is about 13 feet below current grade based on topographic surveys performed following the excavation. Soils within the former excavation areas consist of DTSC-approved soils from an onsite borrow area.

2.2.1.2 Bedrock

The Chatsworth Formation underlies the present FSDF site and is comprised predominantly of sandstone with interbeds of siltstone and shale. There are three stratigraphic members of the Chatsworth Formation within the FSDF Area (MWH 2007). Each is briefly discussed below, from the youngest to the oldest. The Upper Burro Flats Member is predominantly comprised of medium-grained sandstone with minor interbeds of siltstone and shale. The ELV Member lies below the Upper Burro Flats Member and is comprised of thinly interbedded fine-grained sandstone, siltstone, and shale. The Lower Burro Flats Member underlies the ELV Member and is predominantly comprised of medium-grained sandstone with significant siltstone/shale interbeds.

As reported in the Interim Measure Implementation Report – Former Sodium Disposal Facility, the Chatsworth Formation surface at the FSDF was completely exposed and mapped. **Figure 2-2** presents the geologic map of the FSDF and Upper Channel B. The approximate locations of the FSDF wells and corehole C-8 are superimposed onto the original drawing. The following information was obtained from the geologic mapping work performed at the FSDF (IT 2002):

- Chatsworth Formation is silty sandstone, moderate yellow brown, and fine to medium grained;
- Sandstone is well cemented and massive to thick bedded;
- Graded bedding becomes finer grained toward the top in some beds;
- Bedding planes show iron oxide or calcium carbonate staining;
- Siltstones and shales are light olive gray and generally 3 inches to 1.5 feet thick;
- Siltstones and shale bedding planes contain moderate to heavy iron oxide staining; and
- Coarse sand and pebble conglomerate lenses are present, consist of coarse sand and pebbles in a finer sandy matrix, and are 3 inches to 3 feet thick.

The Interim Measure Implementation Report further states the following pertaining to faults and joints mapped at the FSDF:

- Many faults and joints are high angle;
- Three general trends were mapped; N20µE, N60µW, and east-west;
- Appearance varies from a strong, well-defined lineament to a faint, thin (1/8 inch) black or brown line;
- Some faults and joints are clay-filled, coated or filled with calcium carbonate, or exhibit iron oxide staining;
- Iron oxide halos are present along some faults and joints; and
- Up to 40 inches of apparent offset is present along some fault traces.

The bedrock, faults, and joints underlying the SSFL has a controlling influence on groundwater flow and contaminant fate and transport. The Burro Flats Fault separates the Chatsworth and Santa Susana formations to the south of the FSDF. This fault strikes approximately east-west in the vicinity of the ESADA RCRA Facility Investigation (RFI) Site (Dibblee 1992; MWH 2007). To the north of the fault are the Upper Burro Flats, ELV, and Lower Burro Flats members of the Upper Chatsworth Formation, and to the south of the fault is the Santa Susana Formation (Dibblee 1992; MWH 2007). A series of deformation bands is also present east and west of the FSDF. These deformation bands generally strike northeast-southwest and have currently been defined by geologic site mapping to comprise the western extent of the North Fault zone (MWH 2007).

2.2.2 Surface Water

The SSFL is located on top of the Simi Hills and along a surface water divide. Surface water runoff on the northern portion of SSFL drains to the north and eventually into Arroyo Simi in Simi Valley and the southern portion to the south into Bell Creek, which leads to the Los Angeles River. Historically, the FSDF Site included the Upper and Lower Ponds, which were basins filled with water to treat residual sodium and sodium/potassium (NaK) mixtures on equipment and parts. In 1976, the ponds were drained, but water occasionally accumulated there following precipitation at the site (Ebasco 1991). In 1995, the ponds were covered with tarps, and gunite-lined diversion ditches were created around the pond area to prevent water infiltration. Prior to the installation of these diversion ditches, surface water from the FSDF area would drain toward the northeast into Channel B (**Figure 2-3**). After the diversion ditches were installed, the area northwest of the Lower Pond began to drain more directly to the north into Channel A (Rockwell 1995). Following the 2000 soil removal action, the areas of the ponds were backfilled in 2001 and graded to slope gently toward the north-northeast. Most surface water discharge is now directed toward Channel A and a smaller portion is directed toward Channel B (IT 2002).

A drainage channel starts at the former lower pond location (Channel A on Figure 2-3) and flows northward to National Pollutant Discharge Elimination System (NPDES) Outfall 005. Downgradient of Outfall 005 the drainage joins a northeast trending drainage that originates west of the FSDF. Channel A continues northeastward to where it joins Channel C downgradient of Outfall 6. Channel B originates immediately east of the former ponds. The upper portion of Channel B was subject to soil removal during the FSDF soil interim measures. Channel B flows northeast into NPDES Outfall 006 and then northward where it joins Channel A. After this confluence, Channels A and B become Channel C, which continues northeastward into Meier Canyon.

2.2.3 Hydrogeology

2.2.3.1 Near Surface Groundwater

At the FSDF site, five piezometers (PZ-097, PZ-098, PZ-099, PZ-100, and PZ-101) and two shallow wells (RS-54 and RS-18) were installed to monitor near-surface groundwater conditions (Figure 2-3 for the locations of wells). Well PZ-099 was subsequently abandoned in 2006 during the installation of surface water erosion controls at nearby Outfall 005. Groundwater is perched above Chatsworth Formation groundwater in the FSDF area, and the extent of TCE occurring in perched groundwater is shown in plan view in Group 8 RFI Report Figure 2-10 (MWH 2007). At FSDF, near surface groundwater has been encountered at depths ranging from 8 feet below ground surface (bgs; 1,795 feet mean sea level [msl]) at RS-18, to 21 feet bgs (1,825 feet msl) at RS-54. Both of these wells have been dry the last three years. Although near surface groundwater at this site is temporarily present (generally following the winter rains), the lateral extent of this groundwater unit is constrained by surficial bedrock outcrops to the east and west, and has varied over time as a result of groundwater extraction at RS-54. Near surface groundwater flow is to the north, with a horizontal gradient of approximately 0.11 foot/foot (ft/ft) (MWH 2007). **Figure 2-4** presents a cross-section through the FSDF and contains groundwater elevations and TCE concentrations observed in 2014.

2.2.3.2 Chatsworth Formation Groundwater

At the FSDF site, 12 wells (RD-21, RD-22, RD-23, RD-33 [A,B,C], RD-54 [A,B,C], RD-57, RD-64, and RD-65) were installed to monitor Chatsworth Formation (Chatsworth) groundwater. Chatsworth groundwater in the FSDF is encountered at average depths ranging from 101 feet bgs (1,766 feet msl) at RD-21 to 305 feet bgs (1,548 feet msl) in RD-22. Depths to Chatsworth groundwater are variable at this site due to a combination of stratigraphic and topographic features that are discussed further in the Group 8 RI Report (MWH 2007).

Core-hole 8, drilled in 2009, is a 400-ft deep coring drilled to retrieve core for TCE analysis. It currently is fitted with a blank Flexible Liner Underground Technologies (FLUTe) liner. It is of interest as it is located within the RD-54/RS-54 well cluster and with an open bedrock interval from 65 feet to 400 feet it allows for identification of fractures at locations of greatest concern for GWIM aquifer pumping. Adjacent well RD-54A has a casing from ground surface to 119 feet bgs. Core-hole 8 has only been sampled once as a monitoring well and will be the initial focus of the aquifer testing described in Section 3.0.

The FSDF site is very near the groundwater divide that runs the ridge of the SSFL (see Group 8 RFI Report Figure 2-11). Based on water level gradients and contaminant movement, groundwater at the FSDF location appears to be moving to the north/northwest.

Groundwater extraction was initiated in April 1997 at wells RD-21 and RS-54, and continued with few interruptions until 2003, when pumping activities were terminated to allow for Chatsworth groundwater characterization activities. Water levels in FSDF Chatsworth Formation wells were not significantly affected by pumping activities at either of these locations. This observation is consistent with the results of the RD-54B pumping test, which showed little influence at RD-21. RD-21 is located about 440 feet from RD-54B (from the midpoints and the open intervals). In addition, extraction of groundwater from RS-54 does not directly influence water levels in FSDF area Chatsworth Formation wells since it is screened within a perched groundwater unit. Several offsite wells (OS-3, OS-4, OS-5, OS-SA, and the RD-59 cluster) are used to monitor groundwater conditions downgradient of the FDSF. Groundwater elevations measured in these wells are significantly lower than those measured in wells within the FSDF boundary. Artesian conditions are observed in several of these wells. Within the FSDF Chatsworth groundwater flow is toward the northwest. The estimated horizontal gradient is 0.1 ft/ft based on recent groundwater elevations.

2.3 Previous FSDF Site Activities

Previous FSDF site activities and reporting are summarized in the **Table 2-1**.

Table 2-1 FSDF Site Activities

Dates	Activity Type	Reference
1956 - 1978	FSDF – Period of Operation	Rocketdyne, 2000
1978 - 1983	Various radiological surveys	Rocketdyne, 1988
1987	CERCLA Phase II – Site Characterization	Rocketdyne, 1987
1987 -1988	Rocketdyne radiological survey of surrounding areas	Rocketdyne, 1988
1992	SDF lower pond excavation	Rocketdyne, 2000
1993, March 24	RWQCB soil sample investigation	RWQCB, 1993
1993	SDF upper pond & western area excavation	Rocketdyne, 2000
1993, June 10	1st DHS soil sample investigation	DHS, 1993 and 1994
1995, January 5	Rocketdyne final radiation exposure survey report issued	Rocketdyne, 1995
1996, July 29	2nd DHS soil sample investigation	DHS, 1997
1997 - 2002	FSDF interim measure – pumping of RD-21 and RS-54	MWH, 2006
1997, April 8	Rocketdyne final soil sampling report issued	DHS, 1996
1997, September 16	3rd DHS soil sample investigation	DHS, 1997
1998, May 6	DHS releases facility for unrestricted use	DHS, 1998
2000	2000 FSDF IM completed (soil impacted by poly-chlorinated biphenyls and mercury removed)	MWH, 2007
2000	Shallow groundwater investigation work plan	Ogden, 2000
2001	CFOU work plan (groundwater characterization): (1) install multi-level monitoring equipment and transducer (FLUTe), (2) borehole geophysical logging, (3) drill and sample rock at C-8, (4) Slug test, (5) collect depth-discrete water samples, (6) RD-54B pump test.	Montgomery Watson Harza, 2001
2002	Interim Measure Implementation Report, Former Sodium Disposal Facility	IT, 2002
2003 - 2004	RD-54B pumping test	MWH, 2006
2004	Construction and testing of RD-91 (Building 4100/4009)	Haley & Aldrich, 2004
2006	Report of results, FSDF groundwater characterization	MWH, 2006
2007	Group 8 – Western Portion of Area IV RCRA Facility Investigation Report	MWH, 2007
2009	Draft Site-Wide Groundwater Remedial Investigation Report	MWH, 2009b

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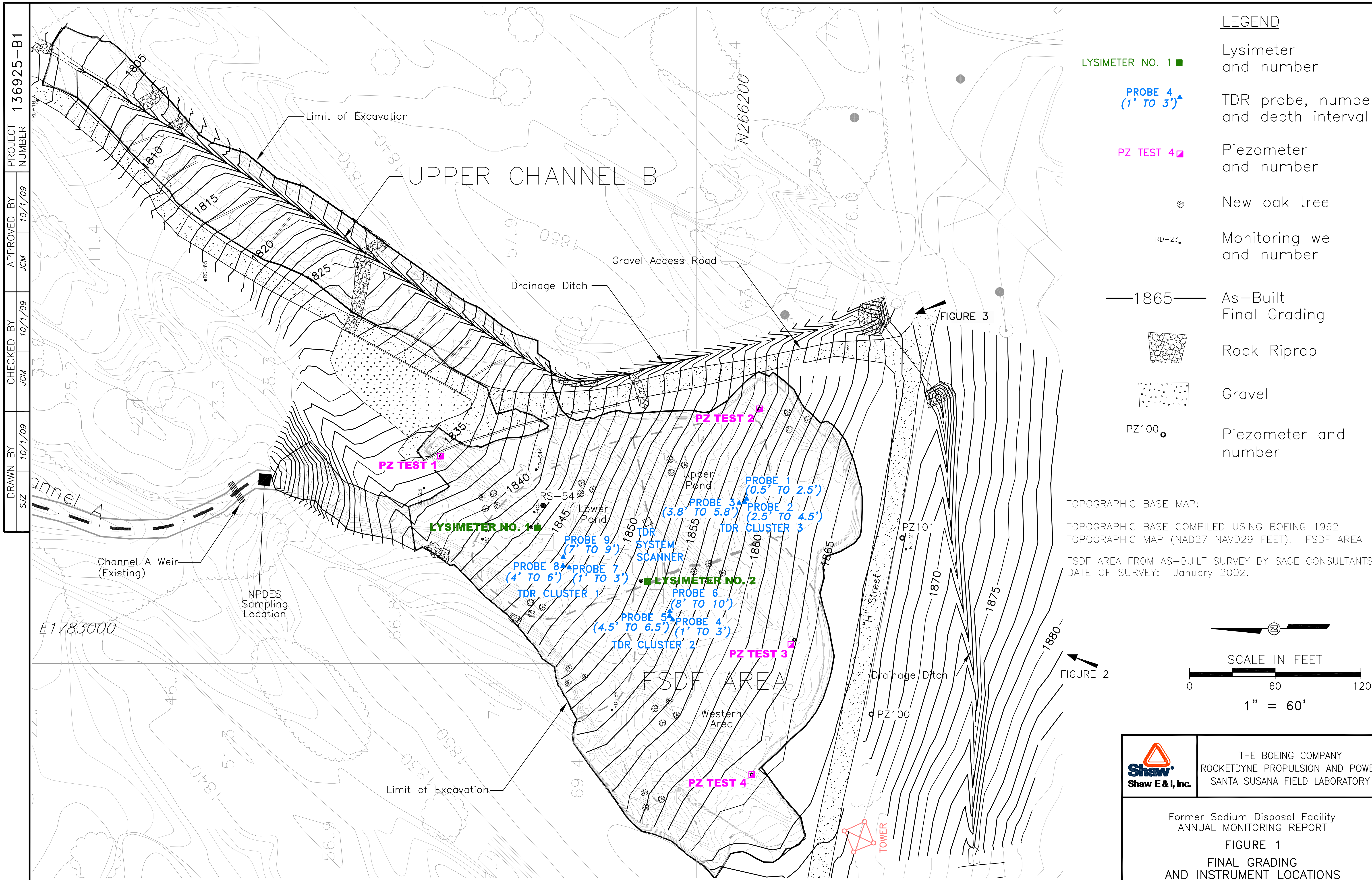


Figure 2-1, **Final Grading and Instrument Locations**

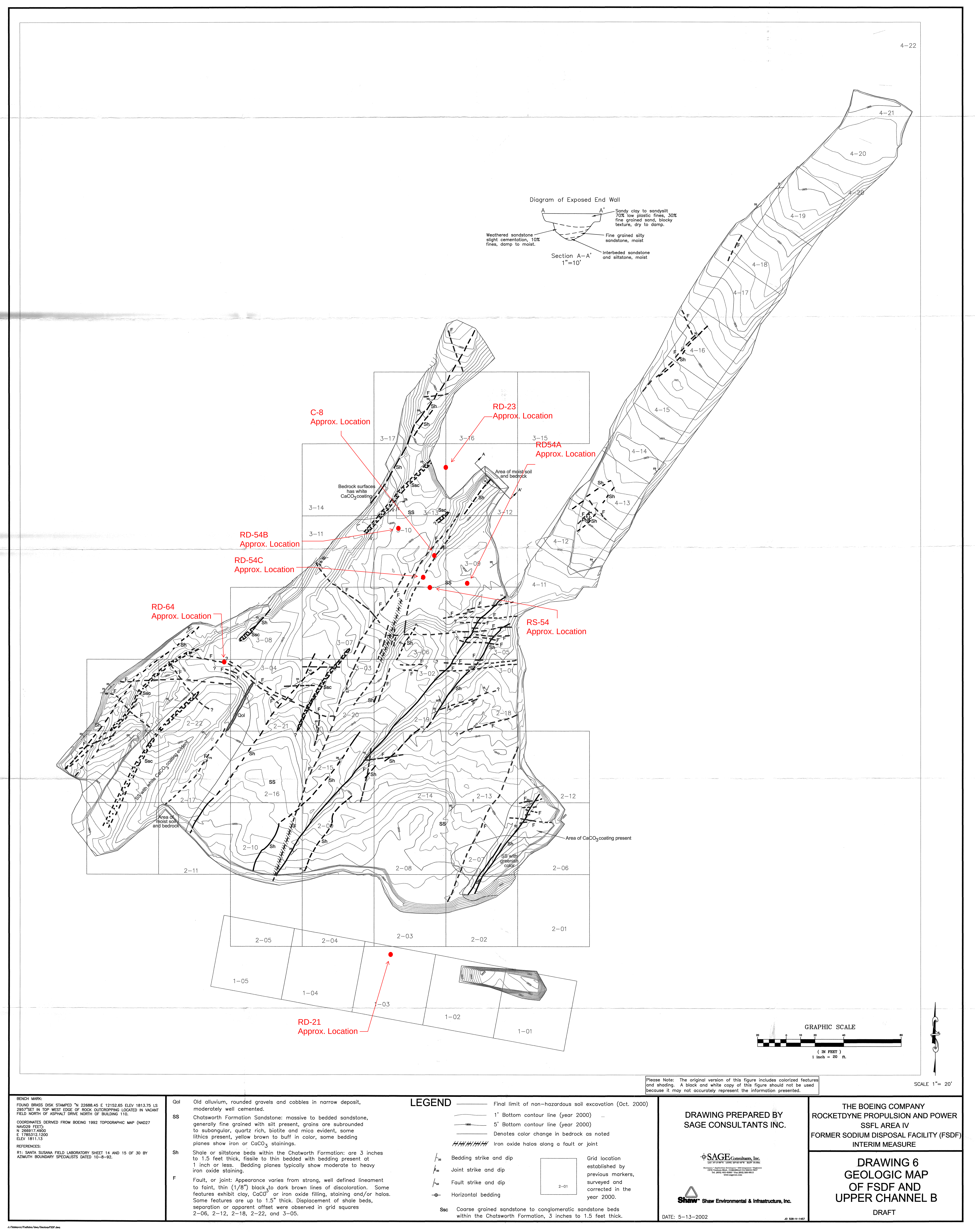
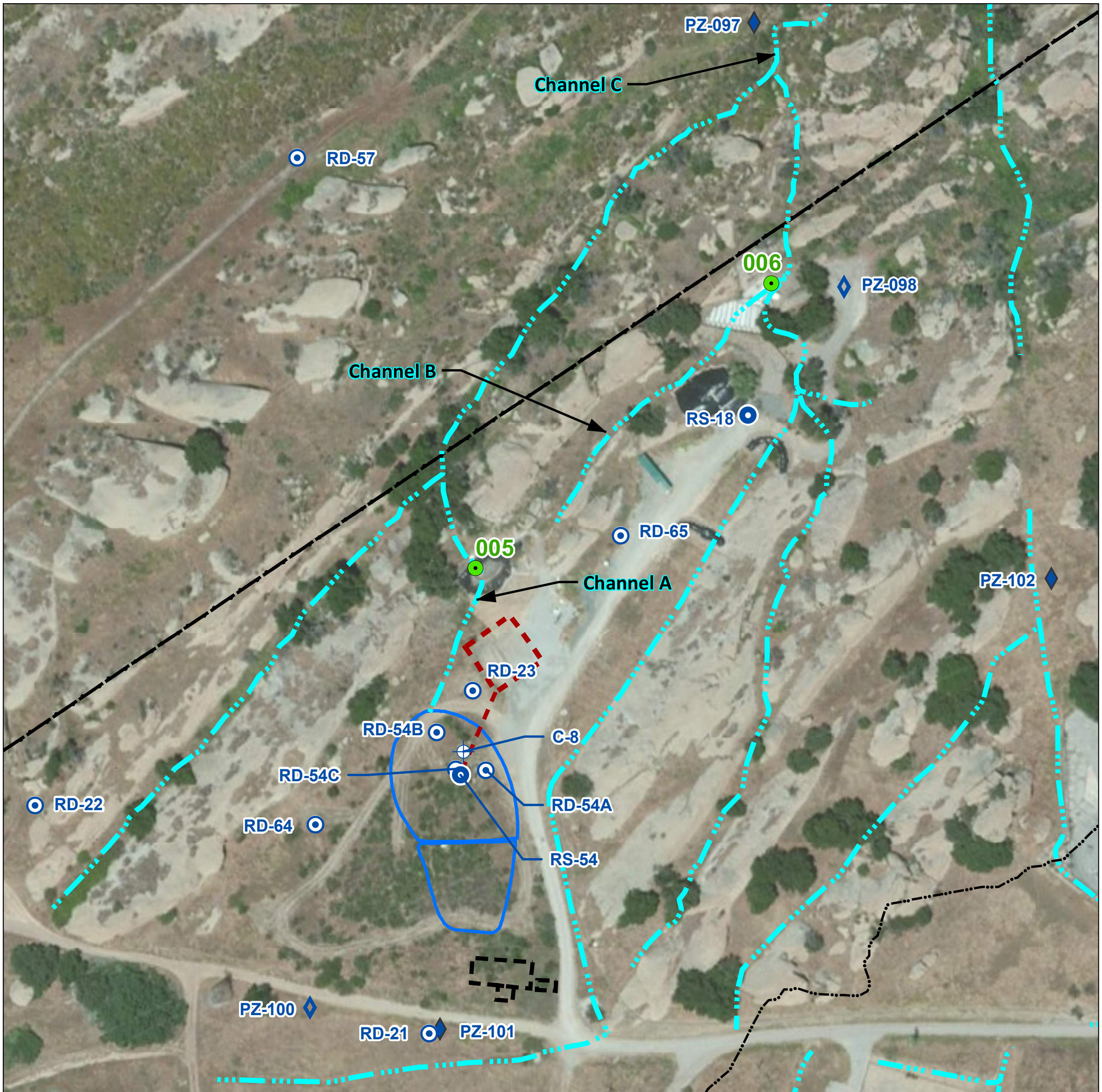


Figure 2-2, **Geologic Map of FSDF and Upper Channel B**



LEGEND

Groundwater Monitoring Wells
- Groundwater Monitoring Well, Perched
- Groundwater Monitoring Well, Near Surface
- Groundwater Monitoring Well, Chatsworth Formation

Piezometers
- Piezometer
- Piezometer, Near Surface

Seeps/Springs
- Seep/spring

Other
- Core Hole
- NPDES Discharge Location
- Drainage
- Drainage Divide

- Proposed Piping Conduits
- Proposed Interim Treatment Location
- Former Concrete Pool
- Former FSDF Pond
- Area IV Boundary

Notes:
- GIS Layers provided by MWH/Boeing.

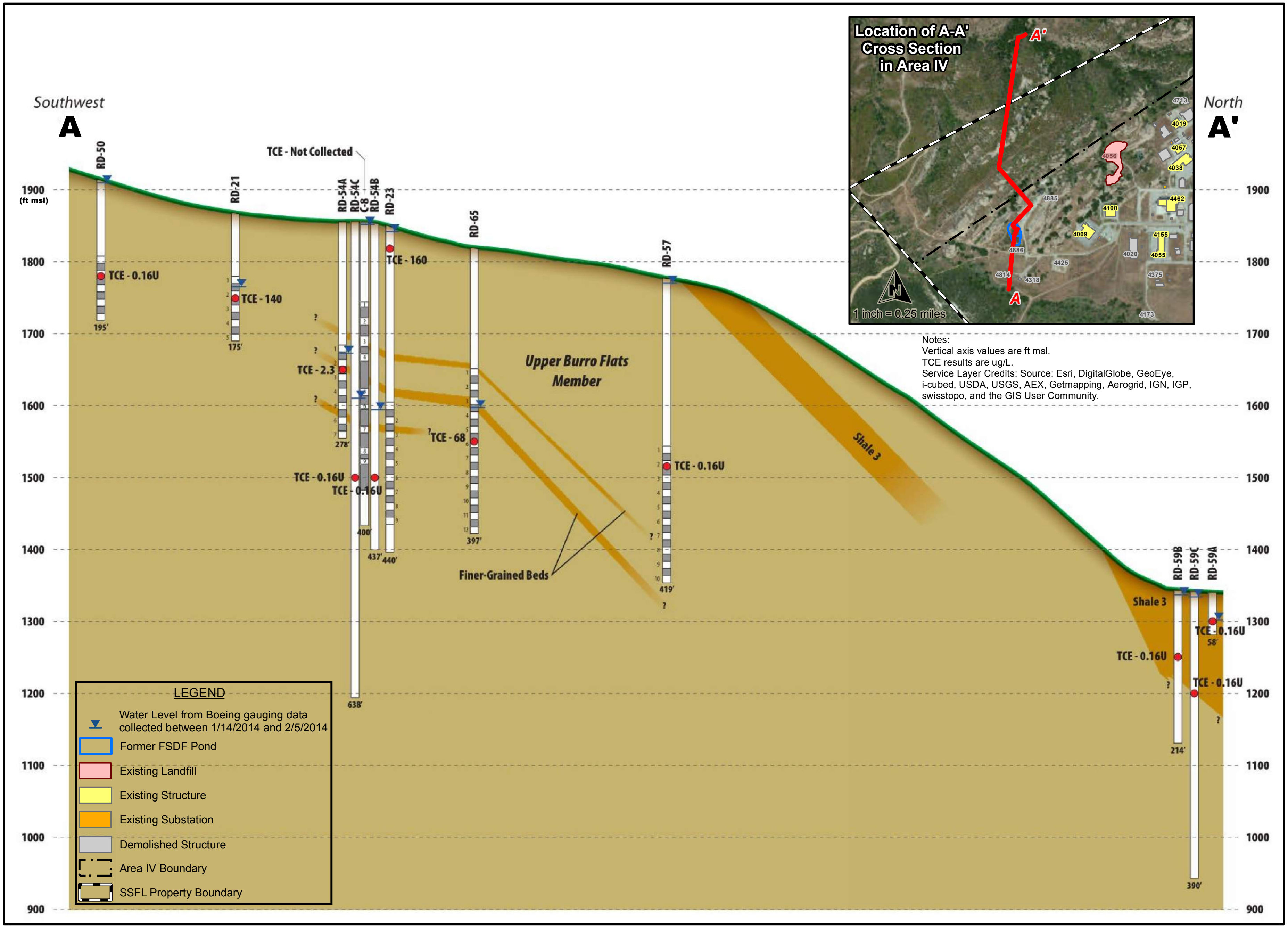
Service Layer Credits:
- Aerial Source: Esri, DigitalGlobe, GeoEye, i-cubed, USDA, USGS, AEX, Getmapping, Aerogrid, IGN, IGP, swisstopo, and the GIS User Community.
- Road Centerline Source: Esri, TomTom.

0 75 150 Feet

C:_projects\SantaSusana\GIS\MXD\SurfaceWater\GWIM\SSFL_AreaIV_GWIM_FSDF_Drainage_Details_20150807.mxd

CDM Smith

FIGURE 2-3
FSDF Drainage Details



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CDM Smith

FIGURE 2-4

TCE Plume Cross Section A-A' through FSDF

Section 3

Aquifer Testing and Monitoring

A series of aquifer testing will be performed using FSDF monitoring wells. The first part of the testing will involve video logging, packer testing, and sampling of selected intervals in selected monitoring wells. The objective of the testing will be to identify bedrock fracture zones that may be contributing to TCE groundwater contamination and to use the results to target which wells and at what depths should pumping be performed during the GWIM. Appendix A of this GWIM Implementation Plan provides details on the GWIM Aquifer Test Plan (ATP).

Aquifer testing will also be performed during GWIM groundwater pumping. The primary purpose of this testing is to evaluate the contaminant mass transfer between groundwater in fractures and the rock matrix in response to pumping. A secondary purpose of this testing is to estimate aquifer properties that can be incorporated into the sitewide groundwater flow and fate and transport model. Corehole C-8, RS-54, and Chatsworth Formation wells RD-23, RD-54A, and RD-64 are the candidate pumping wells for the aquifer testing, depending on their sustainable flow rates. Information presented in this section presents a conceptual aquifer testing approach. The aquifer testing plan describes aquifer testing specifics such as estimated pumping rates, duration of testing, and data quality objectives. The ATP plan provides detailed information on the monitoring well network and aquifer testing performed prior to and during the GWIM (Appendix A).

3.1 Monitoring Well Network

Table 3-1 provides well depth and 2nd Quarter 2013 water level measurements for monitoring wells that will be used for this study. All wells will be sampled for baseline volatile organic compound (VOC) concentrations (particularly TCE and TCA) using EPA Method 8260 and other specific compounds as required by the WDR permit and measured for water levels in the aquifer test wells and all monitoring wells within a 255-foot radius of RS-54. All wells shown in Table 3-1 will be included in this baseline sampling. The FLUTe multiport sampling systems will be removed from RD-23 and RD-64 prior to GWIM field work. The wells will be purged and sampled using standard SSFL groundwater low flow sampling procedures per the Water Quality Sampling and Analysis Plan (SAP) (Haley and Aldrich 2009).

Table 3-1 FSDF Well Information

Well ID	Total Depth (feet bgs)	Screen Interval (feet bgs)	GWD (feet bgs) 4/13	GW Elev (feet msl) 4/13	GWD (feet bgs) 2/14	GW Elev (feet msl) 2/14	GWD (feet bgs) 3/15	GW Elev (feet msl) 3/15
C-8	400	65 - 400	Blank FLUTE	-	Blank FLUTE	-	Blank FLUTE	-
PZ-097	44.5	33 - 43	Dry	-	Dry	-	Dry	-
PZ-098	37.5	24 – 34	NC		ECW	-	28.91	1,768.88
PZ-099	Abandoned	-	-	-	-	-	-	-
PZ-100	16.5	5.7 – 15.7	NC	-	ECW	-	19.10	1,851.02
PZ-101	27	10 – 20	NC	-	22.60	1,847.11	NC	-
PZ-102	59.2	48.5 – 59.2	NC	-	Dry	-	NC	-
RD-21	175	30 – 175	91.54	1,775.42	94.74	1772.22	99.01	1767.96
RD-22	440	30 – 400	FLUTe[2]	-	FLUTe[2]	-	FLUTe[2]	-
RD-23	440	30 – 440	FLUTe[2]	-	FLUTe[2]	-	FLUTe[2]	-
RD-33A	320	100 – 320	FLUTe[2]	-	FLUTe[2]	-	FLUTe[2]	-
RD-33B	415	360 – 415	276.84	1,516.88	278.71	1,515.01	285.31	1,508.42
RD-33C	520	480 – 520	280.04	1,513.57	280.89	1,512.72	287.74	1,505.88
RD-50	195	18 – 195	FLUTe[2]	-	FLUTe[2]	-	FLUTe[2]	-
RD-54A	278	119 – 278	165.33	1,676.39	166.78	1674.94	169.03	1672.70
RD-54B	437	379 – 437	240.05	1,602.49	241.59	1600.95	244.87	1597.68
RD-54C	638	558 – 638	225.57	1,618.20	226.59	1617.18	230.29	1613.49
RD-57	419	19.5 – 419	FLUTe[2]	-	FLUTe[2]	-	FLUTe[2]	-
RD-64	398	19 – 398	FLUTe[2]	-	FLUTe[2]	-	FLUTe[2]	-
RD-65	397	19 – 397	218.29	1,600.85	217.45	1,601.69	218.40	1,600.75
RD-91	140	20 – 140	78.11	1,739.93	88.49	1,729.55	95.98	1,722.07
RS-18	13	7.5 – 13	11.05	1,791.81	Dry	-	5.98	1,796.89
RS-23	13	8 – 13	Dry	-	Dry	-	NC	-
RS-54	38[1]	7 – 38	38.29	1,808.37	44.64	1802.02	Dry	-

1 Total depth of RS-54 is based on installation data; total depth will be verified at start of field program.

2 All Area IV FLUTe systems have failed. Prior to future water level measurements and water quality sampling the FLUTe systems will be removed.

Abbreviations:
bgs = below ground surface
ECW = end cap water
GWD = groundwater depth from ground surface
GW Elev = groundwater elevation at mean sea level (msl)
NC = not collected

3.2 Aquifer Testing Strategy

CDM Smith proposes to perform a series of aquifer tests in Corehole C-8 and wells RD-23, RD-54A, and RD-64. The first part of testing will involve removal of FLUTe systems from Corehole C-8, RD-23, and RD-64, and then video logging all wells. The objective of the video logging will be to ascertain locations of fractures and fracture zones that may be pathways for contaminant migration. Once the fractures and zones are identified, the test areas will be isolated using packer systems. Groundwater within the packer zones will be sampled. Groundwater will also be pumped to ascertain a flow rate from the fractures. Groundwater will be sampled for VOCs, 1,4-Dioxane, metals, and perchlorate prior to, during and following pumping. This initial work will aid in defining the proposed wells for GWIM pumping along with the depths that pumps should be placed.

Once the GWIM treatment system unit has been installed, tested, and proven to meet discharge standards, sustainable flow rates for Corehole C-8, RD-23, RD-54A, and RD-64 will be determined. CDM Smith will conduct an 8-hour step drawdown test in each of the four wells. Once sustainable flow rates are determined, a variety of aquifer tests will be performed. Initially, a 120-hour constant rate discharge test will be performed at the highest determined sustainable flow rate. Water level measurements will be collected automatically using pressure transducer/data loggers from monitoring wells in the vicinity of each pumping well. Groundwater samples will be collected from the adjacent wells prior to and following the step drawdown tests. Water level monitoring and VOC samples will be collected from the monitoring wells presented in the ATP during pumping, including the pumping well, and after the wells are allowed to recharge.

Existing data indicate that the zone of highest TCE concentrations in groundwater at the FSDF is in the upper bedrock, potentially perched above the Chatsworth aquifer. There is at times a 130- to 200-foot difference in water surface elevations between RS-54 and adjacent RD-54A indicating the two aquifer zones are isolated. Field methods will be adjusted in the field accordingly to the response in pumping. CDM Smith is concerned about potentially drawing downward the higher TCE concentration from the shallow bedrock (RS-54) when testing the deeper wells. CDM Smith will cease pumping in the deeper well(s) if there is any indication that pumping is drawing TCE deeper than it currently exists.

The data collected will be analyzed with aquifer test analysis software to estimate the hydraulic conductivity and storage of the aquifer.

3.3 Well Pumping System Details

The GWIM system at the FSDF will consist of below-grade extraction wellheads and approximately 100 lineal feet of above grade, double contained conveyance piping. Electrical power to the wellheads will be provided by existing above ground conveyance and the existing ground-level network serving the extraction wells. There is existing power at the wellheads and at the extracted groundwater treatment sites. Extracted groundwater will be conveyed from the wellheads to the treatment unit at a target rate of 0.5gpm[1]. Extraction rates will vary during aquifer tests when aquifer properties are being ascertained.

During operation of the extraction wells, the pump rate will be manually adjusted until the individual well flow rate is within the required extraction range. The well water level switch will be set at a pre-determined shut off depth which will turn off power to the pump should the groundwater level fall below the pre-determined level. In addition, the extraction well power will be controlled by operational parameter set for the treatment unit. The power to the pumps will be automatically shut off should parameters in the treatment unit (such as filling of the surge tank) dictate cessation of flow to the unit.

[1] 0.5gpm identified as a target only per the original GWIM concept. It is recognized that prior extended pumping of wells at the FSDF could not sustain this rate of pumping.

3.4 Extracted Groundwater Containment and Disposal

The groundwater generated during aquifer testing will be conveyed to a treatment system for treatment. Treated water will be stored in portable tanks for chemical analysis prior to reinjection. Parallel infiltration trenches will be installed for treated water release into the formation. During aquifer testing, nearby monitoring wells will also be assessed as a potential option for release of the treated water. This will allow for conducting variable rate injection tests during disposal with observations of responses within the reinjection well, infiltration trenches, and adjacent monitoring wells. Once an infiltration rate has been determined, longer-term tests using a sustainable treated water release rate and the displacement in the injection and monitoring wells will be monitored and recorded with the transducers.

Section 4 presents the design basis for the treatment system and Section 5 details on the extracted groundwater treatment system. Extracted groundwater will be treated to meet WDR discharge standards and released into infiltration trenches installed parallel to the east and west boundaries of the FSDF site.

Section 4

Design Basis

This section presents the design basis, assumptions, and references for the groundwater extraction and treatment system.

In general, extracted groundwater from the aquifer pumping is required to be treated and comply with the requirements of the WDR permit. After treatment, the water will be reinjected into the aquifer. The primary groundwater contaminants to be treated include VOCs (TCE and its byproducts), perchlorate, metals, and arsenic using appropriate treatment technologies.

4.1 Flow Rates

As discussed in the earlier section, aquifer yield tests will be used to identify flow rates of the treatment and discharge systems. For the treatment design, the treatment process flow rate is expected to be higher than the maximum aquifer yield and will operate in batch mode. Release of treated water will also operate in batch mode as the flow rate will be reduced to match the ability of the aquifer to accept the water. In general, the treatment and discharge flow rates will be designed to exceed the pumping rates.

The flow rates for the aquifer test and treatment system are as follows in **Table 4-1**.

Table 4-1 Flow Rates Summary

Flow Rate	Unit	Expected	Minimum	Maximum	Type of Flow	Notes
Aquifer Pumping	gpm	0.5	0.1	1	Continuous	Aquifer yield based on prior FSDF area pumping
Treatment	gpm	7.5	2	10	Batch	Refer to Section 5
Release / Reinjection	gpm	1	0.5	2	Batch	Infiltration test will be performed to verify actual release rates

4.2 Treatment Parameters

This section discusses the parameters from existing groundwater data and selection of available treatment technology for removing the contaminants from extracted groundwater.

To determine the design-level contaminant concentration for the treatment system, groundwater data collected for wells in the vicinity of the FSDF provide for the maximum and range of the chemical influent parameters for the treatment system (**Table 4-2**). To ensure all conditions that may be present during the GWIM are accounted for, water quality data collected for FSDF-area bedrock wells and piezometers were reviewed for the ranges of reported chemistry results. The maximum influent value in Table 4-2 represents the maximum concentration of that constituent reported in a well at the FSDF. The expected constituent concentration represents recent data from FSDF wells RD-21, RD-23, RD-64, RD-65, and RS-54.

Table 4-2 Groundwater Contaminant Parameter Summary

Constituent	Unit	Influent Value		Treatment Method	GW Screening Level	Expected	See Footnote Below
		Min	Max				
Volatile Organic Compounds							
1,1,1-Trichloroethane	µg/L	830	5600	GAC	200	ND	1
1,1,2-Trichloro-1,2,2-trifluoethane	µg/L	44	450	GAC	1200	ND	1
1,1-Dichloroethane	µg/L	370	1800	GAC	5	ND	1
1,1-Dichloroethene	µg/L	280	3700	GAC	5	ND	1
1,2-Dichloroethane	µg/L	5	16	GAC	0.5	ND	1
Cis-1,2-Dichloroethene	µg/L	12	280	GAC	6	ND	1
Trichloroethene	µg/L	180	1600	GAC	5	ND	1
Xylenes, Total	µg/L	1.6	871	GAC	1,750	ND	1
Semi-Volatile Organic Compounds							
1,4-Dioxane	µg/L	0.46	6.2	Not needed	1	2.2	1, 2
N-Nitrosodimethylamine (NDMA)	µg/L	ND	ND	Not needed	0.01	ND	1, 2
Perchlorate	µg/L	0.9	12	Ion Exch.	6	ND	
Metals							
Antimony	mg/L	ND	0.003	Ion Exch.	0.0025	0.0025	1
Arsenic	mg/L	ND	0.320	Ion Exch.	0.0077	0.0077	1
Barium	mg/L	0.006	0.210	Ion Exch.	0.015	0.015	1
Beryllium	mg/L	ND	ND	Not Needed	0.00014	0.00014	1
Boron	mg/L	0.444	0.580	Ion Exch.	0.34	0.34	1
Cadmium	mg/L	ND	0.006	Ion Exch.	0.002	0.002	1
Calcium	mg/L	98	180	Ion Exch.			1
Chloride	mg/L	47.8	260	Ion Exch.	250	250	1
Cobalt	mg/L	ND	0.230	Ion Exch.	0.0019	0.0019	1
Chromium	mg/L	ND	0.088	Ion Exch.	0.014	0.014	1
Copper	mg/L	ND	0.05	Ion Exch.	0.0047	0.0047	1
Fluoride	mg/L	0.300	0.680	Ion Exch.	.8	.8	1
Iron	mg/L	0.007	4.5	Ion Exch.	4.1	4.1	1
Lead	mg/L	ND	0.033	Ion Exch.	0.011	0.011	1
Mercury	mg/L	ND	0.001	Ion Exch.	0.00063	0.00063	1
Molybdenum	mg/L	0.001	0.071	Ion Exch.	0.0022	0.0022	1
Nickel	mg/L	ND	0.820	Ion Exch.	0.017	0.017	1
Potassium	mg/L	1.60	4.900	Ion Exch.	9.6	9.6	1
Selenium	mg/L	ND	0.016	Not Needed	0.0016	0.0016	1
Silver	mg/L	ND	0.023	Not Needed	0.00017	0.00017	1
Sodium	mg/L	35	110	Not Needed	190	190	1
Strontium	mg/L	0.243	0.737	Ion Exch.	0.8	0.8	1
Sulfate	mg/L	56	270	Ion Exch.	376	376	1
Thallium	mg/L	ND	ND	Ion Exch.	0.00013	0.00013	1
Water Quality							
pH	su	6.74	6.74	Not needed	NA	7	3
Total Dissolved Solids	mg/L	445	1,100	Not Needed	500	500	4

Notes:

1. Historic minimum and maximum values obtained from database query of all wells and piezometers located at FSDF. Historic maximum values do not reflect current groundwater conditions. Expected values presented reflect recent groundwater conditions obtained during 2013 and 2014 annual groundwater sampling events.
2. SVOC values obtained from RD-21 and RS-54 historic data.
3. pH range is derived from RD-54A 1st Quarter 2015 sampling event.
4. TSS values are unavailable and will be obtained prior to implementation.

Preliminary vendor research was performed in early 2013 and reviewed in 2015, and provided general specification for the treatment system.

Groundwater data as presented in Table 4-2 is used to evaluate if one or more contaminants exceeding the groundwater screening levels will require treatment to meet discharge limits; and to select the appropriate type of treatment for the system. The evaluation of specific compounds from the different groups are summarized below:

- Select compounds from the VOC group that exceed the groundwater screening levels will require treatment.
- 1,4-Dioxane observed in the past but has been below groundwater screening level. Hence, treatment is not considered.
- Perchlorate from semi-VOC group will require treatment.
- General metal compounds will require treatment.
- Arsenic will require treatment.

4.3 Treatment Process Design

This section expands the discussion of each treatment technology and the major process for the proposed treatment system.

The overall process for the treatment system is shown in the Process Flow Diagram (PFD) (Drawing P-1; Appendix B). Equipment Specsheet (Appendix C) provides the details on treatment technology from the manufacturer. Technical Calculations are included in Appendix D.

The process and treatment technologies are discussed as follows.

4.3.1 System Influent

As extracted groundwater enters the treatment system, it will be contained in a storage tank inside of a secondary containment prior to treatment. The tank is sized to handle a capacity of at least 3 days such that it can operate continuously over the weekend (Storage Tank Volume Calculation in Appendix D).

A transfer pump will provide the required pressure to flow across the treatment system. The transfer pump is sized to overcome the pressure loss across the system (Pressure Loss Calculation in Appendix D). The transfer pump will be automated by level switches installed inside the tank.

The duplex filters will remove any suspended solids and protect the treatment equipment. The treatment equipment will be placed in secondary containment area (Secondary Containment Calculations in Appendix D).

4.3.2 VOC Treatment

Granular adsorption is a proven process to remove VOCs using Evoqua reactivated GAC media Aquacarb series S. Preliminary isotherm calculation estimates GAC media usage will be 2.78 lbs per day (estimated 500 lbs over six months) (see Appendix D for Isotherm Calculations).

4.3.3 Perchlorate Treatment

Ion exchange process using Dow Dowel PSR-2 resin will be used to remove perchlorate. According to the manufacturer, the Dowel PSR-2 is a strong base anion exchange resin designed to remove negatively charged trace contaminants.

4.3.4 Metals Treatment

Metals will be treated via ion exchange using Evoqua SCU™ Specialty Trace Metals Removal Media. According to the manufacturer, SCU™ specialty media is a proprietary adsorbent that is similar in appearance to GAC or anthracite but with a higher density and particle hardness. It removes trace levels of various heavy metals from complex waters to levels not possible with standard ion exchange resins. Metals to be removed by SCU™ specialty media include cadmium, trivalent chromium, copper, lead, mercury, nickel and zinc.

4.3.5 Arsenic Treatment

Granular adsorption process using Evoqua granular ferric hydroxide (GFH®) media will be used to remove arsenic. According to the manufacturer, GFH® media is a specially designed adsorbent media based on granular ferric hydroxide. It is specifically designed for the removal of arsenic (arsenate [As+5] and arsenite [As+3]) from water and can remove other heavy metals as well. In addition to arsenic, GFH® media has been demonstrated to provide removal of phosphate, antimony and copper.

4.3.6 System Effluent

As extracted groundwater exists the treatment vessels, it will be contained in a storage tank inside of a secondary containment prior to discharge. The tank is sized to handle a capacity of at least 3 days such that it can operate continuously over the weekend (Storage Tank Volume Calculation in Appendix D).

A transfer pump will provide the required pressure for reinjection. The transfer pump will be automated by level switches installed inside the tank.

The duplex filters will remove any suspended solids and comply with permit requirements.

4.3.7 Electrical and Control Scheme

The electrical needs for the treatment system will be supplied from the existing MCC-05 power. Wiring and conduits will be routed from the panel to the treatment area.

Because the treatment system will be operated on a batch process it will be manually started at all times. During treatment operations, the system will be automated to the extent practical so that an operator will not need to be present at all times. The main control strategy for the operation of the system is known as a cascade control system. Upstream equipment cannot run unless the equipment immediately downstream is ready for operation. Consequently, equipment failure in the downstream processes will affect the operation of the upstream processes sequentially, ultimately inducing the shutdown of the system if needed. The cascade order is determined by the water flow direction. The logic for the cascade control scheme is depicted in drawing P-2 (Appendix B) and described below:

- Low and high level switches that are equipped with the aquifer pumps will automate the operation of the aquifer pumps.
- Low and high level switches installed in the influent and effluent tanks will automate the operation of the respective pumps.
- High-High level switch installed in the effluent tank will prevent the influent pump from operating until the liquid level in the effluent tank is cleared.
- High-High level switch installed in the influent tank will prevent the aquifer pump from operating until the liquid level in the influent tank is cleared.
- High level switch installed in the secondary containment will shut down the entire system in the event of a leak.

The treatment system will have a telephone dialer alert system activated when it automatically shuts down.

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Section 5

Treatment System

This section discusses the equipment and components of the FSDF GWIM treatment system. The details of the system are shown in the engineering drawings in Appendix B. PFD (Drawing P-1; Appendix B) shows the overall process for the interim system, Piping and Instrumentation Diagram (Drawing P-2) shows the equipment and interconnections; Mechanical Plan (Drawing M-2) shows the proposed layout for the equipment and other drawings to provide the necessary details.

The treatment system will be operated on a batch basis given that a treatment flow rate exceeds the influent rate pumping rate. The treatment system would be operated during an eight-hour operations shift on Mondays, Wednesdays, and Fridays. Treatment system operators will be present five days per week to monitor effluent response to shallow groundwater levels and downgradient drainages. Discharge of treated water to the infiltration trenches would be operated until the influent tank is emptied.

5.1 Treatment Equipment

The major components of the interim system are described as follows by tag numbers and shown in Drawing P-2 (Appendix B).

5.1.1 Aquifer Submersible Pump

The pump package will be self-contained and consist of its own control panel and appurtenances. The pump will operate based on its level switches and will shut off when the treatment system is not ready to accept flow or is in an alarm mode. Due to varying flow rate from aquifer pumping, a variable frequency drive (VFD) submersible pump will be used. The VFD will allow an operator to control the discharge flow rate.

The groundwater pumping will include but not limited to the following:

- Above grade piping to treatment unit;
- Level controller;
- Flow meter with totalizer;
- Pressure indicator;
- Check valve;
- Globe valve;
- "Y" Strainer (if needed); and
- Sample port.

Electric power for the GWIM extraction wells will be supplied from the treatment system via above grade flexible conduits.

5.1.2 Influent Tank

An influent tank will be used to store extracted groundwater from the aquifer test. With an expected aquifer pump test continuous flow rate of 0.5 gpm, a 6,500-gallon tank would provide adequate storage of more than six days. The influent tank will be a double-wall polyethylene tank and placed within a secondary containment. Level switches will be placed inside the tank to automate and shut off the appropriate devices. A high level switch is designed to shut off the aquifer pump in the event that the tank if full and reenergize upstream devices with tank level reaches normal condition.

5.1.3 Influent Pump

An influent pump will be used to provide the required head pressure to overcome the pressure requirements across each piece of the treatment equipment. The pump will be a centrifugal type placed inside a secondary containment and will be automated by the level floats located inside the influent tank.

5.1.4 Influent Duplex Filter

To protect the treatment equipment, filters will be used to remove particulates prior to treatment placed inside a secondary containment. As recommended by the equipment vendor, a 5 micron bag media will be proposed. A duplex filter in parallel will be specified such that filter media can be changed out one at a time without the need to shut down the system.

5.1.5 Granular Activated Carbon

Three Evoqua 3.6 cubic feet (cu ft) tanks rated for 10 gpm at 75 lbs per square inch gas (psig) max will be used to house the GAC. Each vessel contains 90 lbs of media for a total of 270 lbs of media. Three vessels will be configured in series as lead, lag and polish. The vessels will be placed inside a secondary containment.

5.1.6 Ion Exchange for Perchlorate Removal

An Evoqua 3.6 cu ft tank rated for 10 gpm at 75 psig max will be used for perchlorate removal. The vessel will be placed inside a secondary containment.

5.1.7 Ion Exchange for Metals Removal

Metals will be treated by ion exchange using Evoqua Specialty SCU™ proprietary granular carbonaceous adsorbent ion resin. This resin removes positively charged compounds (dissolved metals). An Evoqua 3.6 cu ft tank rated for 10 gpm at 75 psig max will be used. The vessel will be placed inside a secondary containment.

5.1.8 Granular Ferric Hydroxide for Arsenic Removal

Arsenic will be removed using granular adsorption using GFH® media. An Evoqua 3.6 cu ft tank rated for 10 gpm at 75 psig max will be used. The vessel will be placed inside a secondary containment.

5.1.9 Effluent Tank

Two effluent tanks will be used to store treated effluent prior to release. Once full, the first tank will be sampled to confirm treatment to WDR standards. While the first tank is being discharged, the second tank will be filled. With an expected release rate of about 1 gpm, two 6,500 gallon tanks will provide adequate storage. The effluent tank will be a double-wall polyethylene tank and placed within a secondary containment. Level switches will be placed inside the tank to automate and shutoff the appropriate devices. Since the effluent is treated water, secondary containment for this tank would not be required. A high level switch is designed to shut off the aquifer pump in the event that the tank is full and reenergize upstream devices with tank level reaches normal condition.

5.1.10 Effluent Pump

An effluent pump will be used to provide the required head pressure to convey the treated effluent to the final discharge location. The pump will be a centrifugal type and will be automated by the level floats located inside the effluent tank.

5.1.11 Effluent Duplex Filter

Effluent will be pumped through a duplex filter as part of the discharge process. The filter will capture any fines or particulates prior to discharge to comply with permit requirements. The size of the bag filter will be determined to comply with permit requirements. A duplex filter in parallel will be specified such that filter media can be changed out one at a time without the need to shut down the system. Although it is not required, the effluent duplex filter will be placed inside a secondary containment in case of leaks.

5.1.12 Sampling Points

The system will have multiple monitoring and sampling points so that treatment efficiencies can be checked at each step of the process. Various sampling ports, as shown on the PFD (Drawing P-1) and Piping & Instrumentation Diagram (Drawing P-2), will be installed and used to provide the required sampling needs throughout the treatment system. A typical sampling port would consist of a pressure gauge and 1/4-inch ball valve with a hose barb connection.

5.1.13 Secondary Containment

The treatment system will be installed inside a secondary containment area for the portions of the unit containing and treating contaminated water. The recommended size of the containment is illustrated in the Treatment System Plan (Drawing M-2). Volume calculations are performed and included in Appendix D. Heavy-duty flexible plastic liner will be used to create the bottom layer of the containment. The wall of the containment will be draped and wrapped over sand bags on the edges. Height of the edges will be determined.

5.1.14 Control Panel

Electrical service is available by the existing Motor Control Center (MCC-05) located at the northeast corner of the proposed treatment area. An existing 480-volts, 250-amps, 3-Phase service is currently serving other features at the site. Electrical drawings E-1 and E-2 (Appendix B) show the requirements for power.

5.1.15 Conveyance Piping and Conduits

All conveyance piping and conduits will be installed on the surface. Flexible piping and conduits will be used to route between the treatment unit and the aquifer test well and be protected by temporary ramps or fenced off to prevent traffic. No vehicle traffic will be allowed in the area of the surface piping.

5.1.16 Infiltration Trench

After treatment, treated water will be piped back to the infiltration trenches or injection well for release. Rate of release will be determined by infiltration tests to be conducted prior to system implementation. Infiltration trenches will consist of a series of connected perforated piping, backfilled in crushed rocks in trenches, used to percolate the treated water. See drawing M-3 for details.

5.2 Site Work

The aquifer pump test and temporary treatment system is intended to operate for a limited duration of approximately three months. As such, extensive civil work and permanent construction are not expected. The following subsections discuss the aspects of site work.

5.2.1 Geotechnical

The proposed treatment location will be placed in the parking area used for storing Baker tanks for the nearby storm water NPDES discharge points. This area is selected due to it relatively flat grade, compacted gravel area and near an existing power service. The treatment equipment with secondary containment is not anticipated to need a concrete pad and hence, will not require excavation. No additional geotechnical investigation is anticipated for this scope.

5.2.2 Stormwater Pollution Prevention Plan (SWPPP)

Site-wide SWPPP (MWH 2012) will be used as the guide for the construction of the system and best management practices (BMPs) be augmented as needed. No additional SWPPP revision is anticipated for this scope. Because activities will occur upgradient of NPDES discharge point 005, waddles will be installed downgradient of the treatment system across Channel A to capture any sediment released from the parking area.

5.2.3 Site Grading

No digging or trenching will be required to install the pipeline surface piping. The infiltration trench will be installed in a shallow, 4-ft deep trench. Disturbed soil will be recompacted to match existing grade. Waddles will be installed around the grading area if needed to control any sediment in surface water collected within the construction zone.

5.3 Waste Handling and Disposal

All waste generated from GWIM implementation and operation shall be properly and safely managed from its generation through handling, storage, and preparation for transportation. The management of waste shall be conducted in accordance with all applicable local, state, and federal laws and regulations.

5.3.1 Excavated Soil

Because the backfill soil previously placed over the FSDF location came from the adjacent Area IV borrow site and has been shown to be free of site contaminants, it is expected that all excavated soil during the GWIM construction will be reused for backfill.

5.3.2 Media Changeout

During the operation of the treatment system, when breakthrough occurs for the specific treatment process, the primary vessel may be spent and need to be replaced.

For changeout activity, the vessel that is spent will be swapped out with another vessel containing fresh media. As such, the spent media is not required to be removed from the vessel and handled separately. The vessel with spent media shall be profiled and transported to an approved offsite disposal facility for final disposition.

5.3.3 Spent Filter Bags and Misc Debris

Spent filter bags and miscellaneous debris that came in contact with groundwater will be disposed in a designated disposal bin separate from regular trash and disposed of accordingly.

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Section 6

Permitting and Environmental Considerations

The DOE proposes to discharge treated groundwater into the same aquifer in the immediate vicinity of the extraction wells. DOE will be requesting that a WDR be issued by the LARWQCB. Order No. R4-2014-0187 WDR applies to *in-situ* groundwater remediation/cleanup or the extraction of polluted groundwater with above ground treatment and the return of treated groundwater to the same aquifer zone. This Order was adopted on September 11, 2014.

According to Resolution R14-008, the Regional Board has prepared an Initial Study and Mitigated Negative Declaration for the issuance of general WDRs in accordance with the provisions of the California Environmental Quality Act (CEQA). This Resolution was adopted on September 11, 2014.

Appendix E provides a CEQA Initial Study for the FSDF GWIM. Installation and operation of the FSDF GWIM will not create a significant impact on the human or natural environment. The GWIM FSDF Work Plan will be submitted to the LARWQCB including any conditions of implementation with the Report of Waste Discharge (ROWD) for application of a WDR.

6.1 Discharge Requirements and Local Permitting

The objective of the interim treatment system described in Section 5, is to treat VOCs and other naturally occurring compounds to groundwater screening levels established for SSFL. SSFL screening levels (RWQBC 2008) are based on the following descending order of priority (MWH 2009b):

- Primary Maximum Contaminant Levels (MCLs) promulgated by the Safe Drinking Water Act (SDWA) and 22 CCR, sections 64431 through 64449 and 64672 (listed as Primary MCL and Cal MCL in report tables);
- Regulatory action levels (RALs) for lead and copper;
- Notification levels (NLs);
- Archived advisory levels (AALs);
- Secondary Maximum Contaminant Levels (SMCLs), which address aesthetics, such as taste and odor (listed as Secondary MCL in report tables);
- Site-specific values developed by DTSC (i.e., groundwater comparison concentrations for metals) (listed as SSFL Comparison in report tables), and
- Site-specific values developed for SSFL using risk assessment procedures assuming direct ingestion of groundwater (listed as SWGW RBSL [site-wide groundwater risk-based screening level] in report tables).

Groundwater screening reference values presented in Table 4-2 were obtained from the Report on Annual Groundwater Monitoring for Area IV, 2014 (CDM Smith 2015). It is important to note that SSFL screening reference values are not applicable to release of treated water into the aquifer and is discussed below.

The treated groundwater released into the aquifer will be consistent with the anti-degradation provisions of State Water Resources Control Board Resolution No. 68-16 (Anti-degradation Policy). The GWIM treatment will improve the quality of the affected groundwater. However, many shallow groundwater zones contain general mineral content (total dissolved solids, chloride, and sulfate, etc.) at concentrations that are considered to be naturally occurring and not the result of pollution that could exceed the Basin Plan Objectives. Treated groundwater that contains mineral content that are naturally occurring and exceeds Basin Plan Objectives may be returned to the same groundwater formations from which it is extracted, with concentrations not exceeding the original background concentrations for the FSDF site.

There are no drinking water wells within 2 miles of the FSDF GWIM action. The Chatsworth Formation groundwater unit at the site currently is not being used as a water source. Title 22 Drinking Water Standards should not apply to the discharge of treated groundwater.

6.1.1 WDR Requirements

Condition #12 of the R4-2014-0187 Order references the Basin Plan for the numerical and narrative Water Quality Objectives (WQOs) for surface and groundwater within the basin; and WQOs will be reviewed on case by case basis. Appendix F provides the numeric limits. Many of the limits are not applicable to the FSDF GWIM project.

Creation of surface water flow from treated groundwater discharge into the subsurface is not anticipated for this GWIM. However, there is a potential for treated groundwater discharged to the subsurface to have a surface expression (i.e., seep). The GWIM discharge system or procedures will be modified, as needed, to eliminate any surface expressions. No surface water flows are anticipated to reach either Outfall 005 or 006. The surface water quality objectives are provided for Outfall 005 and 006 as shown in Appendix F, Waste Discharge Requirements for The Boeing Company, Santa Susana Field Laboratory (NPDES No. CA0001309) and Monitoring and Reporting Program No. 6027.

6.1.2 Ventura County

The Ventura County is the local agency for issuing local permits related to construction activities at the site. Initial conversations with Craig Cooper (Building Official) were made in 2014. According to Mr. Cooper, building permits are not required for the implementation of the aquifer testing and the installation of the temporary treatment system.

6.2 Environmental Considerations

The entire FSDF area has been disturbed as part of FSDF operational activities during 1956 to 1978, and soil and debris removal actions of the 1990s and early 2000s. The location of the FSDF ponds has been revegetated by forbs and shrubs. Boeing also planted several oak trees within the FSDF cover. The area surrounding the FSDF ponds remains highly disturbed as roadways and parking.

The following environmental considerations will be implemented as part of the construction and operation of the FSDF GWIM system. These are based on measures currently employed by DOE and Boeing for work within Area IV.

1. The DOE has conducted special status species for plants and animals for the vicinity of the FSDF. As part of site orientation and work preparation activities, site biologists will provide instructions on their presence. The biologists will also conduct a reconnaissance of the FSDF work area. If endangered plants are observed they will be isolated using orange construction fencing. During construction of the GWIM treatment system, a site biologist will be present to oversee general work. GWIM operators will be provided specific instructions on what to do should special status species be encountered when operating the extraction/treatment systems.

2. If construction work occurs during bird breeding season, a biologist will conduct pre-construction surveys for the presence of nesting birds in the vicinity of the FSDF area. If necessary, locations of bird nests will be cordoned off to prevent disturbance.

3. FSDF GWIM treatment system construction work will not occur in the vicinity of oak trees nor will it require clearing of vegetation. The proposed treatment unit site is a parking area used to store Baker tanks for the nearby storm water NPDES discharge points. The extracted groundwater pipeline from the wellhead to the treatment unit will be routed via aboveground piping around any oaks planted at the FSDF site.

4. DOE has completed cultural surveys throughout Area IV and has identified environmentally sensitive areas containing historic artifacts. These areas are marked in the field. As part of preconstruction activities, the site archaeologist will identify the nearest environmentally sensitive area. Should one be located adjacent to the FSDF site, it will be cordoned off using orange construction fencing.

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Section 7

Project Implementation

The proposed implementation schedule shows the general phases and details for the implementation of the GWIM. The actions and milestones that will occur during the duration of the project are identified, and specific task durations and dates are assigned.

7.1 Implementation Plan

The current approach for implementing the aquifer testing and system construction is based on the Design-Build (DB) approach. CDM Smith will perform as the prime contractor for the project. Detail Specifications will not be used during construction. However, compliance with national codes and standards will be adhered.

The following subsections provide the general phases of construction and basic direction for implementation of the system.

7.1.1 Pre-Construction Planning

Prior to construction, the project team will meet to conduct pre-construction meeting among key players and stakeholders for this project.

During the planning phase, appropriate documents will be developed including:

- Site Clearances and Access Agreement;
- Construction Health and Safety Plan;
- Revised Construction Schedule;
- Construction Quality Control Quality Assurance Plan; and
- Sampling Analysis Plan/Quality Assurance Project Plan.

7.1.2 Site Mobilization

Prior to site mobilization, appropriate notifications will be made. In addition, all subcontractors' employees are required to attend a one hour site orientation meeting and will be assigned a site access badge. Subcontractor employees are required to be US citizens per site policy and have a government-issued identification card with them at all times.

Temporary facilities and support equipment will be mobilized to the site not limited to the following:

- Portable Sanitation Facility;
- Construction Support Equipment as needed; and
- Other elements as defined in the Pre-Construction Planning documents.

In addition, environmental survey of the project area for sensitive locations will be performed and a report will be developed.

7.1.3 Long Lead Equipment Procurement

All long lead equipment items will be identified and procured but not limited to the following:

- Treatment Vessels (GAC, ion exchange, etc.);
- Tank, Pumps, Filters and Controls; and
- Secondary Containment Materials.

7.1.4 Preparation Items

Preparation items will be constructed to facilitate the placement of equipment and other items not limited to the following:

- Field measurements will be conducted to verify all dimensions; and
- A secondary containment pad will be constructed.

7.1.5 Treatment System Construction

After all preparation items are complete. Steps will be made for the specific equipment not limited to the following:

7.1.5.1 Aquifer Pump Installation

The Aquifer Test Plan (Appendix A) presents the specific monitor well(s) subject to testing. Wells that may have dedicated sampling pumps will have those pumps removed prior to installing an aquifer test pump. A licensed well driller will be used to remove FLUTe systems and raise and lower pumps.

7.1.5.2 Conveyance Piping and Conduit Installation

Flexible piping and conduits will be delineated and installed between the aquifer pump to the treatment system. The flexible piping and conduits will be installed aboveground.

7.1.5.3 Equipment Installation

After the secondary containment is complete, the GWIM pumps, tanks and treatment vessels will be placed inside the treatment area. After the equipment are placed and secured, flexible piping and conduits will be installed per the installation diagrams.

7.1.6 System Startup

Prior to system startup, the following documents will be prepared, but not limited to the following:

- Operations and Maintenance (O&M) manual;
- Sampling and Analysis Plan (SAP); and
- Acquisition of the WDR permit.

Startup activities will include, but not be limited to the following:

7.1.6.1 Pre-Startup Demonstration Test

Prior to operation, equipment will be started up and tested using potable water and recirculate in a closed loop. During this demonstration test, the system will be subjected to leak test, equipment checkout and alarm testing for a minimum of 48 hours.

Equipment issues that are discovered during the demonstration test will be added to a construction punch list and to be resolved. Demonstration test may be repeated as needed.

7.1.6.2 Permit Compliance Verification

After successful equipment checkout, groundwater will be extracted, treated through the treatment system and effluent be stored in the effluent tank. Required samples in accordance with the WDR permit will be collected and analyzed. The system will be shut down pending analytical results.

7.1.6.3 Equipment Commissioning

After analytical results confirm permit compliance and the construction punch list is resolved, the system will be determined ready for operation.

7.1.7 System Operation

The treatment system will be operated in a batch mode and will be only operated during an eight-hour work period. The system will have automatic shut-off controls such that operators are not required to be onsite full-time during operation.

System operation activities will include but not be limited to the following:

- Field monitoring logs will be completed;
- Water quality sampling and well water level measurements will be made frequently; and
- Shallow groundwater level response and checks for surface water seepage will be conducted twice per day during and following treated water release.

7.1.8 System Monitoring

System monitoring is required to assess the performance of the equipment and maintain compliance. Monitoring includes sampling, inspection and record keeping tasks to verify the system is operating efficiently and in compliance with permit conditions. Results obtained from monitoring the treatment processes will be analyzed to determine whether the treatment equipment is working properly and to identify when maintenance is needed.

Monitoring and data collection activities will include but not be limited to the following:

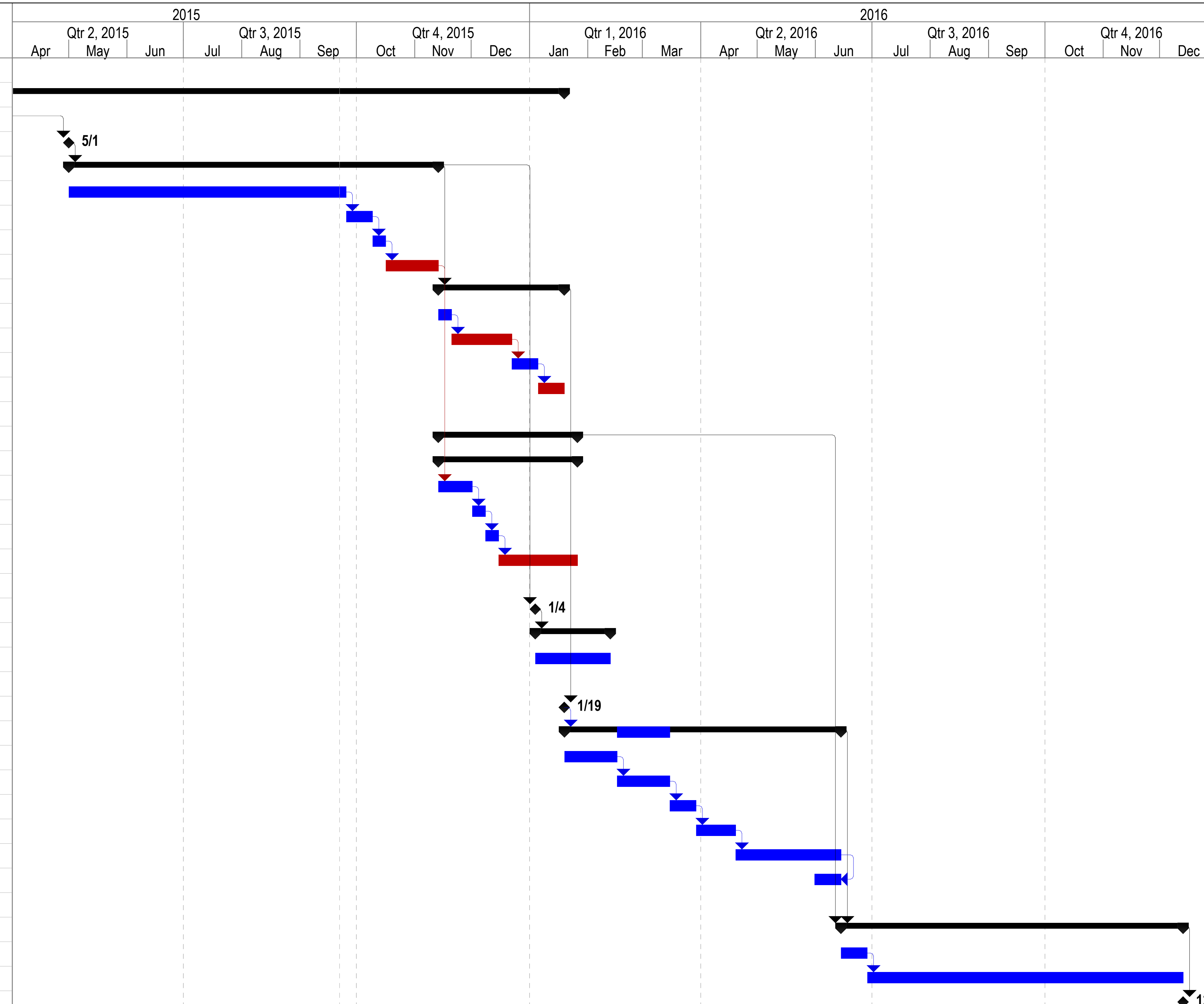
- Aquifer pump flow rates;
- Measurement of water levels in observation wells;
- Collection of water samples from pumping well and observation wells;
- Sampling and analysis of system compliance; and
- Evaluation of data.

7.2 Implementation Schedule

The proposed implementation schedule is shown in **Figure 7-1**.

FSDF GWIM Implementation Schedule
Santa Susana Field Laboratory

ID	Task Name	Work Dur	Start	Finish	Pred	Respon- sibility
1	Approval to start work	0 days	Fri 11/1/13	Fri 11/1/13		
2	**PLANNING AND ENGINEERING PHASE**	**28.08 mons**	**Fri 11/1/13**	**Tue 1/19/16**		**Various**
3	**Conceptual Workplan**	**4.9 mons**	**Fri 11/1/13**	**Mon 3/24/14**	**1**	**Various**
8	Approval to start workplan	0 days	Fri 5/1/15	Fri 5/1/15	3	DOE
9	**Draft Workplan and Design-Build Drawings**	**6.88 mons**	**Fri 5/1/15**	**Fri 11/13/15**	**8**	**Various**
10	Workplan development	20.5 wks	Fri 5/1/15	Fri 9/25/15		CDM Smith
11	Client internal review	2 wks	Fri 9/25/15	Fri 10/9/15	10	DOE
12	Comment revision and submittal	1 wk	Fri 10/9/15	Fri 10/16/15	11	CDM Smith
13	Agency review and comment	4 wks	Fri 10/16/15	Fri 11/13/15	12	DTSC
14	**Final Workplan and Design-Build Drawings**	**2.25 mons**	**Fri 11/13/15**	**Tue 1/19/16**	**9**	**Various**
15	Response to agency comments and submitta	1 wk	Fri 11/13/15	Fri 11/20/15		CDM Smith
16	Agency review and comment	4 wks	Fri 11/20/15	Tue 12/22/15	15	DTSC
17	Comment revision and submittal	2 wks	Tue 12/22/15	Tue 1/5/16	16	CDM Smith
18	Agency approval	2 wks	Tue 1/5/16	Tue 1/19/16	17	DTSC
19						
20	**PERMITTING PHASE**	**2.5 mons**	**Fri 11/13/15**	**Tue 1/26/16**		**Various**
21	**Discharge Permitting**	**2.5 mons**	**Fri 11/13/15**	**Tue 1/26/16**		**Various**
22	Permitting package preparation	2 wks	Fri 11/13/15	Tue 12/1/15	13	CDM Smith
23	Client internal review	1 wk	Tue 12/1/15	Tue 12/8/15	22	DOE
24	Comment revision and submittal	1 wk	Tue 12/8/15	Tue 12/15/15	23	CDM Smith
25	Agency review and approval	6 wks	Tue 12/15/15	Tue 1/26/16	24	RWQCB
26						
27	Approval to start Procurement (2016 Budget Year)	0 days	Mon 1/4/16	Mon 1/4/16	9	DOE
28	**PROCUREMENT PHASE**	**1.5 mons**	**Mon 1/4/16**	**Fri 2/12/16**	**27**	**Various**
29	Equipment Procurement	6 wks	Mon 1/4/16	Fri 2/12/16		CDM Smith
30						
31	Approval to start Implementation (2016 Budget Yea	0 days	Tue 1/19/16	Tue 1/19/16	14	DOE
32	**CONSTRUCTION PHASE**	**5.25 mons**	**Tue 1/19/16**	**Tue 6/14/16**	**31**	**Various**
33	Site Environmental Survey and Mobilization	4 wks	Tue 1/19/16	Tue 2/16/16		CDM Smith
34	Aquifer Testing Setup	4 wks	Tue 2/16/16	Tue 3/15/16	33	CDM Smith
35	Pipeline Installation	2 wks	Tue 3/15/16	Tue 3/29/16	34	CDM Smith
36	Reinjection Gallery	3 wks	Tue 3/29/16	Tue 4/19/16	35	CDM Smith
37	Equipment Installation	8 wks	Tue 4/19/16	Tue 6/14/16	36	CDM Smith
38	Preparation of O&M Documents	2 wks	Tue 5/31/16	Tue 6/14/16	37FF	CDM Smith
39						
40	**OPERATION PHASE**	**6.5 mons**	**Tue 6/14/16**	**Tue 12/13/16**	**32,20**	**Various**
41	Startup and Testing	2 wks	Tue 6/14/16	Tue 6/28/16		CDM Smith
42	Testing and Treatment	6 mons	Tue 6/28/16	Tue 12/13/16	41	CDM Smith
43	Project Complete	0 days	Tue 12/13/16	Tue 12/13/16	40	CDM Smith



LEGEND

Task		Summary		External Milestone		Inactive Summary		Manual Summary Rollup		Finish-only	
Split		Project Summary		Inactive Task		Manual Task		Manual Summary		Progress	
Milestone		External Tasks		Inactive Milestone		Duration-only		Start-only		Deadline	

Notes:
1. The number of days entered as duration are counted as working days excluding weekends and holidays.

Revised: Tue 9/22/15 12:37 PM
by M.Goh, CDM Smith

Section 8
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Appendix A

Aquifer Test Plan

CDM Smith

Prepared by:

CDM Smith

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Santa Susana Field Laboratory Former Sodium Disposal Facility Groundwater Interim Measures Implementation Plan

Appendix A – Aquifer Test Plan

September, 2015

Approved by:

Project Engineer
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Project Hydrogeologist
Michael Hoffman, P.G. _______________

Project Manager
John Wondolleck ___________________

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Acronyms / Abbreviations

µg/L	microgram per liter
ASTM	American Standards for Testing and Measurement
ATP	Aquifer Test Plan
bgs	below ground surface
CDFM	core dynamic fluid testing
cm/s	centimeters per second
cis-1,2-DCE	*cis*-1,2-dichloroethene
COCs	contaminants of concern
DO	dissolved oxygen
DOE	United States Department of Energy
DTSC	Department of Toxic Substance Control
ETS	Extraction and Treatment Center
FLUTe™	Flexible Liner Underground Technologies
FSDF	former Sodium Disposal Facility
ft bgs	feet below ground surface
ft msl	feet above mean sea level
gpd	gallons per day
gpm	gallons per minute
GWIM	Groundwater Interim Measure
HAZWOPER	Hazardous Waste Operations
IDW	investigation derived waste
Km	hydraulic conductivity
MCL	maximum contaminant level
MS/MSD	matrix spike/matrix spike duplicate
ORP	oxidation-reduction potential
OSHA	Occupational Health and Safety Administration
POTW	publicly-owned treatment works
QAPP	Quality Assurance Project Plan
QC	quality control
RFI	Remedial Facility Investigation
RMHF	Radioactive Materials Handling Facility
SCM	Site Conceptual Model
SOP	Standard Operating Procedure
ss	sandstone
SSFL	Santa Susana Field Laboratory
SVOC	semi-volatile organic compounds
TAT	turn-around time
TCE	Trichloroethene
TDS	total dissolved solids
TP	Technical Procedures
trans-1,2-DCE	*trans*-1,2-dichlorethene
TSDF	Treatment, Storage and Disposal Facility
VOC	volatile organic compounds

Section 1

Introduction

The purpose of this document is to describe the activities related to a preliminary aquifer test to be performed within the former Sodium Disposal Facility (FSDF) located within Area IV of the Santa Susana Field Laboratory (SSFL). The results from the aquifer testing will support the final design and implementation of the FSDF Groundwater Interim Measure (GWIM).

In December 2013, the United States Department of Energy (DOE) submitted to the Department of Toxic Substance Control (DTSC) a conceptual work plan for the GWIM to be performed at the FSDF (CDM Smith 2013). The scope of the GWIM included an aquifer pumping test, extended aquifer pumping, and treatment of extracted groundwater. The GWIM Implementation Plan includes an evaluation of onsite treatment of groundwater instead of conveying the water beyond the boundaries of Area IV of the SSFL. This conceptual planning document provided the scope and requirements for the onsite treatment and local release of extracted groundwater. Upon further evaluation, it was determined that RS-54 could not provide extracted water for the GWIM at a sustainable rate.

In response to DTSC comments on the Conceptual Work Plan, CDM Smith has prepared this FSDF GWIM Aquifer Test Plan (ATP), which provides specific detail on how the hydrogeologic portion of the work will be performed.

A brief summary of FSDF's historical operations, removal actions, investigation history, and geology/hydrology/hydrogeology is provided in the GWIM Implementation Plan and has not been repeated in the ATP. However, additional detail and information have been included to support selection and justification of the pumping well, type and duration of the pumping test, groundwater network and observation/data recording requirements, and data evaluation and reporting.

The GWIM ATP is presented in the following sections:

- **Section 1 - Introduction** – Provides a GWIM summary.
- **Section 2 - Aquifer Test Plan Objectives** – Objectives of the Aquifer Test Plan are presented.
- **Section 3 - Site Conceptual Model (SCM) for the GWIM** – General conditions used for the GWIM SCM are presented.
- **Section 4 - General Aquifer Properties** – Hydraulic conductivity, vertical gradients, pumping test, and GWIM studies and conclusions are presented.
- **Section 5 - Well Construction Detail** – Presents pertinent well construction information for each monitoring well.

- **Section 6 - Well Sampling History, Geology/Hydrogeology, GWIM Significance, and Recommendations** – Presents Trichloroethene (TCE) and perchlorate concentrations over time, geologic/hydrogeologic observations, the significance to the GWIM, and recommendations for additional work to satisfy GWIM objectives.

- **Section 7 - FSDF GWIM Preparatory Activities** – Describes work that needs to be performed at the FSDF prior to performing the GWIM.

- **Section 8 - Preparatory Activities Evaluation** – A discussion of how data obtained prior to the GWIM will be used and evaluated.

- **Section 9 - Sequence of Testing, Pumping Rate, and Pumping Test Duration** – Describes which pumping tests will be performed, estimated pumping rate, and duration of the tests.

- **Section 10 - Field Activity Support Information and Procedures** – Presents field activities that will be implemented to support preparatory activities as well as the pumping test and GWIM. Procedures applicable to all activities including health and safety, decontamination, and investigation derived waste (IDW) handling are presented in this section.

- **Section 11 – Aquifer Test Data Analysis and Reporting** – Describes how the data will be analyzed and reported.

- **Section 12 - References** – References are provided in this section.

- **Appendices** – Provides data for evaluation and procedures used during the GWIM.
  - A - Lithologic Logs
  - B - Well Completion Logs
  - C - SSFL Standard Operating Procedures
  - D - Site-Wide Standard Operating Procedures
  - E - Colog, Standard Operating Procedures
  - F - Double-Ring Infiltrometer Test
  - G – Operational Data Sheets/Forms

Section 2

Aquifer Test Plan Objectives

The proposed FSDF GWIM is designed to refine the knowledge of the bedrock hydrology in the area of the FSDF in Area IV, particularly in the identification of fracture zones harboring TCE contamination, and the ability to reduce TCE concentrations within those zones. Reinjection of treated groundwater near the extraction wells is intended to help flush contaminants to the direction of the extraction wells. Groundwater will also be treated for perchlorate, metals, and arsenic prior to reinjection within the FSDF area.

The objectives of the ATP are as follows:

- Identify viable wells that a pumping well can be selected from for the GWIM. For each well the groundwater extraction interval/zone and the sustainable pumping rate will be identified.
- Select pumping well and monitoring well network to be used during the GWIM.
- Predict groundwater contaminant concentrations to confirm the ability of the GWIM treatment system to treat extracted groundwater.
- Estimate infiltration rate to confirm the ability of discharging treated groundwater into the subsurface.
- Estimate aquifer properties for incorporation into the site-wide groundwater flow and fate and transport model.

Figure 2-1 shows monitoring wells at the FSDF and surrounding area. TCE concentrations in groundwater monitoring wells collected in 2014 and 2015 along a cross-section through the FSDF are shown on **Figure 2-2**.

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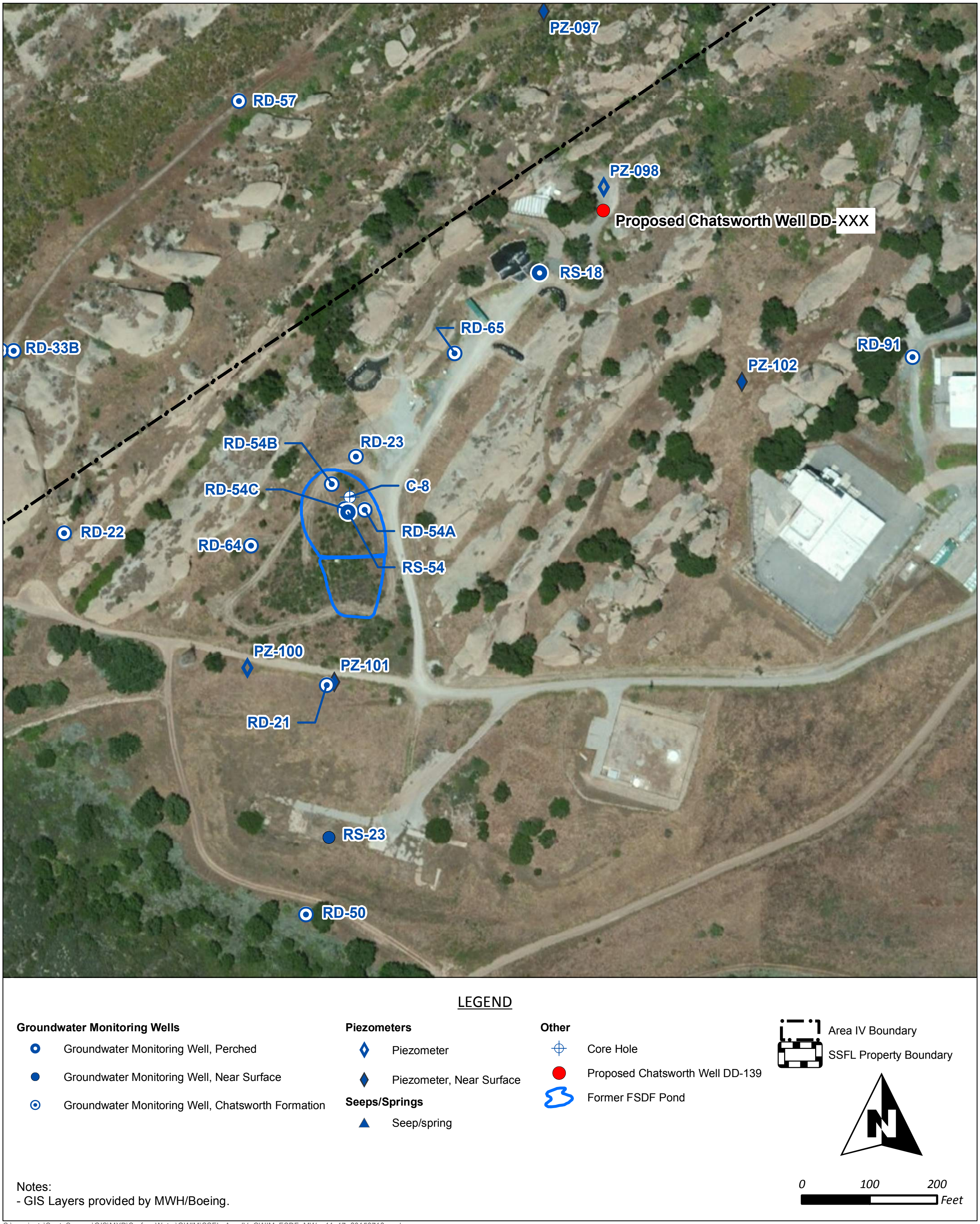

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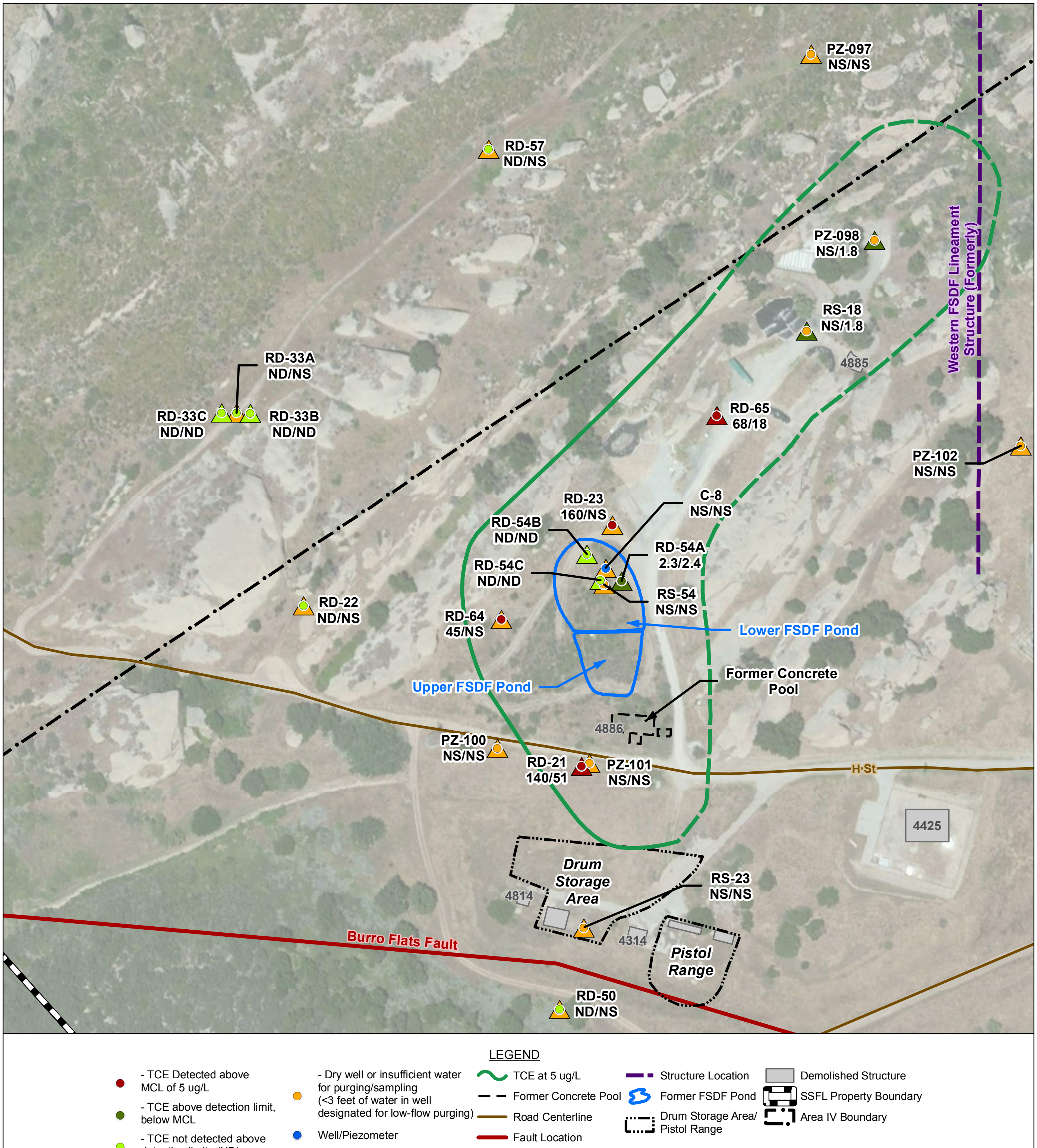
FIGURE 2-1
Monitoring Wells at the FSDF and Surrounding Area



Notes:
- GIS Layers provided by MWH/Boeing.
- Plume boundary dashed where inferred.
- Information provided by MWH following water level survey (February 2014).
- TCE results are ug/L or ppb.
- TCE results displayed: 2014 result/2015 result.
- 2014 results displayed using a circle; 2015 results using a triangle.
- U or ND - Non-detected result; J - Estimated result; NS - Not sampled.

Service Layer Credits:
- Aerial Source: Esri, DigitalGlobe, GeoEye, i-cubed, USDA, USGS, AEX, Getmapping, Aerogrid, IGN, IGP, swisstopo, and the GIS User Community.
- Road Centerline Source: Esri, TomTom.

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FIGURE 2-2
TCE Concentrations in Monitoring Wells, 2014 and 2015

Section 3

Site Conceptual Model for the GWIM

3.1 Site Conceptual Model

A SCM has been developed specifically for the FSDF GWIM. The following SCM information is provided for TCE but is applicable to perchlorate present at the FSDF.

- TCE is present in small, systematic, and interconnected bedrock fractures (solute transport).
- TCE is also present in the porous sandstone matrix (TCE diffusion from fractures into the bedrock matrix).
- TCE concentration has been reduced in the fractures and bedding planes during the groundwater extraction interim measure conducted at RD-21. TCE remains in the sandstone matrix.
- Over time, TCE will continue to diffuse from the bedrock matrix to the fractures and bedding planes. Diffusion of TCE from the sandstone matrix to the fractures will continue as long as a chemical gradient exists between water present in the fractures and the sandstone matrix. A chemical gradient is present due to the fractures containing 'fresh' water from rainfall and infiltration and/or uncontaminated groundwater drawn toward the pumping well.
- The chemical gradient between fractures and the bedrock matrix will decrease over time as TCE diffuses from the sandstone matrix and the TCE concentration in the matrix approaches non-detected levels, as limited by diffusion rates in the rock matrix.

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Section 4

General Aquifer Properties

4.1 Hydraulic Conductivity

Hydraulic conductivity is the proportionality constant that describes the ease with which water can move through pore spaces and/or fractures. Hydraulic conductivity depends on the permeability of the rock and on the degree of saturation. Both matrix and bulk hydraulic conductivity measurements for the Chatsworth Formation have been made across SSFL.

Matrix hydraulic conductivity is a measurement of the unfractured rock including the interconnected open pore spaces between the grains of rock. The matrix hydraulic conductivity for the Burro Flats Member of the Upper Chatsworth Formation has been estimated from measurements of unfractured core samples to range between 1×10^{-7} and slightly less than 1×10^{-6} centimeters per second (cm/s) (MWH 2009).

Bulk hydraulic conductivity is a measure of the matrix hydraulic conductivity plus the influence of other lithologic features, primarily that of fractures. Bulk hydraulic conductivity for the Sandstone 2 members (Burro Flats, ELV, Spa, and Silvernale) has been estimated between 8.3×10^{-8} cm/s and 8.1×10^{-5} cm/s. MWH (2009) hypothesized that the bulk hydraulic conductivity generally decreases with depth because the size of openings in fractures decreases with depth and increasing lithostatic pressure.

Matrix hydraulic conductivity estimated in core samples from Lower Burro Flats Member is presented in **Table 4-1** (MWH 2009).

Table 4-1. Core Samples Tested for Hydraulic Conductivity

Corehole	Avg Depth (ft. bgs)	Sample Description	Modified Rock Type	Rock Type	Estimated Km - sample (cm/s)	Estimated Km – geo-mean* (cm/s)	Test Conducted By
C-8	32.7	*grey coarse ss - Dup*	coarse sandstone	sandstone	2.72E-07	2.5E-05	University of Waterloo, 2002
	32.7	grey coarse ss	coarse sandstone	sandstone	6.21E-07		
	77.3	grey ss		sandstone	4.96E-08		
	83.8	grey ss		sandstone	6.28E-08		
	105.3	grey fine to coarse ss		sandstone	4.81E-07		
	122.4	fine grey ss	fine sandstone	sandstone	2.42E-07		
	167.7	grey ss		sandstone	7.88E-08		
	176.9	grey ss		sandstone	1.94E-07		
	217.1	finer ss		sandstone	5.82E-07		
	247.5	grey ss		sandstone	5.40E-07		
	287.1	grey fine to very coarse ss	coarse sandstone	sandstone	1.79E-07		
	297.3	grey fine to	coarse	sandstone	6.40E-07		

Table 4-1. Core Samples Tested for Hydraulic Conductivity

Corehole	Avg Depth (ft. bgs)	Sample Description	Modified Rock Type	Rock Type	Estimated Km - sample (cm/s)	Estimated Km – geo-mean* (cm/s)	Test Conducted By
		very coarse	sandstone				
	323.1	grey fine to very coarse ss		sandstone	1.52E-07		
	323.1	grey fine to very coarse ss	coarse sandstone	sandstone	2.58E-07		
	338.3	coarse ss	coarse sandstone	sandstone	1.41E-07		
	356.5	coarse ss	coarse sandstone	sandstone	1.04E-07		
	369.5	coarse ss	coarse sandstone	sandstone	6.12E-07		

Notes:
* Geometric mean substituted for duplicate core-sample tests.
Duplicates indicated in italics.
cm/s – centimeters per second
ft bgs – feet below ground surface
Km – matrix hydraulic conductivity
ss - sandstone

FSDF Flexible Liner Underground Technologies multi-level (FLUTe™) system port slug test estimates of hydraulic conductivity is provided in **Table 4-2** (MWH 2009).

Table 4-2. FSDF FLUTe™ System Port Slug Test Estimates of Hydraulic Conductivity

No. of Wells & Ports Tested		Well	Port	Port Mid-Point		Data	K (cm/s)				
				Elev. (ft. msl)	Depth (ft. bgs)		Test Result	Geo-mean of Early & Late Time	Min	Max	Geo-metric Mean
1	1	C-8	5	1,622	213	early time	6.5E-06	2.8E-06	5.6E-08	6.8E-06	1.2E-06
						late time	1.2E-06				
	2		6	1,602	234	early time	6.8E-06	3.2E-06			
						late time	1.5E-06				
	3		7	1,570	265	early time	6.3E-06	2.7E-06			
						late time	1.2E-06				
	4		8	1,540	295	early time	1.8E-06	3.2E-07			
						late time	5.6E-08				
	5		9	1,525	310	early time	4.9E-06	1.4E-06			
						late time	4.2E-07				

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Table 4-2. FSDF FLUTe™ System Port Slug Test Estimates of Hydraulic Conductivity

No. of Wells & Ports Tested		Well	Port	Port Mid-Point		Data	K (cm/s)				
				Elev. (ft. msl)	Depth (ft. bgs)		Test Result	Geo-mean of Early & Late Time	Min	Max	Geo-metric Mean
	6		10	1,480	355	early time	9.5E-07	2.8E-07			
						late time	8.5E-08				
2	7	RD-21	1	1,777	90		1.4E-06	1.4E-06	1.4E-06	6.9E-05	1.3E-05
	8		2	1,757	110		3.5E-05	3.5E-05			
	9		3	1,737	130		3.1E-05	3.1E-05			
	10		4	1,717	150		6.9E-05	6.9E-05			
	11		5	1,697	170		3.8E-06	3.8E-06			
3	12	RD-22	1	1,538	315		2.2E-05	2.2E-05	7.8E-06	2.4E-05	1.8E-05
	13		2	1,518	335		2.4E-05	2.4E-05			
	14		3	1,498	355		2.0E-05	2.0E-05			
	15		4	1,478	375		2.1E-05	2.1E-05			
	16		5	1,458	395		2.3E-05	2.3E-05			
	17		6	1,438	415		7.8E-06	7.8E-06			
4	18	RD-33A	1	1,577	216		3.8E-05	3.8E-05	9.5E-06	5.7E-05	3.0E-05
	19		2	1,557	236		9.5E-06	9.5E-06			
	20		3	1,537	256		2.1E-05	2.1E-05			
	21		4	1,517	276		4.0E-05	4.0E-05			
	22		5	1,497	296		5.7E-05	5.7E-05			
	23		6	1,477	316		4.0E-05	4.0E-05			
						Minimum	5.6E-08	8.3E-08	5.6E-08	6.8E-06	1.2E-06
						Maximum	6.9E-05	6.9E-05	9.5E-05	6.9E-05	3.0E-05
						Geometric Mean	5.3E-06	7.3E-06	8.7E-07	2.7E-05	6.8E-06

Notes:
cm/s – centimeters per second
ft bgs. – feet below ground surface
ft msl – feet above mean sea level
K – hydraulic conductivity

Single-well pumping test estimates of hydraulic conductivity were performed on the following wells presented in **Table 4-3** (Haley & Aldrich 2000):

Table 4-3. Single-well Pumping Test Estimates of Hydraulic Conductivity - Sandstone 2 Wells

Well	K (cm/s)	Test Type
RD-21	<1.0E-06	Non-productive well – assigned default minimum value of K=1.0E-07
RD-33B	1.2E-06	Pumping
RD-33C	8.5E-06	Pumping
RD-50	2.3E-06	Pumping
RD-54A	<1.0E-06	Non-productive well – assigned default minimum value of K=1.0E-07
RD-54B	<1.0E-06	Non-productive well – assigned default minimum value of K=1.0E-07

Table 4-3. Single-well Pumping Test Estimates of Hydraulic Conductivity - Sandstone 2 Wells

Well	K (cm/s)	Test Type
RD-57	1.0E-05	Pumping
	6.0E-06	Recovery
RD-64	1.3E-06	Pumping
RD-65	1.0E-05	Pumping

Notes:
cm/s – centimeters per second
K – hydraulic conductivity

Bulk hydraulic conductivity for the conceptual site model has been assigned a value of 1.0E-06. Following aquifer testing, the bulk hydraulic conductivity will be modified to reflect actual field conditions.

4.2 Vertical Gradients

Vertical gradients observed in Area IV FLUTe™ system wells are shown **Table 4-4**. RD-21, RD-33A, RD-50, and RD-57 exhibited little head change over the Upper Burro Flats Member monitored. Wells RD-23, RD-54A, RD-65 had head declines ranging from 25 to 50 feet and a fairly gradual downward gradient of -0.3 ft/ft (MWH 2009).

Table 4-4. FLUTe™ System Well Gradient Data

Well ID	Dates Measured	Observed Vertical Gradients [a]		
		Direction	Characteristics	Approx. Magnitude (ft./ft.)
RD-07			No data loggers installed.	
RD-21 [b]	02/5/03 - 12/19/08	~ None	Little head change in Upper Burro Flats Member (if data from faulty transducer are not considered).	
RD-23	03/19/03 - 01/13/09	Down	Fairly gradual ~ 25 feet head decline over ~ 80 feet of Upper Burro Flats Member.	-0.3
RD-33A [b]	03/25/03 - 01/13/09	~ None	Little head change over ~ 110-foot interval in Upper Burro Flats Member.	
RD-50 [b]	02/5/03 - 01/13/09	~ None	Little head change over ~ 60-foot interval in Lower Burro Flats Member.	
RD-54A	03/19/03 - 01/13/09	Down	Fairly gradual ~ 30 feet head decline over ~ 100 feet of Upper Burro Flats Member.	-0.3
RD-57	12/19/02 - 01/13/09	Down (net)	Overall 5 to 15 feet head decline in Upper Burro Flats Member.	
RD-65	12/18/02 - 01/13/09	Down	Fairly gradual ~ 50 feet head decline over ~ 160 feet of Upper Burro Flats Member.	-0.3

Notes:
Data source: SCM Element 5-2 (Cherry et al., 2009)
a - Excluding perched zones, except where noted
b - Questionable FLUTe™ seal and/or transducer malfunction or error
ft./ft. – foot per foot
Source: Table 6-6 (MWH 2009)

4.3 RD-54B Pumping Test

From January 12, 2004 through June 24, 2004, a pumping test was performed using RD-54B. The objectives of the pumping test were to determine transmissivity, hydraulic conductivity, storativity, and influence of aquitards on groundwater flow at the FSDF (MWH 2006). A draw down test was performed and it was determined that the well could not sustain a 2.5-gallons per minute (gpm) pumping rate. Groundwater was extracted from RD-54B at a constant rate of 173 gallons per day (gpd) for 165 days. A total of 28,300 gallons of groundwater was extracted from the well at an average pumping rate of 0.12 gpm. **Figure 4-1** shows the approximate period for the RD-54B pumping test (January 2004 through June 2004) and TCE concentrations detected in the open borehole and in the FLUTe™ system ports in RD-54A. During the pumping test, data were collected from 16 adjacent observation wells to monitor potential hydraulic responses. Clear responses to the pumping test were observed in 6 of the 16 observation wells at distances as far as 400 feet from RD-54B.

The bedrock overall provides for low matrix hydraulic conductivities that are resistive to groundwater movement. However, the bedrock fractures appear to be interconnected horizontally and vertically. The bedding parallel fractures and joints are hydraulically active with evidence of fracture interconnectivity. Interconnectivity between monitoring wells can be seen during the RD-54B pumping test at the FSDF.

From *Draft Report of Results, Former Sodium Disposal Facility, Groundwater Characterization* (MWH 2006):

> *Data collected from the RD-54B pumping test were then used to obtain estimates of hydraulic conductivity. An analytical solution provided by Moench (1984) was used to obtain hydraulic conductivity estimates of the pumping well and the monitoring wells in which clear responses were measured. The method developed by Moench (dual-porosity for fractured rock) most closely represents the physical system at the SSFL. The geometric mean hydraulic conductivity using the analytical solution derived by Moench was about 6 x 10 -7 cm/s, or about one order of magnitude lower than the geometric mean value obtained from the slug tests. This value reflects the hydraulic conductivity of wells screened within the Upper Burro Flats member of the Chatsworth formation. The difference in geometric mean values is attributed to the presence of lower-permeability features beneath the FSDF area that were encountered during the pumping test but not in individualized (i.e., localized) slug tests. It is worthy to note that the hydraulic conductivity estimated from the pumping tests is about 2.3 times greater than the bedrock matrix (2.6x10 -7 cm/s, see Section 4.6.1). These data indicate that the fracture network within the FSDF area does not appreciably enhance the bulk hydraulic conductivity of the Chatsworth formation.*

Table 4-5 presents the drawdown water level response in each well during the test. Discussion on locating horizontal connectivity between zones in each well is provided in **Section 6**.

Table 4-5. Wells with Apparent Drawdown during RD-54B Pumping Test

Well ID	Port (depth, ft. bgs)	Drawdown (ft. bgs)	Notes
RD-54B	NA	160	Pumping well
RD-22 *	5 (380 to 400)	0.46	Drawdown and recovery occurred
RD-23 *	3 (271 to 281)	7.91	Drawdown and recovery occurred
	6 (331 to 341)	4.13	Drawdown and recovery occurred
	7 (351 to 361)	8.67	Drawdown and recovery occurred
RD-54A *	7 (270.5 to 278)	7.07	Drawdown and recovery occurred
RD-64 *	12 (390.5 to 400.5)	4.42	Drawdown and recovery occurred
RD-65 *	8 (307 to 317)	2.51	Drawdown and recovery occurred
	11 (367 to 377)	8.36	Drawdown and recovery occurred
C-8 *	7 (260 to 270)	9.16	Drawdown and recovery occurred
	8 (290 to 300)	16.3	Drawdown and recovery occurred
	10 (350 to 400)	58.97	Drawdown and recovery occurred

Notes:
* FLUTe™ system well
ft bgs – foot below ground surface
Wells with no drawdown or recovery; RD-21, RD-33A, RD-33B, RD-33C, RD-50, RD-54C, RD-57, RD-59A, RD-59B, and RD-59C
Source: Table 5-1 Appendix B (MWH, 2006)

4.4 Interim Measure - Groundwater Extraction System at the FSDF

The exact period of previous FSDF GWIM activities is unclear due to naming convention inconsistencies for pumping, Interim Extraction and Treatment Center (ETS), and GWIM activities related to extraction activities conducted at the FSDF from 1995 to 2004. For example, the draft FSDF groundwater characterization report reports the interim measuring was initiated in 1997 while annual site environmental reports report that extraction activities commenced in 1995. Reconciliation of the naming convention or intent was not performed. Instead, documents on extraction of groundwater at the FSDF during this period of time are provided below. The following information was presented in the annual site environmental reports.

1995 Annual Site Environmental Report (Rocketdyne 1996)

A proposed plan for the construction and testing of two pilot groundwater extractions: systems in Area IV was submitted to DTSC in August 1993. Following the approval by DTSC, one well was installed for an extraction test at Radioactive Materials Handling Facility (RMHF) in May 1994 and two wells were installed at T886 in May and August 1994. All three wells were located within the Area IV boundary. The goal of the project was to develop a full-scale, long-term system needed to contain, extract, and treat degraded groundwater at Area IV. Both tests were completed in 1995.*

Two new wells were installed for the test at T886. Cyclic pumping of one to three wells was conducted in the test at T886, an area characterized by low yield of groundwater. The evaluation of the results is in progress.

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* note – Building T886 Former Sodium Disposal Facility Closure Order 1996 Annual Site Environmental Report (Rocketdyne 1997)

Two new wells were installed for the test at T886. Cyclic pumping of one to three wells was conducted in the test at T886, an area characterized by low yield of groundwater.

1997 Annual Site Environmental Report (Rocketdyne 1998)

Cyclic pumping of one to three wells was conducted in the test at this site, an area characterized by low yield of groundwater.

An interim Extraction and Treatment Center was operated at the FSDF from April through December 1997. Approximately 28,000 gallons of degraded groundwater was treated.

1998 Annual Site Environmental Report (Rocketdyne 1999)

Cyclic pumping of one to three wells was conducted in the test at this site, an area characterized by low yield of groundwater.

An interim ETS was operated at the FSDF in 1998. Approximately 43,750 gallons of TCE-contaminated groundwater were treated.

1999 Annual Site Environmental Report (Rocketdyne 2000)

At the FSDF, cyclic pumping of one to three wells continuous at the site.

Extraction and treatment of contaminated groundwater continued on an interim basis at RMHF and the FSDF in 1999. To date, approximately 107,000 gallons and 2.7 million gallons of groundwater have been treated from the FSDF and RMHF areas, respectively.

2000 Annual Site Environmental Report (Rocketdyne 2001)

At the FSDF, cyclic pumping of one to three wells continuous at the site.

To date, approximately 118,000 gallons, 2.7 million gallons, and 1.9 million gallons of groundwater have been treated from the FSDF, RMHF, and building 59 areas, respectively.

2001 Annual Site Environmental Report (Rocketdyne 2002)

The extraction activity at the FSDF was initiated in 1995. The groundwater extraction system at FSDF included extraction of impacted groundwater from wells RD-21 and RS-54 and treatment of the extracted groundwater in a GAC adsorption treatment unit. No groundwater was extracted from the FSDF interim extraction wells in 2001.

2002 Annual Site Environmental Report (Rocketdyne 2003)

The extraction activity at the FSDF was initiated in 1995. The groundwater extraction system at FSDF included extraction of impacted groundwater from wells RD-21and RS-54 and treatment of the extracted groundwater in a GAC adsorption treatment unit. Two ion exchange resin drums were added to the treatment system to remove any perchlorate present. Groundwater was extracted only from FSDF interim extraction well RS-54 during 2002. To date, approximately 123,000 gallons, 3.3 million gallons, and 2.6 million gallons of groundwater have been extracted and treated from the FSDF, RMHF and Building 59 areas, respectively.

2003 Annual Site Environmental Report (Rocketdyne 2004)

The extraction activity at the FSDF was initiated in 1995. The groundwater extraction system at FSDF included extraction of impacted groundwater from wells RD-21 and RS-54 and treatment of the extracted groundwater in a GAC adsorption treatment unit. The FSDF system also uses ion exchange resin in series to treat perchlorate-impacted groundwater prior to discharge. Groundwater was extracted only from FSDF interim extraction well RS-54 during 2003. To date, approximately 123,000 gallons, 3.4 million gallons, and 3.4 million gallons of groundwater have been extracted and treated from the FSDF, RMHF, and Building 59 areas, respectively.

2004 Annual Site Environmental Report (Boeing 2005)

The extraction activity at the FSDF was initiated in 1995. The groundwater extraction system at FSDF included extraction of impacted groundwater from wells RD-21 and RS-54 and treatment of the extracted groundwater in a GAC adsorption treatment unit. The FSDF system also uses ion exchange resin in series to treat perchlorate-impacted groundwater prior to discharge. Groundwater was not extracted from FSDF interim extraction well RS-54 during 2004 in order to accommodate the FSDF-area pumping test. To date, approximately 123,000 gallons, 3.5 million gallons, and 3.8 million gallons of groundwater have been extracted and treated from the FSDF, RMHF, and Building 4059 areas, respectively.

Draft Report of Results, Former Sodium Disposal Facility, Groundwater Characterization (MWH 2006)

In 1997, an interim measure was initiated at the FSDF by extracting and treating groundwater from well RD-21. This interim measure remained operational until the CFOU investigations at the FSDF were initiated in 2002, when groundwater extraction was ceased to allow for the hydraulic studies that are described in this report. Typical extraction rates averaged about 173 gallons per day.

Draft Site-Wide Groundwater Remedial Investigation Report (MWH, 2009)

From Table 6-2 of the RI report, 0.01 million gallons per year was extracted from RS-54 in 1997, 1998, 1999, 2000, and 2002. According to this table, groundwater was not extracted from RS-54 in 2001, 2003, or 2004.

Based on information provided in the annual reports and draft FSDF groundwater characterization report, a pumping rate less than 2 gpm due to low transmissivity is supported. RD-21 was pumped from 1997 until 2000 and typical extraction rates averaged 173 gpd (0.12 gpm). The "two other" wells minimal contributions to the total volume of water extracted and treated during this period. In 2003, only RS-54 was pumped (Rocketdyne 2004). Groundwater was not extracted from RS-54 during 2004 (Boeing 2005).

Figure 4-2 shows the approximate period for the Interim Measure – Groundwater Extraction System at the FSDF (April 1997 through 2000) and TCE concentrations detected in the open borehole and in FLUTe™ system ports in RD-21.

Figure 4-3 shows drawdown (depth to groundwater) in wells in the immediate area of RD-21 during the Interim Measure – Groundwater Extraction System at the FSDF. From inspection of the drawdown in these wells it appears that RS-54 is the only well with appreciable response to the pumping. However, RS-54 is reported to have been pumping during the Interim Measure – Groundwater Extraction System at the FSDF.

Figure 4-4 shows in greater detail the effect of RD-21 on RS-54. It is believed that RS-54 was affected by pumping RD-21 because RS-54 shows a drawdown during pumping and the lack of a response to the 41.24 inches of annual precipitation received in 1998. RS-54 water levels historically respond to increase precipitation years as shown on **Figure 4-5**. However, records are not clear on when RS-54 was pumped.

As shown on **Figure 4-5**, RD-50 does not appear to be affected by extraction of groundwater from RD-21. This conclusion is qualified by either the two wells are not in communication or the volume and extraction rate from RD-21 is not great enough to see a response in RD-50.

Figure 4-6 shows RD-64 groundwater levels and TCE concentrations detected in the open borehole and in FLUTe™ system ports. If RD-64 shows a response to pumping RD-21 it is a very small one. However, TCE detected in groundwater during and after the GWIM may suggest that RD-21 and RD-64 are connected. A further discussion is presented in **Section 6.**

For the SCM, TCE has been removed from fractures and bedding planes from the FSDF area during the RD-54B Pumping Test and the Interim Measure – Groundwater Extraction System at the FSDF. Additional removal of TCE from fractures and bedding planes may be possible and effective if high concentrations TCE zones or fractures can be identified and pumped. Based on the pumping test of RD-54B it is also believed that most wells in at FSDF are in communication both horizontally and vertically with another.

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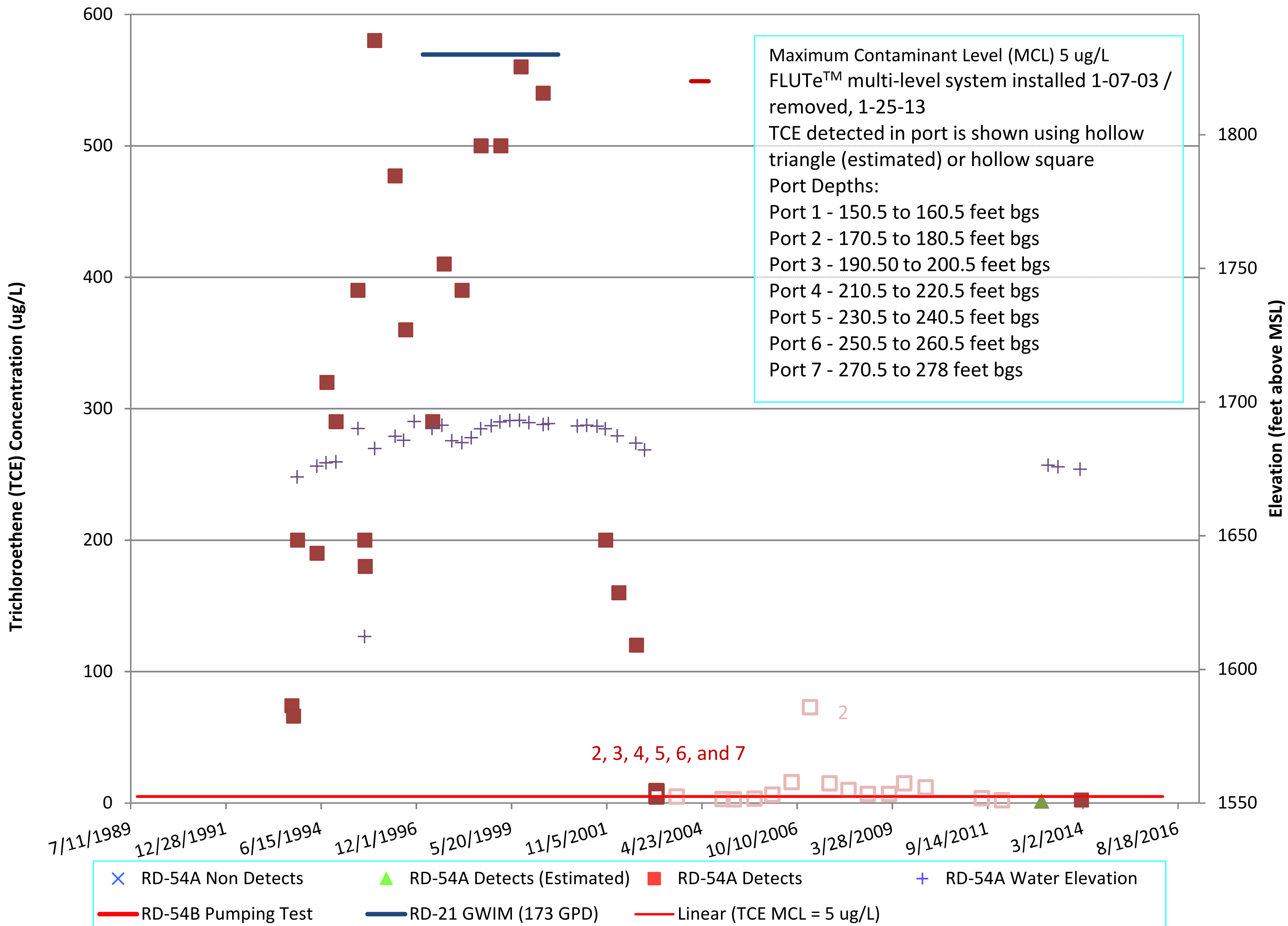

Figure 4-1

TCE Concentrations in RD-54A

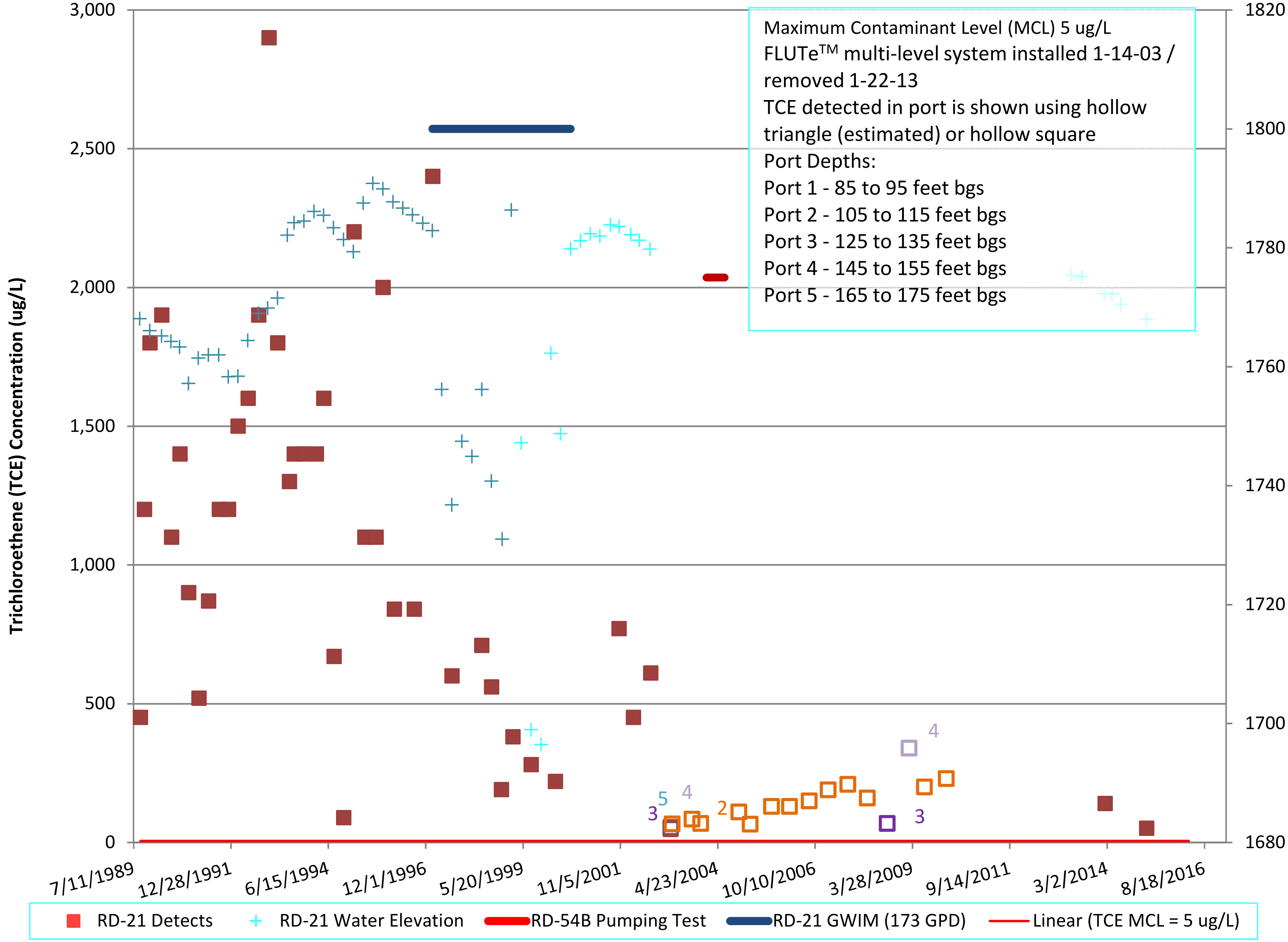

Figure 4-2

TCE Concentrations in RD-21

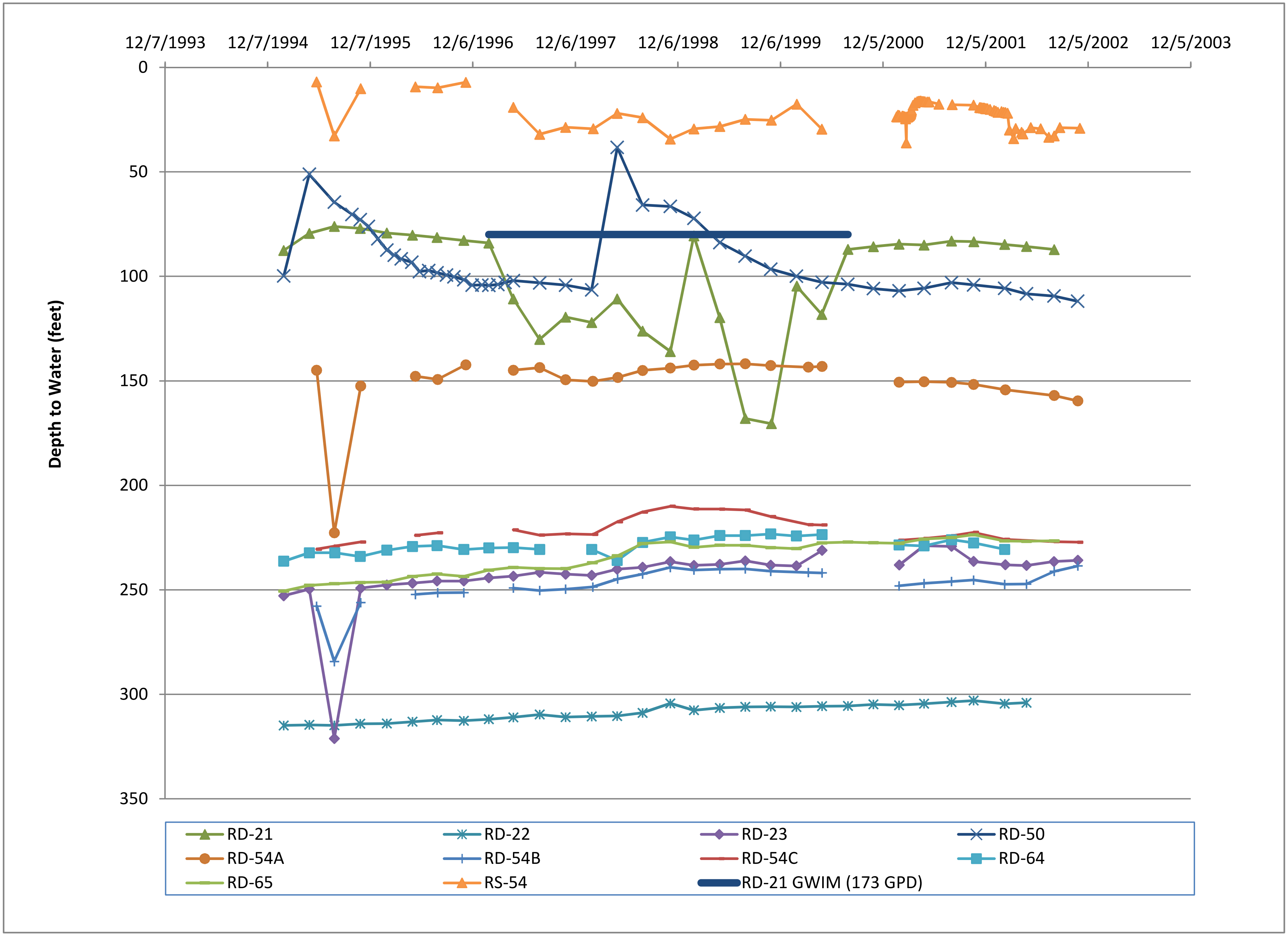

Figure 4-3

Drawdown During RD-21 GWIM

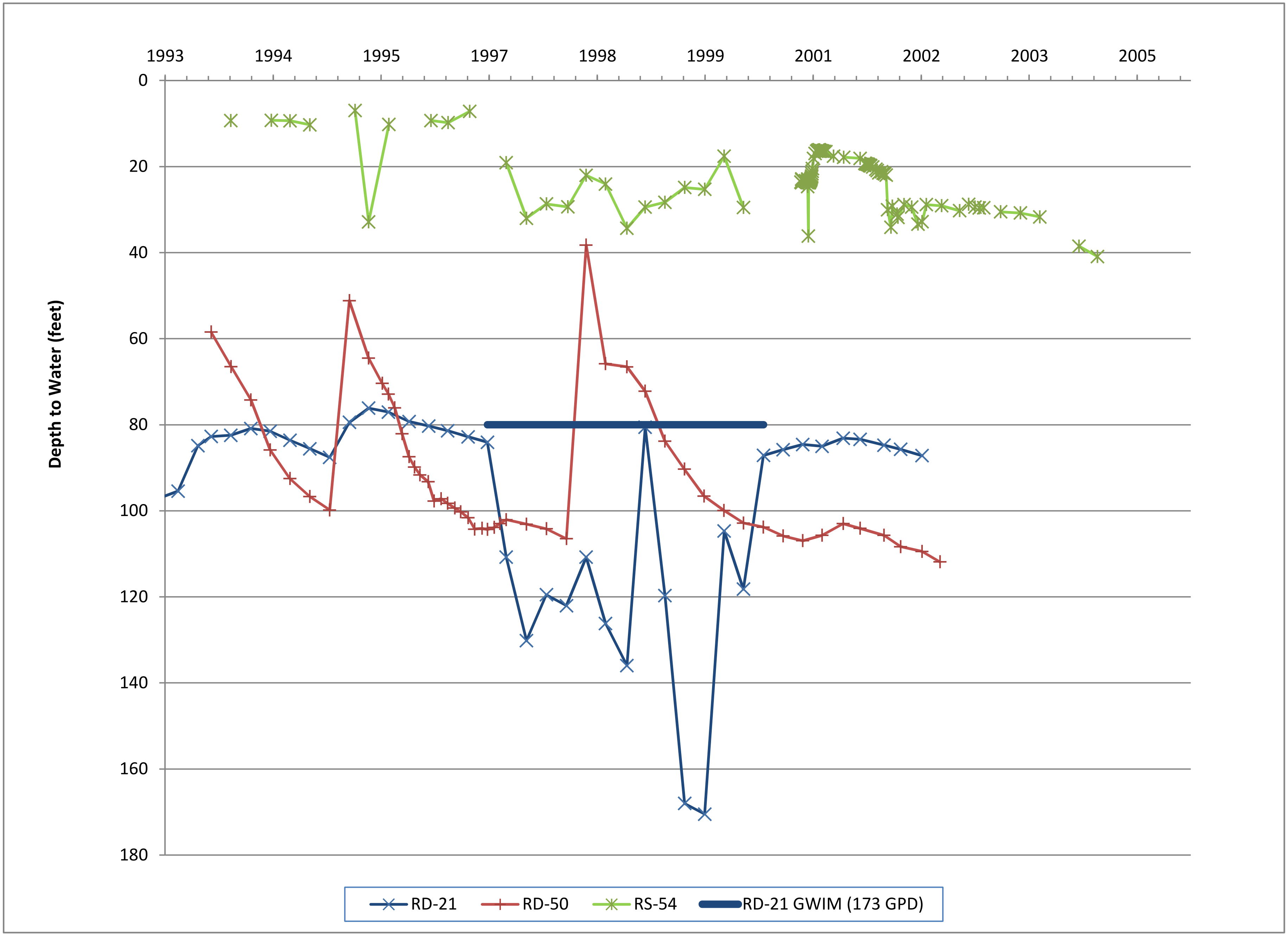

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Figure 4-4

RD-21 Pumping - RD-50 and RS-54 Drawdown

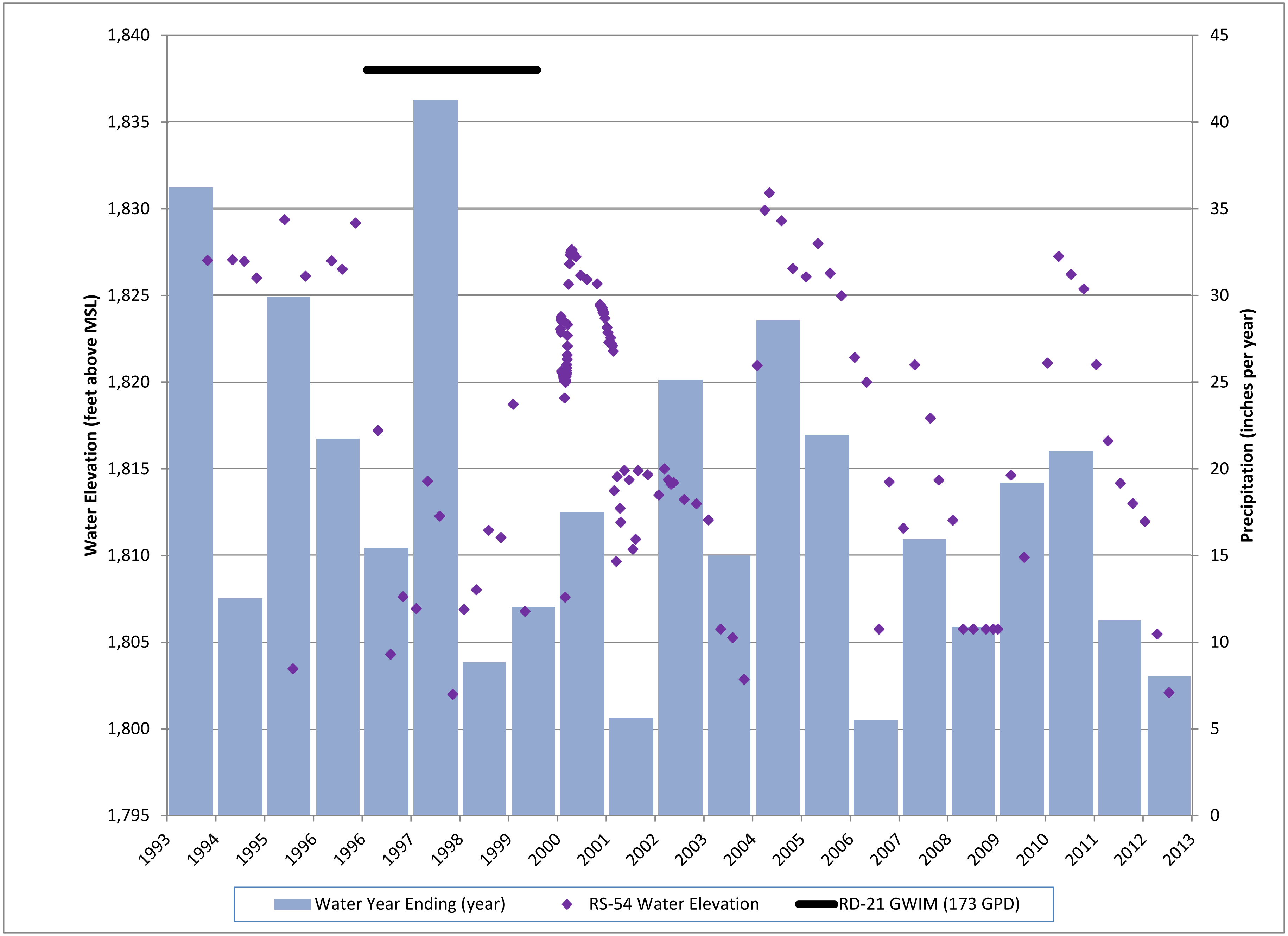

Figure 4-5

RS-54 Water Elevations and Annual Precipitation

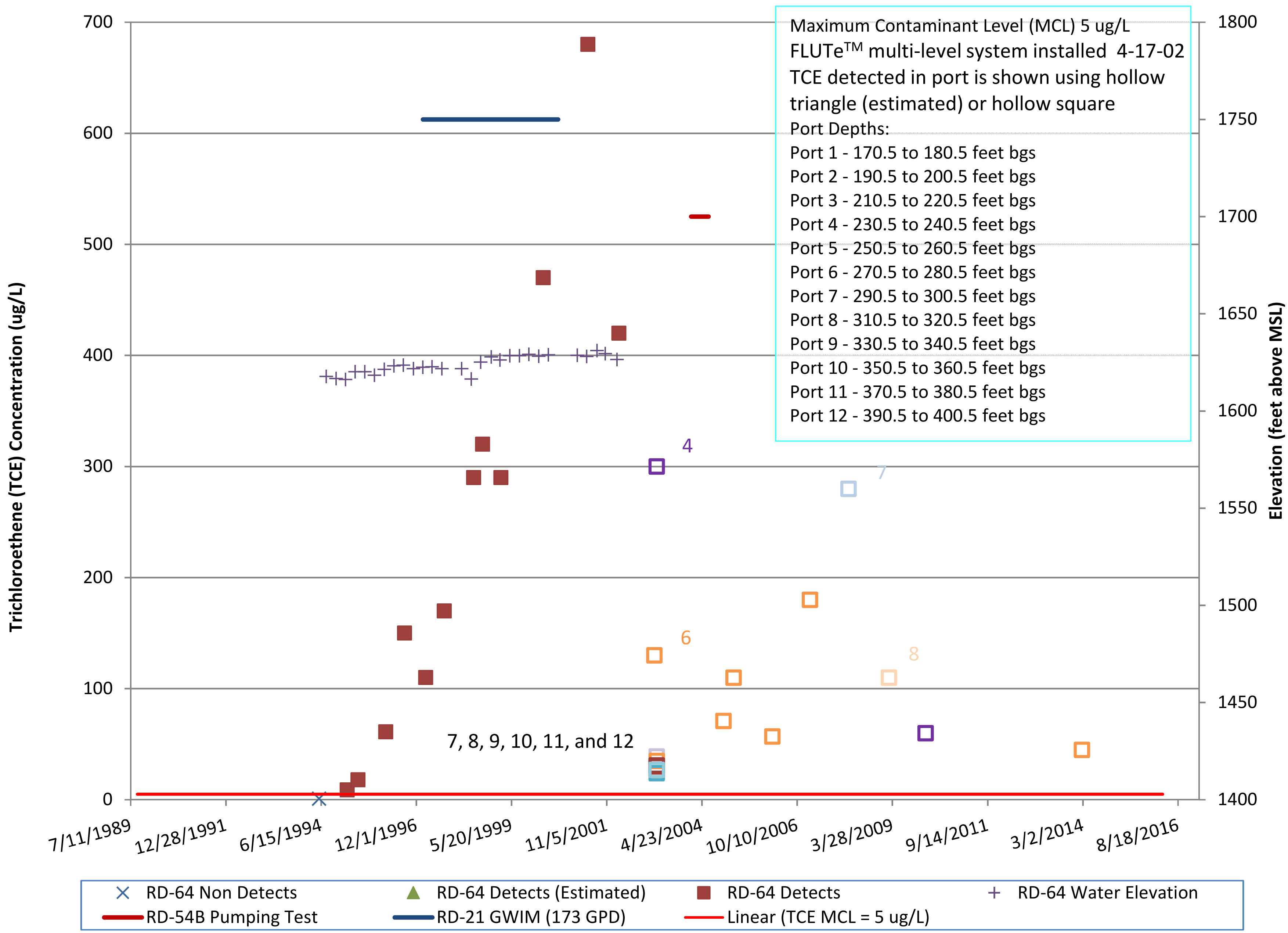

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Figure 4-6

TCE Concentrations in RD-64

Section 5

Well Construction Detail

Monitoring wells located at the FSDF and surrounding areas are presented in **Table 5-1** and shown on **Figure 2-1**. **Appendix A-A** contains lithologic logs for each monitoring well and **Appendix A-B** contains well completion logs.

Table 5-1. Well Construction Detail

Well	Depth	Screen/Open Borehole (ft. bgs)	Well Installation Date	FLUTe™ Installation Date	FLUTe™ Removal Date
C-8	400	65 - 400	May-02	2003*	--
PZ-097	44.5	33 - 43	Oct-01		
PZ-098	37.5	24 - 34	Oct-01		
PZ-099	Abandoned	Abandoned	Abandoned		
PZ-100	16.5	5.7 – 15.7	Oct-01		
PZ-101	27	10 - 20	Oct-01		
PZ-102	59.2	48.5 – 59.2	Oct-01		
RD-21	175	30 - 175	Aug-89	Jan-03	Jan-13
RD-22	440	30 - 440	Aug-89	Feb-03	--
RD-23	440	30 - 440	Aug-89	Jan-03	--
RD-33A	320	100 - 320	Sep-91	Jan-03	--
RD-33B	415	360 - 415	Sep-91		
RD-33C	520	480 - 520	Sep-91		
RD-50	195	18 - 195	May-93	Jan-03	--
RD-54A	278	119 - 278	Aug-93	Jan-03	Jan-13
RD-54B	437	379 - 437	Aug-93		
RD-54C	638	557 - 638	Jul-93		
RD-57	419	19.5 - 419	Feb-94	Sep-03	--
RD-64	398	19 - 398	May-94	Apr-02	--
RD-65	397	19 - 397	Aug-94	Oct-02	Feb-13
RD-91	140	20 - 140	Mar-04		
RS-18	13	7.5 - 13	Jun-85		
RS-23	13	8 - 13	Aug-88		
RS-54	38	7 - 38	Aug-93		

Notes:
* - Installation date of FLUTe™ system is unknown. Blank FLUTe™ liner is currently installed in C-8.
ft. – feet
ft bgs – feet below ground surface

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Section 6

Well Sampling History, Geology/Hydrogeology, Significance, and Recommendation

Although other contaminants have been detected at the FSDF, TCE and perchlorate are the focus of the GWIM and are discussed below. Other area contaminants of concern (COCs) that require treatment, such as semi-volatile organic compounds (SVOCs) and metals, are discussed in the GWIM Implementation Plan.

A data evaluation has been performed for each FSDF well of importance and presented in the *RCRA Facility Investigation Groundwater Work Plan – Area IV (Draft, June 2015)*. A summary of this evaluation for each well is provided below. **Figure 2-1** provides the monitoring well locations at the FSDF and surrounding area. **Table 5-1** provides well construction information.

6.1 Corehole C-8

C-8

C-8 is a 400-foot deep, 12.25-inch diameter borehole, cased from ground surface to 65 feet below ground surface (bgs). It offers the opportunity to observe shallower bedrock conditions as adjacent monitoring well RD-54A is cased off from the surface to 119 feet bgs. Because C-8 was cored within the TCE source area at the FSDF, it may be used in understanding the fracture network where TCE may be harbored.

In May 2002, porewater from rock core samples was collected from vadose and saturated bedrock zone during coring of C-8. **Figure 6-1** provides the porewater profile for TCE for C-8 and shows that most of the TCE mass was detected in the vadose zones (between 20 and 145 feet bgs) (MWH 2006). TCE was detected in three rock core samples collected in the saturated zone at about 188, 264, and 283 feet bgs. The TCE detections at the 188 and 283 foot depths were less than 10 micrograms per liter (µg/L), while the TCE detection at 264 feet bgs was greater than 100 µg/L.

Following collection of rock core samples and completion of the corehole, a FLUTe™ system was believed to be installed in January 2003. Groundwater samples were collected in February and March 2003.

Port information is provided from *Draft, Report of Results, Former Sodium Disposal Facility, Groundwater Characterization, Appendix A, Supporting Documentation on Groundwater* (MWH 2006). Groundwater TCE data are provided from Table C-6 for Volatile Organic Compound (VOC) Groundwater Results (MWH 2006) and *Report of Results, Former Sodium Disposal Facility, Groundwater Characterization, Appendix C, Nature and Extent of Chemicals in Environmental Media at the FSDF* (MHW 2006).

TCE and perchlorate concentrations reported for each C-8 FLUTe™ system port are shown below:

FLUTe™ Port	TCE	Perchlorate
Port 1 (88 - 95 feet, est.)	Not collected	Not collected
Port 2 (109 -119 feet, est.)	Not collected	Not collected
Port 3 (135 - 147 feet, est.)	Not collected	Not collected
Port 4 (160 – 170 feet, est.)	Not collected	Not collected
Port 5 (208 – 218 feet)	9.4 to 16 μg/L	0.8 U to 6.2 μg/L
Port 6 (230 – 237 feet)	11 to 18 μg/L	0.8 U to 1.6 J μg/L
Port 7 (260 – 270 feet)	14 to 23 μg/L	0.8U to 2.5 J μg/L
Port 8 (290 – 300 feet)	6.2 to 7.1 μg/L	0.8 U to 3.3 J μg/L
Port 9 (306 – 314 feet)	5.9 to 7.5 μg/L	0.8 to 5.8 μg/L
Port 10 (350 – 400 feet)	10 μg/L	2.4 J μg/L

Information describing when the FLUTe™ system was removed from C-8 is not readily available. However, C-8 is currently equipped with the Blank FLUTe™ liner. Since groundwater has not been sampled from C-8 since March 2003 and maintenance records of the Blank FLUTe™ liner is not available, the ability of the liner to prevent vertical migration of TCE along the corehole's length is uncertain. As C-8's porewater data indicates, a substantial mass of TCE exists between 20 and 145 feet bgs. Isolation of near-surface groundwater from the deeper Chatsworth Formation groundwater is clearly important and has been considered.

Isolation failure in C-8 is a concern for the following reasons: the conductor casing was not installed deep enough into the unweathered Chatsworth Formation to prevent TCE present from 65 to 145 from entering the corehole; the borehole remained open between completion of drilling and installation of the FLUTe™ system; and/or the failure of the Blank FLUTe™ liner to seal the open borehole between the conductor casing and bottom of the corehole.

C-8 has initially been selected as the extraction well for the FSDF GWIM

6.2 Chatsworth Formation Wells

This subsection presents a summary of the wells in the vicinity of the FSDF. These summaries were collected from the Groundwater Remedial Facility Investigation (RFI) (CDM Smith 2015). Additional details related to these wells can be found in the RFI.

RD-21

RD-21, open from 30 to 175 feet bgs, is located upgradient of the FSDF and near ESADA. It has been sampled multiple times, with and without the FLUTe™ system, which complicates interpretation of water quality data. Historic TCE concentrations reported for the open borehole and each RD-21 FLUTe™ system port are shown below:

FLUTe™ Port	TCE	Perchlorate
Pre-FLUTe (30 -175 feet)	89 to 2,900 µg/L	3.7 to 9 µg/L
Port 1 (85 - 95 feet)	Not collected	Not collected
Port 2 (105 -115 feet)	47 to 230 µg/L	9.7 µg/L
Port 3 (125 - 135 feet)	52 to 69 µg/L	9.8 µg/L
Port 4 (145 -155 feet)	54 to 340 µg/L	11 µg/L
Port 5 (165 - 175 feet)	56 µg/L	12 µg/L
Post-FLUTe (30 - 175 feet)	51 to 140 µg/L	4.1 to 6.2 µg/L

Figure 4-2 illustrates TCE concentrations and water elevations measured in the open borehole and with the FLUTe™ system installed over time.

TCE data suggest that Ports 2 through 5 have been impacted by TCE (85 through 175 feet bgs). Perchlorate data suggest that Ports 4 (145 to 155 feet) and 5 (165 to 175 feet) are in communication with fractures and bedding planes that transmit perchlorate to a greater degree than shallower Ports 2 (105 to 115 feet) and 3 (125 to 135 feet).

Groundwater extraction was performed at FSDF between January 1997 and 2000 using RD-21. The groundwater extraction rate from RD-21 averaged about 173 gpd (0.12 gpm). From previous investigations, the following observations and conclusions from the groundwater extraction interim measure include:

- TCE concentrations declined during the pumping (**Figure 4-2**)
- Relatively large and rapid water level response indicates that there is a small storage capacity in the bedrock
- Gradual decline in water levels after a recharge event indicates low to moderate bulk permeability of the bedrock (water slowly infiltrates into the bedrock)
- TCE was removed from fractures and bedding planes
- Fractures/bedding planes containing TCE may not be in communication with the well when water levels are lowered
- Following the groundwater pumping and prior to FLUTe™ system installation, TCE was detected at lower concentrations indicating that it may have been effectively removed from the fractures and bedding planes
- A slight TCE rebound appears following the aquifer pumping as a result of fractures and bedding planes now being in communication with wells that were not in contact with open borehole during the pumping of the well or diffusion from the matrix into fractures

RD-21 monitors water near ESADA and based on operational history there may be a separate TCE source associated with the ESADA facility. However, due to groundwater flow and pumping at RD-21, separating the ESADA and FSDF groundwater impacts may not be discernable.

RD-22

RD-22 is a 440-foot deep bedrock monitoring well located lateral and downgradient from the FSDF and ESADA. TCE has not been detected at RD-22 either prior to installation of the FLUTe™ system or during sampling of the FLUTe™ ports. RD-22 does not appear to be affected by releases of TCE at the FSDF. It should be noted that MWH reported that the RD-22 FLUTe™ system ruptured during or shortly after installation. The FLUTe™ system remains in this well.

Perchlorate was detected in samples collected from RD-22 in February 2003 from three FLUTe™ system ports:

FLUTe™ Port	TCE	Perchlorate
Pre-FLUTe (30 – 440 feet)	Non-detect	Non-detect
Port 1 (310 to 320 feet)	Sample not collected	Sample not collected
Port 2 (330 to 340 feet)	Non-detect	Non-detect (0.8 μg/L)
Port 3 (350 to 360 feet)	Non-detect	17 μg/L
Port 4 (370 to 380 feet)	Non-detect	6.7 μg/L
Port 5 (390 to 400 feet)	Non-detect	2.9 μg/L
Port 6 (410 to 420 feet)	Non-detect	Non-detect (0.8 μg/L DL)
Port 7 (430 to 440 feet)	Non-detect	Non-detect (0.8 μg/L DL)

Perchlorate data indicated that fractures and bedding planes that contain perchlorate are in communication with the well between 350 and 400 feet. Perchlorate was not detected in samples collected from Port 2 in January 2013, or port 1 in July 2013 and February 2014.

It is presumed that RD-22 was installed to define the vertical and horizontal extent of TCE contamination emanating from the ESADA and FSDF. Based on the simplistic model above and knowing the RD-22 is in communication with wells located at the FSDF, RD-22 is located appropriately and the open interval is of sufficient length to monitor TCE at depth. RD-22 SCM conclusions are:

- RD-22 is used to define the vertical and western horizontal extent of the TCE plume
- RD-22 is in communication with other wells at the FSDF as shown by the perchlorate results
- TCE is not present

RD-23

RD-23 is a 440-foot deep bedrock monitoring well located downgradient from the FSDF. Historic TCE concentrations reported for the open borehole and each RD-23 FLUTe™ system port are shown below:

FLUTe™ Port	TCE	Perchlorate
Pre-FLUTe™ (30 to 440 feet)	38 to 610 µg/L	Non-detect
Port 1 (231 to 241 feet)	26 to 48 µg/L	Non-detect
Port 2 (251 to 261 feet)	29 to 410 µg/L	Non-detect
Port 3 (271 to 281 feet)	28 to 630 µg/L	Non-detect
Port 4 (291 to 301 feet)	Sample not collected	Non-detect
Port 5 (311 to 321 feet)	29 µg/L	3.8 J µg/L
Port 6 (331 to 341 feet)	28 µg/L	Non-detect
Port 7 (351 to 361 feet)	37 µg/L	Non-detect
Port 8 (371 to 381 feet)	18 µg/L	Non-detect
Port 9 (391 to 396.5 feet)	58 µg/L	Non-detect

TCE concentrations detected in RD-23 are variable depending on depth of sample. As shown in **Figure 6-2,** TCE concentrations have generally been increasing since installation of the FLUTe™ system with the highest concentration being 630 µg/L in Port 3 in 2009. Most recently (February 2014) the highest concentration was 160 µg/L (in Port 3). It should be noted that FLUTe™ system Ports 2 and 3 have been the only ports sampled since 2004 and generally reflect the scatter of data points collected prior to the installation of the FLUTe™ system. Because the FLUTe™ system is still present in RD-23, it is unknown what the TCE concentrations would be if collected from an open borehole. MWH (2006a) reported that the RD-23 FLUTe™ system ruptured during the pumping of RD-54B.

Of interest in RD-23 is a marked increase in TCE concentrations between September 1992 (78 µg/L) and March 1993 (540 µg/L) and the highest open borehole TCE detection in the well occurring in February 2000 at a concentration of 610 µg/L (**Figure 6-2**). Water elevations remained relatively stable over the TCE sampling period. In review of previous data, TCE concentrations fluctuated, generally mirroring annual precipitation prior to FLUTe installation. The highest TCE concentration was detected following the highest annual precipitation year. This was followed by decreasing TCE concentrations with decreasing annual precipitation (1993, 1994, 1995, 1996, and 1997). In 1998 an above average precipitation year occurred with a corresponding increase in TCE concentrations, albeit delayed. TCE concentrations in 2001 and 2002 appear to correspond to TCE concentrations detected in 1997 during a similar annual water year. RD-23 water level fluctuations in response to precipitation events are minimal and may be explained by the presence of siltstone (9 to 30 feet bgs) and shale (210 to 225 feet bgs) or higher storage capacity for the bedrock in this area.

An alternative explanation for higher TCE concentrations detected in the open borehole versus the TCE concentrations detected in the FLUTe™ system ports immediately after FLUTe™ installation is that the FLUTe™ sealed the open borehole between the conductor casing (set from

0 to 30 feet bgs) and the first FLUTe™ port. If TCE is present in this interval, the FLUTe™ system prevented TCE from entering the well from this zone.

Lithologic information and the hydraulic relationship to surrounding wells suggest that this well is a candidate for groundwater extraction during the proposed FSDF GWIM. Groundwater levels and TCE concentrations suggest that the optimal extraction zone is above 280 feet bgs; therefore, the borehole below 280 feet bgs should be sealed (with packers) before extraction is initiated.

The following assumptions pertain to RD-23 SCM:

- RD-23 is in communication with other wells at the FSDF (RD-54B pumping test)
- RD-23 water levels do not directly respond to increased annual precipitation
- TCE increases with increased annual precipitation prior to FLUTe installation
- RD-23 may intercept fractures and bedding planes that contained higher TCE concentrations and flow into the well during higher precipitation years

RD-33A

RD-33A is a 320-foot deep bedrock well, cased and sealed from the surface to 100 feet bgs. This well is an important point in the well network as it monitors the vertical and horizontal extent of TCE contamination to the west of the FSDF. Historic TCE concentrations reported for the open borehole and in each RD-33A FLUTe™ system port are shown below:

FLUTe™ Port	TCE	Perchlorate
Pre-FLUTe™ (100 to 320 feet)	2.4 to 14 µg/L	Non-detect
Port 1 (211 to 221 feet)	Non-detect (0.26 µg/L)	Non-detect
Port 2 (231 to 241 feet)	0.1 to 0.44 µg/L	Non-detect
Port 3 (251 to 261 feet)	0.16 to 0.28 µg/L	1.2 to 3.8 µg/L
Port 4 (271 to 281 feet)	0.23 to 0.66 µg/L	Non-detect
Port 5 (291 to 301 feet)	0.9 µg/L	Non-detect
Port 6 (311 to 321 feet)	Non-detect (0.26 µg/L)	Non-detect

TCE concentrations prior to FLUTe™ system installation in 2003 ranged between 2.4 µg/L and 14 µg/L (**Figure 6-3**). Following installation of the FLUTe™ system on January 9, 2003, the TCE concentrations were reported below 0.9 µg/L. The decrease in TCE concentrations is believed to be a result of FLUTe™ system sampling and the post-2003 results may not characterize the extent of TCE concentrations migrating into well RD-33A. TCE concentrations were below the laboratory reporting limit in the February 2014 sample.

The following information pertains to RD-33A SCM:

- Relatively large and rapid water level response indicates that there is a small storage capacity in the bedrock (less response than most)
- Gradual decline in water levels after recharge event indicates low to moderate bulk permeability of the bedrock (water slowly infiltrates into the bedrock)
- TCE was detected in RD-33A prior to FLUTe™ system sampling
- RD-33A is in communication with the FSDF and/or ESADA TCE plume
- The FLUTe™ system ports are not placed to monitor fractures and bedding planes that are transporting TCE from the FSDF to the well

RD-33B

RD-33B is a 415-foot deep bedrock well, cased and sealed from the surface to 360 feet bgs, and open to 415 feet. The borehole was advanced to a total depth of 678 feet bgs and then cemented back to 415 feet bgs during well completion. It does not have a FLUTe™ system. TCE has been reported in RD-33B twice; at a concentration of 0.76 µg/L in December 1991 and at a concentration of 0.18 µg/L in August 2002. These TCE detections are close to the detection limit and are not believed to represent an impact of TCE in the deeper groundwater monitored by this well. TCE was not detected in RD-33B during the 1st quarter 2015 sampling event.

Perchlorate has been sampled for eight times and was not detected.

The following information comprises the SCM for RD-33B:

- Relatively large and rapid water level response indicates that there is a small storage capacity in the bedrock compared to the other wells
- Gradual decline in water levels after recharge events indicates low to moderate bulk permeability of the bedrock (water slowly infiltrates into the bedrock)
- TCE is not present at RD-33B
- RD-33B defines the vertical extent of TCE northwest of the FSDF and ESADA
- TCE migrates in fractures (pathways) above 360 feet (1,433 feet msl) based on RD-33A data

RD-33C

RD-33C is a 520-foot deep well, cased and sealed from the surface to 480 feet bgs and open to 520 feet. TCE and perchlorate have never been detected in RD-33C.

Depth of the borehole is sufficient to detect TCE in this lower zone.

The following information comprises the SCM using data collected from RD-33C:

- Relatively large and rapid water level response indicates that there is a small storage capacity in the bedrock (less response than most)
- Gradual decline in water levels after recharge events indicates low to moderate bulk permeability of the bedrock (water slowly infiltrates into the bedrock)
- TCE has not been detected in RD-33C

RD-50

RD-50 is a 195-foot deep bedrock well that is located upgradient of the FSDF (and upgradient of ESADA). It may be installed within the Santa Susana Formation. TCE has been reported 11 times for the well, with the highest detection at 2.2 µg/L collected from FLUTe™ system port 5 in February 2003. However, TCE has not been detected above the maximum contaminant level (MCL) in this well since sampling commenced in 1993. TCE concentrations detected in the open borehole and in each RD-50 ports are shown below:

FLUTe™ Port	TCE	Perchlorate
Pre-FLUTe™ (18.5 to 195 feet)	0.61 µg/L	Not collected
Port 1 (106 to 116 feet)	Not collected	0.41 to 1.8 J µg/L
Port 2 (126 to 136 feet)	0.1 to 0.68 µg/L	Not collected
Port 3 (146 to 156 feet)	0.69 µg/L	Not collected
Port 4 (166 to 176 feet)	1.5 µg/L	Not collected
Port 5 (186 to 195.3 feet)	2.2 µg/L	Not collected

The following information comprises the SCM for RD-50:

- TCE detected in RD-50 from 2003 through 2009 are slightly above detection limit
- TCE concentrations will not increase following removal of the RD-50 FLUTe™ system and commencement of open borehole sampling
- This well did not respond to RD-21 or RD-54B pumping
- RD-50 relationship with the Burro Flats fault is not known
- The TCE impacted groundwater at the ESADA is bounded on the south by the Burro Flats fault

RD-54A

RD-54A is a 278-foot deep bedrock well. It is cased and sealed from the surface to 119 feet bgs. Historic TCE concentrations reported for samples collected from the open borehole and from each RD-54A port are shown below:

FLUTe™ Port	TCE	Perchlorate
Pre-FLUTe™ (119 to 278 feet)	66 to 580 µg/L	6 to 18 µg/L
Port 1 (150.5 to 160.5 feet)	Sample not collected	Non-detect (0.28 µg/L)
Port 2 (170.5 to 180.5 feet)	2.1 to 73 µg/L	Non-detect (0.8 µg/L)
Port 3 (190.5 to 200.5 feet)	6.9 µg/L	56 µg/L
Port 4 (210.5 to 220.5 feet)	9.5 µg/L	35 µg/L
Port 5 (230.5 to 240.5 feet)	9.2 µg/L	27 µg/L
Port 6 (250.5 to 260.5 feet)	6.7 µg/L	24 µg/L
Port 7 (270.5 to 278 feet)	5.1 µg/L	Non-detect (0.8 µg/L)
Post-FLUTe™ (119 to 278 feet)	1.3 to 2.4 µg/L	0.12 J µg/L

The FLUTe™ system was installed in January 2003 and TCE concentrations exhibited a marked decrease compared to pre-FLUTe™ conditions; however, the shallowest interval (port) was not sampled. The well has been sampled twice since the FLUTe™ system was removed in January 2013. TCE concentrations were 1.3 µg/L in January 2013 and 2.3 µg/L in February 2014. TCE was detected in RD-54A during the 1st quarter 2015 sampling event at 2.4 µg/L.

RD-54A has an unusual TCE-time profile (**Figure 4-1**). In general, following a very wet 1993 water year, TCE concentrations were reported between 70 µg/L and 200 µg/L. An increase in TCE concentrations corresponded with decreased annual precipitation over a 4-year period (1996, 1997, 1998, and 1999). Annual precipitation increased in 2000 and 2001 while TCE concentrations decreased.

Similar to RD-23, an explanation for higher TCE concentrations detected in the open borehole versus the TCE concentrations detected in the FLUTe™ system ports may be the result of the FLUTe™ acting as a seal between the conductor casing (set from 0 to 119 feet bgs) and the first FLUTe™ port. If TCE is present in this interval, the FLUTe™ system prevented TCE from entering the well from this zone and migrated down the well bore due to the observed downward hydraulic gradient.

From the perchlorate data it can be concluded that fractures and bedding planes that contain perchlorate are in communication with the well between 190.5 and 260.5 feet. Perchlorate was not detected in the open borehole in groundwater samples collected February 2013 and 2014. Perchlorate was detected in RD-54A during the 1st quarter 2015 sampling event at 0.12 J µg/L.

RD-54A is located in the center of the FSDF and TCE has been detected along its total depth. RD-54B and RD-54C at this location define the vertical extent of TCE contamination at the location.

RD-54A water level fluctuations in response to precipitation events are considered minimal and may be explained by the presence of claystone (12 to 14 feet bgs) and sandstone - clayey (75 to 90 feet bgs) or higher storage capacity for the bedrock in this area.

The following information comprises the SCM for RD-54A:

- RD-54A is in communication with other wells at the FSDF based on RD-54B pumping test
- RD-54A water levels do not significantly respond to increased or decreased annual precipitation
- TCE increased with decreased annual precipitation; a relationship that is the reverse of that observed in RD-23; this may be due to the depth of the open borehole at RD-54A
- TCE concentrations have decreased two orders of magnitude in the groundwater contained in the fractures and bedding planes that conduct groundwater into RD-54A

RD-54B

RD-54B is a 437-foot deep well at the RD-54 cluster. RD-54B is cased and sealed from the surface to 379 feet bgs, and then open to 437 feet. TCE has been reported four times in RD-54B at concentrations between 1 µg/L and 9.9 µg/L (in 1993 and 2002, respectively). TCE has not routinely been detected in this well and was not detected in February 2014. Perchlorate has been sampled for five times and has not been detected.

RD-54B is located within the FSDF and defines the vertical extent of TCE contamination. RD-54B water level fluctuations in response to precipitation events are considered minimal and may be explained by the presence of siltstone (158 to 164 feet bgs) and sandstone - clayey (384 to 394 feet bgs) or higher storage capacity for the bedrock in this area.

The following information comprises the SCM for RD-54B:

- TCE has not been detected in RD-54B since 2002
- RD-54B is in communication with C-8, RD-22, RD-23, RD-54A, RD-64, and RD-65
- RD-54B currently defines the vertical extent of TCE concentrations above the MCL at the FSDF
- TCE migrates in fractures (pathways) above 379 feet (1,463 feet MSL)

RD-54C

The available well completion information for RD-54C is conflicting. The RD-54C boring log shows a total depth of the borehole as 620 feet bgs. The schematic diagram of monitoring well RD-54C shows a total depth of 520 feet bgs and the database shows a total depth of 638 feet bgs. It is unknown if the borehole was advanced to 638 feet bgs and then cemented to a shallower depth as was done in other boreholes at SSFL. RD-54C is cased and sealed from the surface to 557 feet bgs.

TCE has been detected in RD-54C seven times with a maximum concentration of 1.1 µg/L in a 2006 sample. TCE has not been detected above laboratory reporting limits since 2006, including a sample collected in February 2014. Perchlorate has been sampled for five times and was not detected in this well.

RD-54C is located within the TCE plume and defines the vertical extent of TCE contamination.

RD-54C water level fluctuations in response to precipitation events are considered minimal and may be explained by the presence of claystone (20 to 21 feet bgs) and clayey sandstone (218 to 234 feet bgs) or higher storage capacity for the bedrock in this area.

The following information comprises the SCM for RD-54C:

- TCE has not been detected in RD-54C since 2006
- RD-54C does not appear to be in communication with RD-54A; however, based on the historic presence of TCE in the well it is assumed to be in communication with the upper groundwater zones
- RD-54C confirms the vertical extent of TCE concentrations above the MCL at FSDF with complementary data from RD-54B
- TCE present at lower zones has been diluted since 2006 and is not present above DLs in 2014

RD-57

RD-57 is a 419-foot deep bedrock well located in the Northern Buffer Zone downgradient of the FSDF. RD-57 is cased and sealed between 0 and 19.5 feet bgs, and is an open borehole from 19.5 to 419 feet. TCE was reported in RD-57 once in 2000, at a concentration of 1.9 µg/L. TCE has not been reported above its detection limit since 2000, including the sample collected in February 2014. A FLUTe™ system was installed in September 2003 and has not been removed. It does not appear that the FLUTe™ system sampling has biased reported TCE concentrations in this well. However, the open borehole is quite long (from 19.5 to 419 feet bgs) and TCE impacted water, if present in fractures located above the FLUTe™ (the 228 to 238-foot interval), may not have been sampled. Selected interval sampling may be necessary to confirm that TCE has not impacted shallower zones at this location.

Perchlorate has been sampled from the open borehole and the FLUTe™ system ports and has not been detected above laboratory detection limits.

RD-57 water level fluctuations in response to precipitation events are minimal and may be explained by the presence of clayey sandstone (204 to 206 and 236 to 240 feet bgs) or higher storage capacity for the bedrock in this area.

The following information comprises the SCM using data collected from RD-57:

- TCE has not been detected in RD-57 since 2000
- RD-57 defines the horizontal and vertical extent of TCE north of the FSDF

- TCE may be present in fractures above the FLUTe™ sampling ports selected interval sampling may be required to adequately monitor for TCE in groundwater in this area

RD-64

RD-64 is a 398-foot deep bedrock well installed immediately west and lateral (downgradient) of the FSDF. Historic TCE concentrations reported for the open borehole and in each RD-64 port is shown below:

FLUTe™ Port	TCE	Perchlorate
Pre-FLUTe™ (20 to 400.50 feet)	8.9 to 680 µg/L	Non-detect
Port 1 (170.5 to 180.5 feet)	Not collected	Not collected
Port 2 (190.5 to 200.5 feet)	Not collected	Not collected
Port 3 (210.5 to 220.5 feet)	Not collected	Not collected
Port 4 (230.5 to 240.5 feet)	60 to 300 µg/L	Non-detect (0.8 µg/L)
Port 5 (250.5 to 260.5 feet)	Not collected	Not collected
Port 6 (270.5 to 280.5 feet)	35 to 180 µg/L	Non-detect (0.8 µg/L)
Port 7 (290.5 to 300.5 feet)	27 to 280 µg/L	Non-detect (0.8 µg/L)
Port 8 (310.5 to 320.5 feet)	30 to 110 µg/L	Non-detect (0.8 µg/L)
Port 9 (330.5 to 340.5 feet)	27 µg/L	Non-detect (0.8 µg/L)
Port 10 (350.5 to 360.5 feet)	39 µg/L	Non-detect (0.8 µg/L)
Port 11 (370.5 to 380.5 feet)	31 µg/L	Non-detect (0.8 µg/L)
Port 12 (390.5 to 400.5 feet)	24 µg/L	Non-detect (0.8 µg/L)

RD-64 has an unusual and somewhat uncharacteristic TCE time trend versus other wells at the FSDF. TCE concentrations rose relatively quickly from February 1995 to the highest TCE concentration of 680 µg/L reported for May 2001 (**Figure 4-6**). This is approximately 7 months following the completion of the RD-21 aquifer pumping test. Following installation of the FLUTe™ system in April 2002, TCE concentrations in the FLUTe™ ports range between 24 µg/L and 300 µg/L. Because the FLUTe™ system remains in the well it is unclear if sampling an open borehole will result in higher TCE concentrations (as seen in RD-07; see Section 4.4). MWH (2006a) reported that the RD-64 FLUTe™ system ruptured during or shortly after installation.

After review of annual precipitation data, a correlation between TCE concentration and annual precipitation is not evident.

Possible explanations for this unusual TCE trend are:

- TCE was introduced to lower zones as a result of drilling (pathway from upper zones to lower zones via well core hole, a poor seal, and/or conductor casing not extending entirely through the weathered Chatsworth Formation)

- The TCE source area was removed resulting in no TCE-impacted water moving down into the groundwater system decreasing TCE concentrations after May 2001

- The TCE plume moved across this well via natural groundwater gradient and movement

- Groundwater and TCE were influenced by pumping of RD-21 (or RS-54)
- This is the amount of time for the TCE chemical gradient to occur across the length of the open borehole (20 to 230 feet)TCE was introduced to lower zones via surrounding wells
- Failure of the FLUTe™ system and isolation zone seals allowed TCE migration to deeper zones

RD-64 water level fluctuations in response to precipitation events are considered minimal and may be explained by the presence of low-permeability sediments, not identified in the boring log, between the well screen and ground surface, or higher storage capacity of the bedrock in this area.

Lithologic information and the hydraulic connection to surrounding wells suggest that the well is a candidate for groundwater extraction during the GWIM. Groundwater levels and TCE concentrations suggest that the optimal extraction zone is above 230 feet bgs.

The following comprises the SCM for RD-64:

- RD-64 is in communication with other wells at the FSDF based on the RD-54B pumping test results
- RD-64 water levels do not significantly respond to increased or decreased annual precipitation
- TCE concentration trends do not correlate with annual precipitation changes
- TCE may be present in fractures above the FLUTe™ system ports; open borehole or selected interval sampling may be required to detect TCE present in groundwater in this area
- TCE diffusion (chemical gradient) from the rock matrix is the most likely source into groundwater
- Fractures and bedding planes that contained higher TCE concentrations are not connected to water sampled in RD-64 due to the FLUTe™ system

RD-65

RD-65 is a 397-foot deep bedrock well installed downslope of the FSDF and RD-23. The borehole is cased and sealed from the surface to 19 feet bgs. Historic TCE concentrations detected in the open borehole and in each RD-65 port are provided below:

FLUTe™ Port	TCE	Perchlorate
Pre-FLUTe™ (19 to 397 feet)	360 to 960 µg/L	Non-detect (4 µg/L)
Port 1 (167 to 177 feet)	Not collected	Not collected
Port 2 (187 to 197 feet)	Not collected	Not collected
Port 3 (207 to 217 feet)	Not collected	Not collected
Port 4 (227 to 237 feet)	11 to 58 µg/L	Not collected
Port 5 (247 to 257 feet)	8.4 to 220 µg/L	6.2 µg/L
Port 6 (267 to 277 feet)	3.8 to 130 µg/L	Non-detect (0.8 µg/L)
Port 7 (287 to 297 feet)	9.6 µg/L	Non-detect (0.8 µg/L)
Port 8 (307 to 317 feet)	4.6 µg/L	1.6 µg/L
Port 9 (327 to 337 feet)	7.8 µg/L	1.8 µg/L
Port 10 (347 to 357 feet)	5.8 µg/L	2.7 µg/L
Port 11 (367 to 377 feet)	7.9 µg/L	3.8 µg/L
Port 12 (387 to 397 feet)	Not collected	Non-detect (0.8 µg/L)
Post-FLUTe™ (19 to 397 feet)	5 to 68 µg/L	Non-detect (0.0088 µg/L)

RD-65 had a concentration of 69 µg/L TCE in the February 2014 sample. TCE was detected in RD-65 during the 1st quarter 2015 sampling event at 18 µg/L.

Figure 6-4 shows TCE concentrations in RD-65. TCE concentrations generally remain stable from well installation in 1995 through 2002, which includes the period of pumping of RD-21. There was a decrease in TCE concentrations following installation of the FLUTe™ system. Prior to FLUTe™ installation, chlorinated ethene concentrations may have shown dechlorination trends. Following installation of the FLUTe™ system and selected port sampling, TCE was detected at well below previous TCE concentrations from samples collected from the open borehole. *Cis*-1,2-dichloroethene (*cis-1,2*-DCE) and *trans*-1,2-dichlorethene (*trans*-1,2-DCE) were also detected in this well. The FLUTe™ system was removed in February 2013 and samples collected from the open borehole contained slightly higher concentrations of TCE compared to *cis*-1,2-DCE. TCE concentrations in samples from the open borehole were comparable to TCE concentrations detected from the FLUTe™ system since 2006. It is believed that dechlorination is occurring in RD-65.

From the perchlorate data it can be concluded that fractures and bedding planes that contain perchlorate are in communication with the well at 247 to 257 feet and 307 to 377 feet. Perchlorate was not detected in samples collected from the open borehole in February of 2014 or 2015.

RD-65 water level fluctuation in response to precipitation events are considered minimal and may be explained by the presence of low-permeability sandstones with mudstone between well screen and ground surface at 171 to 172 and 207 to 208 feet bgs or higher storage capacity for the bedrock in this area.

The following information comprises the SCM for RD-65:

- RD-65 is in communication with other wells at the FSDF based on RD-54B pumping test
- RD-65 water levels do not significantly respond to increased or decreased annual precipitation
- No TCE trend and annual precipitation changes are apparent
- TCE may be present in fractures above the FLUTe™ system ports and open borehole or selected interval sampling may be required to detect TCE present in groundwater at this elevation
- Groundwater with relatively higher concentrations of TCE is no longer present in fractures and bedding planes sampled in RD-65

RD-91

RD-91 is a 140-foot deep bedrock well installed at adjacent to Building 4100. The borehole is cased and sealed from the surface to 20-feet bgs. Bedrock groundwater is impacted by TCE. Groundwater samples from this well exhibited 270 µg/L TCE in a sample collected prior to 2010 and 200 µg/L in the sample collected in February 2014. RD-91 is not believed to be affected by activities occurring at the FSDF. However, the well is expected to be included in the GWIM monitoring program.

6.3 Near-Surface Groundwater Monitoring Wells and Piezometers

With the exception of RS-54, no near-surface groundwater monitoring wells or piezometers will be used for extraction of groundwater during this GWIM. Although RS-54 is typically dry, if water becomes available for pumping as a result of natural precipitation or reinjection of treated groundwater in the FSDF area, RS-54 will be pumped and groundwater treated in the GWIM treatment system.

A brief summary of near-surface monitoring wells and piezometers is provided below. Relevant information provided includes location of the monitoring point in comparison to the FSDF; TCE and perchlorate concentrations detected in groundwater; and likelihood that the monitoring point intercepts near-surface water (i.e., typically dry). This information was used in developing the ATP monitoring well network and field activities.

PZ-097

PZ-097, located downgradient of the FSDF, has always been dry and does not provide water quality data.

PZ-098

PZ-098 (37.5 feet deep) was sampled once in April 2003; the TCE concentration was 29 µg/L. It is typically dry. Since PZ-098 is downgradient of both the FSDF and Building 4100, it is not known whether the detection of TCE is a result of a release from either or both facilities. PZ-098 is too shallow to be an effective monitoring point for bedrock water quality; it is typically either dry or contains insufficient water to sample. TCE and perchlorate were detected in PZ-098 during the 1st quarter 2015 sampling event at 1.8 and 0.56 µg/L, respectively.

DOE has proposed to install a deeper monitoring well capable of collecting near-surface and Chatsworth Formation groundwater near PZ-098. This new monitoring well designated at DD-XXX will be included in the GWIM monitoring well network if available during the aquifer testing.

PZ-100

PZ-100, potentially lateral and upgradient of the FSDF and downgradient of ESADA, was sampled twice prior to 2011; TCE was not detected for either event. PZ-100 (16.5 feet deep) has been typically dry and is not a reliable monitoring point. Bedrock well RD-21, located downgradient of ESADA and adjacent to PZ-100, exhibits TCE concentrations exceeding 100 µg/L. Packer testing of RD-21 may provide shallow groundwater data in lieu of a point at PZ-100.

PZ-101

Like the other shallow wells at the FSDF, PZ-101 is typically dry. Packer testing of RD-21 may provide shallow groundwater data for the PZ-101 location.

PZ-102

Although PZ-102 is typically dry, when water is present it is found about 20 feet higher than Chatsworth Formation well, RD-91, indicating a perched condition. PZ-102 was only sampled one time in April 2003 and TCE was reported at a concentration of 6 µg/L. PZ-102 may provide groundwater data between the FSDF and Building 4100/4009.

RS-18

RS-18 is located north-northeast of the FSDF and within the central mass of the TCE plume (screened from 7.5 to 13 feet bgs). The well was dry in 2014 but has shown groundwater is present during its water gauging history. RS-18 is a 13-foot monitoring point. Prior to the GWIM (RD-21 pumping), TCE concentrations ranged between 19 µg/L to 3,200 µg/L with a great deal of fluctuation in the TCE data (**Figure 6-5**). During the GWIM, TCE was detected between 270 µg/L and 1,300 µg/L. TCE was detected between 2 µg/L and 890 µg/L following the GWIM. TCE was most recently detected in RS-18 during the 1st quarter 2015 sampling event at 1.8 µg/L.

RS-54

RS-54 was installed within the boundaries of the FSDF ponds adjacent to deep cluster well RD-54A, 54B, and 54C. RS-54 (38 feet deep, screen from 7 to 38 feet bgs) has typically been dry, although a TCE concentration of 1,600 µg/L was reported for 2013 (**Figure 6-6**). RS-54 was used during the previous Interim Measures – Groundwater Extraction System at the FSDF activities (1995-2004) and therefore is identified as a pumping well for the FSDF GWIM, but obviously cannot serve in the capacity of a continuously pumped well.

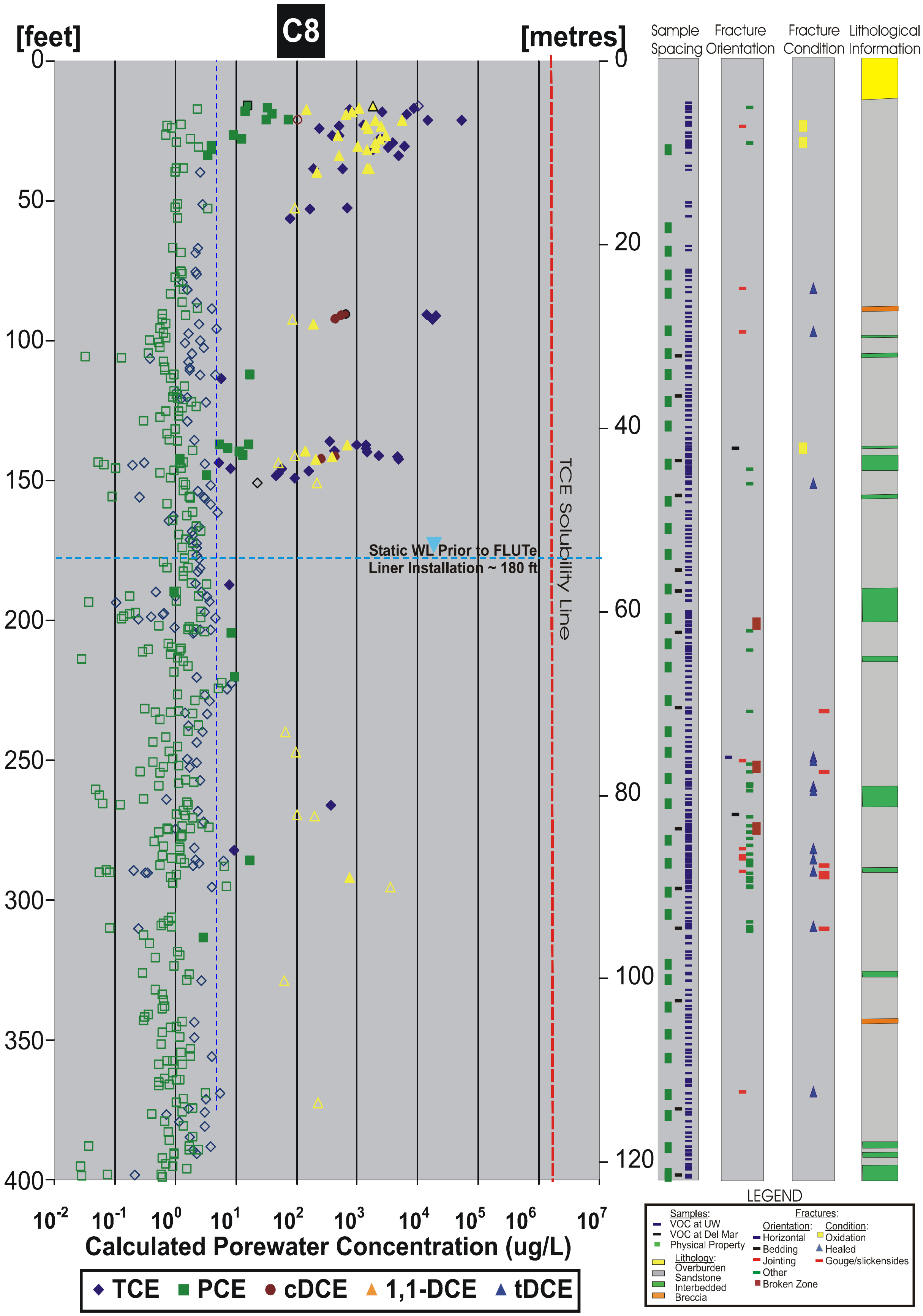

Figure 6. C8 (Former Sodium Disposal Facility) Source Area Profile of Chlorinated Ethene Porewater Concentrations

The dashed blue line represents the maximum TCE concentration in drinking water for the state of California. Open symbols represent values that are estimated (fall between the method detection limit and the method reporting limit) or samples that were qualified or samples that were qualified with a J flag according to the U.S EPA National Functional Guidelines for Organic Data Review (1999). Solid symbols represent quantitative values. Non-detects are not plotted.

Source: Report of Results, Former Sodium Disposal Facility, Groundwater Characterization: Appendix C, Nature and Extent of Chemicals in Environmental Media at the FSDF. (MWH, 2006)

Figure 6-1
C-8 TCE Porewater Profile

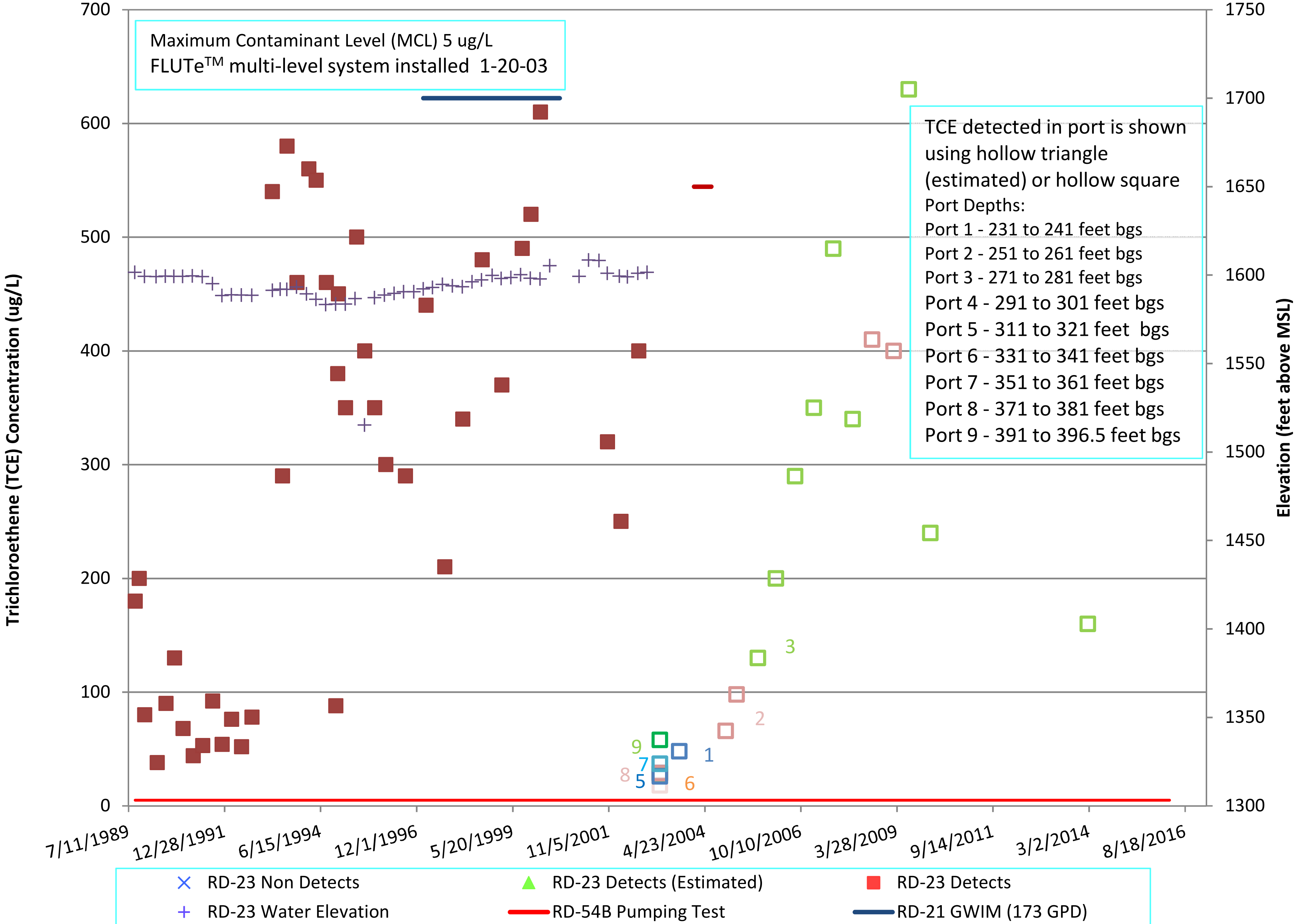

Figure 6-2

TCE Concentrations in RD-23

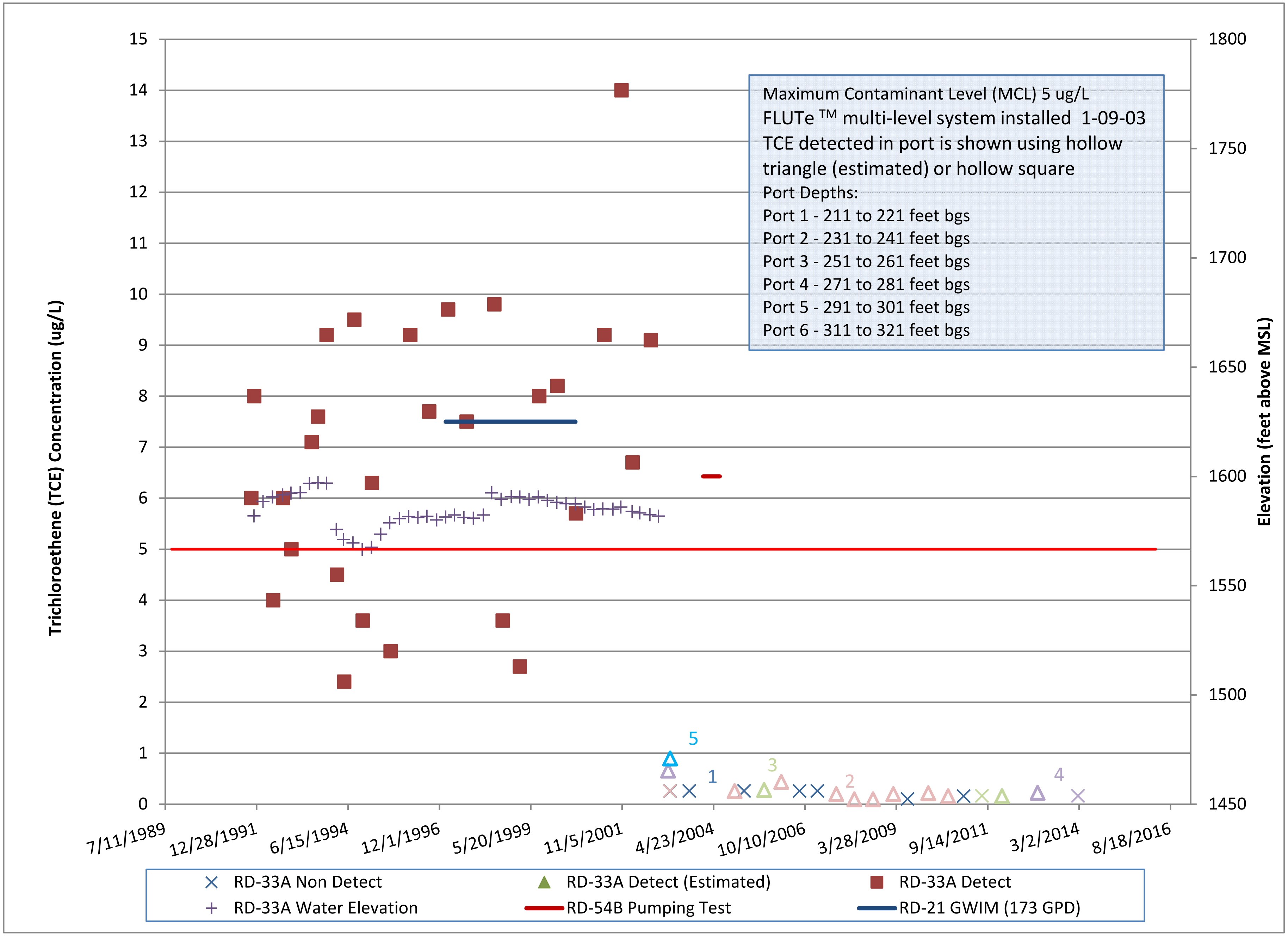

Figure 6-3

TCE Concentrations in RD-33A

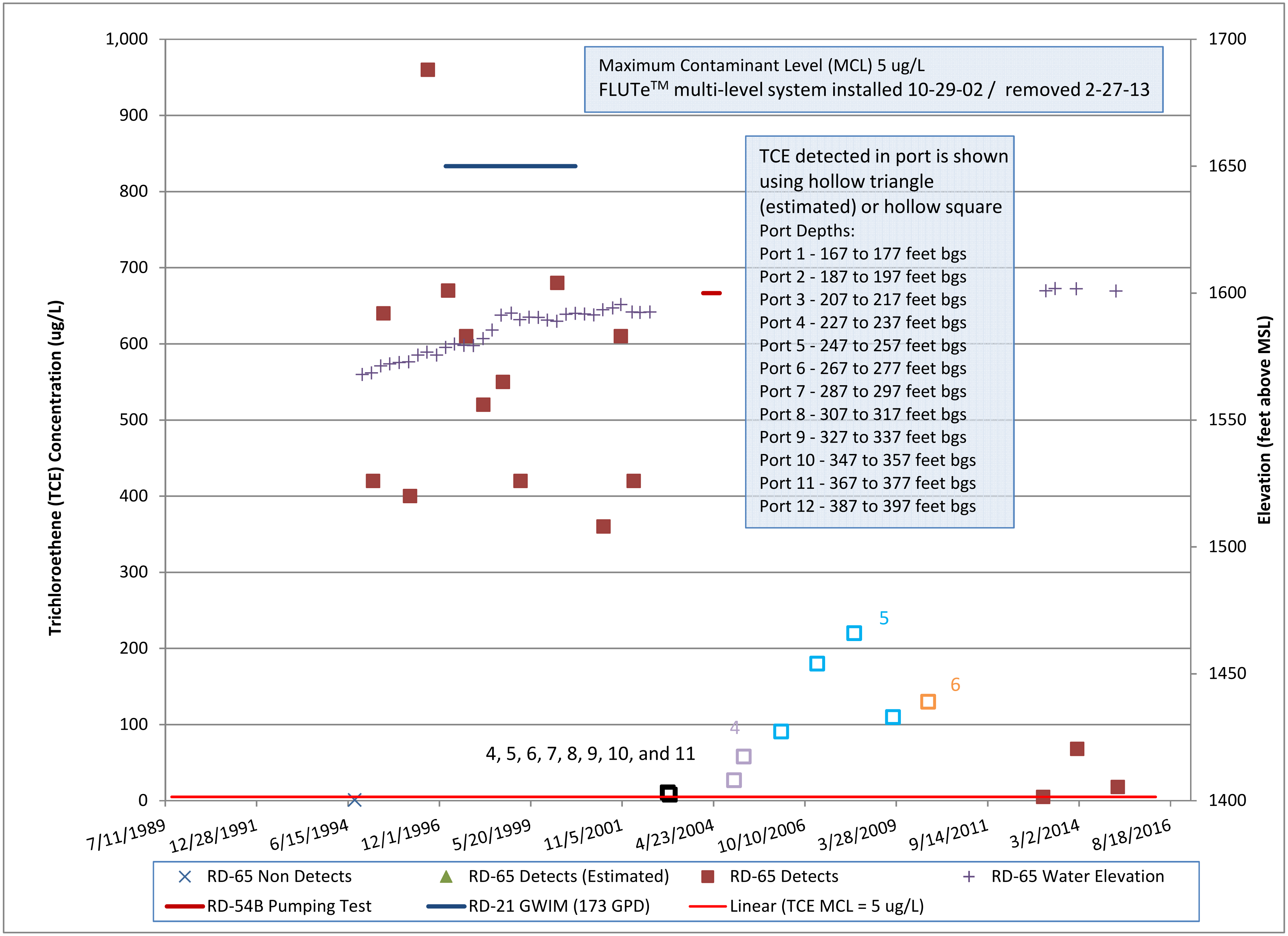

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Figure 6-4

TCE Concentrations in RD-65

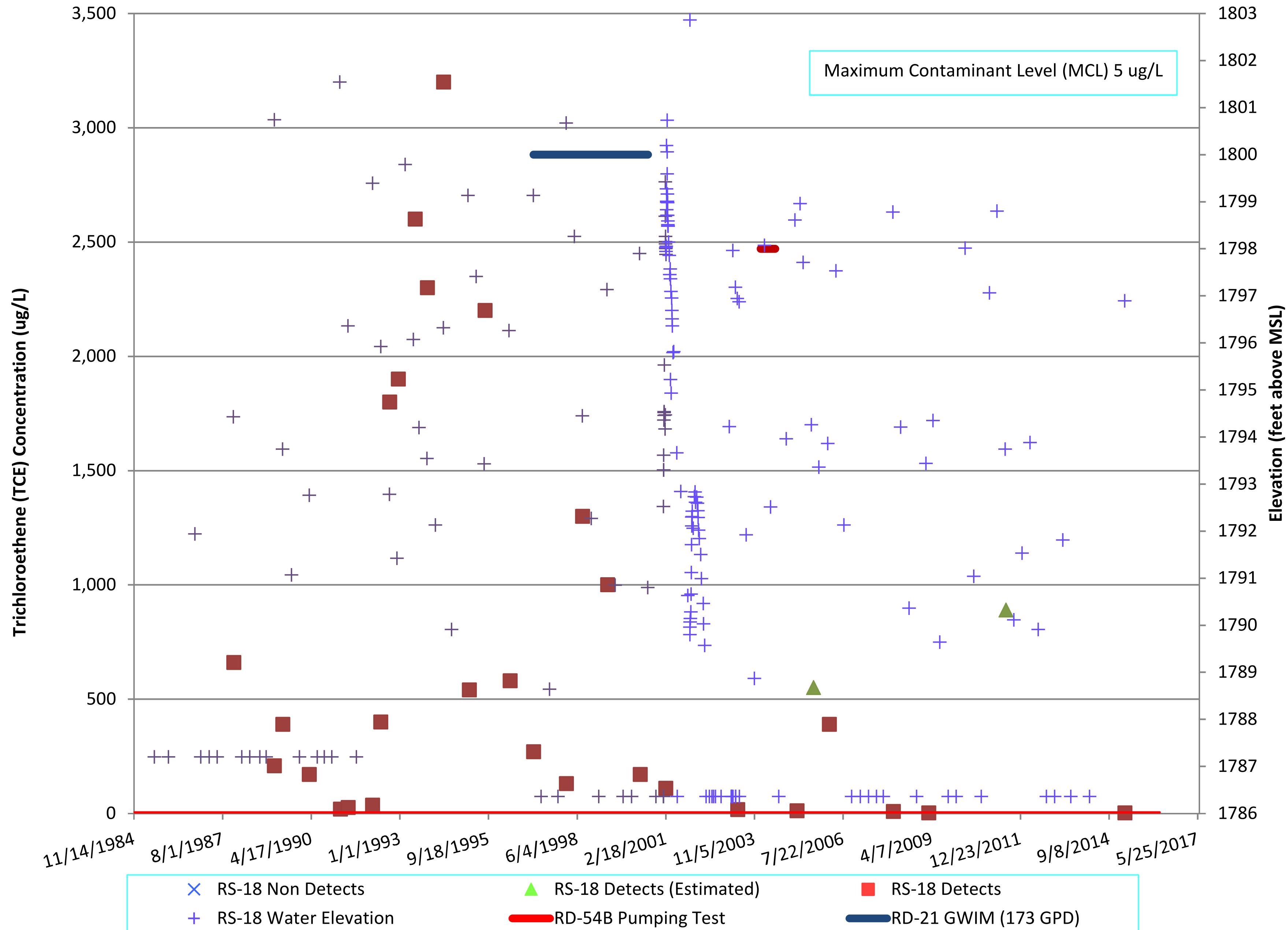

Figure 6-5

TCE Concentrations in RS-18

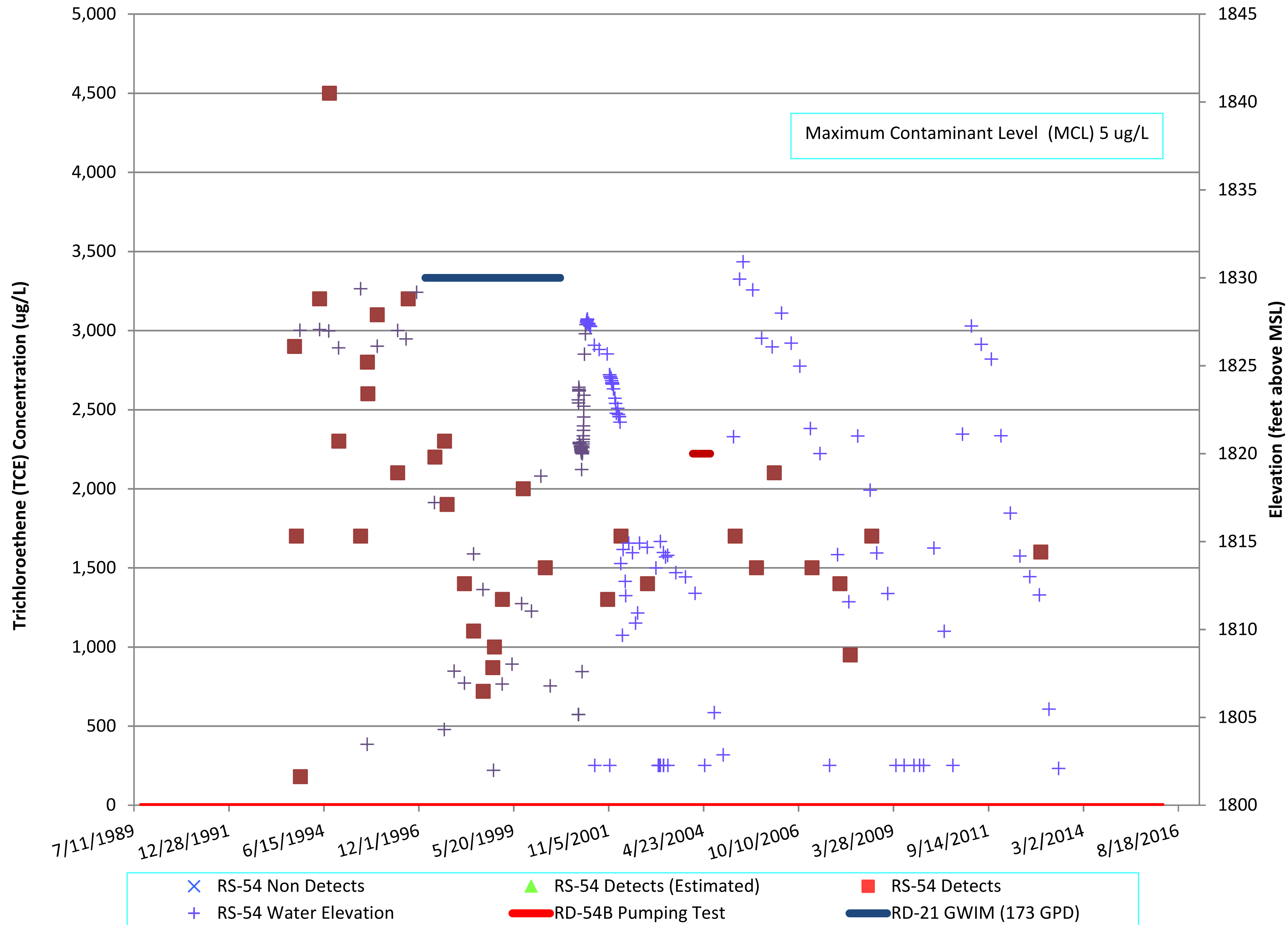

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Figure 6-6

TCE Concentrations in RS-54

Section 7

FSDF GWIM Preparatory Activities

Preparatory activities will be performed at existing surrounding wells near the FSDF prior to commencement of the GWIM. These activities include removal of FLUTe™ systems, geophysical and video logging, packer interval testing, and insolation of borehole/corehole intervals using Blank FLUTe™ liners or packers. The activities are tabulated in **Table 7-1** and discussed in detail in sections that follow.

Additionally, a new Chatsworth Formation well, DD-XXX, has been proposed for installation near PZ-098. A geophysical survey will be conducted in this well if it is installed prior to completing the activities listed in Table 7-1.

Table 7-1. Summary of Preparatory Activities at Existing Wells

Well (Depth to Water - 1st Quarter 2015 - feet below top of casing)	Remove FLUTe™ Multi-Level System or Blank FLUTe™ Liner	Downhole Video	Downhole Geophysics	Packer Test Interval (ft. bgs) (1)	Install Blank FLUTe™ Liner or Packers (2)
C-8 (NA)	Blank liner	Y - Upper 200 feet	N - (previous geophysics log available)	65 – 250 250 - 300 300 - 400	Y
RD-21 (99.01)		Y	Y	30 - 140 140 - 175	Y
RD-22 (NA)	multi-level system	N	N	30 - 405 405 - 440	
RD-23 (NA)	multi-level system	Y	Y	30 - 230 230 - 280 280 - 440	Y
RD-33A (NA)	multi-level system			100 - 320	
RD-50 (NA)	multi-level system	Y	Y		
RD-54A (169.03)		N	N	119 - 190 190 - 278	Y
RD-57 (NA)	multi-level system	N	N	19.5 - 200 200 - 419	
RD-64 (NA)	multi-level system	Y	Y	20 - 230 230 - 325 325 - 398	Y
RD-65 (218.40)		Y	Y	19 - 280 280 - 397	Y
DD-XXX (not yet completed)	N/A	Y	Y		

Notes:
(1) Preliminary sampling intervals. Final intervals will be selected after geophysics and video logging. As many as 5 intervals may be selected for packer testing in each well. Additionally core dynamic fluid testing (CDFM) will be performed in wells where downhole geophysics were performed.
(2) Isolation needs will be developed after packer testing. Recommendations are based on existing information.
ft. bgs – feet below ground surface
NA – not applicable due to FLUTe™ transducer failure
CDFM – corehole dynamic fluid testing

In wells where downhole video/geophysics will be performed, the actual packer intervals will be revised following analysis of the geophysics data collected. Groundwater samples will be collected for COCs during packer sampling. Details on sampling activities are provided in Section 10. The wells where geophysics is not planned currently have FLUTe™ systems installed. Because the integrity of these systems is unknown, packer sampling will be performed after removing the FLUTe™ systems to determine the vertical delineation of COCs.

7.1 FLUTe™ Multi-Level System Removal

To allow access to the boreholes for geophysical logging, packer testing, and groundwater sampling, the FLUTe™ systems will be removed from RD-22, RD-23, RD-33A, RD-50, RD-57, and RD-64 and the Blank FLUTe™ liner will be removed from C-8. FLUTe™ systems and the Blank FLUTe™ liner will be removed by CDM Smith's subcontractor, Flexible Liner Underground Technologies, LLC in accordance with **SSFL Standard Operating Procedure (SOP) 21, *Installation and Removal of Flexible Liner Underground Technologies (FLUTe) Systems***. Removed FLUTe™ systems will be disposed and/or recycled by Flexible Liner Underground Technologies, LLC.

7.2 Geophysical and Video Logging

Although all borings were logged during well installation, the completeness and level of detail varies based on who prepared the lithologic logs. This variation in detail may be the consequence of when the well was installed, the data quality objective for the well, and geologist/driller's experience and documentation requirements. For these reasons and to select intervals of interest (targeting of zones for sampling and groundwater extraction), geophysical and video logging will be performed.

Borehole geophysics and video logging will be performed to identify stratigraphic, lithologic, vadose zone water content, formation porosity, *in-situ* hydraulic conductivity, fracture frequency, location, orientation, and aperture. Geophysical logging will be performed on RD-21, RD-23, RD-50, RD-64, and RD-65.

Video logging at C-8's upper 200 feet of corehole will be performed to identify visual changes in bedrock fracture conditions from its original installation and logging. Additionally, review of previously performed geophysics and video logs will be reviewed from monitoring wells C-8, RD-22, RD-23, and RD-57 and will improve understanding of the area.

It is assumed that wells will not require redevelopment (i.e., surging and bailing) to complete logging of the borehole.

A suite of geophysical tools will be used to collect the data. Tools that will be used include:

1. Spontaneous Potential
2. Single Point Resistance
3. Normal Resistivity
4. Induction
5. Acoustical Televiewer
6. Optical Televiewer

7. Nuclear – natural gamma, gamma-gamma, and neutron
8. Caliper
9. Fluid temperature
10. Fluid conductance
11. Core dynamic fluid testing (CDFM)

Geophysical and video logging will be performed by Colog Inc. (Colog) or equivalent geophysical logging service in accordance with their Technical Procedures (TPs) (**Appendix A-E**). Colog is currently performing geophysical services for NASA and these TPs have been approved by DTSC.

Data will be analyzed as soon as possible following completion of the logging. The following information will be included in the evaluation:

- Identify fractures and bedding planes
- Identify lithologic units
- Identify target zones for groundwater sampling (interval)
- Identify target zone(s) for groundwater extraction (interval)

Geophysical data processing and interpretation of acoustic and optical televiewer and fractures tables, rose plots, stereonets, and well summary plots will be performed by Colog or equivalent geophysical logging service. Results will be presented in WellCAD® or similar format.

Lithologic units or marker beds will be projected using their depth, orientation, and dip to the ground surface. Existing geologic maps will be used to confirm this exposure at the ground surface.

A cross-section showing these features will be generated and compared to the exiting FSDF SCM. The new data will be used to confirm that the intervals of importance are monitored in the existing monitoring well network.

7.3 Straddle-Packer Testing

Pending the completion of the geophysical and video logging, packers will be used to isolate specific intervals/fractures for additional testing. Wells C-8, RD-21, RD-22, RD-23, RD-33A, RD-54A, RD-57, RD-64, and RD-65 will be tested to assess the contribution of contaminants from specific intervals within these wells. The parameters to be tested during straddle-packer testing are provided include VOCs, SVOCs, metals, perchlorate. Additionally, purge parameters will be collected during sample collection. These include temperature, conductivity, pH, dissolved oxygen (DO), oxidation-reduction potential (ORP), and total dissolved solids (TDS). Sample collection will be performed according to site wide SOP 1.3 (Groundwater Sampling).

Wireline straddle-packer sampling is recommended for collecting groundwater samples from isolated borehole intervals using inflatable packers and conducting aquifer tests. Packers are used to isolate specific sections (test intervals) of a bedrock borehole to allow water sample collection and testing of aquifer properties. CDFM will be performed. Straddle-packer testing allows for the defining of contamination in the water and hydraulic conductivity along the total length of the borehole.

Straddle-packer testing will be performed in accordance with SOP 20, Packers – Groundwater Sampling from Isolated Borehole Interval and Aquifer Testing (**Appendix A-C**).

Straddle-packer and CDFM testing will be performed by Colog or equivalent packer service. Colog will perform the work in accordance with their TPs (**Appendix A-E**). Colog is currently performing packer testing for NASA and these TPs have been approved by DTSC.

The specific isolated intervals for packer testing is provide in **Table 7-1**. It should be noted that purpose of the sampling and intervals may be adjusted following completion of geophysics and video logging.

7.4 Seal or Otherwise Isolate Lower Section

Dedicated packers will be placed in RD-21, RD-23, RD-54A, RD-64, RD-65, and C-8 to prevent the open borehole from acting as a conduit and protect deeper zones from contamination that may only be present in the shallower zones. Dedicated packers will be installed within 30 days after all well logging, packer testing, water quality sampling and reporting is complete. Zone(s) to be isolated will be determined after all preparatory testing has been completed.

Depending on the results of the testing and GWIM, a Blank FLUTe™ liner may be used to protect the open borehole following completion of the GWIM. This recommendation and rationale, if necessary to replace dedicated packers with a Blank FLUTe™ liner, will be provided Section 11.

Colog or equivalent packer service will perform the work in accordance with their SOPs (**Appendix A-E**).

7.5 Pressure Transducer and Data Logger Installation and Water Levels

Wells RD-21, RD-23, RD-54A, RD-64, RD-65, and C-8 will be equipped with pressure transducers and data loggers. Water levels in the remaining wells will be manually and in accordance with **Site-Wide SOP 1.1, *Manual Water-Level Measurements* (Appendix A-D)**. Pressure transducer and data loggers will be installed and operational prior to any step-drawdown or pumping tests.

7.6 Infiltration Test

The best method to determine the rejection rate of an aquifer is performing an injection test on the reinjection wells that would be used at the FSDF. This test requires potable water being injected into the well and observing effects on the aquifer. This test is not proposed at this time due to the possibility of increasing TCE migration away from the FSDF during the infiltration test (no groundwater extraction would be occurring at this time). There are no shallow zone FSDF wells that are upgradient of C-8 and not impacted by TCE. RD-21 is located upgradient of RS-54 and is screened from 30 to 175 feet bgs. However, TCE was detected in the well at 140 µg/L (March 2013) and could increase TCE movement away from the well during reinjection of treated water.

A second method that does not require injection of water is conducting a simple slug test in existing wells at FSDF and estimating the rate of reinjection that a well may have. This test has limitations due to limited groundwater displacement (i.e., slug size) and a limited displacement period or duration. Review of groundwater sampling purging records may be helpful in the evaluation but the risk that the wells cannot sustainably accept the treated water at the required reinjection rate exists.

To reduce or minimize risk of not being able to inject treated water at the desired rate, a horizontal injection system (discharge infiltration gallery) has been proposed versus the use of individual injection point (wells). This system is similar to leach fields that have been used within Area IV for various operations.

To determine the viability of this system a double-ring infiltration test will be performed. This test would directly measure the ability of potable water to infiltrate into the subsurface. The double-ring infiltrometer test (American Standards for Testing and Measurement [ASTM] D3385) is a field test to determine the infiltration rate of water into soil. The test provides a direct infiltration rate and is conducted in accordance with ASTM D3385-09 Standard Test method for Infiltration Rate of Soils in Field Using Double-Ring Infiltrometer, and the Geological Survey Water-Supply Paper 1544-F (**Appendix A-F**).

The main limitation of this method is scale and duration of the test. To address the limitation presented by the small scale of the test (a 5-foot radius versus a 40 foot long trench), an infiltration test will be performed at the terminus and mid-point of each proposed discharge infiltration gallery. The test may be repeated in the same area several times to assess how the soil reacts when fully saturated. CDM Smith's geologist or engineer will determine the length of the test, and/or test duplication needs.

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Section 8

FSDF Preparatory Activities Data Evaluation

Preparatory activities will be evaluated and information considered prior to commencement of the GWIM aquifer test. Evaluations will be performed sequentially and to ensure the proper understanding of site conditions and the SCM.

- Video Logging – do data suggest specific intervals that should be targeted for packer testing?
- Geophysical Logging – do data suggest specific intervals that should be targeted for packer testing?
- Straddle-Packer Testing – do data indicate that a specific interval/fractures contain greater COC concentrations? Do data indicate that a specific interval/fracture is capable of producing water? Do the data indicate that upper and lower zones should be isolated to prevent cross contamination within the borehole? Do data agree with estimated influent constituent concentrations used in the GWIM treatment unit model?
- Pressure Transducer and Data Logger – do data indicate that groundwater levels are being recorded correctly? Do data confirm current understanding of SCM?
- Infiltration Test – do data suggest that soil has infiltration rate and capacity to discharge treated water to the subsurface under the anticipated GWIM extraction rate?

Data and interpretation will be presented and discussed with project Stakeholders prior to commencement of step-drawdown or pumping tests.

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Section 9

Sequence of Testing, Pumping Rate, and Pumping Test Duration

Although C-8 has been selected as the GWIM's initial pumping well, other wells located at the FSDF may be candidate wells for groundwater extraction and demonstration of contaminant removal from the aquifer. Potential groundwater extraction candidate wells include RD-23, RD-54A, and RD-64. If needed or desired, an evaluation will be performed and communicated to project Stakeholders prior to any modification to the pumping well selection.

Once the GWIM treatment system has been installed, tested, and proven to meet discharge standards, sustainable flow rates for C-8, RD-23, RD-54A, and RD-64 will be determined. These four wells have been selected for step-drawdown and constant rate discharge tests.

Water removed during the step-drawdown and constant rate discharge test will be transported from the pumping well to the GWIM treatment unit via over-land, double-walled piping. A flow meter and totalizer attached to the piping will be used to collected flow rate and volume data.

9.1 Step-Drawdown Test

CDM Smith will conduct an 8-hour step-drawdown test in each of the four wells. To obtain aquifer properties, a step-drawdown test will be conducted to estimate well yields at varying pumping rates and to select the pumping rate to be used during implementation of the constant rate discharge test. Aquifer 32 or AQTESOLV will be used to analyze the step-drawdown data. The step-drawdown test will be conducted in accordance to **SSFL SOP 20, Packers – *Groundwater Sampling from Isolated Borehole Interval and Aquifer Testing***.

9.2 Constant Rate Discharge Test

A sustainable pumping rate will be determined from the step-drawdown test and will be used during a 72-hour constant rate discharge test. This test will collect aquifer properties when stressed for a 72-hour, steady pumping rate. By conducting the test over a 72-hour period, steady state conditions should be achieved and will confirm the pumping rate used for the long-term GWIM. Constant rate discharge test will be conducted in accordance to **SSFL SOP 20, Packers – *Groundwater Sampling from Isolated Borehole Interval and Aquifer Testing***.

9.3 Recovery Test

Following the constant rate discharge test, the pump will be turned off and the aquifer will be allowed to recover for 72 hours. Groundwater level data collected from pressure transducers during this recovery period will provide similar data collected during the constant rate test.

9.4 Variable Discharge Test

Depending on the results of the 72-hour constant rate discharge test, different testing techniques may be used, such as varying the duration of testing; varying the flow rates during testing and collecting VOC samples at the different flow rates; and pumping at a rate to remove the entire water column from the pumping well, allowing it to recharge, and collecting a VOC sample. If additional tests are needed or desired, a test procedure will be developed and communicated to project Stakeholders prior to any modification to the testing program.

Section 10

Field Activity Support Information and Procedures

10.1 Project Plans, Access Agreement, Permits, and Approvals

The following project plans will govern preparatory activities including installation of a replacement well, data collected during the pumping test, and during the GWIM.

- GWIM Aquifer Test Plan (this document)
- Site-Wide Groundwater Quality Assurance Project Plan (QAPP)
- Applicable documents listed at end of this plan

10.2 Permits

No permits will be required for the aquifer testing.

10.3 Access Agreement and Boeing Site Orientation Meeting

All subcontractor employees (drilling, geophysics, surveyor, etc.) will attend a one-hour Boeing site orientation meeting and will be assigned a Boeing site access badge. Subcontractor employees are required to be United States citizens per Boeing policy and have a government-issued identification card with them at all times. The drilling subcontractor will be escorted by CDM Smith personnel at all times while working at SSFL.

The subcontractor will provide to CDM Smith the names of all subcontractor personnel at least 3 days prior to site activities in order to ensure necessary clearance for access to the site.

10.4 Health and Safety

All site personnel, including subcontractors, are required to have Occupational Health and Safety Administration (OSHA) 40-hour Hazardous Waste Operations (HAZWOPER) certification and current refresher for 2015, if necessary. Proof of training and current standing is required.

10.5 Site Location and Clearance Surveys

The proposed location, work area, and any required vegetation clearance will be cleared by monitors for biological and archeological resources. Any areas that require the moving of overburden soil to improve access and work area will also be approved by monitors. Any disturbances must be reclaimed to pre-disturbance condition by the subcontractor; CDM Smith will approve reclamation efforts.

10.6 Mobilization

1. All onsite personnel will attend a Field Team Meeting led by CDM Smith covering health and safety, work plan and team member roles.

2. All documents, forms, supplies, and equipment will be available and stored in the CDM Smith field office in Area IV.

3. A decontamination pad will be constructed onsite by the drilling or other subcontractor. The pad will be large enough to adequately decontaminate the drill rig and contain all wash water. The pad will be constructed with sides to facilitate containment of the wash water and will be lined with polyethylene sheeting. The pad will also contain a sump to allow for water to pool so it can be pumped into a storage tank provided by CDM Smith. The decontamination pad will be located near the FSDF area.

10.7 Decontamination of Drilling Equipment and Down-Hole Equipment and Instruments

Decontamination of equipment, materials, and instruments will be performed in accordance to **Site-Wide SOP 1.7, *Equipment Decontamination*** and **SSFL SOP 12, *Field Equipment Decontamination***.

1. All drilling equipment and materials including drill bits, rods, tremie pipe, casings, and sampling equipment will be steam-cleaned and void of any external oils or grease prior to use in each well. All contact equipment, including pumps and hoses, will be flushed with water before each use and as directed during the program. All equipment will be cleaned to the satisfaction of CDM Smith prior to use. All fluids will be containerized in the tank provided.

2. All materials and equipment (bits, rods, screens, casings, pump, instruments, etc.) that will be inserted in the drilled borehole or monitoring wells will be steam cleaned prior to use. Casings and screens will be pre-cleaned and factory wrapped, as well as steam cleaned and adequately rinsed with de-ionized water, to ensure cleanliness.

3. All equipment will be decontaminated after use, either steam-cleaned (large equipment) or cleaned with phosphate-free detergent, triple-rinse decontamination procedure (smaller sampling equipment).

10.8 Groundwater Sampling

Groundwater samples will be collected based on **Site-Wide SOP 1.1, *Manual Water-Level Measurements*, Site-Wide SOP 1.2, *Low-Flow Purge***, and **Site-Wide SOP 1.3, *Groundwater Sampling***.

The following steps will be taken to ensure a representative sample is collected:

Water Depth and Purging

1. The depth to water will be measured from the casing reference point and recorded to the nearest 0.01 foot along with time of day measured.

2. The well will be purged until water quality parameters are stable. During purging, the pump will be placed at the mid-point of the saturated column in the open borehole or in the screened interval. Pumping will be maintained at the approximate recharge rate.

3. Teflon tubing will be used for purging and sampling activities as it does not absorb or leach VOCs or create non-representative samples.

Sample Collection

1. The water collection point for submersible pumps is prior to the flow meter and any flow valves.

2. Required sample volumes and bottles will be confirmed with the laboratory prior to sampling.

3. Samples will be analyzed by the following methods per the Water Quality SAP (Haley & Aldrich 2010):
   a. Volatile Organic Compounds by EPA Method 8260B
   b. Semi-volatile Organic Compounds by EPA Method 8270C
   c. Perchlorate by EPA Method 6850
   d. Metals by EPA Method 6020A
   e. Total coliform by EPA Method 1604
   e. TSS by EPA Method 160.2

4. For VOC sample collection, vials will be filled slowly without aerating the sample in pre-preserved sample bottles. Vials will be capped with Teflon-lined caps and firmly tightened. Each vial will be inverted and tapped to check for bubbles. If bubbles are present, the vial will be discarded and the sample recollected in a new bottle.

5. Once a bubble free sample is collected, the vial will be labeled, placed in a plastic bag, and put inside a cooler with ice. The use of cool packs (blue ice) is prohibited. The cooler(s) will remain in possession of the samplers at all times. Chain-of-custody is described below.

10.9 Field QC Samples

1. The following quality control (QC) samples will be collected during sampling
   a. Duplicates
   b. Matrix Spike/Matrix Spike Duplicate (MS/MSD)
   c. Equipment Blank
   d. Trip Blank (VOCs only)
   e. Field Blank

2. Field duplicates and MS/MSD samples will be collected one per 20 samples. Field duplicates will be collected, and provided to the laboratory as a unique and native field sample.

3. An equipment rinsate blanks will be submitted weekly per sampling technique and additionally whenever there are changes in the sample collection procedures, sampling decontamination procedures, or sampling equipment. The equipment rinsate blank will consist of the ASTM Type II water used to rinse sampling equipment as the last step of the decontamination process.

4. The trip blank is a sealed container that contains target analyte-free water shipped by the laboratory to the site. The trip black will be analyzed for VOCs and is maintained in each

cooler that contains samples for VOC analysis throughout the sampling and laboratory shipment.

5. A source blank consists of the ASTM II water used by the sampling personnel for the equipment decontamination. The sample is used to determine the chemical characteristics of the decontaminated water.

10.10 Sample Management

Applicable SOPs to sample management include: **Site-Wide SOP 1.6, *Sample Management,* SSFL SOP 10, *Sample Custody,*** and **SSFL SOP 11, *Packing and Shipping Environmental Samples***.

1. All sample bottles will be labeled, taped, and placed in a plastic bag. Samples are to be placed on ice immediately after sampling and labeling.

2. All sample names will be recorded with a date and time in the field geologists' logbook and on the boring log.

3. Samples will be entered into Scribe data management system in accordance with **SSFL SOP 10, *Sample Custody.*** A chain-of-custody form is generated from Scribe with sample identification numbers, sample times, requested analytical methods, turn-around time (TAT), and bottle type.

4. The field geologist will check the chain-of-custody to the sample label for each bottle prior to packing and shipping each cooler.

5. Coolers will be packed, screened for radioactivity, and shipped to the subcontract laboratory according to **SSFL SOP 11, *Packing and Shipping Environmental Samples***.

10.11 Investigation-Derived Waste Management and Disposal

SSFL SOP 13, *Guide to Handling Investigation Derived Waste* is applicable to field work conducted during the GWIM.

1. IDW will consist of drill cuttings, drilling fluids, development water, decontamination liquids, and disposable protective clothing. The drilling and FLUTe™ subcontractor will be responsible for managing the drilling and FLUTe™ waste. A location will be set up within the RMHF compound for storage until waste characterization data are available allowing for proper disposal.

2. Soil cuttings will be containerized in 55-gallon drums supplied by the drilling subcontractor. The subcontractor will be responsible for transporting the drill cuttings from the drill site to the drum storage area. In the event that grossly contaminated material is encountered, based upon appearance and photoionization detector readings, this material will be containerized in separate 55-gallon drums.

3. Rock cores will be kept in core boxes and stored in Building 4057.

4. Drilling fluids, decontamination, and development water will be containerized at the drilling site in portable polyethylene tanks or 55-gallon drums for transfer to larger polyethylene

tanks stored at the RMHF. Contents of the tank will be sampled and disposed of by CDM Smith once characterization data are available.

5. Radiological and chemical screening is required to be conducted before sending any IDW offsite to a Treatment, Storage and Disposal Facility (TSDF) or publicly owned treatment works (POTW). Two composite samples will be collected; one from the soil drums and one from the central water tank. Manifests are required to accompany any IDW deemed to be hazardous and DOE will direct the handling of the material.

6. Water generated during the development, baseline sampling, and initial step- and pumping tests will be stored in a temporary water tank while awaiting operation of the GWIM treatment unit. This water will be blended into effluent from the extraction well during the pumping test, treated, and discharged into the subsurface.

10.12 Field Forms and Logbook

All field documents and logbooks will be completed and maintained in accordance with **SSFL SOP 8, *Field Data Collection Documents, Content, and Control***. If photographs are used to document field activities, they will be collected in accordance to **SSFL SOP 15, *Photographic Documentation of Field Activities***.

All samples will be recorded in the field log book, on the boring log and tracked as outlined in **SSFL SOP 10, *Sample Custody***. The following forms will be used during this project:

- Field log book
- Boring log form
- Field Sample Data Sheet
- Chain-of-Custody
- Well development form
- Aquifer test form
- Other field forms

10.13 Applicable Documents

The following plans, and state and local regulations and standards are applicable to this project:

- ASTM D2113-08, Standard Practice for Rock Core Drilling and Sampling of Rock of Site Investigation.
- Department of Water Resources, Water Well Standards: State of California Bulletins 74-81 and 74-90.
- California Safe Drinking Water Act Title 22.
- Boeing Santa Susana Field Laboratory, SOP, *Deep Borehole and Rock Core Sampling*, November 2011
- Boeing Santa Susana Field Laboratory, SOP 7, *Borehole and Trench Logging, Soil and Rock Classification*, November 2012.
- Boeing Santa Susana Field Laboratory, SOP 16A, *Monitoring Well Installation*, February 2013.

- Boeing Santa Susana Field Laboratory, SOP 17, *Borehole Geophysical Logging*, February 2013.
- Site Wide Water Quality Sampling and Analysis Plan. Haley & Aldrich, 2010.
- Site-Wide SOP 1.1, *Manual Water-Level Measurements*
- Site-Wide SOP 1.2, *Low-Flow Purge*
- Site-Wide SOP 1.3, *Groundwater Sampling*
- Site-Wide SOP 1.6, *Sample Management*
- Site-Wide SOP 1.7, *Equipment Decontamination*
- SSFL SOP 6, *Field Measurement of Total Organic Vapors*
- SSFL SOP 7, *Field Measurement of Residual Radiation*
- SSFL SOP 8, *Field Data Collection Documents, Content, and Control*
- SSFL SOP 10, *Sample Custody*
- SSFL SOP 11, *Packing and Shipping Environmental Samples*
- SSFL SOP 12, *Field Equipment Decontamination*
- SSFL SOP 13, *Guide to handling Investigation Derived Waste*
- SSFL SOP 15, *Photographic Documentation of Field Activities*
- SSFL SOP 16, *Control of Measurement and Test Equipment*
- SSFL SOP 20, *Packers – Groundwater Sampling from Isolated Borehole Interval and Aquifer Testing*
- SSFL SOP 21, *Installation and Removal of Flexible Liner Underground Technologies (FLUTe) Systems*

Section 11

Aquifer Test Data Analysis and Reporting

11.1 Aquifer Parameters Data Analysis

Aquifer parameters (transmissivity, hydraulic conductivity, and storativity) for wells showing a response to pumping will be calculated. The following methods may be used to analyze the pumping test data:

- AquiferWin32 (Environmental Simulations, Inc. 2013) or AQTESOLV (HydroSOLVE 1998)
- Moench-Slab-Block Flow (1984) method

11.2 Chemical Data Analysis

Constituents in groundwater will be evaluated during initial packer sampling (baseline), during aquifer testing, and after aquifer testing. Pertinent information to this evaluation in response to pumping (magnitude and duration) and constituent concentrations collected from baseline, final aquifer test termination, and recovery periods. COC responses to the aquifer testing will be evaluated for contaminant trends. Monitoring well responses to pumping and recharge will be considered in this evaluation.

11.3 Recommendations

The findings from this aquifer test may result in revised recommendations for GWIM activities to be performed, if needed. Plausible recommendations may include, but not be limited to:

1. Replacement of dedicated packers with a blank FLUTe™ liner for interval isolation.

2. Permanent abandonment of deeper intervals.

3. Continue monitoring recovery water levels and chemical concentration trend.

4. Revised extraction wells for GWIM at FSDF (if necessary).

11.4 Reporting

An aquifer test report will be submitted at the conclusion of the study. The report will contain a compilation of all field data, data reduction and analysis, interpretations, and conclusions. The report will include the following information:

- 1.0 Introduction
- 2.0 Preparatory Field Activities
- 3.0 Step-Drawdown and 72-Hour Constant Rate Discharge Test and Results
- 4.0 Results – Aquifer Response to Pumping and Estimated Aquifer Parameters
- 5.0 Recommendations
- 6.0 References

Appendices

- Data Collection Sheets and Field Log Book
- Calculations
- Analytical Data and Validation Reports

Section 12
References

Boeing, 2005. *Site Environmental Report for Calendar Year 2004 DOE Operations at The Boeing Company, Santa Susana Field Laboratory*. September.

Haley & Aldrich, 2000. Appendix B to Technical Memorandum, Conceptual Site Model, Movement of TCE in Chatsworth Formation, Santa Susana Field Laboratory, Ventura County, CA (Montgomery Watson). April.

MWH, 2002. Technical Memorandum, Corehole Drilling Operations, Former Sodium Disposal Facility (FSDF), Santa Susana Field Laboratory, Ventura County, California. September.

MWH, 2006. Draft, Report of Results, Former Sodium Disposal Facility, Groundwater Characterization: Volume I and II; Appendix A, Supporting Documentation on Groundwater; Appendix B, RD-54B Pumping Test; Appendix C, Nature and Extent of Chemicals in Environmental Media at the FSDF. February.

MWH, 2009. Draft Site-Wide Groundwater Characterization Report, Santa Susana Field Laboratory, Ventura County, California. December.

Rocketdyne, 1996. *Annual Site Environmental Report, Santa Susana Field Laboratory and Desoto Sites, 1995, Rocketdyne Propulsion & Power*. July

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Rocketdyne, 1999. *Site Environmental Report for Calendar Year 1998, DOE Operations at Rocketdyne Propulsion & Power, RD99-115*. September.

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Rocketdyne, 2002. *Site Environmental Report for Calendar Year 2001, DOE Operations at the Boeing Company, Rocketdyne Propulsion & Power*. September.

Rocketdyne, 2003. *Site Environmental Report for Calendar Year 2002, DOE Operations at the Boeing Company, Rocketdyne Propulsion & Power*. September.

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Appendix A-A

Lithologic Logs

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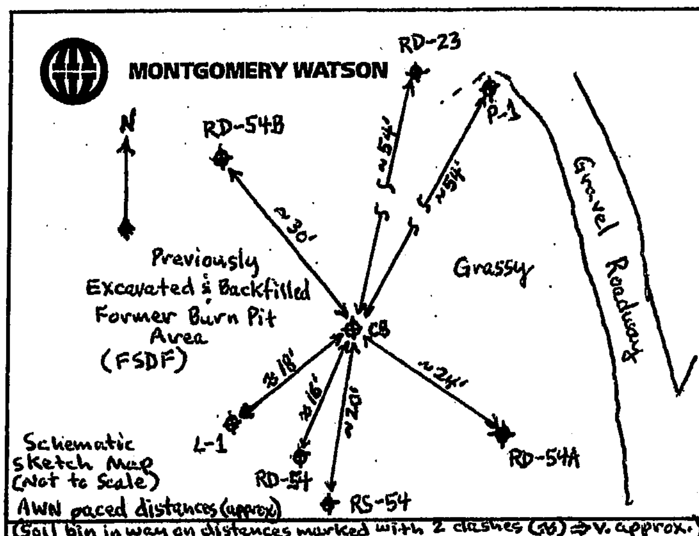
MONTGOMERY WATSON



Boring #: MW#: C8	Sheet 1 of 21
Project: BOEING Rocketdyne SSFL CFOU Investigation	
Job #:	Site: Former Sodium Disposal Facility (FSDF)
Logged By: Adam Norris (AWN)	Reviewed By:
Drilling Contractor: Layne Christensen	
Drill Rig Type/Method: Ingersoll Rand TH-60 / Air Rotary with Water	
Drillers Name: Ernesto Vargas	
Borehole Diam./Drill Bit Type: Ream Conductor Boring to 12¼" @ 0-65' bgs; 9⅞" pilot hole in alluvium; 5" borehole @ 65'-400' bgs (AWN)	Total Depth: 400' bgs; Ref. Elev.:
Sampler Type: 3" ID Continuos Core Sampler (PQ).	
Depth to 1st Water (▽): Time/Date:	Drill Start Time/Date: 1440/4/15/02 Drill Finish Time/Date: 1035/5/1/02
Depth to Water After Drilling (▼): Time/Date:	Well Completion Time/Date: 1035/5/1/02
Depth to other Water Bearing Zones:	Soil Boring Backfill Time/Date: N/A

C8 Well Details:
- → 12¼" diameter conductor boring @ 0-65' bgs
- → 8" ID (8.5" OD) Mild Steel Conductor Casing @ 0-65' bgs
- → 5" diameter corehole @ 65'-400' bgs
- → Cement-bentonite grout sanitary seal in outer conductor casing annulus @ 0-65' bgs (placed w/ tremie pipe.... tremie submerged in grout during grout placement.)

Date/Time: 4/15/02 1440 hrs

PID/OVA (ppm)	Cored Interval	Recovered	Retained for Analysis	Bedding*	Fractures**		Depth (Feet)	Geologic Description
						LOGGED SOIL CUTTINGS		Grass Cover
							ML	SILT (ML), yellowish brown, very stiff, dry to moist, 95% silt, 5% fine sand, nonplastic to very low plasticity silt, sand is subangular to subrounded, [FILL].
							1	
							2	
							3	
							4	
							ML 5	SILT (ML), brown, very stiff, moist, 95% silt, 5% fine sand, very low plasticity silt, sand is subangular to subrounded, [FILL].
							6	
							7	
							8	Color change to Light yellowish brown @ ~8.5' bgs; Grades with increased sand content.
							9	
							SM 10	SILTY SAND (SM), Light yellowish brown, dry to moist, 30% medium sand, 50% fine sand, 20% silt, subang. to subrounded sand, very low plasticity to nonplastic silt, [FILL].

NOTES:
* H=horizontal
Number=<(in degrees from horizontal)
** H=horizontal
V=vertical
B=parallel to bedding
Number=<(in degrees from horizontal)

Date & Time

Boring #:	MW#: C8	Project: Boeing Rockeldyne SSFL-CFOU Investigation	Sheet 2 of 21

Former Sodium Disposal Facility

PID/OVA (ppm)	Cored Interval	Recovered	Retained for Analysis	Bedding*	Fractures**	RQD	Depth (Feet)		Geologic Description
								SM	Trace local silt seams.
							1–5 (LOGGED SOIL CUTTINGS)	SM/ML	Interbedded SILTY SAND and SANDY SILT (SM/ML), yellowish brown; overall composition 20% medium sand, 30% fine sand, 50% silt; subangular to subrounded sand, very low plasticity to nonplastic silt, [FILL]. ~~BEDROCK encountered @ approx. 14' bgs.~~ Color changes to grayish brown @ ~14' bgs.
							4 (FILL / BEDROCK)	SS	SANDSTONE, fine-grained, slightly (sl.) weathered, competent, some silt content. PID @ top of borehole = 0.0 ppm @ 1510 ~~1410~~ hrs AWN.
1505 hrs; 1805 1/16/02	5–10	5–10			45°	4.7/5, 94%	5–10 (CORE)	SS	SANDSTONE (SS), fine grained, sl. weathered, competent, moist, well sorted, brownish gray; becomes fine to med. grained w/depth (@ approx. 16.5' bgs); grades w/ trace v. coarse & coarse sand @ 18' bgs; becomes orange brown @ 18' bgs; becomes poorly sorted @ 18' bgs; subangular to subrounded grains; sl. weathered, competent, local iron oxidation; moderately hard; olive gray, fn to med. SS @ 19' bgs; competent, sl. weathered, some local iron oxidation, mod. well sorted, subang. to subrounded sand grains, trace local coarse sand grains.
0820; 0842	10–15	10–15		25°	60°	5/5, 100%	10–15	SS	Sandstone (SS), fn. to v. coarse, olive brown, sl. weathered, competent, poorly sorted, subang. to subrounded grains, moderately hard; local iron oxidation @ 22' bgs. Bedding laminations visible @ 21'–22' bgs; becomes fine to med. grained, well sorted; orange brown @ 22.5' bgs. Becomes fn. to cs. grained @ 23' bgs, poorly sorted, moderately hard, subang. to subrounded grains, competent, sl. weathered; orange brown. Partially penetrating fracture @ 24' bgs; Iron oxidation on fracture surfaces. SS: fn. to cs, weathered, competent, brown @ 24.5'–25' bgs.
0849 ~~0853~~; ~~0856~~ 0906 AWN; 0912	15–20	15–20				5/5, 100%	15–20 (30)	SS	SANDSTONE (SS), fn. to v. coarse, sl. weathered, competent, hard, poorly sorted, gray to orange brown, some local iron oxidation; some granules (2-4 mm long) & ~~trace~~ some subang. pebbles (4-10 mm long) @ 25.5'–26.5' bgs. Becomes tannish brown @ 27' bgs; SS, fine to coarse sand, sl. weathered, competent, moderate sorting, hard, local iron oxidation. Becomes gray @ 28' bgs, SS, fine to med. gr. mostly w/ trace cs. & v. cs sand grains; subang. to subrounded grains, mod. well sorted; hard, competent; Becomes fn. to med. grain @ 29' bgs; trace local biotite; apparent quartz (silica) cement, massive.

Time

Boring #: | **MW#:** C8 | **Project:** Boeing Rocketdyne SSFL-CFOU Investigation | **Sheet** 3 **of** 21

Former Sodium Disposal Facility

Time	PID/OVA (ppm)	Cored Interval	Recovered	Retained for Analysis	Bedding*	Fractures**	RQD	Depth (Feet)		Geologic Description
11/6/02 0946	0.0	↓	↓	X	AWS	40°			SS	Sandstone(SS), fn. to med. grain, competent, hard, gray, Fracture @ 30.3' bgs has iron oxidation penetrating up to 1".
				X				1		Convoluted laminations @ 30.6 to 31' bgs.
										Some iron oxidation @ 31.5' bgs.
				X			5/5	2		Becomes light brown @ 32' bgs, SS, fn. grn, well sorted, competent, hard, some weathering (slight (sl.) AWS), massive, subang. to subrounded grns.
				X			100%	3		
	0.0									Becomes gray @ 33.5' bgs, SS, fine to med. grn, competent, hard, subang. to subrounded grns., apparent silica cementation, trace horneblende grains, some olive brown weathering discoloration @ ~34' bgs.
				X				4		
	0.0									Becomes orangish brown @ 34.5' bgs; trace coarse sand grns.
0954		↑	↑					5		
		Broken core drill bit off @35' bgs. Overdrilled to 37' bgs w/ 7 7/8" bit. No recovery 35' to 37' bgs.						6		
								7		
1335	0.0	↓	↓						SS	Sandstone (SS), yellowish brown, moist to very moist, competent, hard, fine to coarse grained, poorly sorted, sl. weathered, subangular to subrounded grains.
	0.0							8		
				X			3/3			Becomes gray @ 37.5' bgs, SS, fine to med. grn, mod. sorting, competent, hard, very moist to moist. Becomes fn. to cs. grn. @38' bgs and poorly sorted. Gray SS @ 39' bgs, fn. to cs. grn., poorly sorted, apparent silica cement, some black mineral content: (mafics) → apparent horneblende.
	0.0						100%	9		
1338	0.0	↑	↑	X				40		
1413		↓								
								1		
								2		No Recovery of Core between 40' and 50' bgs. Lithology logged from cuttings.
				No core recovery from 40'-45' bgs; core dropped downhole. Drillers attempted to recover core. During recovery attempt the borehole was apparently deepened to 47' bgs. Failed recovery. Drillers measured bottom of hole @ 47' bgs @ 1500 hrs.					SS	
								3		SANDSTONE (SS), gray, very moist, fine to coarse grain, competent, hard, subangular to subrounded grains, some mafic mineral content: horneblende; apparent silica cement; moderate to poor sorting.
								4		
1419		↑						5		
								6		
								7		
1508		↓							SS	SANDSTONE (SS), gray, very moist, fine to coarse grain, mod. to poor sorting, subangular to subrounded grains, apparent silica cement, competent, hard.
				No core recovery from 47' to 50' bgs.				8		
								9		
1510		↑						50		

Date & time

Boring #:	MW#: C8	Project: Boeing Rocketdyne SSFL-CFOU Investigation	Sheet 4 of 21

Former Sodium Disposal Facility

Date & time	PID/OVA (ppm)	Cored Interval	Recovered	Retained for Analysis	Bedding*	Fractures**	RQD	Depth (Feet)		Geologic Description
4/17/02 0802	0.0	↓	↓						SS	SANDSTONE (SS), gray, fn. to v. cs. grn, poorly sorted, competent, hard, massive, angular to subrounded grains, some mafic mineral content: hornblende; primary mineral content: quartz; apparent Silica (quartz) cementation, very moist to moist.
	0.0			X			5/5	1		
	0.0			X			100%	2		Color change to light brown @ ~52.75' bgs (52'9");
	0.0							3		SANDSTONE (SS), light brown, fn. to v. cs grain, poorly sorted, competent, hard, massive, some mafic mineral content: hornblende; apparent trace biotite; angular to subrounded grains, sl. weathered, some local iron oxidation (orangish), trace granules (up to 4mm long), very moist to moist.
	0.0							4		
0810	0.0							5		
0838	0.3	↓	↓						SS	SANDSTONE (SS), light brown, weathered, fine to very coarse grained (fn. to v. cs. grn.), trace granules (up to 3mm long), poorly sorted, angular to subrounded grains, competent, hard, massive, moist.
	0.2			X		AWN	1.5 ~~0.75~~ / 5 30%	6		
	Partial core recovery; Apparently the core from 56.5' to 60' bgs dropped out of sampler.							7		
								8		
								9		
0844								60		
0912		↓	↓	X					SS	SANDSTONE (SS), light brown, slightly (sl.) weathered (AWN), fn. to v. cs. grn., trace granules (up to 4mm), poorly sorted, competent, hard, angular to subrounded grains, some local iron oxidation (orangish), moist.
					30°			1		Color changes to gray @ 61' bgs.
	0.3						4.5/5			SANDSTONE (SS), gray, fn. to v. cs. grn., trace granules (up to 4mm long), poorly sorted, angular to subrounded grns., competent, moist, hard, some mafic mineral content, apparent quartz (Silica) cementation.
							90%	2		
	0.3							3		SANDSTONE (SS), gray, fn. to v. cs. grn., poorly sorted, angular to subrounded grns., competent, hard, moist, some mafic mineral content, apparent quart (silica) cementation.
	0.1							4		
0917	0.2	↓	↓					5		
4/19/02 1150	0.1	↓	↓				5/5		SS	SANDSTONE (SS), medium gray (N5), fn. to v. cs. grn., poorly sorted, competent, hard, angular to subrounded grains, moist, some mafic mineral content (apparent hornblende),
							100%	6		SANDSTONE (SS), medium light grey (N6), fn. to v. cs. grn., poorly sorted, competent, hard, angular to subrounded grains, moist, some mafic mineral content, predominately composed of quartz grains,
	0.3			X X AWN				7		
								8		SANDSTONE (SS), medium light gray (N6), fn. to cs. grn., poorly sorted, competent, hard, angular to subrounded grains, moist, some mafic ~~ct.~~ mineral content.
	0.9			X X AWN — Took misc. sample @ 68'7" - 69'1"				9		
1155		↓	↓					0		

QA/QC 10-00

Time

Boring #: MW#: C8 Project: Boeing Rocketdyne SSFL - CFOU Investigation Former Sodium Disposal Facility

Time	PID/OVA (ppm)	Cored Interval	Recovered	Retained for Analysis	Bedding*	Fractures**	RQD	Depth (Feet)		Geologic Description
4/19/02 1211			No core recovery from 70'-75' bgs. Core dropped downhole. Drillers attempted to recover core to no avail.					70–75	SS	No Recovery of Core from 70'-75' bgs. Lithology logged from cuttings. SANDSTONE (SS), med. lt. gray (N6), fn. to v. cs. grn., poorly sorted, angular to subrounded grains, hard, competent, moist, some mafic mineral content, ~~predominate grain composition~~ is quartz.
									SS	SANDSTONE (SS), med. gray (N5), fn. to cs. grn., poorly sorted, angular to subrounded grains, hard, competent, some biotite content and hornblende content (mafics), predominate grain composition is quartz, massive, moist.
1217 1321	0.0	A	A	X			2/2			
	0.6			X			100%			
1325 1339	0.0			X — Took misc. sample @ 77'-77.8" AWN			3/3	77	SS	SANDSTONE (SS), medium gray (N5), fn. to v. cs. grn., poorly sorted, trace granules (up to 4mm-long), angular to subrounded grains, hard, competent, moist to very moist, massive, some mafics grains, mostly qtz. grns. Grades with some pebbles up to 9mm-long @ 79' bgs to 79.3' bgs. Fn. to V. cs. grain (without granules or pebbles) @ 79.3-80' bgs.
	0.0			X			100%			
1343	0.0							80		
1354	0.0			X			5/5		SS	SANDSTONE (SS), med. gray (N5), fn. to v. cs grn., ~~trace granules up to 4mm-long~~ AWN, poorly sorted, angular to subrounded grains, hard, competent, moist to very moist. Healed fracture @ 82' bgs.
					(healed fracture symbol)	70°	100%	82		
	0.7			X				83		Grades with trace local granules @ 83' bgs (granules up to 4-mm long).
	0.0							84		Grades with trace pebbles @ 84.5' bgs (pebbles up to 11 mm-long).
1403 1/22/02 0856	0.0						5/5	85	SS	SANDSTONE (SS), med. gray (N5), fn. to v. cs. grn., trace local ~~granules~~ pebbles AWN (up to 8mm-long), poorly sorted, angular to subrounded grains, hard, competent, moist to very moist, massive. (trace local granules (2-4 mm-long)) AWN
	0.0			X			100%	87		
	0.0							88		
	0.0			X				89		Grades with trace ~~granules~~ pebbles AWN up to 10mm-long (slight increase in max. ~~granule~~ pebble AWN size).
0901								90		

Time

Boring #: MW#: C8 Project: Boeing Rocketdyne SSFL-CFOU Investigation - Former Sodium Disposal Facility

Date: 1/22/07

Time	PID/(ppm)	Cored Interval	Recovered	Retained for Analysis	Bedding*	Fractures**	RQD	Depth (Feet)		Geologic Description
0917		↑	↑						Pebbly SS	PEBBLY SANDSTONE (SS), med. dk. gray (N4), trace granules (2-4 mm long), fn. to v. cs. sand grns., poorly sorted, ang. to subrounded grns; moist to very moist, hard, competent.
	0.1			X	25			1	SS	Bedding lamination - contact @ 91' bgs (dips 25°).
	0.2						5/5			Becomes SANDSTONE (SS) @ 91' bgs ~~(grades~~ minimal (trace) pebbles to no pebbles below 91' bgs
	~~0.1~~							2		contact.
	0.3			X			100%			
	0.0							3		
	0.0			X				4		Softens to 'Moderately Hard' @ 94'-95' bgs. Fn. to v. cs. grn; trace local granules (2-3 mm-long), poorly sorted, ang. to subrnd. grns; moist to v. moist, competent.
0920	0.0	↓	↓					5		
0936		↑	↑	X					SS	SANDSTONE (SS), med. dk. gray (N4), fn. to v. cs. grn; trace local granules (2-4 mm-long), poorly sorted,
	0.0							6		moist to v. moist, hard, competent,
							5/5			angular to subrounded grains.
	0.0			X	70/0 AWN	70°	100%	7		Healed fracture @ 97.5' bgs.
	0.0			X				8		
	0.0									
				X				9	SS	Grades with trace local pebbles (up to 6 mm-long).
	0.0				30				SH	SILTY SHALE (very thin bed (12 mm-thick)) @ 95' bgs, med. dk. gray (N4), moist, moderately soft, dips 30°.
0940		✱	✱					100	SS	SANDSTONE (SS), med. dk. gray (N4).
0957				X	25				SLTS	SILTSTONE (SLTS), med. dk. gray (N4), moist, hard to
	0.0						1.3/5	1	SS	moderately hard, thin bed @ 100' to 100'2" bgs approx.; ~50 mm thick) ~~fissile~~ bedding laminations.
1018	0.0	↑	↓↑							SANDSTONE (SS), med. dk. gray (N4), moist to v. moist,
							26%	2		fn. grain; well sorted @ 100.2 to ~100.5' bgs; then poor ~~less~~ sorting (fn. to v. cs. grain) below ~100.5' bgs; hard,
	0.0									competent, angular to subrounded grns; trace
				X				3		granules (2-4 mm-long).
	0.0									
								4		Grades with trace local pebbles (up to 6 mm-long).
1003	0.0	↓		X				5	SS	
				X			4.6/4.6			
1021		✱	✱				100%	6		SHALE (SH), med. dk. gray (N4), hard to mod. hard,
1042				X	30				SH	moist, fissile, thin bed (roughly 50 mm thick).
	0.0							7	SS	SANDSTONE (SS), medium gray (N5), fn. to v. cs. grn.,
							4/4			trace local granules (2-4 mm-long), poorly sorted, angular to subrounded grns., moist, hard, competent.
	0.0			X			100%	8		Grades with pebbles @ 108' to 109.5' bgs (PEBBLY SANDSTONE). Pebbles (4 to 20 mm-long).
	0.0							9		
										Grades without pebbles @ 109.5' bgs.
1045	0.0	↓	↓	X				0	SS	SANDSTONE @ 109.5'-110' bgs; fn. to v. cs. grn., trace granules (2-4 mm) med. gray (N5).

Date/Time

Boring #: MW#: C8 Project: Boeing Rocketdyne SSFL-CFOU Investigation - Former Sodium Disposal Facility

Date/Time	PID (ppm)	Cored Interval	Recovered	Retained for Analysis	Bedding*	Fractures**	RQD	Depth (Feet)		Geologic Description
1/22/02 1114									SS	SANDSTONE (SS), medium gray (N5), fn. to v. cs. grn
	0.0									trace granules (2-4 mm); poorly sorted, angular
							5/5	1		to subrounded grns; moist, hard, competent.
	0.0						100%	2		Grades with some pebbles (4 to 10 mm long) @ ~112' bgs.
									Pebbly SS	PEBBLY SANDSTONE @ ~112 to ~113' bgs.
	0.0							3		Grades without pebbles @ ~113' bgs; fn. to v. cs. grn;
	0.0									trace granules (2-4 mm); poorly sorted, angular
	0.0							4		to subrounded grns; moist, hard, competent.
1119								5		
1142									SS	SANDSTONE (SS), med. gray (N5); fn. to v. cs. grn.,
	0.0						5/5	6		poorly sorted, angular to subrounded grns,
										moist to very moist, hard, competent.
	0.0						100%	7		Grades with trace granules (2-4 mm) and
										trace Pebbles (4-10mm) @ 117' bgs.
	0.0							8		
	0.0							9		Grades without Pebbles @ ~119' bgs; fn. to v. cs grn,
										trace granules (2-4mm); poorly sorted, ang. to
1145	0.0									subrounded grns, moist to v. moist, hard, competent.
								120		
1247									SS	SANDSTONE (SS), medium dk. gray (N4), fine grained, mod.-well sorted, moist, hard, competent; trace local med. to
	0.0				30		5/5	1		v. coarse grns. Bedding visible @ lithologic (grn size) change @ ~120.5' bgs. Becomes fn. to v. cs. grn. below 120.5' bgs,
	0.0						100%	2		poorly sorted, hard, competent, moist.
										Grades with some granules (2-4 mm) @ ~122.5' bgs.
								3		
	0.0				30					Bedding visible @ ~~lithologic contact~~ (AWN) ~123.4' bgs
					30			4		SANDSTONE (SS), fn. to v. cs. grn, poorly sorted, hard, competent.
	0.0									Bedding visible @ lithologic (grn. size) contact @ ~124.1' bgs. Thin bed of fn. grn. SS @ ~124.1 to ~124.2' bgs, well sorted, med. gray (N5);
1252								5		Fn. to v. cs. grn, poorly sorted @ ~124.2' to 125' bgs.
1322	0.0				30				SS	SANDSTONE (SS), med. gray (N5), fn. to v. cs. grn,
							5/5	6		poorly sorted, angular to subrnded. grns., moist to v. moist,
	0.0									hard, competent.
							100%	7		Grades w/ trace granules (2-4 mm) and trace pebbles (4-10mm) (AWN) @ ~127' bgs to ~128' bgs
	0.0				30					
								8		Grades without pebbles @ ~128' bgs.
	0.1				30					128'-130' bgs: SS, fn. to v. cs grn, med. gray (N5), poorly sorted,
								9		angular to subrounded grns, moist, hard, competent,
	0.0									trace local granules (2-4mm).
13[illegible]								130		

Time

Boring #: MW#: C8 Project: Boeing Rocketdyne SSFL-CFOU Investigation - Former Sodium Disposal Facility Sheet 8 of 21

Time	PID (ppm)	Cored Interval	Recovered	Retained for Analysis	Bedding*	Fractures**	RQD	Depth (Feet)		Geologic Description
1/22/02 1349		↑	↑						SS	SANDSTONE (SS), medium gray (N5), fn. to v. cs.
	0.8							1		grn., poorly sorted, trace local granules (2-4 mm),
				X			5/5			angular to subrounded grains, moist, hard,
								2		competent, massive.
							100%			
	0.1							3		
				X						SS, med. gray (N5), fn. to v. cs. grn, trace local
	0.0							4		granules (2-4 mm), poorly sorted, angular to
	0.0									subrounded grns., moist, hard, competent, massive.
1353		↓	↓					5		
1412		↑	↑		30				SS	SANDSTONE, medium gray (N5), fn. to v. cs grn, trace local granules (2-4mm), poorly sorted, ang. to subrnd. grns., sl. moist to moist, hard, competent.
	0.0			X			5/5	6		Convoluted laminations @ 135.5' bgs.
							100%	7		
	0.0			X						
								8		UPPER SIDE OF FRACTURE: SHALE (SH), thin bed ~1/4" thick,
				X						moderately soft, fissile, med. gray (N5), moist to sl. moist, organic rich, iron oxidation does not permeate (penetrate) significantly, trace black lams.
	0.0				25	25		9	SH	Fracture @ 139' bgs w/ iron oxidation on both
				X	30				SS	sides. Iron oxidation permeates further ~~(~0.5ft)~~ ~~on lower side (coarser grns. this side), v. moist to wet.~~ on frac. surfaces. LOWER SIDE OF FRACTURE: SS,
1415		↓	↓	X				140		~~light~~ light brown, fn. to v. cs grn, sl. weathered, trace granules (2-4 mm),
1442		↑	↑						SS	hard, competent, some iron oxidation (greatest closest to fracture).
	0.0							1		SANDSTONE (SS), lt. brown becomes gray gradually downward, f. to v. cs. grn., trace granules (2-4mm), poorly sorted,
				X	30		5/5			angular to subrounded grns., sl. weathered, hard,
										~~competent; contact lt. brown to gray @ ~ 140' 8" bgs.~~
								2	SH	LITHOLOGIC CONTACT @ ~141.8' bgs (dips 30°).
	0.5			X			100%			SHALE (SH), med. lt. gray (N6) to med. dk. gray (N4),
										fissile, friable, some silt content, locally micaceous,
								3		core broken-up (likely mechanical fractures... not native fracs.),
	0.0			X	30					moderately soft.
								4	SS	SANDSTONE (SS), med. gray (N5), fn. to cs. grn, poorly sorted,
				X	30					angular to subrounded grns, some convoluted laminations, hard, competent, moist.
1447	0.2	↓	↓	X				5	SH	SHALE (SH), med. lt. gray (N6), sl. moist, mod. soft, fissile,
1524		↑	↑							friable, some convoluted laminations.
										~~SH/SS contact dips 30°.~~
				X	30				SS	SANDSTONE (SS), med. gray (N5), fine to cs. grn,
	0.0					50 mech	5/5	6		moderate to poor sorting, angular to subrounded grns., hard, competent, moist to v. moist.
				X						Likely mechanical fracture @ ~ 146.5' bgs (dips 50°),
	0.0						100%	7		has no weathering, oxidation, or excess moisture.
				X						
	0.0							8		SH: very thin shale bed (~1/2" thick), fissile, friable,
					30					mod. soft, med. lt. gray (N6), moist.
	0.0							9	SS	SANDSTONE (SS), med. gray (N5), fn. to cs. grn,
	0.0									med. to poor sorting, ang. to subrounded grns, hard,
1529		↓	↓					150		competent, moist.

Date & Time

Boring #: MW#: C8 Project: Boeing Rocketdyne SSFL-CFOU Investigation Sheet 9 of 21

- Former Sodium Disposal Facility -

Date & Time	PID (ppm)	Cored Interval	Recovered	Retained for Analysis	Bedding*	Fractures**	RQD	Depth (Feet)		Geologic Description
1/23/02 0837									SS	SANDSTONE (SS), med. gray (N5), mostly fn. to med. grn., some coarse grns., med. sorting, ang. to subrnd. grns.,
	0.0			X				1		moist, hard, competent, some local bedding laminations
							5/5			visible (dip 30°).
	0.0			X	30	40		2		Healed fracture @ ~151.6' ~~152.3'~~ AWN (dips 40°).
							100%			Grain size and sorting fluctuates gradationally
	0.0							3		somewhat. Local trace v. cs. grn and trace
										granules (2-4 mm) with poor sorting.
	0.0			X				4		
	0.0									SS, fn. to v. cs. grn, med. gray (N5), poorly sorted,
0843										ang. to subrounded grns., moist, hard, competent.
0906								5	SS	SANDSTONE (SS), med. gray (N5), fn. to v. cs. grn, trace local granules (2-4mm), poorly sorted, ang. to subrnd.
	0.0			X	30		5/5	6	SLTS	grns., moist, hard competent.
										slightly convoluted laminations @ ~156' bgs
	0.0				30 to 35		100%	7	SS	(Dipping appox. 30° avg.). Convoluted Laminations within thin
					30-35					siltstone interbed (~2"-thick). SLTS: light gray (N7),
	0.0			X				8		med. soft, some very fine sand, some mica content.
										156.2' to 160': SS: med. gray (N5), fn. to v. cs. grn, some granules
										(2-4 mm), poorly sorted, ang. to subrounded
	0.0							9		grns., some bedding laminations visible @ ~157-158' bgs
	0.0									(Lams dip ~30 to 35°), moist, hard, competent.
0911 0936								160	SS	SANDSTONE (SS), med. gray (N5), fn. to v. cs. grn.,
	0.0							1		some granules (2-4 mm-long), poorly sorted, ang. to
				X			5/5			subrounded grns., moist, hard, competent, massive.
	0.0							2		Grades with some local pebbles (4-10mm)
							100%			@ 162 - 164' ~~165'~~ AWN bgs.
AWN	~~0.6~~ 0.0			X				3		
										164'-165':
	0.0							4		SS, med. gray (N5), fn. to v. cs. grn., trace granules (2-4 mm),
	0.1			X						poorly sorted, ang. to subrounded grns., moist, hard,
0940										competent.
1005					30			5	SS	SANDSTONE (SS), med. gray (N5), fn. to v. cs. grn,
	0.0							6		some local granules (2-4mm), angular to subangular
					AWN		5/5			grns. predominate, trace subrounded grns., poorly
	0.0									sorted; trace pebbles (4-10 mm) @ 165' to 165.5' bgs,
							100%	7		moist, hard, competent. Bedding lamination
										visible @ 165.7' bgs (dips 30°).
	0.0			X	AWN			8		166'-170':
										SS, med. gray (N5), fn. to v. cs. grn., some granules (2-4mm)
	0.0				35			9		poorly sorted, ang. to subrounded grns, moist, hard,
										competent, some bedding laminations visible @ ~169' bgs
1009				X				170		(dip 35°).

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- Former Sodium Disposal Facility -

Date & Time	PID/OVA (ppm)	Cored Interval	Recovered	Retained for Analysis	Bedding*	Fractures**	RQD	Depth (Feet)		Geologic Description
1/23/02 1031	0.0, 0.0, 0.0, 0.0, 0.0						5/5 100	1, 2, 3, 4	SS	SANDSTONE (SS), med. gray (N5), fn. to v. cs. grn., some granules (2-4mm), poorly sorted, subang. to subrounded grns., moist, hard, competent. Trace pebbles (4-8 mm) @ approx 172'-173' bgs. ~~173'-175':~~ SS, med. gray (N5), fn. to v. cs. grn., some granules (2-4 mm), poorly sorted, subang. to subrounded grns., moist, hard, competent.
1034 1102	0.0, 0.0, 0.0, 0.0, 0.0						5/5 100%	5, 6, 7, 8, 9	SS	SANDSTONE (SS), med. gray (N5), fn. to v. cs. grn., some granules (2-4mm), poorly sorted, subang. to subrounded grns., moist, hard, competent, massive.
109 1234	0.0, 0.0, 0.0, 0.0, 0.0						5/5 100%	180, 1, 2, 3, 4	SS	SANDSTONE (SS), medium gray (N5), fn. to v. cs. grn., some granules (2-4 mm), poorly sorted, subang. to subrounded grns., moist, hard, competent. Trace local pebbles (4-10 mm), massive.
1240 1258	0.0, 0.0, 0.0, 0.0, 0.0				30, 45		5/5 100%	5, 6, 7, 8, 9	SS	SANDSTONE (SS), med. gray (N5), fine to v. cs. grn., poorly to mod. sorted, ang. to subrounded grns., moist, hard, competent. 187'-188': SS v. fine to med. grn, moderately sorted, some sl. convoluted laminations (dip approx 30°), hard, competent, moist. ~~188'-189.5': SS, fine to cs. grn, mod. sorted, ang. to subrounded grns., moist, hard, competent.~~
302								190	SH	SHALE (SH), med. gray (N5), moist, mod. soft, fissile, friable, slightly convoluted laminations.

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Date & Time	Depth (Feet)	PID (ppm)	Bedding	Fractures	RQD	Lithology
1/23/02 1329 – 1335	190–195	0.0, 0.0, 0.0, 0.0	30, 25, 25, 25, 35		5/5, 100%	SS/SH
1405 – 1410	195–200	0.0, 0.0, 0.0, 0.0, 0.0	30, 30		5/5, 100%	SS; SH/SS
1447 – 1451	200–205	0.0, 0.0, 0.0, 0.0	30	55	4/5, 80%	SS
1/24/02 0907 – 0911	205–210	0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0	30, 30, 30		5/5, 100%	SS

Geologic Description

190' to 195':
Interbedded SANDSTONE and SHALE, thinly to moderately bedded (~1" to 10" thick beds).
SS: fn to v. cs. grn, trace local granules (2-3mm), moist, hard, competent, med. gray (N5), subang. to subrounded grains.
SH: med. dk. gray (N4) to med. gray (N5); moist to very moist, some convoluted laminations, fissile, friable, moderately soft.
Bedding contacts and laminations visible in core.
Core sample highly fractured (mechanical fractures) due to interbedded competent (SS) and incompetent (SH) beds.
Highly convoluted laminations @ ~194.4' to 194.8' bgs within a Shale Bed.

195'-197': SANDSTONE (SS), med. gray (N5), v. fn. to v. cs. grn, poorly sorted, ang. to subrnd. grns., moist, hard, competent, some visible laminations dip ~30°, some convoluted laminations.

197'-200': Interbedded SHALE and SANDSTONE, thinly bedded to laminations visible within some thin beds; (laminated) thin beds up to ~1"-thick.
SS: v. fn. grn to fn. grn, well sorted, cross-bedding visible within thin sandstone beds, lt. gray (N7), moist, hard, competent.
SH: med. gray (N5) to dk. gray (N4), moist to v. moist, fissile, friable, mod. soft.

200'-203.5': SANDSTONE (SS), med. gray (N5), fn. to cs. grn., mod. sorted, v. moist to wet, hard, competent, angular to subrounded grains.
Highly fractured Zone @ 201.5' to 202.5' bgs; wet, friable within fracture zone, local silt deposited on fracture faces. No apparent oxidation or weathering along fractures.

203.5'-205' bgs: SANDSTONE (SS), med. gray (N5), fn. to v. cs. grn., Some granules (2-4mm), v. moist to wet, hard, competent, angular to subrounded grains.
Fracture @ ~204' bgs (dips 55°): no apparent oxidation or weathering along fracture; wet surfaces.

205'-210': SANDSTONE (SS), med. gray (N5), f. to v. cs. grn., trace granules (2-4 mm), poorly sorted, ang. to subrounded grns., very moist to wet, hard, competent; trace local pebbles (4-15mm long); ~~massive~~ Note: some bedding laminations visible between 205'-206.5' bgs; Massive between 206.5'-210' bgs (i.e. no bedding laminations visible).

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Date & Time	PID (ppm)	Bedding*	Fractures**	RQD	Depth (Feet)		Geologic Description
4/24/02 0932	0.0					SS	SANDSTONE (SS), medium gray (N5), fn. to v. cs. grn., trace granules (2-4 mm), poorly sorted, v. moist to wet, ang. to subrounded grns., hard, competent.
	0.0		50		1		
	0.0			5/5			Fracture @ 210.9' bgs (dips 50°): weathered/friable zone along fracture surface penetrates up to 1/2-inch; wet fracture surface; no obvious oxidation along fracture surfaces.
	0.0	35		100%	2		Some Shale rip-up clasts sporadically occur btwn. 212-213.5' bgs (up to approx. 2"-long) within SS matrix.
	0.0				3		
		35			4	SH	SHALE (SH), med. gray (N5), some fn. to med. sand content, mod. soft, friable, fissile.
	0.0						
0935	0.0				5	SS	SANDSTONE (SS), med. gray (N5), to lt. olive gray (5Y6/1), fn. to v. cs. grn., poorly sorted, ang. to subrounded grns., some weathering, moist to wet, hard, competent; trace granules (2-4 mm).
1013	0.0			5/5	6		
		35					216.5'-217.5' bgs: SANDSTONE (SS), fn. to cs. grn., poorly sorted, ang. to subrounded grns., v. moist to wet, hard, competent, some faint bedding laminations locally visible (dip 35°).
	0.0	35		100%	7		
	0.0				8		217.5'-220': SANDSTONE (SS), med. gray (N5), fn. to v. cs. grn., some granules (2-4 mm), poorly sorted, hard, competent, v. moist to wet, ang. to subrounded grns.
	0.0				9		
1020					220		220'-225' bgs:
1040	0.0			5/5	1	SS	SANDSTONE (SS), med. gray (N5), fn. to v. cs. grn., trace granules (2-4 mm), poorly sorted, angular to subrounded grains, v. moist to wet, hard, competent, massive.
	0.0			100%	2		
	0.0				3		
	0.0				4		
	0.0						
1043					5	SS	SANDSTONE (SS), med. gray (N5), fn. to v. cs. grn., poorly sorted, ang. to subrounded grns., v. moist to wet, hard, competent.
1100	0.0	35		5/5	6		
	0.0	35			7		1"-thick granule-rich layer (approx. 30% granules (2-4mm)) @ ~226.7' bgs. Some bedding laminations visible btwn. 226.3' and 227.3' bgs.
		35		100%			
	0.0				8		228'-230' bgs: SANDSTONE (SS), med. gray (N5), fn. to v. cs. grn., some granules (2-4 mm), trace pebbles (4-6 mm), poorly sorted, angular to subrounded grns., v. moist to wet, hard, competent.
	0.0				9		
1104	0.0				230		

Date & Time

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Date & Time	PID/(ppm)	Cored Interval	Recovered	Retained for Analysis	Bedding*	Fractures**	RQD	Depth (Feet)		Geologic Description
1/24/02 1124	0.0						5/5	1	SS	SANDSTONE (SS), med. gray (N5), fn. to v. cs. grn., trace granules (2-4mm), poorly sorted, ang. to subrnd. grns., v. moist, hard, competent. 'Hanging Wall'
	0.0			X	30°		100%	2		Thin granule rich lenses (≤1" thick) @ approx. 231.7' to 232.2' bgs.
	0.0			X	30°	50° fault		3		Thin fault gouge layer (≤3/4" thick) @ 232.7' bgs Associated fracture dips 50°. Slickenside striations are subparallel to fracture dip (approx. 20° off of fracture dip direction). Gouge is moist, v. dk. gray, smooth, foliated, friable, striated; Steps perpendic. to striations suggest dip-slip fault (steps face down dip of frac. surface)
	0.0			X				4		'Footwall': SANDSTONE (SS), med. gray (N5), fn. to v. cs. grn, some granules (2-4mm), poorly sorted, ang. to subrnd. grns, v. moist to wet, hard, competent, trace local pebbles (4-10mm). (Steep side of steps on footwall (fault) face down footwall face
1127	0.0							5		
1305	0.0			X			5/5	6	SS	235' - 240' bgs: SANDSTONE (SS), med. gray (N5), fn. to v. cs. grn., trace local granules (2-4mm), poorly sorted, ang. to subrounded grns., v. moist to wet, hard, competent, massive.
	0.0						100%	7		
	0.0			X				8		
	0.0							9		
	0.0									
1309				X				240		
1335 AWN	0.0						5/5	1	SS	240' - 241.5' bgs: SANDSTONE (SS), med. gray (N5), fn. to v. cs. grn, trace local granules (2-4 mm), poorly sorted, ang. to subrounded grns., v. moist to wet, hard, competent, massive.
	0.0			X			100%	2		241.5' - 245' bgs:
	0.0							3		SANDSTONE (SS), med. gray (N5), fn. to v. cs. grn, poorly sorted, ang. to subrounded grns., moist to wet, hard, competent, massive.
	0.0			X				4		
	0.0									
1341								5		
1355	0.0			X			4.5/5	6	SS	245' - 250' bgs: SANDSTONE (SS), med. gray (N5), fn. to v. cs. grn, trace local granules (2-3 mm), ang. to subrnd. grns., moist to v. moist, hard, competent.
	0.0						90%	7		
	0.0			X				8		Several subhorizontal healed hairline fractures @ approx. 249' bgs.
	0.0					healed fractures		9		Healed fracture @ 249.5' bgs; filled w/ white mod. soft mineral, apparent calcite, (dips 80°). AWN
1359	0.0			X		80		250		

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Date & Time	PID/OVA (ppm)	Cored Interval	Recovered	Retained for Analysis	Bedding*	Fractures**	RQD	Depth (Feet)		Geologic Description
4/24/02 1439						80			SS	SANDSTONE (SS), med. gray (N5), fn. to v. cs. gn., ~~trace granules & pebbles (2-6mm), moist to wet,~~ poorly sorted, ang. to subrounded grns., hard, competent.
	0.0			X			3/5	1		Healed fracture extended down from 249.5' bgs to 251' bgs. dips 80° and is filled w/ calcite.
	0.0			X		50	60%	2		Fracture @ 251.5' bgs dips 50°, mod. rough wet surface with some silt coating (soft coating), no apparent oxidation.
	0.0			X				3		SANDSTONE grades without granules & pebbles @ 253'-255' bgs.
						35 35				Fracture zone @ 252.5 - 254' bgs; med. gray (N5) silt coats fracture surfaces, wet surfaces, rough surfaces.
	0.0			X		45 fault		4		Fault fracture @ 254.3' bgs dips 45°; smooth surfaces, some calcite precipitation on surfaces, slightly striated, striations subparallel to fault plane dip suggesting a dip-slip ~~fault~~ fault; v. moist surfaces.
1444	0.0							5		
1/25/02 0836	0.0								SS	AWN ~~285'~~ 255' - 259.8': SANDSTONE (SS), med. gray (N5), fn. to cs. grn., moderately to poorly sorted, ang. to subrounded grns., v. moist to wet, hard, competent.
	0.0			X			4.9/5	6		
	0.0			X			98%	7		Grades with trace v. cs. sand @ ~ ~~285.5'~~ 258.5' AWN - ~~289.8'~~ 259.8' AWN bgs
	0.0			X				8		
	0.0			X		50 50 AWN 55 50		9		Two subparallel fractures @ ~ 258.6' and 258.7' bgs; some local trace calcite precipitation on faces; some soft grey silt accumulated on fracture surfaces, wet frac. surfaces. Hairline healed frac. @ 259.5'
0838	0.0				30			260	SH	SHALE (SH), med. dk. gray (N4), mod. soft, fissile, friable, moist. Bedding contact @ 259.8' bgs (w/overlying SS) dips 30°.
0907	0.0			X		40		1	SH/SLTS	260'-265' bgs: Interbedded SHALE and SILTSTONE, med. gray (N5) to med. dk gray (N4), moist, mod. soft, friable, fissile. Healed hairline fracture @ 261' bgs dips 40°. The shale is more friable and fissile than the siltstone. Bedding AWN laminations visible throughout much of core. Core splits easily along bedding planes that dip ~~predom.~~ AWN 30°-35° throughout core from 260'-265' bgs.
	0.0				35		5/5	2		
	0.0			X	30		100%	3		
	0.0									
	0.0			X				4		
0912								5	SS	SANDSTONE (SS), med. gray (N5), v. fn. grn to med. grn., mod. well sorted, ang. to subrnd. grns., moist, hard, competent; bedding contact w/underlying unit dips 30°; some basal shale rip-up clast inclusions (tabular) up to 3/4" long.
0944	0.0			X	30° 30°		5/5	6	SH/SLTS	Interbedded SHALE and SILTSTONE; SH; med. dk gray (N4), mod. soft, moist, fissile, friable; SLTS; med. gray (N5), moist, hard; Bedding laminations visible. Laminated to very thinly bedded, beds up to 3/4" thick, some convolution of lams.
	0.0						100%	7	SS	SANDSTONE (SS), med. gray (N5), v. moist to wet, fn. to coarse grn., mod to poor sorting, ang. to subrnd. grns, hard, competent.
	0.0				30°			8		
	0.0							9		fn. to med. grn. interbed @ 267.8' to 268.7' bgs.
	0.0					30				Fracture @ 269.5' dips 30°; wet surfaces w/soft gray silt accum. on surfaces.
0948								270		

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— Former Sodium Disposal Facility —

Date & Time	PID/(ppm)	Cored Interval	Recovered	Retained for Analysis	Bedding*	Fractures**	RQD	Depth (Feet)		Geologic Description
1/25/02 1022						50			SS	270'-275': SANDSTONE (SS), med. gray (N5), fn. to v. cs. grn., trace local granules (2-4mm), poorly sorted, v. moist to wet, ang. to subrnd. grns., hard, competent.
	0.0						4/5	1		
	0.0				30		80%	2		Thin fn. grn. interbed w/convoluted laminations @ 271.9'-272' bgs.
	0.0							3		
	0.0					45				Fracture @ 273.5' bgs dips 45°, v. moist to wet surface, sl. weathered surfaces, smooth surface to slightly rough.
	0.0					40, 45, 40		4		Fracture zone @ 274'-275' bgs, fracs. dip 40°-45°, ~~wet frac surfaces;~~ clayey silt coats surfaces of fracs and may be result of in place weathering, smooth to sl. rough surfaces, mod. to intensely fractured zone (274'-275'), no apparent oxidation.
1026 / 1100	0.0						4.8/5	5	SS	275'-280' bgs: SANDSTONE (SS), med. gray (N5), fn. to v. cs. grn, poorly sorted, ang. to subrounded grns. v. moist, hard, competent, (trace granules @ 279.2' to 280' bgs).
	0.0					40, 40		6		
	0.0						96%	7		Two fractures @ 275.7' & 275.9' dip 40°, wet surfaces, sl. rough to smooth surfaces, sl. weathered, but no oxidation apparent.
	0.0									
						45		8		Fracture @ 278' bgs dips 45°; surface of frac; ~~slightly rough; silt accumulation (soft) possible~~ result of weathering, no oxidation apparent.
	0.0							9		
	0.0									SS: Grades with trace granules (2-4mm) from 279.2' to 280' bgs.
1105 / 1232						45	3.5/5	280	SS	SANDSTONE (SS), med. gray (N5), fn. to v. cs. grn., trace granules (2-4 mm), poorly sorted, ang. to subrounded grns, v. moist to wet, hard, competent.
	0.0					70		1		Frac @ 280.5' dips 45°, sl. rough surf., wet. Healed fracture @ 281.3'-282' bgs, filled w/calcite apparently, hairline to 1mm wide frac., frac. dips 70°.
	0.0						~~70%~~ 60%	2		SS: sl. to mod. weathered, mod. soft to hard @ 282.5' bgs to 285' bgs.
	0.0							3		
	0.0					45				Fracture @ 283.6' bgs dips 45°, surface slightly rough, wet, sl. weathered, some soft silt on frac. surfaces.
	0.0					85, 60		4		85° dip frac. @ 284.2' bgs, smooth to sl. rough surf., some soft silt, wet.
1235 / 1312						80		5	SS	65° dip frac. @ 284.7' bgs, sl. rough surf., wet. SANDSTONE (SS), med. gray (N5), fn. to v. cs. grn., poorly sorted, ang. to subrounded grns., v. moist to wet, hard, competent.
	0.0					40	5/5	6		
	0.2					40				Healed frac. @ 285'-285.5' dips 80°.
	0.3						100%	7		Frac @ 285.7' dips 40°, wet, sl. rough surface, sl. to mod. weathered surf. some soft silt on surface. ~~Frac. @ 286.5' dips 40°, surfaces: wet, sl. rough, sl. weathered.~~
	0.2					45		8		Frac. @ 287.7' dips 45°, surfaces: smooth, v. moist, some striations subparallel to dip, no gouge.
	0.0							9		Bedding contact dips 25°.
	0.0				25					SILTSTONE (SLTS) and SHALE (SH) interbedded, med. gray (N5), moist, mod. soft, sl. friable, sl. fissile,
1316						70		290	SLTS/SH	Healed partly penetrating frac. @ 289.7' bgs, hairline, apparent calcite in frac. (precipitate).

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Date & Time	PID/OVA (ppm)	Cored Interval	Recovered	Retained for Analysis	Bedding	Fractures	RQD	Depth (Feet)		Geologic Description
1/25/02								290	SLTS/SH	Interbedded SILTSTONE & SHALE (CONTACT @ 290' bgs)
349		↓	↓	X		55, fault	4.5/5		SS	290'-294' bgs: SANDSTONE (SS), med. gray (N5), v. fn grn to cs. grain. poorly sorted, ang. to subrounded, sl. weathered; friable near fault fracture (up to 2" above/below fault). Fault fracture @ 290.4' bgs dips 55°; gouge zone ≈ 3/4" thick. Sub horiz. striations on surface suggest strike-slip, some calcite precip. on surfaces and in gouge, moist.
						50, 50	90%			SS coarsens slightly downward. Frac. @ 291.8' dips 50°; surf.: smooth, v. moist, subhorizontal striations. Frac. @ 292.1' dips 50°; surf.: slightly rough, v. moist.
					30	50				Frac. @ 293.3' dips 50° (but has different strike than next two fracs above; all three fracs discordant w/ bedding though). Sl. rough surf., v. moist. 294'-295': SS, med. gray (N5), fn. grn to v. cs. grn, poorly sorted, ang. to subrnd. grns., v. moist, hard, competent.
353 / 1442		↓	↓	X		50, 45, 45	4.5/5 (4.9/5) AWN; 98% (100 AWN)	295	SS	295'-300': SANDSTONE (SS), med. gray, fn. to v. cs. grn, poorly sorted, ang. to subrnded grns., v. moist, hard, competent. Fracture @ 295' dips 50°; surf.: sl. rough, v. moist. Fracture @ 295.3' dips 45°, surf.: sl. rough, v. moist. Fracture @ 295.4' dips 45°, surf.: sl. rough, v. moist.
1446 / 1/26/02 0842	0.0, 0.0, 0.0, 0.0, 0.0, 0.0	↓	↓	X			5/5; 100%	300	SS	300'-305' bgs: SANDSTONE (SS), med. gray (N5), fn. to v. cs. grn., poorly sorted, ang. to subrounded grns., grades slightly coarser downward (trace granules (2-4 mm) @ 303.3'-305' bgs), v. moist to wet, hard, competent, massive.
0846 / 0925	0.0, 0.0, 0.0, 0.0, 0.0, 0.0	↓	↓	X		55; 55/55	5/5; 100%	305	SS	305'-310' bgs: SANDSTONE (SS), med. gray (N5), fn. to v. cs. grn., poorly sorted, ang. to subrounded grns., (trace granules (2-4 mm) @ 307.8-308.7' bgs), v. moist, hard, competent. Hairline fracture @ 307.7' bgs dips 55%; surface: v. moist, sl. rough. Partly healed fractures @ 309.3' bgs (dip 55° ea in roughly opposite directions) one frac. offsets the other w/ normal separation; fracs. filled w/ gray silty material; fracs. sl. rough to smooth. Silty material is mod. soft.
935								310		

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Date & Time	PID (ppm)	Cored Interval	Recovered	Retained for Analysis	Bedding*	Fractures**	RQD	Depth (Feet)		Geologic Description
1/26/02 0948	0.0			X		Fault 45 / 45	1.6/5		GOUGE	310.0'-310.3': Fault Gouge, platy, silty, apparent calcite interlaminations. Fault Zone @ 310.0-310.3', mod. soft to soft, friable.
	0.0			X		55		1	SS	310.3'-311.6' bgs: SANDSTONE (SS), med. gray (N5), fn. to v. cs. grn., poorly sorted, ang. to subrnd. grns., hard, competent.
	0.0									Fracture @ 310.6' dips 45°, surf. smooth, moist, some calcification; oblique striations (plunge approx. 20°).
1004							32%	2		Fracture @ 311' bgs dips 45°, surf. smooth, moist, some calcification.
	0.0									311.6' bgs - 317' bgs:
				X				3		SANDSTONE (SS), med. gray (N5), fn. to v. cs. grn.,
	0.0									trace granules (2-4 mm), poorly sorted, ang. to
				X				4		subrounded grns., v. moist to wet, hard, competent.
	0.0									
0952								5	SS	
1004	0.0			X			2/2	6		
	0.0						100%			
1006								7		317'-320' bgs:
~~1103~~ 1059 AWN	0.0						3/3	8		SANDSTONE (SS), med. gray (N5), fn. to v. cs. grn., trace granules (2-4 mm), poorly sorted, ang. to
	0.1			X			100%	9		subrnd. grns, moist to v. moist, hard, competent, massive.
AWN 1103 ~~1107~~	0.0			X						
1116								320	SS	320'-325' bgs: SANDSTONE (SS), med. gray (N5), fn. to v. cs. grn.,
	0.0			X			5/5	1		trace granules (2-4 mm), poorly sorted, ang. to subrounded grns., moist to v. moist, hard, competent;
					25					Bedding lamination @ 321.4' bgs dips 25°;
	0.0						100%	2		grades slightly coarser downward w/ increased granule
	0.0			X				3		content and trace pebbles (4-10mm long) @ 322.4-~~325~~ 324' bgs. AWN
	0.0			X				4		
1/26/02 1120	0.0							5		
1136 (1115) 1/29/02					~~20~~ AWN				AWN	
	0.0			X	25			6		
	0.0			X	~~25~~ AWN		6/6		SH/SLTS	~~Interbedded~~ AWN SHALE and SILTSTONE, med. light gray (N6),
	0.0							7		moist, mod. soft; fissile and friable shale; package coarsens downward. Thin shale bed (3/4" thick) overlies
	0.0						100%			siltstone w/ some fine sand content. Siltstone has
	0.0							8	SS	some convoluted laminations.
	0.0			X						327.3'-331': SANDSTONE (SS), med. gray (N5), fn. to v. cs.
	0.0			X				9		grn., moist, ang. to subrounded grns., hard, competent, poorly sorted.
	0.0									
1141								330		

Initial Core Recovery failed on 1/26/02; Overdrilled 1' more ~~foot~~ AWN to 331' on 1/29/02 and recovered 6' of core (325'-331' bgs)

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Date & Time	PID (ppm)	Cored Interval	Recovered	Retained for Analysis	Bedding*	Fractures**	RQD	Depth (Feet)		Geologic Description
1/29/02										
(1120) (1316) 1/30/02								1		
	0.0						5.5/6	2	SS	331.5 – 337'bgs: SANDSTONE (SS), med. gray (N5), fn. to v. cs. grn., ~~trace granules (2-4 mm), trace pebbles (4-8 mm)~~, angular to subrounded grains, v. moist to wet, hard, competent; some bedding laminations visible @ 336 – 337'bgs (dip 35°); grades without granules and pebbles @ 336'-337'bgs.
(1319) 0850	0.0						92%	3		
	0.0							4		
	0.0							5		
	0.0				35 / 35			6		
0855 0905	0.0						3/3	7	SS	337' – 340'bgs: SANDSTONE (SS), med. gray (N5), fn. to v. cs. grn., ang. to subrnded grns., v. moist to wet, hard, poorly sorted, competent;
	0.0						100%	8		Bedding lamination/contact visible @ 339.3'bgs; Some granules (2-4 mm) and pebbles ~~immediately~~ @ below bedding lamination/contact but grades ~~out downward~~ without pebbles @ ~339.6 – 340'bgs. AWW
	0.0 / 0.0				30			9		
0910 0932								340	SS	340' – 343.5'bgs: SANDSTONE (SS), med. gray (N5), fn. to v. cs. grn., ang. to subrounded grns., v. moist to wet, poorly sorted, hard, competent.
	0.0						5/5	1		
	0.0						100%	2		Trace local granules (2-4 mm) and pebbles (4-10 mm) @ ~342.5'bgs.
	0.0				30			3	Pebbly SS	343.5' – 344.2'bgs: PEBBLY SANDSTONE (SS), med. gray (N5), fn. to v. cs. grn. sand, some granules (2-4 mm), ~~some~~ pebbles (4-10 mm), angular to subrounded grains, poorly sorted, v. moist to wet, hard, competent.
	0.0				35			4	SS	344.2'bgs – 345'bgs: SS, med. gray (N5), fn. to v. cs. grn, trace granules (2-4 mm), poorly sorted, ang. to subrounded grns., v. moist to wet, hard, competent.
0937 1010								5		~~345' – 349'bgs:~~ SANDSTONE (SS), med. gray (N5), fn. to very coarse grn., poorly sorted, some fn. to med. grn interbeds (med. sorting), v. moist, hard, competent, ang. to subrnded grns.
	0.0				30		5.5/5.5	6		
	0.0 / 0.0						100%	7		
	0.0							8		Single Flat shale pebble (rip-up clast) @ 348.8'bgs (50mm-long), within SS matrix.
	0.0 / 0.0							9		349' – 350.5'bgs: SS, med. gray (N5), fn. to v. cs. grn, trace granules (2-4 mm), trace local pebbles (4-20 mm), poorly sorted, angular to subrounded grains, v. moist,
	0.0 / 0.0							350		

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Date & Time	PID/(ppm)	Cored Interval	Recovered	Retained for Analysis	Bedding*	Fractures**	RQD	Depth (Feet)		Geologic Description
11/30/02 1015 1034	0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0						4.5/4.5, 100%	350–355	SS	AWN 350.5 - 355' bgs: SANDSTONE (SS), med. gray (N5), fn. to v. cs. grn., trace granules (2-4 mm), poorly sorted, ang. to subrounded grains, v. moist to wet, hard, competent, massive. Individual Shale rip-up clast @ 354.2' bgs (45 mm-long), in SS matrix.
1040 1058	0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0						5/5, 100%	355–360	SS	355 - 360' bgs: SANDSTONE (SS), med. gray (N5), fn. to v. cs. grn., trace granules (2-4 mm), poorly sorted, angular to subrounded grns, v. moist to wet, hard, competent; Coarser inter-layer @ 357.5' - 358.1' bgs: Some granules (2-4 mm) and pebbles (4-10 mm) in SS matrix.
1102 1120	0.0, 0.0, 0.0, 0.0						5/5, 100%	360–365	SS	SANDSTONE (SS), med. gray (N5), ~~moist to v. moist~~ fn. to v. cs. gn w/ trace granules (2-3 mm) @ 360' - 360.3' bgs; fn. to cs. grn. @ 360.3' - 362' bgs; fn. to v. cs. grn w/ trace granules (2-4 mm) @ 362' - 363.8' bgs; fn. to v. cs. grn w/ some granules ~~and~~ (2-4 mm) and some pebbles (4-8 mm) @ 363.8 - ~~365~~ 364.5' bgs; fn. to ~~v.~~ cs. grn. @ 364.5 - 365' bgs; angular to subrounded grns., moist to v. moist, hard, competent.
1127 1252	0.0, 0.0, 0.0, 0.0, 0.0				35	60/75	5/5, 100%	365–370	SS	365' - 370' bgs: SANDSTONE (SS), med. gray (N5), fn. to cs. grn., poorly sorted, ang. to subrounded grns., moist to wet, hard, competent. Some convoluted laminations @ 366.3' bgs. Bedding lamination @ 366.5' bgs dips 35°. Two healed fractures @ 368.2' bgs dip 60° and 75° respectively. Fractures are hairline to 1 mm wide w/ white mod. soft mineral filling (likely calcite). The two fractures intersect at upper end.
1300								370		

QA/QC 10-00

Boring #: MW#: C8 Project: Boeing Rocketdyne SSFL-CFOU Investigation- Former Sodium Disposal Facility

Date & Time	PID/OVA (ppm)	Cored Interval	Recovered	Retained for Analysis	Bedding*	Fractures**	RQD	Depth (Feet)		Geologic Description
11/30/02 1320 – 1332	0.0, 0.0, 0.0, 0.0, 0.0, 0.0	370–375	370–375				5/5 100%	370–375	SS	370'-375' bgs: SANDSTONE (SS), med. gray (N5), fn. to v. cs. grn., trace local granules (2-4 mm), poorly sorted, ang. to subrounded grains, v. moist to wet, hard, competent, massive. Individual Shale rip-up clast observed @ 372.3' bgs (20 mm-long) in SS matrix.
1345 – 1356	0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0	375–380	375–380		30 (at 378)		5/5 100%	375–380	SS	375'-380' bgs: SANDSTONE (SS), med. gray (N5), fn. to v. cs. grn., trace granules (2-4 mm), poorly sorted, ang. to subrounded grains, moist to wet, hard competent. Bedding lamination visible @ 378' bgs dips 30°.
1402 – 1406	0.0, 0.0, 0.0, 0.0, 0.0	380–385	380–385				5/5 100%	380–385	SS	380'-382' bgs: SANDSTONE (SS), med. gray (N5), fn. to v. cs. grn., ~~an. peb~~ trace granules (2-4 mm), trace local pebbles (4-10 mm), poorly sorted, v. moist to wet, hard, competent, massive. 382'-385' bgs: SS, med. gray (N5), fn. to cs. grn., moderate to poor sorting, v. moist to wet, ang. to subrounded grns, hard, competent, massive.
1435 – 1439	0.0, 0.0, 0.0, 0.0, 0.0	385–390	385–390		30, 30 (at ~388)		5/5 100%	385–390	SS	385'-387.8': SANDSTONE (SS), med. gray (N5), fn. to v. cs. grn., trace granules (2-4 mm), poorly sorted, ang. to subrounded grains, moist to v. moist, hard, competent.
									SH	387.8'-388.4' bgs: SHALE (SH), med. gray (N5) to med. dark gray (N4), laminated, fissile, friable, mod. soft, moist to v. moist.
									SS	SANDSTONE (SS), med. gray (N5), v. fn. to med grain w/convoluted lams @ 388.4'-389' bgs; fn. to cs. grn @ 389'-389.4' bgs; fn. to v. cs. grn. w/ trace Shale rip-up clasts (up to 25 mm); angular to subrnd. grns, poorly sorted, moist to v. moist.

Boring #: MW#: C8 Project: Boeing Rocketdyne SSFL - CFOU Investigation - Former Sodium Disposal Facility

Date & Time	PID (ppm)	Cored Interval	Recovered	Retained for Analysis	Bedding*	Fractures**	RQD	Depth (Feet)		Geologic Description
5/1/02 945		↑	↑						SS	SANDSTONE(SS), med. gray (N5), fn. to cs. grn., poorly sorted, ang. to subrounded grns., v. moist to wet, hard, competent.
	0.0			X			5/5	1		
	0.0			X	30				SH/SLTS	Interbedded SHALE (SH), SILTSTONE (SLTS) and SANDSTONE (SS), med gray (N5)
	0.0				30		100%	2	SS	to med. dark gray (N4), some convoluted laminations, moist to v. moist
	0.0				30					SS: fn to cs. grn., poor to med. sorting, hard; SLTS: hard; SH: med. soft, fissile, friable.
	0.0			X				3	SS	SH is the med. dk. gray component; Thin to laminated bedding.
	0.0									392.2'-395.5' bgs: SANDSTONE (SS), med. gray (N5), v. moist to wet,
	0.0							4		hard, competent; 392.2'-393' bgs: v.fn. to med.
	0.0			X						grn., some convoluted laminations @ 392.2'-392.6' bgs;
0950	0.0	↓	↓					5		393'-394.2' bgs: fn. to cs. grn., some local shale rip-up clasts up to 40 mm-long, poorly sorted.
1026		↑	↑	X						394.2-395.5' bgs: fn. to med. grn., mod. sorting, basal shale rip-up clasts.
	0.0			X	35		5/5	6		
	0.0			X	35				SH/SS	Interbedded SHALE (SH) and SANDSTONE (SS), med. gray (N5), ~~moist to wet, some convoluted laminations;~~
	0.0						100%	7		SS: fn. to v. cs. grn, poorly sorted, ang. to subrnd. grns., hard; SH: fissile, friable, med. soft, laminated.
	0.0			X					SS	SANDSTONE (SS), med. gray (N5), fn. to v. cs. grn, trace granules (2-4 mm), poorly sorted, ang. to subrounded grns; moist to wet,
	0.0			X				8		hard, competent.
	0.0			X					SH/SLTS	~~Interbedded SHALE (SH) and SILTSTONE (SLTS); moist; SLTS: med gray~~ (N5), hard; SH: med. dark gray (N4), moist, fissile, friable,
	0.0			X				9		laminated; some convoluted laminations; thin to laminated bedding.
	0.0			X					SS	SANDSTONE (SS), med. gray (N5), v. moist, hard, competent
1032		↓	↓					400		fn. to v. cs. grn, poorly sorted, angular to subrounded grns.
										Bottom of Hole @ 400' bgs.
								1		
								2		
								3		
								4		
								5		
								6		
								7		
								8		
								9		
								0		

TABLE A-98

LITHOLOGIC LOG OF MONITOR WELL RD-21

DEPTH INTERVAL (feet)		DESCRIPTION OF MATERIAL
0 - 5	SANDY CLAY	Dark brown, low plasticity, very slightly moist, no odor.
5 - 27	SANDSTONE	Yellow-brown, fine-grained, well sorted, non-calcareous, slightly moist, no odor. From 9 to 15 feet, trace fine gravel.
27 - 30	SILTSTONE	Blue-grey with calcareous cement, with fine-grained sandstone, slightly moist, no odor.
30 - 100	SANDSTONE	Grey, fine-grained, moderately to well sorted, subrounded to subangular, calcareous, moderately cemented, slightly moist. At 45 feet, grey and brown. At 50 feet, primarily brown. At 60 feet, moderately moist, no calcite cement, continued brown. At 70 feet, slightly fine-grained. At 75 feet, grey and brown. At 80 feet, grey. At 95 feet, brown.
100 - 110	SHALE	Grey and brown, some siltstone, moderate moisture. At 105 feet, higher moisture.
110 - 175	SANDSTONE	Grey, fine-grained, some siltstone and shale, moderately to well sorted, subrounded to subangular, moderate moisture.

TABLE A-98
(continued)
LITHOLOGIC LOG OF MONITOR WELL RD-21

DEPTH INTERVAL (feet)	DESCRIPTION OF MATERIAL
110 - 175 cont'd	At 120 feet, dark grey, high moisture content.
	At 140 feet, well producing approximately 1 gpm.

TOTAL DEPTH OF BOREHOLE: 175 FEET

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TABLE A-100

LITHOLOGIC LOG OF MONITOR WELL RD-23

DEPTH INTERVAL (feet)	DESCRIPTION OF MATERIAL	
0 - 4	SANDY CLAY	Medium brown, low plasticity, fine-grained, very slightly moist, no odor.
4 - 9	SANDSTONE	Yellow-brown, fine-grained, well sorted, non-calcareous, slightly moist, no odor.
9 - 30	SILTSTONE	Blue-grey with calcareous cement, with fine sand interlayers, slightly moist, no odor.
		From 11 to 15 feet, yellow-brown sandstone.
30 - 140	SANDSTONE	Grey, fine-grained, moderately to well sorted, subrounded to subangular, calcareous, moderately cemented, moderate moisture content.
		From 60 to 65 feet, some siltstone.
		From 115 to 140 feet, some siltstone.
		At 130 feet, increased moisture.
140 - 160	SILTSTONE	Grey, moderately cemented, moderate to high moisture content.
160 - 210	SANDSTONE	Grey, fine-grained, moderately to well sorted, subrounded to subangular, moderately cemented, moderate to high moisture content.
		From 209 to 210 feet, possible fracture, brown, clayey, high moisture content.
210 - 225	SHALE	Grey-brown, moderately cemented, moderate moisture content.
		At 220 feet, color changes to grey.
225 - 415	SANDSTONE	Grey, fine-grained, moderately to well sorted, subrounded to subangular, moderately cemented, moderate moisture content.
		From 270 to 280 feet, some siltstone.

TABLE A-100
(continued)
LITHOLOGIC LOG OF MONITOR WELL RD-23

DEPTH INTERVAL (feet)	DESCRIPTION OF MATERIAL	
225 - 415 (con't)		From 340 to 345 feet, slightly coarser. From 380 to 385 feet, some shale, moderate to high moisture content.
415 - 420	SHALE	Dark grey, calcareous, moderately cemented, moderate moisture content.
420 - 440	SANDSTONE	Grey, fine-grained, moderately to well sorted, subrounded to subangular, calcareous, moderately cemented, moderate moisture content.

TOTAL DEPTH OF BOREHOLE: 440 FEET

TABLE A-110

LITHOLOGIC LOG OF MONITOR WELL RD-33A

DEPTH INTERVAL (feet)	DESCRIPTION OF MATERIAL	
0 - 3	SILTY SAND	Brown, trace clay, medium grained, moderately sorted, subangular, to subrounded, loose, slight plasticity, no cementation, dry, no odor.
3 - 30	SANDSTONE	Buff, trace silt, fine grained, moderate to well sorted, dense, non-calcareous, weak to moderate cementation, dry, no odor. From 3 to 5 feet weathered. At 10 feet moderate cementation.
30 - 320	SANDSTONE	Grey, some silt, trace clay, fine to medium grained, moderately sorted, subangular to subrounded, dense, calcareous, moderate to strong cementation, dry, no odor. At 35 feet color change to blue grey, strong calcareous cementation. At 85 feet slight increase in grain size, color change to grey. At 105 feet cementation decreases to moderate. From 125-130 feet color change to brown. At 130 feet color change to grey. From 140 to 145 feet some black claystone layers. From 155 to 160 feet some interbedded claystone. At 170 feet cementation becomes weak. From 170 to 180 feet some black claystone layers. At 180 feet slight increase in grain size.

TABLE A-110
(continued)
LITHOLOGIC LOG OF MONITOR WELL RD-33A

DEPTH INTERVAL (feet)	DESCRIPTION OF MATERIAL	
30 - 320 cont'd	SANDSTONE	From 185 to 190 feet some interbedded claystone. From 210 to 215 feet some brown sandstone. At 235 feet cementation becomes moderate, some coarse sand present. At 275 feet moisture content increases to slightly moist, some black claystone present. At 285 feet moisture content increases to moist. At 295 feet moisture content increases to wet. From 315 to 320 feet some clay present.

TOTAL DEPTH OF BOREHOLE: 320 FEET

TABLE A-111

LITHOLOGIC LOG OF MONITOR WELL RD-33B

DEPTH INTERVAL (feet)	DESCRIPTION OF MATERIAL	
0 - 2	SILTY SAND	Brown, trace clay, medium grained, moderately sorted, subangular, to subrounded, loose, slight plasticity, no cementation, dry, no odor.
2 - 38	SANDSTONE	Buff, trace silt, fine grained, moderate to well sorted, dense, non-calcareous, weak to moderate cementation, dry, no odor. Below 18 feet some medium and coarse grains. At 22 feet color change to light brown, moisture content increases to slightly moist. At 30 feet color change to grey brown.
38 - 455	SANDSTONE	Grey, some silt, trace clay, fine to medium grained, moderately sorted, subangular to subrounded, compact, calcareous, moderate cementation, slightly moist, no odor. At 82 feet becomes dry. At 85 feet strongly calcareous, cementation becomes strong. At 102 feet color change to brown, moderately calcareous cementation decreases to moderate. At 108 feet color change to grey-brown. At 128 feet predominantly fine-grained. At 140 feet strongly calcareous. At 150 feet color change to blue-grey. At 170 feet color change to grey-brown. At 175 feet color change to blue-grey.

TABLE A-111
(continued)
LITHOLOGIC LOG OF MONITOR WELL RD-33B

DEPTH INTERVAL (feet)	DESCRIPTION OF MATERIAL	
38 - 455 cont'd	SANDSTONE	From 175 to 180 feet some claystone present.
		At 232 feet silt and clay content increasing.
		At 260 feet slightly moist.
		From 282 to 283 feet water bearing fracture, producing 1 to 2 gpm on airlift, formation becomes wet.
		From 300 to 310 feet interlayers of brown clayey sandstone.
		At 320 feet cementation weak to moderate.
		Below 335 feet black claystone beds begin to appear.
		Below 345 feet white dolomitic vein filling.
		At 380 feet becomes finer grained.
		Below 395 feet cementation decreases to weak.
455 - 475	CLAYSTONE	Black, some interbedded sandstone, low to moderate plasticity, dense, non-calcareous, moderate cementation, wet, no odor.
		At 470 feet sandstone content increasing.
475 - 495	SANDSTONE	Blue-grey, some black claystone interlayers, fine to medium grained, well sorted, subangular, compact, non-calcareous, moderate cementation, wet, no odor.

TABLE A-111
(continued)
LITHOLOGIC LOG OF MONITOR WELL RD-33B

DEPTH INTERVAL (feet)	DESCRIPTION OF MATERIAL	
495 - 508	SANDSTONE WITH CLAYSTONE	Grey, with black claystone interlayers, fine-grained, moderately sorted, subangular, dense, non-calcareous, moderate cementation, wet, no odor. From 501 to 502 feet large water bearing fracture, yielding 75 to 100 gpm on airlift. At 505 feet sandstone content increasing, claystone interlayers decreasing.
508-678	SANDSTONE	Grey, some interbedded black claystone, fine to medium grained, moderately sorted, subangular, very dense, non-calcareous, moderate to strong cementation, wet, no odor. Below 518 feet claystone interbeds decreasing. At 521 feet fracture present. At 522 feet cementation decreases to moderate. Below 535 feet slight increase in grain size. From 605 to 610 feet some very fine to fine gravel present. From 620 to 630 feet some black claystone interlayers. At 645 feet small fracture. From 660 to 665 feet some black claystone interlayers.

TOTAL DEPTH OF BOREHOLE: 678 FEET[1/]

[1/] Borehole was cemented back to 415 feet during well completion

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TABLE A-112

LITHOLOGIC LOG OF MONITOR WELL RD-33C

DEPTH INTERVAL (feet)	DESCRIPTION OF MATERIAL	
0 - 3	SILTY SAND	Light brown, trace clay, fine to medium grained, moderately sorted, subangular, to subrounded, loose, slight plasticity, no cementation, dry, no odor.
3 - 25	SANDSTONE	Buff, trace silt, fine grained moderate to well sorted, compact, non-calcareous, weak cementation, dry, no odor. From 3 to 5 feet weathered. At 5 feet cementation becomes moderate.
25 - 350	SANDSTONE	Grey-brown, some silt, trace clay, fine to medium grained, moderately sorted, subangular, dense, calcareous, moderate to strong cementation, dry, no odor. At 50 feet slight increase in grain size, moderate cementation At 60 feet color change to blue grey, becomes strongly calcareous. At 82 feet moderate to strong cementation. From 100 to 115 feet slightly moist. From 115 feet becomes dry. From 125 to 130 feet color change to light brown, slight decrease in cementation. From 185-195 feet color change to light brown, decrease in cementation. From 240 to 250 feet very fine grained. At 302 feet water bearing fracture. Below 310 feet some thin claystone beds are present.

TABLE A-112
(continued)
LITHOLOGIC LOG OF MONITOR WELL RD-33C

DEPTH INTERVAL (feet)		DESCRIPTION OF MATERIAL
		Below 340 feet some coarse sand and very fine gravel is present.
350 - 370	SANDSTONE	Grey black, with interbedded claystone, trace gravel, medium grained, poorly sorted, subangular, moderate to strong cement, non-calcareous, wet, no odor.
		Below 365 feet claystone content decreases.
370 - 520	SANDSTONE	Grey, trace very fine gravel, fine to medium grained, well sorted, subrounded, compact, moderate cementation, non-calcareous, wet, no odor.
		At 375 feet cementation becomes weak.
		At 380 feet grain size becomes very fine to fine.
		At 415 feet cementation increases to moderate.
		At 422 feet water bearing fracture, doubles flow rate.
		At 430 feet becomes fine to medium grained.
		At 480 feet becomes finer grained, silty and calcareous.
		From 480 to 485 feet color change to brown.
		At 499 feet small fracture bearing water.
		At 505 feet becomes medium grained.

TOTAL DEPTH OF BOREHOLE: 520 FEET

GROUNDWATER RESOURCES CONSULTANTS, INC.

TABLE A-143

LITHOLOGIC LOG OF MONITOR WELL RD-50

DEPTH INTERVAL (feet)	DESCRIPTION OF MATERIAL	
0 - 4	SANDY CLAY	Dark brown, trace fine-grained sand, loose, low plasticity, slightly moist.
4 - 10	SILTY CLAY	Reddish brown, trace sand, compact, moderate plasticity, slightly moist.
10 - 195	SANDSTONE	Buff, trace silt, fine-grained, very slightly calcareous, poorly graded, subrounded, compact, weak cementation, slightly moist. @ 14' dense, moderate cementation. @ 22' grey brown, very calcareous, moderate to strong cementation, dry. @ 35' light brown, slightly calcareous. @ 56' slightly moist. @ 58' dry. @ 64' non-calcareous, silty. @ 82' grey brown, decreasing silt content, slightly coarser. @ 114' blue grey, very calcareous, strong cementation. @ 145' wet (first groundwater, 5-10 gpm). @ 160' groundwater production increases with depth. @ 168' cementation increasing. @ 190-193' weak cementation.

TOTAL DEPTH OF BOREHOLE = 195 FEET

TABLE A-151

LITHOLOGIC LOG OF MONITOR WELL RD-54A

DEPTH INTERVAL (feet)		DESCRIPTION OF MATERIAL
0 - 12	SANDSTONE	Brown, some silt and clay, poorly graded, subrounded, compact, moderate cementation, slightly calcareous, dry.
		@ 4' blue grey, dense, moderate to strong cementation.
12 - 14	CLAYSTONE	Brown, some sand, compact, low plasticity, weak cementation, noncalcareous, dry.
14 - 278	SANDSTONE	Blue grey, some silt and clay, fine to medium grained, poorly graded, rounded, dense, moderate to strong cementation, slightly calcareous, dry.
		@ 16' slightly moist.
		@ 26' clay content decreasing, becoming more calcareous.
		@ 32' dry.
		@ 36' light grey.
		@ 44' fine grained.
		@ 52' moist.
		@ 64' slightly moist.
		@ 75'-90' clayey.
		@ 96' dry.
		@ 120' slightly moist.
		@ 142' dry.
		@ 148' blue grey, very calcareous, fine grained, strong cementation.
		@ 176' slightly moist.
		@ 180' dry.
		@ 216'-217' thin, yellow brown bed.
		@ 218' blue grey.

TABLE A-151
(continued)
LITHOLOGIC LOG OF MONITOR WELL RD-54A

DEPTH INTERVAL (feet)	DESCRIPTION OF MATERIAL	
14 - 278 (cont'd)	SANDSTONE	@ 237' fracture.
		@ 238' moist.
		@ 246' slightly moist.
		@ 270'-278' fine to medium grained.

TOTAL DEPTH OF BOREHOLE = 278 FEET

TABLE A-152

LITHOLOGIC LOG OF MONITOR WELL RD-54B

DEPTH INTERVAL (feet)		DESCRIPTION OF MATERIAL
0 - 158	SANDSTONE	Light brown, some silt, fine to medium grained, some coarse sand, moderately to poorly graded, subrounded, compact, weak cementation, slightly calcareous, slightly moist.
		@ 4' grey, poorly graded, dense, moderate cementation, dry.
		@ 8-9' brownish grey, fractured, moist.
		@ 14' blue grey, moderate to strong cementation, moderately calcareous, moist.
		@ 18' olive grey, fine grained, subangular and subrounded, moist.
		@ 23' medium grey, very moist.
		@ 24' dense to very dense.
		@ 27' light grey, compact to dense, moderate cementation, slightly moist to moist.
		@ 32' slightly moist.
		@ 38' weak cementation.
		@ 48' moderate to poorly graded, some medium grained sand.
		@ 60' some silt.
		@ 84' none to weak cementation, dry to slightly moist.
		@ 90' weak cementation.
		@ 98' dry
		@ 102' dry to slightly moist.
		@ 108' none to weak cementation.
		@ 124' weak cementation.
		@ 128' weak to moderate cementation, slightly moist.
		@ 134' silty, fine grained sand, poorly graded.
		@ 138' moderate to strong cementation.

TABLE A-152
(continued)
LITHOLOGIC LOG OF MONITOR WELL RD-54B

DEPTH INTERVAL (feet)		DESCRIPTION OF MATERIAL
0 - 158 (cont'd)	SANDSTONE	@ 144' some silt, strong cementation, dry to slightly mois
		@ 148' moderate to strong cementation, slightly moist t moist.
		@ 154' moderately to poorly graded, weak to moderat cementation, dry to slightly moist.
		@ 156' loose to compact.
158 - 164	SILTSTONE	Light olive grey, sandy, clayey, fine grained sand, poor graded, compact to dense, moderate cementation, slight moist.
164 - 206	SANDSTONE	Light grey, medium grained, moderately to poorly grade subangular and subrounded, compact to dense, we cementation, dry.
		@ 168' dry to slightly moist.
		@ 178' weak to moderate cementation, slightly moist.
		@ 184' none to weak cementation, dry to slightly moi
		@ 188' weak cementation
		@ 194' no cementation
		@ 198' fine grained, poorly graded, weak cementati slightly moist.
		@ 205.5-206' fracture
206 - 218	SILTY SANDSTONE	Olive grey, clayey, very fine grained, compact, moderat strong cementation, moist.
		@ 208' light olive grey, strong cementation, moist slightly moist.
		@ 204' some clay
218 - 437	SANDSTONE	Silty, very fine grained, moderate cementation, moist
		@ 228' some silt, strong cementation.
		@ 238' wet

TABLE A-152
(continued)
LITHOLOGIC LOG OF MONITOR WELL RD-54B

DEPTH INTERVAL (feet)	DESCRIPTION OF MATERIAL	
218 - 437 (cont'd)	SANDSTONE	@ 240' fine grained, some silt, scattered medium grained sand.
		@ 244' increasing silt content.
		@ 246-278' no cuttings returned, no water in return.
		@ 278' olive grey, moderately to poorly graded, subangular and angular, compact, weak to moderate cementation, moist.
		@ 282' slightly clayey, strong cementation.
		@ 288' olive grey to light olive grey, fine grained, poorly graded.
		@ 300.5' very moist
		@ 305' olive grey, silty, slightly clayey.
		@ 308' no clay, less silt, moderately cemented.
		@ 312' loose to compact.
		@ 314' light olive grey to grey, compact, strong cementation, moist.
		@ 324' olive grey, slightly clayey.
		@ 358' moist to very moist.
		@ 368' moist
		@ 374' moist to very moist.
		@ 384' small increase in clay content, moist.
		@ 388' moist to very moist.
		@ 394' clay content decreases slightly.
		@ 398' dense, moderate to strong cementation, moist.

TABLE A-152
(continued)
LITHOLOGIC LOG OF MONITOR WELL RD-54B

DEPTH INTERVAL (feet)	DESCRIPTION OF MATERIAL	
218 - 437 (cont'd)	SANDSTONE	@ 404' more clay, compact to dense, strong cementation. @ 418' light olive grey, minor to no clay, moderate to strong cementation, slightly moist. @ 428' olive grey, trace clay, slightly moist to moist. @ 436' slightly moist to dry.

TOTAL DEPTH OF BOREHOLE = 437 FEET

TABLE A-153

LITHOLOGIC AND VIDEO CAMERA LOG SUMMARY OF MONITOR WELL RD-54C

LITHOLOGY			FRACTURES				
DEPTH (ft)		DESCRIPTION	DEPTH (ft) TOP	DEPTH (ft) BOTTOM	OPENNESS (inches)	TYPE	COMMENTS
0 - 620	SANDSTONE	Blue grey to tan, dry to slightly moist, very calcareous fine to medium grained.	4	5	?	?	filled with clay
		@ 12' blue grey.	22.2	24.6	?	structural	seepage @ 23.9-24.6'
		@ 20-21' claystone, calcareous, moist, blue grey.	40.2	41.8	closed	structural	
		@ 28-28.5' siltstone interbed.	56.5	58.2	thin	structural	filled
		@ 90' formation becomes harder with depth.					minor seepage @ 179.5'
		@ 142-156' clayey matrix.	183.5	185.5	1/16-1/2	structural	multiple fractures
		@ 216-234' clay content increases.					static water @ 187'
		@ 230' drill cuttings drying out.	201.6	202.4	thin/closed	structural	
		@ 278-290' increasing clay content.	218	218	0-1/16	bedding plane	minor seepage @ 218'
		@ 310-326' very calcareous.	296	296	0-1/16	structural	
		@ 332-340' some claystone interbeds.	301	304	0-1/16	structural	
		@ 410' silty matrix, slightly calcareous.	327	327	filled	structural	
		@ 420' air-lift discharge rate less than 1 gpm.	405	405	0-1/16	structural	
		@ 430-460' poor cuttings return, discharge system plugging.	417	417	0-1/16	bedding plane	
		@ 478-498' increasing clay content.	426	426	0-1/16	structural	
		@ 500-520' silty sandstone, very fine to fine grained, strongly calcareous, light grey, dry to slightly moist.	429	—	0-1/16	structural	vertical fracture
		@ 520' sandstone is light grey, fine grained,	514	514	0-1/16	bedding plane	
			516	516	0-1/16	structural	
			583	583	0-1/16	structural	

TABLE A-153
(continued)
LITHOLOGIC AND VIDEO CAMERA LOG SUMMARY OF MONITOR WELL RD-54C

LITHOLOGY			FRACTURES				COMMENTS
DEPTH (ft)	DESCRIPTION		DEPTH (ft) TOP	DEPTH (ft) BOTTOM	OPENNESS (inches)	TYPE	
0 - 620	SANDSTONE	@ 540' slight increase in moisture, noticeable decrease in dust. @ 548' silty matrix.@ 580' increase in clay/silt content. @ 583' increase in moisture. @ 596' borehole producing 1-2 gpm during drilling operations. @ 607' increase in moisture. @ 620' decrease in silt/clay content.					
TOTAL DEPTH OF BOREHOLE: 620 FEET			TOTAL VIDEO LOG DEPTH: 597 FEET				

NOTE: Sandstone throughout borehole is predominately massive and fine to medium grained.

The initial video log of the RD-54C borehole was conducted on July 16. The log was relatively clear and the static water level was 187 feet. Unfortunately, the logging contractor's tape system malfunctioned and a copy of the video log tape could not be reproduced. However, detailed notes describing lithology and fractures were compiled during the video logging. After completion of packer testing, the borehole was video logged again on July 18. Unfortunately, the second log was not as clear as the initial log below a depth of 250 feet. The video log summary presented was developed from field notes prepared during the initial video logging and from review of the upper 250 feet of the second video log.

TABLE A-157

LITHOLOGIC AND VIDEO CAMERA LOG SUMMARY OF MONITOR WELL RD-57

LITHOLOGY			FRACTURES				COMMENTS
DEPTH (ft)	DESCRIPTION		DEPTH (ft) TOP	DEPTH (ft) BOTTOM	OPENNESS (inches)	TYPE	
3-380	Silty Sandstone	Light yellow brown, fine grained, some medium grained, slightly micaceous, moderately graded, dense to very dense, moderate cementation, non-calcareous, slightly moist.	24			bedding plane?	
			26			bedding plane	
			27			bedding plane	
			28			bedding plane	
			29			bedding plane	
		@ 10' moderately to well graded.	44			bedding plane	
			64.1	64.6	1/8	structural?	
		@ 16' moderately graded, dense.	64.9	65.4	1/16	structural	
			69.7	70.0		bedding plane?	
		@ 18' some coarse sand, well graded, moderately to strongly calcareous.	70.5	70.9	1/16 - 1/8	structural?	
			84.6	85.1	1/8	structural?	
			87.6	93.9	0 - 1/8	structural	fracture zone
			101.5	101.8	0 - 1/16	structural	
		@ 20' fine grained, poorly graded, slightly clayey, low plasticity, non-calcareous to weakly calcareous, moderate cementation, slightly moist to moist.	108.6	111.1	0 - 1/8	structural	fracture zone
			114.3	115.0	0 - 1/16	structural	fracture zone
			123.4	124.2	0 - 3/16	structural	fracture zone
			136.4	137.1	closed	structural	
			150.6	151.1?	1/8	structural	
		@ 28' No clay, moderately to poorly graded, moderately calcareous, slightly moist.	152.4	154.4	0 - 3/16	structural	fracture zone
			179.5	180.1	closed	structural?	
		@ 31' very silty, poorly graded.	207.8	208.6	1/16 - 1/4	structural	fracture zone
			209.7	211.0	0 - 1/16	structural?	fracture zone?
		@ 32' very fine grained, very silty, clayey, moderate plasticity, moderate to strong cementation, strongly calcareous, harder, dry.	211.3	212.7	1/16 - 1/8	structural	fracture zone
			213.3	213.7	1/8 - 3/4	structural	largest fracture
			217.3	218	0 - 1/16	structural?	
			231.4			bedding plane?	
		@ 41' very pale brown, clay absent or minor, no plasticity, moderate to strong cementation.	232.4	233.6	1/16	structural	
			238.1	240.0		stratigraphic	blebs
			242.8	244.3		bedding plane?	
		@ 46' light yellow brown.	249.0			bedding plane?	
			267.4	269.1		bedding plane?	
			270.1			bedding plane?	
		@ 50' moderate cementation, moderately to strongly calcareous, slightly moist.	270.5	272.5	0 - 1/4	structural	fracture zone
			273.6	274.4		stratigraphic	blebs or bedding
			281.4	281.9	closed	structural	
		@ 55' moderate to strong cementation, strongly calcareous, damp.	283.4	283.7?	closed	structural	
			285			bedding plane?	
			286.2	287.0	closed	structural?	
		@ 58' very pale brown, predominantly fine grained, some medium grained, moderately to poorly graded, dry.	296.8	297.3	closed	structural	
			308.2	308.6		bedding plane?	

TABLE A-157
(continued)
LITHOLOGIC AND VIDEO CAMERA LOG SUMMARY OF MONITOR WELL RD-57

LITHOLOGY			FRACTURES				
DEPTH (ft)		DESCRIPTION	DEPTH (ft) TOP	DEPTH (ft) BOTTOM	OPENNESS (inches)	TYPE	COMMENTS
3-380 cont'd	Silty Sandstone	@ 72' slightly moist to moist.	314.4	314.7		bedding plane	
		@ 74' light grey, some medium grained sand, moderately to poorly graded, dense to very dense, strong cementation, slightly moist.	322.0	322.3		bedding plane?	
		@ 78' light brown grey, no to low plasticity.	329.1	329.5		bedding plane?	
		@ 82' light grey, no clay, poorly graded, dense, no plasticity, moderate cementation.	330.5	330.8		bedding plane?	
		@ 89' light yellow brown, moist.	332.7	333.2		bedding plane?	
		@ 91' light grey, minor clay, no to low plasticity.	336.8	337.1	0 - 1/16	structural	
		@ 96' no clay, no plasticity, moderate to strong cementation.	343.2	343.8	0 - 1/16	structural	
		@ 97' slightly moist to moist.	347.0	347.4		bedding plane	
		@ 102' slightly moist.	349.4?	351.8?	1/16 - 1/8	structural	filled, steep
		@ 109' dry.	352.6	352.9	0 - 1/16	structural	filled
		@ 114.5' light yellow brown, slightly clayey, compact to dense, low plasticity, moderate cementation, slightly moist to moist.	355.7?	356.6	1/16	structural	filled, steep
		@ 120' light grey, dense, no plasticity, moderate to strong cementation.	360.1			bedding plane?	
		@ 122' slightly harder, dense to very dense.	360.9	361.3		bedding plane?	ravelled (partially)
		@ 130' slight increase in moisture.	361.7				No water seepage observed above static water level at 361.7
		@ 141' moisture decreases.	363.0		0 - 1/16	structural?	murky below water surface, filled
		@ 149' very strongly calcareous, strong cementation, dry.	364.3		0 - 1/16	structural	filled
			364.6			bedding plane	
			365.8	366.4?	0 - 1/16	structural	filled
			366.9	367.2	0 - 1/16	structural	filled
			368				water somewhat clearer

TABLE A-157
(continued)
LITHOLOGIC AND VIDEO CAMERA LOG SUMMARY OF MONITOR WELL RD-57

LITHOLOGY		FRACTURES				COMMENTS
DEPTH (ft)	DESCRIPTION	DEPTH (ft)		OPENNESS (inches)	TYPE	
		TOP	BOTTOM			
3-380 cont'd	@ 154' grey, slightly moist to moist.					
	@ 156' slightly clayey, low plasticity.					
	@ 160' less silty, moderately to strongly calcareous, dense, no plasticity, moist.					
	@ 166' strongly calcareous.					
	@ 180' slightly moist.					
	@ 181' moist.					
	@ 190' trace of clay, no to low plasticity, moderately calcareous.					
	@ 193' slight decrease in moisture.					
	@ 196' no clay, some medium grained sand, moderately to poorly graded, no plasticity, strongly calcareous.					
	@ 200' light grey, very fine grained, very silty, minor clay, poorly graded, no to low plasticity, moderately calcareous.					
	From 204 to 205.5' clayey, strongly calcareous, dry.					
	@ 205.5' slightly moist.					
	@ 210' grey.					
	@ 217' dry, no plasticity.					
	@ 219' slightly moist, no to low plasticity.					
	@ 226' damp, no plasticity.					
	@ 230' slightly moist.					

TABLE A-157
(continued)
LITHOLOGIC AND VIDEO CAMERA LOG SUMMARY OF MONITOR WELL RD-57

LITHOLOGY			FRACTURES				COMMENTS
DEPTH (ft)		DESCRIPTION	DEPTH (ft) TOP	DEPTH (ft) BOTTOM	OPENNESS (inches)	TYPE	
3-380 cont'd		@ 236' clayey, low to medium plasticity, damp.					
		@ 240' no to low plasticity.					
		@ 243' dry.					
		@ 250' damp, no plasticity.					
		@ 256' slightly moist.					
		@ 270' slightly moist to moist.					
		@ 272' moist.					
		@ 274' damp.					
		@ 275' slightly moist, low plasticity.					
		@ 308' no to low plasticity, moderate cementation, moderately to strongly calcareous, slightly moist to moist.					
		@ 316' moderately calcareous, no plasticity.					
		@ 328' moderately to strongly calcareous.					
		@ 340' moderate to strong cementation, strongly calcareous.					
		@ 350' moderate cementation, moderately to strongly calcareous.					
		From 357 to 359' fractures.					
		From 357 to 358' dry.					
		@ 358' slightly moist to moist.					
		From 365 to 375' no cutting returns.					

TABLE A-157
(continued)
LITHOLOGIC AND VIDEO CAMERA LOG SUMMARY OF MONITOR WELL RD-57

LITHOLOGY			FRACTURES				COMMENTS
DEPTH (ft)	DESCRIPTION		DEPTH (ft) TOP	DEPTH (ft) BOTTOM	OPENNESS (inches)	TYPE	
380-419	Sandstone	Fine to medium grained, slightly silty, moderately graded, subangular and subrounded, dense, weak to moderate cementation, weakly calcareous, damp. @ 386' very silty, fine grained only, poorly graded, clayey, moderate cementation, moderately to strongly calcareous, slightly moist. @ 390' strongly calcareous. @ 396' moderate plasticity. @ 400' some medium grained sand, trace of coarse, possibly less silt, weakly to moderately calcareous. @ 406' non-calcareous to weakly calcareous. From 410 to 415' some silty and sandy claystone layers.	381 390.8 412 415.5 417.2	 391.3		 bedding plane? stratigraphic bedding plane?	visibility decreases bit marks? blebs bottom

TOTAL DEPTH OF BOREHOLE: 419 | **TOTAL VIDEO LOG DEPTH: 419**

TABLE A-168

LITHOLOGIC LOG OF MONITOR WELL RD-64

DEPTH INTERVAL (feet)	DESCRIPTION OF MATERIAL	
0 - 5	CLAYEY SAND	Dark brown, fine to medium grained sand, compact, low plasticity, no cementation, moist.
5 - 21	SILTY SANDSTONE (weathered)	Tan, fine-grained, some medium to coarse grained, moderately graded, dense, no plasticity, weak to moderate calcareous cementation, slightly moist. @ 13' dry, color changing to yellowish grey and grey, density increasing, slightly calcareous. @ 15' grey, moderately graded, dense to very dense, no plasticity, moderate cementation, slightly calcareous dry. @ 19' yellow grey, slightly moist.
21 - 398	SILTY SANDSTONE	Medium grey, dry, fine grained, dense to very dense, contains some medium and coarse grained sand. @ 37' light grey, slight increase in grain size, calcareous. @ 45' possible fractures. @ 50' coarse sand to gravel sized clasts, very dense. @ 68' coarse sand. @ 70' finer grained. @ 82' slightly coarser grained, calcareous. From 111 to 113', very dense, hard. From 132 to 140', very light grey, very dense and hard, calcareous. @ 140' light grey, slightly calcareous. @ 160' some very coarse sand grains. From 166 to 173', possible fracture zone. @ 172' very slightly moist. From 182 to 184', light grey, very coarse sand, some fine gravel clasts, slightly moist.

TABLE A-168
(continued)
LITHOLOGIC LOG OF MONITOR WELL RD-64

DEPTH INTERVAL (feet)	DESCRIPTION OF MATERIAL	
21 - 398 (cont'd)	SILTY SANDSTONE	@ 188' very fine to fine grained.
		@ 196' dry.
		From 201 to 206', decreased density.
		@ 248' very dense and hard, calcareous.
		@ 255' very light grey, fine to medium grained, very slightly moist.
		@ 264' possible fracture.
		@ 270' light grey, increased silt content.
		@ 273' Yellowish grey, fine to medium grained, calcareous.
		@ 276' light grey.
		@ 294' very dense and hard.
		@ 360' slightly moist.
		@ 370' dry.
		@ 375' very dense and hard.
		@ 380' increase to medium grained, slightly moist.
		@ 382' possible fracture.
		@ 386' dry.
		@ 390' very light grey, very fine to fine grained.
		@ 398' dry.

TOTAL DEPTH OF BOREHOLE: 398 FEET

TABLE A-169

LITHOLOGIC AND VIDEO CAMERA LOG SUMMARY OF MONITOR WELL RD-65

LITHOLOGY			FRACTURES				COMMENTS
DEPTH (ft)		DESCRIPTION	DEPTH (ft) TOP	DEPTH (ft) BOTTOM	OPENNESS (inches)	TYPE	
0 - 5	SANDY CLAY	Dark brown, firm, dry.					
5-397	SANDSTONE	Light yellow brown, dry, fine to very coarse grained, dense, noncalcareous.	26.5	27.5	0 - 1/8	Structural	Borehole walls muddy to 212 feet.
			28.9			Bedding?	
			36.0	36.5		?	
		@ 20' some very light grey sandstone, harder.	38.0			Bedding	
			42.0			Bedding?	
		@ 23' dense.	45.1			?	
			59.3		0 - 1/16	Structural	Fracture?
		@ 24' very dense, hard, light grey, calcareous.	62.6			?	
			63.9			Bedding	
		@ 40' calcareous to noncalcareous.	74.5			Structural?	Small open fractures? or mud cake cracks.
			102.2			Structural?	Small open fractures? or mud cake cracks.
		@ 43' some yellow brown sandstone with mudstone partings.	114.7			Bedding?	
			116.6			Bedding	
			158.8	159.2	0 - 1/16	Structural	Fracture?
		@ 45' very coarse grained, noncalcareous.	159.5	160.0	0 - 1/8	Structural	Fracture?
			163.1		0 - 1/16	Structural	
		@ 47' light grey and light yellow brown, very fine to fine grained, silty.					
		@ 50' light grey, calcareous, dense.					
		@ 63' medium to coarse grained; trace of mudstone.					
		From 71-75' light yellow brown, fine to medium grained.					
		@ 75' very light grey, very fine to fine grained, but some medium to coarse grained grains, contains some very dense, calcareous, very fine to fine grained silty sandstone.					
		@ 104' very fine to coarse grained.					
		@ 112' very fine to fine grained, silty.					

TABLE A-169
(continued)

LITHOLOGIC AND VIDEO CAMERA LOG SUMMARY OF MONITOR WELL RD-65

LITHOLOGY			FRACTURES				COMMENTS
DEPTH (ft)	DESCRIPTION		DEPTH (ft) TOP	DEPTH (ft) BOTTOM	OPENNESS (inches)	TYPE	
5-397 cont'd	SANDSTONE	@ 125' very calcareous.	164.3	164.6	0 - 1/16	Structural	Fracture?
			169.3			Bedding?	
		@ 142' fine to medium grained, calcareous, dense to very dense, very slightly moist.	170.5			Bedding?	
			172.1	172.5	0 - 1/16	Structural	Fracture?
			190.4			?	@ 185' walls mud-caked.
		@ 156' dry.	196.5				Mud cake cracks?
			207.5		0 - 1/16	Structural	Fracture parallel to bedding.
		@ 158' very coarse to coarse grained.	207.6			Bedding	
			209.5		0 - 1/8	Structural	Fracture or ravelling parallel to bedding.
		@ 159' soft zone (6"), moist.	210.7		0 - 1/16	Structural	As above.
			211	217		Bedding	@ 212' borehole walls cleaner.
		From 160-161' possible fracture, moist, very fine to medium grained.	218.2			Bedding	@ 218' borehole walls muddy.
			219	219.8		Bedding	
			229.4	230 ±	0 - 1/16	Structural?	
		@ 163' very slightly moist, fine to medium grained, silty.	250			Structural?	
			276.2		0 - 1/8	Structural	
			277.3		0 - 1/8	Structural	
		@ 166' dry.	285.2			Structural?	Small cavity?
			310.5			Structural?	
		From 171 to 172' sandy mudstone, brown grey, very fine to fine grained sand, calcareous.	312.2			Structural?	
			313.0			Structural?	
			314.3	315.2	0 - 1/4	Structural?	Fracture or ravelling parallel to bedding.
		@ 172' sandstone, very light grey, dense, very fine to coarse grained.	315.5		0 - 1/16	Structural	
			317.1		0 - 1/8	Structural?	Fracture or mud cake cracks.
			319.5		0 - 1/16	Structural	
		@ 178' medium to coarse grained.	335.6		0 - 1/16	Structural	
			340.2		0 - 1/16	Structural?	Fracture or mud cake crack.
		@ 185' very hard and dense, fine to very coarse grained, noncalcareous.					
		@ 190' noncalcareous to slightly calcareous.					
		@ 197' calcareous.					
		@ 204' very fine to fine grained, silty.					
		From 207 to 208' silty interbed grades to mudstone, soft.					

TABLE A-169
(continued)
LITHOLOGIC AND VIDEO CAMERA LOG SUMMARY OF MONITOR WELL RD-65

LITHOLOGY			FRACTURES				COMMENTS
DEPTH (ft)	DESCRIPTION		DEPTH (ft) TOP	DEPTH (ft) BOTTOM	OPENNESS (inches)	TYPE	
5-397 cont'd	SANDSTONE	From 209 to 210' soft zone or possible fracture; sandy mudstone, medium brown grey, slightly moist to moist. @ 211' silty sandstone, light grey, very fine to fine grained, dense, dry. @ 216' sandstone, light grey, very fine to coarse grained, calcareous, very dense. From 220' to 222' mudstone interbed, brown grey, trace of black asphalt or terry. @ 222' sandstone, fine to coarse grained, light grey, very dense, calcareous. @ 228' predominantly medium grained. @ 246' slightly moist to very slightly moist. @ 256' moist, fine to medium grained, dense. @ 270' slightly moist. From 274.5 to 277.5' soft, possibly a fracture zone, moist. @ 279' some thin interbeds of brown grey mudstone partings or interbeds; sandstone is very fine to fine grained, medium light grey, calcareous, some silt, slightly moist. @ 292' very slightly moist to slightly moist. @ 299' coarse to medium grained. From 305 to 305.5' soft zone, possibly a fracture or silt interbed, slightly moist.					

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TABLE A-169
(continued)
LITHOLOGIC AND VIDEO CAMERA LOG SUMMARY OF MONITOR WELL RD-65

LITHOLOGY			FRACTURES				COMMENTS
DEPTH (ft)		DESCRIPTION	DEPTH (ft)		OPENNESS (inches)	TYPE	
			TOP	BOTTOM			
5-397 cont'd	SANDSTONE	From 316 to 317' possible fracture, moist, soft zone, very fine to medium grained, increase in silt, moist. From 319 to 322' very dense and hard, fine to coarse grained, very slightly moist to dry. @ 323' slight increase in moisture, decrease in grain size, decrease in density. @ 325' increase in density, dry to very slightly moist. @ 338' slightly moist. @ 345' very dense and hard. @ 354' very slightly moist to dry. @ 369' dense and hard. @ 376' dry. @ 383' fine to coarse grained.					@ 348.1' static water level. Camera did not log beneath water level. No visibility below.

TOTAL DEPTH OF BOREHOLE: 397'

TOTAL VIDEO LOG DEPTH: 348.2'

TABLE B-2
RD-91 ROTARY DRILLING DATA
BOEING SANTA SUSANA FIELD LABORATORY
VENTURA COUNTY, CALIFORNIA

Logged By: Chris Brooks / Eric Pigati
Boring Number/Location: RD-91
Length, Kelly: 10 ft. Rods: 20 ft. Collars:
Type/Diameter of Bit: 6 in. Hammer

Client: Boeing - SSFL ETEC
Drilling Co: WDC Exploration
Subs: 5.7 ft. Bit: 0.5
Drilling Fluid: Air

Job No: 26411-019
Height of K.B.: Date Started: 03/11/04
Rig Type: Speedstar 30K Date Finished: 03/12/04

Depth (feet)	Time		Color	Moisture Content (Air Rotary)	Sample	Description	Maximum Size (in.)	Particle Size Distribution %					Sorting			Grain Shape				Apparent Density					Plasticity				Odor Gas, etc (Air Rotary)	Reaction w/ HCL			
	Begin	End						Boulders	Cobbles	Gravel	Sand	Silt & Clay	Well	Medium	Poor	Angular	Subangular	Rounded	Subrounded	Very Loose	Loose	Compact	Dense	Very Dense	None	Low	Medium	High		None	Weak	Moderate	Strong
0																																	
																													None				
5			7.5YR 5/2	sl. moist	x	very dark brown loamy soil, clayey SILT																											
											5	95	x									x			x								
			5YR 3/2			at 8' transitions into dark reddish brown																											
						WEATHERED SANDSTONE below 10'																											
10				sl. moist	x	becoming harder from 13-15'																											
											90	10		x								x			x							x	
15			10YR 6/4	sl. moist	x	light yellowish brown, WEATHERED SANDSTONE	1/24																										
						primarily fine sand with silt to 20'					90	10		x								x			x							x	
20			10YR 5/6	sl. moist	x	SANDSTONE, fine to medium grained																											
											90	10		x									x		x							x	
25			10YR 5/6	sl. moist	x	SANDSTONE, light brown, fine to medium grained	1/16																										
						slightly moist, trace silt					95	5		x									x		x							x	

Total Depth of Borehole (feet): 140 ft.
Groundwater, Depth Encountered: ~100 ft.
Static Water Level: 80 ft.

TABLE B-2
RD-91 ROTARY DRILLING DATA
BOEING SANTA SUSANA FIELD LABORATORY
VENTURA COUNTY, CALIFORNIA

Logged By: Chris Brooks
Boring Number/Location: RD-91
Length: Kelly: 10 ft. Rods: 20 ft. Collars:
Type/Diameter of Bit: 6 in. Hammer

Client: Boeing - SSFL ETEC
Drilling Co: WDC Exploration
Subs: 5.7 ft. Bit: 0.5 Height of K.B.:
Drilling Fluid: Air

Job No: 26411-019
Date Started: 03/11/04
Rig Type: Speedstar 30K Date Finished: 03/12/04

Depth (feet)	Time		Color	Moisture Content (Air Rotary)	Sample	Description	Maximum Size (in.)	Particle Size Distribution %					Sorting			Grain Shape				Apparent Density					Plasticity				Odor Gas, etc (Air Rotary)	Reaction w/ HCL			
	Begin	End						Boulders	Cobbles	Gravel	Sand	Silt & Clay	Well	Medium	Poor	Angular	Subangular	Rounded	Subrounded	Very Loose	Loose	Compact	Dense	Very Dense	None	Low	Medium	High		None	Weak	Moderate	Strong
30			10YR 5/6	sl. moist	x	SANDSTONE, light brown, fine to medium grained	1/16				95	5		x					x				x		x								x
						slightly moist, some silt																							None				
35			2.5Y 5/2	sl. moist	x	SANDSTONE, color change to grayish brown,					95	5		x					x				x		x								x
						slightly moist, predominantly fine to medium grained, with some coarse																											
						at 8' transitions into dark reddish brown																											
						WEATHERED SANDSTONE below 10'																											
40			GL2 5/1	sl. moist	x	SANDSTONE, bluish gray, fine to coarse grained, slightly moist	1/8				95	5		x					x				x		x							x	
						predominantly fine to medium grained																											
						thin mudstone partings from 42-43'																											
						possible healed bedding plane fracture ~42.8'																											
						faint oxidation staining below to ~46'																											
45			GL2 5/1	sl. moist	x	SANDSTONE, fine to medium grained, bluish gray, slightly moist					95	5		x					x				x		x								x
50			GL2 5/1	sl. moist	x	SANDSTONE, bluish gray, fine to medium grained, slightly moist	1/16				95	5		x					x				x		x							x	
55			GL2 5/1	sl. moist	x	same as above, moisture content increasing slightly					95	5		x					x				x		x							x	

Total Depth of Borehole (feet): 140 ft.
Groundwater, Depth Encountered: ~100 ft.
Static Water Level: 80 ft.

TABLE B-2
RD-91 ROTARY DRILLING DATA
BOEING SANTA SUSANA FIELD LABORATORY
VENTURA COUNTY, CALIFORNIA

Logged By: Chris Brooks	Client: Boeing - SSFL ETEC		Page 3 of 5
Boring Number/Location: RD-91	Drilling Co: WDC Exploration		Job No: 26411-019
Length, Kelly: 10 ft. Rods: 20 ft. Collars:	Subs: 5.7 ft. Bit: 0.5	Height of K.B.:	Date Started: 03/11/04
Type/Diameter of Bit: 6 in. Hammer	Drilling Fluid: Air	Rig Type: Speedstar 30K	Date Finished: 03/12/04

Depth (feet)	Time: Begin	Time: End	Color	Moisture Content (Air Rotary)	Sample	Description	Maximum Size (in.)	Boulders	Cobbles	Gravel	Sand	Silt & Clay	Well	Medium	Poor	Angular	Subangular	Rounded	Subrounded	Very Loose	Loose	Compact	Dense	Very Dense	None	Low	Medium	High	Odor Gas, etc (Air Rotary)	None	Weak	Moderate	Strong
	Time							Particle Size Distribution %					Sorting			Grain Shape				Apparent Density					Plasticity					Reaction w/ HCL			
	Begin	End																															
60			GL2 5/1	sl. moist	x	SANDSTONE, bluish gray, slightly moist					95	5	x						x				x		x						x		
						predominantly fine grained																							None				
65			GL2 5/1	sl. moist	x	SANDSTONE, bluish gray, slightly moist	1/20				95	5	x						x				x		x							x	
						predominantly fine grained																											
						at 8' transitions into dark reddish brown																											
						WEATHERED SANDSTONE below 10'																											
70			GL2 5/1	sl. moist	x	SANDSTONE, bluish gray, slightly moist					95	5	x						x				x		x								x
						predominantly fine grained with some medium grained																											
75			GL2 5/1	sl. moist	x	SANDSTONE, bluish gray, slightly moist	1/16				95	5	x						x				x		x						x		
						predominantly fine grained with some medium grained																											
80			GL2 5/1	sl. moist	x	SANDSTONE, bluish gray, slightly moist					95	5	x						x				x		x						x		
						predominantly fine grained with some medium grained																											
85			GL2 5/1	sl. moist	x	SANDSTONE, bluish gray, slightly moist	1/16				95	5	x						x				x		x								x
						predominantly fine grained with increase in medium grained																											
						slightly darker, increase in fines from 88-90'																											

Total Depth of Borehole (feet): 140 ft.
Groundwater, Depth Encountered: ~100 ft.
Static Water Level: 80 ft.

TABLE B-2
RD-91 ROTARY DRILLING DATA
BOEING SANTA SUSANA FIELD LABORATORY
VENTURA COUNTY, CALIFORNIA

Logged By: Chris Brooks
Boring Number/Location: RD-91
Length, Kelly: 10 ft. Rods: 20 ft. Collars:
Type/Diameter of Bit: 6 in. Hammer
Client: Boeing - SSFL ETEC
Drilling Co: WDC Exploration
Subs: 5.7 ft. Bit: 0.5 Height of K.B.:
Drilling Fluid: Air
Rig Type: Speedstar 30K
Page 4 of 5
Job No: 26411-019
Date Started: 03/11/04
Date Finished: 03/12/04

Depth (feet)	Time: Begin	Time: End	Color	Moisture Content (Air Rotary)	Sample	Description	Maximum Size (in.)	Particle Size Distribution %: Boulders	Cobbles	Gravel	Sand	Silt & Clay	Sorting: Well	Medium	Poor	Grain Shape: Angular	Subangular	Rounded	Subrounded	Apparent Density: Very Loose	Loose	Compact	Dense	Very Dense	Plasticity: None	Low	Medium	High	Odor Gas, etc (Air Rotary)	Reaction w/ HCL: None	Weak	Moderate	Strong
90			GL2 5/1	sl. moist	x	SANDSTONE, bluish gray, slightly moist	1/24				95	5	x																				
						predominantly fine grained, slight increase in moisture content													x				x		x							x	
						light and dark bluish gray banding from 90-105'																							None				
95			GL2 5/1	sl. moist	x	SANDSTONE, bluish gray, slightly moist																											
						predominantly fine grained, increase in medium grained					95	5	x						x				x		x							x	
						at 8' transitions into dark reddish brown																											
						WEATHERED SANDSTONE below 10'																											
100			GL2 5/1	moist	x	same as above, slightly darker gray due to increased moisture	1/16																										
											95	5	x						x				x		x							x	
105			GL2 5/1	sl. moist	x	same as above																											
						predominantly fine grained					95	5	x						x				x		x								x
110			GL2 5/1	moist	x	same as above	1/16																										
											95	5	x						x				x		x								x
115			GL2 5/1	moist	x	same as above																											
											95	5	x						x				x		x							x	

Total Depth of Borehole (feet): 140 ft.
Groundwater, Depth Encountered: ~100 ft.
Static Water Level: 80 ft.

TABLE B-2
RD-91 ROTARY DRILLING DATA
BOEING SANTA SUSANA FIELD LABORATORY
VENTURA COUNTY, CALIFORNIA

Logged By: Chris Brooks | Client: Boeing - SSFL ETEC
Boring Number/Location: RD-91 | Drilling Co: WDC Exploration | Job No: 26411-019
Length, Kelly: 10 ft. | Rods: 20 ft. | Collars: | Subs: 5.7 ft. | Bit: 0.5 | Height of K.B.: | Date Started: 03/11/04
Type/Diameter of Bit: 6 in. Hammer | Drilling Fluid: Air | Rig Type: Speedstar 30K | Date Finished: 03/12/04

Depth (feet)	Time		Color	Moisture Content (Air Rotary)	Sample	Description	Maximum Size (in.)	Particle Size Distribution %					Sorting			Grain Shape				Apparent Density					Plasticity				Odor Gas, etc (Air Rotary)	Reaction w/ HCL			
	Begin	End						Boulders	Cobbles	Gravel	Sand	Silt & Clay	Well	Medium	Poor	Angular	Subangular	Rounded	Subrounded	Very Loose	Loose	Compact	Dense	Very Dense	None	Low	Medium	High		None	Weak	Moderate	Strong
120			GL2 6/1	moist	x	SANDSTONE, bluish gray, moist	1/16				95	5	x						x				x		x							x	
						predominantly fine grained																							None				
125			GL2 6/1	moist	x	SANDSTONE, bluish gray, moist					95	5	x						x				x		x							x	
						predominantly fine grained																											
						at 8' transitions into dark reddish brown																											
						WEATHERED SANDSTONE below 10'																											
130			GL2 6/1	moist	x	SANDSTONE, bluish gray, moist	1/24				95	5	x						x				x		x								x
						predominantly fine grained																											
						increased fines below 130'																											
						predominantly mudstone from 132-138'																											
						very dark bluish gray, slightly moist																											
135			GL2 3/1	sl. moist	x	predominantly SANDSTONE from 138-140', but significant					70	30		x					x			x			x								x
						mudstone																											
140			GL2 3/1	sl. moist	x		1/24				85	15		x					x				x		x						x		

Total Depth of Borehole (feet): 140 ft.
Groundwater, Depth Encountered: ~100 ft.
Static Water Level: 80 ft.

TABLE A-29

LITHOLOGIC LOG OF MONITOR WELL RS-18

DEPTH INTERVAL (feet)	DESCRIPTION OF MATERIAL	
0 - 9.0	CLAYEY SAND	Brown, 2-inch layer of asphalt on surface, some red mottling; clay content decreasing with depth, no odor, damp. At 5.0 feet, light brown; trace fine pebbles.
9.0 - 13.0	SANDSTONE (CHATSWORTH FORMATION)	Yellow-brown, damp, weathered, friable; some siltstone interlayers, damp, no odor.

TOTAL DEPTH OF BOREHOLE: 13.0 FEET

TABLE A-34

LITHOLOGIC LOG OF MONITOR WELL RS-23

DEPTH INTERVAL (feet)	DESCRIPTION OF MATERIAL	
0 - 6.5	SILTY CLAY	Light brown, low plasticity, soft, slightly moist.
6.5 - 10.0	SILTY CLAY	Mottled light brown and light grey, moderately plastic, firm, slightly moist.
10.0 - 13.0	SILTY SAND (WEATHERED CHATSWORTH FORMATION)	Very light brown, cementation increasing with depth, slightly moist.
		At 13.0 feet, Chatsworth Formation.

TOTAL DEPTH OF BOREHOLE: 13.0 FEET

TABLE A-43

LITHOLOGIC LOG OF MONITOR WELL RS-54

DEPTH INTERVAL (feet)	DESCRIPTION OF MATERIAL	
0 - 38	SANDSTONE	Brown, some silt, fine to medium grained, poorly graded, subrounded, compact, moderate cementation, slightly calcareous, dry. @ 2' blue grey. @ 8' light brown. @ 10' blue grey. @ 18' brown, fractured and weathered, very fine to fine grained, silty, weak cementation. @ 26' blue grey, dry. @ 34' brown, silty and clayey, fractured, weak cementation, moist.

TOTAL DEPTH OF BOREHOLE = 38 FEET

Appendix A-B

Well Completion Logs

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Table 1
Corehole and Conductor Casing Construction Summary
Santa Susana Field Laboratory

Corehole Number	Corehole Location	Estimated Ground Elevation *	Begin Conductor Install	End Conductor Install	Begin Drilling	End Drilling	Borehole Diameter	Casing Diameter	Casing Type	Conductor Interval (feet)	Centralizers	Corehole Depth (feet)	Corehole Diamter (inches)
C8	FSDF	1835	4/18/02	4/18/02	4/15/02	5/1/02	12.25"	8" ID 8.5" OD	Mild Steel	0-65	~3' from bottom and 4' from top.(2 total)	400	5

* Feet above mean sea level
ID = Inside Diameter
OD = Outside Diameter

TABLE A-3
PIEZOMETER CONTRUCTION DETAILS

PIEZOMETER ID	LOCATION					PIEZOMETER DESIGN DETAILS						
	Area	SWMU	Northing	Easting	MPE Elevation	Date Drilled	Total Depth	Screened Interval	Sand Interval	Bentonite Interval	Grout Interval	Concrete Interval
			[feet]	[feet]	[feet]	[m/d/y]	[feet bgs]	[feet bgs]	[feet bgs]	[feet bgs]	[feet bgs]	[feet bgs]
PZ-096	II	Coca Rd W	265475.3	1787620.7	1766.30	4/21/2001	45.0	33.5-43.5	31-45	28-31	2-28	0-2
PZ-097	UDL	FSDF	267048.9	1783400.3	1761.87	10/15/2001	44.5	33-43	31-44.5	11.5-28	2-11.5	0-2
PZ-098	IV	FSDF	266788.9	1783488.8	1797.78	10/16/2001	37.5	24-34	21.5-37.5	19-21.5	2-19	0-2
PZ-099	IV	FSDF	266508.7	1783141.0	1819.57	10/17/2001	33	18-28	16-33	13.5-16	12-13.5	N/A
PZ-100	IV	FSDF	266078.3	1782962.2	1870.11	10/17/2001	16.5	5.67-15.67	4.67-16.5	2-4.67	N/A	0-2
PZ-101	IV	FSDF	266057.5	1783090.6	1869.71	10/17/2001	27	10-20	7-27	5-7	1.75-5	0-1.75
PZ-102	IV	Central Area IV	267080.8	1784684.4	1827.78	10/18/2001	59.2	48.5-59.2	45-59.2	43-45	2-43	0-2
PZ-103	IV	Central Area IV	266281.2	1784400.9	1815.93	10/22/2001	39	28.5-38.5	26-39	23.5-26	2-23.5	0-2
PZ-104	IV	Central Area IV	266270.2	1784924.2	1797.47	10/22/2001	38.5	18-28	16-30	13-16	2-13	0-2
PZ-105	IV	Central Area IV	265935.5	1784787.9	1803.87	10/23/2001	28	17-27	15-28	12-15	2-12	0-2
PZ-106	IV	EEL	266411.9	1785469.6	1784.17	10/23/2001	35	18-28	16-30.5	12.75-16	2-12.75	0-2
PZ-107	IV	Eastern Area IV	266876.4	1785822.0	1793.62	10/24/2001	11	5-10	4-11	2-4	N/A	0-2
PZ-108	IV	HMSA	268032.6	1785076.3	1763.01	10/24/2001	30	16-26	13-28.5	10-13	2-10	0-2
PZ-109	IV	Central Area IV	267332.4	1785248.2	1809.36	10/25/2001	36.5	25-35	22-36.5	19-22	2-19	0-2
PZ-110	IV	Eastern Area IV	267204.0	1786209.6	1818.90	10/25/2001	17.5	7-17	5-17.5	2-5	N/A	0-2
PZ-111	IV	Eastern Area IV	266948.4	1786433.9	1794.90	10/26/2001	20.0	7.5-17.5	5-20	N/A	N/A	N/A
PZ-112	IV	Eastern Area IV	267435.9	1786720.8	1829.14	10/26/2001	35.0	24-34	22-35	19-22	2-19	0-2
PZ-113	IV	Eastern Area IV	267682.9	1787367.8	1823.68	10/29/2001	15.0	7-15	5-15	2-5	N/A	0-2
PZ-114	IV	Old Con Yard S	268304.0	1787913.1	1818.19	10/30/2001	48.2	37-47	35-48.2	32-35	2-32	0-2
PZ-115	IV	Eastern Area IV	268006.8	1787536.5	1817.81	10/30/2001	40	25.5-37.5	25-40	22-25	2-22	0-2
PZ-116	UDL	RMHF	266501.1	1783693.0	1827.78	10/31/2001	34	22-32	20-34	17-20	2-17	0-2
PZ-117	I	Happy Valley	266712.9	1796184.6	1763.01	11/1/2001	25.5	14.5-24.5	12.5-25.5	9.5-12.5	2-9.5	0-2
PZ-118	I	B-1 Area	269389.4	1796988.7	1907.84	11/2/2001	30.0	19.5-29.5	16.5-30	13.5-16.5	2-13.5	0-2
PZ-119	Offsite	Sage Ranch	269025.4	1795863.3	1857.64	11/2/2001	44	33-43	30-44	27-30	2-27	0-2
PZ-120	IV	HMSA / SCTI	267230.1	1785009.7	1810.96	3/18/2003	26	15-25	12-26	9-12	2-9	0-2
PZ-121	IV	HMSA / SCTI	267491.6	1785120.7	1808.98	3/19/2003	33	15-25	12-28	8.4-12; 28-33	1.5-8.4	0-1.5
PZ-122	IV	HMSA / SCTI	267091.9	1785176.5	1810.80	3/19/2003	27.5	15.5-25.5	12-27.5	9-12	2-9	0-2
PZ-123	UDL	Happy Valley	264643.9	1797304.3	1610.81	3/20/2003	23.5	11.5-21.5	8.7-23.5	5.7-8.7	1-5.7	0-1
PZ-124	IV	B056 Landfill	267166.7	1784015.9	1764.11	3/21/2003	31	14.7-24.7	11.3-31	8.3-11.3	1-8.3	0-1
PZ-125	II	RD-9 Area	268357.1	1789379.4	1783.91	3/24/2003	41	23.5-33.5	20-34	16.5-20; 34-38	1.5-16.5	0-1

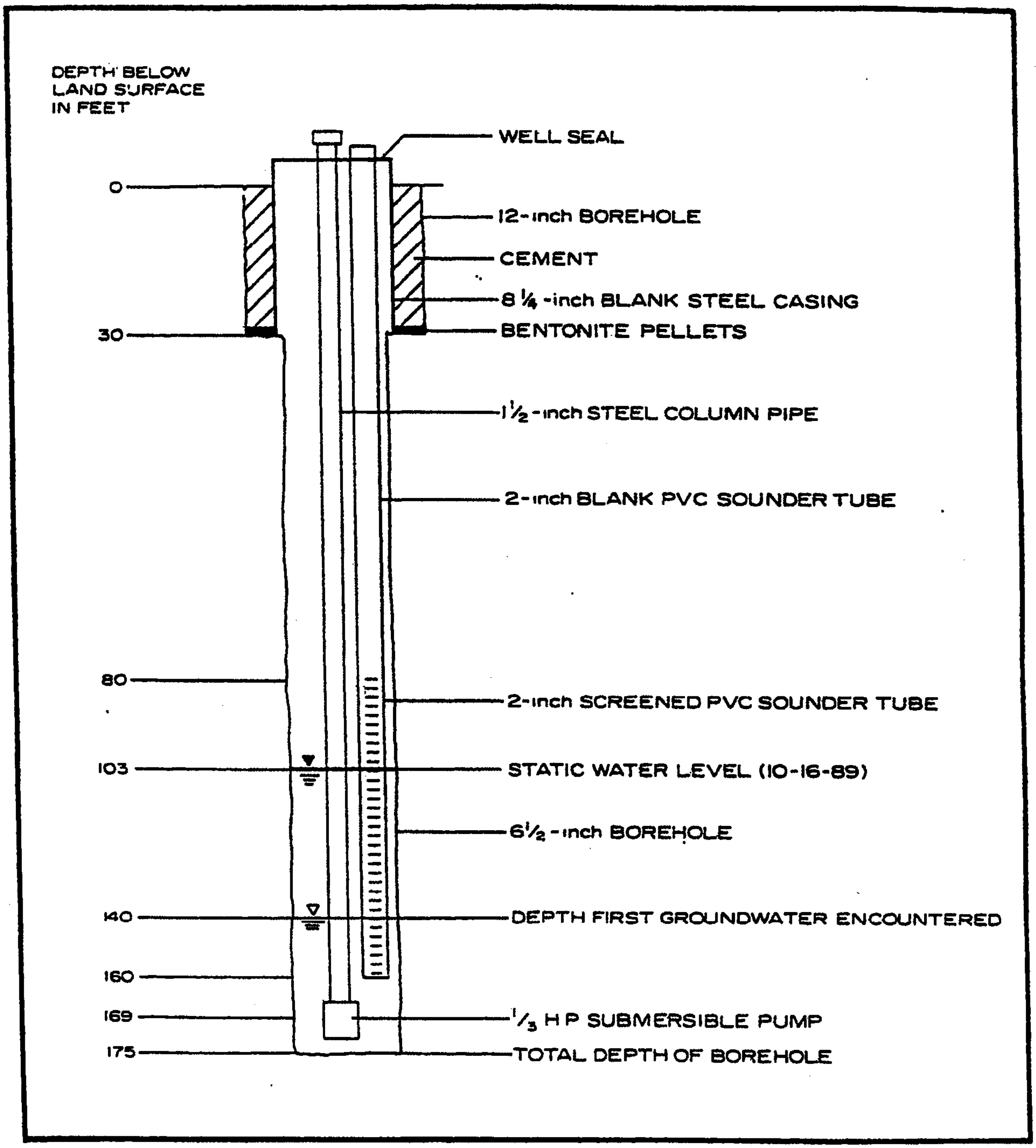


FIGURE E-23
SCHEMATIC DIAGRAM OF MONITOR WELL RD-21

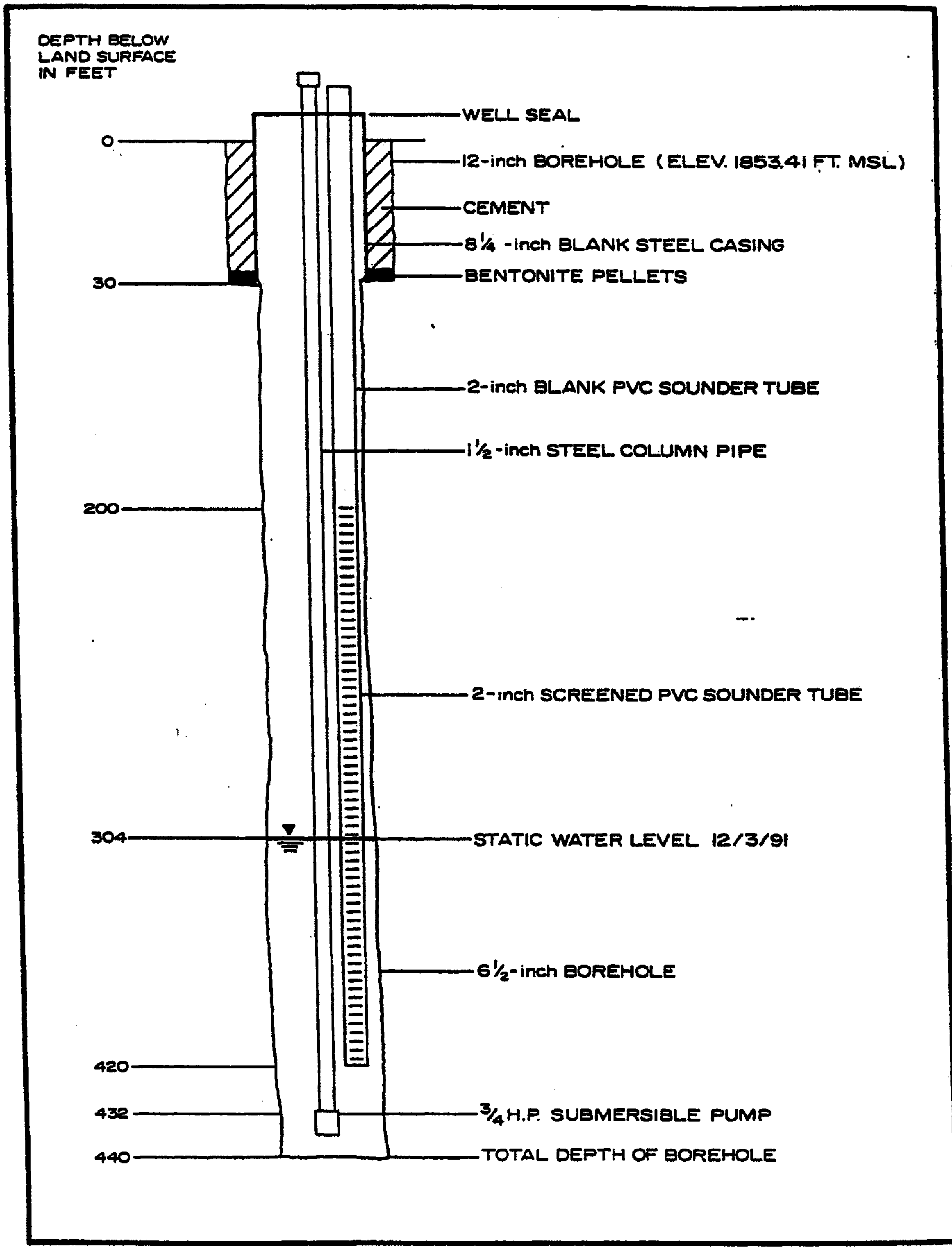


FIGURE E-24
SCHEMATIC DIAGRAM OF MONITOR WELL RD-22

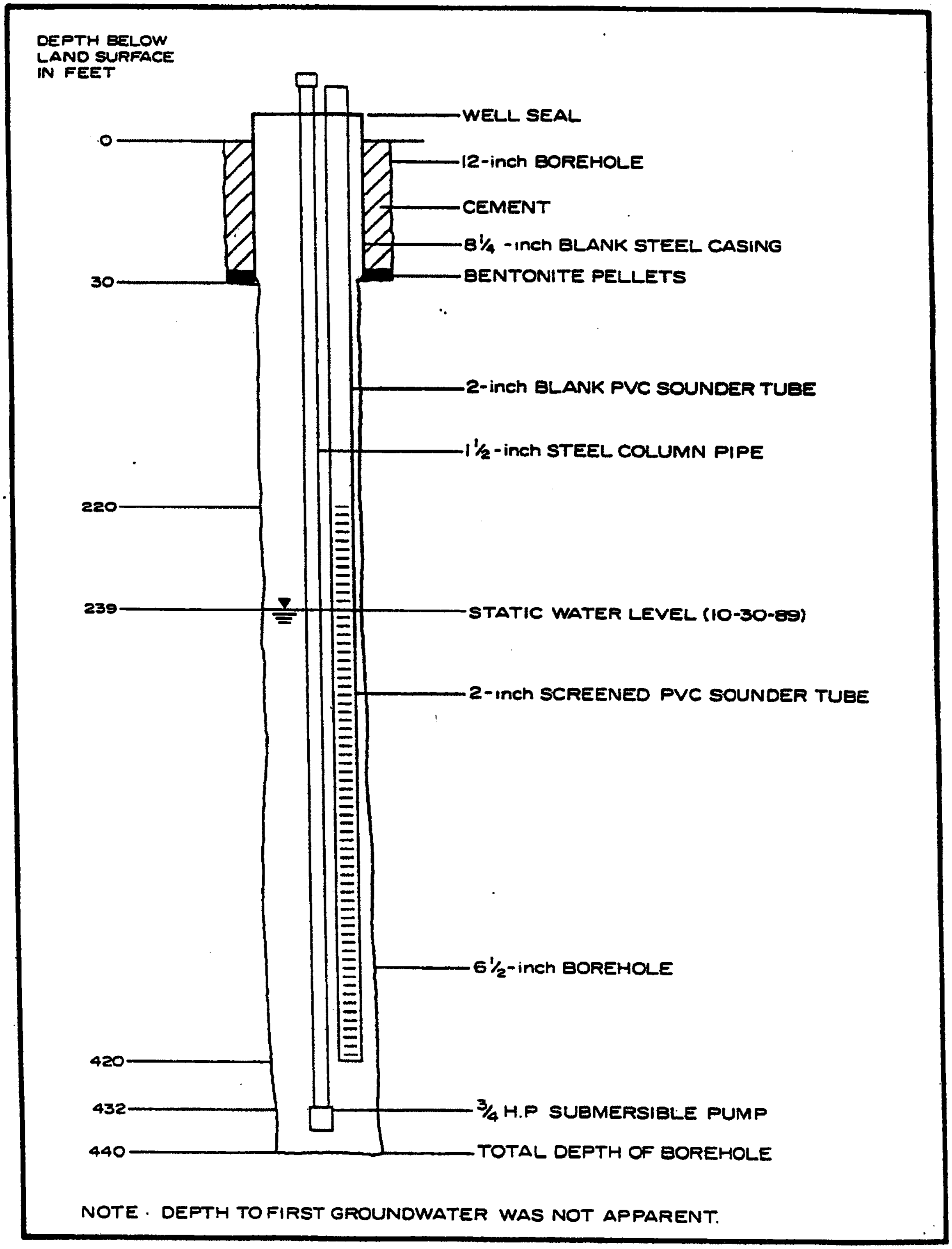


FIGURE E-25
SCHEMATIC DIAGRAM OF MONITOR WELL RD-23

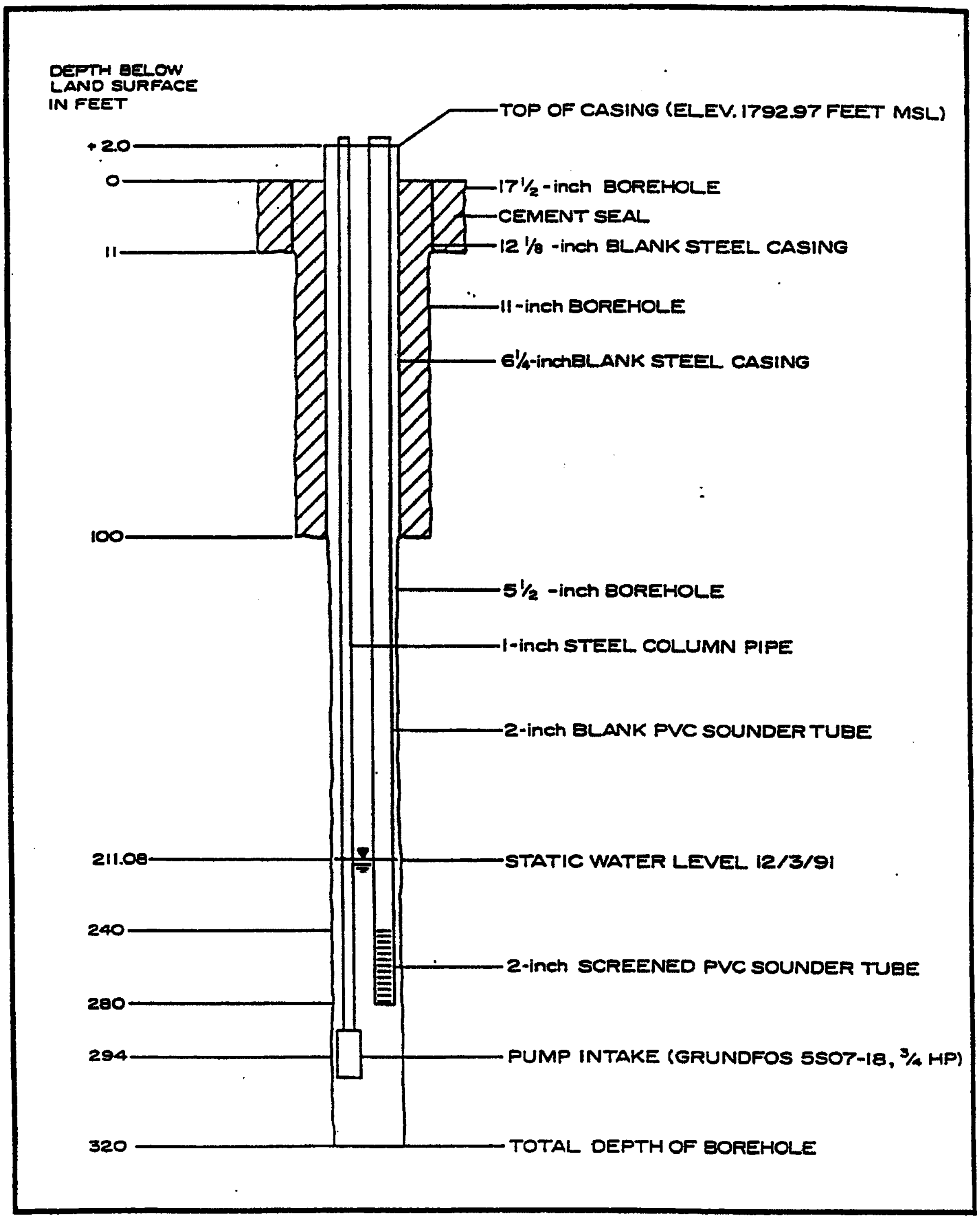


FIGURE E-35
SCHEMATIC DIAGRAM OF MONITOR WELL RD-33A

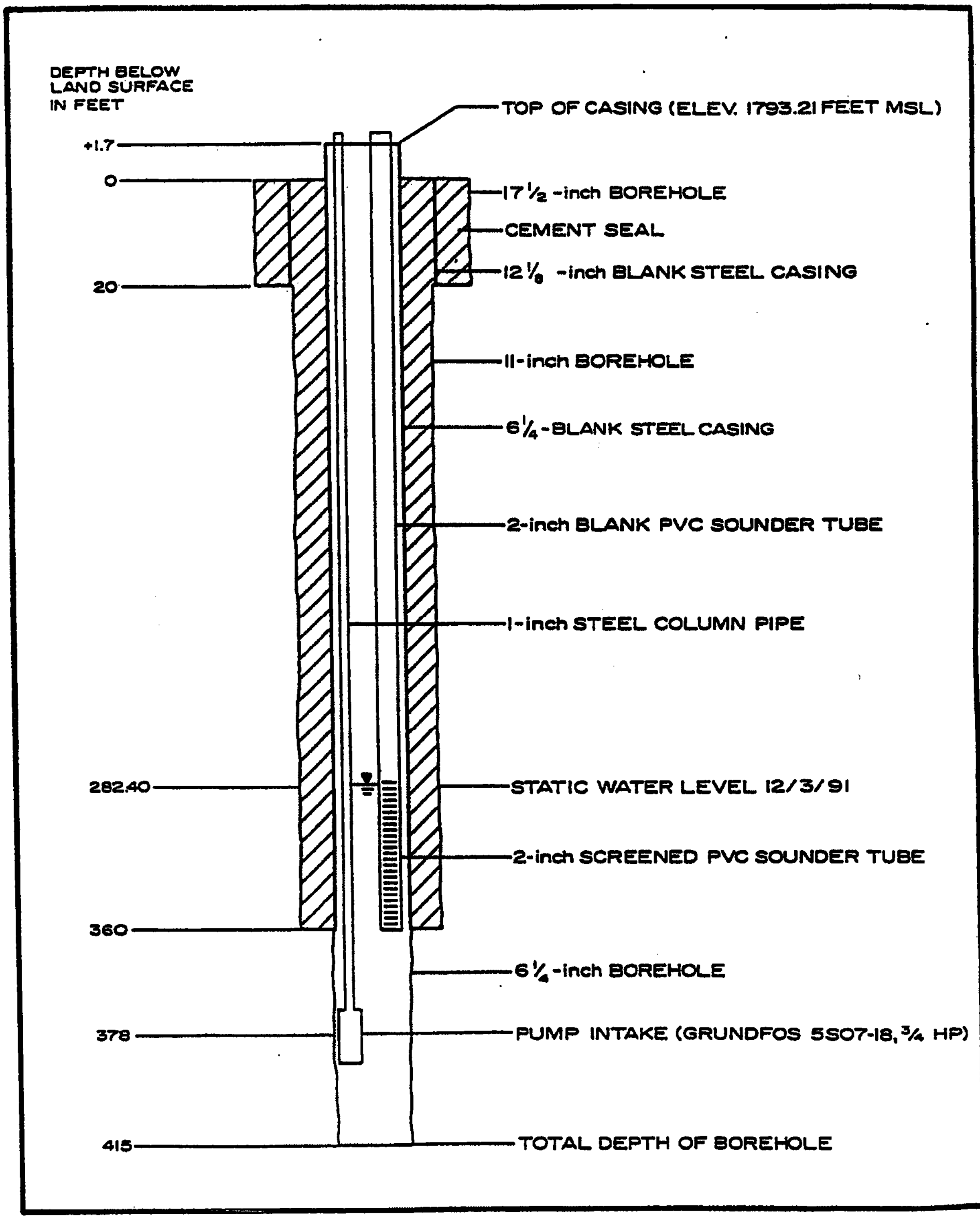


FIGURE E-36
SCHEMATIC DIAGRAM OF MONITOR WELL RD-33B

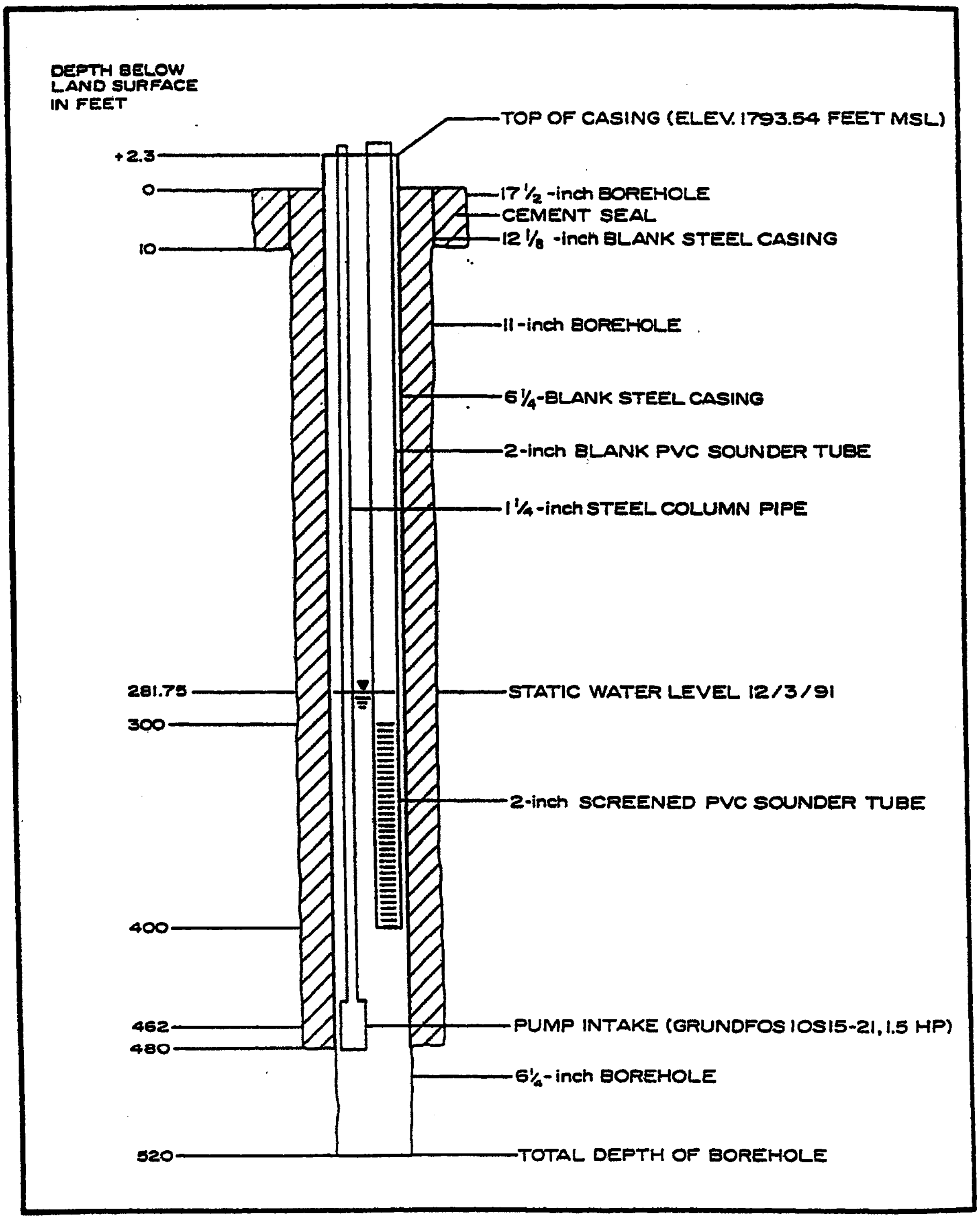


FIGURE E-37
SCHEMATIC DIAGRAM OF MONITOR WELL RD-33C

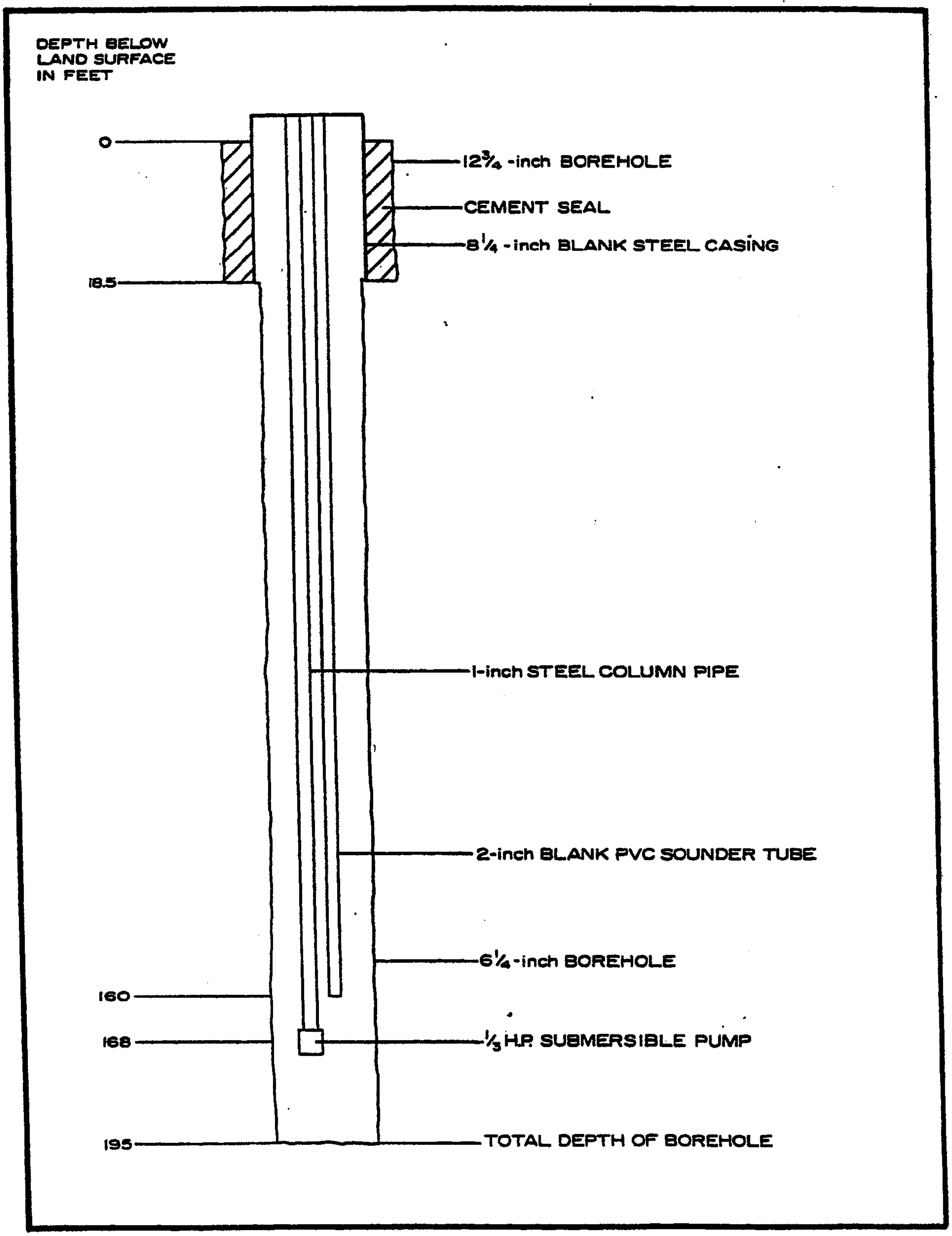


FIGURE E-68
SCHEMATIC DIAGRAM OF MONITOR WELL RD-50

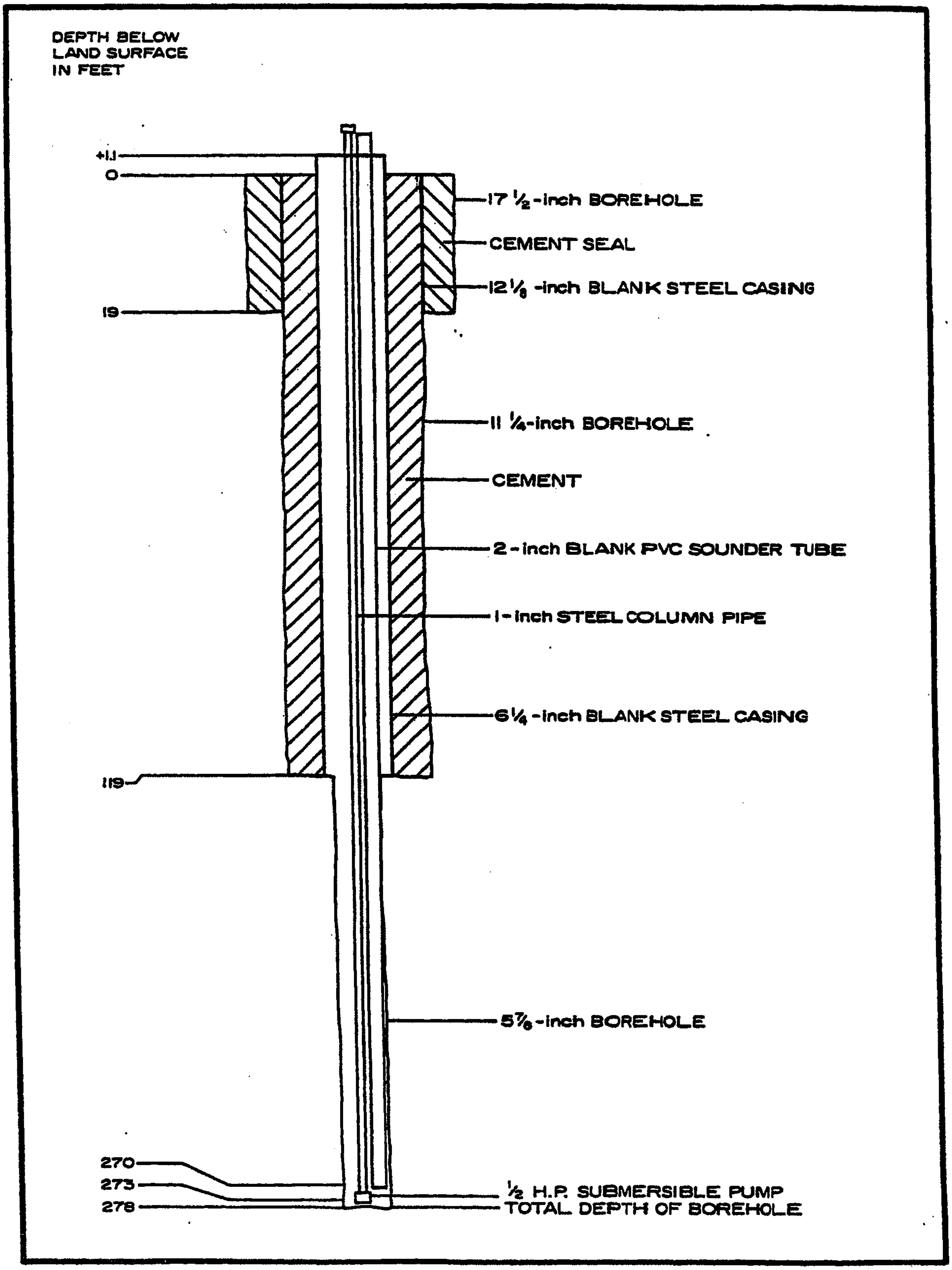


FIGURE E-76
SCHEMATIC DIAGRAM OF MONITOR WELL RD-54A

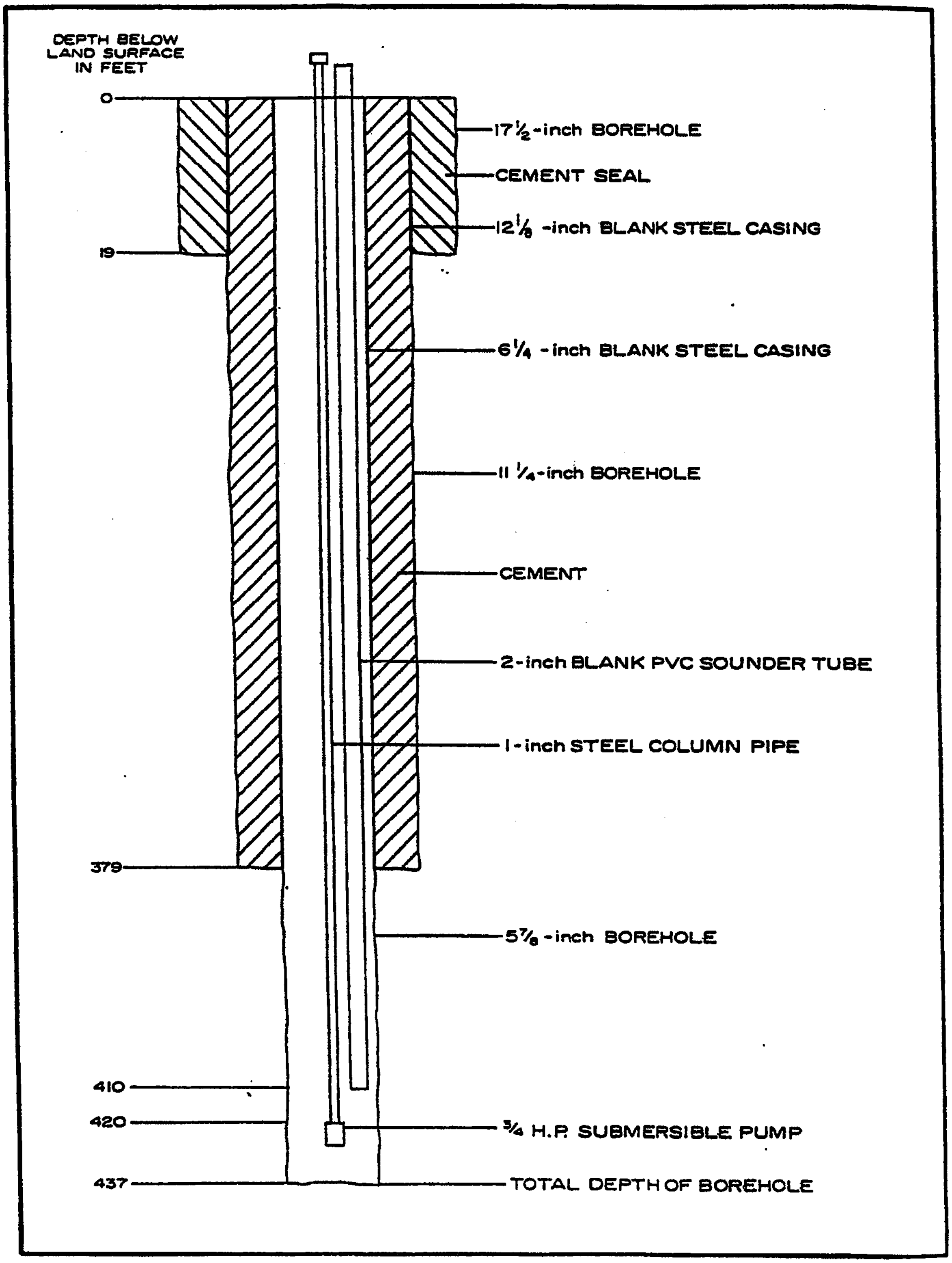


FIGURE E-77
SCHEMATIC DIAGRAM OF MONITOR WELL RD-54B

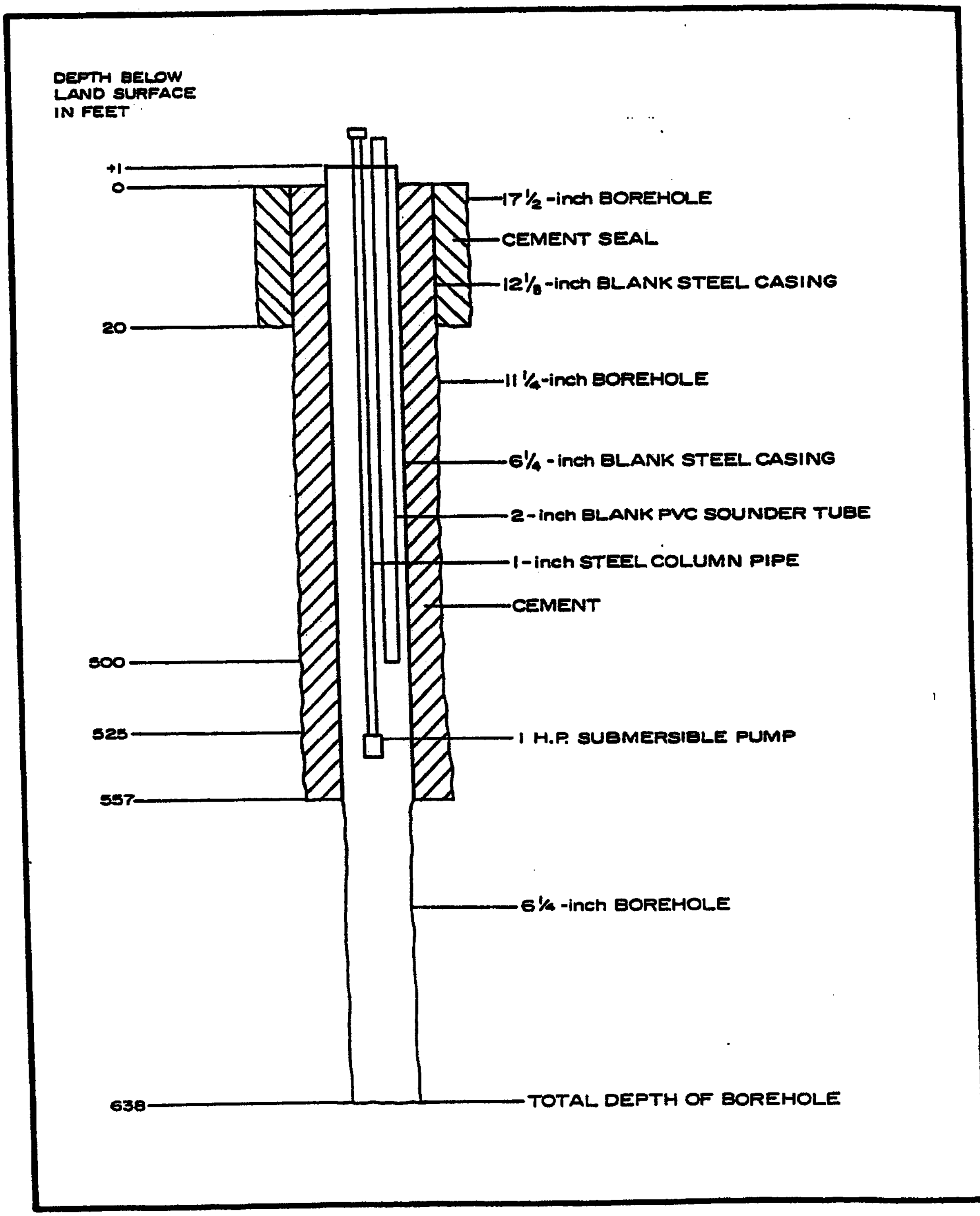


FIGURE E-78
SCHEMATIC DIAGRAM OF MONITOR WELL RD-54C

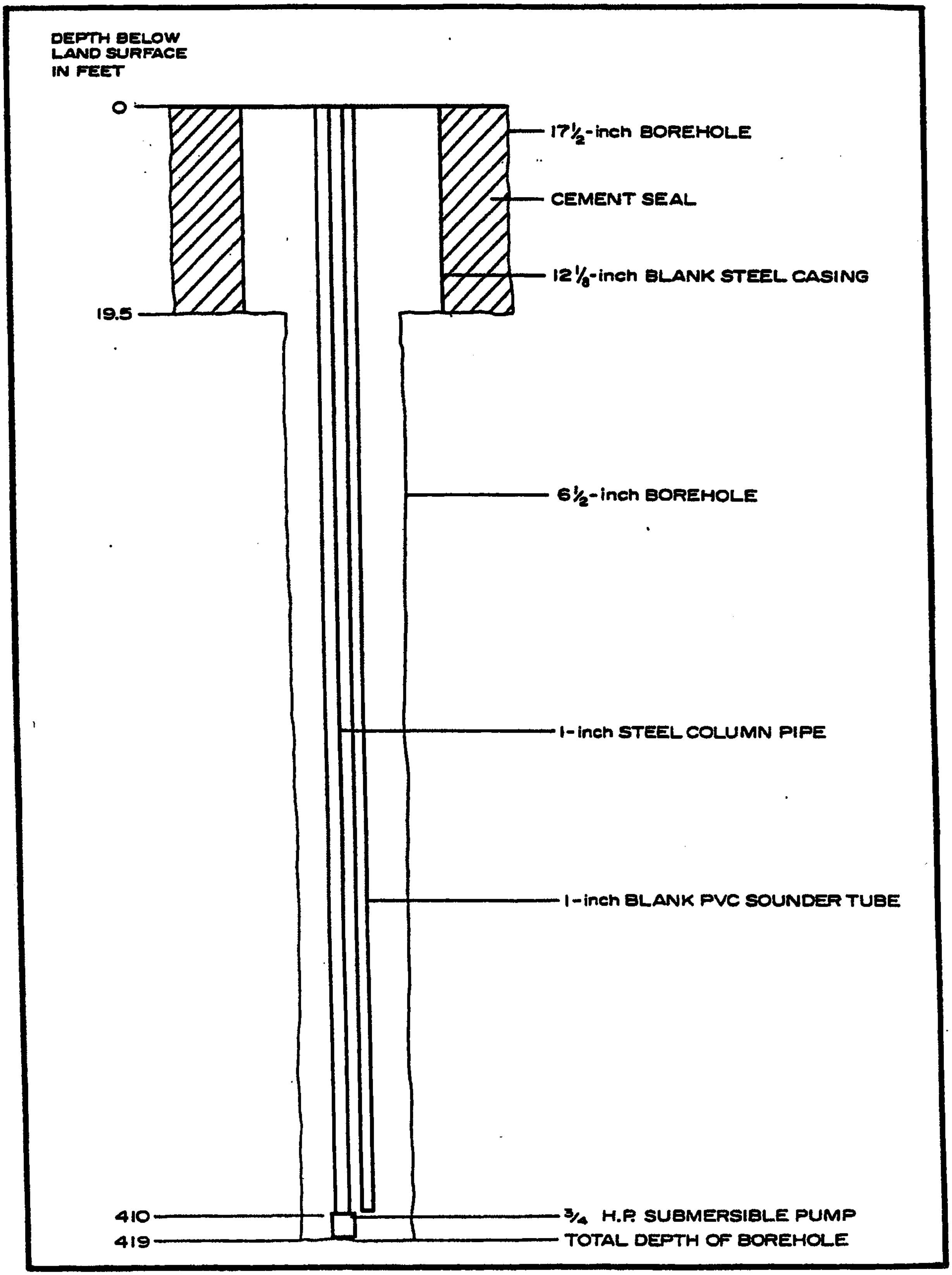


FIGURE E-82
SCHEMATIC DIAGRAM OF MONITOR WELL RD-57

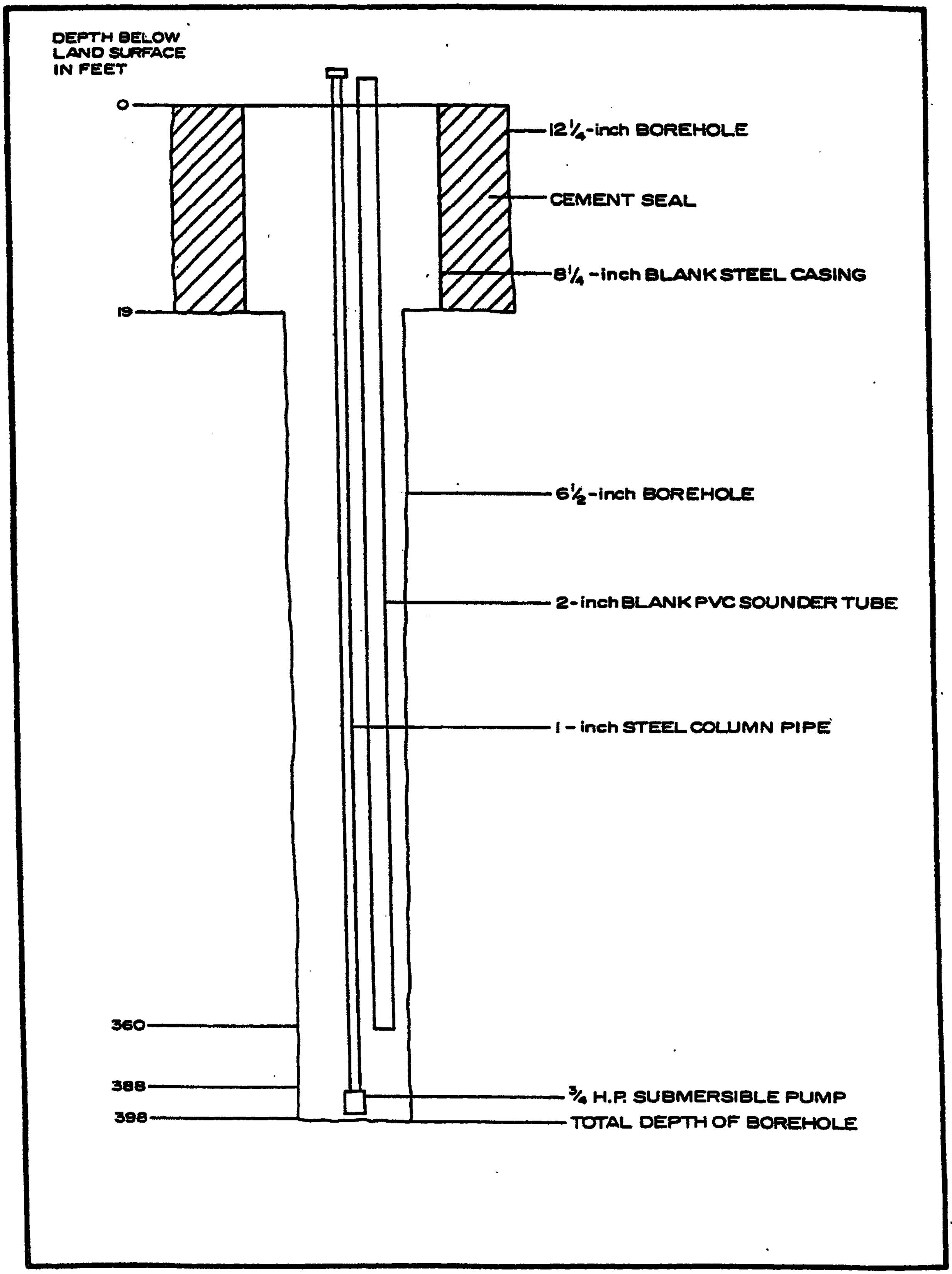


FIGURE E-93
SCHEMATIC DIAGRAM OF MONITOR WELL RD-64

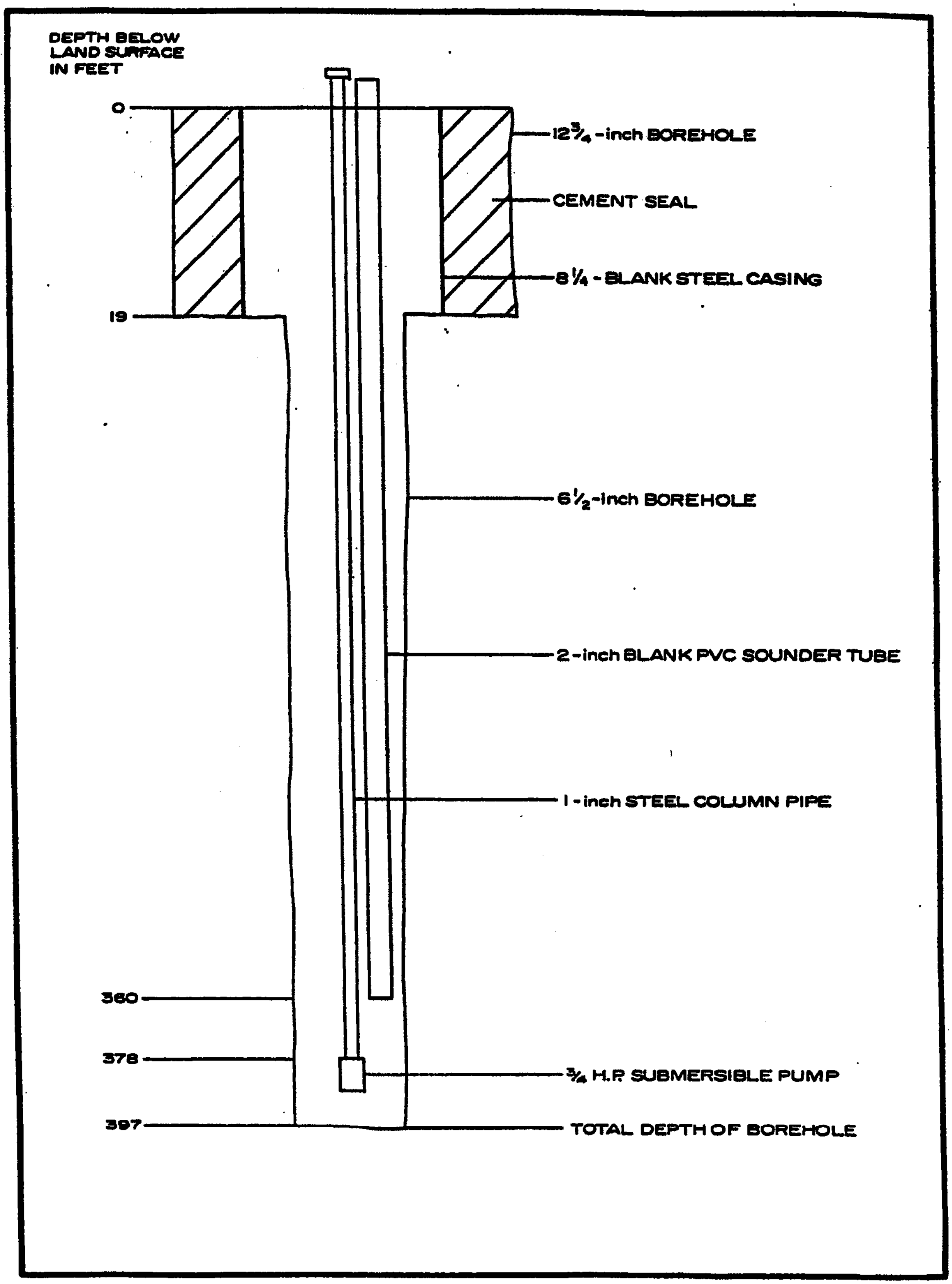
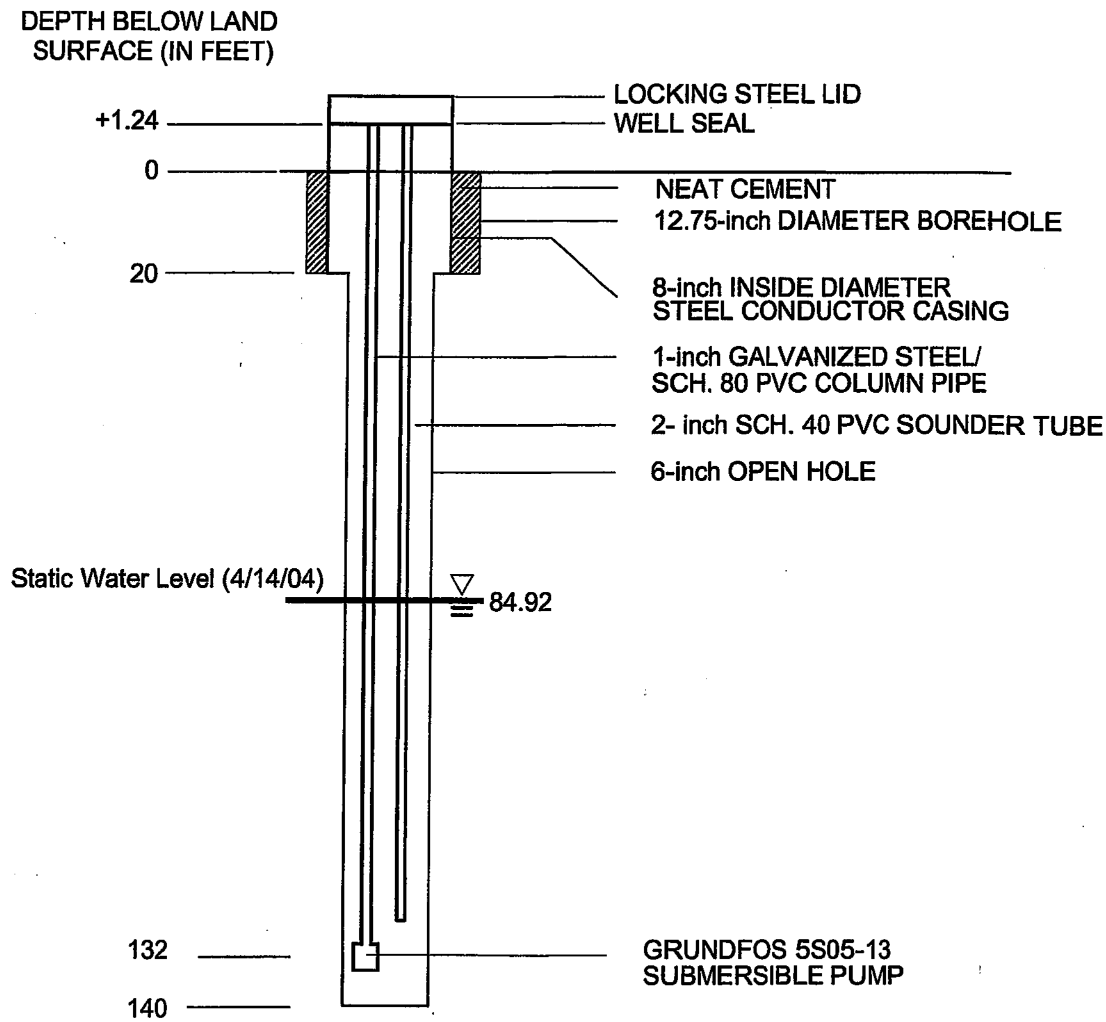


FIGURE E-94
SCHEMATIC DIAGRAM OF MONITOR WELL RD-65



HALEY & ALDRICH

THE BOEING COMPANY
ROCKETDYNE PROPULSION AND POWER
SANTA SUSANA FIELD LABORATORY

WELL SCHEMATIC
FOR RD-91

SCALE: AS SHOWN

JUNE 2004

26473-024 A66

FIGURE A-2

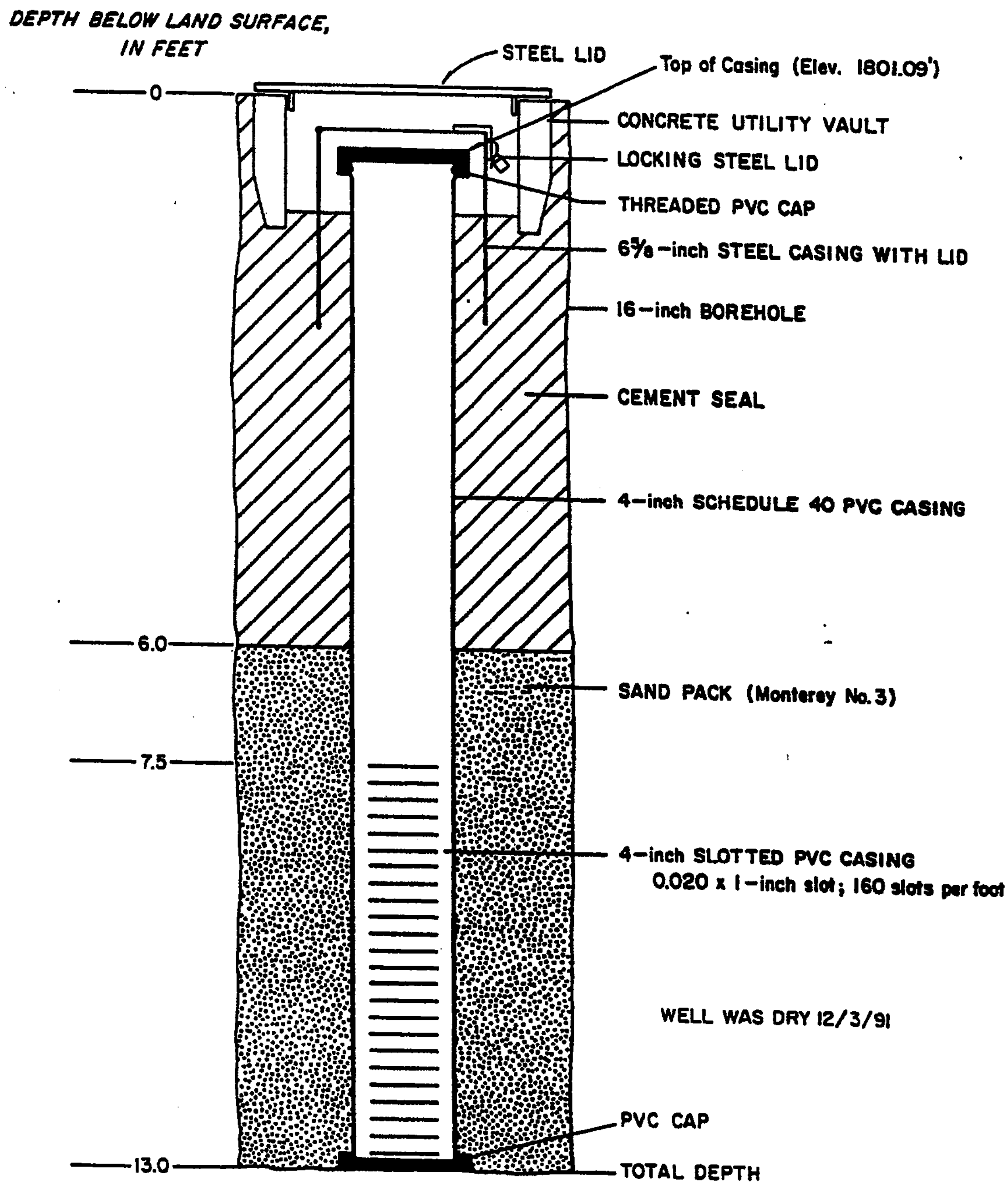


FIGURE C-18 SCHEMATIC CONSTRUCTION DIAGRAM OF MONITORING WELL RS-18

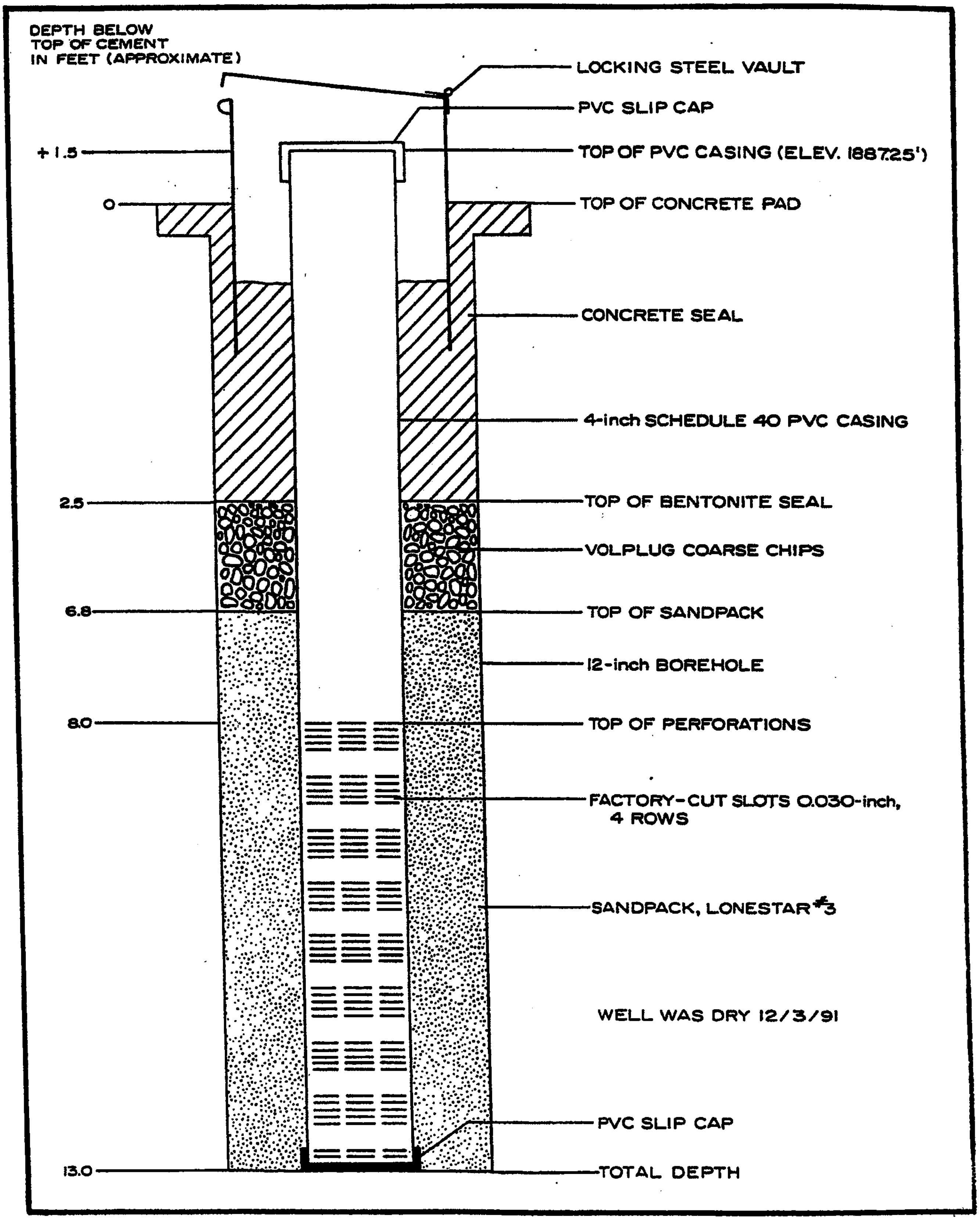


FIGURE C-23
SCHEMATIC DIAGRAM OF SHALLOW ZONE
MONITOR WELL RS-23

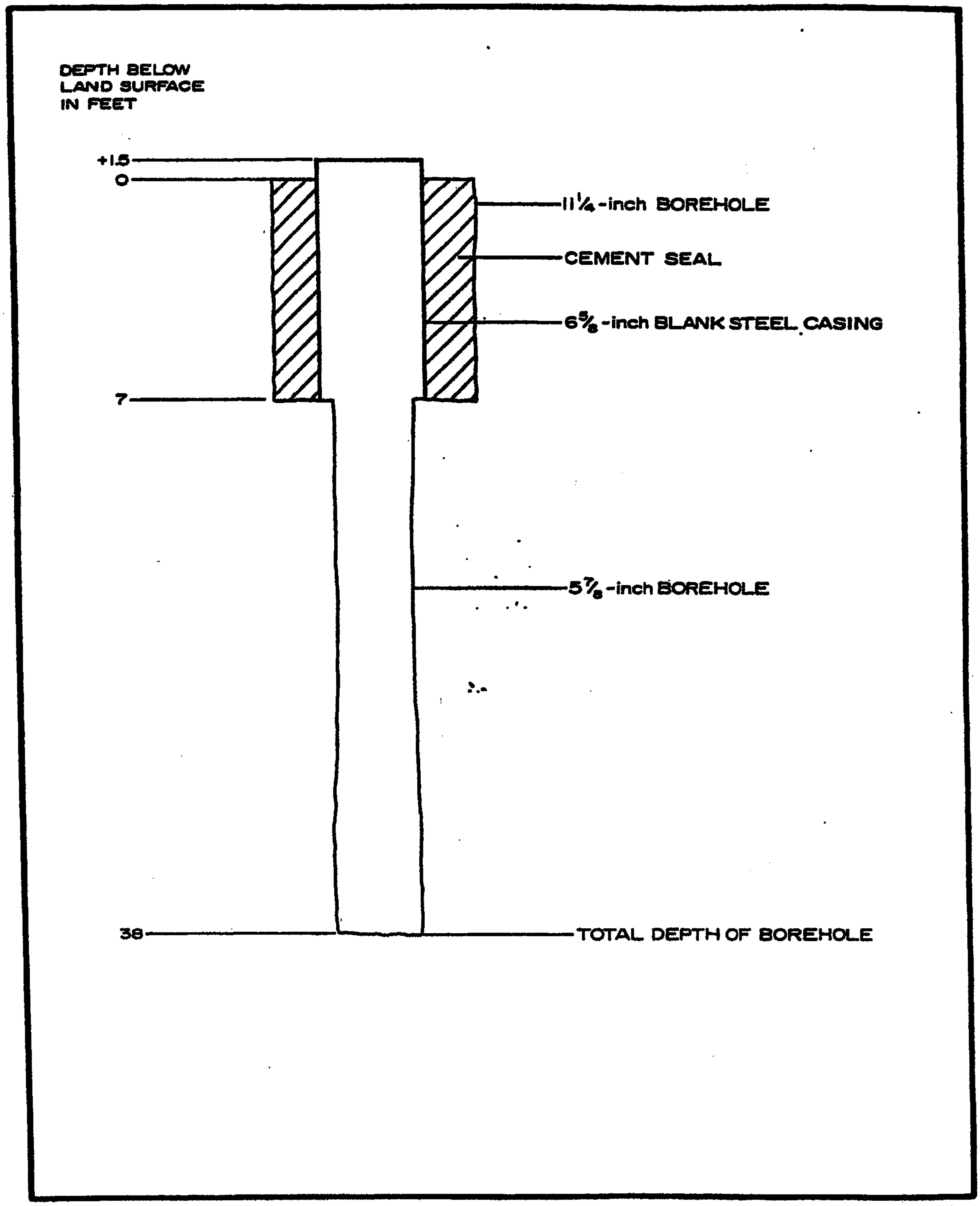


FIGURE C-32
SCHEMATIC DIAGRAM OF MONITOR WELL RS-54

Appendix A-C

SSFL Standard Operating Procedures

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Field Measurement of Total Organic Vapors	SSFL SOP 6 Revision: 1 Date: June 2012

Prepared: J. Sobol

Technical Review: C. Werden

QA Review: J. Oxford

Approved and Issued: [signature] 6/12/2012
Signature/Date

1.0 Objective

The objective of this technical standard operating procedure (SOP) is to define the techniques and the requirements for the measurement of total organic vapors in the breathing zone and in field samples at the Santa Susana Field Laboratory (SSFL) site.

2.0 Background

2.1 Definitions

Photoionization detector (PID) – A portable, hand-held instrument that measures the concentration of gaseous organic compounds through the photoionization of organic vapors.

2.2 Associated Procedures

- SSFL SOP 1, *Procedures for Locating and Clearing Phase 3 Samples*
- SSFL SOP 2, *Surface Soil Sampling*
- SSFL SOP 3, *Subsurface Soil Sampling with Hand Auger*
- SSFL SOP 4, *Direct Push Technology (DPT) Sampling*
- SSFL SOP 5, *Backhoe Trenching/Test Pits for Sample Collection*
- SSFL SOP 9, *Lithologic Logging*

2.3 Discussion

The measurement of organic vapors is a required step during numerous field activities. The measurement of organic vapors is being performed for two purposes. The first objective is to address health and safety concerns to determine if the breathing zone in a work area is acceptable or if personal protective equipment such as a respirator or a supplied air device is necessary for field personnel. The second objective is to assist in the identification of contamination and possible sample intervals for field judgment decisions on where samples for volatile organic compounds (VOCs) should be collected.

Samples to be screened include excavation spoils, hand auger cuttings, sample material from an acetate liner or stainless steel sleeve, as well as in situ screening. All sample material will be screened for the presence of volatile organic chemicals.

2.3.1 PID Operation

The PID is preferred when the compounds of interest are aromatics or halogenated VOCs. The PID ionizes the sampled vapors using an ultraviolet lamp that emits light energy at a specific electron voltage (eV - labeled on the lamp). Every organic compound has a specific ionization potential (measured in electron volts). The energy emitted by the lamp must be higher than the ionization potential of the compound for the compound to become ionized and emit an electron. If the ionization potential of the compound is higher than the eV of the lamp, there will be no response on the instrument. Therefore, the ionization potential of the known or suspected compounds shall be checked against the energy of the ultraviolet lamp (i.e., typically 10.2 eV, 10.7 eV, or 11.7 eV) to verify that the energy provided by the lamp is greater. Consult the manufacturer's manual to determine the appropriate ultraviolent lamp to be used and obtain the appropriate correction factors for known or suspected contaminants.

Water vapor associated with samples can interfere with the PID detector and cause the instrument to stop responding. This can be caused by using the PID on a rainy day or when sampling headspace samples that have been in the sun. If moisture is suspected, use the calibration gas to check the instrument response by inserting the gas as a check sample, not by recalibrating. If the response is lower than the gas level, then dry out the probe and the ionization chamber before reusing the instrument.

Do not insert the sampling probe directly into soil samples or dusty areas, as the instrument vacuum will pull dirt into the ionization chamber. Under particularly dirty or dusty conditions, the lamp may become covered with a layer of dust. If dirty conditions are encountered, or if the instrument response seems to have decreased, then clean the lamp. The instrument comes with an inlet filter that can be used to control dust and moisture. The instrument manual provides instructions on removing the instrument cover to access the lamp, and cleaning the screen in the ionization chamber as well as the surface of the lamp. In addition, the ultraviolet lamp in the PID is sensitive to shock, especially when using the higher eV lamps. Therefore, handle and transport the equipment carefully.

Finally, make sure the battery is fully charged before use. The average battery life is on the order of 8 to 12 hours of continuous use. Also, make sure the unit is allowed to equilibrate to ambient outdoor temperatures.

3.0 Responsibilities

Field Team Leader– The field team leader (FTL) is responsible for ensuring that field personnel conduct field activities in accordance with this SOP and the Field Sampling Plan (FSP) Addendum.

Site Geologist – The person responsible for overseeing soil sample collection, documentation, and lithologic logging.

Sampling Personnel – Field team members responsible for physically collecting samples and decontamination of equipment.

Site Health and Safety Technician – The person who will use field screening instruments to monitor all field activities for VOCs and radiological contaminants and pre-shipment sample coolers.

4.0 Required Equipment

- Site-specific plans (i.e., FSP Addendum)
- Health and safety plan
- Field logbook
- Photoionization detector with appropriate lamp rating
- Calibration gases in a range appropriate for the expected use
- Pint- to quart-sized zip-top plastic bags
- Waterproof black ink pen
- Personal protective clothing and equipment

5.0 Procedures

5.1 Direct Reading Measurement

1. Charge the instrument overnight.

2. Connect the measurement probe to the instrument (if necessary), turn on the probe, and make necessary operational checks (e.g., battery check) as outlined in the manufacturer’s manual.

3. Calibrate the instrument using appropriate calibration gas and following the applicable manufacturer’s manual.

4. Make sure the instrument is reading zero and all function and range switches are set appropriately.

5. Prior to the start of sampling, a background reading shall be made at the surface of the location to be sampled. Read the total organic vapor concentration in parts per million (ppm) from the instrument display. Apply the appropriate correction factor if necessary. Record the highest instrument response.

6. While sampling, hold the tip of the probe within the samplers breathing zone, and read the total organic vapor concentration in parts per million (ppm) from the instrument display. Apply the appropriate correction factor if necessary. Record the highest instrument response.

7. For samples collected using a slide hammer, measurements will be made from the bottom end of the sampling liner or

from auger cuttings placed into a plastic bag. Record the measurements in the field logbook or on appropriate field form.

8. For subsurface samples, once the acetate sleeve is split open, the entire cut surface of the core will be screened with the PID. Based on the measurements, the soil in the sleeve will be sampled in accordance with SSFL SOP 4. If measurements are made on any soil sample above background, headspace measurements will be made in accordance with the next section to determine the maximum VOC reading achieved. Record all measurements in the field logbook or on the appropriate field form.

5.2 Headspace Measurement

1. Once on and operational, calibrate the instrument (as needed) following the appropriate manufacturer's manual.

2. Make sure the instrument is reading zero and all function and range switches are set appropriately.

3. Fill one zip-top plastic bag approximately one-half full of the sample to be measured. Quickly seal the bag minimizing volume of air in bag.

4. Allow headspace to develop for approximately 10 minutes. It is generally preferable to knead the bag for 10 to 15 seconds to break apart the sample and maximize sample surface area.

Note: When the ambient temperature is below 0 degrees Celsius (32 degrees Fahrenheit), perform the headspace development and subsequent measurement within a heated vehicle or building.

5. Quickly puncture the bag wall and insert the probe, wrapping the bag wall around the probe stem to minimize loss of vapors. Insert the instrument probe to a point approximately one-half of the headspace depth. Do not let the probe contact the soil, and ensure the probe does not get plugged by the plastic during puncturing. If using a PID and there is condensation on the inside of the bag, only leave the probe in the jar or bag long enough to obtain a reading. Remove the probe and allow fresh air to flow through the instrument to avoid excess water vapor build-up.

6. Read the total organic vapor concentration in ppm from the instrument display. Apply the appropriate correction factor if necessary. Record the highest instrument response.

7. Immediately record the reading in the field logbook or on the appropriate field form.

6.0 Restrictions/Limitations

The PID provides quantitative measurement of total organic vapors, but generally is not compound-specific. The typical measurement range of the PID is 0 to 2,000 ppm. In addition, the instrument will not detect/measure VOCs with an associated ionization potential (in eVs) above the rating of the lamp, so lamp rating is critical to monitoring for selected VOCs.

Note: The presence of methane will cause erratic PID measurements.

7.0 References

No references were used in development of this SOP.

Field Measurement of Residual Radiation	SSFL SOP 7 Revision: 0 Date: April 2012

Prepared:	J. Sobol	**Technical Review:**	D. Chambers, C. Zakowski
QA Review:	J. Oxford	**Approved and Issued:**	[signature] 4/6/2012 *Signature/Date*

1.0 Objective

The objective of this technical standard operating procedure (SOP) is to define the techniques and the requirements for the detection of residual radiation in the breathing zone and in soil at the Santa Susana Field Laboratory (SSFL). The Department of Energy (DOE) surface contamination criteria are also defined herein with footnotes which reflect acceptable approaches for demonstrating achievement of such criteria.

2.0 Background

2.1 Definitions

MicroR detector–A portable, hand-held scintillation counter that measures gamma radiation in air. Although measurements are typically made about one meter above the ground surface, such sodium iodide scintillation detectors can also be used qualitatively measure radiation emitted from soil samples and soil cores. In this instance the detectors will be held about 0.5 to 1 inch above the samples. When used to evaluate soil sample activity, measurements will be compared against background count rates for the same material taken in a consistent manner (i.e., 0.5 to 1 inch above soil material). Background is established by taking measurements in an area that produced count rates that are relatively low and uniform.

Dual Phosphor Alpha Beta Scintillator–A portable, hand-held field radiation survey instrument that may detect alpha and beta emissions and, with proper calibration, can measure gamma emissions.

2.2 Associated Procedures

- SSFL SOP 1, *Procedures for Locating and Clearing Phase 3 Samples*
- SSFL SOP 2, *Surface Soil Sampling*
- SSFL SOP 3, *Subsurface Soil Sampling with Hand Auger*
- SSFL SOP 4, *Direct Push Technology (DPT)Sampling*
- SSFL SOP 5, *Backhoe Trenching/Test Pits for Sample Collection*
- SSFL SOP 9, *Lithologic Logging*

2.3 Discussion

Radiation screening of soil samples and ambient air is necessary because of the prior use of Area IV for nuclear research. Radiation measurement data will be used pursuant to health and safety monitoring to determine if radiation exposure rates for field personnel in a work area is acceptable or if additional personal protective equipment or exposure limitations are necessary for field personnel. In addition to health and safety monitoring, radiation monitoring will be used to screen surface and subsurface soil and sediment samples for levels above background. Background readings are important because they provide a point of departure for elevated readings.

Two types of instruments will be used to measure residual radiation: the MicroR gamma detector and Dual Phosphor alpha/beta detector.

2.3.1 MicroR Operation

The MicroR detector is a scintillation meter used to measure low levels of gamma radiation. Although sodium iodide detectors can be set up to operate as a single channel analyzer, thereby reporting a specific radionuclide, the instruments for this project will be set up to report all gamma emissions, irrespective of radionuclide. The instrument has a speaker which provides an audible measure of the radiation emitted, as an audible click. The rate at which the clicks occur allows real-time monitoring of the strength of the radiation sources. Readout is generally in terms of microroentgens per hour (µR/hr).These instruments are energy dependant, commonly over-responding by as much as a factor of 8 or more for lower energy gamma emissions and under-responding by about 20 percent for cobalt-60.

2.3.2 Dual Phosphor Alpha Beta Scintillation Operation

For this project a Model 43-89 Dual Phosphor alpha/beta scintillation detector will be primarily used to detect alpha/beta emissions.

Although these detectors can also detect alpha emissions, alpha particles generally have a range of about an inch or less in air with relatively few able to penetrate the detector window such that they are counted. Alpha/beta detectors are generally calibrated to the gamma emissions of cesium-137 with instrument response being energy dependent. Beta efficiency also varies with energy such that 4 pi efficiency ranges from about 13 percent to 50 percent for beta particles with average energies of 50 and 550 kiloelectron volts (keV), respectively. If the instrument has a speaker, the pulses also give an audible click. The readout can be displayed in multiple different units (e.g., roentgens per hour (R/hr), milliroentgens per hour (mR/hr), rem per hour (rem/hr), millirem per hour (mrem/hr), and counts per minute (cpm)) when the control switch is in the “Ratemeter” position. Alpha/beta probes including, the pancake type, are commonly used with a variety of different hand held scalers/ratemeters for contamination measurements. Given the energy dependence of the instruments and their variable response to different types of radiation, radiation control/health physics personnel should be consulted if any activity exceeding instrument background is detected.

3.0 Responsibilities

Field Team Leader–The field team leader (FTL) is responsible for ensuring that field personnel conduct field activities in accordance with this SOP and the Field Sampling Plan [FSP] Addendum.

Site Health and Safety Technician–The person who will use field screening instruments to monitor all field activities for VOCs and radiological contaminants and pre-shipment sample coolers. This person is a trained radiological technician who works under the guidance of Science Application International Corporation’s (SAIC’s) Certified Health Physicist (CHP).

Certified Health Physicist–The person who oversee radiation survey activities, confirm background levels, and provide field direction when background levels are exceeded per the Health and Safety Plan.

4.0 Required Equipment

- Ludlum Model 19 or Model 192 Micro R Detector (or equivalent)
- Ludlum Model 43-89 Dual Phosphor Alpha/Beta Scintillation Detector (or equivalent)[1]
- Site-specific plans (i.e., FSP Addendum)
- Health and safety plan (HASP)
- Field logbook
- Waterproof black ink pen
- Personal protective clothing and equipment

5.0 Determination of Radiation Background

As set forth in the HASP (health and safety plan monitoring and action levels) and for the selection of soil sample intervals (SSFL SOP 2, 3, 4, and 5), background radiation levels for various media will be established prior to soil sampling. Because radiation levels vary based on composition of the media and multimedia that will effect radiation measurements at the site, the following background radiation levels will be developed initially at the site.

- Unconsolidated soil
- Bedrock

[1] Ludlum Model 2360, Ludlum Model 26

- Concrete slab/rubble
- Asphalt

Additional media may be added as it is encountered in the field. Background of these media will be established using the following procedure.

1. Ensure instrument is functioning properly and check source readings are acceptable per requirements of this SOP.
2. Demarcate background radiation SAMPLE AREA for each media with wooden Stakes. The Area IV background survey location established by EPA will serve as a starting point. Minimum requirements for the background SAMPLE AREA is as follows:
   a. 20 square feet of surface area
   b. made up of 80% intended media
   c. area does not consist of imported fill or debris
   d. area is absent of contamination (identified by visually inspection, and from EPA HSA, EPA gamma surveys, EPA soil sample results, RFI and Co-located Chemical data)
3. Obtain and Record GPS coordinates of SAMPLE AREA
4. Using appropriate radiation instrument (Micro R Meter Model 19/192, Dual Phosphor Alpha/Beta Detector Model 43-89) collect 10 gamma, alpha, and beta measurement about 0.5 to 1 inch above the media, equally distribute throughout the SAMPLE AREA. Each measurement will be at least 1 minute in duration.
5. Record the ten radiation measurements in log book.
6. Following collection of background measurements, ensure instrument is functioning properly and check source readings are acceptable per this SOP.
7. Discuss readings with site Certified Health Physicist (SAIC) for review and receive approval of background radiation level.
8. The Certified Health Physicist will provide approved background radiation level for the media to DOE and CDM Smith. This will include background level, mean, and standard deviation.
9. CDM Smith FTL will record the Certified Health Physicist's recommendations and discuss the background action level with all field personnel as part of safety briefings.
10. Following establishment of, and periodical renewal of background readings throughout project, background radiation levels will be discussed during project meetings and daily tailgate safety meetings.

6.0 Procedures

6.1 MicroR Detector

Background Gamma Scan

1. Prepare the instrument and check batteries. The meter needle should move to area on scale marked battery, indicating the batteries are good.
2. Measure background radiation level away from sample and source area. Measure the background radiation for approximately 60 seconds to allow determination of the range and relative mean background exposure rates and write

down the readings. Note that background commonly ranges from about 5 to 20 µR/h, but can be higher as a result of increased elevation or higher concentrations of naturally occurring radioactive materials. In addition, it is often necessary to reevaluate background for different areas within the site. Upon completion of background determination, verify proper instrument operation using a National Institute of Standards and Technology (NIST) traceable check source to confirm proper instrument operation.

Surface Soil Gamma Scan

1. Beginning at the highest scale, proceed to lower scales until a reading is encountered. Set the instrument selector switch to the most sensitive range of the instrument. Holding the probe approximately 0.5 to 1 inch from the surface soil sample, move the detector slowly (about 1 inch per second) over the core and/or sample being evaluated with the detector parallel to the length of the core.

2. Do not let the probe touch anything and try to maintain a constant distance.

3. Areas that register more than background levels may be considered contaminated and a health physicist should be consulted.

6.2 Dual Phosphor Alpha/Beta Scintillation Detector

Background Alpha/Beta Scan

1. Prepare the instrument and check batteries. The meter needle should move to area on scale marked battery, indicating the batteries are good. Measure background radiation level away from source area.

2. Measure the background radiation at 0.5 to 1 inch above the media for ten 2-minute counting periods and record each of the readings. Background commonly ranges from about 5 to 20 µR/h but can be higher as a result of increased elevation or higher concentrations of naturally occurring radioactive materials.

3. Obtain ten 1-minute source activity measurements using a NIST traceable source of the appropriate beta energy.

4. Upon completion of the background and source efficiency counts, input the associated data into the spreadsheet provided to determine parameter limits (e.g., background and source efficiency within 20 percent of the mean). Subsequent counts of both background and source efficiency should be performed daily before instrument use, at the end of each duty day, and any time that instrument operation is questionable.

Soil Sample Beta Scan

1. Set the instrument selector switch to the most sensitive range of the instrument.

2. Holding the probe approximately 0.5 to 1 inch from the sample and move the probe slowly (about 1 inch per second). (***Note***: Alpha emissions are reliably detectable only with the detector as close as practicable to the item being surveyed. In addition, it should be noted that variation in beta background can preclude the ability to detect alpha emissions at levels prescribed in 10 CFR 835, Appendix D.)

3. Do not let the probe touch anything and try to maintain a constant distance.

4. Areas that register more than background level may be considered contaminated and a health physicist should be consulted.

Surface Contamination Scanning

In addition, every sample, piece of equipment, and container of material used at the site and/or that leaves the site will be surveyed and results will be used to document that residual total and removable surface contamination are compliant with criteria contained in Appendix D, 10 CFR 835. I

Surface Contamination Values[1] in dpm/100 cm[2] **Radionuclide**	**Removable [2, 4]**	**Total (Fixed + Removable) [2, 3]**
U-nat, U-235, U-238, and associated decay products	1,000[7]	5,000[7]
Transuranics, Ra-226, Ra-228, Th-230, Th-228, Pa-231, Ac-227, I-125, I-129	20	500
Th-nat, Th-232, Sr-90, Ra-223, Ra-224, U-232, I-126, I-131, I-133	200	1,000
Beta-gamma emitters (nuclides with decay modes other than alpha emission or spontaneous fission) except Sr-90 and others noted above [5]	1,000	5,000
Tritium and STCs [6]	10,000	See Footnote 6

1. The values in this appendix, with the exception noted in footnote 6 below, apply to radioactive contamination deposited on, but not incorporated into the interior or matrix of, the contaminated item. Where surface contamination by both alpha- and beta-gamma-emitting nuclides exists, the limits established for alpha- and beta-gamma-emitting nuclides apply independently.

2. As used in this table, disintegrations per minute (dpm) means the rate of emission by radioactive material as determined by correcting the counts per minute observed by an appropriate detector for background, efficiency, and geometric factors associated with the instrumentation.

3. The levels may be averaged over one square meter provided the maximum surface activity in any area of 100 cm^2 is less than three times the value specified. For purposes of averaging, any square meter of surface shall be considered to be above the surface contamination value if: (1) from measurements of a representative number of sections it is determined that the average contamination level exceeds the applicable value; or (2) it is determined that the sum of the activity of all isolated spots or particles in any 100 cm^2 area exceeds three times the applicable value.

4. The amount of removable radioactive material per 100 cm^2 of surface area should be determined by swiping the area with dry filter or soft absorbent paper, applying moderate pressure, and then assessing the amount of radioactive material on the swipe with an appropriate instrument of known efficiency. (Note—The use of dry material may not be appropriate for tritium.) When removable contamination on objects of surface area less than 100 cm^2 is determined, the activity per unit area shall be based on the actual area and the entire surface shall be wiped. It is not necessary to use swiping techniques to measure removable contamination levels if direct scan surveys indicate that the total residual surface contamination levels are within the limits for removable contamination.

5. This category of radionuclides includes mixed fission products, including the Sr-90 which is present in them. It does not apply to Sr-90 which has been separated from the other fission products or mixtures where the Sr-90 has been enriched.

6. Tritium contamination may diffuse into the volume or matrix of materials. Evaluation of surface contamination shall consider the extent to which such contamination may migrate to the surface in order to ensure the surface contamination value provided in this appendix is not exceeded. Once this contamination migrates to the surface, it may be removable, not fixed; therefore, a “Total” value does not apply. In certain cases, a “Total” value of 10,000 dpm/100 cm^2 may be applicable either to metals, of the types which form insoluble special tritium compounds that have been exposed to tritium; or to bulk materials to which particles of insoluble special tritium compound are fixed to a surface.

7. These limits only apply to the alpha emitters within the respective decay series.

[58 FR 65485, Dec. 14, 1993, as amended at 63 FR 59688, Nov. 4, 1998; 72 FR 31940, June 8, 2007; 74 FR 18116, Apr. 21, 2009]

7.0 Restrictions/Limitations

Micro R and Dual Phosphor detectors are principally used for the detection of presence of radionuclides above background, not measurement devices. They are prone to breaking if the thin entrance window (found on pancake and end-window designs) is punctured. This can easily occur if the window comes in contact with a variety of objects (such as a blade of grass, paper clip, nail, and paint flecks). Once the window is broken the instrument ceases to operate and must, therefore, be returned for repair and calibration.

8.0 References

Integrated Environmental Management, Inc., 1998, *Measuring Radioactivity*

Oak Ridge Institute for Science and Education and Radiation Emergency Assistance Center/Training Site (REAC/TS), 1992, *Using a Typical Geiger-Mueller (GM) Counter to Survey*

Title 10, Code of Federal Regulations, Part 835, Occupational Radiation Protection

DOE Standard Radiological Control, DOE-STD-1098-2008 with change 1 dated May 2009

DOE Order 426.2, Personnel Selection, Training, Qualification, and Certification Requirements for DOE Nuclear Facilities, 21 April 2010

DOE Standard 1107-97 with Change 1 dated November 2007, Knowledge, Skills, and Abilities for Key Radiation Protection Positions

Ludlum Measurements, Inc. Operators Manuals for Model 2241 Survey Meter with Model 19/192 Detector

Ludlum Measurements, Inc. Operators Manuals for Model 43-80 Alpha/Beta Scintillator

Field Data Collection Documents, Content, and Control

SSFL SOP 8
Revision: 1
Date: December 2012

Prepared: D. Lange

Technical Review: C. Werden

QA Review: J. Oxford

Approved and Issued: 12/1[illegible]/2012
Signature/Date

1.0 Objective

The objective of this technical standard operating procedure (SOP) is to set criteria for content entry and form of field logbooks and the SSFL Field Sample Data Sheet (FSDS) used to document field work at the Santa Susana Field Laboratory (SSFL) site. The FSDS is also used for data entry into the Scribe database.

2.0 Background

A permanently bound and consecutively paginated field logbook will be maintained daily by the CDM Smith field team in accordance with the procedures below.

2.1 Discussion

Information recorded in field logbooks includes field team member names, visitors, observations, data, calculations made onsite, date/time, weather, and description of the data collection activity, methods, instruments, and results. Additionally, the logbook must contain deviations from plans, observations of fill, and site features including sketches, maps, or drawings as appropriate. In addition, all SOPs will be on hand with the field sampling team.

2.2 Associated Procedures

- SSFL SOP 1, *Procedures for Locating and Clearing Phase 3 Samples*
- SSFL SOP 2, *Surface Soil Sampling*
- SSFL SOP 3, *Subsurface Soil Sampling with Hand Auger*
- SSFL SOP 4, *Direct Push Technology Sampling*
- SSFL SOP 5, *Backhoe Trenching/Test Pits for Sample Collection*
- SSFL SOP 9, *Lithologic Logging*
- SSFL SOP 14, *Geophysical Survey*
- SSFL SOP 15, *Photographic Documentation of Field Activities*
- SSFL SOP 16, *Control of Measurement and Test Equipment*

3.0 General Responsibilities

Field Team Leader (FTL)–The FTL is responsible for ensuring that the format and content of data entries are in accordance with this procedure. The FTL will provide field logbooks and FSDSs to the site geologist who will be responsible for their care and maintenance while in his or her possession.

Site Geologist–The site geologist is responsible for documenting site activities into the logbook and completing a FSDF for each soil sample collected. .

Other Site Personnel–All CDM Smith employees who make entries in field logbooks during onsite activities are required to read this procedure before engaging in this activity. Site personnel will return field logbooks to the FTL at the end of the assignment.

4.0 Required Equipment

- Site-specific plans (Field Sampling Plan [FSP] Addendum, health and safety plan, and all SSFL SOPs)
- Field logbook
- Scribe Version 3.8 (or later)
- Indelible black or blue ink pen
- SSFL Field Sample Data Sheet (FSDS)

5.0 Procedures

5.1 Preparation

In addition to this SOP, site personnel responsible for maintaining logbooks must be familiar with all procedures applicable to the field activity being performed. These procedures should be consulted as necessary to obtain specific information about equipment and supplies, health and safety, sample collection, packaging, decontamination, and documentation. These procedures should be located at the field office and field vehicle for easy reference.

Field logbooks are bound, with lined and consecutively numbered pages. All markings and notes will be made with indelible black or blue ink pen. All pages must be numbered before initial use of the logbook. Before use in the field, the FTL will title and sequentially number each page of each logbook and set up the table of contents (TOC). Record the following information on the cover of the logbook:

- Field logbook number (if applicable).
- Site name and location.
- Activity (if the logbook is to be activity-specific).
- Start date of entries.
- End date of entries.
- Name of CDM Smith contact and phone number(s) (typically the project manager).

The first few (approximately two) pages of the logbook will be reserved for a TOC. Mark the first page with the heading "Table of Contents" and enter the following:

Table of Contents

Date/Description	Pages
(Start Date)/Reserved for TOC	1-2

The remaining pages of the TOC will also be designated as such with "Table of Contents" written on the top center of each page. The TOC should be completed as activities are completed and before returning the logbook back to the FTL.

5.2 Log Book Requirements

Documentation requirements for logbooks are:

- Record work, observations, quantity of materials, field calculations and drawings, and related information directly in the logbook. If data collection forms are specified by an activity-specific plan, this information does not need to be duplicated in the logbook. However, forms (e.g., SSFL-FSDSs) used to record site information must be referenced in the logbook.
- Do not start a new page until the previous one is full or has been marked with a single diagonal line so that additional entries cannot be made. Use both sides of each page.
- Do not erase or blot out any entry at any time. Indicate any deletion by a single line through the material to be deleted. Initial and date each deletion. Take care to not obliterate what was written previously.
- Do not remove any pages from the book.

Specific requirements for field logbook entries include:

- Initial and date each page.
- Sign and date the final page of entries for each day.
- Initial and date all changes.
- If authors change within the course of the day, the original author must insert the following:
  Above notes authored by:
  - (Sign name)
  - (Print name)
  - (Date)
- The new author must sign and print his/her name before additional entries are made.
- Draw a diagonal line through the remainder of the final page at the end of the day.

- Record the following information on a daily basis:
  -Date and time
  -Name of individual making entry
  -Names of field team and other persons onsite
  -Description of activity being conducted including station or location (i.e., boring, sampling location number) if appropriate
  -Weather conditions (i.e., temperature, cloud cover, precipitation, wind direction and speed) and other pertinent data
  -Level of personal protection used
  -Serial numbers of instruments
  -Equipment calibration information (initial and ongoing date and time activity)
  -Serial/tracking numbers on documentation (e.g., carrier air bills)

Entries into the field logbook shall be preceded with the time (written in military units) of the observation. The time should be recorded frequently and at the point of events or measurements that are critical to the activity being logged. All measurements made and samples collected must be recorded.

A sketch of station location may be warranted. All maps or sketches made in the logbook should have descriptions of the features shown and a direction indicator.

Other events and observations that should be recorded include:
- Changes in weather that impact field activities.
- Deviations from procedures outlined in any governing documents. Also, record the reason for any noted deviation.
- Problems, downtime, or delays.
- Upgrade or downgrade of personal protection equipment.
- Visitors to the site.

5.3 Field Sample Data Sheets

- An example FSDS that will be use to record the sample details and subsurface conditions is included as Attachment 1 to SOP 8.
- The FSDS will be completed by the Site Geologist and include general from observations of the soil core, cuttings, and sidewalls of trenches and test pits.
- The FSDS is a single page, double-sided form that will be completed in indelible ink.
- All portions of the form will be completed. If any portion is not applicable to the activity being recorded, that portion will be crossed out with a single line and initialed by the Site Geologist.
- The FSDS must be reviewed and signed by another field team member before being copied into a pdf file.
- The pdf file will be transferred to CDM Smith's main database weekly by the sample coordinator. The original of the FSDS will be maintained in a binder at the site office until completion of all field activities.
- Sample description information (sample characteristics, presence of fill, staining, odor, etc.) will be transferred to the electronic database on a weekly basis by the FTL or sample coordinator or his/her designee.
- Copies of the FSDS documents will be included in the data report presenting the findings of the investigation.
- The completed FSDS form will be kept as a quality record in CDM Smith's SSFL project file for period of 10 years as stated in Section 7.9 of the Administrative Order on Consent.

5.4 Scribe Database Requirements

The Scribe database will be used to capture the data from the FSDS and perform the following tasks (at a minimum):

- Document field sample collection
- Generate chain of custody forms
- Track field samples to laboratories
- Query database and produce reports

- The FSDS information is entered into the field database, Scribe.
- The Scribe data entry is reviewed by another staff.
- The Scribe database is backed up daily off-site to CDM Smith servers. In the event of internet outages, the backups will

be made to an external device such as an external hard-drive, thumb drive or CD/DVD. Once internet service is restored the most current backup will be used and placed on the CDM Smith servers.
- Changes to the finalized FSDS are documented on the FSDS and Scribe.

5.5 Photographs

Photography is restricted at SSFL. All cameras require permits from The Boeing Company (Boeing) to be onsite. Photographs may be taken at the site to visually document field activities and site features, as needed and in accordance with SSFL SOP 15. Digital photographs will be submitted to the electronic project files.

All digital photographs will be documented on a photographic log in the logbook or on a separate form (reference in the logbook). Captions must be added to the file name after the photographs are downloaded. The caption should be a unique identifier – number or date and short description. The photographic log should contain the following information:

- Photograph sequence number
- Description of activity/item shown (e.g., SSFL and sampling activity)
- Date and time
- Direction (if applicable)
- Name of photographer

5.6 Post-Operation

To guard against loss of data as a result of damage or disappearance of logbooks, photocopy or scan completed pages daily and forward to the field or project office weekly (at a minimum). Photocopy or scan other field records (e.g., Field Sample Data Sheets, photographic logs) weekly and upload to CDM Smith servers weekly (at a minimum), or as requested.

At the conclusion of each day, the individual responsible for the logbook will ensure that all entries have been appropriately signed and dated and that corrections were made properly (single lines drawn through incorrect information then initialed and dated). Completed logbooks will be returned to the FTL.

6.0 Restrictions/Limitations

Field logbooks constitute the official record of onsite technical work, investigations, and data collection activities. Their use, control, and ownership are restricted to activities pertaining to specific field operations carried out by CDM Smith personnel and their subcontractors. They may be used in court to indicate dates, personnel, procedures, and techniques employed during site activities. Entries made in these logbooks should be factual, clear, precise, and non-subjective. Field logbooks, and entries within, are not to be used for personal use.

7.0 References

No references used.

8.1 Attachments

Attachment A – SSFL Phase 3 – Field Sample Data Sheet

SSFL Phase 3 – Field Sample Data Sheet

CDM Smith

FSDS Checked By ____________________

Sample ID ____________________ **Date/Time** ____________________

Matrix (circle one)

Soil   Sediment   Water

Plant

Start Depth ____________________

End Depth ____________________

Depth Units (circle one)

Inches   Feet

Check if Composite ☐

Collection Method (circle one)

DPT   Slide Hammer   Hand Auger/Slide Hammer   Trenching   Sediment

Cutting   Shovel

QC Type (circle one)

N   FD   FB   RB

Parent Sample ID ____________________

Field Geologist ____________________

Sampler ____________________

Analysis

	Parameters	Method	Analyze?
	Metals	EPA 6010	
		EPA 6020	
		EPA 7471 (Soil)	
		EPA 7470 (Water)	
	Fluoride	EPA 300.0/9056	
	SVOCs	EPA 8270	
	TIC	EPA 8270	
	PAHs	EPA 8270 SIM	
	1,4 Dioxane	EPA 8270 SIM	
	Dioxins	EPA 1613	
	PCBs/PCTs	EPA 8082	
	Perchlorate	EPA 314.0/331	
	Perchlorate Confirmation	EPA 6850/6860	
	pH	EPA 9045 (Soil)	
		EPA 9040 (Water)	
	Hexavalent Chromium	EPA 7196/7199	
	Herbicides	EPA 8151	
	Pesticides	EPA 8081	

	Parameters	Method	Analyze?
Encores	VOCs	EPA 8260	
	1,4 Dioxane	EPA 8260 SIM	
	TPH-GRO	EPA 8015	
	TPH-EFH	EPA 8015	
	Glycols	EPA 8015	
	Alcohols	EPA 8015	
	Terphenyls	EPA 8015	
	Nitrates	EPA 300.0/9056	
	Energetics	EPA 8330	
	Cyanide	EPA 9012	
	Formaldehyde	EPA 8315	
	NDMA	EPA 1625	
Sediment	Organotin	NOAA Status and Trends, Krone et al.	
	Methyl Mercury	EPA 1630	
	Total Nitrogen	ASTM D5373	
	TOC	ASTM D5310	
	Grain Size	ASTM 2488-09a	

NA – Not Applicable

SSFL Phase 3 – Field Data Sample Sheet (Sample Descriptions)

Soil Classification (circle one)

MAJOR DIVISION			GROUP SYMBOL	LETTER SYMBOL	GROUP NAME
COARSE GRAINED SOILS CONTAINS MORE THAN 50% FINES	GRAVEL AND GRAVELLY SOILS MORE THAN 50% OF COARSE FRACTION RETAINED ON NO. 4 SIEVE	GRAVEL WITH * 5% FINES		GW	Well-graded GRAVEL
				GP	Poorly graded GRAVEL
		GRAVEL WITH BETWEEN 5% AND 15% FINES		GW-GM	Well-graded GRAVEL with silt
				GW-GC	Well-graded GRAVEL with clay
				GP-GM	Poorly graded GRAVEL with silt
				GP-GC	Poorly graded GRAVEL with clay
		GRAVEL WITH ≥ 15% FINES		GM	Silty GRAVEL
				GC	Clayey GRAVEL
	SAND AND SANDY SOILS MORE THAN 50% OF COARSE FRACTION PASSING ON NO. 4 SIEVE	SAND WITH * 5% FINES		SW	Well-graded SAND
				SP	Poorly graded SAND
		SAND WITH BETWEEN 5% AND 15% FINES		SW-SM	Well-graded SAND with silt
				SW-SC	Well-graded SAND with clay
				SP-SM	Poorly graded SAND with silt
				SP-SC	Poorly graded SAND with clay
		SAND WITH ≥ 15% FINES		SM	Silty SAND
				SC	Clayey SAND
FINE GRAINED SOILS CONTAINS MORE THAN 50% FINES	SILT AND CLAY	LIQUID LIMIT LESS THAN 50		ML	Inorganic SILT with low plasticity
				CL	Lean inorganic CLAY with low plasticity
				OL	Organic SILT with low plasticity
		LIQUID LIMIT GREATER THAN 50		MH	Elastic inorganic SILT with moderate to high plasticity
				CH	Fat inorganic CLAY with moderate to high plasticity
				OH	Organic SILT or CLAY with moderate to high plasticity
HIGHLY ORGANIC SOILS				PT	PEAT soils with high organic contents

Fill Material

1. Is Fill Material Present Yes No

2. Percentage Fill (%) ____________________

3. Fill Description (circle all that apply)

Asphalt Metal Plastic

Concrete Wood Glass

Igneous/Metamorphic Gravel N/A

Other ________________________

Is Staining Present Yes No

Color ________________________

Odor

1. Odor Strength (circle one)

None Slight Strong

2. Odor Description (circle one)

Organic Petroleum Chemical

N/A Other ________________

Moisture Condition (circle one)

Dry Moist Wet

PG Signature ________________________ **PG Registration #** ____________

Additional Comments ____

____

____

____

NA – Not Applicable

Sample Custody	SSFL SOP 10 Revision: 1 Date: November 2012

Prepared:	J. Sobol	**Technical Review:**	C. Werden
QA Review:	J. Oxford	**Approved and Issued:**	John T Wondolleck 11/20/2012 *Signature/Date*

1.0 Objective

Because of the evidentiary nature of samples collected during environmental investigations, possession must be traceable from the time the samples are collected until their derived data are used to support remedial or other decisions. To maintain and document sample possession, sample custody procedures, as described in this technical standard operating procedure (SOP) are followed. All paperwork associated with the sample custody procedures at the Santa Susana Field Laboratory (SSFL) site will be retained in CDM Smith files unless Department of Energy (DOE) requests that it be transferred to them.

2.0 Background

2.1 Definitions

Sample – A sample is material to be analyzed that is contained in single or multiple containers representing a unique sample identification number.

Sample Custody–A sample is under custody if:

1. It is in your possession
2. It is in your view, after being in your possession
3. It was in your possession and you locked it up
4. It is in a designated secure area
5. It is in transit by a delivery or courier service

Chain-of-Custody Record–A chain-of-custody record is a form used to document the transfer of custody of samples from one individual to another. The forms are electronic and managed in the Scribe software. An example form is included in the Field Sampling Plan (FSP) Addendum and attached to this SOP.

Custody Seal–A custody seal is a tape-like seal that is part of the chain-of-custody process and is used to detect tampering with samples after they have been packed for shipping. Custody seals are placed on coolers not individual samples.

Sample Label– A sample label is an adhesive label placed on sample containers to designate a sample identification number and other sampling information.

2.2 Associated Procedures

- SSFL SOP 2, *Surface Soil Sampling*
- SSFL SOP 3, *Subsurface Soil Sampling with Hand Auger*
- SSFL SOP 4, *Direct Push Technology Sampling*
- SSFL SOP 5, *Backhoe Trenching/Test Pits for Sample Collection*
- SSFL SOP 8, *Field Data Collection Documents, Content, and Control*

3.0 General Responsibilities

Field Team Leader–The field team leader (FTL) is responsible for ensuring that strict chain-of-custody procedures are maintained during all sampling events. The FTL is also responsible for coordinating with the subcontract laboratory to ensure that adequate information is recorded on custody records. The FTL determines whether proper custody procedures were followed during the fieldwork.

Field Sample Coordinator–The field sample coordinator, designated by the FTL, is responsible for accepting custody of samples from the sampler(s) and properly packing and shipping the samples to the laboratory assigned to do the analyses.

Sampler–The sampler is personally responsible for the care and custody of the samples collected until they are properly transferred or dispatched.

Site Health and Safety Technician– The person who will use field screening instruments to monitor all field activities for VOCs and radiological contaminants and pre-shipment sample coolers. This person is a trained radiological technician who works under the guidance of Science Application International Corporation's (SAIC's) Certified Health Physicist (CHP).

4.0 Required Supplies

- Chain-of-custody record forms
- Sample labels
- Computer
- Waterproof pen
- Custody seals
- Clear tape
- Printer and paper
- Ball point ink pen

5.0 Procedures

5.1 Chain-of-Custody Record

This procedure establishes a method for maintaining custody of samples through use of a chain-of-custody record. This procedure will be followed for all samples collected.

Field Custody

1. The quantity and types of samples to be collected and the proposed sample locations are documented in the Field Sampling Plan Addendum.

2. Complete sample labels for each sample using waterproof ink.

3. Maintain personal custody of the samples (in your possession) at all times until custody is transferred to the FTL or sample coordinator for sample shipment.

Transfer of Custody and Shipment

1. Complete a chain-of-custody record for all samples (see Attachment A).To transfer the possession of samples, the individuals relinquishing and receiving will sign, date, and note the time on the record. This record documents sample custody transfer from the sampler, often through another person, to the laboratory sample manager in the appropriate laboratory.

   - The date/time will be the same for both signatures when custody is transferred directly to another person. When samples are shipped via common carrier (e.g., Federal Express), the date/time will not be the same for both signatures. In all cases, it must be readily apparent that the person who received custody is the same person who relinquished custody to the next custodian.
   - If samples are left unattended or a person refuses to sign, this must be documented and explained on the chain-of-custody record.

   Note: The FTL or field sample coordinator will initiate the chain-of-custody record, sign, and date as the relinquisher. The individual sampler(s) must sign in the appropriate block, but does (do) not need to sign and date as a relinquisher.

2. Package samples properly for shipment and dispatch to the appropriate laboratory for analysis. Each shipment must be accompanied by a separate chain-of-custody record. If a shipment consists of multiple coolers, the original, or a copy of the chain-of-custody record shall accompany each cooler in the shipment.

3. The original record will accompany the shipment. Copies are retained by the FTL and distributed to the appropriate sample coordinator(s). Freight bills will also be retained by the FTL as part of the permanent documentation. The shipping number from the freight bill shall be recorded on the applicable chain-of-custody record and field logbook (in accordance with SSFL SOP 8).

Completing Chain-of-Custody Record

Sample Custody	SSFL SOP 10 Revision: 1 Date: November 2012

Scribe generates a COC that shall include the following information:

1. Site name, CDM Smith contact name and phone number, COC number.
2. Name, phone number and address of the laboratory where the samples are being shipped.
3. Date shipped, courier's name, and airbill number (if applicable).
4. Sample ID number.
5. Sample date and military time.
6. Matrix and preservative.
7. Type and Number of Containers.
8. Turnaround times.
9. Analyses requested.
10. List any special instructions. Also, note which samples may have high PID or RAD concentrations as advanced notice for the laboratory.
11. Sign the COC record in the space provided, including the date and time relinquished.
12. The sampler must sign each original COC.

Review the form to ensure that all information is completed and that all entries are correct.

5.2 Sample Labels

Sample labels will be used for all samples collected at the SSFL site.

1. Complete one label with the following information for each sample container collected. For Encore Samplers, the label will be placed on the zip-top bag that contains all Encores for one sample:

   - sample identification number.
   - Date (i.e., month, day, and year of collection).
   - Time (i.e., military) of sample collection.
   - Mark to indicate soil or water sample.
   - Sampler will place their initials in the space provided.
   - List preservative type.

List or mark the "Analyses" for which the sample is to be analyzed.

2. Place adhesive labels directly on the sample containers so that the label is completely below the lid of the container. Place clear tape over the label to protect from moisture.

Note: The EnCore sampler is very small; therefore, the sample label is placed on the zip-top bag that contains the samplers.

3. Double-check that the information recorded on the sample label is consistent with the information recorded on the chain-of-custody record.

5.3 Custody Seals

Two custody seals must be placed on opposite corners of all shipping containers (e.g., cooler) before shipment. The seals shall be signed and dated by the shipper.

5.4 Sample Shipping

SSFL SOP 11 defines the requirements for packaging and shipping environmental samples. Following packing, all coolers must be screened for radiation by the Site Health and Safety Technician (SSFL SOP 7).

6.0 Restrictions/Limitations

There are no identified restrictions/limitations.

7.0 References

U. S. Environmental Protection Agency. Revised March 1992 or current revision. *National Enforcement Investigations Center, Multi-Media Investigation Manual*, EPA-330/9-89-003-R. p.85.

__________. 2006-2011. Scribe Manuals. http://www.ertsupport.org/scribe_home.htm and http://www.epaosc.org/scribe

__________. 2011 or current revision. *Sampler's Guide, Contract Laboratory Program Guidance for Field Samplers*, EPA-540-R-09-03. January.

8.0 Attachments

Attachment A – Example Chain of Custody Form

Attachment A

Example Chain of Custody Form

SSFL Phase 3 Chain of Custody

CDM Smith
DateShipped: Contact Name: COC No:
CarrierName: Contact Phone: Cooler #:
AirbillNo: Lab:
Lab Phone:
Lab Address

Sample	Date/ Time	Matrix	Preserv.	Type/No of Containers	Turn Around Time	Metals 6010 and 6020	Mercury 7471 (Soil)	Mercury 7420 (Water)	Fluoride 300.0/9056	SVOC 8270	TIC 8270	PAHs 8270 SIM	1,4 Dioxane 8270 SIM	Dioxins 1613	PCBs/PCTs 8082	Perchlorate 314.0/331	Perchlorate Confirm 6850/6860	pH 9045 (Soil)	pH 9040 (Water)	Hex Cr 7196/7199	Herbicides 8151	Pesticides 8081	VOCs 8260	1,4 Dioxane 8260 SIM	TPH-GRO 8015	TPH-EFH 8015	Glycols 8015	Alcohols 8015	Terphenyls 8015	Nitrates 300.0/9056	Energetics 8330	Cyanide 9012	Formaldehyde 8315	NDMA 1625	Organotin	Methyl Mercury 1630	Other Analysis/Notes

Special Instructions: Sampler:

Relinquished by	Date	Time	Received by	Date	Time	Relinquished by	Date	Time	Received by	Date	Time

COC Rev 2 COC: , Page1 of1

Packaging and Shipping Environmental Samples	SSFL SOP 11 Revision: 1 Date: December 2012

Prepared: D. Lange

Technical Review: C. Zakowski

QA Review: K. Zilis

Approved and Issued: [signature] 12/13/2012
Signature/Date

1.0 Objective

The objective of this technical standard operating procedure (SOP) is to outline the requirements for the packaging and shipment of environmental samples for the Santa Susana Field Laboratory (SSFL) site. Additionally, Sections 2.0 and 3.0 outline requirements for the packaging and shipping of regulated environmental samples under the Department of Transportation (DOT) Hazardous Materials Regulations, the International Air Transportation Association (IATA), and International Civil Aviation Organization (ICAO) Dangerous Goods Regulations for shipment by air and apply only to domestic shipments. This SOP does not cover the requirements for packaging and shipment of equipment (including data or bulk chemicals) that are regulated under the DOT, IATA, and ICAO. However, packaging and shipment of hazardous material and radioactive samples is not expected.

1.1 Packaging and Shipping of All Samples

This SOP applies to the packaging and shipping of all environmental samples. Samples displaying radioactivity above background concentrations will not be collected or shipped.

Note: This SOP does not address shipment of hazardous or radioactive materials. Do not ship a hazardous or radioactive material unless you have received training that meets the requirements of the Department of Energy (DOE), The Boeing Company (Boeing), CDM Smith, and the DOT.

2.0 Background

2.1 Definitions

Environmental Sample - An aliquot of sample representative of the site. This definition applies only to environmental samples that contain less than reportable quantities for any foreseeable hazardous constituents according to DOT regulations promulgated in 49 CFR - Part 172.101 Appendix A.

Custody Seal - A custody seal is a narrow adhesive-backed seal that is applied to individual sample containers and/or the container (i.e., cooler) before offsite shipment. Custody seals are used to demonstrate that sample integrity has not been compromised during transportation from the field to the analytical laboratory.

Inside Container - The container, normally made of glass or plastic, that actually contacts the shipped material. Its purpose is to keep the sample from mixing with the ambient environment.

Outside Container - The container, normally made of metal or plastic, that the transporter contacts. Its purpose is to protect the inside containers.

Secondary Containment - The outside container provides secondary containment if the inside container breaks (i.e., plastic over packaging if liquid sample is collected in glass).

Excepted Quantity - Excepted quantities are limits to the mass or volume of a hazardous material below which DOT, IATA, ICAO regulations do not apply. The excepted quantity limits are very low. Most regulated shipments will be made under limited quantity.

Limited Quantity - Limited quantity is the amount of a hazardous material exempted from DOT labeling or packaging requirements in 49 CFR. Authorized exemptions are noted under column 8A in the Hazardous Materials Table in 49 CFR 172.101.

Qualified Shipper - A qualified shipper is a person who has been adequately trained to perform the functions of shipping hazardous materials.

2.2 Associated Procedures

- SSFL SOP 10, *Sample Custody*

2.3 Discussion

Proper packaging and shipping is necessary to ensure the protection of the integrity of environmental samples shipped for analysis. These shipments are potentially subject to regulations published by DOT. Failure to abide by these rules places both CDM Smith and the individual employee at risk of serious fines. The analytical holding times for the samples must not be exceeded. If necessary, the samples shall be packed in time to be shipped for overnight delivery or for pick-up by the laboratory courier. Make arrangements with the laboratory before sending samples for weekend delivery.

3.0 General Responsibilities

Field Team Leader–The field team leader (FTL) is responsible for:

- Ensuring that field personnel package and ship samples in accordance with this SOP.
- Ensuring samples are shipped such that holding times can be met by the laboratory.
- Ensuring normal samples collected and QC samples are documented on the Chain of Custody (CoC).

Site Health and Safety Technician–The person who will use field screening instruments to monitor all field activities for VOCs and radiological contaminants and pre-shipment sample coolers. This person is a trained radiological technician who works under the guidance of Science Application International Corporation's (SAIC's) Certified Health Physicist (CHP).

4.0 Required Equipment

The following equipment will be needed in the field trailer to conduct sample packing and shipping:

- Site-specific plans (e.g., Field Sampling Plan [FSP] Addendum, health and safety plan)
- Insulated coolers
- Heavy-duty plastic bags
- Plastic zip-top bags, small and large
- Clear tape
- Duct tape
- Nylon reinforced strapping tape
- Rubber bands (optional)
- Bubble wrap (optional)
- Ice in bags
- Custody seals
- Chain-of-custody record
- This End Up and directional arrow labels
- Overnight courier airbills

5.0 Procedures

5.1 Packaging Environmental Samples

Preservatives in samples are not anticipated to meet threshold criteria to be classified as hazardous materials for shipping purposes. The following steps must be followed when packing sample bottles and jars for shipment:

1. Verify the samples undergoing shipment meet the definition of "environmental sample" and are not a hazardous material as defined by DOT. Professional judgment and/or consultation with qualified persons such as the appropriate health and safety coordinator or the health and safety manager shall be observed.

2. Select a sturdy cooler in good repair. Tape any interior opening in the cooler (drain plug) from the inside to ensure control of interior contents. Also, tape the drain plug from the outside of the cooler. Line the cooler with a large heavy-duty plastic bag.

3. Be sure the caps on all bottles are tight (will not leak); check to see that labels and chain-of-custody records are completed properly (SSFL SOP 10).

4. Place all bottles in separate and appropriately sized plastic zip-top bags and close the bags. Up to three VOA vials may be packed in one bag. Binding the vials together with a rubber band on the outside of the bag, or separating them so that they do not contact each other, will reduce the risk of breakage. Bottles may be wrapped in bubble wrap or placed into foam bottle holders.

Note: Trip blanks must be included in coolers containing VOA samples.

5. Place bubble wrap in the bottom of an empty cooler followed by a large plastic bag, and place the sample containers in the bag with sufficient space to allow for the addition of packing material between any glass containers. It is preferable to place glass sample bottles and jars into the cooler vertically. Glass containers are less likely to break when packed vertically rather than horizontally. The containers may alternatively be placed into foam or cardboard holders that fit within the coolers.

6. While placing sample containers into the cooler, conduct an inventory of the contents of the shipping cooler against the chain-of-custody record.

7. Put ice in large plastic zip-top bags (double bagging the zip-tops is preferred) and properly seal. Place the ice bags on top of and/or between the samples. Several bags of ice are required (dependant on outdoor temperature, staging time, etc.) to maintain the cooler temperature at approximately 4° Celsius (C) ± 2° C . Fill all remaining space between the bottles or cans with packing material. Securely fasten the top of the large plastic bag with fiber or duct tape or a zip tie.

8. Print copies of the electronic CoC form. Place one copy of the completed CoC record for the laboratory into a plastic zip-top bag, seal the bag, and tape the bag to the inner side of the cooler lid. Retain a second copy of the CoC for sample management records. Close the cooler lid.

9. The cooler lid shall be secured with nylon reinforced strapping tape by wrapping each end of the cooler a minimum of two times. Attach a completed chain-of-custody seal across the opening of the cooler on opposite sides. The custody seals shall be affixed to the cooler with half of the seal on the strapping tape so that the cooler cannot be opened without breaking the seal. Complete two more wraps around with fiber tape and place clear tape over the custody seals.

10. The shipping container lid must be marked **"THIS END UP"** and arrow labels that indicate the proper upward position of the container shall be affixed to the cooler. Labels used in the shipment of hazardous materials (such as Cargo Only Air Craft, Flammable Solids, etc.) are not permitted on the outside of containers used to transport environmental samples and shall not be used. The name and address of the laboratory is included on the shipping label (i.e., overnight delivery service label).

11. Screen the cooler with the radiation meter before shipment and document that a background level (at most) exists. The cooler will be surveyed by the RAD Technician to ensure that Radiation flux on exterior surfaces does not exceed 0.5 mrem/hr on all sides. This survey will be documented and the results reviewed by the qualified shipper, as needed.

5.2 Packaging of Limited-Quantity Radioactive Samples

Samples containing radioactivity above background will be handled in accordance with DOT shipment regulations and the requirements of the analytical laboratory receiving the samples. Per DOT shipment regulations, packages cannot exceed 200 millirem per hour and/or 2,200 disintegrations per minute as measured at any point on the package surface. Samples with exceedence of radiological screening levels (per the health and safety plan or SSFL SOP 7) will be set aside and the DOE, California Department of Toxic Substance Control (DTSC), and Boeing will be contacted. Screening limits are 30 millirem per hour and 200 disintegrations per minute.

6.0 Restrictions/Limitations

This SOP addresses the packing and shipping of environmental samples exhibiting typical radioactivity for SSFL (less than 30 millirem per hour for gamma emitters and 200 disintegrations per minute for alpha/beta emitters). Being a site that has a history of radioactive occurrences, the sample locations, samples, and coolers will be screened for radioactivity. However, CDM Smith will not handle, package, or ship samples with radioactivity that exceeds DOT regulations or the requirements of the receiving laboratory. If radioactivity above these levels is detected, packing and shipping work will be temporarily suspended and DOE, DTSC, and Boeing will be contacted for further direction. The cooler or samples will be set aside, and work with those samples will not resume until approved for shipment by DOE. Any effort beyond stop work will require modified SOPs.

7.0 References

U. S. Environmental Protection Agency. (EPA). 2007 or current revision. *Sampler's Guide, Contract Laboratory Program, Guidance for Field Samplers*, EPA-540-R-07-06.

Title 49 Code of Federal Regulations, Department of Transportation. 2005 or current revision. *Hazardous Materials Table, Special Provisions, Hazardous, Materials Communications, Emergency Response Information, and Training Requirements*, 49 CFR 172.

Title 49 Code of Federal Regulations, Department of Transportation. 2005 or current revision. *Shippers General Requirements for Shipments and Packaging*, 49 CFR 173.

Field Equipment Decontamination	SSFL SOP 12 Revision: 1 Date: November 2012

Prepared:	R. Kaspzyk	**Technical Review:**	C. Werden
QA Review:	J. Oxford	**Approved and Issued:**	[signature] 11/26/2012 *Signature/Date*

1.0 Objective

The objective of this technical standard operating procedure (SOP) is to describe the general procedures required for decontamination of non-disposable field equipment for the Santa Susana Field laboratory (SSFL) site. Given the history of radioactive material usage at SSFL, screening for radioactive materials will occur with all field operations. Decontamination of field equipment is necessary to ensure acceptable quality of samples by preventing cross-contamination. Further, decontamination reduces health hazards and prevents the spread of contaminants off site.

2.0 Background

Decontamination of equipment will occur before sampling begins and between each sample collection (for sampling equipment). All decontamination water will be collected for future disposal.

2.1 Definitions

ASTM Type II Water – Reagent grade water defined by American Society for Testing and Materials (ASTM) that is used in the final rinse of surfaces of contaminated equipment.

Clean – Free of contamination and when decontamination has been completed in accordance with this SOP.

Cross-Contamination – The transfer of contaminants through equipment or personnel from the contamination source to less contaminated or non-contaminated samples or areas.

Decontamination – The process of rinsing or otherwise cleaning the surfaces of equipment to rid them of contaminants and to minimize the potential for cross-contamination of samples or exposure of personnel.

Material Safety Data Sheets – These documents discuss the proper storage and physical and toxicological characteristics of a particular substance used during decontamination. These documents, generally included in site health and safety plans, shall be kept on site at all times during field operations.

Potable Water – Potable water is provided by local city sources and is safe for consumption. Chemical analysis of the water source will not be required before it is used.

Site Health and Safety Technician–The person who will use field screening instruments to monitor all field activities for VOCs and radiological contaminants and pre-shipment sample coolers. This person is a trained radiological technician who works under the guidance of Science Application International Corporation's (SAIC's) Certified Health Physicist (CHP).

Sampling Equipment – Equipment that comes into direct contact with the sample media.

Soap – Low-sudsing, non-phosphate detergent such as Liquinox™.

2.2 Associated Procedures

- SSFL SOP 2, *Surface Soil Sampling*
- SSFL SOP 3, *Subsurface Soil Sampling with Hand Auger*
- SSFL SOP 4, *Direct Push Technology Sampling*
- SSFL SOP 5, *Backhoe Trenching/Test Pits for Sample Collection*

- SSFL SOP 6, *Field Measurement of Total Organic Vapors*
- SSFL SOP 7, *Field Measurement of Residual Radiation*
- SSFL SOP 13, *Guide to Handling Investigation-Derived Waste*

3.0 Responsibilities

Field Team Leader (FTL)-ensures that field personnel are trained in the performance of this procedure and that decontamination is conducted in accordance with this SOP. The FTL may also be required to collect and document rinsate samples (also known as equipment blanks) to provide quantitative verification that these procedures have been correctly implemented.

Field Team Member-performs decontamination of field sampling equipment and/or or oversees subcontractors performing decontamination activities. Ensures the procedures are followed, equipment is clean, and collects field equipment rinseate blanks.

4.0 Required Equipment

- Stiff-bristle scrub brushes
- Plastic buckets and troughs
- Portable hot-water/steam, high pressure spray cleaners
- Soap
- Nalgene or Teflon sprayers or wash bottles or 2- to 5-gallon, manual-pump sprayer (pump sprayer material must be compatible with the solution used)
- Plastic sheeting, plastic bags, and/or aluminum foil to keep decontaminated equipment clean between uses
- Disposable wipes, rags, or paper towels
- Potable water
- ASTM Type II water
- Trough or collection pool to contain wash waters during decontamination
- Sheet plastic to place beneath trough to contain any splash water
- Gloves, safety glasses, and other protective clothing as specified in the health and safety plan
- Tools for equipment assembly and disassembly (as required)
- 55-gallon drums for temporary storage of decontamination water
- Drum labels
- Pallets for drums holding decontamination water
- Pump to transfer water to drums (as needed)

5.0 Procedures

Decontaminate all reusable equipment (non-dedicated) used to collect and/or handle samples before coming into contact with any sampled media or personnel using the equipment. Screen all used equipment for radioactivity before transport to the decontamination area (SSFL SOP 7). Decontaminate equipment at portable decontamination stations set up at the sampling location. Transport equipment to and from the decontamination station in a manner to prevent cross-contamination of equipment and/or area. Take precautions such as enclosing large equipment (rods) in plastic wrap while being transported .

Construct the decontamination area so that contaminated water is either collected directly into appropriate containers (5-gallon buckets or steel wash tubs) suitable for collecting the decontamination water. If needed construct small soil berm or depression lined with plastic to collect any overspray or splash. Transfer water from the collection pool and containment area into 55-gallon drums for temporary storage. Stage decontamination water until sampling results or waste characterization results are obtained and evaluated and the proper disposition of the waste is determined (SSFL SOP 13).

Decontaminate all items that come into contact with potentially contaminated media before use and between sampling and/or drilling locations. If decontaminated items are not immediately used, cover them with either clean plastic or aluminum foil depending on the size of the item. Decontamination procedures for equipment are as follows:

Field Equipment Decontamination

SSFL SOP 12
Revision: 1
Date: November 2012

General Guidelines

- Potable and ASTM Type II water will be free of all contaminants of concern.
- Decontaminated equipment will be allowed to air dry before being used.
- Equipment type, date, time, and method of decontamination along with associated field quality assurance sampling shall be recorded in the appropriate logbook.
- Gloves, boots, safety vest, safety glasses, and any other personnel protective clothing and equipment shall be used as specified in the health and safety plan.

5.1 Heavy Equipment Decontamination

The following steps will be used when decontaminating heavy equipment (i.e., backhoes):

1. Establish a decontamination area (e.g., large troughs or plastic sheeting with temporary wood bermed sides) that is large enough to fully contain the equipment to be cleaned. All decontamination areas must be upwind of the area under investigation.

2. Screen the backhoe bucket and arm for radioactivity. If measured above background, take measures to contain decontamination water separately from non-radioactive-impacted water.

3. With the heavy equipment in place, spray areas (e.g., bucket of the backhoe) exposed to contaminated media using a hand-handle sprayer. Be sure to spray down all surfaces that contact soil.

4. Use brushes, soap, and potable water to remove dirt whenever necessary.

5. Remove equipment from the decontamination pool and allow it to air dry before returning it to the work site.

6. After decontamination activities are completed, collect all contaminated wastewater, plastic sheeting, and disposable gloves, boots, and clothing in separate containers or receptacles (i.e., solids and liquids). A decontamination area may be used for multiple day/weeks provided the containment integrity is maintained. All receptacles containing contaminated items must be properly labeled for disposal. Liquids must be separated from solids and drummed.

5.2 Downhole Equipment Decontamination

Downhole equipment includes rods, stems, etc. Follow these steps when decontaminating this equipment:

1. Set up a centralized decontamination area (e.g., large trough or plastic bermed area), if possible. This area shall be set up to collect contaminated rinse waters and to minimize the spread of airborne spray.

2. Set up a “clean” area upwind of the decontamination area to receive cleaned equipment for air-drying. At a minimum, clean plastic sheeting must be used to cover tables or other surfaces on which decontaminated equipment is to be placed. All decontamination areas shall be upwind of any areas under investigation.

3. Screen all equipment for radioactivity before decontamination. If measured above background, take measures to contain decontamination water separately from non-radioactive-impacted water.

4. Place the object in a 5-gallon bucket or tub for detergent wash. If needed, longer equipment may be placed on aluminum foil or plastic-covered wooden sawhorses or other supports. The objects to be cleaned shall be at least 2 feet above the ground to avoid splash back when decontaminating.

5. Using soap and potable water wash the contaminated equipment. When using hand-held sprayers aim nozzle downward to avoid spraying outside the decontamination area. Be sure to spray inside corners and gaps especially well. Use a brush, if necessary, to dislodge dirt.

6. Move the equipment to a second bucket and rinse the equipment using clean, potable water.

7. Using a suitable sprayer, conduct a final rinse of the equipment thoroughly with ASTM Type II water.

8. Remove the equipment from the decontamination area and place in a clean area upwind to air dry.

9. After decontamination activities are completed, collect all contaminated wastewaters, plastic sheeting, and disposable gloves, boots, and clothing in separate containers or receptacles. All receptacles containing contaminated items must be properly labeled for disposal. Liquids must be separated from solids and drummed. Any radioactive decontamination water must be contained in separate drums.

5.3 Sampling Equipment Decontamination

Follow these steps when decontaminating sampling equipment:

1. Set up a decontamination line (e.g., buckets or trough). The decontamination line shall progress from "dirty" to "clean." A clean area shall be established upwind of the decontamination wash/rinse activities to dry the equipment. At a minimum, clean plastic sheeting must be used to cover the tables or other surfaces that the decontaminated equipment is placed for drying.

2. Disassemble any items that may trap contaminants internally. Do not reassemble the items until decontamination and air drying are complete.

3. Wash the items with potable water and soap using a stiff brush as necessary to remove particulate matter and surface films.

4. Thoroughly rinse the items with potable water.

5. Rinse the items thoroughly using ASTM Type II water.

6. Allow the items to air dry completely.

7. After drying, reassemble the parts as necessary and wrap the items in clean plastic wrap, place in plastic baggies or in aluminum foil if not used immediately.

8. After decontamination activities are completed, collect all contaminated waters, plastic sheeting, and disposable personal protective equipment. Separate solid waste from liquid investigation-derived waste. Place solid items in trash bags for municipal disposal. Liquids must be separated from solids and drummed. Any radioactive decontamination water must be contained in separate drums. Refer to site-specific plans for labeling and waste management requirements.

5.4 Waste Disposal

Refer to site-specific plans and SSFL SOP 13 for waste disposal requirements. The following are guidelines for disposing of wastes:

- All wash water, rinse water, and decontamination solutions that have come in contact with contaminated equipment are to be handled, packaged (55-gallon drums), labeled, marked, stored, and disposed of as investigation-derived waste.
- Small quantities of decontamination solutions may be allowed to evaporate to dryness.
- Unless otherwise required, plastic sheeting and disposable protective clothing may be treated as solid, nonhazardous waste and placed in trash bags for disposal.
- Waste liquids shall be sampled, analyzed for contaminants of concern in accordance with disposal regulations, and disposed of accordingly.

6.0 Restrictions/Limitations

If the field equipment is not thoroughly rinsed and allowed to completely air dry before use, volatile organic residue, which interferes with the analysis, may be detected in the samples. The occurrence of residual organic solvents is often dependent on the time of year sampling is conducted. In the summer, volatilization is rapid, and in the winter, volatilization is slow.

7.0 References

American Society for Testing and Materials (ASTM). 2002. *Standard Practice for Decontamination of Field Equipment at Nonradioactive Waste Sites*, ASTM D5088-02. January 10.

U. S. Environmental Protection Agency. 1987. *A Compendium of Superfund Field Operations Methods*, EPA/540/P-87/001.1.

Guide to Handling Investigation-Derived Waste	SSFL SOP 13 Revision: 1 Date: November 2012

Prepared:	R. Kaspzyk	**Technical Review:**	C. Werden
QA Review:	J. Oxford	**Approved and Issued:**	John T Wondolleck 11/26/2012 *Signature/Date*

1.0 Objective

This technical standard operating procedure (SOP) presents guidance for the management of investigation-derived waste (IDW) generated at the Santa Susana Field Laboratory (SSFL) site during soil sampling, trenching, and equipment decontamination activities. The primary objectives for managing IDW during field activities include:

- Leaving the site in no worse condition than existed before field activities
- Removing wastes that pose an immediate threat to human health or the environment
- Segregating radiological wastes above background or "permissible" concentrations
- Complying with federal, state, local, regulations
- Minimizing the quantity of IDW

2.0 Background

2.1 Definitions

Hazardous Waste - Discarded material that is regulated listed waste, or waste that exhibits ignitability, corrosivity, reactivity, or toxicity as defined in 40 CFR 261.3 or state regulations.

Investigation-Derived Wastes - Discarded materials resulting from field activities such as sampling, surveying, drilling, excavation, and decontamination processes that, in present form, possess no inherent value or additional usefulness without treatment. Wastes will be personal protective equipment, (e.g., nitrile gloves, paper towels, polyethylene sheeting) and decontamination fluids that may be classified as hazardous or nonhazardous.

Mixed Waste - Any material that has been classified as both hazardous and radioactive.

Radioactive Wastes - Discarded materials that are contaminated with radioactive constituents with specific activities in concentrations greater than the latest regulatory criteria (i.e., 10 CFR 20).

Treatment, Storage, and Disposal Facility (TSDF) - Permitted facilities that accept hazardous waste shipments for further treatment, storage, and/or disposal. These facilities must be permitted by the U.S. Environmental Protection Agency (EPA) and appropriate state and local agencies.

2.2 Discussion

Field investigation activities result in the generation of waste materials that may be characterized as hazardous or radioactive. IDWs may include solutions from decontaminating sampling equipment; and other wastes or supplies used in sampling and testing potentially hazardous or radiological contaminated material. Personal protective equipment (PPE) and other solid waste (paper towels, plastic sheeting, etc) are not considered IDW. DPT cuttings, excess sample spoils, and excavated soil will be returned to the borehole/excavation and are not considered IDW.

3.0 General Responsibilities

Field Team Leader-The field team leader (FTL) is responsible for ensuring that field personnel conduct field activities in accordance with this SOP and the Field Sampling Plan (FSP) Addendum.

Field Team Members-Field team members are responsible for implementing this SOP and communicating any unusual or unplanned condition to the FTL's attention.

Site Health and Safety Technician–The person who will use field screening instruments to monitor all field activities for VOCs and radiological contaminants and pre-shipment sample coolers. This person is a trained radiological technician who works under the guidance of Science Application International Corporation's (SAIC's) Certified Health Physicist (CHP).

4.0 Required Equipment and Handling

4.1 IDW Containment Devices

Currently, the anticipated IDW containment device is:

- Department of Transportation (DOT)-approved 55-gallon steel containers (drums)

4.2 IDW Container Labeling

An "IDW Container" label shall be applied to each drum using indelible marking. Labeling or marking requirements for IDW are as detailed below.

- The Site Health and Safety Technician will screen all containers for radioactivity using hand-held field instruments.
- Include the following information on labels and markings: project name, generation date, location of waste origin, container identification number, sample number (if applicable), and contents (i.e., decontamination water).
- Apply each label or marking to the upper one-third of the container at least twice, on opposite sides.
- Position labels or markings on a smooth part of the container. The label must not be affixed across container bungs, seams, ridges, or dents.
- Use weather-resistive material for labels and markings and permanent markers or paint pens capable of enduring the expected weather conditions. If markings are used, the color must be easily distinguishable from the container color.
- Secure labels in a manner to ensure that they remain affixed to the container.

Labeling or marking requirements for hazardous (or radioactive) IDW expected to be transported offsite must be in accordance with the requirements of 49 CFR 172 (not anticipated for this work). Wastes determined to be hazardous or radioactive will be staged onsite until disposal options are determined by Department of Energy (DOE) or The Boeing Company (Boeing). Boeing will notify the California Department of Toxic Substances Control of disposal in accordance with Boeing's RCRA permit. Contact information is provided in the health and safety plan.

4.3 IDW Container Movement

Predetermine staging areas for IDW containers in accordance with SSFL requirements. Determine the methods and personnel required to safely transport IDW containers to the staging area before field mobilization. Handling and transport equipment will be consistent with the associated weight for both lifting and transporting. Transportation of IDW containers offsite via a public roadway is prohibited unless 49 CFR 172 requirements are met.

Wastes determined to be hazardous or radioactive will be handled as directed by DOE or Boeing and segregated from standard IDW and solid wastes.

4.4 IDW Container Storage

Stage containerized IDW awaiting results of chemical analysis at a pre-determined location on the SSFL site. Store containers such that the labels can be easily read. Provide a secondary/spill container for liquid IDW storage (e.g., steel drums shall not be stored in direct contact with the ground).

5.0 Procedures

All liquid IDW generated at the site will be disposed offsite. The field screening and chemical analyses will determine the ultimate disposition of the waste. Formal plans for the management of IDW will be determined by CDM Smith and submitted to DOE, Boeing, and DTSC for approval. Interim management of IDW is discussed below.

5.1 Collection for Offsite Disposal

Radiological screening and laboratory analysis are required before sending any IDW to an offsite TSDF or to a publicly owned treatment works (POTW). Manifests are required to accompany any IDW determined to be hazardous, and DOE will direct the handling of this material. Arrange with DOE and/or Boeing who are responsible for the site and signing as generator on any waste profile and all manifests or bill of ladings; it is CDM Smith's policy not to take ownership of the waste, but may sign waste profiles or manifests on behalf of DOE or Boeing, as an authorized contractor. Use permitted TSDFs and transporters for the respective wastes. Non-bulk containers (e.g., drums) must have a DOT-approved label affixed to the container and all required associated placard stickers before leaving SSFL for an offsite TSDF. Include information as required in 49 CFR 172.

5.1.1 Aqueous Liquids

Store used decontamination fluids in appropriate containers (e.g., 55-gallon drums) at a pre-designated staging area at SSFL. Prior to being disposed offsite by a disposal vendor, ship a sample of the fluids for laboratory analysis.

5.2.2 Disposable PPE and Other Solid Waste

Dispose of personal protective equipment and other solid waste (paper towels, plastic, etc.) offsite as solid waste. After screening for radioactivity, these wastes may be contained in standard plastic trash bags and placed in trash cans.

6.0 Restrictions/Limitations

The project managers will determine the most appropriate disposal option for solid waste and used decontamination fluids. Parameters to consider, especially when determining the level of protection, include the volume of IDW and the level of contaminants present in the surface and subsurface soils. Under no circumstances will IDW materials be stored in a site office or warehouse.

7.0 References

Title 49 Code of Federal Regulations, Department of Transportation. 2005 or current revision. *Hazardous Materials Table, Special Provisions, Hazardous, Materials Communications, Emergency Response Information, and Training Requirements*, 49 CFR 172.

U. S. Environmental Protection Agency (EPA).1990. *Low-Level Mixed Waste: A RCRA Perspective for NRC Licensees*, EPA/530-SW-90-057. August

__________. January 1992. *Guide to Management of Investigation-Derived Wastes*, 9345.3-03FS.

Photographic Documentation of Field Activities

SSFL SOP 15
Revision: 0
Date: April 2012

Prepared: A. Herrington

Technical Review: C. Werden

QA Review: J. Oxford

Approved and Issued: John T Wondolleck 4/6/2012
Signature/Date

1.0 Objective

The purpose of this technical standard operating procedure (SOP) is to provide standard guidelines and methods for photographic documentation. All photography should be digital – camera and/or video – and document field activities and site features (geologic formations, core sections, lithologic samples, general site layout, etc.). This SOP is intended for circumstances when formal photographic documentation is required.

All photography at SSFL is highly restricted. The use of cameras or video equipment at the SSFL site requires a permit secured through the primary site manager – The Boeing Company (Boeing). Unpermitted photography is strictly prohibited.

2.0 Background

2.1 Definitions

Standard Reference Marker - A standard reference marker is a reference marker that is used to indicate a feature size in the photograph and is a standard length of measure, such as a ruler, meter stick, etc. In limited instances, if a ruled marker is not available or its use is not feasible, it can be a common object of known size placed within the visual field and used for scale.

2.2 Associated Procedures

- SSFL SOP 2, *Surface Soil Sampling*
- SSFL SOP 3, *Subsurface Soil Sampling with Hand Auger*
- SSFL SOP 4, *Direct Push Technology Sampling*
- SSFL SOP 5, *Backhoe Trenching/Test Pits for Sample Collection*
- SSFL SOP 8, *Field Data Collection Documents, Content, and Control*
- SSFL SOP 14, *Geophysical Survey*

2.3 Discussion

Photographs taken during field investigations are used as an aid in documenting and describing site features, sample collection activities, equipment used, and possible lithologic interpretation. This SOP provides basic details for taking photographs during fieldwork. The use of a photographic logbook or log form and standardized entry procedures are also outlined. In addition, all SOPS will be on hand with the field sampling team.

3.0 General Responsibilities

Field Team Leader-The field team leader (FTL) is responsible for ensuring that the format and content of photographic documentation are in accordance with this procedure. The FTL is also responsible for supporting decisions of items to be photographed - specific situations, site features, or operations that the photographer will be responsible for documenting.

Photographer-The photographer is one of the field crew. The photographer is responsible for maintaining a logbook or photographic log form per Sections 5.1 and 5.2 of this SOP.

4.0 Required Equipment

A general list of equipment that may be used:

- 35mm digital camera
- Standard reference markers

- Logbook
- Indelible black or blue ink pen
- Extra batteries for 35mm camera
- Storage medium (disks or cards) for digital camera

5.0 Procedures

5.1 Documentation

Use a photographic log form and/or project specific logbook to log and document photographic activities. Review SSFL SOP 8.

5.2 Operation

5.2.1 General Photographic Activities in the Field

The following sections provide general guidelines that should be followed to visually document field activities and site features using digital cameras and video equipment. Listed below are general suggestions that the photographer should consider when performing activities under this SOP:

- The photographer should be prepared to make a variety of shots, from close-up to wide-angle. Many shots will be repetitive in nature or format, especially close-up site feature photographs.

- The lighting for sample and feature photography should be oriented toward a flat condition with little or no shadow. Or, a flash may be used.

- Digital cameras have multiple photographic quality settings. A camera that obtains a higher resolution (quality) has a higher number of pixels and will store less photographs per digital storage medium.

5.2.2 General Guidelines for Still Photography

Caption Information

All photographs will have a full caption on a photo log sheet. The caption should contain the following information (digital photographs should have a caption added after the photographs are downloaded):

- Date and time
- Direction (if applicable)
- Photographer
- Description of activity/item shown (e.g., name of facility/site, specific project name, project number)
- Any other relevant information

When possible, a standard reference marker should be used in all documentary visual media. While the standard reference marker will be predominantly used in close-up feature documentation, inclusion in all scenes should be considered.
Digital media should be downloaded at least once each day to a personal computer; the files should be in either “JPEG” or “TIFF” format. Files should be renamed at the time of download to correspond to the logbook. It is recommended the electronic files be copied to a compact disc for backup.

Close-Up and Feature Photography

Any close-up photographs should include a standard reference marker of appropriate size as an indication of the feature size. Feature samples, core pieces, and other lithologic media should be photographed as soon as possible after they have been removed from their *in situ* locations. This enables a more accurate record of their initial condition and color.

Site Area Photography

Site area and background photography is not allowed without prior permission of Boeing.

Panoramic

Panoramic photography is not allowed without prior permission of Boeing.

5.2.3 Photographic Documentation

Photographic activities must be documented in a photographic log or in a section of the field logbook. The photographer will be responsible for making proper entries.

In addition to following the technical standards for logbook entry as referenced in SSFL SOP 8, the following information should be maintained in the appropriate logbook:

- Photographer name
- If required, an entry shall be made for each new roll control number assigned
- Sequential tracking number for each photograph taken (the camera-generated number may be used)
- Date and time (military time)
- Location
- A description of the activity/item photographed
- Record as much other information as possible to assist in the identification of the photographic document

5.3 Post Operation

5.3.1 Documentation

At the end of each day's photographic session, the photographer(s) will ensure that the field logbook (in accordance with SSFL SOP 8) and/or photographic log is complete.

5.3.2 Archive Procedures

- Photographs and the associated digital media will be submitted to the project files and handled according to contract records requirements. The project manager will ensure their proper distribution.
- Completed pages of the appropriate logbook will be copied weekly and submitted to the project files.

6.0 Restrictions/Limitations

This document is designed to provide a set of guidelines for the field amateur photographer to ensure that an effective and standardized program of visual documentation is maintained.

Note: Photography is restricted at SSFL; a camera permit from Boeing is required.

7.0 References

No references were used to develop this SOP.

Control of Measurement and Test Equipment	SSFL SOP 16 Revision: 0 Date: April 2012

Prepared:	R. Kaspzyk	**Technical Review:**	C. Zakowski
QA Review:	J. Oxford	**Approved and Issued:**	[signature] 4/6/2012 *Signature/Date*

1.0 Objective

The objective of this technical standard operating procedure (SOP) is to establish the baseline requirements, procedures, and responsibilities inherent to the control and use of all measurement and test equipment (M&TE; e.g., hand-held field monitoring equipment, global positioning system (GPS) unit) for the Santa Susana Field Laboratory (SSFL) site.

2.0 Background

2.1 Definitions

Requisitioner – The person responsible for ordering the leased or purchased equipment.

Traceability – The ability to trace the history, application, or location of an item and like items or activities by means of recorded identification.

2.2 Associated Procedures

- SSFL SOP 6, *Field Measurement of Total Organic Vapors*
- SSFL SOP 7, *Field Measurement of Residual Radiation*
- SSFL SOP 8, *Field Data Collection Documents, Content, and Control*
- Manufacturer's operating and maintenance and calibration procedures

2.3 Discussion

All M&TE used will be rented or leased from an outside vendor, or purchased. It is essential that measurements and tests resulting from the use of equipment be of the highest accountability and integrity. The equipment user should completely understand the operational instructions and comply with the specifications in the manufacturer's operations and maintenance manual and follow calibration procedures and in accordance with the Field Sampling Plan (FSP) Addendum.

3.0 Responsibilities

All staff with direct control and/or use of M&TE are responsible for being knowledgeable of and understanding and implementing the requirements contained herein. In addition, all field staff will be required to review the FSP Addendum, particularly as where the Addendum affects this SOP. It is possible that a variance from this SOP be identified as part of the Data Gap Investigation which would be described in the FSP Addendum.

The field team leader (FTL) or designee (equipment coordinator, quality assurance coordinator, etc.) is responsible for initiating and tracking the requirements contained herein.

4.0 Requirements for M&TE

- Determine and implement M&TE-related project-specific requirements.
- Follow the maintenance and calibration procedures when using M&TE.
- Obtain the maintenance and calibration procedures if they are missing or incomplete.
- Attach or include the maintenance and calibration procedures with the M&TE.
- Prepare and record maintenance and calibration in an equipment log or a field log as appropriate (Attachment A).
- Maintain M&TE records.
- Label M&TE requiring routine or scheduled calibration (when required).
- Perform calibration using the appropriate procedure and calibration standards; maintenance will be discussed with the supplier before conduct.

- Identify and take action on nonconforming M&TE.

5.0 Procedures

5.1 Obtain the Operating and Maintenance and Calibration Documents

For leased equipment, the requisitioner will request the maintenance and calibration procedures, the latest calibration record, and the calibration standards certification be provided to CDM Smith. If this information is not delivered with the M&TE, ask the procurement division to request it from the vendor.

5.2 Prepare and Record Maintenance and Calibration Records

The FTL or designee will record the initial daily maintenance and calibration events in a field logbook. Subsequent maintenance and calibration events will be reported to the FTL and recorded at the end of the each day.

5.3 Operating, Maintaining, or Calibrating an M&TE Item

The FTL or designee and user must operate, maintain, and calibrate M&TE in accordance with the maintenance and calibration procedures. Record maintenance and calibration actions in the equipment log or field log.

5.4 Shipment

The rental equipment supplier must inspect the item to ensure that the maintenance and calibration procedures and latest calibration and standards certification records are included before shipment. If any documentation is missing or incomplete, the item should not be shipped.

The receiver (FTL or field requisitioner) will communicate all documentation requirements to the shipper. They must also inspect and confirm the requested equipment and records were provided upon receipt. If documentation is missing, immediately contact the procurement division and request that they obtain the documentation from the vendor.

5.5 Records Maintenance

The receiver must also forward the packing slip to the procurement division.

The user must:

- Forward the completed field log to the FTL and SSFL project manager for inclusion in the project files.
- Retain the most current maintenance and calibration record and calibration standards certifications with the M&TE item and forward previous versions to the FTL and project manager for inclusion in the project files.

5.6 Traceability of Calibration Standards

The FTL or designee and user must:

- Order calibration standards designated by the supplier.
- Request and obtain certifications for standards that clearly state the traceability.
- Request and obtain material safety data sheets for the standards.
- Monitor standards that are perishable and consume or dispose of them on or before the expiration date.

5.7 M&TE That Fails Calibration

The FTL or designee must:

- Immediately discontinue use of the equipment and segregate the item from other equipment. Notify the FTL and take immediate action to replace the item.
- Review the current and previous maintenance and calibration records to determine if the validity of current or previous measurement and test results could have been affected and notify the FTL of the results of the review.

5.8 Determine if Other Related Project Requirements Apply

In the event a different or unique piece of equipment is needed on short notice for site-specific activity, the FTL or designee will determine if other M&TE project-related requirements could apply. If M&TE-related requirements apply, obtain a copy of them and review and implement as appropriate.

6.0 Restrictions/Limitations

Calibration and maintenance for field instruments are critical to collecting reputable data. If field monitoring equipment is not working properly, it should not be used. Work will be suspended until functional monitoring equipment is available.

7.0 References

No references used to develop this SOP.

8.0 Attachments

Attachment A – Maintenance and Calibration Form

Attachment A

CDM Smith A subsidiary of Camp Dresser & McKee Inc.

Maintenance and Calibration

Date: Time: (a.m./p.m.)	
Employee Name:	Equipment Description:
Contract/Project:	Equipment ID No.:
Activity: ______________________________	Equipment Serial No.: ________________________
Maintenance	
Maintenance Performed:	
Comments:	
Signature: ______________________________	Date: ______________________________
Calibration/Field Check	
Calibration Standard:	Concentration of Standard:
Lot No. of Calibration Standard:	Expiration Date of Calibration Standard:
Pre-Calibration Reading:	Post-Calibration Reading:
Additional Readings:	Additional Readings:
Additional Readings:	Additional Readings:
Pre-Field Check Reading:	Post-Field Check Reading:
Adjustment(s):	
Calibration: ☐ Passed ☐ Failed	
Comments:	
Signature: ______________________________	Date: ______________________________

Packers - Groundwater Sampling from Isolated Borehole Interval and Aquifer Testing	SSFL SOP 20 Revision: 0 Date: September2015

Prepared:	S. Fundingsland	**Technical Review:**	C. Werden
QA Review:	C. Sayler	**Approved and Issued:**	[signature] 9/17/15 *Signature/Date*

1.0 Objective

The purpose of this technical standard operating procedure (SOP) is to define the techniques and requirements for collecting groundwater samples from isolated borehole interval using inflatable packers and conducting aquifer tests. Packers are used to isolate specific sections (test intervals) of a bedrock borehole to allow water sample collection and testing of aquifer properties. Packer testing allows the definition of contamination in the water and hydraulic conductivity along the total length of the borehole. Additionally, monitoring and observations in nearby monitoring wells can identify permeable intervals within the aquifer.

2.0 Background

2.1 Definitions

Monitoring Well Network – surrounding monitoring wells that will be monitored during packer task

Potable water or distilled water – clean water used in “pump-in” test

Packer – an inflatable bladder used to provide a seal to isolate vertical zones in a borehole

Pump-In Test - test were water is injected into the test interval at a constant rate or pulsed and water-level response is measured

Pump-Out Test – test were well is pumped in steps or at a constant rate and water-level response is measured

Test Interval – section of borehole isolated for aquifer testing and groundwater sampling using packers

Test Plan – plan used to describe and implement test program

2.2 Associated Procedures

Associated procedures listed below provide direction to be followed to complete those tasks described in the standard operating procedure (SOP). Where possible, SOPs from the Site-Wide Water Quality Sampling Analysis Plan (Groundwater sampling plan for SSFL) have been adopted. However, the Site-Wide SOPs must be reviewed for applicability to aquifer testing, current conditions at the site, and regulatory requirements.

CDM Smith SSFL Standard Operation Procedures

- SSFL SOP 8, *Field Data Collection Documents, Content and Control*
- SSFL SOP 10, *Sample Custody*
- SSFL SOP 11, *Packaging and Shipping Environmental Samples*
- SSFL SOP 12, *Field Equipment Decontamination*
- SSFL SOP 13, *Guide to Handling Investigation Derived Waste*
- SSFL SOP 15, *Photographic Documentation of Field Activities*
- SSFL SOP 16, *Control of Measurement and Test Equipment*
- SSFL SOP 21, *FLUTe Multilevel System Removal and Installation*

Site-Wide Water Quality Sampling and Analysis Plan (Revision 1, December 2010)

- Site-Wide SOP 1.1, *Manual Water-Level Measurements*
- Site-Wide SOP 1.2, *Low-Flow Purge*
- Site-Wide SOP 1.3, *Groundwater Sampling*
- Site-Wide SOP 1.5, *FLUTe Multilevel System*
- Site-Wide SOP 1.6, *Sample Management*
- Site-Wide SOP 1.7, *Equipment Decontamination*

2.3 Discussion

Aquifer tests are used to determine the apparent hydraulic conductivity of the rock surrounding a borehole by measuring the flow rate of water pumped into or out of a discrete depth interval and associated potentiometric response. The discrete depth interval is isolated using rubberized inflatable packers under known pressures. Isolation of a targeted interval or length can be accomplished using single, double, or straddle packers. In situ tests can be "pump-in" tests, which consists of water injected into the test interval at constant applied pressure (constant head), or a constant rate of flow, or as a pressure pulse or a "pump-out" test which removes water from the test interval.

Packers will also be used to isolate test intervals in a borehole to collect groundwater samples for analytical analysis.

Pump-In Test - Generally, three types of "pump-in" test are used when packers are deployed. The Constant Head Test and Pressure Pulse Test are used for relatively low-permeability formations or intervals, and the Constant Rate of Flow Test used for higher-permeability formations or intervals and higher flow rates. Because the permeability at Area IV is considered low, Constant Head and Pressure Pulse testing are mostly likely the tests that will be performed. However, for completeness and should a test interval be found to have higher permeability, the Constant Rate of Flow test has been included in this SOP.

Packer tests will be conducted in general accordance with ASTM D 4630, "Standard Test Method for Determining Transmissivity and Storage Coefficient of Low-Permeability Rocks by In Situ Measurements Using the Constant Head Injection Test," and ASTM D 4631, Standard Test Method for Determining Transmissivity and Storativity of Low Permeability Rocks by In Situ Measurements Using the Pressure Pulse Technique."

Pump-out Test - Step drawdown tests and long-term constant rate tests will be used to calculate aquifer properties when groundwater is extracted from the monitoring well.

Packer - To isolate the test interval, the packer will be of a diameter compatible with the borehole. Borehole diameters will be obtained from driller's log and any borehole geophysical reports. The packer configuration, material, diameter, and will be determined in consultation with field service subcontractor.

Transducers – Electronic pressure transducers will be placed above, below, and within the test interval to monitor pressure changes and ensure proper sealing of the packers. The transducer will have an accuracy of at least +/- 0.1 pound per square inch (psi).

Electronic Data Loggers – Pressure transducers will be attached to data loggers capable of monitoring and recording pressure versus time. The data loggers will be capable of downloading data to laptop computer for reduction and processing.

Water Supply Reservoir – Provides water for 'pump-in' test.

Water Collection Tank – Collection vessel for 'pump-out' test.

Variable-Area Flow Meter – Flow meter system capable of measuring flow rates as low as 0.001 gallon per minute (gpm).

Pipes, Manifold, By-Passes, and Shut-Off valves – used to convey water to/from test interval.

3.0 General Responsibilities

Site Manager – Translates DOE requirements into technical direction of project. Sets technical criteria, reviews, and approves technical progress. Ensures that all participating personnel have proper training. Note: Other titles such as project manager may be used.

Field Team Leader (FTL) – Supervises field operations. Ensure that all necessary equipment, including safety equipment, is available and functioning properly before project operations begin. Ensures that all necessary personnel are mobilized on time. Maintains daily log of activities each work day.

Project Hydrogeologist – Plans test, oversees, analyzes, and interprets test. Provides instruction and approves changes during implementation of the test.

Field Geologist/Engineer/Scientist/Technician – Collects and maintains data. Coordinates and consults with site manager on decisions relative to unexpected encounters during implementation and deviations from this SOP. Directs overall activities of implementation procedures and support subcontractors.

Site Health and Safety Technician– The person who will use field screening instruments to monitor all field activities for volatile and radiological contaminants and pre-shipment sample coolers. This person is a trained radiological technician who works under the guidance of a Leidos Certified Health Physicist (CHP).

Field Service Subcontractor – The Subcontractor provides equipment appropriate to the task as described in the project statement of work, provides appropriately trained and qualified personnel, and responds to administration of the FTL. The Subcontractor ensures proper calibration or standardization maintenance checks, system checks, completed and well-maintained data documentation, and identification and protection against potential hazards.

4.0 Required Equipment

4.1 Water Measuring and Recording

- Pressure transducers and data logger
- Personal computer for viewing and downloading data
- Water level measuring device
- Stopwatch
- Field logbook
- Decontamination equipment and supplies
- Data on construction of the pumping/monitoring well(s) (depth to screen/borehole and screen/borehole length)

4.2 Water Pumping, Treating, Storing, and Discharging

- Packers
- Pump (sufficient capacity to withdraw at the required rate) with electric wiring
- Discharge hosing/piping
- Electrical source (e.g., generator)
- Flowmeter with totalizer
- Sampling valve
- Logbook/data forms

- Water treatment unit (if required)
- Water storage container (if required)
- Ancillary equipment and supplies to install and/or operate the main equipment
- Decontamination equipment and supplies

A field service subcontractor will typically be responsible for providing and operating the equipment for packer testing. However, in some cases, it may be appropriate for site personnel to provide and operate the equipment. The project requirements will need to be evaluated to determine the most suitable arrangement for providing and operating the necessary equipment.

5.0 Procedures

5.1 Office Preparation

5.1.1 Test Plan

Adequate attention to the planning and design of the aquifer test and test interval isolation is a significant phase of the procedure and will ensure accurate test data. A planning meeting shall be held to identify the objectives of the test and then scope of the test and packer isolation shall be developed. After the objectives are identified and the scope is developed, a Test Plan shall be prepared that describes the procedures to be followed. The Test Plan shall identify and describe the details to be followed for each component of the test.

Monitoring wells subject to the packer testing have a long history of data that may be useful in developing the Test Plan. Data that will be reviewed include driller's log, geophysical reports, FLUTe installation data, and groundwater sampling history and water level elevations. Important information obtained from the data review will be selecting suitable intervals for testing and intervals that may present difficulties in seating the packers with the borehole.

Groundwater Sampling from Isolated Test Intervals

Components to be considered for collection of groundwater samples from isolated test intervals and included in the test design include:

- Purpose of sample
- Test interval (depth and length)
- Packer configuration
- Sampling technique
- Sampling equipment

Aquifer Test Design

For development of the aquifer test design the following components will be considered.

- Purpose of test
- Hydrogeological environment
- Pumping well location
- Depth interval
- Pumping rate
- Pump selection
- Location and depth of observation wells
- Test duration
- Discharge/injection rate measurements and devices
- Interval and method of water measurements
- Method of analyzing the data

Additionally, the Test Plan will include additional tasks that will be performed in combination with the groundwater sampling and/or aquifer testing. Additional activities may include:

- Natural attenuation testing
- Soil vapor extraction (SVE) testing
- Temperature logging
- Trace testing
- Vertical groundwater flow gradient
- Acoustic borehole televiewing
- Optical borehole televiewing
- Water management, treatment, and re-use

5.1.2 Site-Specific Health and Safety Plan
The site-specific health and safety plan shall be reviewed along with project plans before initiating field activities. The field service subcontractor and FTL or designee will confer before field activities to ensure a complete understanding of scope and technical details.

5.1.3 Required Documents
The following documents, certificates, and inspections are required to be completed and available prior to field activities.
- Test Plan
- Field logbook
- Appropriate log sheet (installation or removal data sheet)
- Site-Specific Health and Safety Plan
- SSFL SOPs
- Site-Wide SOPs
- Field Service Subcontractor Health and Safety Plan
- Field Service Subcontractor Standard Operating Procedures or JSA
- Copy of Driller License (may be required for well abandonment)

5.2 Borehole Preparation Prior to Testing
DOE, Boeing, and other parties will be pre-notified of site personnel and subcontractors of date and time of field work. Prior to initiating any field work or activity a field planning meeting will be conducted, the site-specific health and safety plan and the Test Plan will be reviewed. Site personal will don the appropriate personal protective clothing as indicated in the site-specific health and safety plan. Assemble required support/buddy system and review communication system.
The Test Plan will describe borehole preparation requirements for each monitoring well to be tested. Preparatory tasks may include the following activities.
- Decontamination of all tools, equipment, and instruments prior to and after each use (Site-Wide SOP 1.7 and SSFL SOP 12)
- Collection of water levels from monitoring well network (Site-Wide SOP 1.1)
- Collection of water samples from open borehole (Site-Wide SOP 1.2 and 1.3)
- Collection of water samples from FLUTe ports (Side-Wide SOP 1.5)
- Sample management and packaging and shipping environmental samples (Site-Wide SOP 1.6, SSFL SOP 10 and 11)
- Removal of Water FLUTe (SSFL SOP 21)
- Handling investigation derived waste (SSFL SOP 13)
- Inspection of borehole to ensure suitable for packer testing (i.e., caliper and/or other geophysical investigation)
- Installation of packers and/or transducers in monitoring well network per Test Plan

5.3 Packer Placement
The packer configuration will be based on the Test Plan. In most cases, a straddle packer arrangement will be used to test a segment of a borehole isolated between two packers, or a single packer can be used to test a segment of borehole between the hole bottom and the packer. If necessary, a double packer arrangement with a pressure transducer between the two packers may be used to detect slow leaks around the packers. Double packers can be used in straddle packer arrangement

with two packers positioned above and two packers positioned below the interval of interest. This arrangement may be used for low-permeability formations or zones of special interest (i.e. zones of elevated contamination or zones showing dechlorination).

The packer configuration will be inserted in the borehole and lowered to the testing interval. Once placed, the packers will be inflated to a pressure approximately 200 psi above the maximum anticipated test pressure. Lower inflation pressures may be used if rock fracturing is a concern, however, lower packer inflation pressures may increase the likelihood of leakage between packers.

Note: All materials/tools/instruments placed in the borehole will require decontamination before and after use.

5.4 Pump-In Tests

5.4.1 Constant Head Test

Following packer placement and the supply tube filled with water and all entrapped air removed, the downhole valve will be shut and the shut-in test interval pressures allowed to dissipate. Following dissipation and pressure stabilization, the reservoir pressure will be increased to the desired test pressure and the downhole valve opened.

The pressure (head) will be maintained at a constant value using flow rate versus time. Water will be injected into the test interval at a constant head until the flow rate stabilizes or a minimum of 20 minutes. Stabilization will be considered achieved when at least 3 consecutive five-minute flow reading do not vary by more than 10 percent. The maximum test duration will be 120 minutes.

If pressure recorded above or below the test interval increase during the test, the packers will be reseated to eliminate leakage around the packer. In some cases, the test interval may be modified (raised or lowered) to obtain proper seating of the packer and sealing of the test interval.

Data loggers will record pressure versus time from each pressure transducer. This data will be transferred to and stored on field computer for later analysis.

Note: the maximum injection pressure at the test interval must not exceed the effective overburden pressure to avoid hydraulic fracturing. The maximum injection pressure for each test interval will be provided in the plan.

5.4.2 Pressure Pulse Test

Set up for the pressure pulse test is the same as described in Section 5.4.1 with the exception of using a fast-acting value between the pressure source and the water supply tube and relocating the pressure transducer from the test interval to the water-supply line at the top of the borehole between the fast-acting valve and the test interval.

Following placement of the packers, the water supply tubing will be rapidly pressurized and then shut in by opening and closing the fast-acting valve. The pressure pulse and decay transient will be recorded by the data logger. Pressure above and below the test interval will be recorded and evaluated to determine if a proper seal has been established. If leakage is observed, the packers will require reseating and/or modifying the test interval depth.

Note: the maximum injection pressure at the test interval must not exceed the effective overburden pressure to avoid hydraulic fracturing. The maximum injection pressure for each test interval will be provided in the plan.

5.4.3 Constant Rate of Flow Test

The constant rate of flow test is essentially the same as the consent head test except that the injection rate is held constant and readings of pressure versus time are obtained. Injection of water into the test interval is continued at a constant rate until the pressure stabilizes or for minimum of 20 minutes.

Stabilization will be considered achieved when at least 3 consecutive five-minute flow readings do not vary by more than 10 percent. The maximum test duration will be 120 minutes.

If pressure recorded above or below the test interval increases during the test, the packers will be reseated to eliminate leakage around the packer. In some cases, the test interval may be modified (raised or lowered) to obtain proper seating of the packer and sealing of the test interval.

Data loggers will record pressure versus time from each pressure transducers. This data will be transferred to and stored on field computer for later analysis.

Note: the maximum injection pressure at the test interval must not exceed the effective overburden pressure to avoid hydraulic fracturing. The maximum injection pressure for each test interval will be provided in the plan.

5.5 Pump-Out Test

Continuous Background Monitoring

Water levels shall be collected continuously prior to performing the long-term test. Adjacent surface water bodies (if present) should also be monitored. The water levels shall be used to reduce and analyze the data collected during the long-term test. The background data is also useful in characterizing the hydrogeologic framework.

Transducers/loggers shall be installed in the pumping well and the observation wells. Each transducer/logger shall be checked and set following the manufacturer's manual, including setting the internal clock to a common external standard.

Each transducer shall be installed to a depth that does not exceed the working capacity of the transducer and where the water level will not drop below the transducer during ambient water level changes. After the selected depth is reached with the transducer:

- Securely attach the cable to the well head and mark a reference point with electrical tape to allow verification that the transducer position does not change during the test
- Read the depth of water using the transducer (note that the transducer may need to equilibrate with the water temperature following the manufacturer's specifications and recover from displacement of water caused by submersion of the transducer)
- Collect a manual water level measurement from the well's measuring point
- Begin recording water levels on a linearly rate of 1 reading per 30 minutes

Transducers shall be programmed so that water level recording begins at the same time at each well. Having water levels recorded at the same time for each well simplifies the data reduction and evaluation activity contrasted to having water levels recorded at different times for different wells.

Background water levels shall be recorded for 7 days. During the monitoring period, the transducers/loggers should be occasionally checked (e.g., check the transducers on day two and day five) to verify that the equipment is working properly. Manual water level measurements should be taken and recorded during this check. Replace any transducer that is identified to be not operating correctly.

At the end of the monitoring period, stop the test recording and download the recorded data.

Barometric pressure (BP) and precipitation shall be recorded during the background monitoring period. These two elements are commonly considered the main natural factors to impact groundwater levels. If publicly available data can be obtained from a weather station located nearby (within approximately 5 miles of the project), the data from that station may be used. BP and precipitation data shall also be recorded during the long-term test.

5.5.1 Step Drawdown Test

The step drawdown test (or simply, step test) is required to determine the constant pumping rate that will be used for the subsequent long-term test and to assess well efficiency. Step test data may also be used to evaluate the hydrogeologic characteristics. The step test is performed at the pumping well. In summary, the step drawdown test consists of pumping water from the well at short incrementally increased rates (steps) so that a withdrawal rate can be determined for the long term test.

A pump capable of yielding 1.5 times the estimated yield of the pumping well shall be installed to the specified depth. A vertical check valve will be placed in the discharge line immediately above the pump or intake to prohibit water from draining into the well when the pumping ceases. A 1-inch diameter polyvinyl chloride line will be placed in the well with the bottom end open to a depth within 1 foot from the top of the pump. Several ¼-inch diameter holes should be drilled in the bottom 5 feet of this stilling pipe. The water level transducer will be installed in the pipe. After the pumping equipment and transducer are installed, the following steps will be followed:

1. Connect a flow meter/totalizer and sample tap with valve to the discharge line from the pump; direct the discharge line to the system to handle the water. Care must be taken to provide sufficient straight sections of pipe above and below the flow meter to obtain accurate measurements. Recent calibration certificates should be obtained for the flow meter.
2. Record the volumetric reading on the totalizer (Note: Prior to pumping and increasing pumping rate and after ending pumping, the volumetric reading should be recorded).
3. Measure and record the static water level in the pumping well.
4. Begin logging with the transducer (according to the table below) and then start pumping water from the pumping well at a relatively low (approximately ½ of the estimated yield) but steady rate (STEP 1); logging should be started approximately 2 to 5 seconds prior to starting pumping. Flow should be adjusted to maintain a constant rate, noting when changes are made.
5. Record the time at which pumping is started, using a clock that is synchronized with the transducer clocks, and the flow rate; check operation of the transducer.
6. Monitor the water level in the pumping well with the transducer and confirm periodically with manual measurements.
7. After approximately 1½ hours, increase the pumping rate to approximately ¾ of the estimated yield, and continue to monitor the water level for approximately 2 hours (STEP 2).
8. Record the time at which the pumping rate is increased and the new flow rate; check operation of the transducer.
9. Approximately 2 hours after increasing the pumping rate for STEP 2, increase the pumping rate to approximately equal to the estimated yield, and continue to monitor the water level for approximately 2 hours (STEP 3).
10. Record the time at which the pumping rate is increased and the new flow rate.
11. Approximately 2 hours after increasing the pumping rate for STEP 3, increase the pumping rate to approximately 1.5 x the estimated yield, and continue to monitor the water level for approximately 2 hours (STEP 4).
12. Record the time at which the pumping rate is increased and the new flow rate.
13. Shut off the pump at the end of STEP 4 (maximum of 8 hours has elapsed since pumping started at the beginning of the test) and download data. The transducer should continue recording during the recovery period.

A step test is dynamic. During each step the operator will gain more information on how the well's water level responds to specified pumping rates. The estimated increases identified above for each step should only be used as a guide. Each successive increase should be based on the operator's general understanding of well hydraulics, observations made while installing and developing the well, and on the well's response during the previous step(s). The goal, in summary, is to achieve the well yield at STEP 3 and exceed the well yield at STEP 4.

During the test, water levels at the pumping well shall be recorded logarithmically following the recommended schedule in the following chart. Typical data loggers have default sample intervals except for the largest sample interval, which is set by the user (in the table below, the 10-minute sample interval is set by the user). The default sample intervals shall be equal to or similar to the table below.

Log Cycle	Elapsed Time	Sample Interval	Points/Cycle
1	0 to 20 seconds	0.2 second	101
2	20 to 60 seconds	1 second	40
3	1 to 10 minutes	10 seconds	54
4	10 to 100 minutes	2 minutes	45
5	100 to 1,000 minutes	10 minutes	90

The drawdown-time data shall be plotted semi-logarithmically. The drawdown (y-axis) shall be plotted on a linear scale and time (x-axis) shall be plotted on a logarithmic scale. The drawdown curves shall be extrapolated to the specified time of the proposed long-term test. The rate that results in the maximum drawdown without dropping the water level below the design pumping level within the time period of the long-term test shall be considered the flow rate to be used for the long-term test. The specific capacity versus pumping rate should also be plotted to determine if excessive well losses occur at the selected rate.

5.5.2 Constant Rate Test

The long-term constant rate test will be performed at the pumping well. Water levels will be monitored in the pumping well and the observation wells. The same pumping equipment used for the step test will be used for the long-term test. BP and precipitation shall be recorded during the long-term test. If publicly available data can be obtained from a weather station located nearby (within approximately 5 miles of the project), the data from that station may be used. Adjacent surface water bodies should also be monitored if the surface water is potentially connected to the groundwater system.

The time interval for the long-term constant rate test shall be specific to the project. However, at a minimum, a confined aquifer should be pumped for 24 hours and an unconfined aquifer to be pumped for 72 hours (American Water Works Association 1997). The project objectives will need to be reviewed and aquifer test solution requirements considered so that the correct pumping period is selected. The following steps shall be followed to conduct the long-term test after the step test is completed.

1. Install transducers in the pumping well and the observation wells (note that transducers can be installed in observation wells prior to the day the long-term test starts).
2. Read the water level depths with the transducers and record the values; measure and record the static water levels with the electronic water level meter from the wells' measuring points.
3. Record the volumetric reading on the totalizer.
4. Begin logging water level data with the transducers and then start pumping at the predetermined rate (determined based on the step-drawdown test results).
5. Periodically monitor discharge rate and transducers; maintain constant pumping rate.
6. Stop pumping at the end of the specified time, record volumetric reading on the totalizer.
7. Continue to record water level data with transducers until the water level in the pumping well has recovered so that sufficient data are collected to adequately analyze the recovery or a maximum of 24 hours has elapsed.

The water level data will be transferred to disk form so that it may be reduced, analyzed, and put into report format.
The water levels in the wells will be recorded logarithmically following the recommended schedule in the following chart:

Log Cycle	Elapsed Time	Sample Interval	Points/Cycle
1	0 to 20 seconds	0.2 second	101
2	20 to 60 seconds	1 second	40
3	1 to 10 minutes	10 seconds	54
4	10 to 100 minutes	2 minutes	45
5	> 100 minutes	10 minutes	unspecified

When the pump is shut off and recovery begins, a new logarithmic series will be started for the transducer in the pumping well. The series shall be started 1 to 5 seconds prior to ending the pumping activity. The transducers in the observation wells will continue to monitor on the first logarithmic cycle series. If the aquifer is expected to recover quickly, the observation well transducers may also be restarted on a new series. Data will be recorded until the water level in the pumping well has returned so that sufficient data are collected to adequately analyze the recovery or until a maximum of 24 hours has elapsed. A manual water level measurement shall be collected from the wells, measuring points, and a reading should be taken with the transducers during recovery.

At the conclusion of the recovery test, the data logging shall be stopped at each well and the transducers shall be removed and the data downloaded.

5.6 Sample Collection

Sample collection will be dependent on the method used to collect the environmental sample. Applicable SOPs include:

- Low-flow purg (Site-Wide SOP 1.2)
- Groundwater sampling (Site-Wide SOP 1.3)
- FLUTe Multilevel system (Site-Wide SOP 1.5)
- Monitored natural attenuation (Site-Wide SOP 22)

5.7 Sample Packing and Shipment

- Store samples at 4°C (±2°C) until samples are delivered to the designated analytical laboratory.
- Pack all samples per SSFL SOP 11 and/or laboratory requirements. Include properly completed documentation (chain-of-custody) and affix signed and dated custody seals to the cooler lid.
- See Site-Wide SOP 1.6, SSFL SOP 10 and 11 for guidance on sample management and custody procedures.

5.8 Decontamination

Equipment and tool decontamination will be performed according to Site-Wide SOP 1.7 and SSFL SOP 12.

5.9 Water Management

Each well has different requirements for water management and water removed from the FLUTe liner, FLUTe port or borehole will be managed according to the Test Plan. Several methods may be used to handle the discharge water from the FLUTe or borehole. Water management will be conducting according to SSFL SOP 13.

Water management may include:

- To a holding tank, sampled and analyzed after the work, and then released to the ground surface or water body after analytical results prove that discharge requirements are met.
- To a unit designed and constructed to treat the water to meet discharge criteria; treated and then released to the ground surface or water body.

Other discharge options may also be available and followed and will described in the Test Plan. Several different methods are typically available to handle discharge water. The governing agency shall be contacted so that required water handling practices are followed and discharge criteria are met.

6.0 Data Reduction and Analysis

Data reduction and analysis will be conducting using analytical procedures and computer software appropriate for the hydraulic conditions encountered during the test. The project hydrogeologist will be responsible for selecting the analysis and interpreting the test results. The calculation brief and technical review will be provided for all work products.

6.1 Pump-In Tests

Constant head and constant rate of flow test data are recommended to be analyzed with computer software; however, data may also be analyzed manually. The groundwater modeling tool kit contains AQTESOLV, which is a program that may be used to assist in analyzing test data. Other programs are also available. Software packages are useful since they can be used to manage a significant amount of data in short time periods and contain many different confined, leaky and fractured test solutions. Regardless of the analytical method employed or whether the data is analyzed manually or by computer, the analyst should review the original technical paper or textbook summary of the method in order to understand the mechanics and assumptions underlying the method prior to attempting any analysis and verify the method is appropriate for the site conditions.

Constant head data analyses and hydraulic property calculations shall be performed by an experienced professional, documented in a calculation brief, and reviewed. Data analysis and parameter calculations are beyond the scope of this SOP and, therefore, are not discussed here.

6.2 Pump-Out Tests

The data sets from aquifer test are typically very robust. The data may be reduced and analyzed to:

- Determine the specific capacity and safe yield of the well
- Calculate the properties (Transmissivity and Storativity) of the aquifer
- Characterize the hydrogeologic framework at and near the investigation area

These three items, or one of the items at a minimum, are typically evaluated with test data. Other pumping test data may also be available and evaluated.

Test data are recommended to be analyzed with computer software; however, data may also be analyzed manually. The groundwater modeling tool kit contains AquiferWin32, which is a program that may be used to assist in analyzing test data. Other programs are also available. Software packages are useful since they can be used to manage a significant amount of data in short time periods and contain many different confined and unconfined test solutions. The trained user can use these benefits to generate detailed response curve graphs, precise hydraulic values, and insights into the hydrogeologic framework near the well. Regardless of the analytical method employed or whether the data is analyzed manually or by computer, the analyst should review the original technical paper or textbook summary of the method in order to understand the mechanics and assumptions underlying the method prior to attempting any analysis and verify the method is appropriate for the site conditions.

Test data analyses and hydraulic property calculations shall be performed by an experienced professional, documented in a calculation brief, and reviewed. Data analysis and parameter calculations are beyond the scope of this SOP and, therefore, are not discussed here.

7.0 Restrictions/Limitations

This procedure describes the standard steps used to conduct a packer test in existing monitoring well. Since packer testing is complex and each monitoring well may have different geohydraulic conditions, not every step or possible method was incorporated in the procedure.

A planning meeting shall be held to identify the objectives of packer test, then the scope of the test program shall be developed. The plan shall be prepared that describes the project-specific (or monitoring well specific) procedures to be followed. The objects of the test program shall be specific so that the necessary data to reach the objectives are collected when the test is performed.

8.0 References

ASTM. 2008. Standard Test Methods for Determining Transmissivity and Storage Coefficient of Low-Permeability Rocks by In Situ Measurements Using the Constant Head Injection Test. D 4630-96 (reapproved 2008)

_________. 2008. Standard Test Methods for Determining Transmissivity and Storativity of Low Permeability Rocks by In Situ Measurements Using Pressure Pulse Technique. D 4631-95 (reapproved 2008)

_________. 2004. Standard Guide for Selection of Aquifer Test Method in Determining Hydraulic Properties by Well Techniques. D 4043-96 (Reapproved 2010).

_________. 2002. Standard Test Method (Field Procedure) for Withdrawal and Injection Well Tests for Determining Hydraulic Properties of Aquifer Systems. D 4050-96 (Reapproved 2011).

American Water Works Association. 1997. AWWA Standard for Water Wells (ANSI/AWWA A 100-97).

Environmental Simulations, Inc. 2000. Guide to Using AquiferWin32.

U.S. Department of Energy Rocky Flats Plants, Environmental Monitoring and Assessment Division. 1991. Standard Operating Procedures, Volume II of IV, Groundwater, Pump-In Borehole Packer Tests, Procedure 2.3, Revision 0. February.

U. S. Environmental Protection Agency. 1993. Ground Water Issue Suggested Operating Procedures for Aquifer Pumping Tests (EPA/540/S-93/503). February.

U. S. Geological Survey. 1976. Techniques of Water-Resources Investigations of the United States Geological Survey (Chapter B1 Aquifer Test Design, Observation and Data Analysis).

9.0 Attachments

Attachment 1 – Example of Pump-In Borehole Packer Test Summary Sheet
Attachment 2 – Example of Pump-Out Test Data Sheet

PUMP-IN BOREHOLE PACKER TEST SUMMARY SHEET (page 1 of 1)

Project No. ______________________________ Date ______________________________

Borehole/Well Identification ______________________________

Packer Testing Subcontractor ______________________________

Project Geohydrologist/Scientist ______________________________

Type of Test ______________________________

Formation/Rock Type Tested ______________________________

Top and Bottom Depths of Test Interval (below ground surface) ______________________________

Description/Elevation of Depth Reference ______________________________

Water Level in Borehole Before Testing ______________________________

Packer Inflation Pressure ______________________________

Shut-In Pressure/Stabilization Pressure ______________________________

Data Logger File Name ______________________________

DOCUMENTATION CHECKLIST

Diagram of test setup prepared? (Y/N) by ______________________________

Documentation of calibration received? (Y/N) by ______________________________

Documentation of flow meter calibration checks received? (Y/N) by ______________________________

Documentation of gauge/transducer calibration checks received? (Y/N) by ______________________________

____

Pressure versus time data for each gauge/transducer obtained/recorded? (Y/N) by ______________________________

COMMENTS: ______________________________

____

____

____

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Pump-Out Test Data Sheet (page 1 of 2)

Project Name: ______________________________ Date: ______________________________

Pumped Well ID: ______________________________ Weather: ______________________________

Observation Well ID: ______________________________ Personnel: ______________________________

Well locations (provide sketch or attach map):

Include: Scale/dimensions, north arrow, and significant features (e.g., surface water)

This sheet records data for (well ID): ______________________________

Measuring Point: ______________________________ (e.g., notch or inner casing)

Static Water Level: ______________________________ (feet below measuring point [ft BMP])

Static Water Level Date: ______________________________ Time: ______________________________

Interval Open/Screened to Aquifer (ft BMP): ______________________________

Pump Setting Depth (ft BMP): ______________________________

Pump Model: ______________________________ Serial No.: ______________________________

Flow Meter Model: ______________________________ Serial No.: ______________________________

Logger/Transducer Model: ______________________________ Serial No.: ______________________________

Totalizer Reading before Pumping: ______________________________

Date/Time Pumping Started: ______________________________

Discharge Rate (gpm): ______________________________

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Pump-Out Test Data Sheet (page 2 of 2)

Date	Time	Manual Water level Measure (ft BMP)	Discharge (gpm)	Comments

*Use more sheets if more rows are needed.

Date/Time pumping ended: ______________________________

Totalizer reading at end of pumping: ______________________________

Installation and Removal of Flexible Liner Underground Technologies (FLUTe) Systems	SSFL SOP 21 Revision: 0 Date: September 2015

Prepared:	S. Fundingsland	**Technical Review:**	C. Werden
QA Review:	C. Sayler	**Approved and Issued:**	[signature] 9//17/15 *Signature/Date*

1.0 Objective

The purpose of this site specific technical standard operating procedure (SOP) is to define requirements for installing and removing Water FLUTes and FLUTe blank liners from SSFL Area IV monitoring wells.

2.0 Background

The Water FLUTe system is a propriety multi-level water sampling and measurement system that have been used at the SSFL Area IV site since 2002. These FLUTes were installed by the manufacturer, Flexible Liner Underground Technologies, LLC.

Since installation, the data quality objective(s) for the monitoring wells may have changed, which has resulted in the need to physical modify the wells. In some cases, the FLUTe may have failed and is no longer capable of monitoring groundwater. Modifications to the well may include isolation of vertical discrete zones or the complete abandonment of the well. A FLUTe Installation/Removal Plan will be developed for each and will describe modifications to the well.

Removal of a Water FLUTe has been included and may be needed to access the borehole for additional investigation (geophysical logging, open borehole sampling, packer testing, etc.) and/or when the FLUTe is not operational or functioning properly. Installation of a Water FLUTe has been included if an additional or replacement Water FLUTe is needed within Area IV.

The Installation of a FLUTe blank liner has been included to allow sealing the borehole and prevent vertical cross connection flow along the saturated length of the borehole. The removal procedure has been included to allow additional modifications or investigation (geophysical logging, open borehole sampling, packer testing, etc.) of the borehole.

2.1 Definitions

FLUTe Installation/Removal Plan – a plan that describes all work to be performed at a monitoring well. The plan will include a FLUTe Installation Data Sheet and/or FLUTe Removal Data Sheet.

Water FLUTe systems – a flexible liner emplaced in the borehole with the liner pressed against the borehole wall by the excess head in the liner above the local water table and equipped with spacer, check values, tubing, sampling ports, and pressure transducers.

FLUTe blank liner – a blank liner used for sealing the borehole and consists of a flexible liner without sample ports. This liner can be removed and re-installed in the same borehole. While the FLUTe liner is removed additional investigation of an open borehole can be performed. Immediately following the investigation the FLUTe can be re-installed to seal the borehole and reduce/eliminate vertical cross connection flow along the saturated length of the borehole.

High resolution transmissivity profile – a transmissivity profile obtained during the installation of a blank liner (enversion) in a borehole.

Head profile - a stepwise removal of a liner that provides a continuous transmissivity profile during removal (inversion) of the liner from a borehole.

2.2 Associated Procedures

Associated procedures listed below provide direction to be followed to complete those tasks described in the standard operating procedure (SOP). Where possible, SOPs from the Site-Wide Water Quality Sampling Analysis Plan (Groundwater sampling plan for SSFL) have been adopted. However, the Site-Wide SOPs must be reviewed for applicability to activity, current conditions at the site, and regulatory requirements. For example, water management protocol may have been revised since 2010 and will need to be updated prior to using the SOP.

CDM Smith Standard Operation Procedure

- SSFL SOP 8, *Field Data Collection Documents, Content and Control*
- SSFL SOP 10, *Sample Custody*
- SSFL SOP 11, *Packaging and Shipping Environmental Samples*
- SSFL SOP 12, *Field Equipment Decontamination*
- SSFL SOP 13, *Guide to Handling Investigation Derived Waste*
- SSFL SOP 15, *Photographic Documentation of Field Activities*
- SSFL SOP 16, *Control of Measurement and Test Equipment*
- SSFL SOP 20, *Packers – Groundwater Sampling from Isolated Borehole Interval and Aquifer Testing*

Site-Wide Water Quality Sampling and Analysis Plan (Revision 1, December 2010)

- Site-Wide SOP 1.1, *Manual Water-Level Measurements*
- Site-Wide SOP 1.2, *Low-Flow Purge*
- Site-Wide SOP 1.3, *Groundwater Sampling*
- Site-Wide SOP 1.5, *FLUTe Multilevel System*
- Site-Wide SOP 1.6, *Sample Management*
- Site-Wide SOP 1.7, *Equipment Decontamination*

2.3 Discussion

2.3.1 FLUTe Operational Condition Assessment

Prior to collection of data (i.e., water levels or water samples) or removal of an existing Water FLUTe or FLUTe blank liner, an operational condition assessment of the FLUTe needs to be performed. The purpose of the assessment is to ensure integrity of the FLUTe prior to sampling or FLUTe removal activities.

The operational condition of the Water FLUTe is also important information for preplanning FLUTe removal activities. For example, if the FLUTe is known to be compromised (hole in the liner), then special consideration and procedures must be given when removing the FLUTe.

2.3.2 Water FLUTe Removal

The Water FLUTe multilevel system (Water FLUTe) has been used at SSFL Area IV since 2002. There is no life expectancy data published for Water FLUTes, however, Flexible Liner Underground Technologies LLC personal have stated that Water FLUTes installed in Area IV are approaching their life expectancy and may not be operating per their original specifications. If the Water FLUTe is determined to not be operating properly or additional investigation of the borehole is required, the Water FLUTe will be removed to allow access to the borehole and final borehole deposition.

Because of the complexity of removal of a Water FLUTe, Flexible Liner Underground Technologies, LLC, personnel will be used to remove Water FLUTes from any Area IV wells.

2.3.3 Water FLUTe Installation

Similar to removal of a Water FLUTe for a well, only Flexible Liner Underground Technologies, LLC, personnel will be used to install a Water FLUTe into Area IV wells. Installation may include replacement of a non-functioning Water FLUTe in a well. General installation of a Water FLUTe consists of a flexible liner emplaced in the borehole with the liner pressed against the borehole wall by the excess head in the liner above the local water table. The Water FLUTe system includes the ability to sample water through ports that penetrate the liner. The sampling system includes a liner, spacer, port, tubing, and pumping system for individual sampling ports. Depending on the configuration of the well, up to 12 sampling ports may be present in the well. Pressure transducers are attached to the sampling tubing just below the first check valve to measure the head of the formation at the port location.

Prior to installation of a Water FLUTe, Flexible Liner Underground Technologies, LLC recommends that a high resolution transmissivity profile be obtained using a FLUTe blank liner. Generally, these profiles are performed prior to manufacturing the Water FLUTe. This profile allows targeting specific intervals with higher transmissivity for port placement (i.e., port design configuration of the Water FLUTe). Because both transmissivity and head profiling was developed after the installation of Water FLUTes in Area IV wells, this tool was not available at the time the existing FLUTe were installed. Obtaining tranmissivity and head profiles would be additional data that is not available in current FLUTe data set.

2.3.4 FLUTe Blank Liner Installation

FLUTe blank liner is a flexible liner without sampling ports used to seal long open borehole completions and prevent vertical migration of contaminants within the borehole. In addition to sealing the borehole to prevent cross-contamination between transmissive zones, installation of a FLUTe blank liner can provide transmissivity profile along the entire water saturated length of the borehole.

Installation of FLUTe blank liner may be performed by properly trained personnel or Flexible Liner Underground Technologies, LLC personnel.

2.3.5 FLUTe Blank Liner Removal

FLUTe blank liner can be removed from a borehole to allow open borehole or discrete interval sampling (packer testing), geophysical logging or other activity that requires access to the open borehole. During removal of a FLUTe blank liner and assuming a pressure transducer is present in the bottom of the borehole, a formation head distribution profile can be obtained.

FLUTe blank liner removal may be performed by properly trained personnel or Flexible Liner Underground Technologies, LLC personnel.

2.3.6 High Resolution Transmissivity Profile

A transmissivity profile is obtained during the installation of a blank liner in a borehole. As the liner descends by eversion, the water in the borehole is driven continuously into the flow paths (fractures, bedding plans or rock matrix). The water level inside the liner is maintained at a consent level and as the liner descends, the groundwater flow pathways in the borehole are sealed from top to bottom. Each time a flow path is covered, the transmissivity of the borehole beneath the liner is reduced. The liner decent rate is recorded and analyzed to identify location and flow rate of significant flow zones along the entire length of the borehole.

2.3.7 Head Profile

A head profile is a stepwise removal of a liner that provides a continuous transmissivity profile during removal (inversion) of the liner from a borehole. A pressure transducer is located in the bottom of the borehole to record pressure (head) as the blank liner uncovers discrete intervals in the borehole. The pressures are recorded and analyzed to identify the transmissivity along the entire saturated length of the borehole.

3.0 General Responsibilities

Site Manager – Translates DOE requirements into technical direction of project. Sets technical criteria, reviews, and approves technical progress. Ensures that all participating personnel have proper training. **Note**: Other titles such as project manager may be used.

Field Team Leader (FTL) – Supervises field operations. Ensures that all necessary equipment, including safety equipment, is available and functioning properly before project operations begin. Ensures that all necessary personnel are mobilized on time. Maintains daily log of activities each work day.

Field Geologist/Engineer/Scientist/Technician – Collects and maintains data. Coordinates and consults with FTL and site manager on decisions relative to unexpected encounters during implementation and deviations from this SOP. Directs overall activities of implementation procedures and support subcontractors.

Site Health and Safety Technician– The person who will use field screening instruments to monitor all field activities for volatile and radiological contaminants and pre-shipment sample coolers. This person is a trained radiological technician who works under the guidance of Leidos Certified Health Physicist (CHP).

Field Service Subcontractor – The Subcontractor provides equipment appropriate to the task as described in the project statement of work, provides appropriately trained and qualified personnel, and responds to administration of the FTL. The Subcontractor ensure proper calibration or standardization maintenance checks, system checks, completed and well-maintained data documentation, and identification and protection against potential hazards.

4.0 Required Equipment and Documentation

4.1 General Equipment

- Field logbook
- Decontamination equipment and supplies
- Personal Protective Equipment (PPE)
- Water storage tank and management equipment

4.2 FLUTe Operational Condition Assessment

- TAG tube, pump tube or associated pressure transducer for each port
- Water-level indicator
- Water quality meters
- Potable water (fill liner)
- Water purging equipment

4.3 Water FLUTe Removal

- All equipment and supplies provided by Field Service Subcontractor

4.4 Water FLUTe Installation

- All equipment and supplies provided by Field Service Subcontractor

4.5 FLUTe Blank Liner Installation

- All equipment and supplies provided by Field Service Subcontractor
  or
- Liner on shipping reel
- Reel stands and axle to support shipping reel
- Wellhead roller
- Perforated air vent tube
- Potable water (fill liner)
- Groundfos II type pump
- Generator for pump
- Bubbler monitor

- Nitrogen bottle with regulator for bubbler
- Air compressor to drive vacuum pump
- Venturi vacuum pump
- Hose and valve for water supply control
- Clamps and tape for securing liner to well casing or barb fitting
- Slit hose of casing edge
- Camlock barb fitting with double eye cap
- Tag line for water level measurements
- Miscellaneous tools and fittings

4.6 FLUTe Blank Liner Removal

- All equipment and supplies provided by Field Service Subcontractor
  or
- Wellhead roller,
- Winch plate and hand winch or other pulling device, (Green Machine™ or Liner Capstan Machine™)
- Pump
- Water tank
- Shipping real
- Poly film for protection of the liner from abrasion as it is withdraw from borehole
- Kellum strap
- Safety line for connection to an anchor while kellum straps are being repositioned
- Plastic liner

4.7 High Resolution Transmissivity Profile

- FLUTe blank liner
- Potable water (fill liner)
- Pressure transducer (inside liner)
- Liner reel or Green Machine™ or Liner Capstan Machine™
- Velocity meter and tension controller or Profiling Machine™

4.8 Head Profile

- FLUTe blank liner
- Water Tank
- Pressure transducer (bottom of borehole)
- Liner reel or Green Machine™ or Liner Capstan Machine™
- Velocity meter and tension controller or Profiling Machine™

A field service subcontractor will typically be responsible for providing and operating the equipment for installation and/or removal. However, training is available from Flexible Liner Underground Technologies, LLC to train non-FLUTe employees in proper operation and procedures for installation/removal of FLUTe blank liners. The project requirements will need to be evaluated to determine the most suitable arrangement for providing and operating the necessary equipment.

4.9 Documents

- Field logbook
- Appropriate log sheet (installation or removal data sheet)
- Health and Safety Plan
- SOPs
- Field Service Subcontractor Health and Safety Plan

- Field Service Subcontractor Standard Operating Procedures

5.0 Procedures

5.1 Office Preparation

5.1.1 FLUTe Installation/Removal Plan

Adequate attention to the planning and design of the FLUTe installation/removal is a significant phase of the procedure and will ensure proper installation/removal. A planning meeting shall be held to identify the objectives of the project and then scope of the installation/removal shall be developed. After the objectives are identified and the scope is developed, a FLUTE Installation/Removal Plan shall be prepared that describes the procedures to be followed. The FLUTe Installation/Removal Plan shall identify and describe the details to be followed for each component of the FLUTe installation/removal program. This plan may include specifications for field testing and borehole deposition (grouting lower section of borehole, abandonment, etc.).

- Water levels in surrounding wells
- Water sample from FLUTe ports, if operational
- Water sample from open borehole
- Natural attenuation sample
- Geophysical test
- Packer test

The plan will also include water management for each monitoring well.

5.1.2 Site-Specific Health and Safety Plan

The site-specific health and safety plan shall be reviewed along with project plans before initiating field activities. The field service subcontractor and FTL or designee will confer before field activities to ensure a complete understanding of scope and technical details.

5.1.3 Required Documents

The following documents, certificates, and inspections are required to be completed and available prior to field activities.

- FLUTe Installation/Removal Plan
- Field logbook
- Appropriate Installation/Removal Data Sheet
- Site-Specific Health and Safety Plan
- SOPs
- Field Service Subcontractor Health and Safety Plan
- Field Service Subcontractor Standard Operating Procedures
- Copy of Driller License (may be required for well abandonment or modification)

5.2 Field Preparation Activities

DOE, Boeing, and other parties will be pre-notified of site personnel and subcontractors of date and time of field work. Prior to initiating any field work or activity a field planning meeting will be conducted, the site-specific health and safety plan and the FLUTe Installation/Removal Plan will be reviewed. Site personnel will don the appropriate personal protective clothing as indicated in the site-specific health and safety plan. Assemble required support/buddy system and review communication system.

The FLUTe Installation/Removal Plan will describe field preparation requirements for each monitoring well. The plan will also include a FLUTe Installation Data Sheet (specifications and configurations of new FLUTe) or a FLUTe Removal Data Sheet (historic design specification and as-built of existing FLUTe). Preparatory tasks may include the following activities.

- Decontamination of all tools, equipment, and instruments prior to and after each use (Site-Wide SOP 1.7 and SSFL

SOP 12)
- Collection of water levels from monitoring well network (Site-Wide SOP 1.1)
- Collection of water samples from open borehole (Site-Wide SOP 1.2 and 1.3)
- Collection of water samples from FLUTe ports (Side-Wide SOP 1.5)
- Sample management and packaging and shipping environmental samples (Site-Wide SOP 1.6, SSFL SOP 10 and 11)
- Handling investigation derived waste (SSFL SOP 13)
- Inspection of borehole to ensure suitable for packer testing (i.e., caliper and/or other geophysical investigation)

5.3 FLUTe Operational Condition Assessment

The FLUTe operational condition assessment is used to confirm the integrity of the FLUTe and its present/current ability to seal flow pathways within the borehole. FLUTe Integrity will be assessed in Section 6.

5.3.1 Visual Inspection

A visual inspection of the surface completion will be performed to identify torn, worn and/or non-working components at the well head.
- Surface casing
- Exposed liner
- Liner clamps
- FLUTe well cap
- Tag tube and cap
- Sampling tube and plug
- Pump quick connects
- Pressure transducer connects
- Bubbler tube and cap
- Tether and security hook
- Tether tension

Any worn or non-working components will be noted on FLUTe Operational Condition Assessment form.

5.3.2 Static Water Level in FLUTe Liner and Formation

Water levels will be measured in FLUTe liner and from each sampling port (formation head). The following steps will be performed:
- Measure water level in liner (TAG tube)
- Measure formation water level in each port (pressure transducer or pump tube)
- Identify highest formation water level in FLUTe

Water level in the FLUTe liner should be 5 to 10 feet above the highest formation water level to provide a good seal of the liner in the borehole. Record water levels on FLUTe Operational Condition Assessment form. If water level in FLUTe liner is less than 5 feet above the highest formation water level water should be added per Section 5.3.3.

5.3.3 Dynamic Water Level in FLUTe Liner

Water will be added to the FLUTe liner so that water in the liner is 5 to 10 feet above the highest formation water level. The following steps will be performed:
- Measure water level in FLUTe liner (TAG tube)
- Measure formation water level in each port (pressure transducer or pump tube)
- Add water to liner to desired “final” water level
- Measure “final” water level in liner one hour after water addition
- Measure “24 hour” water level in liner 24 hours after water addition
- Measure “48 hour” water level in liner 48 hours after water addition

- Measure “7 day” water level in liner seven days after water addition
- Measure “7 day” formation water level in each port (pressure transducer or pump tube) after water addition
- Chart water level in FLUTe liner overtime

Record water levels on FLUTe Operational Condition Assessment form. The “final” water level in the FLUTe liner should remain at the level over time. If a decrease from the “final” water level is observed, a leak in the liner may be present.

5.3.4 Port Pump Test

Use of this test will be stated in the FLUTe Installation/Removal Plan. In some cases the FLUTe will be sampled and this test would be a duplication of effort. To measure the operational condition of the FLUTe port, water sampling will be conducted per Site-Wide SOP 1.5, *FLUTe Multilevel System*, except no water samples would be collected. Observations will be recorded on the FLUTe Operational Condition Assessment form.

5.3.5 Water Sample from FLUTe Liner

The FLUTe Installation/Removal Plan will state if a water sample will be collected from the FLUTe liner. A FLUTe liner water sample will be collected from below the TAG tube using Site-Wide SOP 1.3, *Groundwater Sampling*. Site contaminants present in the liner may indicate leak in the liner. This information will also be used for water management during removal of the FLUTe (i.e., required to managed and treated before discharge). Observations and activity will be recorded on FLUTe Operational Condition Assessment form.

5.4 Water FLUTe Removal

Several Water FLUTe have been removed from Area IV monitoring wells. Due to the complexity of Water FLUTe removal, a field service subcontractor will be used. The FLUTe Installation/Removal Plan will contain details. A FLUTe Removal Data Sheet will contain historic design specifications and as-built for the FLUTe to be removed.

5.5 Water FLUTe Installation

Installation of a new Water FLUTe at Area IV, a field service subcontractor will provide design, manufacturing, and installation services. The FLUTe Installation/Removal Plan will include installation details as well as the FLUTe Installation Data Sheet with design specifications.

5.6 FLUTe Blank Liner Installation

A FLUTe blank liner can be installed by a field service subcontractor or properly trained personal. The FLUTe Installation/Removal Plan will state if a transmissivity profile (Section 5.8) or head profile (Section 5.9) will be performed. The following steps will be performed. Flexible Liner Underground Technologies, LLC will provide the most current installation procedure or SOP. Flexible Liner Underground Technologies, LLC has an instructional video that discuss each step in greater detail and should be reviewed and understood before installation of the liner.

1. Set the shipping reel on the stands
2. Remove the wrapping without using a knife
3. Set the wellhead roller over the well
4. Invert 4 to 5 feet of liner on itself
5. Attach the vacuum pump to the axle and the jumper tube to the vent check valve, if used
6. Add water only until liner descends easily to the water table. Let it descend to the water table
7. Add water to obtain the desired excess head as the liner descends below the water table
8. Tie off the tether when the liner slows to a near stop
9. Disconnect the bubbler and cover the open end of the liner

The FLUTe Installation/Removal Plan will include installation details and FLUTe Installation Data Sheet will contain FLUTe design specifications.

5.7 FLUTe Blank Liner Removal

Removal of a FLUTe blank liner can be performed by a field service subcontractor or properly trained personal. The FLUTe Installation/Removal Plan will state if a transmissivity profile (Section 5.8) or head profile (Section 5.9) will be performed.

Flexible Liner Underground Technologies, LLC will provide the most current removal procedure or SOP and instructional video that discuss each step in greater detail. All steps should be reviewed and understood before removal of the liner.

If removed and stored properly, the FLUTe blank liner can be reused (i.e., re-installed in the same well to seal borehole). The following steps will be performed.

1. Position the wellhead roller over hole
2. Anchor wellhead roller
3. Disconnect the tether from anchor at the well
4. Drape tether (or liner) over the wellhead roller, under the smaller roller, and route the tether to the winch drum
5. Wrap the tether clockwise onto the winch drum from the bottom up
6. Support winch plate
7. Anchor the winch securely and safely to an immoveable object
8. Take up the slack on the tether
9. Lower the pump into the liner to remove water as the liner is being inverted (5 to 10 feet above the normal water table in the formation)
10. Direct the pump hose to avoid swamp forming at the wellhead
11. Develop about 150 pounds of tension on the liner
12. Start the pump and let it pump until it stops flowing (the excess head in now 5 to 10 feet)
13. Winch the tether out of the hole until the liner appears (keep the tension below about 300 pounds)
14. Adjust the pump speed so that the flow matches the rate of rise of water level in the liner
15. Direct the tether from the winch onto the shipping reel
16. When the liner appears over the top of the wellhead roller, attach a Kellum strap to the liner
17. Replace the tether on the winch with a tether rope connected to the Kellum strap
18. Pull the Kellum tether to the winch, anchor the Kellum with a short safety line, and tie a new strap to the liner at the roller
19. Disconnect the first Kellum tether to the winch and replace with a second Kelllum tether. Winch and disconnect the safety
20. Repeat until the liner is out of hole. Roll the liner onto the shipping reel so as to not damage the liner
21. When the liner reaches the water table, remove the pump from inside the liner, and finish removal

The FLUTe Installation/Removal Plan will contain removal details and the FLUTe Removal Data Sheet will contain historic design specifications and as-built information.

5.8 High Resolution Transmissivity Profile

Only Flexible Liner Underground Technologies, LLC, or a licensed operator, has the expertise and the equipment to perform the tranmissivity measurements.

5.9 Head Profile

FLUTe head profiling can be performed by Flexible Liner Underground Technologies, LLC or licensed operator.

5.10 Decontamination

Equipment and tool decontamination will be performed according to Site-Wide SOP 1.7 and SSFL SOP 12.

5.11 Water Management

Water removed from the liner and borehole shall be managed according FLUTe Installation/Removal Plan. Several methods may be used to handle the discharge water from the liner and borehole. Water management will be conducting according to SSFL SOP 13.

Water management may include:

- Water collected in a holding tank, sampled and analyzed after the work, and then released to the ground surface or

water body after analytical results prove that discharge requirements are met.
- Water transferred to a unit designed and constructed to treat the water to meet discharge criteria; treated and then released to the ground surface or water body.

Other discharge options may also be available and followed and will be described in the plan. Several different methods are typically available to handle discharge water. The governing agency shall be contacted so that required water handling practices are followed and discharge criteria are met.

6.0 Data Reduction and Analysis

FLUTe operational condition assessment data will be reduced and analyzed to determine the integrity of the FLUTe. The FLUTe condition will be reported to all data users. The final data user will determine if data obtained is usable or should be rejected. This analysis is beyond the scope of this SOP and, therefore, are not discussed here.

FLUTe transmissivity and/or head profiles may be reduced and analyzed to:
- Calculate properties of the aquifer and/or fractures
- Determine inter-connectives of surround wells
- Contaminant vertical profile
- Determine integrity of the liner and sealing of borehole

Data analysis and calculations shall be performed by an experienced professional, documented in a calculation brief, and technically reviewed. Data analysis and calculations are beyond the scope of this SOP and, therefore, are not discussed here.

7.0 Restrictions/Limitations

These procedures describe the standard steps used to installation or removal a Water FLUTe or a FLUTe blank liner. Since each monitoring will have different data quality objectives as stated in the FLUTe Installation/Removal Plan, not every step or possible method was incorporated in the procedure.

A planning meeting shall be held to identify the objectives of data collection and disposition of the monitoring well, then the scope of the FLUTe program shall be developed. The plan shall be prepared that describes the project-specific (or monitoring well specific) procedures to be followed. The objects of the FLUTe program shall be specific so that the necessary data to reach the objectives are collected when the test is performed.

8.0 References

Flexible Liner Underground Technologies, LLC. 2010. Sampling Guidelines for Water FLUTe Systems Installed Prior to May 2009, Rev. April 2010.

_______. 2014. DVD Teaching Video.

_______. 2015. www.flut.com.

9.0 Attachments

Attachment 1 - FLUTe Operational Condition Assessment Form
- Visual Inspection
- Static Water Level in FLUTe Liner and Formation
- Dynamic Water Level in FLUTe Liner
- Port Pump Test
- Water Sample from FLUTe Liner

Attachment 2 – FLUTe Installation Data Sheet
Attachment 3 – FLUTe Removal Data Sheet

Attachment 1 - FLUTe Operational Condition Assessment Form

- Visual Inspection
- Static Water Level in FLUTe Liner and Formation
- Dynamic Water Level in FLUTe Liner
- Port Pump Test
- Water Sample from FLUTe Liner

SSFL

FLUTe Operational Condition Assessment Form (page 1 of 8)

Visual Inspection

Project No. ______________________________ Date ____________________

Borehole/Well Identification ____

Field Service Subcontractor ____

Project Geohydrologist/Scientist ____

Component	Condition O, I, U, W, M, D, B	Action/Comment
Surface casing	____________	______________________________
Exposed liner	____________	______________________________
Liner clamps	____________	______________________________
FLUTe well cap	____________	______________________________
Tag tube and cap	____________	______________________________
Sampling tube and plug	____________	______________________________
Pump quick connects	____________	______________________________
Pressure transducer connects	____________	______________________________
Bubbler tube and cap	____________	______________________________
Tether and security hook	____________	______________________________
Tether tension	____________	______________________________

Condition - Operational (O) /Inoperable (I) /Unknown (U) /Worn-out (W) /Missing (M) /Damaged (D) /Blocked (B)

COMMENTS: ____

____

____

SSFL

FLUTe Operational Condition Assessment Form (page 2 of 8)

Static Water Level in Liner and Formation

Project No. ______________________________ Date ____________________

Borehole/Well Identification ______________________________

Field Service Subcontractor ______________________________

Project Geohydrologist/Scientist ______________________________

Survey Point ______________________________

Measuring Point	Water Depth (ft below Survey Point)	Time
TAG (Liner)		
FLUTe Port 1		
FLUTe Port 2		
FLUTe Port 3		
FLUTe Port 4		
FLUTe Port 5		
FLUTe Port 6		
FLUTe Port 7		
FLUTe Port 8		
FLUTe Port 9		
FLUTe Port 10		
FLUTe Port 11		
FLUTe Port 12		

SSFL

FLUTe Operational Condition Assessment Form (page 3 of 8)

Static Water Level in Liner and Formation (continued)

Highest Formation Water Level Measured in FLUTe

FLUTe Port Number ____________ Water Level ____________________________________

Water Level in FLUTe Liner greater than Formation Water Level by 5 to 10 feet ? (Y/N) ____________

Water Added to FLUTe Liner? (Y/N) __________________ Gallons Added __________________

Final Water Level in FLUTe Liner _______________ Time _______________________________

COMMENTS: ____

____

____

____

SSFL

FLUTe Operational Condition Assessment Form (page 4 of 8)

Dynamic Water Level in FLUTe Liner

Project No. ________________________ Date ____________________

Borehole/Well Identification ________________________

Field Service Subcontractor ________________________

Project Geohydrologist/Scientist ________________________

Survey Point ________________________

Measuring Point	Water Depth (ft below Survey Point)	Time
TAG (Liner)	______	______
FLUTe Port 1	______	______
FLUTe Port 2	______	______
FLUTe Port 3	______	______
FLUTe Port 4	______	______
FLUTe Port 5	______	______
FLUTe Port 6	______	______
FLUTe Port 7	______	______
FLUTe Port 8	______	______
FLUTe Port 9	______	______
FLUTe Port 10	______	______
FLUTe Port 11	______	______
FLUTe Port 12	______	______

SSFL

FLUTe Operational Condition Assessment Form (page 5 of 8)

Dynamic Water Level in FLUTe Liner (continued)

Highest Formation Water Level Measured in FLUTe

FLUTe Port Number ____________________ Water Level __________________________________

Water Level in FLUTe Liner greater than Formation Water Level by 5 to 10 feet ? (Y/N) _____________

Water Added to FLUTe Liner? (Y/N) ___________________ Gallons Added ___________________

Final Water Level in FLUTe Liner ______________________ Time ____________________________

Water Level Measured Over Time in FLUTe

Measuring Point	Water Depth (ft below Survey Point)	Time/Date
TAG (Liner)	___________________________	"Final": _________________________________
TAG (Liner)	___________________________	"24 hours": ______________________________
TAG (Liner)	___________________________	"48 hours":______________________________
TAG (Liner)	___________________________	"7 days": _______________________________
FLUTe Port 1	___________________________	"7 days": _______________________________
FLUTe Port 2	___________________________	"7 days": _______________________________
FLUTe Port 3	___________________________	"7 days": _______________________________
FLUTe Port 4	___________________________	"7 days": _______________________________
FLUTe Port 5	___________________________	"7 days": _______________________________
FLUTe Port 6	___________________________	"7 days": _______________________________
FLUTe Port 7	___________________________	"7 days": _______________________________
FLUTe Port 8	___________________________	"7 days": _______________________________

SSFL

FLUTe Operational Condition Assessment Form (page 6 of 8)

Dynamic Water Level in FLUTe Liner (continued)

Measuring Point	Water Depth (ft below Survey Point)	Time/Date
FLUTe Port 9	______________________	"7 days": __________________________
FLUTe Port 10	______________________	"7 days": __________________________
FLUTe Port 11	______________________	"7 days": __________________________
FLUTe Port 12	______________________	"7 days": __________________________

TAG (Liner) Water Level Change

TAG (Liner) "Final" ______________________

TAG (Liner) "7 Days" minus (-) ________________

TAG (Liner) Water Level Change over a 7 Day Period ________________

COMMENTS: ____

____

____

____

SSFL

FLUTe Operational Condition Assessment Form (page 7 of 8)

Port Pump Test

Project No. ____________________ Date ____________________

Borehole/Well Identification ____________________

Field Service Subcontractor ____________________

Project Geohydrologist/Scientist ____________________

Port	Purge Stroke 1 Volume	Purge Stroke 2 Volume	Purge Stroke 3 Volume	Operational (Y/N)
Port 1				
Port 2				
Port 3				
Port 4				
Port 5				
Port 6				
Port 7				
Port 8				
Port 9				
Port 10				
Port 11				
Port 12				

NOTE: Water quality meter may be used during purging to ensure formation water is being withdrawn from sample port. Additional forms found in Site-Wide SOP 1.2, Low-Flow Purge may be requied.

COMMENTS: ____________________

SSFL

FLUTe Operational Condition Assessment Form (page 8 of 8)

Water Sample from FLUTe Liner

Project No. ______________________________ Date ______________

Borehole/Well Identification ______________________________

Field Service Subcontractor ______________________________

Project Geohydrologist/Scientist ______________________________

Survey Point ______________________________

TAG (Liner) Water Level ______________________________

Sampling Method (Low-Flow, bailer, etc.) ______________________________

Sample Identification ______________________________

Sample Time/Date ______________________________

Sampler ______________________________

Analysis Requested ______________________________

COMMENTS: ______________________________

____

____

____

Attachment 2 – FLUTe Installation Data Sheet

SSFL

FLUTe Installation Data Sheet (page 1 of 4)

Project No. ____________________ Date ____________________
Borehole/Well Identification ____________________
Field Service Subcontractor ____________________
Project Geohydrologist/Scientist ____________________
History of Borehole/Well (i.e., replacement of existing FLUTe, initial completion, etc.) ____________________
____
____

Well Completion Data

Completion (Stick Up/Flush) ____________________
Vertical Data - Ground Surface Elevation (above Mean Sea Level (MSL)) ____________________
Horizontal Data – Coordinates (NAD) ____________________
Survey Point (Notch) ____________________ Survey Point Elevation (MSL) ____________________

Borehole Data

Date Drilled ____________________ Borehole Total Depth ____________________

Item	Diameter (in.)	Length (ft.)	Depth (ft. bgs) / Top Elevation (MSL)	Depth (ft. bgs) / Bottom Elevation (MSL)
Conductor Casing			/	/
Borehole Casing			/	/
Borehole			/	/

Pre FLUTe Installation Activities

Describe Pre-FLUTe Testing Completed (i.e., water sampling, geophysical testing, packer testing, etc.)
____
____
____
____

Inspection of FLUTe of Paperwork (Y/N, Comment) ____________________
____
____
____

SSFL

FLUTe Installation Data Sheet (page 2 of 4)

Pre FLUTe Installation Activities (continued)

Item	Total Length on Reel (ft.)	Proposed Installation Starting Depth (ft.)	Proposed Installation Ending Depth (ft.)	Port Transducer (Y/N)	Borehole Transducer (Y/N)/(Depth ft.)
Blank Liner				NA	/
WATER FLUTe					NA
Port 1					NA
Port 2					NA
Port 3					NA
Port 4					NA
Port 5					NA
Port 6					NA
Port 7					NA
Port 8					
Port 9					
Port 10					
Port 11					
Port 12					

Inspection of FLUTe and Reel (Y/N, Comment) ________/________________________________

____

____

Inspection of Installation Equipment (Y/N, Comment) ________/__________________________

____

____

Vertical Data - Survey/Verification of Wellhead Survey Point Elevation (MSL) ____________

Horizontal Data - Survey/Verification of Wellhead Survey Point Coordination (NAD) ________

Vertical and Horizontal Data - Method Used / Date ________________/__________

Water Elevation Depth (ft. below Wellhead Survey Point) / Method ________/__________

Total Borehole Depth (ft. below Wellhead Survey Point) / Method ________/__________

Borehole Obstruction Performed (Y/N) / Method / Comment ___/____________________

____

____

____

SSFL

FLUTe Installation Data Sheet (page 3 of 4)

FLUTe Installation

Preparation to Perform High Resolution Transmissivity Profile Test Completed (see Testing during FLUTe Installation) (Y/N) ________

Installed By ____ Date ___________________________

Beginning Time ____________________________________ Ending Time ____________________

Open Borehole Water Level Depth (ft.) ____

Water Added to FLUTe above Saturated Zone (vadose zone) (gallons/time) ____Complete Eversion Log

Rate of FLUTe Eversion in Borehole above Saturated Zone (feet/minute) _______Complete Eversion Log

Comments pertaining to Eversion of FLUTe in the Vadose Zone _________________________________

____

____

Water Added to FLUTe below Saturated Zone (water table) (gallons/time) _____Complete Eversion Log

Rate of FLUTe Eversion in Borehole below Saturated Zone (feet/minute) _______Complete Eversion Log

Comments pertaining to Eversion of FLUTe in the Saturated Zone (water table) ____________________

____

____

____

Collect Water Level in Ports or Liner (ft.) ________________________________Complete Eversion Log

Water Level in FLUTe greater than Formation Water Level by 5 to 10 feet ? (Y/N)___________________

Final Water Level in FLUTe __________________________ Date/Time ______________________

Testing during FLUTe Installation

High Resolution Transmissivity Profile Testing (Y/N) / Time and Date ________/__________________

Test Performed By ____

Water Management

Describe Water Management and Final Deposition ____

____

____

____

____

SSFL

FLUTe Installation Data Sheet (page 4 of 4)

FLUTe As-Built Data

Wellhead Survey Point Used ______________________________

As-Built Performed and Recorded By / Data ______________________________

Item	Installed Starting Depth (ft.)	Installed Ending Depth (ft.)	Installed Port Transducer (Y/N)	Installed Borehole Transducer (Y/N) / Depth (ft.)
FLUTe Blank Liner			NA	/
WATER FLUTe				NA
Port 1				NA
Port 2				NA
Port 3				NA
Port 4				NA
Port 5				NA
Port 6				NA
Additional Ports				NA

Comments ______________________________

Attachment 3 - FLUTe Removal Data Sheet

SSFL

FLUTe Removal Data Sheet (page 1 of 2)

Project No. ______________________ Date ______________
Borehole/Well Identification ______________________
Field Service Subcontractor ______________________
Project Geohydrologist/Scientist ______________________
History of Borehole/Well (i.e., replacement of existing FLUTe, initial completion, etc.) ______________
____
____

Well Completion Data

Completion (Stick Up/Flush) ______________________
Vertical Data - Ground Surface Elevation (above Mean Sea Level (MSL)) ______________
Horizontal Data – Coordinates (NAD) ______________________
Survey Point (Notch) ____________ Survey Point Elevation (MSL) ____________

Borehole Data

Date Drilled ____________ Borehole Total Depth ______________

Item	Diameter (in.)	Length (ft.)	Depth (ft. bgs) / Top Elevation (MSL)	Depth (ft. bgs) / Bottom Elevation (MSL)
Conductor Casing			/	/
Borehole Casing			/	/
Borehole			/	/

Pre FLUTe Removal Activities

Inspection of FLUTe of Paperwork (Y/N, Comment) ______________________
____
Inspection of FLUTe, Tethe, and Reel (Y/N, Comment) ________/________________
Inspection of Removal Equipment (Y/N, Comment) ________/________________
Water Elevation Depth (ft. below Wellhead Survey Point) / Method ________/____________

FLUTe Removal

Preparation to Perform Head Profile Test Completed (see Testing during FLUTe Installation) (Y/N) ___
Removed By ______________________ Date ______________
Beginning Time ______________________ Ending Time ______________
Liner or Port Water Level Depth(s) (ft.) ______________________ Complete Inversion Log

Remove Water from FLUTe (gallons/time) ______________________ Complete Inversion Log

Rate of FLUTe Inversion (feet/minute) ______________________ Complete Inversion Log

SSFL

FLUTe Removal Data Sheet (page 2 of 2)

FLUTe Removal (continued)

Comments pertaining to inversion of FLUTe ______________________________

____
____
____
____
____
____

Collect Water Level in Open Borehole (ft.) ______________ Complete Inversion Log ____

Total Borehole Depth (ft. below Wellhead Survey Point) / Method ________/________

Testing during FLUTe Removal

Head Profile Testing (Y/N) / Time and Date ________/________________

Test Performed and Recorded By ______________________________

Water Management

Describe Water Management and Final Deposition ______________________________

____
____
____

Post-FLUTe Testing

Describe any Post-Removal Borehole Test (i.e., water sampling, geophysical logging, etc.) ________

____
____
____
____

Appendix A-D

Site-Wide Standard Operating Procedures

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APPENDIX A
SECTION 1.1

MANUAL WATER-LEVEL MEASUREMENT STANDARD OPERATING PROCEDURE

TABLE OF CONTENTS

1. INTRODUCTION

This procedure describes the measurement of water levels in groundwater monitoring and extraction wells, piezometers, and boreholes using an electric water-level indicator. This procedure does not cover automated measurement of water levels with a transducer/datalogger. Measurements for the potential presence and thickness of light non-aqueous phase liquid (LNAPL) or dense non-aqueous phase liquid (DNAPL) in monitor wells may be performed during water level measurement activities.

Water levels will be acquired using a methodology selected to provide accurate and precise data. This data may then be used to calculate groundwater elevations, determine hydraulic gradients and construct groundwater elevation contour maps. Accuracy and precision in obtaining the measurements are critical to the usability of the data.

2. BACKGROUND

Water-level measurements should be made from a fixed reference point marked on the well. The fixed reference mark will be located on the top of the well casing or on the top of the water-level access point into the well, depending on the completion of the well at the surface. Following well installation, a survey mark is placed on the top of the well casing as a reference point for groundwater-level measurements. If a survey mark is not present, the reference point is typically established and marked on the north side of the well casing.

If possible, avoid using steel protective casings or flush-mounted road boxes as a measurement reference point due to the greater potential for damage. Field personnel shall be made aware of the measurement reference point being used in order to ensure the collection of comparable data. The well reference point elevation is surveyed to the nearest 0.01 foot for later use in calculating groundwater elevation.

Before measurements are made, water levels in monitor wells and piezometers should be allowed to stabilize for a minimum of 24 hours after well construction and development. In low-yield situations, recovery of water levels to equilibrium may take longer. Measurements will be made to an accuracy of 0.01 foot. Water-level measuring equipment will be decontaminated prior to measurement activities at each well.

To help to provide reliable data, water levels should be collected within the shortest time practical. However, certain situations may produce rapidly changing groundwater levels that require taking measurements as close in time as possible. Large changes in water levels within wells may be indicative of such conditions. Rapid groundwater level changes may occur due to:

- Barometric pressure changes
- Tidal fluctuations
- Navigation controls on rivers
- Rainfall events
- Groundwater pumping

The time of data collection at each station should be accurately recorded. Personnel collecting water-level data shall record if the above conditions are known or suspected to be occurring during the groundwater-level collection period.

In conjunction with groundwater-level measurements, surface water elevations (e.g., ponds, lakes, rivers, and lagoons) may be monitored as well.

3. EQUIPMENT

An electric water-level indicator consists of a battery-operated, non-stretch, electric water-level probe with permanent markings. Measurements for LNAPL or DNAPL will be made with an oil/water interface probe. Water level indicators and interface probes will be operated and maintained pursuant to the manufacturers' instructions.

The calibrated cable will be checked against a surveyor's steel tape prior to field activities or on a quarterly basis. The difference between the electric water-level indicator calibrated cable and the surveyor's steel tape (the Calibration Correction Factor) will be used to calculate the water-level elevation as indicated in Section 5 of this SOP.

A new cable will be installed if the water-level indicator cable becomes difficult to read.

Other field equipment may include:

- Air monitoring instrumentation (photo ionization detector (PID) or flame ionization detector (FID))
- Steel survey tape for calibration
- Pocket tape
- Paper towels and trash bags
- Decontamination supplies, if applicable to the project
- Water-Level Measurement Form (Table A-I)

4. PREPARATION/PROCEDURE

4.1 Preparation

1. Review the Health and Safety Plan (Appendix C of the Water Quality Sampling and Analysis Plans) to determine project health and safety requirements. Determine and obtain the equipment and supplies needed. Obtain previous water-level monitoring data, if available.

2. Obtain site access, and necessary well keys or well wrenches.

3. Decontaminate or pre-clean equipment, and ensure that it is in working order and calibrated. Calibration of water sounders will be performed prior to each quarterly monitoring event.

4. Identify water-level monitoring locations on site plan prior to going into the field.

4.2 Procedures

Procedures for determining water levels are as follows:

1. Remove exterior lock and steel protective cover. Bail down or remove precipitation or surface water that may have accumulated in the well vault or the annulus between the steel protective cover and the casing, to prevent the water from draining into the well when opened.

2. Monitor the headspace of the well within the well vault or locking cover with a photoionization detector (PID) or flame ionization detector (FID) to determine the presence of volatile organic compound vapors, and record the reading in parts per million (ppm). If necessary, initiate personal protective measures indicated by the Health and Safety Plan (Appendix C of the Water Quality Sampling and Analysis Plans).

3. Remove interior lock and cap or plug. Record the well ID, time of day (military format) and other pertinent information.

4. Turn on the electric water-level indicator and adjust the sensitivity, if necessary. Care should be taken to prevent contact of the water-level indicator with the ground prior to insertion in the well. Lower the water-level measuring device into the well until the audible or visual signals indicate that the probe has contacted the water surface.

5. Measure and record the depth to water from the marked reference point and also record a description of the reference point used for the measurement (e.g., top of four-inch PVC casing). Dates should be recorded in the following format MM/DD/YY. Times should be based on a 24-hour military type format for the given time zone (Pacific Standard Time [PST] or Pacific Daylight Time [PDT]). For example, 8:45 a.m. should be recorded as 0845. The time 2:45 p.m. should be recorded as 1445.

6. If groundwater contact is not indicated by the audio signal, visual signal or meter, compare the total depth probed with the Well Depth indicated on the Water-Level Measurement Form (Table A-I). If the probed depth is at least equal to the Well Depth, the well is dry and this and the probed depth shall be recorded on the Water-Level Measurement Form in the comments. If the probed depth is less than

the Well Depth, remove the water-level indicator from the well and test it for proper operation by submersing the probe in water to confirm that it is functioning. If proper operation is determined, repeat the measurement. If the water-level measuring devise continues to indicate the well is "dry" at a probed depth less than the well total depth, the condition will be recorded and recommendations for evaluating maintenance or repair will be made.

7. Record the distance from the water surface (as determined by the audio signal, visual signal or meter) to the reference measuring point.

8. Two water-level readings should be collected and the results compared. If results do not agree to within 0.01 foot, additional measurements will be taken until two readings within 0.01 foot are obtained. Consistent failure of readings to agree could suggest an anomalous condition with the well or equipment is precluding a correct measurement. Such an occurrence will be noted in the Water-Level Measurement Form and the proper operation of the electric water-level indicator shall be determined prior to measuring additional water levels with that equipment.

9. Remove the down hole measurement equipment; replace well caps, plugs, locks, and protective steel cover.

10. Record physical changes, such as evidence of tampering with the well or cover, vandalism, erosion or cracks in protective concrete pad.

Procedures for determining LNAPL presence and thickness are as follows:

1. Access the well according to steps 1 through 3, above.

2. Turn on the interface probe. Care should be taken to prevent contact of the interface probe with the ground prior to insertion in the well. Lower the interface probe into the well until the audible or visual signals indicate that the probe has contacted LNAPL or the water surface.

3. If the audible or visual signal indicates contact with LNAPL, two readings should be collected and the results compared. If results do not agree to within 0.01 foot, additional measurements will be taken until two readings within 0.01 foot are obtained. Record the depth from the marked reference point to floating LNAPL, if present, in the comments section of the Water Level Measurement Form (Table A-1).

4. Lower the interface probe until the audible or visual signal indicates contact with water. Two readings should be collected and the results compared. If results do not agree to within 0.01 foot, additional measurements will be taken until two readings within 0.01 foot are obtained. Consistent failure of readings to agree during this or the previous step could suggest an anomalous condition with the well or equipment is precluding a correct measurement. Such an occurrence will be noted in the Water-Level Measurement Form and the proper operation of the interface probe shall be determined prior to making additional measurements with that equipment.

5. Record the distance from the marked reference point to the water surface. Also record a description of the reference point used for the measurement (e.g., top of four-inch PVC casing). Dates should be recorded in the following format MM/DD/YY. Times should be based on a 24-hour military type

format for the given time zone (Pacific Standard Time [PST] or Pacific Daylight Time [PDT]). For example, 8:45 a.m. should be recorded as 0845. The time 2:45 p.m. should be recorded as 1445.

6. If contact with LNAPL or groundwater is not indicated by the audio signal, visual signal or meter, compare the total depth probed with the Well Depth indicated on the Water-Level Measurement Form (Table A-I). If the probed depth is at least equal to the Well Depth, the well is dry and this and the probed depth shall be recorded on the Water-Level Measurement Form in the comments. If the probed depth is less than the Well Depth, remove the water-level indicator from the well and test it for proper operation by submersing the probe in water to confirm that it is functioning. If proper operation is determined, repeat the measurement. If the water-level measuring device continues to indicate the well is "dry" at a probed depth less than the well total depth, the condition will be recorded and recommendations for evaluating maintenance or repair will be made.

7. Remove the down-hole measurement equipment. Based on any residual liquid on the interface probe, an attempt will be made to describe the characteristic(s) of the residual product (if any) which may distinguish the material (such as odor, color, and viscosity with respect to water). Descriptions of residual product, if present, will be recorded in the comments section of the Water Level Measurement Form (Table A-1).

8. Replace well caps, plugs, locks, and protective steel cover.

9. Record physical changes, such as evidence of tampering with the well or cover, vandalism, erosion or cracks in protective concrete pad.

5. CALCULATIONS

To calculate groundwater elevation above mean sea level when using a water-level indicator, use the following equation:

$$E_W = E - D + C$$

Where:

E_W	=	Elevation of water above mean sea level (feet) or local datum
E	=	Elevation above sea level or local datum at point of measurement (feet)
D	=	Depth to water (feet)
C	=	Calibration correction factor (feet)

Apparent LNAPL thickness will be calculated by subtracting the measured depth to LNAPL from the depth to groundwater.

$$T_{LNAPL} = D_{water} - D_{LNAPL}$$

Where:

T_{LNAPL}	=	Thickness of LNAPL (feet)
D_{water}	=	Depth to water (feet)
D_{LNAPL}	=	Depth to LNAPL (feet

Apparent DNAPL thickness will be calculated by subtracting the measured depth to DNAPL from the depth of the well.

$$T_{DNAPL} = D_{well} - D_{DNAPL}$$

Where:

T_{DNAPL}	=	Thickness of DNAPL (feet)
D_{well}	=	Depth of well (feet)
D_{DNAPL}	=	Depth to DNAPL (feet

APPENDIX A
SECTION 1.2

LOW-FLOW PURGE
STANDARD OPERATING PROCEDURE

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Page A1.2-

1. SCOPE AND APPLICATION

The purpose of this Standard Operating Procedure (SOP) is to set guidelines for the purging of monitor wells using the low-flow method. Generally, purging of wells will be conducted based on U.S. Environmental Protection Agency guidelines described in *Low-Flow (Minimal Drawdown) Ground-water Sampling Procedures,* dated April 1996, and additional guidance provided by DTSC in the memoranda entitled *"Post Closure Permits"*, dated 25 March 2008 and *"Santa Susana Field Laboratory Site-Wide Water Quality Sampling and Analysis Plan, dated December 14, 2007"*, dated 07 October 2008.

The low-flow purge method entails pumping a well at a flow rate approximately equal to the recharge rate of the aquifer, which may be near or slightly greater than the capacity of the well. The flow rate should not result in significant drawdown within the well. Minimal drawdown should inhibit vertical mixing within the well and result in drawing water directly from the aquifer media. The water level will be monitored regularly during the purging process to determine that the well is not being purged at a rate that induces drawdown in excess of the thresholds described in this SOP.

Exceptions to low-flow sampling protocols may include monitor wells not included in the Regulated Unit or Site-Wide programs, wells equipped with Westbay sampling systems or FLUTe Multilevel Sampling Systems, artesian wells, off-site private wells and groundwater extraction wells. These standard operating procedures may be varied or changed as required, dependent on site conditions, and equipment limitations.

2. INTERFERENCES AND POTENTIAL PROBLEMS

1. Placing the low-flow purge pump at the vertical midpoint of the water column in a well may be difficult for wells that experience large water level fluctuations.

2. Drawdown may be induced in low-yield wells at even the lowest flow rates produced by purge pumps. This may result in wells being purged to dryness.

3. Parameters may not stabilize within a reasonable time period. If parameters do not stabilize within one hour of the commencement of low-flow purging, even if flow rates have been minimized, samples will be collected and a notation will be made on the sampling form. DTSC will be notified within 30 days after the completion of field activities of instances where groundwater samples were collected but the stabilization criteria were not met within one hour. After evaluating well data and witnessing purging activities, DTSC may concur in writing that the subject well(s) cannot meet the stabilization requirements within a reasonable time period and modify stabilization requirements specific to that well(s). Such notification will amend purging requirements, as indicated, for that well(s). If DTSC concludes that modifications to the purging rates and duration will facilitate parameter stabilization, modifications to the purge rate and/or duration of purge for that well will be implemented as indicated by DTSC. Modifications to the WQSAP will be submitted to DTSC as an addendum.

3. EQUIPMENT

Prior to going to the field, instrumentation shall be assembled, calibrated in a manner consistent with manufacturers recommendations (if applicable), and tested. Listed below are types of equipment, instruments, and supplies necessary for well purging:

- Pump controllers (Variable Frequency Drive and Bladder Pump controllers) for low-flow sampling pumps
- Compressed gas cylinder or oil-less compressor for bladder-pump operation
- Generator for Variable Frequency Drive style low-flow pump operation
- Air-hoses, couplers and adaptors, as needed
- Tools necessary for set-up and field maintenance of pumping equipment
- Fuel for generator or compressor
- Flow cell for measurement of groundwater parameters
- Discharge tubing, hose or piping
- Calibrated vessel or flow meter to measure water volume purged
- Labeled vessels (e.g., drums or tanks) for containing purge water
- Water-level measurement equipment
- Calculator
- Keys to well box locks
- Measuring tape
- Cellular phone or radio to communicate with project managers and other field staff
- Watch with a stopwatch function
- Personal Protective Equipment (PPE), including nitrile gloves and safety glasses
- Paper towels and trash bags
- Decontamination supplies
- Field sampling and instrument calibration records
- Material safety data sheets (MSDS)
- Water Quality Sampling and Analysis Plans
- Instrument calibration forms
- Sample collection, labeling and documentation supplies.

4. REAGENTS

No chemical reagents are used in this procedure; however, decontamination solutions and calibration solutions may be necessary for the equipment used.

5. PROCEDURES

5.1 Preparation

1. Review past purging information for equipment types, well size, purge depth, purge rates, purge volumes, pump inlet interval set point, etc.

2. Determine the low-flow purge pumps to be used, and the number and type of samples needed.

3. Obtain the equipment and supplies needed to operate the pumps, to contain and transport purge water, and to collect, handle, and transport the samples.

4. Decontaminate or pre-clean non-dedicated equipment, and ensure that it is in working order.

5.2 Procedures

Procedures for low-flow purging are described below.

5.2.1 Setting Up Low-Flow Purge Equipment

1. Clean non-dedicated sampling equipment in accordance with the Equipment Decontamination SOP.

2. Unlock the well vault. If the presence of volatile organic vapors was indicated in a well during water-level monitoring activities, remove the well cap and allow the well to vent for approximately 2 minutes prior to purging and sampling.

3. Measure the water level following the Manual Water-Level Measurement SOP.

4. If the well is dry or the measured difference in depth between the depth to water and the well depth is less than three feet, the well contains insufficient water for sampling. Remove the water-level indicator and secure the well pursuant to Section 5.2.3.

5. If using a portable pump, retrieve dedicated tubing, connect to the pump apparatus according to the manufacturer's instructions, and install the non-dedicated pump intake at a depth halfway between the depth to water and the bottom of the saturated screened or open interval of the well.

6. Install the appropriate power supply and controls for the specific type, manufacturer, size, and model of the pump.

7. Install the in-line parameter monitoring equipment flow cell. Prior to performing purging, make sure the parameter monitoring equipment is calibrated at the beginning of each day.

8. Set up an in-line flow meter or a calibrated container to monitor volume purged.

9. Initiate operation of the low-flow purge pump.

5.2.2 Low-Flow Purge Set-up Using Electric Submersible Pumps

Dedicated electric submersible Variable Frequency Drive (VFD) pumps are installed in some wells. Pumps are installed on steel or PVC column pipe, which conveys water from the pump to the surface. Power is supplied by a portable generator or fixed electrical source. The procedure for setting up the sampling apparatus on a well equipped with a dedicated VFD pump is the same as described above with the following additional procedures and considerations:

- If using a portable generator to power the well, ensure that the generator is downwind of the well.
- Connect discharge piping at the wellhead; usually a riser pipe that threads into the top of the column pipe with an elbow or tee above the top of the well vault. Downstream from the tee is the typical location of the flowmeter used to measure flow rate and total volume evacuated. Between the tee and the flowmeter and gate valve should be connections to divert flow through a flow cell for parameter measurements and a sample port for collection of samples.
- A garden hose or similar should be used to convey water from the discharge piping to the appropriate waste containment vessel.
- To operate the submersible pump, the electrical lead from the motor is plugged into the pump control box. The pump control box controls the flow rate at which the well will be pumping. The control box is then plugged into the generator or fixed power source. DO NOT plug in the control box until the generator has been started and allowed to warm up. The control boxes are very sensitive to power fluctuations and could be damaged if the generator creates power surges or dips.
- When the equipment is properly connected and the generator is warmed up, the power to the control box may be switched on, starting the pump.

5.2.3 Purging

The goal of low-flow purge methodology is to pump water from the well at a rate that is, to the extent practicable, equal to the rate of recharge to the well. This is accomplished by implementing the following methodology:

1. The water level in the well is measured immediately after the pump starts to determine if drawdown is occurring in the well.
2. If there is drawdown greater than 0.3 foot upon start-up of the well, the discharge from the pump should be decreased using the pump control box until the water level becomes stable.
3. If no drawdown is observed, the pumping rate should be increased until drawdown is observed. The pumping rate should then be reduced to the level at which the water level is stable.
4. If the pump cannot withdraw water at a rate which induces noticeable drawdown, the maximum pump capacity should be utilized.

5. After a sufficient volume of water has been pumped to purge the discharge piping or tubing once, parameter measurements shall commence. Parameter measurements shall be recorded at fixed time intervals, until parameter stabilization occurs, as specified below.

6. Measure and record the depth to water at intervals not greater than five minutes. Dates should be recorded in the format MM/DD/YY. Times should be based on a 24-hour military type format for the given time zone (Pacific Standard Time [PST] or Pacific Daylight Time [PDT]). For example, 8:45 a.m. should be recorded as 0845. The time 2:45 p.m. should be recorded as 1445.

7. Adjust the pump flow rate as necessary so that excessive drawdown, greater than 0.3 feet, does not occur in the well screen or open hole interval of the well.

8. Monitor the following groundwater parameters at intervals not greater than five minutes: pH, conductivity, ORP, turbidity, dissolved oxygen (DO) and temperature. Record the measurements until stabilized.

   Stabilization has been achieved when three successive readings are within:

   - +/- 0.1 for pH,
   - +/- 3% for conductivity,
   - +/-10 mV for ORP,
   - +/-10% for turbidity, and
   - +/-10% for DO.

   Temperature should be monitored even though it is not considered for stabilization.

9. If parameters do not stabilize within one well volume or one hour of the commencement of purging, even if flow rates have been minimized, samples will be collected and a notation will be made on the sampling form.

10. Water samples cannot pass through the in-line parameter flow cell. If there is no sample port "upstream" of the flow cell, remove the flow cell and associated plumbing before sampling.

11. Collect the required groundwater samples. When sampling, make sure the sampler maintains the same flow rate sustained during the purging process. Label and store the samples on ice in an ice chest.

12. Turn off pump and remove the non-dedicated equipment, pump power supply and controls, if necessary.

13. Secure well cap and lock the well box.

14. Decontaminate non-dedicated equipment.

15. Remove equipment, supplies, and wastes from the well site. At all times during purging, sampling, and clean-up, care must be taken to prevent accidental spillage of purged groundwater.

16. Complete field record as necessary and in accordance with FSP.

6. PERSONNEL QUALIFICATIONS

Field samplers are required to take the 40-hour health and safety training course and refresher courses as required by 29 CFR 1910.120 prior to engaging in field collection activities. In addition, field personnel should be trained in the method before initiating the procedure alone.

7. HEALTH AND SAFETY

Low-flow purging techniques with bladder pumps involve the use of compressed gases supplied either by a compressor or a compressed gas cylinder. Compressed gas cylinders present special hazards due to the low temperature of the gas under high pressure and the potential for sudden uncontrolled release of the compressed gas.

Care will be taken when handling and transporting compressed gases. When transporting compressed gas cylinders in a vehicle, the cylinders will be adequately secured to prevent shifting, and regulators should be removed and valve caps secured before moving.

If the sampling crew is utilizing a gas powered air-compressor, note the fire hazards associated with gas powered equipment. When operating the air compressor, make sure the compressor is placed downwind from the location where the samples will be collected and make sure the compressor is not located in close proximity to dry brush or grass. When refueling gas powered equipment, use the proper PPE for personal protection and to eliminate the chance of cross contamination. Never refuel the compressor while it is still hot.

8. QUALITY ASSURANCE/QUALITY CONTROL

The following general quality assurance/quality control (QA/QC) procedures apply:

1. Pertinent data will be recorded.

2. Low-flow purge and parameter measurement equipment will be operated in accordance with operating instructions as supplied by the manufacturer.

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APPENDIX A
SECTION 1.3

GROUNDWATER SAMPLING
STANDARD OPERATING PROCEDURE

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1. SCOPE AND APPLICATION

The purpose of this Standard Operating Procedure (SOP) is to provide general reference information on proper procedures for sampling groundwater wells. This guideline is primarily concerned with the collection of representative groundwater samples from the saturated zone of the subsurface. The goal is to collect samples that are representative of the particular zone of water being sampled at the time of collection. These procedures are to be used in conjunction with analyses for groundwater constituents (e.g., volatile and semi-volatile organic compounds, general minerals, metals).

These are standard (i.e., typically applicable) operating procedures which may be varied or changed as required, dependent upon site conditions, equipment limitations, or limitations imposed by the procedure. The actual procedures employed should be documented.

This procedure is intended for use by field samplers and others associated with performing field investigations at hazardous waste sites. It applies to the collection and handling of groundwater samples from existing and newly installed wells. It addresses the specific activities to be performed prior to going to the field and upon arrival at each sampling location. This procedure also explains the process of groundwater sample collection, preparation or collection of quality control and quality assurance (QA/QC) samples, and sampling event documentation.

Sample containers and preservatives for water samples are described in the Quality Assurance Project Plan (QAPP), and in Table A-II of this FSP. Chain-of-Custody protocols for sample shipment to analytical laboratories are provided in the Sample Management SOP.

Guidelines for purging monitor wells using a low-flow purge method are presented in the Standard Operating Procedure for Low-Flow Purge included in the Field Sampling Plan.

2. METHOD SUMMARY

To obtain a representative groundwater sample for chemical analysis, it is important that the sample is formation water, originating from outside the well. This can be accomplished either by purging the complete volume of water in the borehole/casing one to three times, or alternatively, by purging the well at a rate approximately equal to recovery. Pumping at a rate near or slightly greater than well capacity minimizes drawdown, and ensures that water will be pumped from the aquifer adjacent to the pump or tubing intake. Mixing of water from the borehole, above or below the intake, is minimized or eliminated in this manner. In the low-flow method, the well is purged at the low-flow rate until a specified set of parameters (pH, temperature, specific conductance, dissolved oxygen, turbidity, oxidation reduction potential) are stabilized. At that point samples are collected from the pump discharge.

3. INTERFERENCES AND POTENTIAL PROBLEMS

3.1 General

The primary goal in performing groundwater sampling is to obtain a representative sample of the groundwater aquifer. Field personnel can compromise analysis in two primary ways: (1) taking an unrepresentative sample or (2) by incorrect handling of the sample.

3.2 Purging

In a non-pumping well, there may be little or no vertical mixing of the water, and stratification may occur. Mixing may occur in the screened or open section of a well, but the well water above the screened or open section may remain isolated, become stagnant, and may not be representative of the groundwater. A non-representative sample can result from excessive pre-pumping of the monitoring well. Excessive pumping could dilute or increase the constituent concentrations from what is representative of the sampling point of interest. To safeguard against collecting non-representative stagnant water, the following guidelines and techniques should be adhered to during sampling:

- As a general rule, monitor wells will be purged prior to sampling. Purging until the parameters have stabilized is recommended for a representative sample.
- When purging, the pump should generally be set at the approximate mid-point of the saturated screened interval, or saturated open borehole.
- The flow rate for pumped wells should be maintained at a rate that is approximately equal to the recharge rate of the well by following the procedures described in the Low-Flow Purge SOP (Section 1.5).

3.3 Materials

Equipment used in multiple wells should be decontaminated between uses. Disposable or dedicated equipment should be employed when practicable to help reduce the likelihood of cross-contamination.

The tendency of VOCs to adsorb onto many materials makes the selection of appropriate purging and sampling equipment materials important for reliable trace analyses. VOCs may sorb onto (and subsequently leach from) material made of silicone rubber, polyvinyl chloride, polypropylene, polyethylene and Teflon. Materials made from Teflon are considered the optimal material for use in sample tubing and other flexible components of groundwater sampling equipment. For rigid components, stainless steel is considered to be the optimum material of construction. Other materials may also be deemed appropriate for well construction and sampling apparatus. A record of construction materials utilized in each well will be maintained as part of well maintenance activities.

4. EQUIPMENT

Planning for a sampling event entails assessing, selecting, and assembling the equipment, instruments, and supplies necessary to perform the work. Prior to going to the field, instrumentation shall be assembled, calibrated in a manner consistent with manufacturers recommendations (if applicable), and tested. Listed below are types of equipment, instruments, and supplies used for groundwater sampling from wells:

- Water-level indicator
- Discharge piping or tubing,
- Flow meter or calibrated vessel
- Pump controllers (Variable Frequency Drive and Bladder Pump controllers) for low-flow sampling pumps
- Compressed gas cylinder or oil-less compressor for bladder-pump operation
- Generator for Variable Frequency Drive style low-flow pump operation
- Flow cell for measurement of groundwater parameters
- Air-hoses, couplers and adaptors, as needed
- Tools necessary for set-up and field maintenance of pumping equipment
- Fuel for generator or compressor
- Containers (e.g., drums and/or tanks) for purged well water
- Personal Protective Equipment (PPE), including nitrile gloves and safety glasses
- Measuring tape
- Sample containers and preservatives supplied by the laboratory
- Filtration equipment and 0.45-micron filters (if field filtering for dissolved constituents is required)
- Field sampling and field instrument calibration records
- Coolers and ice for preserving samples
- Decontamination supplies
- Keys to well box locks
- Cellular phone and radio to communicate with project managers and other field staff
- Watch with a stopwatch function
- Calculator
- Sample labels and fine-point permanent markers
- Chain-of-Custody forms
- Custody seals
- Instrument calibration forms
- Material safety data sheets (MSDS)
- Water Quality Sampling and Analysis Plans.

5. REAGENTS

Reagents may be used for preservation of samples and for decontamination of sampling equipment. The preservatives required are specified by the analysis to be performed, and summarized in the QAPP. The analytical laboratory that will perform the sample testing should provide the reagents required for sample containers. Decontamination solutions are specified in the Equipment Decontamination SOP.

6. PROCEDURES

This procedure addresses the specific activities to be performed to accomplish a groundwater sampling event or round. The procedure includes:

- a review of the FSP,
- preparation of a delivery order for analytical laboratory services,
- procurement of equipment and supplies,
- field inspection of wells to be sampled,
- well water-level measurement,
- well purging and measurement of field parameters,
- groundwater sample collection, and
- field documentation requirements.

6.1 Preparation

In preparation for a groundwater sampling event, the field sampler shall review the site WQSAPs, FSP, and QAPP to obtain the following information:

- Identification number(s) of the well(s) to be sampled,
- Locations of the wells,
- Well location access requirements (e.g., locked gates, road conditions),
- Field data recording requirements,
- Field and analytical parameters to be tested,
- Type and number of sample containers needed,
- Volume of sample required for analysis,
- Type and number of QA/QC samples to be collected (e.g., duplicates, splits, and blanks),
- Anticipated weather conditions, and
- Type of equipment needed for the scheduled sampling activity.

A well location map and summaries of well completion data and pump specifications shall be available for field reference.

A request for sample containers, which specifies the sample media, number of samples, and analytical parameters to be tested shall be prepared with sufficient advance notice and forwarded to the laboratory(-ies) contracted to complete the analyses. The analytical laboratory, in accordance with the sampling schedule and the sample volume requirements, will provide sample containers, preservatives, and quality control samples, as requested.

Equipment shall be calibrated according to the equipment manufacturers' protocols prior to use.

6.2 Well Inspection

Prior to sampling a well, its condition shall be inspected and recorded. Signs of vandalism, unauthorized entry, settlement, or ponding around the well shall be documented, along with the well identification number and the date.

If the presence of volatile organic vapors was indicated in a well during water-level monitoring activities, the well vault shall be unlocked and the well cap removed to allow the well to vent for approximately 2 minutes prior to purging and sampling.

6.3 Water-Level Measurement

The depth to water shall be measured from the well reference point in accordance with the Manual Water-Level Measurement SOP. The water level shall be recorded to the nearest 0.01 foot along with the time of day when the measurement was obtained.

6.4 Well Purging

Wells will generally be purged according to the procedures described in the Low Flow Purge SOP (Section 1.2). Exceptions to low-flow purging protocol include wells equipped with Westbay or FLUTe multilevel sampling systems, off-site private wells, artesian wells, groundwater extraction wells or other wells not equipped with low-flow apparatus (such as bladder pumps or Variable Frequency Drive electric submersible pumps). Procedures for wells not equipped with low-flow apparatus are presented in Section 4.2.2 of the Field Sampling Plan, the Westbay Multilevel System SOP (Section 1.4) and the FLUTe Multilevel System SOP (Section 1.5).

6.5 Groundwater Sample Collection

Samples collected from dedicated pump systems (low-flow or submersible) will be collected from the pump discharge. For low-flow purge systems, the sample point is prior to the flow cell. Water samples can not pass through the flow cell. If there is no sample port "upstream" of the flow cell, remove the in-line parameter flow cell and associated plumbing before sampling. For wells with submersible pumps, the sample point is prior to the flow meter and any flow control valves.

Wells shall be sampled for analytes in the following sequence, as applicable:

1. Volatile Organic Analysis:
    - Volatile Organic Compounds including
        - 1,2-Dibromo-3-chloropropane
        - 1,2-Dibromoethane
        - 1,2,3-Trichloropropane
        - 1,4-Dioxane
        - Isopropanol
2. Extractable Organic Analysis:
    - Semi-Volatile Organic Compounds including
        - 1,3-Dinitrobenzene
        - Hexachlorophene
        - N-nitrosodimethylamine (NDMA)

Nitrobenzene
Pentachlorophenol
Chloroxphenoxy Herbicides
Dioxins/Furans
Formaldehyde
Gasoline and Diesel Range Organics
Organophosphorus Pesticides
Pesticides
Polychlorinated Biphenyls (PCBs)
Total Petroleum Hydrocarbons

3. Hydrazines
4. Unfiltered Metals
5. Perchlorate
6. Cyanide
7. Chloride, Fluoride, Sulfate
8. Sulfide
9. Nitrate and Ammonia
10. General Minerals and Parameters:
    - Bicarbonate and carbonate (or alkalinity)
    - pH
    - specific conductance (or electroconductivity)
    - total dissolved solids
    - turbidity
11. Unfiltered Radiochemicals
12. Filtered Metals

The project WQSAPs shall be consulted for the specific analytes required to be sampled for from each well.

Groundwater samples designated to be tested for volatile organic compounds have special requirements. The sample vials shall be slowly filled without aerating the sample by tilting the vial until it is nearly full then holding it upright until a convex meniscus forms at the top of each vial. The vial shall be capped with a Teflon-lined cap and the cap firmly tightened. Each VOA vial shall then be inverted and sharply tapped to check for air bubbles. If bubbles are observed, the vial shall be discarded and the sample re-collected. Samples shall be labeled and put in a sealable plastic bag and placed inside a cooler with ice. The use of cool packs (blue ice) is not recommended.

Samples to be submitted for analysis of dissolved metals will be filtered prior to acidifying. The samples are filtered in the field prior to filling the pre-preserved container. Alternatively, they may be filtered by the laboratory if the samples are collected in unpreserved containers and prior arrangements are made with the lab to assure filtering within the required time frame (QAPP). If samples are to be field filtered, a 0.45-micron, in-line filter should be attached to the sample port on the discharge piping or tubing. Approximately 200 milliliters of discharge water shall be flushed through the filter prior to collecting the sample. The filter shall be replaced when flow of water through the filter is impaired.

Whenever feasible, samples should be collected in the following recommended sampling order by sample type:

1. Equipment rinse blank samples, if applicable
2. Samples for verification or follow-up sampling
3. Primary samples
4. Matrix spike and matrix spike duplicate samples
5. Field duplicate samples
6. Field split samples
7. Field blank samples

Prior to placement into the cooler, each sample should be double-checked to make certain it is properly identified and appropriately labeled. Sample handling, labeling, and transportation are discussed in the Sample Management SOP (Section 1.6).

6.6 Recording of Information

Relevant information pertaining to field activities should be recorded on a regular basis. In order to avoid the potential to not document important information, the record should be in plain sight near the work area and be readily accessible so that observations, readings, and other pertinent information can be easily recorded whenever possible. Observations and other information should be recorded as soon as practicable, or at a minimum, a brief note and the time recorded for later elaboration. The types of information to be recorded may include:

- Arrival and departure times at the site and at individual wells. Dates should be recorded in the format MM/DD/YY. Times should be based on a 24-hour military type format for the given time zone (Pacific Standard Time [PST] or Pacific Daylight Time [PDT]). For example, 8:45 a.m. should be recorded as 0845. The time 2:45 p.m. should be recorded as 1445.
- Information regarding instrument calibrations and the calibration standards used.
- Readings of organic vapor concentrations in the well vault.
- Depth to water.
- Damage or concerns regarding wells or access.
- Method and equipment used to purge wells.
- Pump depths.
- Method and equipment used to collect samples.
- Groundwater parameters.
- Purge volumes, times and estimated flow rates.
- Dates, times and volumes of samples collected.
- Decontamination procedures, if required.
- Times and names of visitors on the site and their purpose.
- Problems or potential problems with equipment.
- Potential health or safety issues that may require revision to the HASP.
- Accidents or injuries.

6.7 Sample Containers and Preservatives

Requirements for groundwater sample containers, preservation requirements, and holding times are addressed in the QAPP.

6.8 Quality Control Samples

For each sampling event, additional samples are required for quality assurance and quality control (QA/QC) purposes. Quality assurance and quality control samples shall be collected, preserved, and handled at the same time and in the same manner as the other groundwater samples collected. The various types of QA/QC samples are discussed in the QAPP (Appendix B of the WQSAPs).

6.9 Sample Documentation

6.9.1 Chain of Custody

The appropriate sample custody documentation shall be completed in accordance with the Sample Management SOP. Entries on the Chain-of-Custody form shall be entered using indelible ink. Identified errors shall be lined out with a single line, initialed, and dated. Chain-of-Custody forms shall be fully completed, with applicable blocks having entries and the signatures of samplers and recipients.

6.9.2 Field Activities Record

The groundwater samples collected from each well, along with the QA/QC samples prepared or collected, shall be identified in the field record. The field sampler shall be responsible for completing the entries. The record shall be submitted to the project manager for review and kept in the project file.

6.9.3 Well Conditions

Any observations by the sampler on the condition of the well pad, well vault, well seal or downhole equipment should be noted on the water-level measurement record (Table A-I) and the field sampling record (Table A-III).

7. PERSONNEL QUALIFICATIONS

Field samplers are required to take the 40-hour health and safety training course and refresher courses as required by 29 CFR 1910.120 prior to engaging in field collection activities. In addition, field personnel should be trained in the appropriate methods before initiating the procedure alone.

8. HEALTH AND SAFETY

Site personnel perform air monitoring at the well head as the monitoring well cover is removed during the initial water-level measurement phase of each monitoring event. The results of air monitoring during the water-level measurements may indicate the need for additional monitoring during the groundwater sampling phase and possible upgrade of the personal protection level according to the current approved site Health and Safety Plan (Appendix C of the WQSAPs).

9. QUALITY ASSURANCE/QUALITY CONTROL

The following general quality assurance/quality control (QA/QC) procedures apply:

- Pertinent data and activities will be recorded.
- Equipment will be calibrated and operated in accordance with operating instructions as supplied by the manufacturer.

APPENDIX A
SECTION 1.6

SAMPLE MANAGEMENT
STANDARD OPERATING PROCEDURE

TABLE OF CONTENTS

1. SCOPE AND APPLICATION

The purpose of this Standard Operating Procedure (SOP) is to set guidelines for sample handling, shipping of samples from the field to the laboratory, and documentation of sample shipment using chain-of-custody protocols.

Sample handling and shipping (also known as sample management) is the continuous care given to each sample from the point of collection to receipt at the analytical laboratory. Good sample management is intended to result in samples that are properly recorded, properly labeled, and not lost, broken, or exposed to conditions that affect the sample's integrity.

The sample submissions will be accompanied with a Chain-of-Custody document to record sample collection and submission (Table A-IV in this Field Sampling Plan).

2. EQUIPMENT

- Sample labels
- Chain-of-Custody forms
- Well list
- Map
- Water-proof re-sealable bags
- Fine-point indelible markers
- Prepared sample containers, labels, markers, ice chests, and ice or cool packs/blue ice
- Shipping forms and labels
- Field sampling record

3. PROCEDURES

3.1 Preparation

Prior to entering the field area where sampling is to be conducted the sampler should ensure that materials necessary to complete the sampling are available.

If samples are required to be maintained at a specified temperature after collection, coolers and ice will be present at the sampling site. Consideration should be given to keeping reserve ice on hand if sampling events will be of long duration and ambient temperatures are elevated. Conversely, when sampling in extremely cold weather, proper protection of water samples, equipment rinse blanks, trip blanks, and field blanks from freezing will be considered.

Personnel performing groundwater sampling tasks will check the sample preparation and preservation requirements presented in the Quality Assurance Project Plan (Appendix B of the Water Quality sampling and Analysis Plans).

The sampling personnel will also confirm before the sample event the amount of bottle filling required for the respective sample containers.

3.2 Procedures

Samples will be properly labeled as soon as practical after collection.

The Quality Assurance Project Plan should be reviewed to determine additional requirements.

3.2.1 Sample Labels/Sample Identification

The samples will be labeled with:

- a unique sample name;
- Grab or composite sample
- date and time;
- analyses to be performed;
- preservative (no preservative indicated as "none")
- analytical laboratory
- file number and project;
- comments, if any; and
- sampler's initials.

Labels should be secured to the bottle and should be written in indelible ink. Note that the data identified for the sample label are the minimum required.

The unique sample identification number may follow the format recommended below, or a specific sample protocol for labeling may be determined prior to sampling. Recommended sample names will include the following:

1. Well identifier
2. If applicable, multi-level port code indicated in parentheses [e.g.,(Z01), (Z06)]
3. Underscore
4. Date, *mmddyy*
5. Underscore
6. Two digit sample type
7. If applicable, H for samples submitted on hold
8. If applicable, R for equipment rinsate samples
9. Underscore
10. If applicable, DISS for filtered samples
11. If applicable TOT for unfiltered samples
12. Underscore
13. One- to four-character laboratory code

Two digit sample types are defined as the following:

- Primary samples = 01.
- Duplicate samples = 36.
- Split samples = 03.
- Trip blanks = 78.
- Field or equipment rinse blanks = 19.
- Spiked samples = 06.

Trip blanks will be labeled with a well ID that was sampled during that shipment. Each sampler will carry a trip blank. Trip blanks should be labeled with the first well he/she samples for the day. Example: RD-45C_050808_78_L.

Field blanks will be labeled with a well ID that was sampled during the event. Example: ES-06_050808_19_L.

Equipment rinse blanks will be labeled with a well ID that was sampled during the event. Example: SH-04_050808_19R_L.

For composited samples, list each sample to be composited on the Chain-of-Custody form (e.g., RD-10(Z1)_050808_01_L, RD-10(Z2)_050808_01_L, RD-10(Z3)_050808_01_L). In the comment section of the Chain-of-Custody form, direct the lab to composite the samples into one sample with a sample name such as RD-10(Comp)_050808_01_L.

The following table provides sample name examples.

Type of Sample	Object ID (well; well&flute port)	Sample Date	Sample Type Number	Lab Code	Sample Name
Primary sample	RD-01_	050808_	01	L	RD-01_050808_01_L
Duplicate sample	RD-01_	050808_	36	L	RD-01_050808_36_L
Split sample	RD-01_	050808_	03	T	RD-01_050808_03_T
Field blank	RD-01_	050808_	19	L	RD-01_050808_19_L
Trip blank	RD-01_	050808_	78	L	RD-01_050808_78_L
Equipment rinse blank	RD-01_	050808_	19R	L	RD-01_050808_19R_L
Spike	RD-01_	050808_	06	L	RD-01_050808_06_L

3.2.2 Packaging

Whenever possible, sample container preparation and packing for shipment should be completed in a well-organized and clean area, free of potential cross-contaminants.

Sample containers should be prepared for shipment as follows:
1. Containers should be wiped clean of debris and water using paper towels.
2. If the container size and number of containers allow, the sample containers collected from an individual well for an individual laboratory will be placed into one cooler.
3. Tighten the bottle caps to prevent leakage.

The following packing guidelines should be followed.
1. Plan time to pack samples (and make delivery to shipper if applicable). Proper packing and manifesting takes time. A day's worth of sampling can be easily wasted due to a few minutes of neglect when packing the samples.
2. Allow for more coolers and more padding rather than crowd samples in the shipping containers. The cost associated with the packing and shipment of additional coolers is usually small in comparison with the cost of having to resample due to breakage during shipment.
3. Line the bottom of the cooler with packing material. Line the cooler with a plastic bag to prevent leakage and tie shut around samples.
4. Do not bulk pack. For containers larger than 40 milliliters (ml), each container will be individually padded and will stand upright in the cooler.
5. 40-ml volatile organic analysis (VOA) vials should be placed in separate, re-sealable plastic bags for each sample for each analysis. Groups of VOA vials should be placed in a larger, re-sealable plastic bag, which should then be wrapped in bubble wrap.
6. One-liter or larger glass containers require much more space between containers. Glass containers will be individually wrapped in bubble wrap and sealed.
7. Ice is not a packing material due to the reduction in volume when it melts.

The following is a list of standard guidelines that should be followed when packing samples for shipment.

1. Double bag ice in plastic, re-sealable bags.
2. Double-check to ensure trip blanks have been included for shipments containing volatile organic compounds (VOCs) and gasoline-range organics (GROs), or where otherwise specified in the Quality Assurance Project Plan (QAPP), Appendix B of the WQSAPs.
3. Enclose the Chain-of-Custody form in a plastic re-sealable bag and attach to the inside top of the cooler.
4. Place custody seals (two, minimum) on each cooler if the cooler is shipped by means other than laboratory supplied courier. Coolers with hinged lids should have both seals placed on the opening edge of the lid. Coolers with "free" lids should have seals placed on opposite diagonal corners of the lid. Place clear tape over custody seals.
5. Ensure that the stickers, markings and prior address labels have been removed from coolers being used that previously contained such materials.

3.2.3 Chain-of-Custody Records

Chain-of-Custody forms (Table A-IV) will be completed for the samples collected. The form documents the transfer of sample containers.

The Chain-of-Custody record, completed at the time of sampling, will contain, but not be limited to:

- Sample name (corresponding to the sample ID on the sample labels)
- Project or file number
- Project/client name and location
- Sampler's(s') signature(s)
- Date/time of sample collection
- Type of samples (composite or grab; soil or water matrix)
- Analytical requirements
- Number and type of containers
- Remarks (e.g., analyze MS/MSD, etc.)
- Date and time samples were relinquished
- Date and time samples were received

Each sample cooler being shipped to the laboratory will contain an original Chain-of-Custody form. The sampler will make and retain a copy. The original Chain-of-Custody form will be enclosed in a waterproof envelope taped inside to the inside of the lid of the cooler containing the samples. The cooler will then be sealed for shipment. The laboratory, upon receiving the samples, will complete the original Chain-of-Custody form and prepare a copy. The laboratory will retain the copy for their records. The original Chain-of-Custody form will be returned with the data deliverables package.

The following list provides guidance for the completion and handling of Chain-of-Custody forms.

1. Custody forms used should be standard forms (as in Table A-IV) or those supplied by the analytical laboratory. Do not use custody forms from other labs, even if the heading is blocked out.
2. Custody forms will be completed in indelible ink only.

3. Custody forms will be completed neatly using printed text.
4. Do not use "Ditto" or quotation marks to indicate repetitive information in columnar entries. If repetitive entries will be made in the same column, place a continuous vertical arrow between the first entry and the next different entry.
5. If necessary, place additional instructions directly onto the custody form. Do not enclose separate loose instructions.
6. When shipping samples via an overnight express service (i.e., Federal Express), the air-bill number for the shipment should be noted on the custody form.
7. Include a contact name and phone number on the custody form in case there is a problem with the shipment.
8. Before using an acronym on a custody form, define clearly the full interpretation of your designation [i.e., polychlorinated biphenyls (PCBs)].

3.2.4 Shipment

The samples will be delivered to the laboratory by the samplers, transported by a laboratory-supplied courier or shipped to the laboratory using an overnight carrier. Prior to the start of the field sampling, the laboratory or shipper should be contacted to determine if pickup can be made at the field site location. If pickup at the field site can be made, the "no-later-than" time for having the shipment ready will be determined.

If pickup is unavailable at the site, the nearest pickup or drop-off location should be determined. Again, the "no-later-than" time for each location should be determined.

Sufficient time will be allowed not only for packaging but also for delivery of samples.

Sample shipments will not be left at unsecured drop locations (i.e., if the cooler will not fit in a remote drop box, do not leave the cooler unattended next to the drop box).

Some overnight carriers do not provide "overnight" shipment to/from some locations. Do not assume. Call the carrier in advance before the start of the fieldwork.

4. PERSONNEL QUALIFICATIONS

The field samplers are required to take the 40-hour health and safety training course and refresher courses as required by 29 CFR 1910.120 prior to engaging in field collection activities. In addition, field personnel should be trained in the method before initiating the procedure alone.

5. HEALTH AND SAFETY

In some instances, sample containers may contain preservatives that can cause bodily injury if they come in contact with eyes or skin, or are ingested. Care should be taken to wear the appropriate personal protective equipment (PPE) during sample handling, in conformance with the Health and Safety Plan (Appendix C of the WQSAPs) and material safety data sheets (MSDS).

6. QUALITY ASSURANCE/QUALITY CONTROL

The following general quality assurance/quality control (QA/QC) procedures apply:

1. The data will be documented in the record.

2. Any corrections to entries will have a single line through the information being corrected along with the correct information and the person's initials and date.

3. Dates should be recorded in the format MM/DD/YY. Times should be based on a 24-hour military type format for the given time zone (Pacific Standard Time [PST] or Pacific Daylight Time [PDT]). For example, 8:45 a.m. should be recorded as 0845. The time 2:45 p.m. should be recorded as 1445.

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APPENDIX A
SECTION 1.7

EQUIPMENT DECONTAMINATION
STANDARD OPERATING PROCEDURE

TABLE OF CONTENTS

1. SCOPE AND APPLICATION

The purpose of this Standard Operating Procedure (SOP) is to provide a description of the methods used for preventing, minimizing, or limiting cross-contamination of samples due to inappropriate or inadequate equipment decontamination. This SOP also provides general guidelines for developing decontamination procedures for sampling equipment to be used during hazardous waste operations. This SOP does not address personnel decontamination.

These are standard (i.e., typically applicable) operating procedures, which may be varied or changed as required, dependent upon site conditions, equipment limitations, or limitations imposed by the procedure. The ultimate procedures employed will be documented.

2. METHOD SUMMARY

Equipment utilized for groundwater sampling at multiple locations requires decontamination prior to reuse.

The decontamination procedure may be summarized as follows:

1. Physical removal
2. Non-phosphate detergent wash
3. Tap water rinse
4. Distilled/deionized water rinse
5. Air dry

Any modifications to the standard procedure should be documented.

3. EQUIPMENT

The following standard materials and equipment are recommended for decontamination activities:

3.1 Decontamination Solutions

- Non-phosphate detergent
- Tap water
- Distilled or deionized water

3.2 Decontamination Tools/Supplies

- Brushes
- Drop cloth/plastic sheeting
- Paper towels
- Plastic or galvanized tubs or buckets
- Pressurized sprayers (H_2O)
- Aluminum foil
- Tables, plastic sheeting, or other devices to keep equipment off of the ground

3.3 Health and Safety Equipment

Personal protective equipment shall include safety glasses or splash shield, and appropriate gloves [as per the Health and Safety Plan, Appendix C of the Water Quality Sampling and Analysis Plans (WQSAPs)].

3.4 Waste Disposal

- Trash bags
- Labeled drums provided by the Boeing-contracted waste-handler
- Containers for storage and disposal of decontamination solutions
- Container labels and permanent markers

4. REAGENTS

Water and non-phosphate detergent are utilized for decontamination purposes.

5. PROCEDURES

Procedures can be established to minimize the potential for contamination. This may include:

- work practices that minimize contact with potential contaminants;
- using remote sampling techniques;
- covering monitoring and sampling equipment with plastic, aluminum foil, or other protective material;
- watering down dusty areas;
- avoid laying down equipment in areas of obvious contamination; and
- use of disposable sampling equipment.

5.1 Field Sampling Equipment Decontamination Procedures

Steps 1 and 2: Physical Removal and Detergent Wash

Place plastic sheeting on the ground to minimize impacts from spillage of decontamination fluids.

Fill a wash basin, a large bucket, child size plastic swimming pool or other suitable container with non-phosphate detergent and tap water. A brush or brushes to physically remove contamination should be dedicated to this station. The volume of water required will depend upon the amount of equipment to decontaminate and the amount of contamination. Scrub equipment with soap and water using brushes.

Step 3: Tap Water Rinse

Fill a wash basin, a large bucket, child size swimming pool or other suitable container with tap water. A brush or brushes should be dedicated to this station. Use a volume of water similar to that used for Step 1. Wash soap off of equipment with water by immersing the equipment in the water while brushing.

Step 4: Distilled/Deionized Water Rinse

Fill a low-pressure sprayer with distilled/deionized water. Provide a 5-gallon bucket or basin to contain the water during the rinsing process. Rinse sampling equipment with distilled/deionized water with the low-pressure sprayer.

Step 5: Air Dry

Lay clean equipment on plastic sheeting to dry. Once dry, the sampling equipment may be wrapped with aluminum foil, plastic, or other protective material.

Follow these steps at the completion of decontamination:

1. Empty soap and water liquid wastes from basins and buckets and store in appropriate drum or container. Refer to the Boeing Company requirements for appropriate containers based on the contaminant of concern.

2. Use low-pressure sprayers to rinse basins and brushes. Place liquid generated from this process into the wash water rinse container.

3. Empty low-pressure sprayer water into an appropriate waste container.

4. Place solid waste materials generated from the decontamination area (i.e., gloves and plastic sheeting, etc.) in a labeled drum provided by the Boeing-contracted waste-handler.

5. Complete labels for waste containers and make arrangements for disposal by the Boeing-contracted waste-handler. Consult Boeing procedures for the appropriate label for each drum generated from the decontamination process.

6. PERSONNEL QUALIFICATIONS

Field samplers are required to take the 40-hour OSHA HAZWOPER training course and refresher courses as required by 29 CFR 1910.120 prior to engaging in field collection activities. In addition, field personnel should be trained in the method before initiating the procedure alone.

7. HEALTH AND SAFETY

When working with potentially hazardous materials, follow OSHA, U.S. EPA, corporate, and the Health and Safety Plan (Appendix C of the WQSAPs).

Decontamination can pose hazards under certain circumstances. Hazardous substances may be incompatible with decontamination materials. For example, the decontamination solution may react with contaminants to produce heat, explosion, or toxic products. Also, vapors from decontamination solutions may pose a direct health hazard to workers by inhalation, contact, fire, or explosion.

The decontamination solutions will be determined to be acceptable before use. Decontamination materials may degrade protective clothing or equipment. If decontamination materials do pose a health hazard, measures should be taken to protect personnel or substitutions should be made to eliminate the hazard.

Material generated from decontamination activities requires proper handling, storage, and disposal. Personal Protective Equipment may be required for these activities.

Material safety data sheets (MSDS) are required for the decontamination solutions.

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Appendix A-E

Colog Standard Operating Procedures

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Technical Procedure and Work Instructions for

Geophysical Logging - General Procedure

TP-1

Prepared by: David A. Renner Date: 7/6/15

Approved by: Nathan O. Davis Date: 7/6/15

CONTROL DOCUMENT No. TP1011409

Colog, Inc. Technical Procedure TP-1

Revision History

Revision Level	Issue Date	Change Summary
0.00	3/10/97	New procedure, issued as TP-13.
1.00	6/17/97	Changes to original draft, renamed to TP-1 from TP-Gen.
1.10	7/9/97	Minor grammatical corrections and clarification of deliverables. Procedural change with regard to depth system, cablehead checkouts.
1.11	7/28/97	Clarification of how "A.S.D.E." is to be measured. Added
		procedure to include diagram of well construction.
1.12	3/12/98	Minor grammatical changes, added copyright protection.
1.20	2/5/99	Included revisions to incorporate the purchase of COLOG, Inc. by Layne GeoSciences, Inc.
1.21	2/3/00	Include revisions for name change Layne GeoSciences, Inc. to Layne Christensen Company
1.22	2/15/07	Tightened tolerance for depth check from 0.4% to 0.1%. Added 7-conductor cable to the Wireline Integrity Check.
1.23	5/4/07	Revised to include new logging acquisition systems and ASDE to 0.2%
1.24	1/14/09	Revised with new image of Logging Report form
1.30	7/6/15	Included revisions to incorporate the sale of the COLOG division of Layne Christensen Company to Colog, Inc.

Table of Contents

1.0 SCOPE

This document describes the general procedures for acquiring geophysical logging measurements for Colog, Inc. In addition to this document, detailed technical procedures also exist for each of the specific geophysical log measurements to be acquired.

1.1 Purpose

1.1.1 This procedure provides instructions for performing geophysical logging measurements, to assure the accuracy, validity, and applicability of the methods used.

1.1.2 This procedure further describes the components of geophysical logging systems common to all such measurements, and provides specific guidelines for calibration, standardization and performance verification of the equipment, and for data acceptance.

1.1.3 This procedure also describes the possible interactions between logging measurements and the considerations which shall be applied to ensure a minimal level of degradation of one log by a previously recorded measurement.

1.1.4 This procedure is intended to replace those sections of the Technical Procedures for the individual log measurements which are common to all measurements.

1.1.5 In applying this procedure to an individual measurement, the requirements of this procedure shall be superseded by those stipulated in the Technical Procedure applicable to that measurement.

1.1.6 This procedure does not include a description of the methods to be used in the analysis and synthesis of the results of geophysical logging.

1.1.7 Requirements for data tracking and the use of field notebooks and other documentary materials are addressed in the work plan for each individual project.

1.2 Applicability

This procedure applies to Colog, Inc. personnel who perform work referred to in paragraph 1.1

2.0 REFERENCES

2.1 Standard Guide for Planning and Conducting Borehole Geophysical Logging, ASTM Designation D5753-05, October, 2005.

2.2 Appropriate instrument manufacturer instruction manuals, and Colog, Inc. operational and procedures manuals.

2.3 Site specific Quality Assurance Plans (QAPs).

3.0 DEFINITIONS

Definitions shall be in accordance with ASTM D5753-05.

3.1 Logging is the process of recording one or more measurements as a function of depth in a borehole.

3.2 Wireline - Typically, a multistrand steel cable which connects the logging sonde at one end to the logging truck at the other. Provides a means to raise and lower the sonde in the borehole, and allows electronic communication and transmission of power between the sonde and the surface electronics.

3.3 Sonde or probe - Instrument package which is attached to the end of a wireline and lowered into a borehole to provide one or more measurements as a function of depth in the hole.

3.4 Surface electronics - Electronic equipment which provides control and may provide power to run a wireline log. The raw signals from the measurement device(s) may be translated to engineering values by this equipment. The surface electronics may also include a means of printing a hard copy display of the results of the log, and a means to digitally record the data.

3.5 Validation or Standardization - The process of verifying that a measurement is repeatable.

3.6 Calibration - The process used to adjust the raw signal of a logging instrument to measurable units via a known standard.

3.7 Checks - The process of demonstrating that a measurement is accurate.

3.8 Measurement device - A device which provides one or more measurements. A single sonde may include a number of measurement devices.

3.9 Wireline tension - the sum of the weight of a downhole probe and wireline, and the force applied due to motion of the probe. When the probe is stationary, this typically represents the weight of the equipment as suspended in the wellbore fluid. When running into the hole the tension is typically a bit lower than when stationary; when coming out it is typically greater. Tension provides a means of monitoring the motion of the tool thus providing an indication of points where the probe may get stuck.

3.10 Depth Measurement - Depth is measured with a pulse digital encoder which outputs a specific number of pulses for each rotation of a measure wheel of known circumference. The pulse frequency is translated to a logging speed which can be monitored and controlled by the Logging Engineer. The pulses are counted and normalized to provide depth measurements which are recorded by the surface recording equipment along with the data from the logging probe.

3.11 Personnel:

In addition to the Technical Program Director and other people identified by the client, the people specifically defined based on their responsibilities during the acquisition of geophysical logging measurements are:

3.11.1 Logging Engineer - Employee or designate of the company providing the measurement device who is responsible for overall operations and data quality.

The Logging Engineer typically monitors tool operations by watching surface displays, keeps track of field records, and ensures that acquired data are properly transported and archived.

The Logging Engineer is responsible for ensuring full compliance with this procedure and with the specific Technical Procedure for the measurement being made, and for ensuring that all assigned personnel are adequately trained and qualified to perform these activities.

3.11.2 Technician: Responsible for electrical and mechanical integrity of the logging sonde, the wireline, and the logging truck. The technician typically runs the wireline, monitors depths, and assists in general operations as required.

The Logging Engineer and the Technician may be the same person.

4.0 REQUIREMENTS

4.1 Prerequisites

4.1.1 The well site shall be prepared in a manner that provides adequate access to the well and a reasonably level surface on which to position the wireline truck.

The site shall have sufficient space available to perform all necessary procedures, including equipment and depth checks, in a safe and efficient manner.

4.1.2 The well should be drilled in a manner that permits the intended measurements to be recorded and interpreted in a meaningful way. Although Colog, Inc. may not have control over the drilling process, adjustments will be made to the logging program as necessary, to acquire the most accurate geophysical data as possible under the given well condition(s).

The Logging Engineer shall have access to all information necessary in order to acquire the best possible data for the given conditions. This includes the information necessary to complete the "Well Sketch" (Appendix 7.3) and the "Logging Report" form (Appendix 7.5) of this TP. It is the responsibility of the Project Director to provide this information to the logging engineer in order that the appropriate equipment is brought to the site. Additional information should be obtained from the driller on site if possible.

4.1.3 A general plan for all downhole measurements shall be established prior to drilling the first hole. This allows consideration in the drilling plan of factors affecting the measurements. Furthermore, it makes it possible to schedule operations in such a way as to prevent a situation in which one measurement damages the hole and prevents successful performance of subsequent measurements.

4.1.4 All calibration standards including but not limited to multi-meters, oscilloscopes, and measuring tapes shall be certified and referenced to ANSI standards if such standards exist. If these standards do not exist, the manufacturer's guidelines shall be followed.

4.1.5 All logging instruments shall be calibrated at the manufacturer, in the logging operator's shop, or in an applicable calibration facility. Calibration records shall be maintained by the logging contractor.

4.1.6 All equipment which is quality affecting shall be identified uniquely, and documentation and records pertaining to that equipment shall include the identification number.

4.2 Tools, Material, Equipment

4.2.1 Calibration

All quality affecting devices which provide data to be interpreted in a quantitative manner shall be calibrated. These calibrations shall be made prior to the first use on this project of such devices, whenever a quality affecting device is repaired for any reason, and if the Logging Engineer is concerned about the level of performance of the measurement device. Reasons for repair include but are not limited to 1) damage during operations, 2) field check or standardization failure.

4.2.1.1 Calibration records shall be maintained by Colog, Inc.

All measurement devices which require calibration shall also have standardization checks performed to verify their operation. These checks shall be made prior to and following each use of the measurement device, except if specifically detailed otherwise in the individual Technical Procedure.

4.2.2 Standardization (Validation)

All probes used for qualitative comparison of data obtained either at different times in the same well, or in different wells, or using different probes for the same measurement, shall have standardization checks performed to verify the repeatability of the measurements. Use of an external standard shall be deemed acceptable for validation.

4.2.2.1 Standardization using external standards: When using this approach, standards should be selected which cover the range of output values expected to be encountered in the logged boreholes if possible. Standardization checks should be made before and after logging each measurement, or as appropriate to the goals of the project (checks made daily or even weekly).

4.2.2.3 The conditions for acceptance using standardizations of each wireline log measurement shall be detailed in the appropriate Technical Procedure.

4.2.3 Calibrations and standardizations shall be conducted as detailed in the Technical Procedure for each measurement.

4.3 Precautions and Limits

All geophysical measurement devices are designed for operation within a specific range of conditions. These include but are not limited to temperature, wellbore size, rock type, fluid pressure, and fluid salinity. Furthermore, many devices deliver results which are dependent on these and other conditions.

4.3.1 The operating range of each measurement device shall be detailed in the Technical Procedure for that device.

4.3.2 Specifics of the factors affecting output results shall be detailed in the Technical Procedure for that device.

4.4 Acceptance Criteria

4.4.1 Acceptance shall be dependent on each device having met the criteria for calibration and validation.

4.4.2 Acceptance shall depend on an adequate level of repeatability for the repeat section of each log. The criteria for acceptance shall be spelled out in the TP for each log.

4.4.3 Acceptance shall require that the depth measurement be repeatable and the after survey depth error (A.S.D.E.) shall fall below a value of 0.2%, or 2 feet per 1000 feet of logged depth.

4.4.4 Acceptance shall require the approval of the results of each measurement by the Logging Engineer. The criteria employed shall be detailed in the Technical Procedure for each measurement.

5.0 DETAILED PROCEDURE

All operations shall be carried out in conformance with this procedure and with ASTM standards for the specific tool, if those standards exist. If such standards do not exist, the manufacturer's standard operating procedures (SOP's) shall be substituted, provided such procedures do not conflict with specific instructions in this or any other Technical Procedure. If a conflict arises, it shall be resolved by modification of this procedure and of the Technical Procedure for the specific measurement device, to incorporate the manufacturer's SOP's in a manner which does not degrade the quality or affect the ability to document the quality of the resulting data.

5.1 Prior to mobilization

5.1.1 If possible, determine hole size, the type of wellbore fluid and the fluid level, and select the optimum device(s) for use in each hole.

5.1.2 Examine other logs (if run), noting in particular conditions which may cause tool sticking or variations in data quality.

5.1.3 If logging sondes that include hazardous materials such as active nuclear sources are to be run, client must sign a written agreement addressing paragraph 8 of Colog's "Terms and Conditions".

5.1.4 If possible, discuss hole conditions with drillers.

5.1.5 Develop a preliminary logging plan, based on all available information.

5.1.6 Prepare a list of materials requirements for completion of the logging plan.

5.1.7 Calibrate all quality affecting measurement devices.

5.1.8 The depth measurement system shall be calibrated by running 100 feet of wireline out of the truck (measured with a measurement tape) and verifying that as the wireline is spooled off and back onto the drum the wireline depth counter reads the wireline length to an accuracy of 0.2 ft per 100 feet of wireline motion. Calibrate the depth measurement system as follows:

5.1.8.1 Set up the logging vehicle to perform a depth measurement system checkout (preferably as shown in Appendix 7.1). Mark the wireline with tape at some convenient reference point as shown in the figure. Be sure to keep tension on the wireline when marking the reference point. Set depth in the appropriate data acquisition program to 0.0 (***Note: If more than one program is to be used, a separate checkout form should be completed for each program).***

5.1.8.2 Run out 100 feet of wireline, measured using the digital output from the data acquisition program or panel mounted depth display

5.1.8.3 Measure length of wireline between the tape and the original reference position using a steel measurement tape. Be sure to hold tension on both the wireline and the measurement tape when making the measurement as shown in Appendix 7.1. The measured length should be within 0.2 feet of 100.

5.1.8.4 Spool wireline back to the original zero point (tape back at the reference point).

5.1.8.5 Determine the A.S.D.E. When the wireline is returned to the original zero point. The A.S.D.E. is equivalent to whatever is displayed in the acquisition software with the tape back at the original reference point. The A.S.D.E. may be positive or negative, and should always be reported in feet (if the acquisition program outputs depth in meters, simply convert the values to feet. The A.S.D.E. should be within ±0.2 feet of zero.

5.1.8.6 Alternately, a log of a designated borehole may be substituted for the wireline calibration. In implementing this procedure a log shall be used which repeatably identifies a measurement anomaly at a characteristic depth (for example, caliper will identify the depth of the bottom of casing, a known wellbore enlargement (washout), or a known change of bit size). The depth to the measurement anomaly should be at least 50' from ground level.

Comparison of the "calibration log" to previous logs of the same hole for purposes of depth calibration shall meet the same criteria for depth validation based on the expectation that depth errors shall not exceed 0.2 feet per 100 feet of measured depth.

5.1.9 Complete the "Depth Measurement System Checkout Form" (Appendix 7.2). Be sure to indicate the acquisition program being checked on the form.

5.2 <u>On arrival</u>

5.2.1 Calibration records for all equipment requiring calibration prior to arrival shall be made available to the client or designate upon request.

5.2.2 The truck should be situated on as level ground as possible adjacent to the *****well head.

***Caution - Be sure to keep the well head covered during <u>all</u> surface operations (rig up, calibrations/checks, rig down) to prevent inadvertently dropping a foreign object down the hole.**

5.2.3 The wireline shall be rigged for access to the wellbore in such a manner that wireline tension can be monitored to prevent endangering the wireline, the measurement sonde, or individuals on the site.

5.2.4 The site shall be inspected to mitigate any potential hazard to ensure the safety of all personnel.

5.2.5 All pertinent wellbore information shall be recorded on the front side of the "Logging Report" form shown in Appendix 7.5. Also, in the "Comments/Other Information" box, document (or draw a rough sketch) of the wellhead itself. Include the stick-up of the pipe (if any) and, if the zero point is on a reference other than the measure point (such as the knurl), document how the depth reference was determined. An example sketch is shown in Appendix 7.3.

5.2.6 The electrical integrity of the wireline shall be checked prior to each continuous logging operation. Typically, the cross-conductance (between individual conductors and between conductor and armor) is less than 10 nanoSiemens. Cable line resistance varies depending the type of logging cable being used. The results shall be recorded on the "Wireline Integrity Check" form (Appendix 7.4).

If more than one logging system is used, complete a separate form for each individual cable line. Indicate the cable line type on the form.

5.2.7 A detailed diagram of cable head dimensions shall be provided, in order to select appropriately sized "fishing tools" if necessary to remove a stuck tool from a wellbore (Appendix 7.7). Furthermore, diagrams for each specific logging probe shall be provided (in the individual Technical Procedures) which shall include the locations of each measurement point relative to a reference (usually, the top or bottom of the logging tool), as well as the diameters of each section of the tool.

5.3 <u>During logging</u>

All procedures detailed in the individual Technical Procedures for each measurement shall be adhered to.

5.3.1 Discuss borehole conditions with drillers.

5.3.2 Examine logs previously run in the same well (if available), noting in particular, conditions which could cause tool sticking or variations in data quality.

5.3.3 Logging sondes which include hazardous materials such as active nuclear sources shall be run only with the approval of the client (including signed agreement addressing paragraph 8 of Colog's "Terms and Conditions"), after verifying that conditions in the well are such that the risk of losing the tool is minimized. Conditions which shall prevent the use of such tools include but are not limited to (a) problems encountered with a previous tool, and (b) wellbore deviation which exceeds safe limits as determined by the Logging Engineer.

5.3.4 If possible, note depths of water table, surface casing, and total depth of well to compare with depths supplied by client.

5.3.5 Minimize the total time the probe is in the borehole, thus minimizing the risk of being stuck. Be particularly careful when the probe is sitting at the bottom of the hole as it is much more vulnerable to sticking.

5.3.6 Wireline tension and other relevant parameters shall be monitored while running into the hole to verify continued motion of the logging sonde.

5.3.6 A minimum 50 foot repeat section shall be recorded for all measurements (if appropriate for the particular measurement), as input to the acceptance criteria. Additional footage may be logged at client's request. Failure to meet the acceptance/ criteria shall require a re-logging of the entire interval which shall include a repeat interval. Measurements which do not normally require a repeat log are detailed in the individual Technical Procedures.

5.3.7 At the completion of each logging run, determine the After Survey Depth Error (A.S.D.E.) as shown in Appendix 7.8 and record it in the "Depth Error" box on the back of the "Logging Report" form next to last file recorded for the particular run.

5.3.7 All measurements shall be checked prior to and following their acquisition in the well (or as appropriate to the goals of the project) to ensure that they meet calibration standards established in the individual TP. The results shall be recorded on forms for each measurement detailed in the specific Technical Procedure. For measurements which are interpreted quantitatively, criteria for acceptance shall be detailed in the Technical Procedure for that measurement which utilize the results of such validations in a quantitative manner.

5.4 Prior to departure

5.4.1 If operations at the site revealed any deviation from the wellbore conditions recorded on arrival, or resulted in any change to those conditions, such changes shall be annotated on the "Logging Report" form (Appendix 7.5).

5.4.2 All equipment which has been exposed to potential contamination shall be cleaned prior to departure. Cleaning procedures shall be in compliance with established site-specific Health and Safety plans.

5.4.3 All quality assurance forms pertaining to all measurements obtained at the site shall be initialed and dated by the Logging Engineer.

5.5 Site Operational record

A record of operations at each site shall be maintained on the back side of the "Logging Report" form as shown in Appendix 7.5.

5.6 Measurement record

A record of each measurement shall be maintained on the back side of the "Logging Report" form as shown in Appendix 7.5.

6.0 RECORDS

The following records generated from the performance of activities under this procedure shall be maintained in accordance with the Project's records procedure, Reference 2.3. Although record keeping and documentation adds significantly to the time and effort required to obtain the data necessary to fulfill project objectives, the overriding concern of all persons associated with these operations shall be to fulfill the requirement for full and complete documentation of the measurements while the measurements are acquired.

6.1 Data records

Records of the data obtained from each measurement shall be produced as follows:

6.1.1 A paper copy of the log values shall be provided as described in ASTM D5753-95.

6.1.2 A digital record of the log shall be recorded for each measurement.

For most measurements, this record shall consist of space-delimited depth data gathers, one gather per line, as either:

A single file which includes both the raw data and translations of that data to engineering units accomplished using conversion factors established during pre-log validations.

(or)

Separate files of the raw and converted log data.

The conversion factors shall be recorded as stipulated in each individual Technical Procedure. Headers shall identify the depth and measurement columns, and the calibration values used to convert the raw data values to engineering units. The filename should designate the name of the well along with the unique run it correlates to.

Exceptions to this type of digital record are described in the individual Technical Procedures for each logging probe.

A backup copy of the digital record(s) shall be created and archived according to data handling procedures established for this project.

6.1.3 Digital record(s) of the pre- and post- log calibrations/checks shall be provided either as part of the digital record(s) of the log or as separate file(s).

6.1.4 Forms shall be completed as specified in this and the specific technical procedures so as to document conformance.

6.2 Exceptions

All exceptions shall be documented on the "Daily Log" form (Appendix 7.6) and verified by client's signature.

6.3 Field Modifications

A field modification is considered to be an exception.

6.3.1 Field modifications of these procedures shall be permitted only if: 1) the activity cannot be performed as defined in this Procedure and the normal change process would cause unreasonable delays, and 2) the modification would either not affect or would enhance the quality of the data, or 3) the modification would result in more efficient operations and would not degrade data quality or the ability to qualify the data. Of course, the Logging Engineer may modify any procedure at the request of the client (or client's representative); however, if the modification is quality affecting, client assumes full responsibility for the data.

6.3.2 Any field modification(s) shall be documented on a "Daily Log" form (Appendix 7.6). This documentation should describe the modification, the new procedure, the name(s) of the person(s) requesting and approving the change along with their signatures.

6.3.3 If the modification results in an improvement in the quality of the data this Procedure shall be modified to incorporate the change.

6.4 Deliverables

Deliverables shall be prepared and provided as detailed in Colog's original proposal or contract. The following shall also be provided upon client's request if applicable for the specific type of measurement being recorded.

6.4.1 A copy of all forms as detailed in this and the individual Technical Procedure for the specific measurement.

6.4.2 For logs which consist of one or more single measurements as a function of depth, a digital data file in ASCII format of the data described in 6.1.2.

6.4.3 A paper copy of the log data described in 6.1.1.

6.4.4 For logs which cannot be stored digitally as described in 6.3.2, the specific format shall be detailed in the controlling Technical Procedure.

7.0 APPENDICES

7.1 Example set up to perform depth measurement system checkout.

7.2 "Depth Measurement Checkout" Form

7.3 Example well sketch

7.4 "Wireline Integrity Check" Form

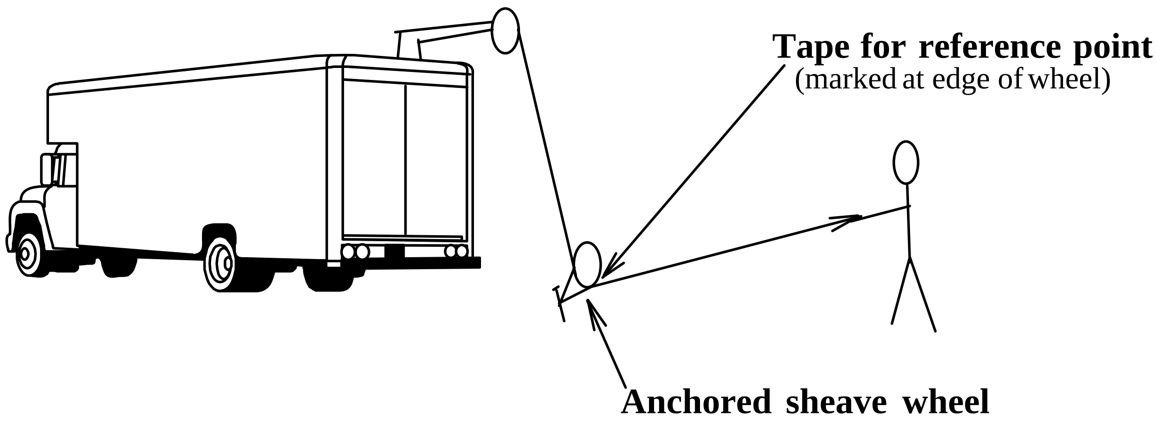
7.5 "Logging Report" Form

7.6 "Daily Log" Form

7.7 "Cablehead Diagrams"

7.8 After Survey Depth Error Calculation

Appendix 7.1



Tape for reference point
(marked at edge of wheel)
Anchored sheave wheel

Appendix-7.2

borehole geophysics / hydrophysics

Depth Measurement System
Checkout Form

Engineer:_______________ Location:_______________ Unit No:___________

Data Acquisition Program or Type of Counter:_____________________________

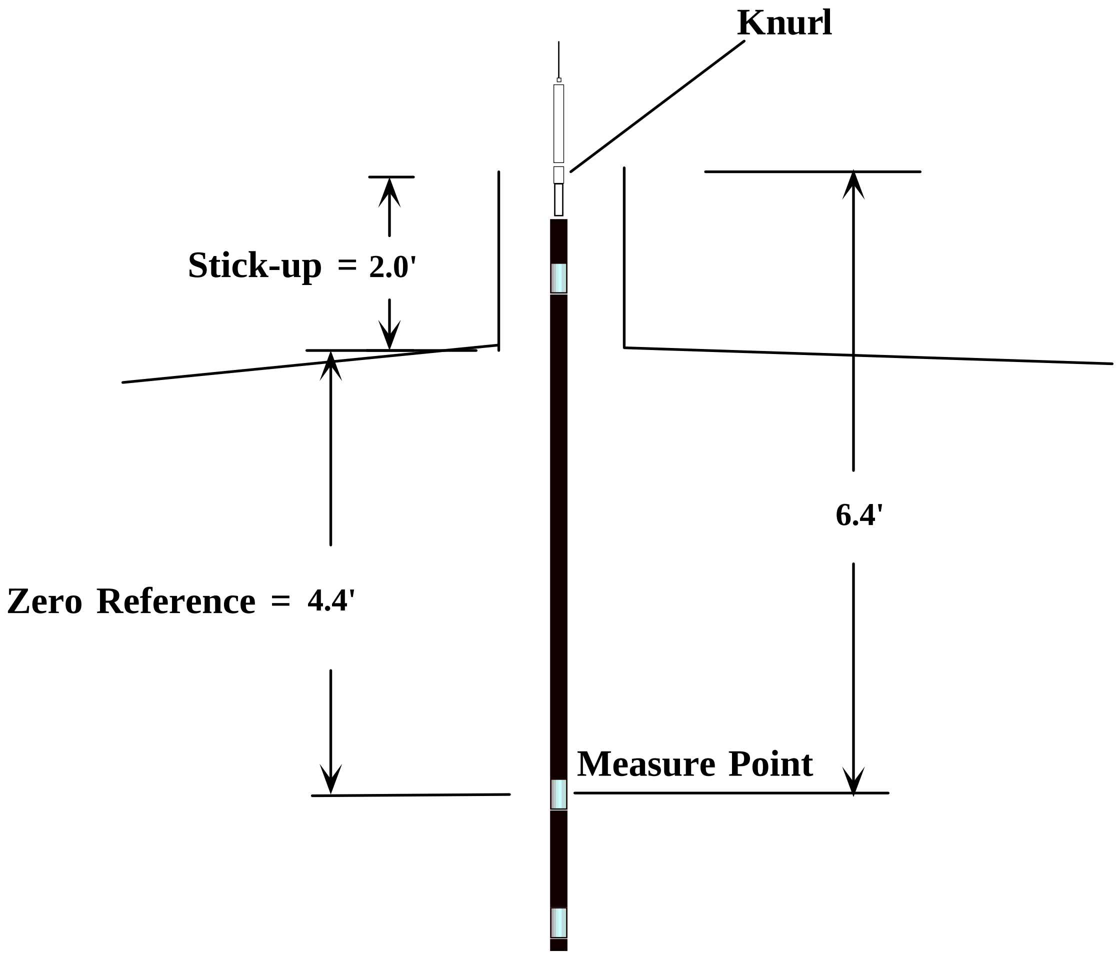
Depth Indicated in Acquisition Software _________________ Feet (Typically 100.0 ft)
_________________ Meters (if applicable)

*Measured Length ________________ Feet (or reported length of characteristic feature)
________________ Meters (if applicable)

Calculated Depth Error_______________ Feet per 100’
After Survey Depth Error_______________ Feet (Indicate if “+” or “-”)

Date:________________ Time:________________

*Length measured with approved steel measuring tape only. If using a designated borehole (with repeatable anomaly) the anomaly depth must be verified by an alternate means such as: 1) Driller’s strap (when comparing bottom of casing measurement), or 2) Depth verified by previously calibrated depth measurement system.


Knurl
Stick-up = 2.0'
6.4'
Zero Reference = 4.4'
Measure Point

Wireline Integrity Check

Date	
Time	
Location	
Well Designation	
Person Completing Form	

Type of Wireline: (Check One)   Length _______________ Feet

	Wireline Type	Conductor Resistance (Ohms/1000ft) @ 68° F
	1/8” Armored Single Conductor	25.3
	3/16” Armored Four Conductor	26.0
	3/16” Armored Single Conductor	12.5
	7/32” Armored Four Conductor	26.0
	¼” Armored Seven Conductor	26.0
	¼” Armored Coaxial Single Conductor	12.0
	¼” Armored Four Conductor	16.6

Line Resistance (Ohms)

Line 1________________

Line 2________________

Line 3________________

Line 4________________

Line 5________________

Line 6________________

Line 7________________

Armor________________

Cross Conductance (nS)							
	L1	L2	L3	L4	L5	L6	L7
L2		------	------	------	------	------	------
L3			------	------	------	------	------
L4				------	------	------	------
L5					------	------	------
L6						------	------
L7							------
Arm							

Appendix-7.5 "Logging Report" Form

COLOG
borehole geophysics / hydrophysics

LOGGING REPORT

Date ____________
Page ____________
Engineer ____________

Computer ________ Matrix / RG ________ Truck Number ________ Radioactive Sources ________

Well Name ________ Project ________ Client ________

Location ________
State County Qtr. Sec. Section Twp Rge P.M. Other

Elevation ________ Depth Reference ________ Witness ________

Drilling Co. ________

Driller TD ________ COLOG TD ________

Bit Size 1 ________ from ________ to ________ Casing Size 1 ________ from ________ to ________
2 ________ 2 ________
3 ________ 3 ________

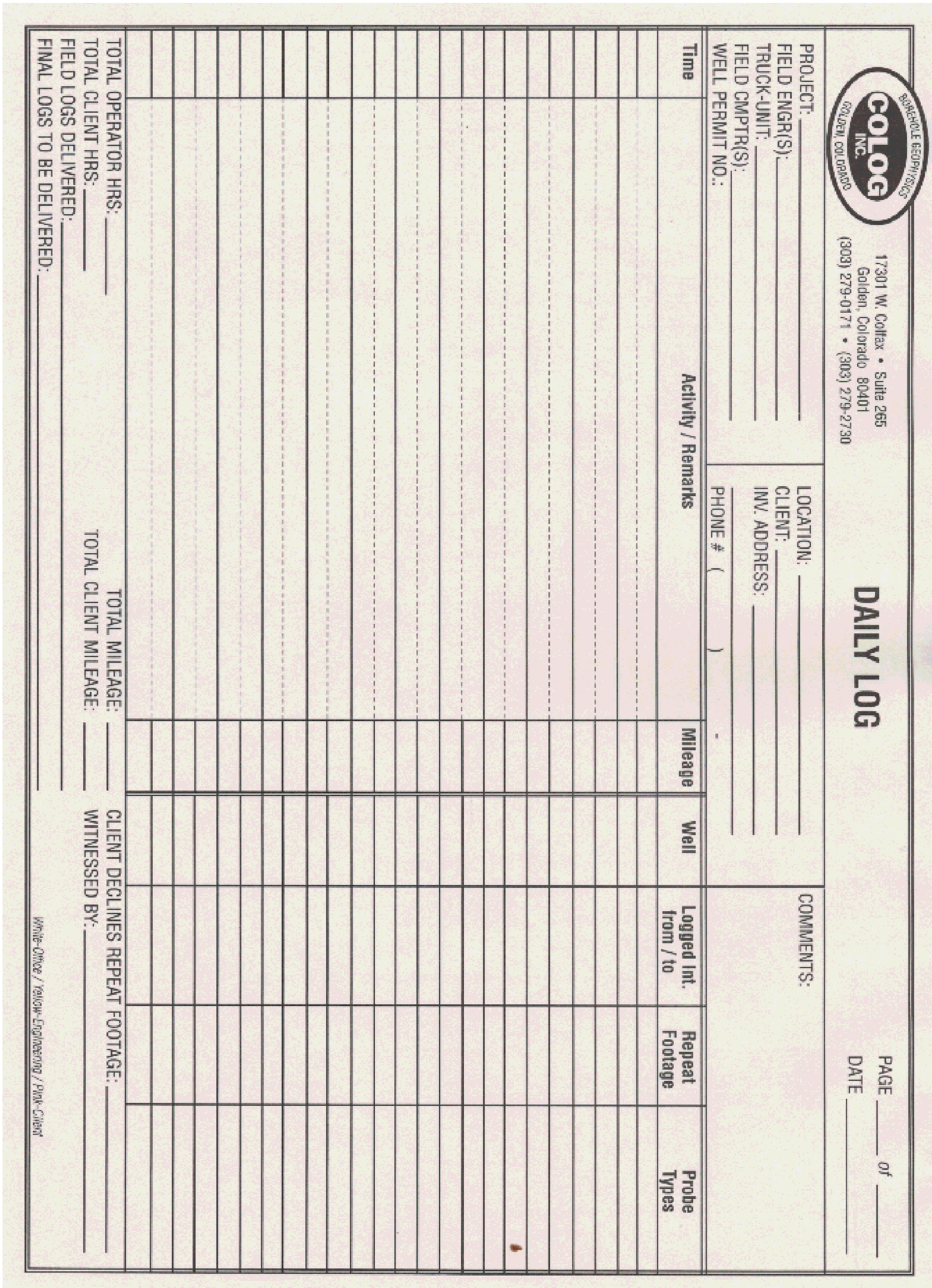
Comments and Information:

810 Quail Street, Suite E, Lakewood Colorado 80215
office.303.279.0171, fax.303.278.0135

Run No.	Tools	Speed ft/min Digitize Int.	Time Start Stop	Depth Start Stop	Depth Error	Digital File Name "tol" or "pb1" File Name	Remarks/Comments	Fluid Level
	Model SN Module							
	Model SN Module							
	Model SN Module							
	Model SN Module							
	Model SN Module							
	Model SN Module							
	Model SN Module							
	Model SN Module							
	Model SN Module							
	Model SN Module							
	Model SN Module							
	Model SN Module							
	Model SN Module							

Comments and Information

Appendix-7.6 “Daily Log” Form



BOREHOLE GEOPHYSICS
COLOG INC.
GOLDEN, COLORADO

17301 W. Colfax • Suite 265
Golden, Colorado 80401
(303) 279-0171 • (303) 279-2730

DAILY LOG

PAGE ____ of ____
DATE ____

PROJECT: ____
FIELD ENGR(S): ____
TRUCK-UNIT: ____
FIELD CMPTR(S): ____
WELL PERMIT NO.: ____

LOCATION: ____
CLIENT: ____
INV. ADDRESS: ____
PHONE # ( ) -

COMMENTS:

Time	Activity / Remarks	Mileage	Well	Logged Int. from / to	Repeat Footage	Probe Types

TOTAL OPERATOR HRS: ____
TOTAL CLIENT HRS: ____
FIELD LOGS DELIVERED: ____
FINAL LOGS TO BE DELIVERED: ____

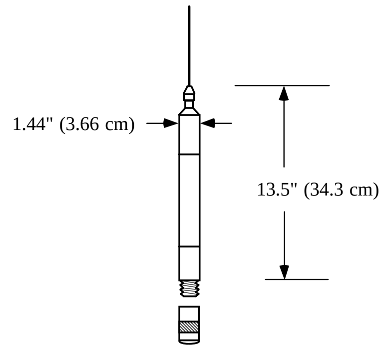
TOTAL MILEAGE: ____
TOTAL CLIENT MILEAGE: ____

CLIENT DECLINES REPEAT FOOTAGE: ____
WITNESSED BY: ____

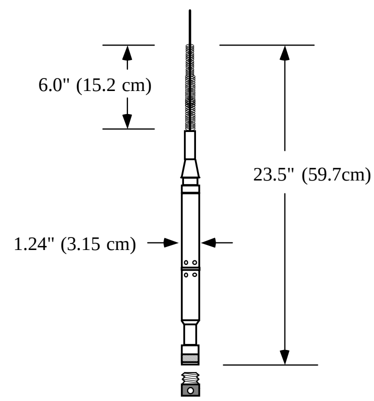
White-Office / Yellow-Engineering / Pink-Client

Appendix-7.7 Cablehead Diagrams

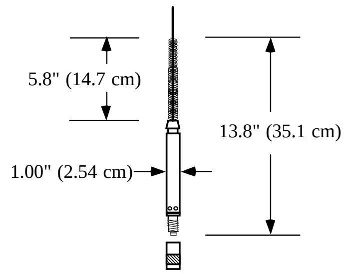
Laval Single Conductor
Cablehead



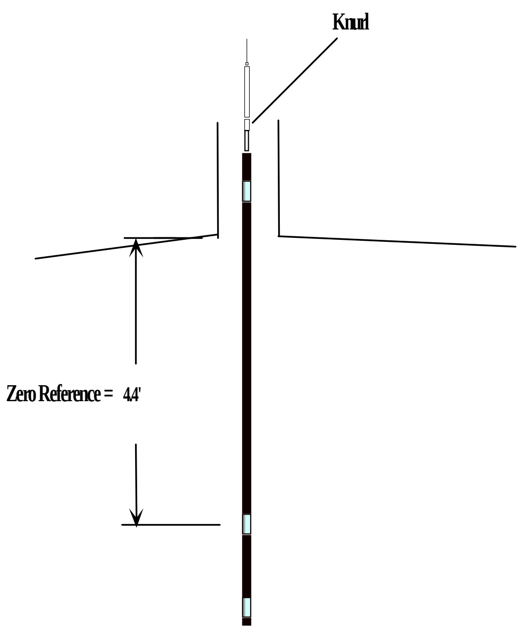
MSI Four Conductor
Cablehead



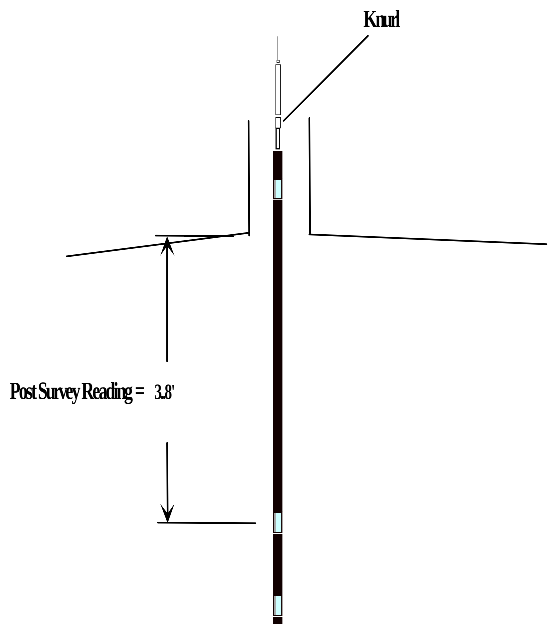
MSI Single Conductor
Cablehead



Pre-Log Zero



Post Log Zero



A.S.D.E. is determined by subtracting the zero reference depth (4.4’) from the depth indicated in the acquisition program (or depth counter) after the log survey is completed with the tool returned to the same reference point (3.8’). Therefore, in this example the A.S.D.E. is calculated as:

A.S.D.E. = (3.8 - 4.4) = -0.6 ft

Note: In most cases, the tool is zeroed at the measure point, so the zero reference depth is 0.0 ft. In this case, the A.S.D.E. is equivalent to whatever is indicated on the digital output (or counter) for depth with the tool back at the zero reference point.

Technical Procedure and Work Instructions for

FAC-40 Acoustic Televiewer

TP-3

Prepared by: David A. Renner Date: 7/6/15

Approved by: Nathan O. Davis Date: 7/6/15

CONTROL DOCUMENT No. TP3020300

Colog, Inc. Technical Procedure TP-3

Revision History

Revision Level	Issue Date	Change Summary
0.00	3/10/97	New procedure.
1.00	6/17/97	Changes to original draft.
1.10	7/9/97	Minor grammatical changes, clarification of records to be provided
1.11	3/12/98	Minor grammatical changes, added copyright protection.
1.20	6/21/99	Included revisions to incorporate the purchase of COLOG, Inc. by Layne GeoSciences, Inc.
1.21	2/3/00	Include revisions for name change Layne GeoSciences, Inc. to Layne Christensen Company
1.30	7/6/15	Included revisions to incorporate the sale of the COLOG division of Layne Christensen Company to Colog, Inc.

Table of Contents

1.0 SCOPE

1.1 Purpose

1.1.1 This procedure provides instructions for performing FAC-40 Acoustic Televiewer (ATV) measurements to assure the accuracy, validity, and applicability of the methods used.

1.1.2 This procedure further describes the components of FAC-40 logging, the principles and limits of the methods used, the methods used for calibration and performance verification of the equipment, and the requirements for data acceptance and for documentation.

1.1.3 This procedure includes by reference those sections of TP-1 which are common to all measurements.

1.1.4 In applying this procedure to the FAC-40 measurement, the requirements of this procedure shall supersede those stipulated in TP-1.

1.2 Applicability

1.2.1 This procedure applies to all personnel who perform work referred to in paragraph 1.1.

1.2.2 This procedure applies to ATV data acquisition using the FAC-40 Acoustic Televiewer.

1.2.3 All data derived from this procedure, and any equipment calibrations or re-calibrations that may be required shall be in accordance with this technical procedure. Deviation from these procedures shall be permitted only under the conditions set forth in Section 6.3 of TP-1.

2.0 REFERENCES

2.1 Keys, W. Scott, and MacCary, L.M., Application of Borehole Geophysics to Water-Resources Investigations: USGS, Techniques of Water-Resources Investigations, Book 2, Chapter E1.

2.2 Hearst, J.R., and Nelson, P.H., Well Logging for Physical Properties, McGraw Hill, 1985.

2.3 Standard Guide for Planning and Conducting Borehole Geophysical Logging, ASTM Designation D 5753-95, October, 1995.

2.4 SPWLA Reprint Series, Borehole Imaging, 1990.

2.5 COLOG, Inc. FAC-40 ATV Data Acquisition Procedures, 1997.

2.6 Rockware, Inc. ROSE™ and ROCKWORKS™/STEREO software instruction manuals, 1991.

2.7 Advanced Logic Technology (ALT), FAC-40, The New Slimhole Televiewer operations manual, 1996.

2.8 Advanced Logic Technology (ALT), WELLCAD for Windows software instruction manual, 1997.

3.0 DEFINITIONS

Definitions shall be in accordance with ASTM D 5753-95. In addition, definitions common to all logging procedures are provided in TP-1.

3.1 Facsimile 40 (FAC-40) downhole probe

The FAC-40 Acoustic Televiewer (ATV) utilizes a fixed transducer and a variable speed, rotating reflective surface which measures variations in the acoustic properties (Amplitude and Travel Time) of the borehole wall, and transmits the digital information uphole (Appendix 7.1).

3.2 Surface recording equipment

The surface panel mounted in the logging truck provides DC power to the probe, which is otherwise entirely self-contained and runs independently of the surface system. The computer receives the digital output from the probe along with orienting pulses and processes them for recording and real-time display.

3.3 3-axis magnetometer orientation

The downhole probe also contains a 3-axis magnetometer which provides an orienting pulse at a known azimuth with respect to magnetic North, and a reference mark for use in magnetically active materials.

3.4 Raw Data

Although the "real-time" display of the images on the computer screen can be oriented to magnetic North, the raw data from the probe are recorded in an "non-oriented" state. Orientation of the raw data is accomplished subsequent to the data acquisition during processing.

3.5 Processed Data

The processed data is obtained by importing the raw data into the processing software "WellCAD™". During this process, the raw data is oriented to magnetic North using the various output vectors from the three-axis magnetometer, along with the known offset between the position of the magnetometer and the tool reference. The data can then be re-displayed and stored so as to provide an image for interpretation which represents the borehole as a rectangular image with the left-hand margin aligned with magnetic North determined by the 3-axis magnetometer. Vertical position in the borehole varies along the "y axis" of the image, and orientation varies along the "x axis". An example is shown in Appendix 7.2.

3.6 Personnel

Personnel are as defined in TP-1.

3.7 Colog, Inc.

Colog, Inc. located in Lakewood, CO, is one of the leading providers of FAC-40 ATV services in the U.S.

4.0 REQUIREMENTS

4.1 Prerequisites

In addition to the prerequisites stipulated in TP-1:

4.1.1 The borehole shall be fluid-filled with either water or light mud. Heavier mud may diminish the amplitude of the acoustic signal particularly in larger holes.

4.1.2 The borehole shall be clear of restrictions which prevent entry of the tool (including centralizers).

4.2 Tools, Material, Equipment

The FAC-40 ATV provides oriented digital acoustic images of both the 1st arrival Amplitude as well as the Travel Time. It features a variable speed reflective surface, adjustable scan rate and automatic gain control for superior horizontal and vertical resolution in hole sizes ranging from 46 to 400 mm depending on mud conditions. The digital data is transmitted from the probe to the surface on the logging cable. The "real-time"amplitude and travel time images are displayed on a computer monitor in the logging truck (similar to Figure 7.2). The raw log data is stored on the computer's hard disk until it is backed up onto a storage media.

The FAC-40 ATV collects oriented "rings" of data composed of either 72, 144 or 288 amplitude and travel time values in each ring depending on the sample rate selected (typically 144). The rings are then stacked vertically (typically every centimeter) to produce an image of the well as if it were sliced along magnetic North and laid flat. This digital image is displayed on the computer monitor, and the data values are recorded on the computer's hard disk.

4.2.1 Colog, Inc. utilizes the FAC-40 ATV manufactured by Advanced Logic Technology (ALT) sarl of Luxembourg.

4.2.2 The FAC-40 may be run on either coaxial logging cable, or armored single or multi-conductor steel wireline.

4.2.3 Recording Equipment: The raw data shall be recorded on the acquisition computer's hard drive.

The raw data recorded in the field may be processed using the "WellCAD™" software developed by ALT, sarl. Both the raw and processed data shall be archived on suitable storage media.

4.2.4 Tool stand to facilitate assembly and breakdown of the probe.

4.2.5 Sprayer and a clean water supply to clean drilling fluid from tool after use.

4.2.6 ATV centralizers.

4.2.7 Calibration Apparatus (Appendix 7.3)

The calibration apparatus consists of an aluminum cylinder large enough for the FAC-40 ATV probe to fit inside, enclosed on one end. A smaller diameter, half cylinder sleeve, fits inside the outer cylinder, resting in a circular groove cut into the base of the apparatus. The top of the sleeve is marked with "N" , "W" and "S" which are to be matched up with similar markings on the outer cylinder (see Appendix 7.3). A circular notch is cut into the center of the base which the probe will sit in during the calibration. two semi-circular caps, with notches cut for the probe, will hold the probe centered vertically inside the calibration apparatus.

4.2.8 Brunton compass or equivalent for orientation of calibration apparatus.

4.2.9 FAC-40 ATV calibration forms and operating procedures.

4.2.10 The FAC-40 probe shall be calibrated for the following purposes:

1) To verify (and re-orient if necessary) the stability of the 3-axis magnetometer used to provide image orientation.

2) To provide reference diameter standards with which to convert travel time values to acoustic caliper measurements.

4.2.11 Calibration Procedure

Calibration of the magnetometer shall be performed under controlled conditions in a laboratory when calibration checks indicate a problem or after probe repair.

Calibrations shall be performed before leaving the home office for the logging location.

In the field, the probe shall be calibrated prior to logging and the calibration shall be checked following logging every borehole.

4.2.11.1 Set up the calibration apparatus vertically with a minimum of two feet lateral clearance from any magnetic objects. Use a Brunton compass (or equivalent) to orient the North and South reference marks on the top of the calibration tube to magnetic North and South (ensure that the inner sleeve is aligned properly with the outer tube).

4.2.11.2 Attach the FAC-40 tool to the cable.

4.2.11.3 Fill the calibration apparatus with water (or sample fluid from the hole to be logged).

4.2.11.4 Place the tool vertically in the calibration apparatus and insert the caps to hold the probe centered.

4.2.11.5 Set up the “ALTLogger” acquisition program to record a data file as described in Reference 2.5. Set up the image and caliper displays to “Orient to North”.

4.2.11.6 Record the calibration.

Record a data file on time drive as described in Reference 2.5.

4.2.11.7 Check proper image orientation. The sleeve should be apparent as a lighter (higher reflectivity) image on the S-W-N half of the amplitude image on the computer monitor. The caliper display should also indicate the same relative position (S-W-N) for the sleeve which should show a faster travel time than the outer cylinder.

4.2.11.8 Complete the “Pre-Log” portion of the “FAC-40 ATV Checkout/Calibration” form (Appendix 7.4)

4.2.12 Post-Log Calibration Check Procedures

A calibration check is performed after the log has been completed to verify that no change in system performance has occurred during logging.

4.2.13 Calibration Records

Calibration data shall be recorded on the form specified for both the pre-log calibration and the post-log check. These shall be performed prior to and at the completion of “continuous” logging operations for a particular well. The calibration forms shall include the probe identification number, well location, date and time calibration was performed, person executing calibration procedure, and any pertinent observations.

4.3 Precautions and Limits

4.3.1 The FAC-40 ATV log shall be run in an uncased hole unless the condition of casing is to be investigated. When logging in casing, steel casing may necessitate turning off the 3-axis magnetometer resulting in non-oriented images.

4.3.2 The quality of the image depends on the acoustic properties of the fluid in the borehole and the condition of the borehole wall.

4.3.3 The image is interpreted as if the tool is perfectly centralized. If the tool is eccentered, the geometry of the observed features may be distorted.

4.3.4 During analysis, the tool axis is assumed to be aligned with the axis of the borehole.

4.3.5 The operational temperature and pressure limits for the FAC-40 probe provided by the manufacturer should be adhered to while running the log. The maximum operating pressure is approximately 4650 PSI (240 bars). The practical operational temperature range is from 0 to 70°C (32 to 158°F).

4.3.6 The recommended minimum borehole diameter is 46 mm (1.81”). The recommended maximum diameter is 400 mm (15.75”). In ideal circumstances, the FAC-40 can be run successfully in holes as large as 432 mm (17”).

4.3.7 Washout zones will adversely affect the resolution of the acoustic image.

4.3.8 Bridges or constrictions in the borehole diameter will make it impossible to lower the probe into the borehole and difficult to retrieve the probe.

4.3.10 The magnetometer is approximately 2 feet above the transducer assembly. Thus, if the borehole is cased with magnetically active material, the image immediately below casing will be more difficult to orient.

4.3.11 The log is generally recorded with the tool moving up the borehole, but can be logged downward if necessary.

4.4 Acceptance Criteria

This log shall be accepted for use based on the expectation that the results will be interpreted quantitatively.

The following acceptance criteria shall be evaluated using the images generated on the computer monitor during data acquisition.

4.4.1 The orientation of the pre- and post-logging calibration images shall be within 5° of magnetic North.

4.4.2 The orientation of features on the repeat section shall be within 5° of their orientation recorded during the main logging run.

4.4.3 After Survey Depth Error (ASDE) shall be within required tolerances as specified in TP-1.

5.0 DETAILED PROCEDURE

The real-time FAC-40 images show the borehole wall as if it were split vertically and laid flat. Vertical fractures appear as vertical straight lines, while bedding and fractures dipping between vertical and near horizontal appear as sinusoidal traces.

The FAC-40 images can be used:

- To evaluate the stratigraphic, structural, diagenetic, weathering, textural and mineralogical features detectable in the borehole wall.

- To locate and orient fractures and bedding planes to aid in the analysis and interpretation of in situ physical and hydrologic properties.

- To locate and orient any stress-induced wellbore failure (breakouts) for determination of the orientation and magnitude of in situ stresses.

- Casing integrity and/or completion evaluation.

FAC-40 ATV logs are typically run as one of a suite of logs during a single visit to a well site. Procedures prior to and upon arrival as described here pertain only to the specific requirements of the FAC-40. Where they do not conflict with the procedures detailed here, all of the procedures specified in TP-1 shall also be adhered to.

5.1 Prior to mobilization

In addition to those procedures detailed in TP-1.

5.1.1 Select the appropriate centralizers for use in the well.

5.1.2 Assure that the logging truck has a sufficient cable length to perform the log.

5.2 On arrival

No added procedures are necessary beyond those detailed in TP-1.

5.3 During Logging

5.3.1 The FAC-40 ATV shall be run centralized in the borehole. Adjust the probe centralizer for optimal centralization in the interval to be logged.

5.3.2 Visually inspect all connections and screws on the logging probe to be sure they are tight.

5.3.3 Attach the probe to the logging cable and turn power to the tool on.

5.3.4 Perform a pre-log calibration.

5.3.5 Set the software depth counter to read zero when probe measuring point is depth referenced to the measurement datum (land surface, top of casing, etc.). The depth zero should be set with tension on the wireline similar to that expected while logging, to prevent slack in the cable from biasing the datum.

5.3.6 Maintain a record of depth measurements according to procedures specified in TP-1.

5.3.7 Lower the probe to the bottom of the interval to be logged. Monitor the tool's response, and adjust settings for recording as stipulated in Reference 2.5.

5.3.8 Begin logging up at appropriate speed for the sample rate selected (Reference 2.5). Typically, a 50 foot repeat section is run first, followed by the main log. However, the repeat may be run after the main log in order to identify a more interesting interval to repeat. Correct tool operation is verified by observing the Amplitude, Travel Time and Caliper images on the computer monitor. Note the orientation of key features to use to verify the repeatability during the 2nd run.

5.3.9 If logging needs to be stopped for any reason a brief overlap interval (typically 10 feet) should be recorded, to ensure that no data are missed.

5.3.10 After completion of the 1st logging run, lower the probe back down to the bottom of the interval to be logged. Verify that the orientation of features is within 5° between the repeat and main logs. At the completion of each run, the data file should be played back to verify that it was recorded properly.

5.3.11 After completion (and acceptance) of both a repeat section and a main run, all of the data (including the pre-log calibration) should be backed up onto a storage media.

5.3.12 Unless otherwise noted all azimuth orientation data shall be recorded on magnetic North orientation. Field plots unless otherwise noted shall be based upon magnetic North.

5.3.13 Determine after survey depth error.

5.3.14 Record a Post-log calibration check, and back up the file with the log data.

5.4 Prior to departure

In addition to the requirements of TP-1:

5.4.1 A black and white paper copy of both the repeat and main logging runs which includes the Travel Time and Amplitude plots shall be provided as detailed in Reference 2.5.

5.5 After return to Colog's Lakewood office:

5.5.1 The digital backed up data shall be uploaded to Colog's computer network for additional processing and interpretation prior to archiving.

6.0 RECORDS

Records shall be provided as detailed in TP-1. In addition the following records shall be provided upon client's request:

6.1 A black and white paper copy of the FAC-40 ATV log (see 5.4.1). Additionally, FAC-40 ATV data may be processed with interactive software to provide a variety of data presentations depending on project objectives.

6.2 Data Deliverables

Digital data may be provided in raw (proprietary manufacturer's format), ASCII or WellCAD™ format.

7.0 APPENDICES

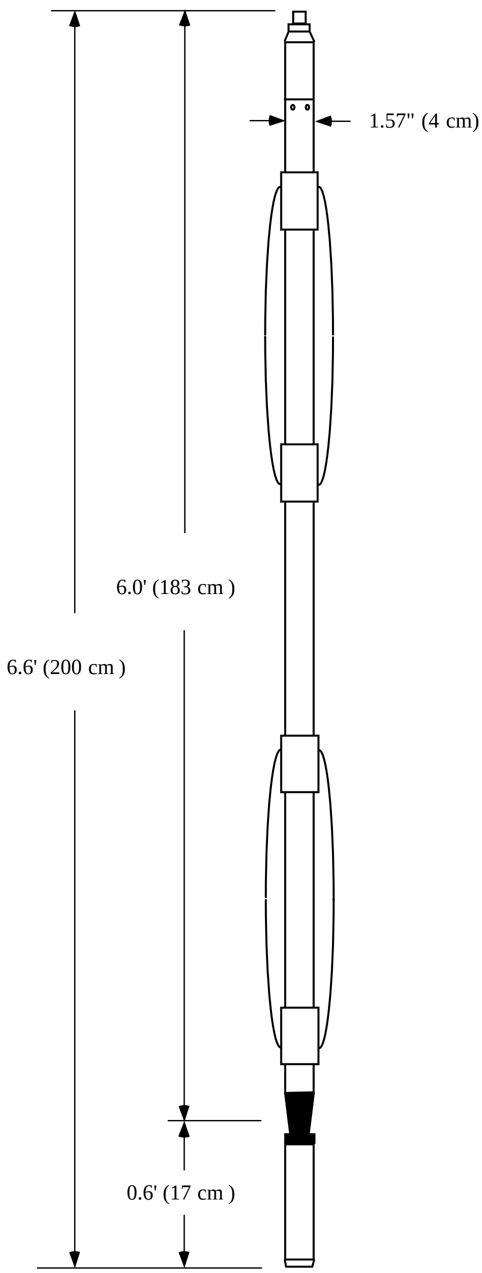
7.1 FAC-40 ATV Tool diagram.

7.2 Example FAC-40 Image display (Travel Time and Amplitude).

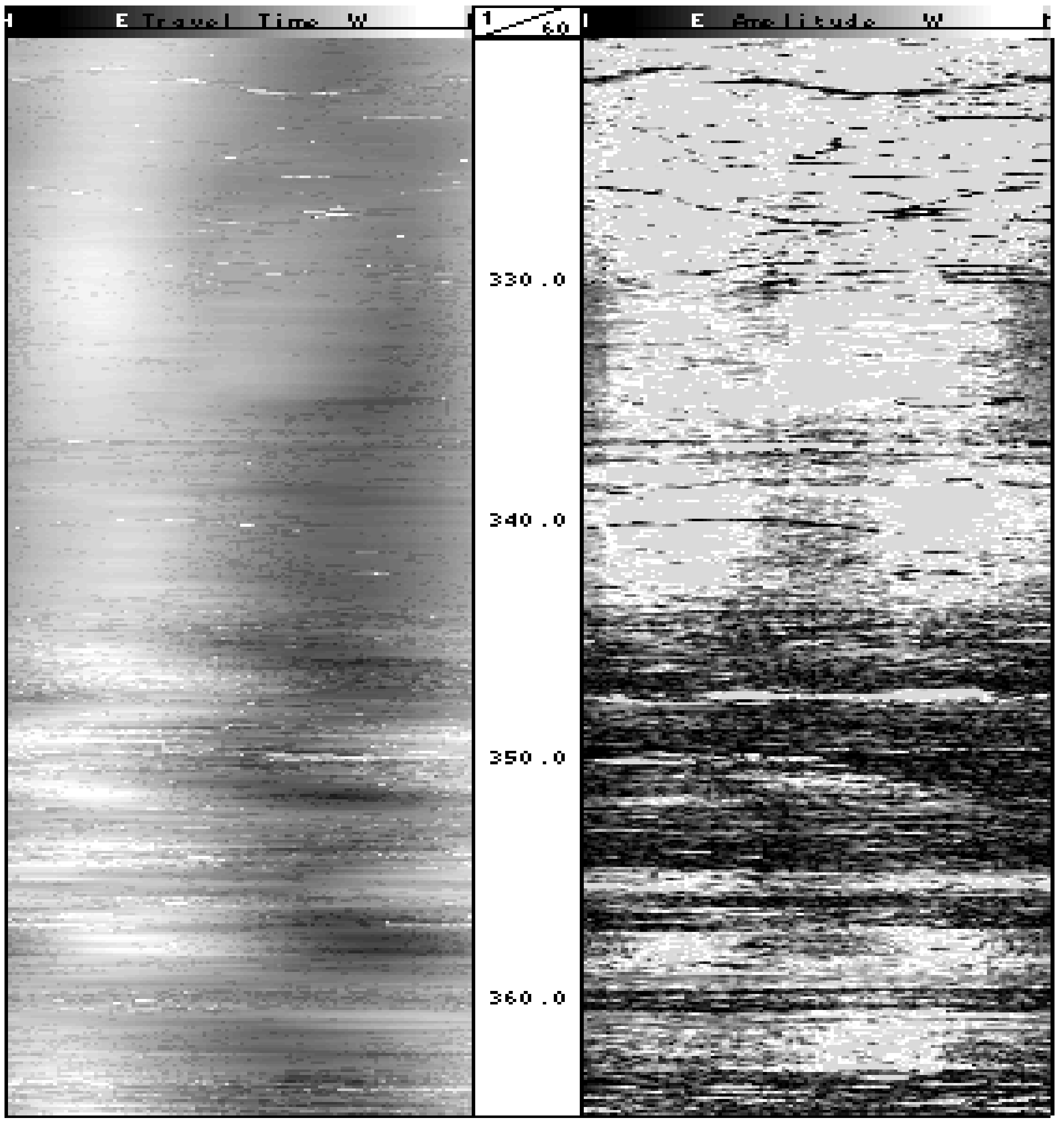
7.3 Calibration Apparatus.

7.4 "FAC-40 ATV Calibration/Checkout" Form.

Facimile 40 (FAC-40) Acoustic Televiewer

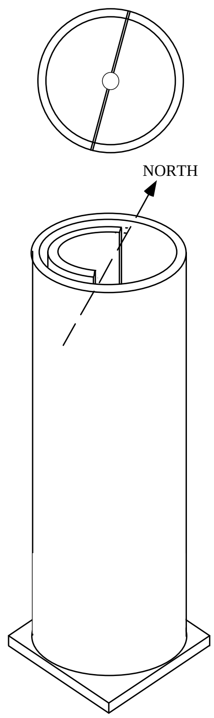


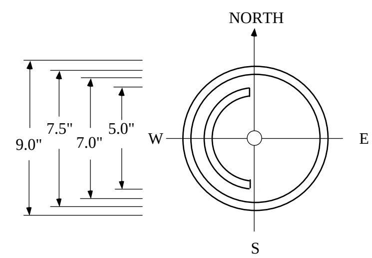
Appendix 7.1 FAC-40 ATV Tool Diagram



Appendix 7.2 Example FAC-40 Image Display

Appendix 7.3 FAC-40 Calibration Apparatus





Fac-40 ATV
Checkout/Calibration

Engineer:____________________ Location or Well Name:___________________ Truck/Unit No:___________

Probe Serial No:___________________

Pre-Log Calibration:

Date:_______________ Time:_______________

Calibration Filename:__________________

Post-Log Check:

Date:_______________ Time:_______________

Calibration Filename:__________________

Calibration Standards:

1.) Calibration Apparatus oriented to North and South, using a Brunton compass, set clear of metal objects.

Technical Procedure and Work Instructions for

Normal Resistivity

TP-4

Prepared by: David A. Renner Date: 7/6/15

Approved by: Nathan O. Davis Date: 7/6/15

CONTROL DOCUMENT No. **TP4062308**

Colog, Inc. Technical Procedure TP-4

Revision History

Revision Level	Issue Date	Change Summary
0.00	3/10/97	New procedure.
1.00	7/15/97	Changes to original draft, renamed to TP-4.
1.10	7/28/97	Added instructions for measuring mud resistivity (Rm).
1.11	8/5/97	Corrections to calibration procedures.
1.12	3/12/98	Minor grammatical changes, added copyright protection.
1.20	6/21/99	Included revisions to incorporate the purchase of COLOG, Inc. by Layne GeoSciences, Inc.
1.21	2/3/00	Include revisions for name change Layne GeoSciences, Inc. to Layne Christensen Company
1.22	6/23/08	**Incorporate MSI PEA probe & probe from Robertson Geologging**
1.30	7/6/15	Included revisions to incorporate the sale of the COLOG division of Layne Christensen Company to Colog, Inc.

Table of Contents

1.0 SCOPE

1.1 Purpose

1.1.1 This procedure provides instructions for performing normal resistivity logging measurements, including the measurements of spontaneous potential and single point resistanc, to assure the accuracy, validity, and applicability of the methods used.

1.1.2 This procedure further describes the components of normal resistivity logging probes, the principles and limits of the methods used, the methods used for calibration and performance verification of the equipment, and the requirements for data acceptance and for documentation.

1.1.3 This procedure includes, by reference, those sections of TP-1 which are common to all measurements.

1.1.4 In applying this procedure to electrical logging measurement, the requirements of this procedure shall supersede those stipulated in TP-1.

1.2 Applicability

1.2.1 This procedure applies to electrical properties measured using normal resistivity probes.

1.2.2 This procedure applies to all personnel who perform work referred to in paragraph 1.1.

1.2.3 All data derived from this procedure, and any equipment calibrations or recalibrations that may be required, shall be in accordance with this technical procedure. Deviation from these procedures shall be permitted only under the conditions set forth in Section 6.3 of TP-1.

2.0 REFERENCES

2.1 Keys, W. Scott, and MacCary, L.M., Application of Borehole Geophysics to Water-Resources Investigations: USGS, Techniques of Water-Resources Investigations, Book 2, Chapter E1.

2.2 Hearst, J.R., and Nelson, P.H., Well Logging for Physical Properties, McGraw Hill, 1985.

2.3 Standard Guide for Planning and Conducting Borehole Geophysical Logging, ASTM Designation D 5753-95, October, 1995.

3.0 DEFINITIONS

Definitions shall be in accordance with ASTM D 5753-95. In addition, definitions common to all logging procedures are provided in TP-1.

3.1 Electrical properties logging involves measuring the resistivity of the formation surrounding a borehole, a single point resistance (SPR), and a spontaneous potential (SP) difference, as a function of depth in the hole.

3.2 Resistivity is defined as the ratio of voltage to current per unit distance per unit area. The units are typically Ohm-meters. Conductivity is the inverse of resistivity.

3.3 Single point resistance is the ratio of voltage to current in Ohms.

3.4 Spontaneous potential (SP) is a passive measurement of the voltage potential between a point on the logging probe and a surface reference electrode. The source of this voltage potential is the sum of a number of effects.

3.5 Normal resistivity is a technique whereby formation resistivity is measured by delivering current to the formation directly and measuring the voltage difference between pairs of electrodes. This technique requires a direct electrical connection between the formation and the electrodes. Thus, the borehole must be filled with electrically conductive fluid, typically water or drilling mud.

3.6 Recording equipment - Data from the probe is sent to the surface as electrical signals which are translated into engineering units and recorded, along with depth, to produce an electrical log of the hole. The log data is recorded digitally as engineering values and displayed, while the log is being run.

3.7 Personnel

Personnel are as defined in TP-1.

4.0 REQUIREMENTS

4.1 Prerequisites

4.1.1 Normal resistivity logs (including SP and SPR) require direct electrical coupling to the formation. Thus, the borehole to be logged must be open (uncased) and filled with a conductive fluid, typically water or drilling mud.

4.1.2 A section of insulated wireline (usually about 15-25 feet wrapped in electrical tape) is required above the logging probe in order to obtain accurate measurements.

4.2 Tools, Material, Equipment

4.2.1 Measurement apparatus

Colog, Inc. utilizes four probes to collect normal resistivity logs: A digital Mount Sopris Instruments (MSI) RABEPF (combination Gamma, 16-64” Normal, SP, SPR) powered by an MSI Unimod; an MSI analog RLP-4980 (Analog probe without a Gamma measurement), powered with an RLM or ELM module; an MSI 2PEA1000 mated with a 2PGA1000 (digital combination Gamma, 8”, 16”, 32” & 64” Normal, SP, SPR) powered by an MSI MGX II or MSI Matrix; and a Robertson Geologging (RG) model 25-056 Electric Log probe (digital combination Gamma, 16” & 64” Normal, SP, SPR), powered by an RG Micrologger-II. The RABEPF actually consists of two separate functions, an RABPF-4991 modem with Gamma detector (also contains the 64 inch normal electrode), and an EPF-4283 Normal Resistivity function. The digital combination probes derive all of their electrical measurements (except for the SP) from calibrated voltages at the Normal electrodes as well as a calibrated voltage and current at the Current electrode. The RLP probe is calibrated by simply forcing the probe to read precision resistance values (corrected for probe geometry) at two different points. Once calibrated, the responses of all probes are essentially identical.

4.2.2 Variable resistor calibration box.

4.2.3 Pre-project calibration procedure for the RABEPF

This procedure shall be performed before each project. The required tolerances are specified in 4.4.4.

The purpose of the pre-project calibration is to adjust conversion factors to force the probe output to read measurable values supplied by precision resistors (converted to resistivity by applying appropriate geometric factors) and a battery (used to calibrate SP voltage) in the calibration box.

4.2.3.1 Configure the RABEPF probe to do a voltage calibration using the calibration box, cables and digital voltmeters as shown in Appendix 7.2. If possible, determine the formation resistivities to be expected in the well. Set the Current Generator on the Unimod to the appropriate setting for the anticipated formation resistivity (for formation resistivities below 2000 Ohm-m use "High", above 2000 use "Low"). Set the probe type switch to "JLP".

4.2.3.2 ***Voltage Calibration*** - Set the cal box to 5 Ohms and turn the probe power "ON" **(*Warning: Always check to make sure that no one is handling the probe when power is turned on*)**. Let the probe warm up for about 10 minutes, then read the AC Voltage (mVAC) from the meter and enter this value as the "LValue" for the 16", 64" and Current Electrode Voltages. Then, force each of these channels to read this value. Switch the cal box to 500 Ohms, and repeat the procedure above to calibrate the "Rvalue for each voltage channel.

4.2.3.3 ***Current Calibration*** - Once the voltages are calibrated, the current channel cal values can be calculated from Ohm's law. Simply divide the "LValue" for the Current Electrode Voltage by 5 (voltage measured at 5 Ohms) and enter this as the "LValue" (be sure to convert units to mAAC) for the current channel. Divide the "Rvalue" of the Current Electrode Voltage by 500 and enter this as the "Rvalue" for the current channel.

Once the voltage and current channels are calibrated, confirm that the 16N and 64N (normal resistivities) and SPR (Single Point Resistance) are reading the correctly at various cal box settings. The SPR should read whatever resistance value is on the cal box, the 16N should read 5 times the value and the 64N should read 20 times the value.

4.2.3.4 ***SP Calibration*** - The SP is calibrated with a 9V battery inside the calibration box. With probe power still "ON", switch the SP setting on the cal box to (-) and change the Ohms setting to 100 to output a negative 100 mV. Use the voltmeter to measure the actual output from the box (ie. -99.8 mV). Enter this value into the "LValue" of the SP channel and then force the channel to read this value. Repeat the procedure with +100 mV, to calibrate the "Rvalue".

4.2.3.5 With the time sample rate at 1 second, record 5 separate calibration files for cal box settings at 0, 20, and 500 Ohms, and -100 and +100 mV, for a minimum of 30 seconds each. Each filename should include the probe type and serial number, while the extension will increment for each individual measurement. For example, if using EPF #1567, the first calibration file (cal box set at 0 Ohms) might be:

EPF1567.EA0

4.2.3.6 Complete the Pre-Project portion of the "Normal Resistivity Checkout/Calibration" form as specified on the form itself (example in Appendix 7.3).

4.2.4 Pre-Project calibration procedure for the RLP

4.2.4.1 Configure the RLP probe to do a calibration using the calibration box and cables as shown in Appendix 7.2 (no voltmeter readings are necessary).

4.2.4.2 Insert an RLM (or ELM) module in the NIM rack and if possible, determine the formation resistivities to be expected in the well. Set the Ohm-m/div setting on the front of the panel to the appropriate setting for the anticipated formation resistivity (20. Turn the probe power "ON". Set the cal box to 0 Ohm-m, and make sure the "Lcal" values for CH02 (16" normal), CH04 (64" normal) and DV87 (SPR) are all set to 0 and hit F3 for all three channels. Switch the cal box to 20 Ohms and make sure "Rcal" for CH02 is 100 and for CH04 is 400, then hit F4 to calibrate the 16 and 64" normal channels. Switch the cal box to 500 Ohms, change the "RCal" value for DV87 to 500 and hit F4 to calibrate the SPR. Calibrate the SPDir channel (CH05) at -100 and +100 mV as described earlier in the RABEPF section. Once the probe is calibrated, hit "F2" to save the new values into the "RLP.PB1" file within the well's sub-directory.

4.2.3.1 Record calibration files, and complete the "Pre-Project" portion of the "Normal Resistivity Checkout/Calibration" form as described earlier.

4.2.5 Pre-Project calibration Check for the 2PEA-2PGA combination

4.2.5.1 Configure the probe to do the check using the calibration box and cables according to the labels on the ports in the box.

4.2.5.2 When intending to log in formations between 0 and 250 Ohm-m, use the ports in the top row for the low end of the low range calibration check. Use the second row for the high end of the low range check.

When intending to log in formations between 0 and 2500 Ohm-m, use the ports in the second row for the low end of the high range calibration check. Use the lowest row for the high end of the high range check.

4.2.5.3 Record calibration files, and complete the “Pre-Project” portion of the “Normal Resistivity Checkout/Calibration” form as described earlier.

4.2.6 Pre-log calibration Check for the RG 25-056 Electric probe

This sonde measures real units downhole, so there is no calibration procedure to be followed for these channels.

For increased precision the values measured downhole are scaled for transmission to the surface. There is a fixed conversion between the sonde response and real units as follows:

Long / Short Normal Resistivity	: 5 per Ohm-m
Single Point Resistance	: 5 per Ohm
Spontaneous Potential	: 10 per milliVolt

Note that Spontaneous Potential can read positive or negative. The data format does not permit the transmission of negative numbers, so the count rate is biased in the following way:

Spontaneous Potential: 0 volts = 10,000 cps

4.2.7 Post-Project Calibration Check Procedure

The purpose of the post-project calibration check is to verify that no change in system performance has occurred during logging.

In performing the post-log calibration check, repeat the procedures for the pre-log calibration. Similar file names should be used for the post-log checks as were used for the pre-log calibrations.

Complete the “Post-Project” portion of the “Normal Resistivity Checkout/Calibration” form.

4.3 Precautions and Limits

4.3.1 Temperature and pressure limits are specified in the operations manuals of the specific logging probes.

4.3.2 The range within which a given device is accurate is different for the different measurement techniques. This range shall be specified for each device, and the appropriate device shall be selected for the borehole under investigation.

4.3.3 The properties of the borehole fluid influence the response of normal resistivity logs in what is commonly known as “Borehole Effects”. As the hole diameter increases or the fluid conductivity increases, these effects become more pronounced. These effects have been quantified, and log data may be corrected based on standard techniques.

4.3.4 The geometry of the logging probe, such as the positions of the current and measurement electrodes, of resistivity type probes affects the measurement values.

4.3.4.1 The ability of a given measurement to accurately measure resistivity across a thin bed is a function of the geometry and of the resistivity contrast and bed thickness.

4.3.4.2 The distance away from the borehole which influences a given measurement is a function of the geometry and the radial distribution of electrical properties.

4.3.5 The log should be recorded with the probe moving **up** the borehole, but measurements can also be made while lowering. In fact, in deep wells, it is suggested that data be recorded while running in the well, just in case hole conditions or probe problems prevent getting a good log in the up direction.

4.4 Acceptance Criteria

Normal resistivity and single-point resistance values shall be accepted for use based on the expectation that the results will be interpreted quantitatively.

SP shall be accepted based on the expectation that the results will be used qualitatively.

4.4.1 Repeat sections for all measurements shall be similar to the main log, such that features visible in each match in depth and in the value of the measured data.

4.4.2 Depths of features in the log shall agree with other logs, if run.

4.4.3 After Survey Depth Error (ASDE) shall be within required tolerances as specified in TP-1.

5.0 DETAILED PROCEDURE

Normal Resistivity logs are typically recorded at 0.1, 0.2, or 0.5 foot sample intervals. They are used to obtain information on the electrical properties of the hydrogeologic section including the soil, rock, and groundwater.

Normal Resistivity logs are typically run as one of a suite of logs during a single visit to a well site. Procedures prior to and upon arrival, as described here, pertain only to the specific requirements of Normal Resistivity logs. Where they do not conflict with the procedures detailed here, all of the procedures specified in TP-1 shall also be adhered to.

5.1 Normal Resistivity/SP/Single-point resistance

This type of electric probe is a simple Werner Array comprised of a current electrode, two measure electrodes spaced at 16 and 64 inches from the current electrode, and a surface electrode. The single point resistance (SPR) is derived from Ohm's law based on voltage changes between the current electrode and the surface electrode while maintaining a constant current. Spontaneous potential (SP) is a passive voltage potential between the current electrode and the surface electrode. The normal resistivities reflect the voltage drop from the current electrode to the respective measure electrodes spaced at 16 and 64 inches (plus 8 and 32 inch electrodes on the 2PEA-1000) from the current electrode. This voltage drop is converted to resistivity based on Ohm's law which assumes a spherically shaped electrical field between the current electrode and the measure electrodes.

5.2 Prior to arrival

No added procedures are necessary beyond those detailed in TP-1.

5.3 On arrival

Place the surface electrode in a location that provides a definite electrical connection to the earth, ideally as far from the logging unit as possible. It may be necessary to add water to the dry ground to facilitate the connection.

5.4 While Logging

5.4.1 Attach the logging probe to the wireline; if necessary, use electrical tape to wrap about 20 feet of the wireline to isolate it from the cable head.

5.4.2 Perform a pre-log functionality check.

The purpose of the pre-log functionality check is to quickly verify that the probe is functioning in the same manner as during its pre-project calibration. The pre-log check also provides data for comparison to a post-log validation check.

5.4.3 Set wireline depth zero at the connection between the probe top and the cable head. The depth zero should be taken with tension on the wireline similar to that expected while logging, to prevent slack in the cable from biasing the datum.

5.4.4 Lower the probe to the bottom of the interval to be logged.

5.4.5 Begin logging up at a rate not to exceed: 20 feet per minute for the RABEPF or 2PGA-2PEA probes with gamma measurements; 40 feet per minute for electric-only probes; or for the RG 25-056 3ft/min for 0.1’ sampling, 6 ft/min for 0.2’ sampling, or 15ft/min for 0.5’ sampling (this probe samples every 2 seconds, regardless of the specified depth sampling rate).

5.4.6 Typically, a 50 foot repeat section is run first, followed by the main log. However, the repeat section may be run after the main log in order to identify a more interesting interval to repeat.

5.4.7 After completion of the first run, lower the probe back down to the bottom of the interval to be logged. Verify that the log response between the two runs is repeatable.

5.4.8 Upon completion of the second (or last) run, all of the data (including the pre-log check) should be backed up onto a portable storage media.

5.4.9 Return probe to the surface and determine the A.S.D.E.

5.4.10 Perform a post-log check, and back up the file with the log data.

5.5 Prior to departure - no additional requirements beyond TP-1.

6.0 RECORDS

Records shall be provided as detailed in TP-1.

6.1 Data Deliverables

Data deliverables shall be as described in TP-1

7.0 APPENDICES

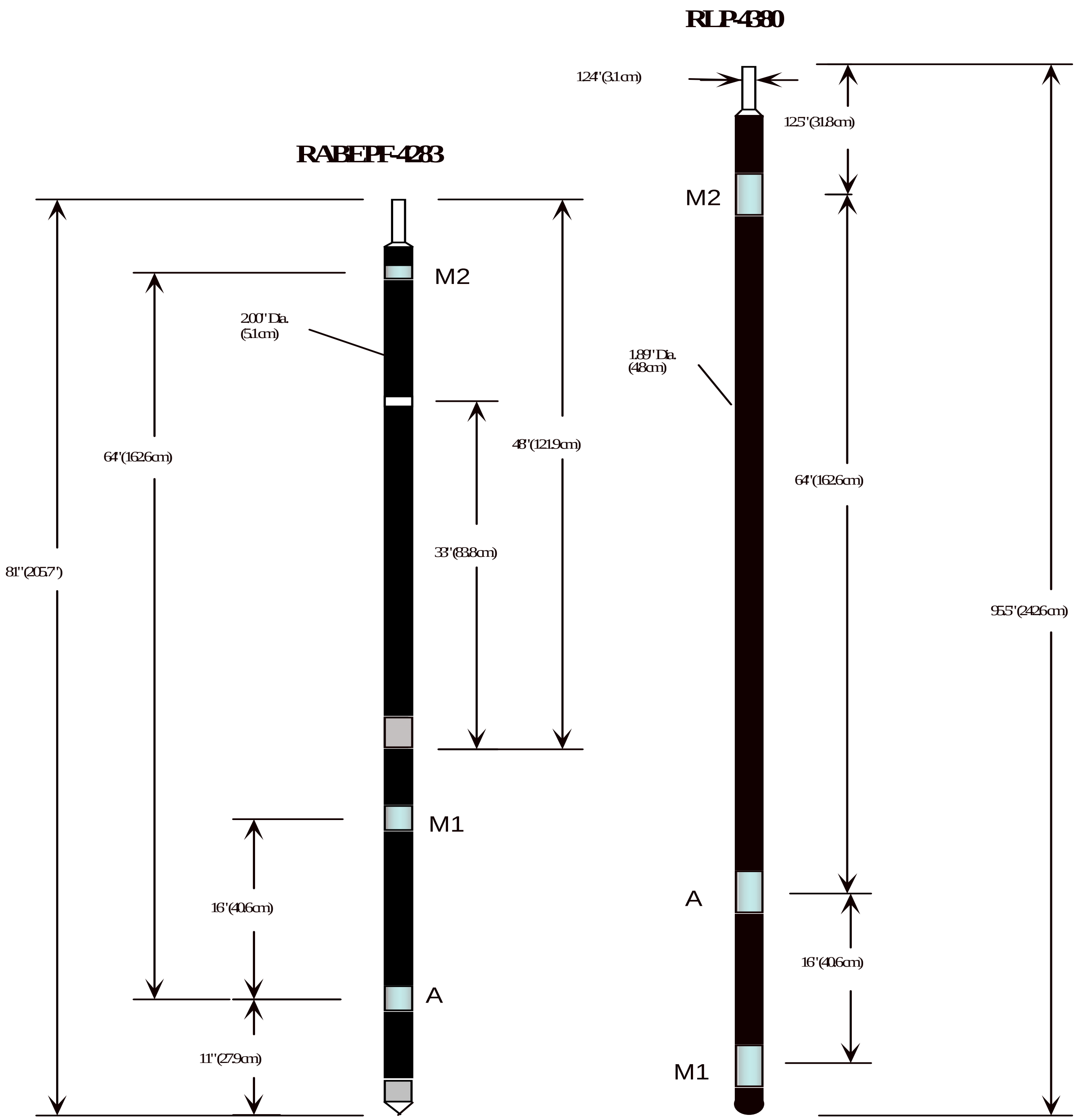
7.1 Normal Resistivity Probe Diagrams

7.2 Calibration Apparatus

7.3 "Normal Resistivity Checkout/Calibration" Forms

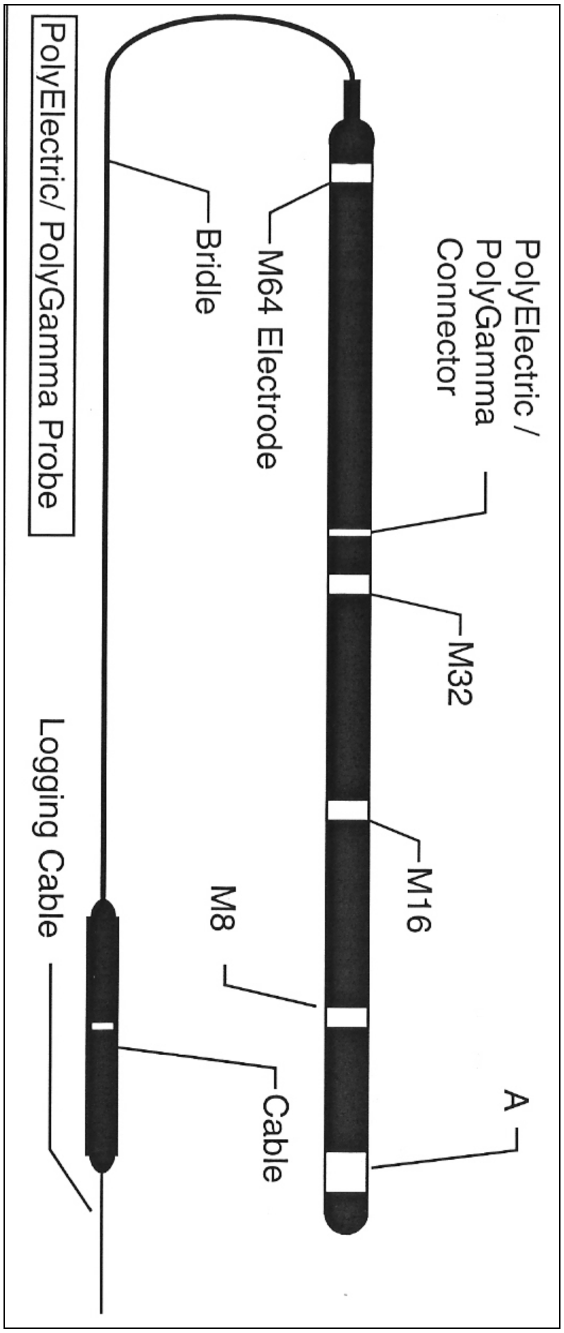
Appendix 7.1

Normal Resistivity Probes

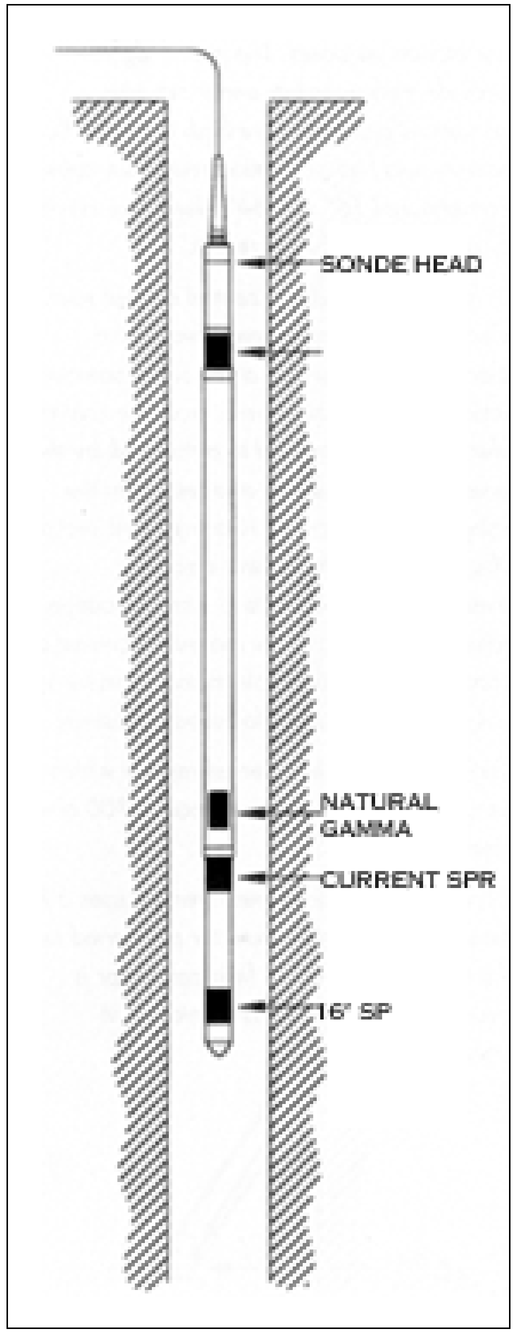


Normal Resistivity Probes - Continued

2PEA-2PGA



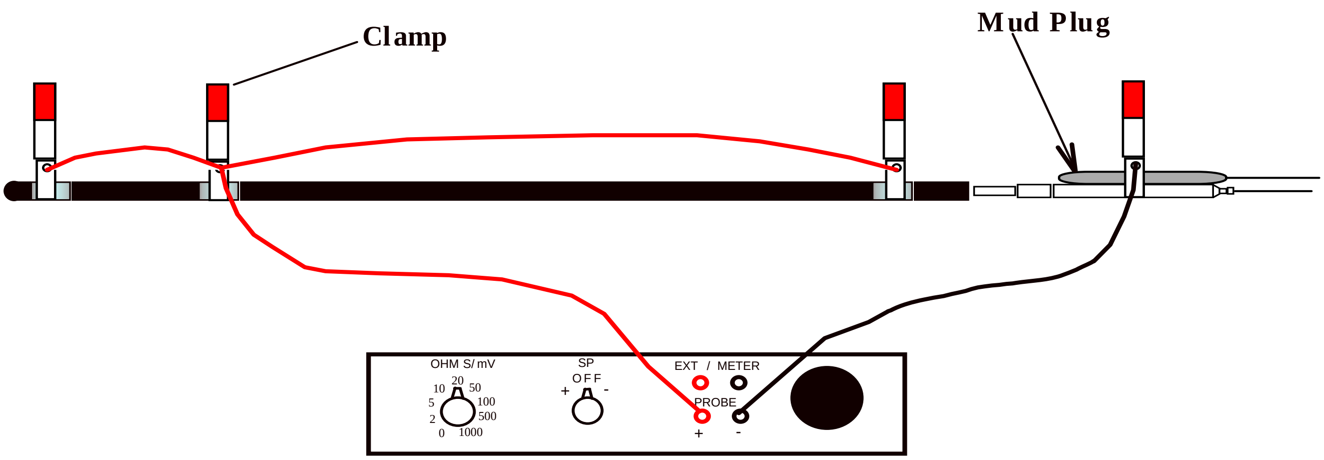
RG 25-056



Appendix 7.2

Calibration Apparatus and Set-up

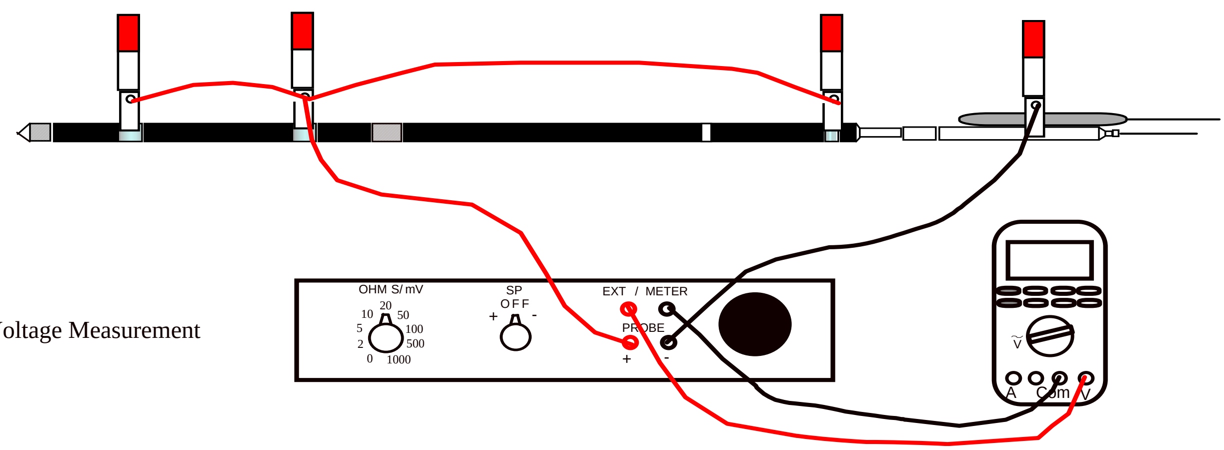
RLP Set-up



Calibrat ion Box

RAB EPF Set- up

Voltage Measurement



The RABEPF requires AC voltage and current measurements. Take the voltage measurement as shown, then put the multi-meter in line with the probe to measure the current (plug the “Probe +” lead from the probe into “mA” on the Fluke then from “COM” on the multi-meter back to the “Probe +” connection on the calibration box, and switch the knob to read AC milliamps).

Appendix 7.3

borehole geophysics / hydrophysics

Normal Resistivity
(RLP, RABEPF, or RG 25-056)
Checkout/Calibration

Engineer:____________________ Location or Well Name:___________________ Unit No:___________

Probe Type:___________________(RLP, RABEPF, or RG 25-056)

Probe Serial No(s):___________________(If using a combination, list SNs for both pieces)

RABPF S.N.:______________ EPF S.N.:__________________

RLM (ELM) Setting: ____________Ohm-m/Div UNIMOD Current Setting: LOW / HIGH

Pre-Project Calibration:

Date:_______________ Time:_______________

		16" (Ohm-m)		64" (Ohm-m)		SP (mV)		SPR (Ohms)		
Cal. Box		**TRUE**	**MEAS**	**TRUE**	**MEAS**	**TRUE**	**MEAS**	**TRUE**	**MEAS**	**Filename**
0	Ohm	0		0				0		
20	Ohm	100		400						
500	Ohm							500		
-100	mV					-100				
+100	mV					100				

Post-Project Calibration:

Date:_______________ Time:_______________

		16" (Ohm-m)		64" (Ohm-m)		SP (mV)		SPR (Ohms)		
Cal. Box		**TRUE**	**MEAS**	**TRUE**	**MEAS**	**TRUE**	**MEAS**	**TRUE**	**MEAS**	**Filename**
0	Ohm	0		0				0		
20	Ohm	100		400						
500	Ohm							500		
-100	mV					-100				
+100	mV					100				

Calibration files are recorded at a 1 second time digitize interval, for a minimum of 30 seconds. "Measured" values represent average values.

borehole geophysics / hydrophysics

Normal Resistivity
(2PEA-2PGA)
Checkout/Calibration

Engineer:____________________ Location or Well Name:___________________ Unit No:___________

Probe Serial No(s):___________________(If using a combination, list SNs for both pieces)

2PEA-1000 S.N.:______________ 2PGA1000 S.N.:__________________

Tool File Range Selection:____0-250 Ohm-m (use Top and 2nd Port Rows)
____0-2500 Ohm-m (use 2nd and Bottom Port Rows)

Pre-Log Calibration:

Date:_______________ Time:_______________

	8" (Ohm-m)		16" (Ohm-m)		32" (Ohm-m)		64" (Ohm-m)		SP (mV)		SPR (Ohms)		
Cal Box	TRUE	MEAS	TRUE	MEAS	TRUE	MEAS	TRUE	MEAS	TRUE	MEAS	TRUE	MEAS	Filename
Top Row	0.25		0.5		1.0		2.0				5.1		
2nd Row	25		50		100		200				20		
Btm Row	250		500		1000		2000				130		
-100 mV									-100				
+100 mV									100				

Post-Log Calibration:

Date:_______________ Time:_______________

	8" (Ohm-m)		16" (Ohm-m)		32" (Ohm-m)		64" (Ohm-m)		SP (mV)		SPR (Ohms)		
Cal Box	TRUE	MEAS	TRUE	MEAS	TRUE	MEAS	TRUE	MEAS	TRUE	MEAS	TRUE	MEAS	Filename
Top Row	0.25		0.5		1.0		2.0				5.1		
2nd Row	25		50		100		200				20		
3rd Row	250		500		1000		2000				130		
-100 mV									-100				
+100 mV									100				

Calibration files are recorded at a 1 second time digitize interval, for a minimum of 30 seconds. "Measured" values represent average values.

Technical Procedure and Work Instructions for

Single Detector Neutron

TP-6

Prepared by: David A. Renner Date: 7/6/15

Reviewed by: Nathan O. Davis Date: 7/6/15

CONTROL DOCUMENT No. **TP6062408**

TP- 6

Revision History

Revision Level	Issue Date	Change Summary
0.00	2/21/97	New procedure.
1.00	8/6/97	Changes to original draft, renamed to TP-6.
1.10	3/12/98	Minor grammatical changes, added copyright protection.
1.20	6/21/99	Included revisions to incorporate the purchase of COLOG, Inc. by Layne GeoSciences, Inc.
1.21	2/3/00	Include revisions for name change Layne GeoSciences, Inc. to Layne Christensen Company
1.30	6/24/08	Incorporate procedures for logging with the Robertson Geologging system
1.31	7/6/15	Included revisions to incorporate the sale of the COLOG division of Layne Christensen Company to Colog, Inc.

Table of Contents

1.0 SCOPE

1.1 Purpose

1.1.1 This procedure provides instructions for performing neutron measurements to assure the accuracy, validity, and applicability of the methods used.

1.1.2 This procedure further describes the components of neutron logging, the principles and limits of the methods used, the methods used for calibration and performance verification of the equipment, and the requirements for data acceptance and for documentation.

1.1.3 This procedure also provides standards for data traceability.

1.1.4 This procedure includes, by reference, those sections of TP-1 which are common to all measurements.

1.1.5 In applying this procedure to the neutron porosity measurement, the requirements of this procedure shall supercede those stipulated in TP-1.

1.1.6 This procedure does not describe the methods for analysis of the results, nor for integration of those results into the site characterization process.

1.2 Applicability

1.2.1 This procedure applies to neutron porosity data acquired using a radioactive source of thermal neutrons.

1.2.2 This procedure applies to all personnel who perform work referred to in paragraph 1.1.

1.2.3 All data derived from this procedure, and any equipment calibrations or recalibrations that may be required shall be in accordance with this technical procedure. Deviation from these procedures shall be permitted only under the conditions set forth in Section 6.3 of TP-1.

2.0 REFERENCES

2.1 Keys, W. Scott, and MacCary, L.M., Application of Borehole Geophysics to Water-Resources Investigations: USGS, Techniques of Water-Resources Investigations, Book 2, Chapter E1.

2.2 Hearst, J.R., and Nelson, P.H., Well Logging for Physical Properties, McGraw Hill, 1985.

2.3 Standard Guide for Planning and Conducting Borehole Geophysical Logging, ASTM Designation D 5753-95, October, 1995.

3.0 DEFINITIONS

Definitions shall be in accordance with ASTM D 5753-95. In addition, definitions common to all logging procedures are provided in TP-1.

3.1 A neutron probe consists of a radioactive source of thermal neutrons (typically made of $Americium^{241}$/Berillium) and one or more gamma ray or neutron detectors. The source is inserted into the probe, prior to logging, and removed following logging for storage in a protective shield or "pig".

3.2 Recording equipment - Data from the neutron probe is sent to the surface as electrical signals which are translated into engineering units (CPS) and recorded, along with depth, to produce a neutron log of the hole. Variations in neutron count rate are directly related to changes in the hydrogen content of the formation (or material) being sampled. In the open (uncased) borehole, these variations are directly related to porosity. The log data is recorded digitally as engineering values and displayed while the log is being run.

3.3 Personnel - Personnel are as defined in TP-1.

4.0 REQUIREMENTS

4.1 Prerequisites

The use of radioactive materials requires that specific permissions are granted prior to their deployment into the borehole. Reciprocal license recognition is required when logging outside Colorado, or within Colorado on Federal property. Logging on Federal property requires reciprocity permission from the NRC, while radioactive materials in most states is regulated by the state's specific health authority. Authorities granting reciprocity will require detailed location and timing information to allow for field inspections. No other prerequisites are required other than as stipulated in TP-1.

4.2 Tools, Material, Equipment

4.2.1 Neutron measurement apparatus

COLOG utilizes two types of single-detector neutron probes: a Mount Sopris Instruments (MSI) digital RABOPF (which includes a natural gamma probe section), powered by an MSI Unimod; and an MSI analogue OLP or LLP, powered by an MSI Unimod or OLM.

4.2.2 Neutron calibration apparatus.

Single-detector neutron probes report only relative differences in porosity and can not be calibrated. Though dual-neutron probes can be calibrated to quantitative porosity, the process requires the apparatus be of the same diameter, and if applicable, be lined with the same casing materials, as the borehole in which the probe will be run. Maintaining all possible combinations of borehole sizes and casing materials is prohibitive, and is not within Colog’s ability at this time.

4.2.3 Pre-Log Functionality Check

The purpose of the pre-log calibration is to verify that the detector is counting neutrons, and that the count rate changes with proximity to a neutron source.

4.2.3.1 This procedure may be performed at Colog’s shop prior to mobilizing, or at any project site.

4.2.3.2 Attach the probe to the wireline, and attach the source to the end of the probe. Leave the source sub in the source pig, and initialize the probe power, and logging software.

4.2.3.3 Record data for about 30 seconds and determine the average count rate for the detector(s). Input these values in the appropriate sections of the “Neutron Functionality Check” form.

4.2.3.4 Remove the source sub from the source pig, and place it face-down on the ground (this attitude allows for a change in neutron counts, at the detector(s) while, minimizing the neutron exposure to any proximate personnel.

4.2.3.5 Record data for about 30 seconds and determine the average count rate for the detector(s). Input these values in the appropriate sections of the “Neutron Functionality Check” form.

4.2.4 Post-Log Functionality Check Procedure

The purpose of the post-log functionality check is to verify that no change in system performance has occurred during logging.

4.2.4.1 In performing the post-log functionality check, the procedures for pre-log functionality check shall be followed. The count rate within the source pig should be within 10% of the pre-log check, but the count rate with the probe on the ground may vary more widely, as the circumstances on the ground may have changed during the logging event.

4.2.4.2 Input these values in the appropriate sections of the “Neutron Functionality Check” form.

4.3 <u>Precautions and Limits</u>

4.3.1 Temperature and pressure limits are specific to each probe. Typical operational limits are 20 MPa fluid pressure and 70°C. Some probes may require correction of the measurements for temperature and pressure.

4.3.2 Neutron measurements are typically made in formations with porosities ranging from near zero to more than 40 percent.

4.3.3 Because the neutron log relies on a process which is inherently statistical, errors are inversely proportional to the number of events. Higher porosities, lower source energies, higher source-receiver distances, and the presence of neutron absorbers all tend to decrease the count rate thus increasing the statistical error.

4.3.4 Colog, Inc. utilizes a free standing neutron probe with a single Helium-3 detector spaced 14 inches up from the mid-point of the source housing on the bottom of the probe (see Appendix 7.1). This probe is not shielded or decentralized within the borehole. Since the depth of investigation is about 7”, the neutron log will be affected by borehole enlargements. The borehole fluid itself will also have an attenuating affect on the neutrons which becomes more pronounced as hole size increases.

4.3.5 Vertical resolution of Colog’s neutron probes is about 12 inches.

4.3.6 The log shall be recorded with the probe moving up the borehole at a rate not to exceed 30 feet per minute.

4.3.7 The active neutron source is intrinsically hazardous and requires additional precautions beyond those associated with other log measurements. In general, sources are stored in neutron-proof containers during transit and while awaiting use. The source is removed from the container immediately prior to running the log, and is returned to the container immediately following completion of the post-log check. With the exception of the Logging Engineer, no one shall be within 20 feet of the source while it is exposed. If a collimated source is used, it shall be pointed away from all personnel and the logging truck, especially during establishment of a depth zero point.

4.3.8 Personnel shall be trained and have appropriate licenses to transport and operate the equipment.

4.3.10 Because interaction of neutrons with the formation may temporarily raise the background level of gamma radiation, this log should be run either in combination with or after logs which measure natural gamma radiation. If that is not possible, a suitable period of time shall be allowed following this log prior to running a gamma measuring probe.

4.4 Acceptance Criteria

This log shall be accepted for use based on the expectation that the results may be interpreted qualitatively.

4.4.1 Repeat section shall be similar to the main log, such that features visible in each match in depth (see depth error criterion for re-zero) and count rate (see validation criterion).

4.4.2 Depths of features in the log agree with those in other logs, if run.

4.4.3 Depth rezero is within required tolerances.

4.4.4 Validation is within required tolerances for repeatability, and calibration checks are within 10% of previously documented count rates for the specific probe and source combination, as outlined in sections 4.2.3 and 4.2.4.

4.4.5 Log shows reasonable values consistent with experience (i.e.there is no drift, and variations in count rate are recorded which are consistent with data from other logs). For example, density and porosity exhibit an inverse response.

5.0 DETAILED PROCEDURE

Neutron logs are recorded by measuring the flux of neutrons generated by interactions of the neutrons with the formation, received at a detector as a consequence of injection into the formation of thermal neutrons from a radioactive source. The injected neutrons interact with atoms in the formation by elastic scattering, which results in a loss of energy, by inelastic scattering, which results in a loss of energy and production of gamma ray quanta, or by capture, which results in production of gamma rays of capture. Neutrons interact most strongly with hydrogen and with neutron absorbers such as chlorine. Therefore, assuming that all of the hydrogen is contained in the pore fluid, the neutron count can be used to estimate formation porosity. However, for a single detector (non-compensated) neutron probe, the conversion to porosity is difficult in that it requires an algorithm developed from logging the same probe (and source) in a known standard with similar hole conditions (i.e. same diameter and lithology). Even then, anomalous porosity readings can occur due to hole enlargements, excessive buildup of mud cake or variations from the lithology of the know standard. Consequently, formation porosity values converted from the count rates, especially from a single detector neutron probe, should be treated qualitatively.

Typically, the depth of investigation of a neutron probe is from 6 inches to one foot. This decreases with increasing porosity (lower count rates). The vertical resolution depends on the design of the probe. Typical resolutions are on the order of one to two feet. Neutron logs can be used to estimate formation porosity. In combination with other logs such as density or electrical resistivity, additional information can be obtained. For a given rock type, porosity controls elastic moduli and rock strength. Porosity and permeability are often related for a given rock type.

Neutron logs are typically run as part of a suite of logs during a single visit to a well site. Procedures prior to and upon arrival as described here pertain only to the specific requirements of this measurement. Where they do not conflict with the procedures detailed here, all of the procedures specified in TP-1 shall also be adhered to.

5.1 Prior to arrival

In addition to the procedures stipulated in TP-1:

5.1.1 The Logging Engineer shall provide evidence of compliance with all applicable laws regarding transport and use of radioactive materials upon request.

5.1.2 All personnel shall provide evidence of having applicable safety training upon request.

5.2 On arrival

In addition to the procedures stipulated in TP-1:

5.2.1 The site shall be inspected for conditions that affect safety related to the handling of the neutron source. Identified hazards shall be eliminated.

5.2.2 A survey of the site shall be undertaken to establish a background level of radiation, for comparison to a post-logging survey.

5.2.3 The site shall be clearly labeled with signs to identify the specific hazards associated with the presence on site of the neutron source.

5.2.4 A safe perimeter shall be established and appropriately marked to prevent unauthorized access.

5.3 While Logging

5.3.1 Attach the neutron source to the logging probe, then attach the neutron probe to the wireline following approved procedures.

5.3.2 Perform a pre-log functionality check and complete the “Pre-Log” section of the “Neutron Functionality Check” form (see Appendix 7.1)

The pre-log functionality check provides a check of probe operations and provides data for comparison to a post-log validation check.

5.3.3 Set wireline depth zero at the midpoint between the detector and the source. If multiple measurements are taken on a single lowering (as in the case of the RABOPF combination Gamma/Neutron probe), set the appropriate depth zero based on the probe offsets in the probe identifier file. The probe should be zeroed hanging freely in the hole to prevent slack in the cable from biasing the datum.

5.3.4 Lower the neutron probe to the bottom of interval to be logged.

5.3.5 Begin logging up at a rate not to exceed 30 feet per minute. Typically, a 50 foot repeat section is run first, followed by the main log. However, the repeat may be run after the main log in order to identify a more interesting interval to repeat. Tool operation is verified as stipulated in 4.4.4.

5.3.6 After completion (and acceptance) of both a repeat section and a main run, all of the data (including the pre-log calibration) shall be backed up onto a portable storage media.

5.3.7 Return the probe to the zero reference and determine the After Survey Depth Error (A.S.D.E) as stipulated in TP-1.

5.3.8 The logging probe may be cleaned at this time.

5.3.9 Perform a post-log functionality check following the procedure detailed in 4.2.4.

5.3.10 Place the neutron source back in the shield, remove the wireline and detach the probe from the source.

5.4 Prior to departure

In addition to the requirements stipulated in TP-1:

5.4.1 A post-logging radiation survey shall be conducted to demonstrate that no radiation hazards were created during logging.

6.0 RECORDS

Records shall be provided as detailed in TP-1.

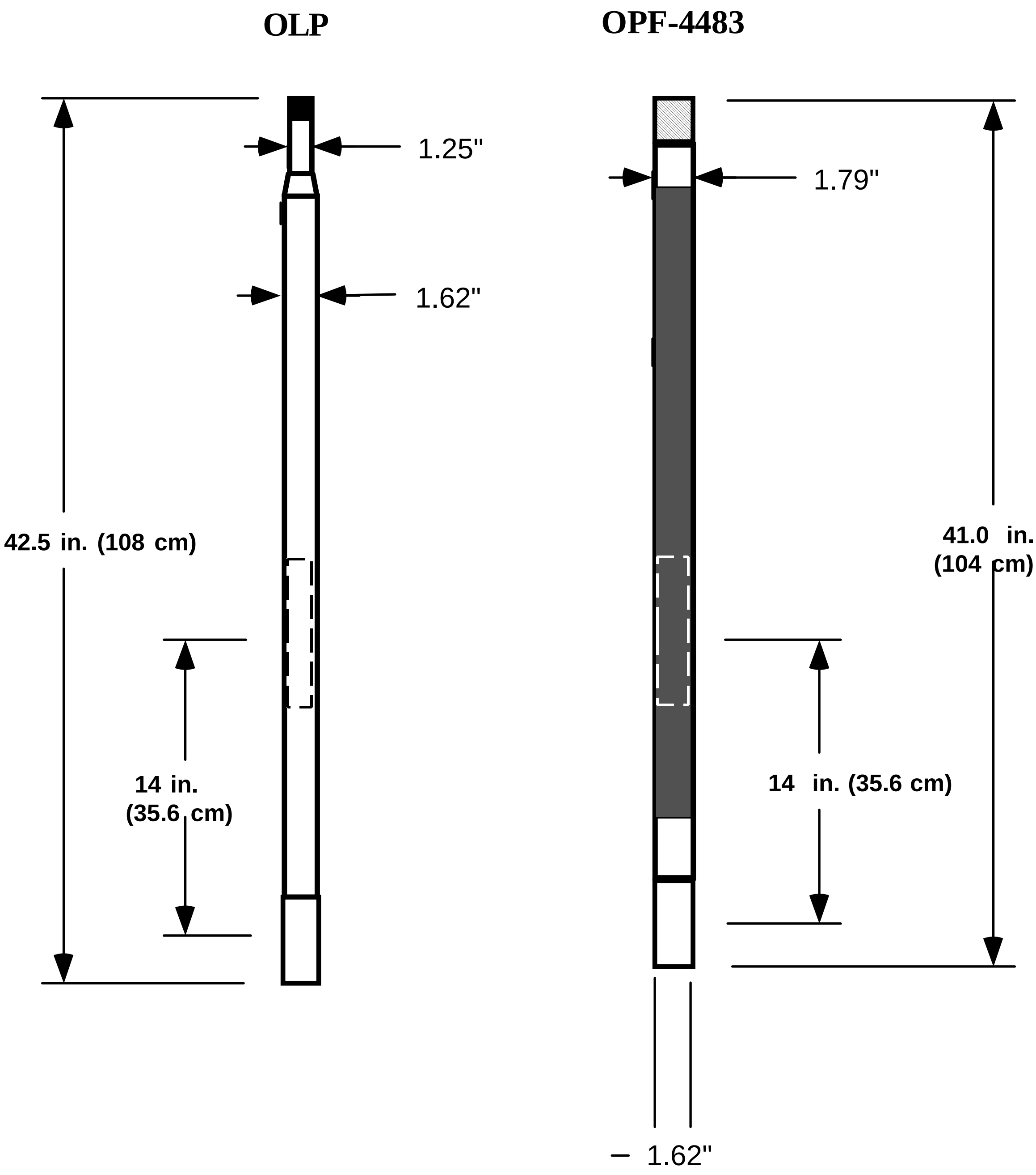
7.0 APPENDICES

7.0 Neutron Tool Diagrams.

7.1 "Neutron Functionality Check" Form.

Appendix 7.0

Neutron Probes



Appendix 7.1

borehole geophysics / hydrophysics

Neutron
Functionality Check

Engineer:____________________ Location or Well Name:___________________ Unit No:___________

Probe Type & Serial No:_______________________________ Source Serial No._________________

Pre-Log Check:

Date:_______________ Time:_______________

	Measured Counts	**Filename**
Source in Pig	____________________	____________________
Source on Ground	____________________	____________________

Post-Log Check:

Date:_______________ Time:_______________

	Measured Counts	**Filename**
Source in Pig	____________________	____________________
Source on Ground	____________________	____________________

Check files are recorded at a 1 second time digitize interval for approximately 30 seconds. “Counts” and “Measured” values are averages determined with Excel or with Colog’s “WLCHECK” program.

Technical Procedure and Work Instructions for

Compensated Density Logging

TP-7

Prepared by: David A. Renner Date: 7/6/15

Reviewed by: Nathan O. Davis Date: 7/6/15

CONTROL DOCUMENT No. **TP7062408**

COLOG Technical Procedure TP-7

Revision History

Revision Level	Issue Date	Change Summary
0.00	3/12/98	New procedure.
1.00	2/5/99	Included revisions to incorporate the purchase of COLOG, Inc. by Layne GeoSciences, Inc.
1.01	2/3/00	Include revisions for name change Layne GeoSciences, Inc. to Layne Christensen Company
1.02	5/4/07	Revised to include RG Density probe.
1.10	6/24/08	Addition of Functionality Check procedures.
1.20	7/6/15	Included revisions to incorporate the sale of the COLOG division of Layne Christensen Company to Colog, Inc.

Table of Contents

1.0 SCOPE

1.1 Purpose

1.1.1 This procedure provides instructions for performing compensated density measurements to assure the accuracy, validity, and applicability of the methods used.

1.1.2 This procedure further describes the components of borehole compensated density logging (hereafter referred to as density logging), the principles and limits of the methods used, the methods used for calibration and performance verification of the equipment, and the requirements for data acceptance and for documentation.

1.1.3 This procedure includes, by reference, those sections of TP-1 which are common to all measurements.

1.1.4 In applying this procedure to density measurement, the requirements of this procedure shall supersede those stipulated in TP-1.

1.1.5 This procedure does not describe the methods for analysis of the results, nor for integration of those results into the site characterization process.

1.2 Applicability

1.2.1 This procedure applies to density measurements using a compensated density probe.

1.2.2 This procedure applies to all personnel who perform work referred to in paragraph 1.1, and who have been certified by the Radiation Safety Officer as Radiological Well-Logging Supervisors.

1.2.3 All data derived from this procedure, and any equipment calibrations or recalibrations that may be required shall be in accordance with this technical procedure. Deviation from these procedures shall be permitted only under the conditions set forth in Section 6.3 of TP-1.

2.0 REFERENCES

2.1 Keys, W. Scott, and MacCary, L.M., Application of Borehole Geophysics to Water-Resources Investigations: USGS, Techniques of Water-Resources Investigations, Book 2, Chapter E1.

2.2 Hearst, J.R., and Nelson, P.H., Well Logging for Physical Properties, McGraw Hill, 1985.

2.3 Standard Guide for Planning and Conducting Borehole Geophysical Logging, ASTM Designation D 5753-05, June, 2005.

3.0 DEFINITIONS

Definitions shall be in accordance with ASTM D5753-05. In addition, definitions common to all logging procedures are provided in TP-1.

3.1 The density probe utilizes a gamma-emitting radioactive source, along with two detectors placed at discreet intervals from the source, to measure electron density. The different detector spacings provide a means to "compensate" for near borehole anomalies. A mechanical arm is used to force the source and detectors up against the wall of the borehole, and is also used to measure borehole size. The radioactive source is inserted into the probe, prior to logging, and removed following logging for storage in a protective shield or "pig".

3.2 Recording equipment - Data from the density probe is sent to the surface as electrical signals which are translated into engineering units (g/cc) and recorded along with depth to produce both near and far detector density values, as well as a caliper log of hole size. The log data is recorded digitally as raw counts and as engineering values and displayed while the log is being run.

3.3 Personnel - Personnel are as defined in TP-1, and is limited to operators who have been certified by the Radiation Safety Officer as Radiological Well-Logging Supervisors.

4.0 REQUIREMENTS

4.1 Prerequisites

The use of radioactive materials requires that specific permissions are granted prior to their deployment into the borehole. Reciprocal license recognition is required when logging outside Colorado, or within Colorado on Federal property. Logging on Federal property requires reciprocity permission from the NRC, while radioactive materials, in most states, are regulated by the state's specific health authority. Authorities granting reciprocity will require detailed location and timing information to allow for field inspections. No other prerequisites are required other than as stipulated in TP-1.

4.2 Tools, Material, Equipment

4.2.1 Density measurement apparatus.

Colog, Inc. utilizes three types of compensated density probes: a Mount Sopris Instruments (MSI) digital RABHPF (which includes a natural gamma probe section) and an MSI analog HLP, both powered by the MSI Unimod; and a Robertson Geologging (RG) model 25-007 Sidewall Density probe, powered by the RG Micrologger-II. The operation of the density and caliper arm measurements for all probes are essentially identical. This shall be a measurement device as described in section 3.1.

4.2.2 Calibration apparatus.

The density probe is calibrated using two solid calibration blocks made of aluminum and Lucite. The electron density of the aluminum block is known to be 2.60 gm/cc, while that of the Lucite block is known to be 1.28 gm/cc.

4.2.3 Pre-project calibration procedure

The purpose of pre-project calibration is to establish the semi-log relationship between count rate at the detector(s) and apparent bulk density.

The pre-project calibration also provides data for comparison to a post-log calibration check.

4.2.3.1 This procedure shall be performed at Colog's shop prior to mobilizing to a project site. The calibration blocks may also be mobilized to the project site for onsite calibrations depending on the specific requirements of the project, though their bulk inhibits mobility. The required tolerances are specified in 4.4.4.

4.2.3.2 Attach the density probe to the wireline and place the source end of the probe on the Lucite block with the caliper arm facing up, as shown in Appendix 7.2. The bottom of the source sub should butt up against the pin on the Lucite block. Use a jack or stand to support the upper end of the probe, such that the source, and both detectors are flush against the block.

4.2.3.3 Record data for at least 30 seconds, and determine the average count rate for both the near and far detectors. Then, input these average values to force the computer channels, which converts the count rate of the long and short detectors to gm/cc, to read the density of the Lucite block (1.28 gm/cc).

4.2.3.4 Place the probe on the aluminum block and repeat the procedure above for the aluminum block (density 2.60 gm/cc).

4.2.3.5 Confirm and record the now calibrated response of the probe for the two calibration blocks as follows:

With the probe still positioned on the aluminum block, confirm the output for both detectors is within 0.05 gm/cc of the block density (2.60 gm/cc). Record the output (both in counts/second and gm/cc) using time sampling at 1 second for a minimum of 30 seconds. The filename for this data should include the probe type and serial number (Example: "HLP895.HA0" is a calibration file for the HLP probe, Serial #895 on the aluminum block).

Repeat this procedure with the probe placed back on the Lucite block. Using the example above, the filename might be "HLP895.HA1".

4.2.3.6 Determine the nominal size of the borehole to be logged and select two caliper validation rings which will span the range of hole diameters expected in the borehole (For example: If the hole is 6 inches, a 4.5 inch ring and a 7 inch ring may be used to perform the calibration).

4.2.3.7 Move the probe back onto the aluminum block with the source sub positioned about midway on the block. Open the caliper arm to its full open position, then compress the caliper arm, place the smaller ring over the end of the arms, and allow the arm to open with the tip inside the ring. Force the computer channel, which converts the potentiometer output (in counts/sec) into to inches, to read the diameter of the smaller ring.

Repeat this procedure with the larger ring, thus establishing the linear coefficients for the caliper response.

4.2.3.8 Trigger the software to calculate the linear equation and to save the new equation to the probe file.

4.2.3.9 Confirm the now calibrated response of the probe for the two ring sizes as follows:

Place the smaller ring back on the caliper arms and confirm the output is within 5%. Record the output (both in counts/second and engineering units) using time sampling for a minimum of 30 samples. The filename for this data should include the tool type and serial number and the ring size.

Repeat this procedure for the larger ring and confirm that the caliper value is within 5% of the ring size. The filename should be identical to that used for the smaller ring except for the ring size indication.

4.2.3.10 Save all calibration values (that is, the raw output and the engineering value for both detectors and the caliper arm) and the scale factors selected during the above procedure. From the calibration files recorded during the block calibrations, determine the average of the raw counts and the measured density for both detectors on both blocks and use these average values to complete the “Pre-Project” portion of the “Compensated Density Checkout/Calibration” form (Appendix 7.3)

4.2.4 Post-Project Calibration Check Procedure

The purpose of the post-project calibration check is to verify that no change in system performance has occurred during logging.

In performing the post-project calibration check, the procedures for pre-project calibration shall be followed, with the exception that no adjustments to the linear equation or probe file, as described in section 4.2.3.3 shall be allowed.

4.2.5 Complete the “Post-Project” portion of the “Density Checkout/Calibration” form.

4.2.6 Pre-Log Functionality Check

The purpose of the pre-log functionality check is to verify that both detectors are counting gammas, and that the count rate changes with proximity to a gamma source.

4.2.6.1 This procedure may be performed in Colog's shop or at any job site, as necessary, when it is not practical to bring along the large, heavy calibration blocks.

4.2.6.2 Attach the density probe to the wireline and attach the source to the end of the probe. Leave the source sub in the source pig, and power on the probe.

4.2.6.3 Record data for at least 30 seconds and determine the average count rate for both the near and far detectors. Input these values in the appropriate section of the "Density Functionality Check" form.

4.2.6.4 Remove the source sub from the source pig, and place it face-down on the ground (this attitude allows for a change in gamma counts at the detectors while minimizing the gamma exposure to any proximate personnel).

4.2.6.5 Record data for at least 30 seconds and determine the average count rate for both the near and far detectors. Input these values in the appropriate section of the "Density Functionality Check" form.

4.2.6.6 Check the functionality of the caliper as described in section 4.2.3.9. Caliper values should be within 5% inches of the ring diameter.

4.2.7 Post-Log Functionality Check

The purpose of the post-log functionality check is to verify that no change in system performance has occurred during logging.

4.2.7.1 In performing the post-log functionality check, the procedures for pre-log functionality check shall be followed. The count rate within the source pig should be within 5% of the pre-log check, but the count rate with the probe on the ground may vary more widely, as the circumstances on the ground may have changed during the logging event. Caliper values should be within 5% inches of the ring diameter.

4.2.7.2 Input the post-log functionality values in the appropriate sections of the "Density Functionality Check" form.

4.3 <u>Precautions and Limits</u>

4.3.1 Temperature and pressure limits shall be adhered to as specified in the operating manual for the specific probe. Density and caliper readings may drift slightly with temperature due to temperature induced changes in the electrical properties of the device.

4.3.2 Since the caliper arm is an electro-mechanical device. Errors are due to: 1) non-linearity of the measurement resistor, and 2) tolerance in the mechanical movement of the caliper arms (mechanical hysteresis). The sensitivity to small features is limited by the width of the contact point at the end of the caliper arm, and by the logging speed and the vertical sampling rate. Errors in the measured density values are due primarily to near borehole anomalies such as rugosity or breakouts.

4.3.3 Because the density log relies on a process which is inherently statistical, errors are inversely proportional to the number of events. Higher densities, lower source energies, higher source-receiver distances, and the presence of more dense absorbers all tend to decrease the count rate thus increasing the statistical error.

4.3.3 The log shall be recorded with the probe moving up the borehole, with the caliper arm fully extended, at a rate not to exceed 20 feet per minute.

4.3.4 The active gamma source is intrinsically hazardous and requires additional precautions beyond those associated with other log measurements. In general, sources are stored in gamma-absorbing containers during transit and while awaiting use. The source is removed from the container immediately prior to running the log, and is returned to the container immediately following completion of the post-log check. With the exception of the Logging Engineer, no one shall be within 20 feet of the source while it is exposed. If a collimated source is used, it shall be pointed away from all personnel and the logging truck, especially during establishment of a depth zero point.

4.3.5 Personnel shall be trained and have appropriate licenses to transport and operate the equipment.

4.4 Acceptance Criteria

This log shall be accepted for use based on the expectation that the results will be interpreted quantitatively.

4.4.1 Repeat section shall be similar to the main log, such that features visible in each, match in depth (see depth error criterion for re-zero) and apparent density, with allowances for the fact that the probe may be pressed against a different side of the borehole for the main and repeat logs.

4.4.2 Depths of features in the log agree with logs from other probes, if run.

4.4.3 Re-zero is within required tolerances.

4.4.4 Calibration(s), calibration check(s), and functionality check(s) are within 5% of the actual values.

4.4.5 Log shows reasonable values consistent with experience (i.e., there is no drift, and reasonable variations in hole size are recorded).

5.0 DETAILED PROCEDURE

Density logs are typically recorded at a 0.1, 0.2, or 0.5 foot sample interval, while the probe is moving up the borehole.

Density logs are typically run as part of a suite of logs during a single visit to a well site. Procedures prior to and upon arrival, as described here, pertain only to the specific requirements of the compensated density probe. In addition, procedures as specified in TP-1, shall be adhered to where they do not conflict with the specific requirements of this procedure.

5.1 Prior to mobilization

In addition to the procedures stipulated in TP-1:

5.1.1 The Logging Engineer shall provide evidence of compliance with all applicable laws regarding transport and use of radioactive materials upon request.

5.1.2 All personnel shall provide evidence of having applicable safety training upon request.

5.2 On arrival

In addition to the procedures stipulated in TP-1:

5.2.1 The site shall be inspected for conditions that affect safety related to the handling of the gamma source. Identified hazards shall be eliminated.

5.2.2 A survey of the site shall be undertaken to establish a background level of radiation, for comparison to a post-logging survey.

5.2.3 The site shall be clearly labeled with signs to identify the specific hazards associated with the presence on site of the gamma source.

5.2.4 A safe perimeter shall be established and appropriately marked to prevent unauthorized access.

5.3 While Logging

5.3.1 Attach the density probe to the logging cable.

5.3.2 If the project demands on-site calibrations of the density probe, perform a pre-log calibration of the density probe as describe in Section 4.2.3. Otherwise, simply open the caliper arm (prior to attaching the source sub) and check that the measured values of the calibration rings are still within 5% inches of the actual ring sizes recorded on the calibration form during the shop calibration. If not, repeat the procedure in Section 4.2.3.7, and update the values in the pre-log portion of the calibration form.

5.3.3 Close the caliper arm and attach the source sub to the bottom of the density probe. Be sure that the screw that holds the source sub to the probe is screwed in tight.

5.3.4 Set the software depth counter to read zero when the top is depth referenced to the measurement datum (ground surface, top of casing, etc.). The depth zero should be set with tension on the wireline similar to that expected while logging, to prevent slack in the cable from biasing the datum.

5.3.5 Lower density probe to bottom of interval to be logged.

5.3.6 Open caliper arm.

5.3.7 Begin logging up at a rate not to exceed 20 feet per minute. Typically, a 50 foot repeat section is run first, followed by the main log. However, the repeat may be run after the main log in order to identify a more interesting interval to repeat.

5.3.8 Close arms and lower the probe to the bottom of the interval to be logged.

5.3.9 After completion (and acceptance) of both a repeat section and a main run, all of the data (including the pre-log calibration) shall be backed up onto a portable storage media.

5.3.10 Return density probe to surface.

5.3.11 Determine the After Survey Depth Error (A.S.D.E) as stipulated in TP-1.

5.3.12 The logging probe may be cleaned at this time.

5.3.13 If the project demands on-site calibrations of the density probe, perform a post-log calibration of the density probe as describe in Section 4.2.3. Otherwise, remove the source sub and open the caliper arm. Check that the measured values of the calibration rings are within 5% of the actual ring sizes, and record the count rate and measured values for both rings in post-log portion of the calibration form. The Post-Log Check of the density values should be performed back at Colog’s shop unless the project demands on-site density calibrations.

5.3.14 If sections of the hole measure larger than the full extension of the caliper arm, a longer arm may be added to increase the range, and those sections re-logged (on client’s request). If this occurs, the caliper function must be recalibrated using a larger ring (as close to the anticipated diameter of the enlarged interval as possible).

5.4 Prior to departure

In addition to the requirements stipulated in TP-1:

5.4.1 A post-logging radiation survey shall be conducted to demonstrate that no radiation hazards were created during logging.

6.0 RECORDS

Records shall be provided as detailed in TP-1.

7.0 APPENDICES

7.1 Density Tool Diagrams.

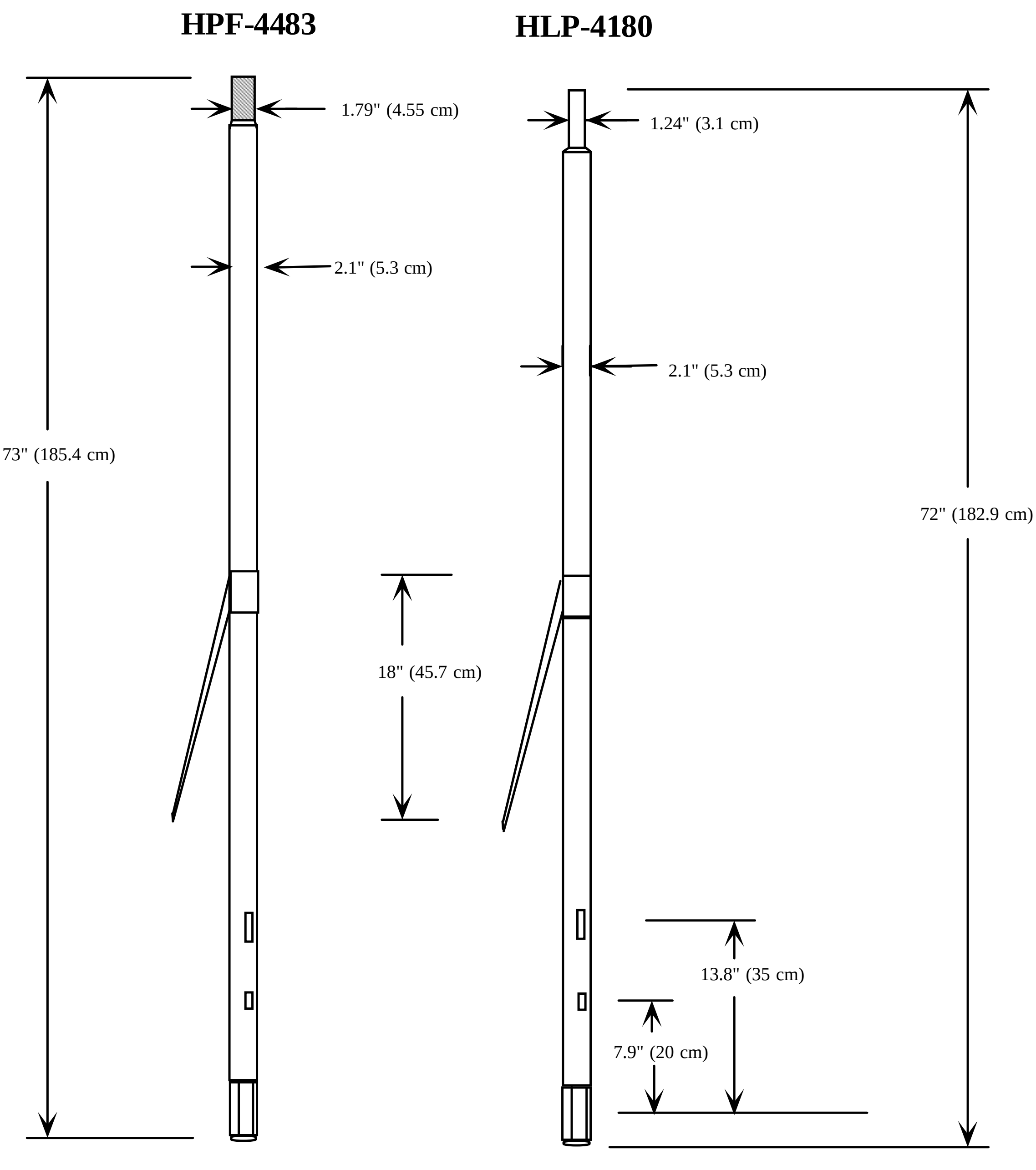
7.2 Density Calibration Apparatus

7.3 "Compensated Density Checkout/Calibration" Form

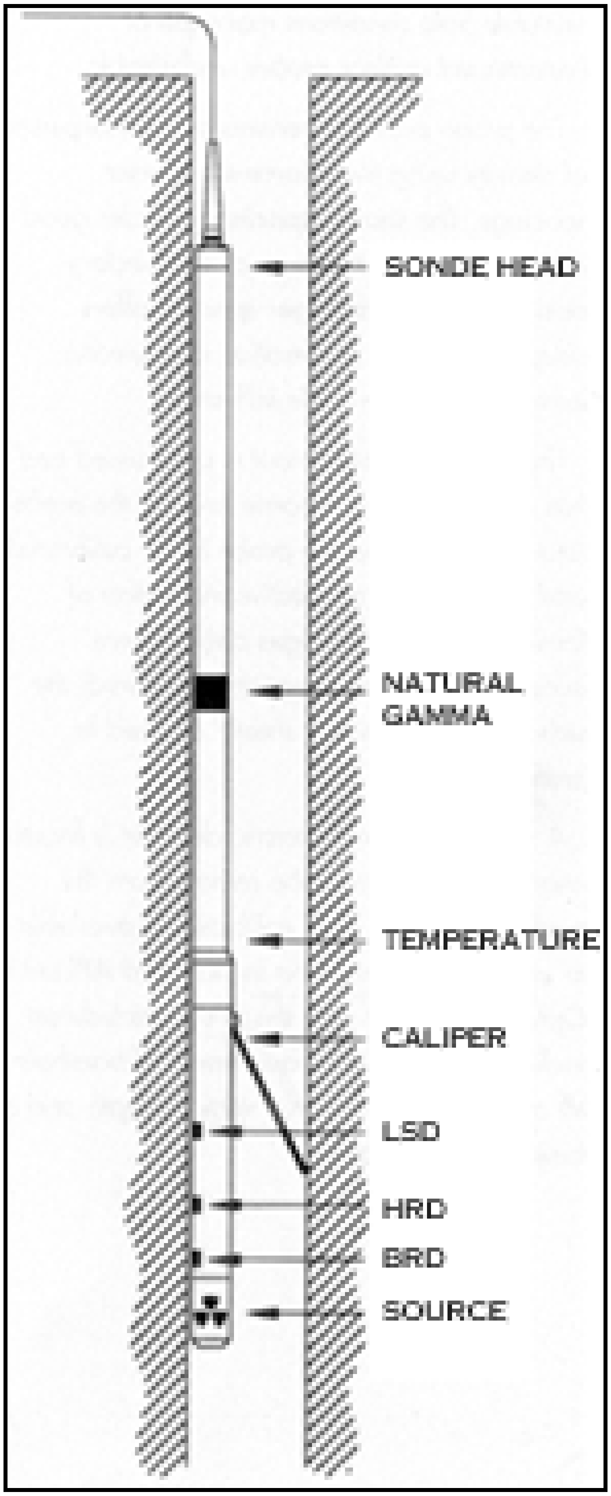
7.4 "Compensated Density Functionality Check" Form

Appendix 7.1

Compensated Density Probes



RG 25-007



MEASUREMENTS
Compensated density
Natural gamma
Caliper

SPECIFICATIONS

Diameter	50mm
Length	2.88m
Weight	20kg
Max. temperature	70ºC
Max. pressure	20MPa

Density
detectors type: NaI(Tl) scintillation crystal
detector spacings: 48cm (LSD) 24cm (HRD)
calibrated density range (LSD): 1 to 3.0g/cc

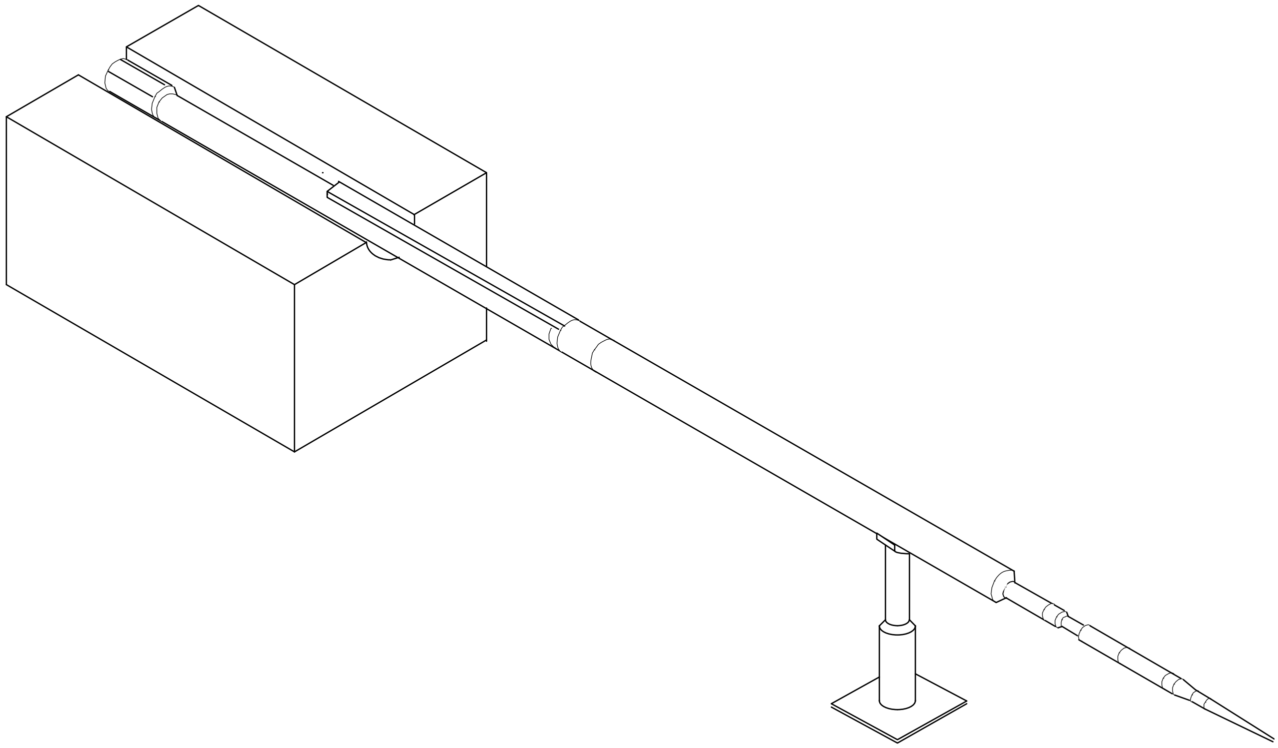
Natural Gamma
detector: 50 x 25mm NaI (Tl) scintillation crystal

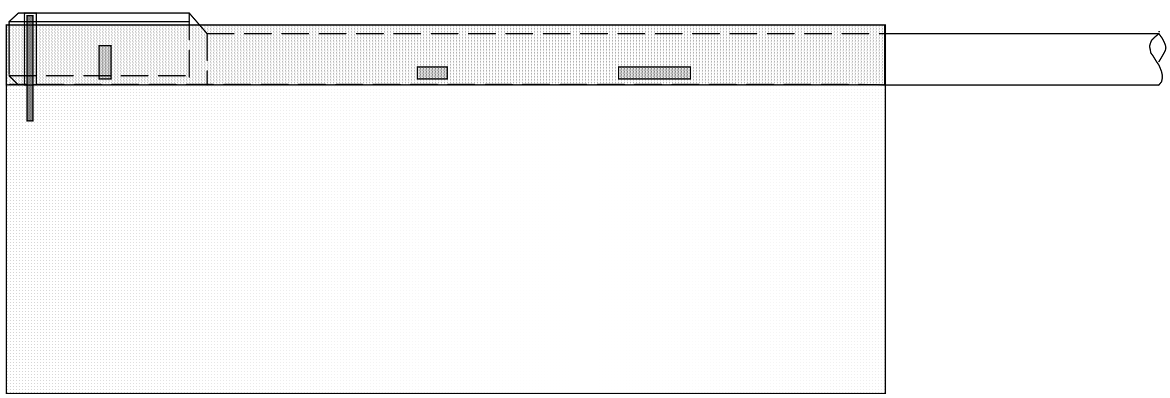
Caliper
range: 50 to 300mm (1.98 to 11.81 inches)

ACCESSORIES
3.7GBq (100mCi) Cs^{137} gamma source

Please Note: Optional items (temperature and BRD) not provided with Colog's current probe configuration

Appendix 7.2





Appendix 7.3

borehole geophysics / hydrophysics

Compensated Density Checkout/Calibration

Engineer:____________________ Location or Well Name:___________________ Unit No:___________

Probe Type:____________ (HLP, HPF or 25-007) Probe Serial No:____________________

Source Serial No:____________________

Pre-Log Check:

Date:________________ Time:________________

Block	SS Counts	SS Density (gm/cc)	LS Counts	LS Density (gm/cc)	Filename
Aluminum					
Lucite					

Caliper:	Ring Size (in.)	Count Rate	Measured (in.)	

Post-Log Check:

Date:________________ Time:________________

Block	SS Counts	SS Density (gm/cc)	LS Counts	LS Density (gm/cc)	Filename
Aluminum					
Lucite					

Caliper:	Ring Size (in.)	Count Rate	Measured (in.)	

Calibration files are recorded at a 1 second time digitize interval for approximately 30 seconds. “Counts” and “Measured” values for the Density are averages determined using Excel or Colog’s “WLCHECK” program.

Appendix 7.4

Compensated Density
Functionality Check

Engineer:____________________ Location or Well Name:___________________ Unit No:___________

Probe Type:____________ (HLP, HPF or 25-007) Probe Serial No:___________________

Source Serial No:___________________

Pre-Log Check:

Date:_______________ Time:_______________

_____	SS Counts	SS Density (gm/cc)	LS Counts	LS Density (gm/cc)	Filename
Source in Pig					
On Ground					

Caliper:	Ring Size (in.)	Count Rate	Measured (in.)	

Post-Log Check:

Date:_______________ Time:_______________

_____	SS Counts	SS Density (gm/cc)	LS Counts	LS Density (gm/cc)	Filename
Source in Pig					
On Ground					

Caliper:	Ring Size (in.)	Count Rate	Measured (in.)	

Validation files are recorded at a 1 second time digitize interval for approximately 30 seconds. “Counts” and “Measured” values for the Density are averages determined using Excel or Colog’s “WLCHECK” program.

Technical Procedure and Work Instructions for

Electromagnetic **Dual Induction** Conductivity

TP-15

Prepared by: David A. Renner Date: 7/6/15

Approved by: Nathan O. Davis Date: 7/6/16

CONTROL DOCUMENT No. TP15050407

Colog, Inc. Technical Procedure TP-15

Revision History

Revision Level	Issue Date	Change Summary
0.00	2/16/07	New procedure.
1.00	5/4/07	Formatting, pagination and spelling revisions
1.10	7/6/15	Included revisions to incorporate the sale of the COLOG division of Layne Christensen Company to Colog, Inc.

Table of Contents

1.0 SCOPE

1.1 Purpose

1.1.1 This procedure provides instructions for performing electromagnetic induction conductivity logging measurements (EM), with a dual detector spacing, to assure the accuracy, validity, and applicability of the methods used.

1.1.2 This procedure further describes the components of dual induction probes, the principles and limits of the methods used, the methods used for calibration and performance verification of the equipment, and the requirements for data acceptance and for documentation.

1.1.3 This procedure includes by reference those sections of TP-1 which are common to all measurements.

1.1.4 In applying this procedure to dual induction logging measurement, the requirements of this procedure shall supersede those stipulated in TP-1.

1.2 Applicability

1.2.1 This procedure applies to conductivity measured using dual induction probes.

1.2.2 This procedure applies to all personnel who perform work referred to in paragraph 1.1.

1.2.3 All data derived from this procedure, and any equipment calibrations or recalibrations that may be required shall be in accordance with this technical procedure. Deviation from these procedures shall be permitted only under the conditions set forth in Section 6.3 of TP-1.

2.0 REFERENCES

2.1 Keys, W. Scott, and MacCary, L.M., Application of Borehole Geophysics to Water-Resources Investigations: USGS, Techniques of Water-Resources Investigations, Book 2, Chapter E1.

2.2 Hearst, J.R., and Nelson, P.H., Well Logging for Physical Properties, McGraw Hill, 1985.

2.3 Standard Guide for Planning and Conducting Borehole Geophysical Logging, ASTM Designation D 5753-05, June, 2005.

3.0 DEFINITIONS

Definitions shall be in accordance with ASTM D 5753-05. In addition, definitions common to all logging procedures are provided in TP-1.

3.1 Induction logging involves measuring the conductivity of the formation surrounding a borehole, and typically also reporting the calculated resistivity.

3.2 Resistivity is defined as the ratio of voltage to current per unit distance per unit area. The units are typically Ohm-meters. Conductivity is the inverse of resistivity, and is expressed in milliSiemens/meter.

3.5 Electromagnetic induction is a technique whereby formation conductivity is measured by inducing an electromagnetic field the formation and measuring the ability of the formation to sustain that field. This technique requires no direct electrical connection between the formation and the coils (i.e. The presence of electrically conductive fluid, typically water, in the borehole, is not required).

3.6 Recording equipment - Data from the dual induction probe is sent to the surface as electrical signals which are translated into engineering units and recorded along with depth to produce a conductivity log of the hole. The log data is recorded digitally as engineering values and displayed while the log is being run.

3.7 Personnel

Personnel are as defined in TP-1.

4.0 REQUIREMENTS

4.1 Prerequisites

4.1.1 The borehole to be logged need not be filled with a conductive fluid. The log may be run in dry holes, or with water or drilling mud.

4.1.2 The borehole to be logged must be either open (uncased) or cased with non-conductive pipe, such as PVC or fiberglass.

4.2 Tools, Material, Equipment

4.2.1 Measurement apparatus

Colog, Inc. utilizes two probes to collect dual induction logs: The Advanced Logic Technology DIL-45 probe, with source to detector spacings at 22” & 33”, and an operating frequency of 25.6

kHz. The probe communicates with uphole interface consoles, including the Advanced Logic Technology ALT Logger, the Mount Sopris Instruments MGX-II Digital Logging System, and the Mount Sopris Instruments Matrix Geophysical Logging System. The Robertson Geologging DUIN 25-061 probe, with source to detector spacings at 20" & 32", and an operating frequency of 39 kHz, communicates with the Robertson Geologging Micrologger 2. Once calibrated, the responses of both probes are essentially identical.

4.2.2 Model specific calibration coil.

4.2.3 Pre-log calibration procedure for the MSI DIL-45

This procedure shall be performed before logging each well. The required tolerances are specified in 4.4.4.

The purpose of the pre-log calibration is to adjust conversion factors to force the tool output to read known conductivity values induced in a manufacturer supplied conductive coil.

4.2.3.1 Using a nonconductive jig, suspend the probe at least 60" above the ground, away from metallic objects (including the logging vehicle) and away from sources of electromagnetic noise (high voltage power lines, generators, motors, and engines). Place the calibration coil around the probe, so that the coil's center tube is centered between the marks on the probe (the marks should be at 20.25" and 28.75" from the bottom of the probe). In this configuration the probe output should be forced to 1986 mS/m and 576 mS/m on the Medium and Deep channels, respectively.

4.2.3.2 While still suspended in the nonconductive jig, remove the calibration coil. In this configuration the probe output should be forced to 0 mS/m on both the Medium and Deep channels.

4.2.3.2 Pressing the "Store" button in the software will automatically calculate a linear equation to convert the probe's counts/second into mS/m.

4.2.3.4 With the time sample rate at 1 second, record a calibration file for a minimum of 30 seconds each with and without the calibration coil. The filename should indicate the probe model and serial number. For example, if using the DIL-45 SN2599, the calibration file name would be DIL2599a.RD (or DIL2599a.TFD if using the Matrix). Subsequent files should use “b”, “c”, etc. to differentiate pre from post, and with coil from without

4.2.3.5 Complete the Pre-Log portion of the “Dual Induction Checkout/Calibration” form.

4.2.4 Pre-log calibration procedure for the RGL DUIN

This procedure shall be performed before logging each well. The required tolerances are specified in 4.4.4.

The purpose of the pre-log calibration is to adjust conversion factors to force the tool output to read known conductivity values induced in a manufacturer supplied conductive coil.

4.2.4.1 Using a nonconductive jig, suspend the probe at least 60” above the ground, away from metallic objects (including the logging vehicle) and away from sources of electromagnetic noise (high voltage power lines, generators, motors, and engines).

4.2.4.2 Place the calibration coil around the probe, so that the coil’s center is directly over the lower mark on the probe (this marks should be at 18.75” from the bottom of the probe). In this configuration the probe output should be forced to 5231 mS/m on the Medium channel.

4.2.4.3 Place the calibration coil around the probe, so that the coil’s center is directly over the upper mark on the probe (this marks should be at 30.75” from the bottom of the probe). In this configuration the probe output should be forced to 6009 mS/m on the Deep channel.

4.2.4.4 While still suspended in the nonconductive jig, remove the calibration coil. In this configuration the probe output should be forced to 0 mS/m on both the Medium and Deep channels.

4.2.4.5 Pressing the “Store” button in the software will automatically calculate a linear equation to convert the probe’s counts/second into mS/m.

4.2.4.6 With the time sample rate at 1 second, record a calibration file for a minimum of 30 seconds each with and without the calibration coil. The filename should indicate the probe model and serial number. For example, if using the DUIN SN5550, the calibration file name might be DUI5550a.LOG. Subsequent files should use “b”, “c”, etc. to differentiate pre from post, and with coil from without.

4.2.4.7 Complete the Pre-Log portion of the “Dual Induction Checkout/Calibration” form.

4.2.4 Post-Log Calibration Check Procedure

The purpose of the post-log calibration check is to verify that no change in system performance has occurred during logging.

To perform the post-log calibration check, repeat the procedures for the pre-log calibration. The same file name should be used for the post-log check as was used for the pre-log calibrations, but “b”, “c”, etc. should be substituted, to differentiate pre from post, and with-coil from without..

Complete the “Post-Log” portion of the “Dual Induction Checkout/Calibration” form.

4.3 Precautions and Limits

4.3.1 Temperature and pressure limits are specified in the operations manuals of the specific logging probes.

4.3.2 Extreme differences between the downhole logging temperature and the uphole calibration temperature will cause a shift in the data.

4.3.3 The range within which a given device is accurate is different for the different measurement techniques. This range shall be specified for each device, and the appropriate device shall be selected for the borehole under investigation.

4.3.4 The properties of the borehole fluid should not influence the response of dual induction logs, provided the borehole diameter is less than about 10 inches. As the hole diameter increases, these effects become more influential.

4.3.5 The geometry of the logging probe, such as the positions of the source and measurement coils, affects the measurement values.

4.3.5.1 The ability of a given measurement to accurately measure resistivity across a thin bed is a function of the geometry and of the conductivity contrast and bed thickness.

4.3.5.2 The radius of investigation, away from the borehole, is a function of the geometry and the radial distribution of electrical properties.

4.3.6 The log should be recorded with the tool moving up the borehole, but measurements can be made while logging down, also. In fact, it is suggested that data be recorded while running into the well, just in case hole conditions or tool problems prevent getting a good log in the up direction.

4.4 Acceptance Criteria

Induction conductivity, and calculated resistivity, values shall be accepted for use based on the expectation that the results will be interpreted quantitatively.

4.4.1 Repeat sections for all measurements shall be similar to the main log, such that features visible in each match in depth and in the value of the measured data.

4.4.2 Depths of features in the log shall agree with other logs, if run.

4.4.3 After Survey Depth Error (ASDE) shall be within required tolerances as specified in TP-1.

5.0 DETAILED PROCEDURE

Dual Induction logs are typically recorded at 0.1 foot sample intervals. They are used to obtain information on the electrical properties of the geologic section including the soil, rock, and groundwater.

Dual Induction logs are typically run as one of a suite of logs during a single visit to a well site. Procedures prior to and upon arrival as described here pertain only to the specific requirements of Dual Induction logs. Where they do not conflict with the procedures detailed here, all of the procedures specified in TP-1 shall also be adhered to.

5.1 Prior to arrival

No added procedures are necessary beyond those detailed in TP-1.

5.2 On arrival

Establish the borehole total depth, diameter, and expected fluid temperature.

5.4 During Logging

5.4.1 Attach the logging probe to the wireline.

5.4.2 Perform a pre-log calibration.

The purpose of pre-log validation is to adjust conversion factors to achieve desired accuracy for the desired range.

The pre-log validation also provides data for comparison to a post-log validation check.

5.4.3 Set wireline depth zero at the measurement point. The depth zero should be taken with tension on the wireline similar to that expected while logging, to prevent slack in the cable from biasing the datum.

5.4.4 Lower the probe to the bottom of the interval to be logged.

5.4.5 Begin logging up at a rate not to exceed 30 feet per minute (20 ft/min, if a gamma is logged in conjunction).

5.4.6 Typically, a 50 foot repeat section is run first, followed by the main log. However, the repeat section may be run after the main log in order to identify a more interesting interval to repeat.

5.4.7 After completion of the first run, lower the probe back down to the bottom of the interval to be logged. Verify that the log response between the two runs is repeatable.

5.4.8 Upon completion of the second (or last) run, all of the data (including the pre-log calibration) should be backed up onto a storage media.

5.4.9 Return probe to the surface and determine the A.S.D.E.

5.4.10 Perform a post-log calibration check, and back up the file with the log data.

5.5 Prior to departure - no additional requirements beyond TP-1.

6.0 RECORDS

Records shall be provided as detailed in TP-1.

6.1 Data Deliverables

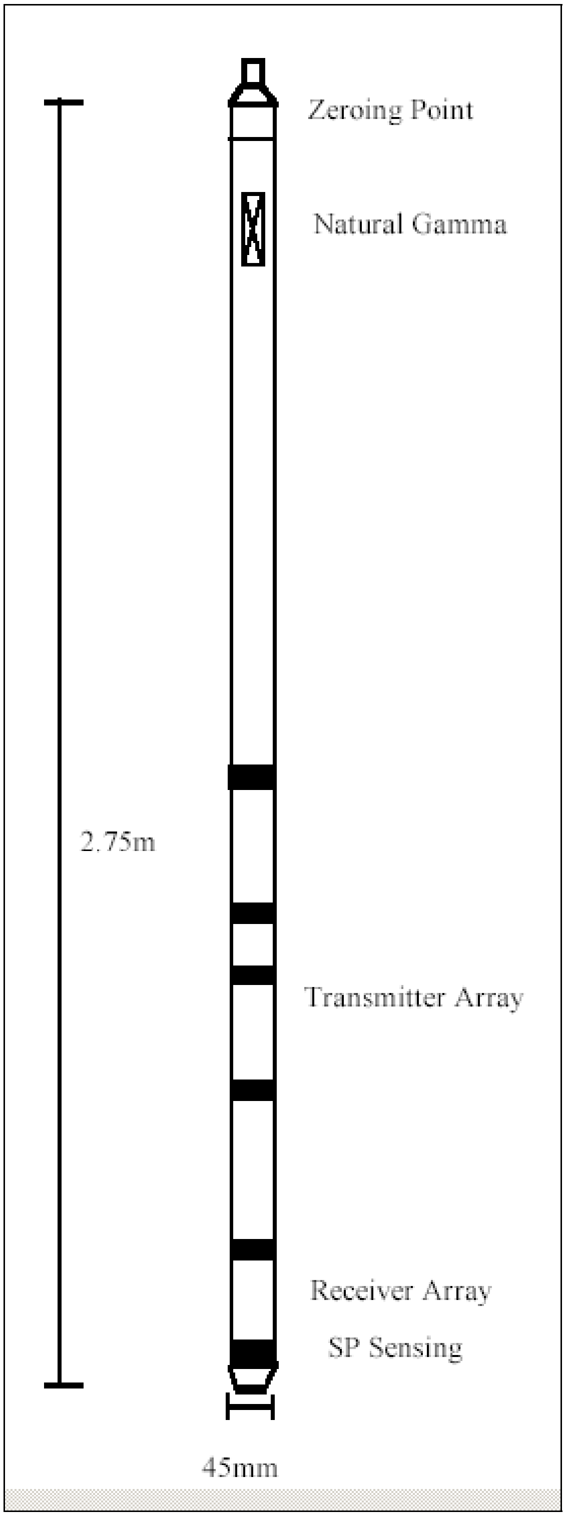
Data deliverables shall be as described in TP-1

7.0 APPENDICES

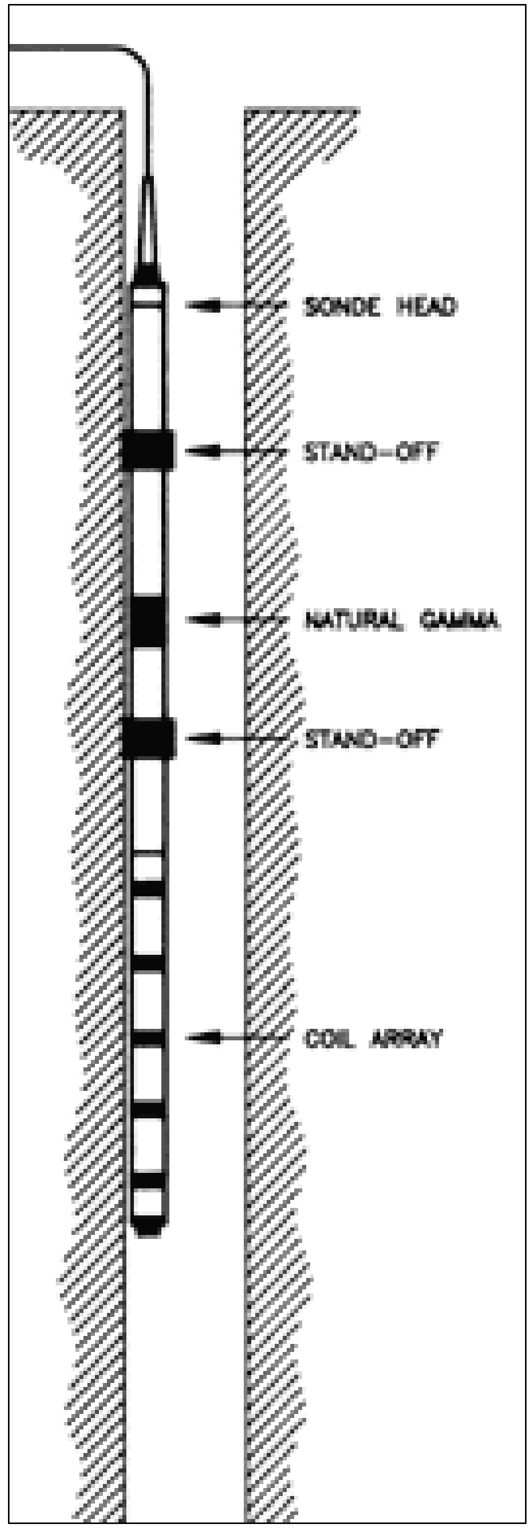
7.1 Dual Induction Tool Diagrams

7.2 "Dual Induction Checkout/Calibration" Form

Appendix 7.1



DIL-45



DUIN

Appendix 7.2

borehole geophysics / hydrophysics

Dual Induction Checkout/Calibration

Engineer:___________________ Location or Well Name__________________Unit No:___________

Probe Type & Serial No:______________________

Acquisition System Type & Serial No.:______________________

Pre-Log Check:

Date:_______________ Time:_______________

	Coil Value	Measured Value	Coil Value	Measured Value	File Name
Deep Induction	_________	___________	_________	___________	_____________
Medium Induction	_________	___________	_________	___________	_____________

Post-Log Check:

Date:_______________ Time:_______________

	Coil Value	Measured Value	Coil Value	Measured Value	File Name
Deep Induction	_________	___________	_________	___________	_____________
Medium Induction	_________	___________	_________	___________	_____________

Appendix A-F

Double-Ring Infiltrometer Test

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Designation: D3385 – 09

Standard Test Method for Infiltration Rate of Soils in Field Using Double-Ring Infiltrometer[1]

This standard is issued under the fixed designation D3385; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (ε) indicates an editorial change since the last revision or reapproval.

This standard has been approved for use by agencies of the U.S. Department of Defense.

1. Scope

1.1 This test method describes a procedure for field measurement of the rate of infiltration of liquid (typically water) into soils using double-ring infiltrometer.

1.2 Soils should be regarded as natural occurring fine or coarse-grained soils or processed materials or mixtures of natural soils and processed materials, or other porous materials, and which are basically insoluble and are in accordance with requirements of 1.5.

1.3 This test method is particularly applicable to relatively uniform fine-grained soils, with an absence of very plastic (fat) clays and gravel-size particles and with moderate to low resistance to ring penetration.

1.4 This test method may be conducted at the ground surface or at given depths in pits, and on bare soil or with vegetation in place, depending on the conditions for which infiltration rates are desired. However, this test method cannot be conducted where the test surface is below the groundwater table or perched water table.

1.5 This test method is difficult to use or the resultant data may be unreliable, or both, in very pervious or impervious soils (soils with a hydraulic conductivity greater than about 10^{-2} cm/s or less than about 1×10^{-6} cm/s) or in dry or stiff soils that most likely will fracture when the rings are installed. For soils with hydraulic conductivity less than 1×10^{-6} cm/s refer to Test Method D5093.

1.6 This test method cannot be used directly to determine the hydraulic conductivity (coefficient of permeability) of the soil (see 5.2).

1.7 The values stated in SI units are to be regarded as the standard.

1.8 *This standard does not purport to address all of the safety concerns, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.*

2. Referenced Documents

2.1 *ASTM Standards:*[2]

D653 Terminology Relating to Soil, Rock, and Contained Fluids
D1452 Practice for Soil Exploration and Sampling by Auger Borings
D2216 Test Methods for Laboratory Determination of Water (Moisture) Content of Soil and Rock by Mass
D2488 Practice for Description and Identification of Soils (Visual-Manual Procedure)
D3740 Practice for Minimum Requirements for Agencies Engaged in Testing and/or Inspection of Soil and Rock as Used in Engineering Design and Construction
D5093 Test Method for Field Measurement of Infiltration Rate Using Double-Ring Infiltrometer with Sealed-Inner Ring

3. Terminology

3.1 *Definitions*—For common definitions of terms in this standard, refer to Terminology D653.

3.2 *Definitions of Terms Specific to This Standard:*

3.2.1 *incremental infiltration velocity*—the quantity of flow per unit area over an increment of time. It has the same units as the infiltration rate.

3.2.2 *infiltration*—the downward entry of liquid into the soil.

3.2.3 *infiltration rate*—a selected rate, based on measured incremental infiltration velocities, at which liquid can enter the soil under specified conditions, including the presence of an excess of liquid. It has the dimensions of velocity (that is, $cm^3 cm^{-2} h^{-1} = cm\ h^{-1}$).

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[1] This test method is under the jurisdiction of ASTM Committee D18 on Soil and Rock and is the direct responsibility of Subcommittee D18.04 on Hydrologic Properties and Hydraulic Barriers.

Current edition approved March 1, 2009. Published March 2009. Originally approved in 1975. Last previous edition approved in 2003 as D3385 – 03. DOI: 10.1520/D3385-09.

[2] For referenced ASTM standards, visit the ASTM website, www.astm.org, or contact ASTM Customer Service at service@astm.org. For *Annual Book of ASTM Standards* volume information, refer to the standard's Document Summary page on the ASTM website.

3.2.4 *infiltrometer*—a device for measuring the rate of entry of liquid into a porous body, for example, water into soil.

4. Summary of Test Method

4.1 The double-ring infiltrometer method consists of driving two open cylinders, one inside the other, into the ground, partially filling the rings with water or other liquid, and then maintaining the liquid at a constant level. The volume of liquid added to the inner ring, to maintain the liquid level constant is the measure of the volume of liquid that infiltrates the soil. The volume infiltrated during timed intervals is converted to an incremental infiltration velocity, usually expressed in centimetre per hour or inch per hour and plotted versus elapsed time. The maximum-steady state or average incremental infiltration velocity, depending on the purpose/application of the test is equivalent to the infiltration rate.

5. Significance and Use

5.1 This test method is useful for field measurement of the infiltration rate of soils. Infiltration rates have application to such studies as liquid waste disposal, evaluation of potential septic-tank disposal fields, leaching and drainage efficiencies, irrigation requirements, water spreading and recharge, and canal or reservoir leakage, among other applications.

5.2 Although the units of infiltration rate and hydraulic conductivity of soils are similar, there is a distinct difference between these two quantities. They cannot be directly related unless the hydraulic boundary conditions are known, such as hydraulic gradient and the extent of lateral flow of water, or can be reliably estimated.

5.3 The purpose of the outer ring is to promote one-dimensional, vertical flow beneath the inner ring.

5.4 Many factors affect the infiltration rate, for example the soil structure, soil layering, condition of the soil surface, degree of saturation of the soil, chemical and physical nature of the soil and of the applied liquid, head of the applied liquid, temperature of the liquid, and diameter and depth of embedment of rings.[3] Thus, tests made at the same site are not likely to give identical results and the rate measured by the test method described in this standard is primarily for comparative use.

5.5 Some aspects of the test, such as the length of time the tests should be conducted and the head of liquid to be applied, must depend upon the experience of the user, the purpose for testing, and the kind of information that is sought.

NOTE 1—The quality of the result produced by this standard is dependent on the competence of the personnel performing it, and the suitability of the equipment and facilities used. Agencies that meet the criteria of Practice D3740 are generally considered capable of competent and objective testing/sampling/inspection/etc. Users of this standard are cautioned that compliance with Practice D3740 does not in itself assure reliable results. Reliable results depend on many factors; Practice D3740 provides a means of evaluating some of those factors.

6. Apparatus

6.1 *Infiltrometer Rings*—Cylinders approximately 500 mm (20 in.) high and having diameters of about 300 and 600 mm (12 and 24 in.). Larger cylinders may be used, providing the ratio of the outer to inner cylinders is about two. Cylinders can be made of 3-mm (⅛-in.), hard-alloy, aluminum sheet or other material sufficiently strong to withstand hard driving, with the bottom edge bevelled (see Fig. 1). The bevelled edges shall be kept sharp. Stainless steel or strong plastic rings may have to be used when working with corrosive fluids.

6.2 *Driving Caps*—Disks of 13-mm (½-in.) thick hard-alloy aluminum with centering pins around the edge, or preferably having a recessed groove about 5 mm (0.2 in.) deep with a width about 1 mm (0.05 in.) wider than the thickness of the ring. The diameters of the disks should be slightly larger than those of the infiltrometer rings.

6.3 *Driving Equipment*—A 5.5-kg (12-lb) mall or sledge and a 600 or 900-mm (2 or 3-ft) length of wood approximately 50 by 100 mm or 100 by 100 mm (2 by 4 in. or 4 by 4 in.), or a jack and reaction of suitable size.

6.4 *Depth Gage*—A hook gage, steel tape or rule, or length of steel or plastic rod pointed on one end, for use in measuring and controlling the depth of liquid (head) in the infiltrometer ring, when either a graduated Mariotte tube or automatic flow control system is not used.

6.5 *Splash Guard*—Several pieces of rubber sheet or burlap 150 mm (6 in.) square.

6.6 *Rule or Tape*—Two-metre (6-ft) steel tape or 300-mm (1-ft) steel rule.

6.7 *Tamp*—Any device that is basically rigid, has a handle not less than 550 mm (22 in.) in length, and has a tamping foot

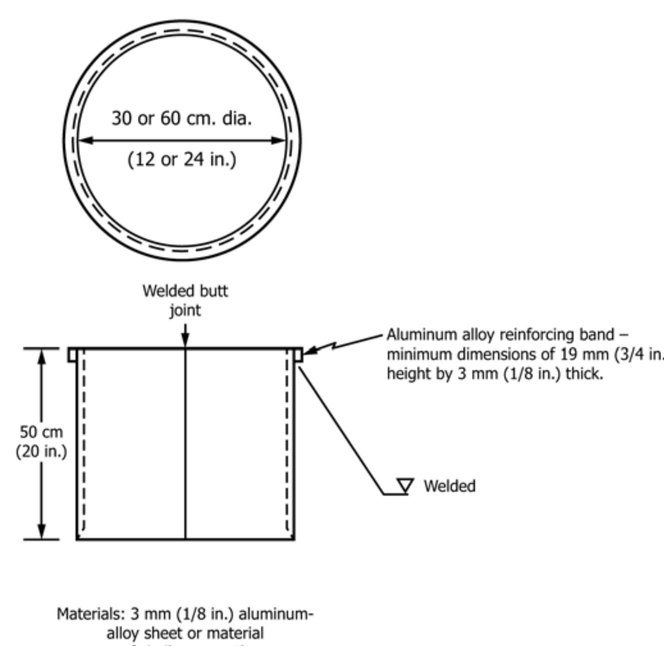


FIG. 1 Infiltrometer Construction

[3] Discussion of factors affecting infiltration rate is contained in the following reference: Johnson, A. I., *A Field Method for Measurement of Infiltration*, U.S. Geological Survey Water-Supply Paper 1544-F, 1963, pp. 4–9.

with an area ranging from 650 to 4000 mm^2 (1 to 6 in.^{2}) and a maximum dimension of 150 mm (6 in.).

6.8 *Shovels*—One long-handled shovel and one trenching spade.

6.9 *Liquid Containers:*

6.9.1 One 200-L (55-gal) barrel for the main liquid supply, along with a length of rubber hose to siphon liquid from the barrel to fill the calibrated head tanks (see 6.9.3).

6.9.2 A 13-L (12-qt) pail for initial filling of the infiltrometers.

6.9.3 Two calibrated head tanks for measurement of liquid flow during the test. These may be either graduated cylinders or Mariotte tubes having a minimum volume capacity of about 3000 mL (see Note 2 and Note 3 and Fig. 2).

NOTE 2—It is useful to have one head tank with a capacity of three times that of the other because the area of the annular space between the rings is about three times that of the inner ring.

NOTE 3—In many cases, the volume capacity of these calibrated head tanks must be significantly larger than 3000 mL, especially if the test has to continue overnight. Capacities of about 50 L (13 gal) would not be uncommon.

6.10 *Liquid Supply*—Water, or preferably, liquid of the same quality and temperature as that involved in the problem being examined. The liquid used must be chemically compatible with the infiltrometer rings and other equipment used to contain the liquid.

NOTE 4—To obtain maximum infiltration rates, the liquid should be free from suspended solids and the temperature of the liquid should be higher than the soil temperature. This will tend to avoid reduction of infiltration from blockage of voids by particles or gases coming out of solution.

6.11 *Watch or Stopwatch*—A stopwatch would only be required for high infiltration rates.

6.12 *Level*—A carpenter's level or bull's-eye (round) level.

6.13 *Thermometer*—With accuracy of 0.5°C and capable of measuring ground temperature.

6.14 *Rubber Hammer (mallet).*

6.15 *pH Paper,* in 0.5 increments.

6.16 *Recording Materials*—Record books and graph paper, or special forms with graph section (see Fig. 3 and Fig. 4).

6.17 *Hand Auger*—Orchard-type (barrel-type) auger with 75-mm (3-in.) diameter, 225-mm (9-in.) long barrel and a rubber-headed tire hammer for knocking sample out of the auger. This apparatus is optional.

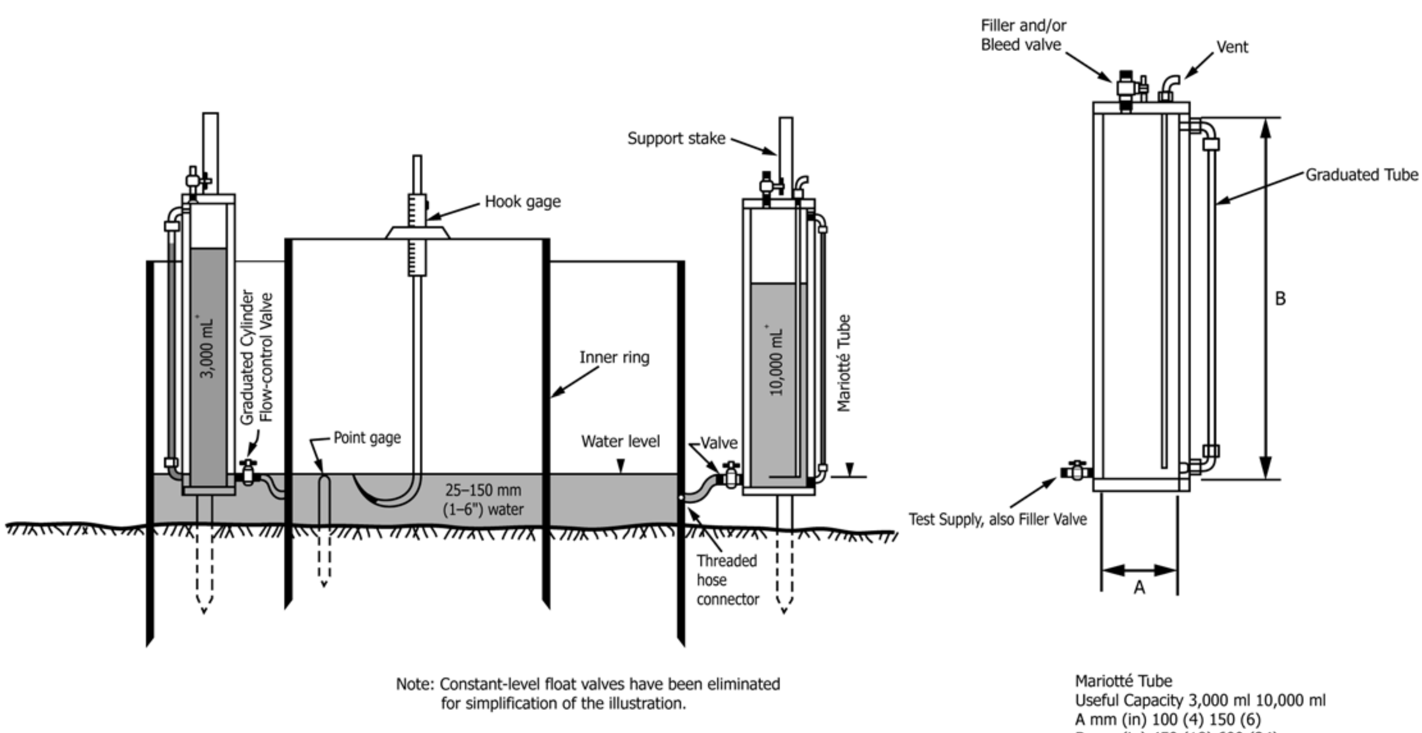
6.18 *Float Valves*—Two constant level float valves (carburetors or bob-float types) with support stands. This apparatus is optional.

6.19 *Covers and Dummy Tests Set-Up*—For long-term tests in which evaporation of fluid from the infiltration rings and unsealed reservoirs can occur (see 8.2.1).

7. Calibration

7.1 *Rings:*

7.1.1 Determine the area of each ring and the annular space between rings before initial use and before reuse after anything has occurred, including repairs, which may affect the test results significantly.



NOTE 1—Constant-level float valves have been eliminated for simplification of the illustration

FIG. 2 Ring Installation and Mariotte Tube Details

Project Identification: NRTS	Constants	Area (cm^2)	Depth of Liquid (cm)	Liquid No.	Containers Vol/ΔH (cm^2/cm)
Test Location: IDAHO - Lost River Alluvium	Inner Ring	707	4.0	1	78.54
Liquid Used: River water pH = 8.0	Annular Space	2106	4.1	2	176.7

Tested by IJA CWJ Liquid level maintained using: Mariotte Tube

Depth to water table: 5.2 m Penetration of rings -- Inner: 7.5 cm ; Outer: 17.5 cm Date: 10/14/1982

Trial No.		Time (hr:min)	Elapsed Time: Δ/total (min)	Flow Readings: Inner Reading: Reading (cm)	Flow (cm^3)	Annular Space: Reading (cm)	Flow (cm^3)	Liquid Temp (°C)	Incremental Infiltration Rate: Inner (cm/h)	Annular (cm/h)	Ground Temperature = 14°C at depth of 30 cm Remarks: Weather Conditions, etc.
1	S	10:00	15	30	114	2.2	389	15	0.64	0.74	Cloudy, slight wind
	E	10:15	(15)	4.45		4.4		"			
2	S	10:15	15	4.45	212	4.4	795	15	1.2	1.5	
	E	10:30	(30)	7.15		8.9		"			
3	S	10:30	15	7.15	263	8.9	848	15	1.5	1.6	
	E	10:45	(45)	10.5		13.7		"			
4	S	10:45	15	10.5	306	13.7	945	15	1.7	1.8	
	E	11:00	(60)	14.4		19.05		15.5			
5	S	11:00	30	14.4	758	19.05	2324	15.5	2.1	2.2	
	E	11:30	(90)	24.05		32.2		16			
6	S	11:30	30	24.05	848	32.2	2580	16	2.4	2.45	
	E	12:00	(120)	34.85		46.8		16.5			
7	S	12:10	60	3.5	1944	2.2	5902	16.5	2.75	2.8	Refilled tubes
	E	13:10	(180)	28.25		35.6		17			
8	S	13:20	60	2.4	1877	3.2	5690	17.5	2.65	2.7	" "
	E	14:20	(240)	26.3		35.4		"			
9	S	14:30	60	4.3	1696	4.7	5054	17.5	2.4	2.4	" "
	E	15:30	(300)	25.9		33.3		18			
10	S	15:40	60	2.2	1586	4.5	4842	18	2.2	2.3	" "
	E	16:40	(360)	22.4		31.9		"			Cloudy, slight wind

FIG. 3 Data Form for Infiltration Test with Sample Data

7.1.2 Determine the area using a measuring technique that will provide an overall accuracy of 1 %.

7.1.3 The area of the annular space between rings is equal to the internal area of the 600-mm (24-in.) ring minus the external area of the 300-mm (12-in.) ring.

7.2 *Liquid Containers*—For each graduated cylinder or graduated Mariotte tube, establish the relationship between the change in elevation of liquid (fluid) level and change in volume of fluid. This relationship shall have an overall accuracy of 1 %.

8. Procedure

8.1 *Test Site:*

8.1.1 Establish the soil strata to be tested from the soil profile determined by the classification of soil samples from an adjacent auger hole.

NOTE 5—For the test results to be valid for soils below the test zone, the soil directly below the test zone must have equal or greater flow rates than the test zone.

8.1.2 The test requires an area of approximately 3 by 3 m (10 by 10 ft) accessible by a truck.

8.1.3 The test site should be nearly level, or a level surface should be prepared.

8.1.4 The test may be set up in a pit if infiltration rates are desired at depth rather than at the surface.

8.2 *Technical Precautions:*

8.2.1 For long-term tests, avoid unattended sites where interference with test equipment is possible, such as sites near children or in pastures with livestock. Also, evaporation of fluid from the rings and unsealed reservoirs can lead to errors in the measured infiltration rate. Therefore, in such tests, completely cover the top of the rings and unsealed reservoirs with a relatively airtight material, but vented to the atmosphere through a small hole or tube. In addition, make measurements to verify that the rate of evaporation in a similar test configuration (without any infiltration into the soil) is less than 20% of the infiltration rate being measured.

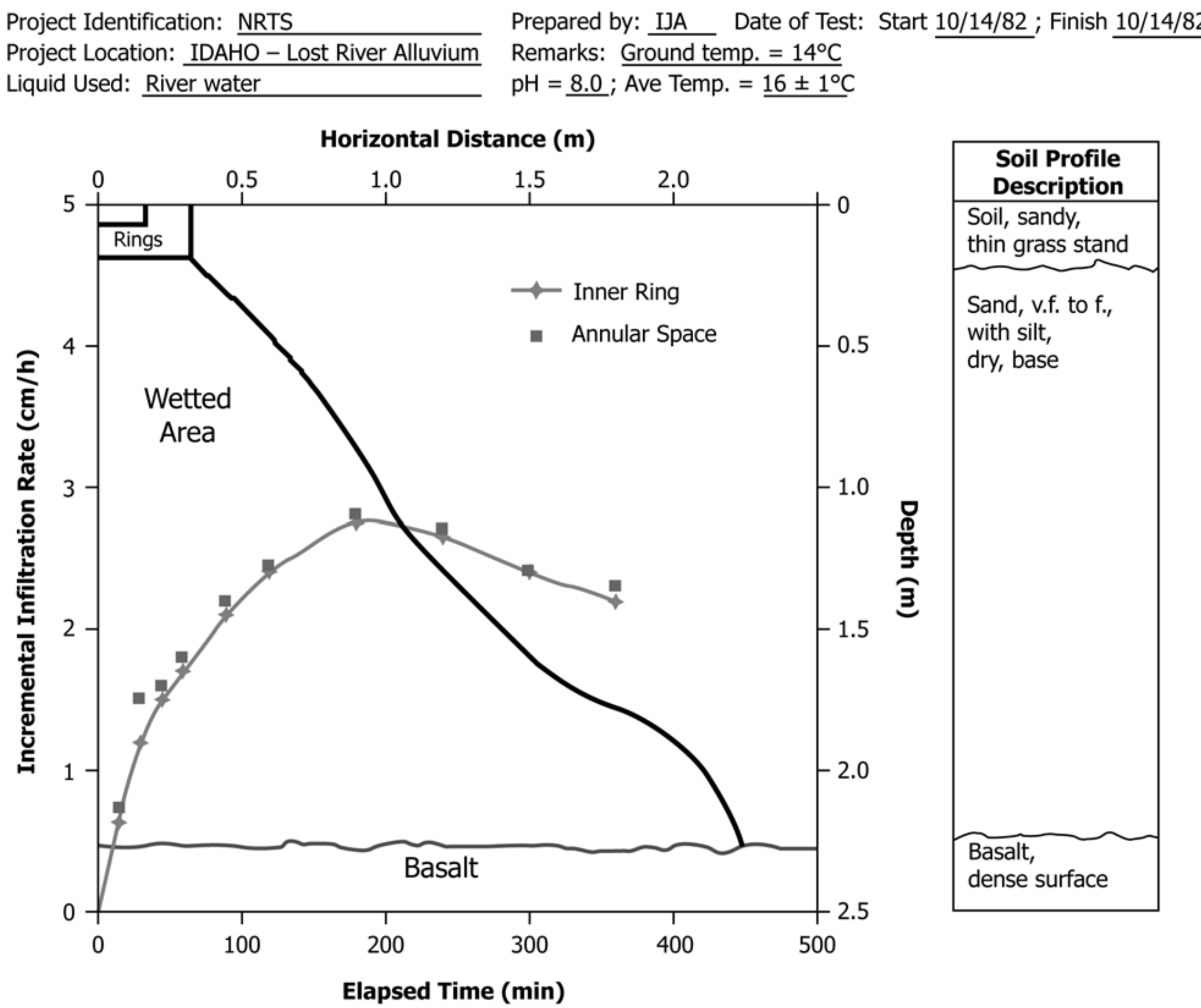


FIG. 4 Report Form for Infiltration Test With Sample Data

8.2.2 Make provisions to protect the test apparatus and fluid from direct sunlight and temperature variations that are large enough to affect the slow measurements significantly, especially for test durations greater than a few hours or those using a Mariotte tube. The expansion or contraction of the air in the Mariotte tube above the water due to temperature changes may cause changes in the rate of flow of the liquid from the tube which will result in a fluctuating water level in the infiltrometer rings.

8.3 *Driving Infiltration Rings with a Sledge:*

NOTE 6—Driving rings with a jack is preferred; see 8.4.

8.3.1 Place the driving cap on the outer ring and center it thereon. Place the wood block (see 6.3) on the driving cap.

8.3.2 Drive the outer ring into the soil with blows of a heavy sledge on the wood block to a depth that will (*a*) prevent the test fluid from leaking to the ground surface surrounding the ring, and (*b*) be deeper than the depth to which the inner ring will be driven. A depth of about 150 mm (6 in.) is usually adequate. Use blows of medium force to prevent fracturing of the soil surface. Move the wood block around the edge of the driving cap every one or two blows so that the ring will penetrate the soil uniformly. A second person standing on the wood block and driving cap will usually facilitate driving the ring, and reduce vibrations and disturbance.

8.3.3 Center the smaller ring inside the larger ring and drive to a depth that will prevent leakage of the test fluid to the ground surface surrounding the ring, using the same technique as in 8.3.2. A depth of between about 50 and 100 mm (2 and 4 in.) is usually adequate.

8.4 *Driving Infiltration Rings with Jacks:*

8.4.1 Use a heavy jack under the back end of a truck to drive rings as an alternative to the sledge method (see 8.3).

8.4.2 Center the wood block across the driving cap of the ring. Center a jack on the wood block. Place the top of the jack and the assembled items vertically under the previously positioned end of a truck body and apply force to the ring by means of the jack and truck reaction. Also, tamp near the edges or near the center of the ring with the rubber mallet, as slight tamping and vibrations will reduce hang-ups and tilting of the ring.

8.4.3 Add additional weight to the truck if needed to develop sufficient force to drive the ring.

8.4.4 Check the rings with the level, correcting the attitude of the rings to be vertical, as needed.

8.5 *Tamping Disturbed Soil:*

8.5.1 If the surface of the soil surrounding the wall of the ring(s) is excessively disturbed (signs of extensive cracking, excessive heave, and the like), reset the ring(s) using a technique that will minimize such disturbance.

8.5.2 If the surface of the soil surrounding the wall of the ring(s) is only slightly disturbed, tamp the disturbed soil adjacent to the inside and outside wall of the ring(s) until the soil is as firm as it was prior to disturbance.

8.6 *Maintaining Liquid Level:*

8.6.1 There are basically three ways to maintain a constant head (liquid level) within the inner ring and annular space between the two rings: manually controlling the flow of liquid, the use of constant-level float valves, or the use of a Mariotte tube.

8.6.2 When manually controlling the flow of liquid, a depth gage is required to assist the investigator visually in maintaining a constant head. Use a depth gage such as a steel tape or rule for soils having a relatively high permeability; for soils having a relatively low permeability use a hook gage or simple point gage.

8.6.3 Install the depth gages, constant-level valves, or Mariotte tubes as shown in Fig. 2, and in such a manner that the reference head will be at least 25 mm (1 in.) and not greater than 150 mm (6 in.). Select the head on the basis of the permeability of the soil, the higher heads being required for lower permeability soils. Locate the depth gages near the center of the center ring and midway between the two rings.

8.6.4 Cover the soil surface within the center ring and between the two rings with splash guards (150-mm (6-in.) square pieces of burlap or rubber sheet) to prevent erosion of the soil when the initial liquid supply is poured into the rings.

8.6.5 Use a pail to fill both rings with liquid to the same desired depth in each ring. Do not record this initial volume of liquid. Remove the splash guards.

8.6.6 Start flow of fluid from the graduated cylinders or Mariotte tubes. As soon as the fluid level becomes basically constant, determine the fluid depth in the inner ring and in the annular space to the nearest 2 mm (1⁄16 in.) using a ruler or tape measure. Record these depths. If the depths between the inner ring and annular space varies more than 5 mm (1⁄4 in.), raise the depth gage, constant-level float valve, or Mariotte tube having the shallowest depth.

8.6.7 Maintain the liquid level at the selected head in both the inner ring and annular space between rings as near as possible throughout the test, to prevent flow of fluid from one ring to the other.

NOTE 7—This most likely will require either a continuing adjustment of the flow control valve on the graduated cylinder, or the use of constant-level float valves. A rapid change in temperature may eliminate use of the Mariotte tube.

8.7 *Measurements:*

8.7.1 Record the ground temperature at a depth of about 300 mm (12 in.), or at the mid-depth of the test zone.

8.7.2 Determine and record the volume of liquid that is added to maintain a constant head in the inner ring and annular space during each timing interval by measuring the change in elevation of liquid level in the appropriate graduated cylinder or Mariotte tube. Also, record the temperature of the liquid within the inner ring.

8.7.3 For average soils, record the volume of liquid used at intervals of 15 min for the first hour, 30 min for the second hour, and 60 min during the remainder of a period of at least 6 h, or until after a relatively constant rate is obtained.

8.7.4 The appropriate schedule of readings may be determined only through experience. For high-permeability materials, readings may be more frequent, while for low-permeability materials, the reading interval may be 24 h or more. In any event, the volume of liquid used in any one reading interval should not be less than approximately 25 cm^3.

8.7.5 Place the driving cap or some other covering over the rings during the intervals between liquid measurements to minimize evaporation (see 8.2.1).

8.7.6 Upon completion of the test, remove the rings from the soil, assisted by light hammering on the sides with a rubber hammer.

9. Calculations

9.1 Convert the volume of liquid used during each measured time interval into an incremental infiltration velocity for both the inner ring and annular space using the following equations:

9.1.1 For the inner ring calculate as follows:

$$V_{IR} = \Delta V_{IR}/(A_{IR} \cdot \Delta t) \quad (1)$$

where:

V_{IR} = inner ring incremental infiltration velocity, cm/h,
ΔV_{IR} = volume of liquid used during time interval to maintain constant head in the inner ring, cm^3,
A_{IR} = internal area of inner ring, cm^2, and
Δt = time interval, h.

9.1.2 For the annular space between rings calculate as follows:

$$V_A = \Delta V_A/(A_A \cdot \Delta t) \quad (2)$$

where:

V_A = annular space incremental infiltration velocity, cm/h,
ΔV_A = volume of liquid used during time interval to maintain constant head in the annular space between the rings, cm^3, and
A_A = area of annular space between the rings, cm^2.

10. Report

10.1 Report the following information in the report or field records, or both:

10.1.1 Location of test site.

10.1.2 Dates of test, start and finish.

10.1.3 Weather conditions, start to finish.

10.1.4 Name(s) of technician(s).

10.1.5 Description of test site, including boring profile, see 10.1.12.

10.1.6 Type of liquid used in the test, along with the liquid's pH. If available, a full analysis of the liquid also should be recorded.

10.1.7 Areas of rings and the annular space between rings (nearest 1 cm^2 or better).

10.1.8 Volume constants for graduated cylinders or Mariotte tubes (nearest 0.01 cm^3 or better).

10.1.9 Depth of liquid in inner ring and annular space (nearest 2 mm or better).

10.1.10 Record of ground and liquid temperatures (nearest 0.5°C), incremental volume measurements (nearest 1 cm^3 or better), and elapsed time (nearest 1 min. or better).

10.1.11 Incremental infiltration velocities (use 3 significant digits) for inner ring and annular space. The rate of the inner ring should be the value used if the rates for inner ring and annular space differ. The difference in rates is due to divergent flow.

10.1.12 If available, depth to the water table and a description of the soils found between the rings and the water table, or to a depth of about 1 m (3 ft).

10.1.13 A plot of the incremental infiltration rate versus total elapsed time (see Fig. 4).

10.2 An example field records form is given in Fig. 3.

10.3 See Appendix X1 for information on the determination of the moisture pattern.

11. Precision and Bias

11.1 No statement on precision and bias can be made due to the variability in soils tested and in the types of liquids that might be used in this test method. Because of the many factors related to the soils, as well as the liquids that may affect the results, the recorded infiltration rate should be considered only as an index value.

12. Keywords

12.1 coefficient of permeability; hydraulic conductivity; infiltration rate; infiltrometer; in-situ testing; Mariotte tube

APPENDIX

(Nonmandatory Information)

X1. DETERMINATION OF MOISTURE PATTERN

X1.1 Although not considered a required part of the test method, the determination of the moisture pattern in the moistened soil beneath the infiltration rings commonly provides information useful in interpreting the movement of liquid through the soil profile. For example, horizontal liquid movement may be caused by lower-permeability layers and will be identified by a lateral spreading of the wetted zone. Thus, the exploration of the soil moisture pattern below an infiltration test in an unfamiliar area may identify subsurface conditions that may have affected the test and later applications of the data.

X1.2 If the investigator wishes to make such a study, dig a trench so that one wall of the trench passes along the center line of the former position of the rings. Orient the trench so that the other wall is illuminated by the sun, if the day is sunny. If feasible, dig the trench large enough to include all of the newly moistened area. Collect samples from the shaded wall of the trench for determination of water content. If preferred, an auger, such as the orchard barrel type, may be used to determine the approximate outline of the moistened area below the rings and to collect samples for water content.

X1.3 Plot the visibly moistened area on graph paper or on the cross-section part of the report form (see Fig. 4). If samples were collected and water contents were determined, contours of water content also can be plotted on the graph.

Appendix B

Construction Drawings

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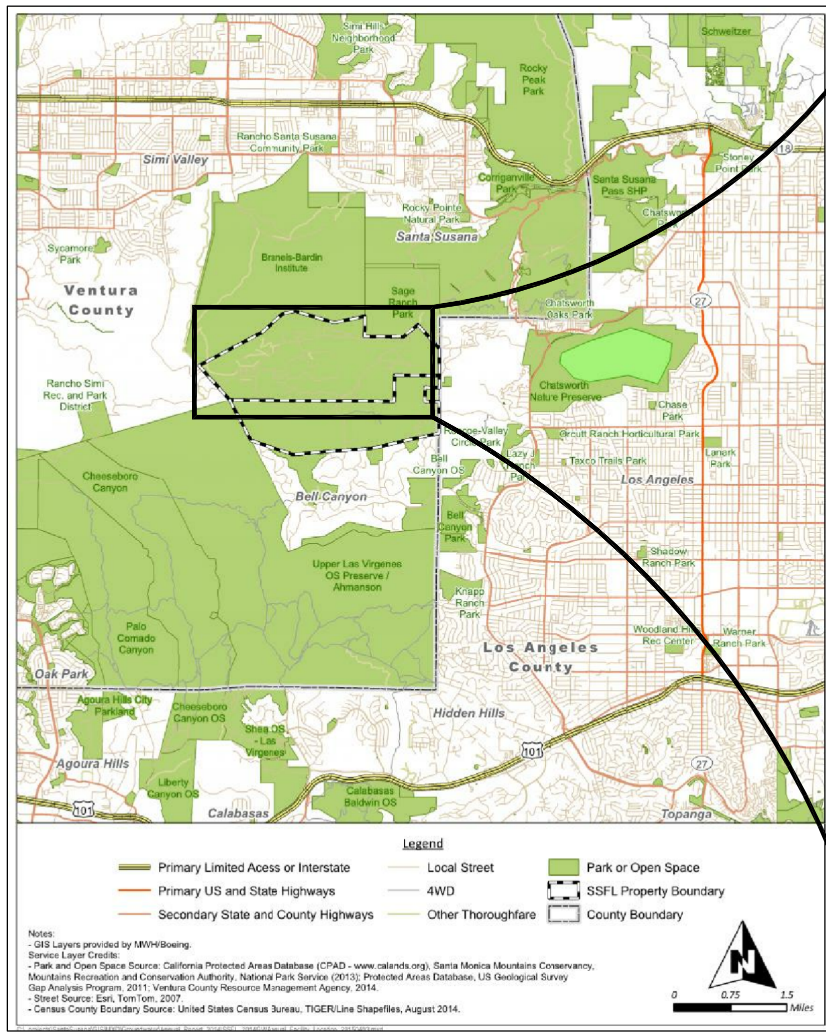
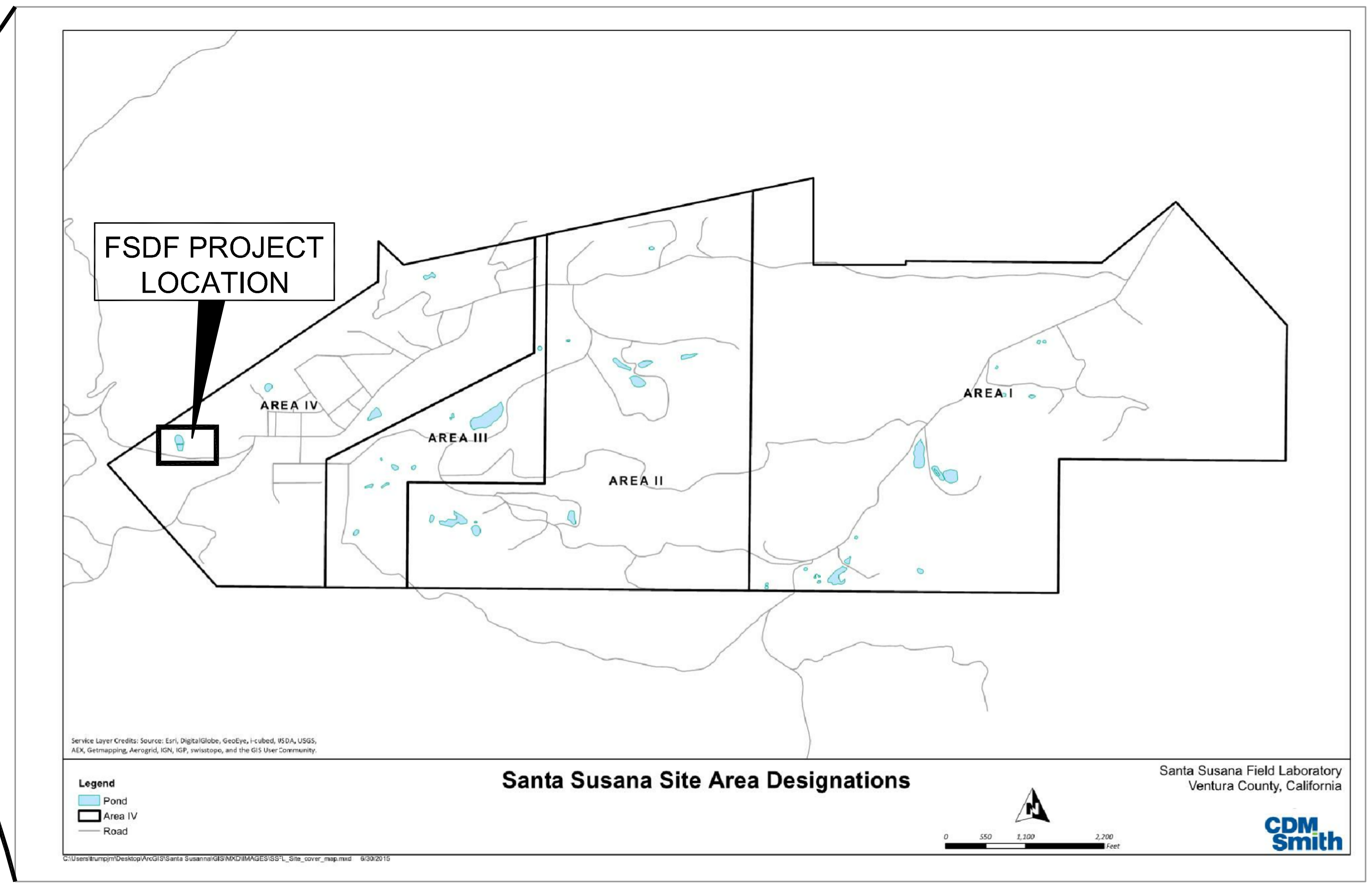
SANTA SUSANA FIELD LABORATORY
FORMER SODIUM DISPOSAL FACILITY
GROUNDWATER INTERIM MEASURE
IMPLEMENTATION PLAN
CONSTRUCTION DRAWINGS - SEPT 2015



VICINITY MAP



PROJECT LOCATION MAP

SHEET INDEX

SHEET NO.	DWG TITLE
G-1	COVER SHEET
G-2	EQUIPMENT SPECIFICATIONS SHOWING GENERAL INFORMATION FOR TREATMENT EQUIPMENT AND APPURTENANCES.
P-1	PROCESS FLOW DIAGRAM SHOWING THE MAJOR EQUIPMENT AND INTERCONNECTION AND MASS BALANCE.
P-2	PIPING AND INSTRUMENTATION DIAGRAM EXPANDING ON THE EQUIPMENT INFORMATION, INTERCONNECTION PIPING AND RELATED INSTRUMENTATION.
M-1	SITE PLAN FOCUSING ON THE FSDF AREA INCLUDING TOPOGRAPHIC, EXISTING FEATURES, PONDS, WELLS, UTILITIES AND PROPOSED WORK.
M-2	MECHANICAL PLAN SHOWING THE LAYOUT, AND LOCATIONS OF TREATMENT EQUIPMENT AND INTERCONNECTED PIPING.
M-3	CONSTRUCTION DETAILS SHOWING THE SECTIONS AND DETAILS TO FACILITATE CONSTRUCTION OF SYSTEM.
E-1	ELECTRICAL SINGLE LINE AND LOAD SCHEDULE PROVIDING INFORMATION ON POWER REQUIREMENTS.
E-2	ELECTRICAL LAYOUT AND DETAILS SHOWING THE PLACEMENTS OF PANELS AND DEVICES AND ELECTRICAL CONNECTIONS...

PROJECT INFORMATION

ABOUT SSFL
SOURCE:
www.dtsc.ca.gov/SiteCleanup/Santa_Susana_Field_Lab/.

THE SANTA SUSANA FIELD LABORATORY (SSFL) IS LOCATED 30 MILES NORTHWEST OF DOWNTOWN LOS ANGELES IN SOUTHEASTERN VENTURA COUNTY, NEAR THE CREST OF THE SIMI HILLS AT THE WESTERN BORDER OF THE SAN FERNANDO VALLEY. A FORMER ROCKET ENGINE TEST AND NUCLEAR RESEARCH FACILITY, THE 2,849-ACRE FIELD LABORATORY IS CURRENTLY THE FOCUS OF A COMPREHENSIVE ENVIRONMENTAL INVESTIGATION AND CLEANUP PROGRAM, CONDUCTED BY BOEING, THE UNITED STATES DEPARTMENT OF ENERGY (DOE) AND THE NATIONAL AERONAUTICS AND SPACE ADMINISTRATION (NASA), AND OVERSEEN BY THE DEPARTMENT OF TOXIC SUBSTANCES CONTROL.

AREA IV

AREA IV CONSISTS OF 290 ACRES OWNED AND OPERATED BY ROCKETDYNE AND 90 ACRES LEASED BY THE DOE. DOE AND ITS CONTRACTORS OPERATED SEVERAL NUCLEAR REACTORS AND ASSOCIATED FUEL FACILITIES AND LABORATORIES WITHIN THIS AREA. THIS AREA ALSO INCLUDES FIVE SURFACE WATER DISCHARGE OUTFALLS MONITORED BY THE LOS ANGELES REGIONAL WATER QUALITY BOARD.

FSDF LOCATION

THE FORMER SODIUM DISPOSAL FACILITY (FSDF) IS LOCATED AT THE WESTERN PORTION OF AREA IV OF THE SANTA SUSANA FIELD LABORATORY AS SHOWN IN THE LOCATION MAP.

SCOPE

THE SCOPE OF THIS ACTION WILL INCLUDE AQUIFER PROPERTY TESTING, EXTENDED AQUIFER PUMPING, TREATMENT OF EXTRACTED GROUNDWATER, AND RELEASE OF TREATED WATER AT THE FSDF SITE.

THE DESIGN INCLUDES PUMPING FROM ONE OF THE SELECTED AQUIFER WELLS. THE EXTRACTED GROUNDWATER IS CONVEYED VIA ABOVEGROUND PIPING TO A TEMPORARY TREATMENT LOCATION FOR TREATMENT. THE TREATED WATER IS CONVEYED TO A INFILTRATION TRENCH.

CLIENT TEAM

US DEPARTMENT OF ENERGY
JOHN B JONES, ETEC FEDERAL PROJECT DIRECTOR
STEPHANIE JENNINGS, ETEC FEDERAL DEPUTY PROJECT DIRECTOR

BOEING
DAVE DASSLER, PROJECT DIRECTOR

CONTRACTOR TEAM

CDM SMITH
JOHN WONDOLLECK, PROJECT MANAGER
STEVE FUNDINGSLAND, LEAD GEOLOGIST
MIKE HOFFMAN, SENIOR GEOLOGIST
MIKE GOH, SENIOR ENGINEER

REGULATOR TEAM

DEPARTMENT OF THE TOXIC SUBSTANCES CONTROL
RAY LECLERC, PROJECT DIRECTOR
MARK MALINOZSKI, PROJECT TEAM MANAGER

LOS ANGELES REGIONAL WATER QUALITY CONTROL BOARD
CASSANDRA OWENS, UNIT CHIEF
ERIC WU, ENGINEER, GROUNDWATER PERMITTING

CDM Smith

C:\cdmxm\riehlepj\d1260228\ RD-2013-G-01 01/23/14 08:00 riehlepj XREFS: RD-Vicinity, 2014 RECORD DWG-A-ALTERNATE

Tag No.	Equipment Description	Purpose	Manufacturer	Model No.	Capacity / Rating	Type / Material	Dimension	Inlet/Outlet	Weight (Lbs)
P-AQF	Aquifer Pump	Aquifer testing	Grundfos	Rediflow or approved equal	8 gpm @ 40 psig	Centrifugal, 2 HP, 120 V, Standard duty, Stainless Steel, incl pump controls	Apprx. 3" dia x 5' long	Built-in Inlet and 1" FPT outlet	-
T-INF	Influent Tank	Equilization and holding prior to treatment	Baker Tank	6500 Gallon Poly Tank	6,500 Gallon	Double-Wall High Density Polyethylene	10' Diameter x 12'-8" High	4" Butterfly #150 Flange	Tank Empty: 1700 lbs. – 1975 lbs.
P-INF	Influent Pump	Boost pressure and transfer liquid	Goulds or equal	TBD	7.5 gpm @ 30 psig (50% efficiency)	Centrifugal, 2 HP, 120 V, Standard duty, Carbon Steel	10" high x 7-3/8" width x 18" depth	1.5" FPT Inlet and outlet	-
F-INF1 and F-INF2	Influent Duplex Filters	Remove particulates and solids	Spears or approved equal	TBD	20 gpm rated with 5 micron filtration	Particulate Filtration, Carbon Steel Housing and filter bag	7" Diameter x 30" Tall	2" FPT Inlet and outlet	-
--	--	Vessel to house treatment media	Evoqua	3.6	3.6 cuft	3.6 cuft fiberglass	14" dia x 4' high	1" FPT Inlet and outlet	-
GAC-1, -2, & -3	Granular Activated Carbon	VOCs removal in Lead, Lag & Polish	Evoqua	Aquacarb S Carbon Media	90 lbs each	Reactivated Coconut/Coal	--	--	-
IX-DOW-1 & -2	Ion Exchange	Perchlorate removal in Lead & Lag	Evoqua	DOW (PSR-2TM) Anion resin	90 lbs each	Anion resin	--	--	-
IX-SCU-1 & -2	Ion Exchange	Metals removal in Lead & Lag	Evoqua	Specialty Trace Metals (SCU) media	90 lbs each	media	--	--	-
GFH-1 & -2	Granular Adsorption	Arsenic removal in Lead & Lag	Evoqua	Granular Ferric Hydroxide (GFH) media	90 lbs each	media	--	--	-
T-EFF	Effluent Tank	Equilization and holding prior to discharge	Baker Tank	6500 Gallon Poly Tank	6,500 Gallon	Double-Wall High Density Polyethylene	10' Diameter x 12'-8" High	4" Butterfly #150 Flange	Tank Empty: 1700 lbs. – 1975 lbs.
T-EFF2	Effluent Tank (Temporary)	Temporary storage pending compliance sampling	Baker Tank	6500 Gallon Poly Tank	6,500 Gallon	Double-Wall High Density Polyethylene	10' Diameter x 12'-8" High	4" Butterfly #150 Flange	Tank Empty: 1700 lbs. – 1975 lbs.
P-EFF	Effluent Pump	Boost pressure and transfer liquid	Goulds or equal	TBD	10 gpm @ 38 psig	Centrifugal, 2 HP, 120 V, Standard duty, Carbon Steel	10" high x 7-3/8" width x 18" depth	1.5" FPT Inlet and outlet	-
F-EFF1 and F-EFF2	Effluent Duplex Filters	Remove particulates and solids	Spears or approved equal	TBD	20 gpm rated with 5 micron filtration	Carbon Steel Housing and filter bag	7" Diameter x 30" Tall	2" FPT Inlet and outlet	-
FQI-EFF	Effluent Flow Totalizer	Monitor flow prior to discharge	Badger Meter or approved equal	TBD	0-30 gpm rated	Manual Propeller, Carbon Steel Housing	6" L x 2" W	1" FPT Inlet and outlet	-
PI	Pressure Indicator	Measure pressure	Ashcroft or approved equal	TBD	Range 0-60 psig	Water filled, Carbon Steel	1/4" dia	1/4" MPT	-
SP-#	Sample Ports	Water sampling	Spears or approved equal	TBD	-	1/4" ball valve, PVC	1/4" dia	1/4" MPT Inlet and 1/4" barb	-
SV-INF and SV-EFF	Solenoid Valve	Shutoff tank from draining in the event of an alarm condition.	Asco or approved equal	8210G100	150 psig max	ASCO 120/60AC 2-Way Solenoid Valve, Normally Closed, General Service, Brass	4" high x 3' long	2" FPT Inlet and outlet	-
PP-FLEX	Flexible Piping	Where flexibility is needed.	Spears or approved equal	TBD	125 psig	Flexible clear PVC Hose	1" dia x length as needed. 2" diameter x length for secondary containment hose.	-	-
PP-PVC	PVC Piping	Where rigidity is needed.	Spears or approved equal	TBD	300 psig	Rigid PVC Schedule 40	Diameter and Length as required	-	-
--	Secondary Containment	Materials to construct secondary containment	AccuGeo or approved equal	40-mill	--	PVC Liner	Diameter and Length as required	-	-

REV. NO.	DATE	DRWN	CHKD	REMARKS

DESIGNED BY: M. GOH
DRAWN BY: M. GOH
SHEET CHK'D BY: D. NGUYEN
CROSS CHK'D BY: S. FUNDINGSLAND
APPROVED BY: M. GOH
DATE: SEPT 2015

CDM Smith
consulting * engineering * construction * operations

SANTA SUSANA FIELD LABORATORY
FORMER SODIUM DISPOSAL FACILITY
GROUNDWATER INTERIM MEASURE

GWIM IMPLEMENTATION
EQUIPMENT SPECIFICATIONS

PROJECT NO. 128979.94489
FILE NAME:
SHEET NO.
G-2

DESIGN-BUILD SUBMITTAL

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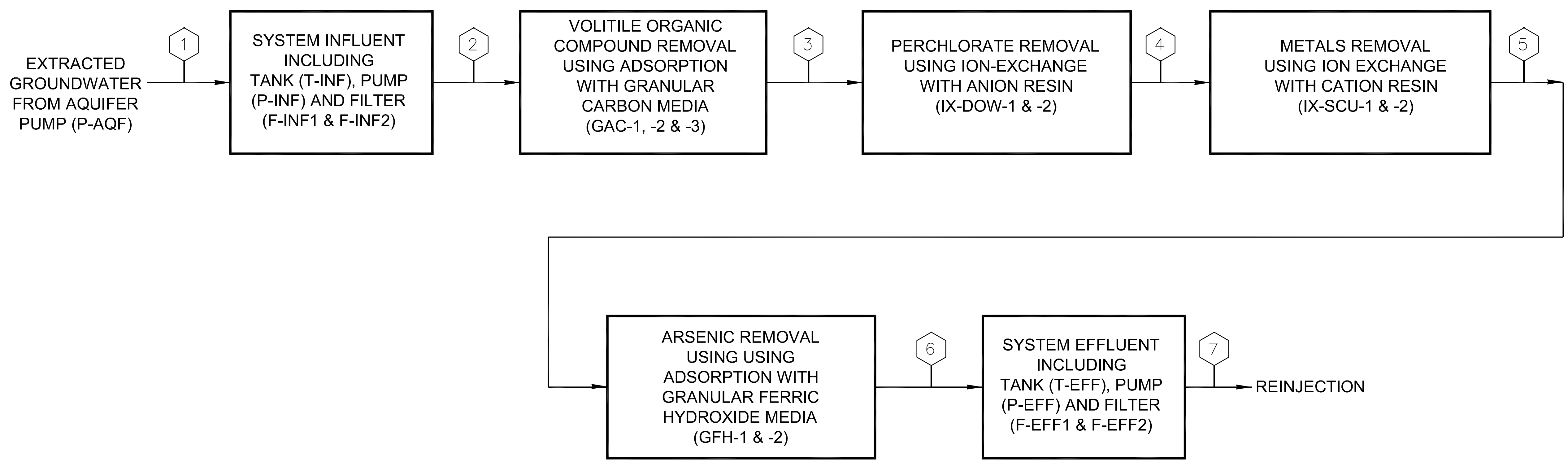
NOTES

1. FOR EQUIPMENT LIST AND ACRONYMS, SEE DRAWING G-2.

Process Node		1	2	3	4	5	6	7
Node Description		Extracted Groundwater	System Influent and Inlet to VOC Treatment	Outlet of VOC Treatment and Inlet to Perchlorate Treatment	Outlet of Perchlorate Treatment and Inlet to Metals Treatment	Outlet of Metals Treatment and Inlet to Arsenic Treatment	System Effluent and Outlet of Arsenic Treatment	Discharge to Reinjection
Operating Mode		Continuous flow depending on aquifer yield	Batch flow increased to maintain hydraulic efficiency through the treatment equipment					Batch flow reduced to match percolation rate
Operating Limits and Conditions								
Flow Rate (gpm)	Min	0	2	2	2	2	2	2
	Max	1	10	10	10	10	10	10
	Operating	0.5	7.5	7.5	7.5	7.5	7.5	7.5
Pressure (psig)	Min	8	8	-	-	-	-	8
	Max	20	60	-	-	-	-	60
	Operating	10	40	30	20	10	0	40
	Delta P	-	-	-10	-10	-10	-10	-
Temperature (deg F)	Min	65	65	65	65	65	65	65
	Max	100	100	100	100	100	100	100
	Operating	70	70	71	72	73	74	94
	Delta T	-	-	1	1	1	1	-



REV. NO.	DATE	DRWN	CHKD	REMARKS

DESIGNED BY: M. GOH
DRAWN BY: M. GOH
SHEET CHK'D BY: D. NGUYEN
CROSS CHK'D BY: S. FUNDINGSLAND
APPROVED BY: M. GOH
DATE: SEPT 2015

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SANTA SUSANA FIELD LABORATORY
FORMER SODIUM DISPOSAL FACILITY
GROUNDWATER INTERIM MEASURE

GWIM IMPLEMENTATION
PROCESS FLOW DIAGRAM

PROJECT NO. 128979.94489
FILE NAME:
SHEET NO.
P-1

DESIGN-BUILD SUBMITTAL

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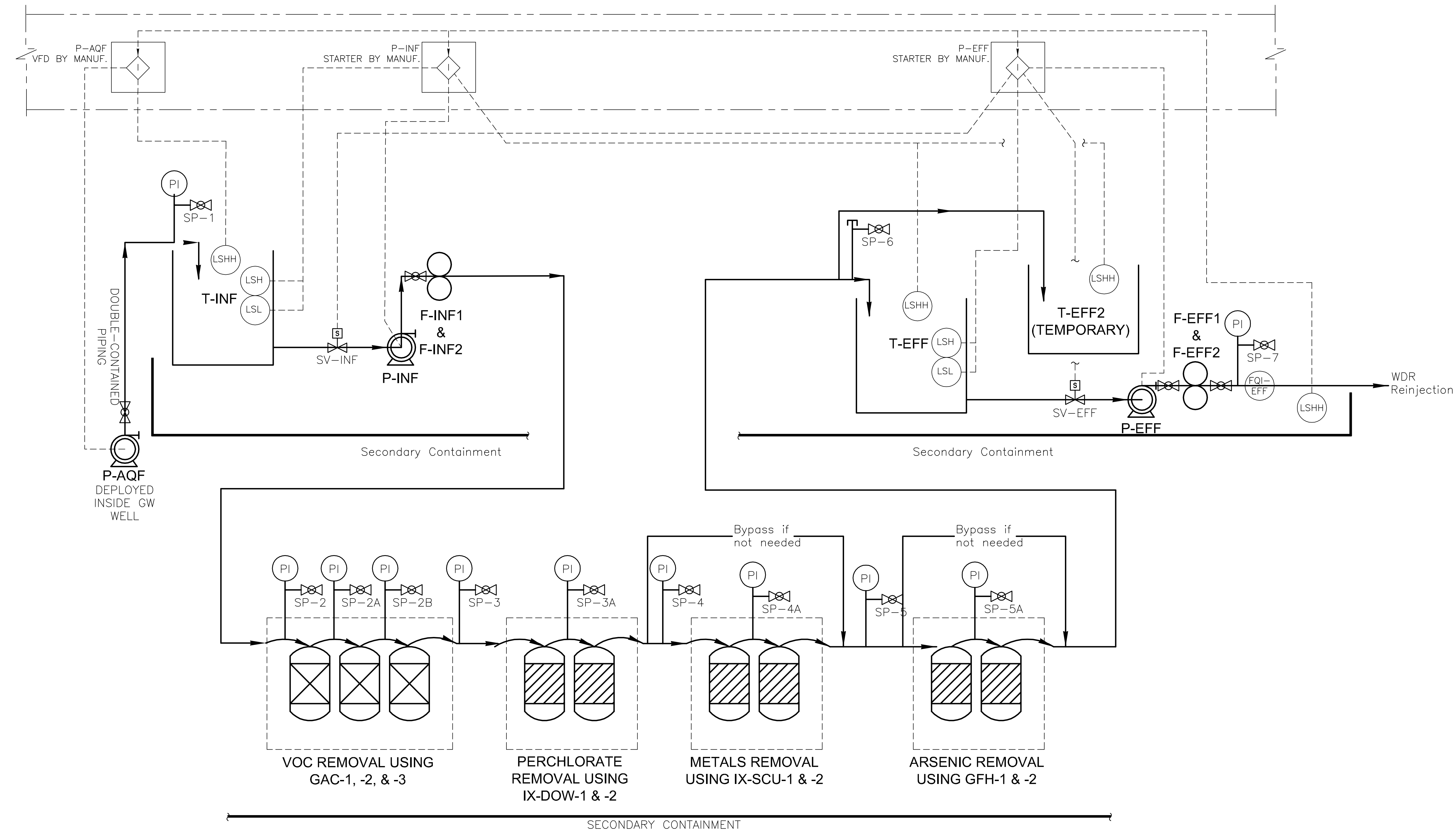
NOTES

1. FOR EQUIPMENT LIST AND ACRONYMS, SEE DRAWING G-2.
2. FLEXIBLE PIPING SHALL BE USED TO CONVEY EXTRACTED GROUNDWATER FROM SELECTED AQUIFER PUMPING WELL TO THE TREATMENT AREA. A 1" DIAMETER SHALL BE SELECTED.
3. PIPING OUTSIDE OF THE TREATMENT AREA SHALL BE DOUBLE-CONTAINED WITH A SECONDARY HOSES WITH A LARGER DIAMETER. A 1.5" OR LARGER DIAMETER SHALL BE SELECTED.



REV. NO.	DATE	DRWN	CHKD	REMARKS

DESIGNED BY: M. GOH
DRAWN BY: M. GOH
SHEET CHK'D BY: D. NGUYEN
CROSS CHK'D BY: S. FUNDINGSLAND
APPROVED BY: M. GOH
DATE: SEPT 2015

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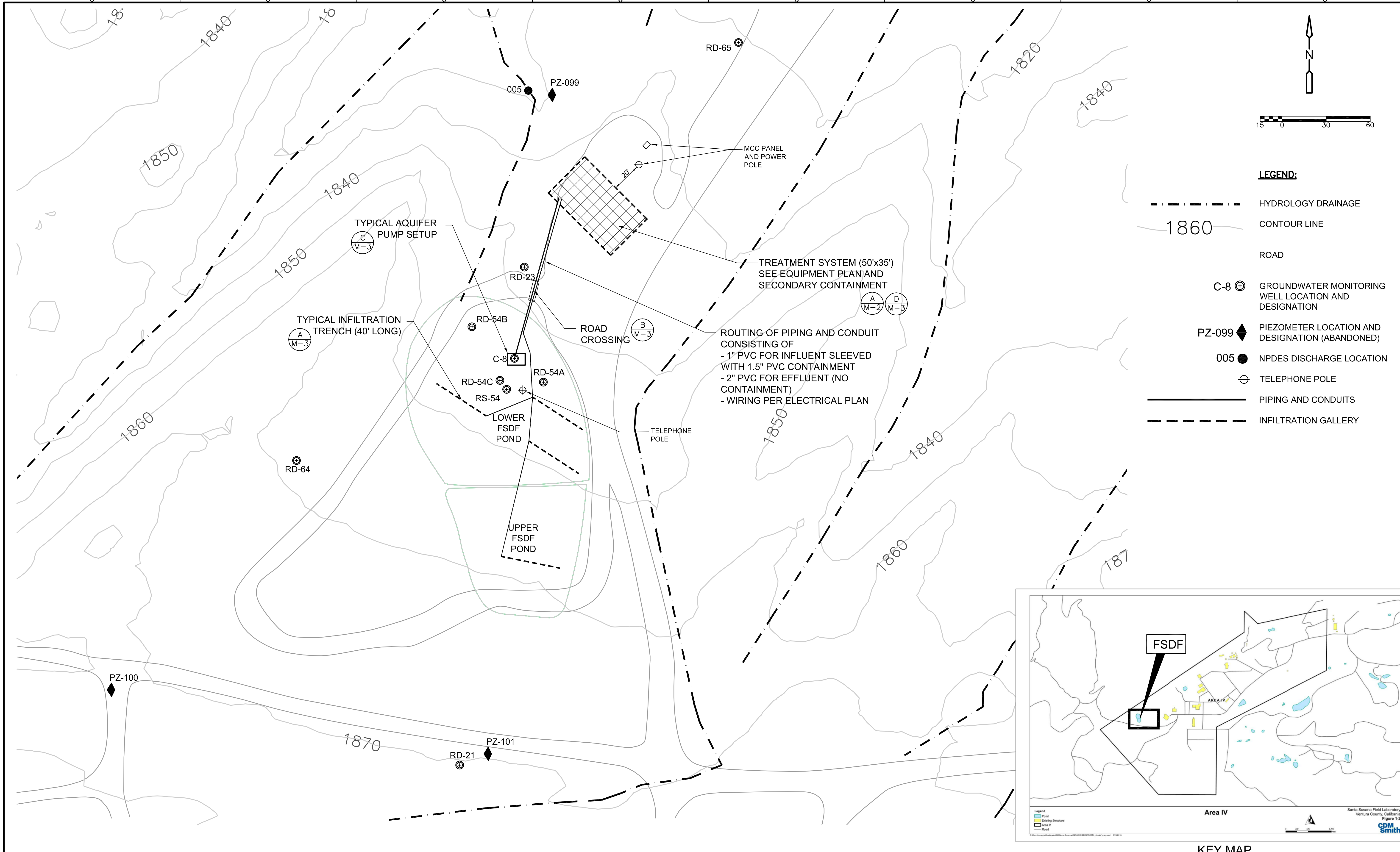
SANTA SUSANA FIELD LABORATORY
FORMER SODIUM DISPOSAL FACILITY
GROUNDWATER INTERIM MEASURE

GWIM IMPLEMENTATION
PIPING & INSTRUMENTATION DIAGRAM

PROJECT NO. 128979.94489
FILE NAME:
SHEET NO.
P-2

DESIGN-BUILD SUBMITTAL



REV. NO.	DATE	DRWN	CHKD	REMARKS

DESIGNED BY: M. GOH
DRAWN BY: P. RIEHLE
SHEET CHK'D BY: D. NGUYEN
CROSS CHK'D BY: S. FUNDINGSLAND
APPROVED BY: M. GOH
DATE: SEPT 2015

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SANTA SUSANA FIELD LABORATORY
FORMER SODIUM DISPOSAL FACILITY
GROUNDWATER INTERIM MEASURE

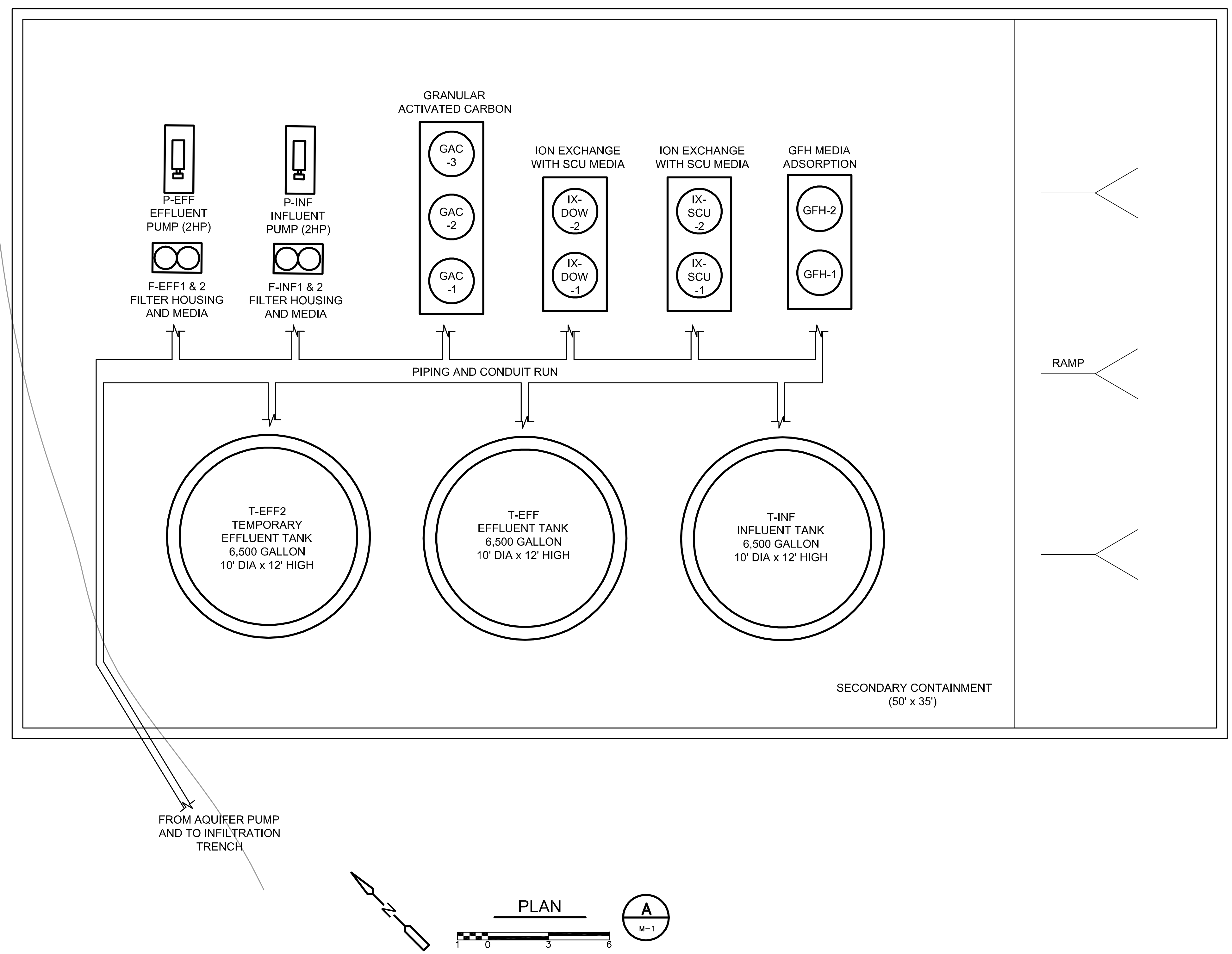
GWIM IMPLEMENTATION
SITE PLAN

PROJECT NO. 128979.94489
FILE NAME:
SHEET NO.
M-1

DESIGN-BUILD SUBMITTAL

NOTES

1. VERIFY EQUIPMENT SPECIFICATIONS FROM THE PFD AND P&ID DRAWINGS.
2. PIPING SHALL BE FIELD ROUTED TO RESPECTIVE EQUIPMENT AND NOT DETAILED TO ITS ENTIRETY ON THIS PLAN.
3. TREATMENT VESSELS SHALL BE PLACED AND SECURED ON WOODEN PALLETS FOR STABILITY.



PLAN

REV. NO.	DATE	DRWN	CHKD	REMARKS

DESIGNED BY: M. GOH
DRAWN BY: P.RIEHLE
SHEET CHK'D BY: D. NGUYEN
CROSS CHK'D BY: S. FUNDINGSLAND
APPROVED BY: M. GOH
DATE: SEPT 2015

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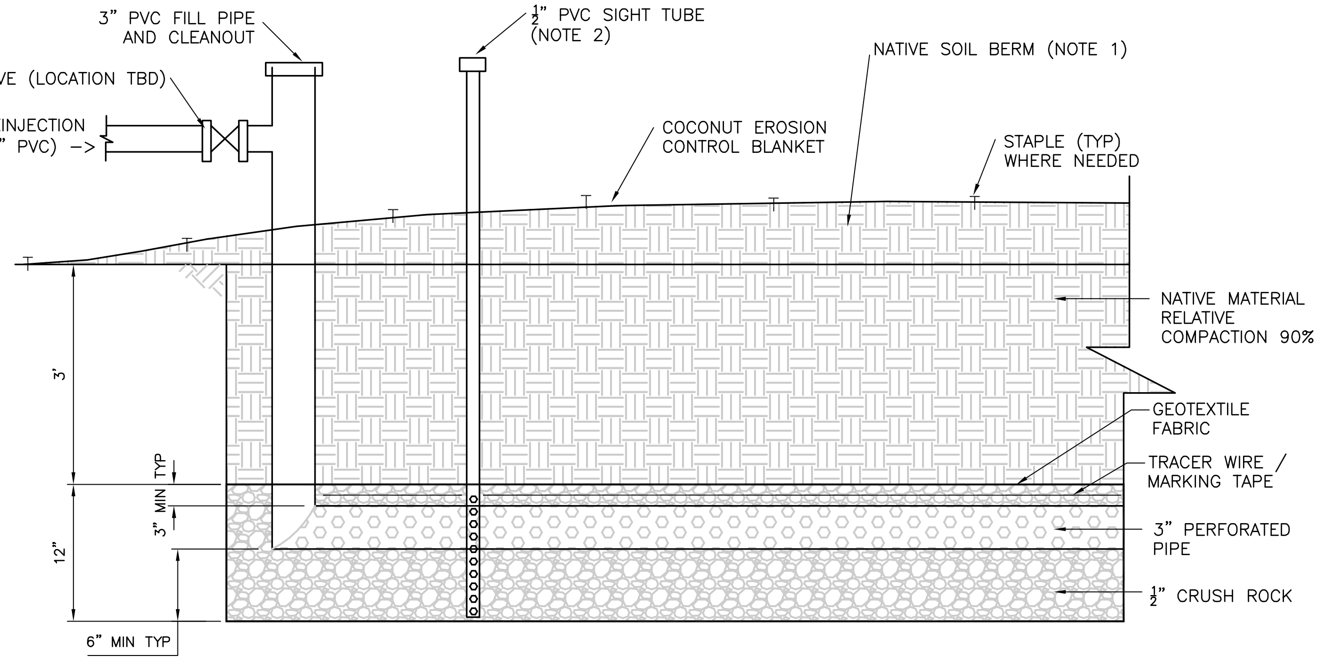
SANTA SUSANA FIELD LABORATORY
FORMER SODIUM DISPOSAL FACILITY
GROUNDWATER INTERIM MEASURE

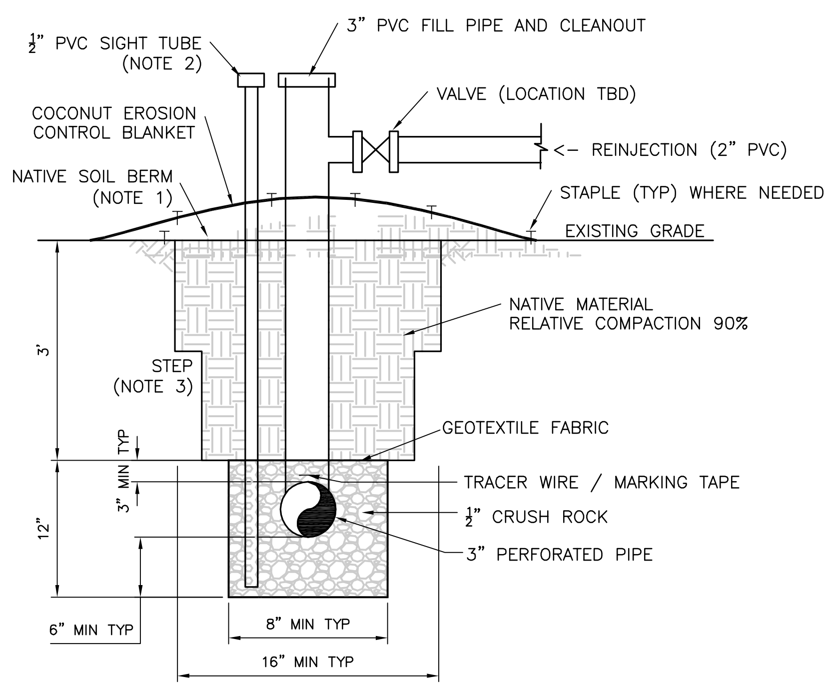
GWIM IMPLEMENTATION
EQUIPMENT PLAN

PROJECT NO. 128979.94489
FILE NAME:
SHEET NO.
M-2

DESIGN-BUILD SUBMITTAL



TYPICAL PROFILE

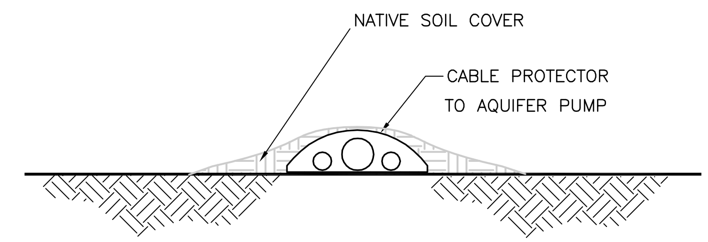


TYPICAL SECTION

NOTE
1. EXCESS NATIVE MATERIAL SHALL BE USED TO CONSTRUCT BERM. VOLUME TO BE DETERMINED IN THE FIELD.
2. SIGHT TUBE SHALL BE EXTENT INTO CRUSH ROCK.
3. TRENCH WALL SHALL BE STEPPED AS NEEDED TO PREVENT CAVE-IN AND MAINTAIN WALL INTEGRITY.

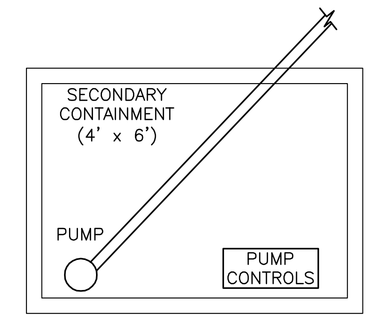
INFILTRATION TRENCH PROFILE AND SECTION (A / -)

NOT TO SCALE



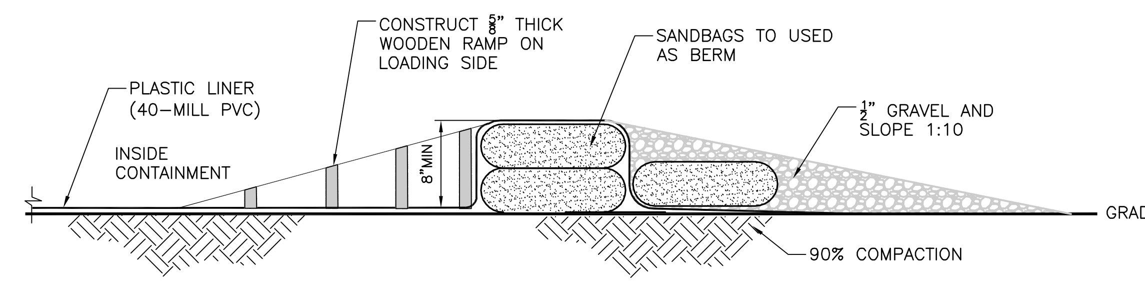
ROAD CROSSING CABLE PROTECTOR DETAIL (B / -)

NOT TO SCALE



AQUIFER PUMP DETAIL (C / -)

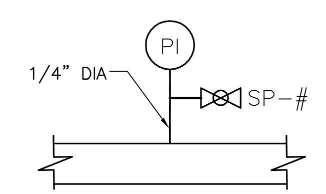
NOT TO SCALE



NOTE: ALTERNATIVE METHOD OR MATERIAL COULD BE USED TO CONSTRUCT THE BERM IN LIEU OF SANDBAGS AS APPROVED BY ENGINEER.

SECONDARY CONTAINMENT PLASTIC LINER DETAIL (D / -)

NOT TO SCALE



NOTE: WHERE PI IS NOT NEEDED, FITTING SHALL BE CAPPED.

TYPICAL PRESSURE INDICATOR AND SAMPLE PORT DETAIL (E / -)

NOT TO SCALE

REV. NO.	DATE	DRWN	CHKD	REMARKS

DESIGNED BY: M. GOH
DRAWN BY: M. GOH
SHEET CHK'D BY: D. NGUYEN
CROSS CHK'D BY: S. FUNDINGSLAND
APPROVED BY: M. GOH
DATE: SEPT 2015

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consulting * engineering * construction * operations

SANTA SUSANA FIELD LABORATORY
FORMER SODIUM DISPOSAL FACILITY
GROUNDWATER INTERIM MEASURE

GWIM IMPLEMENTATION
CONSTRUCTION DETAILS

PROJECT NO. 128979.94489
FILE NAME:
SHEET NO. M-3

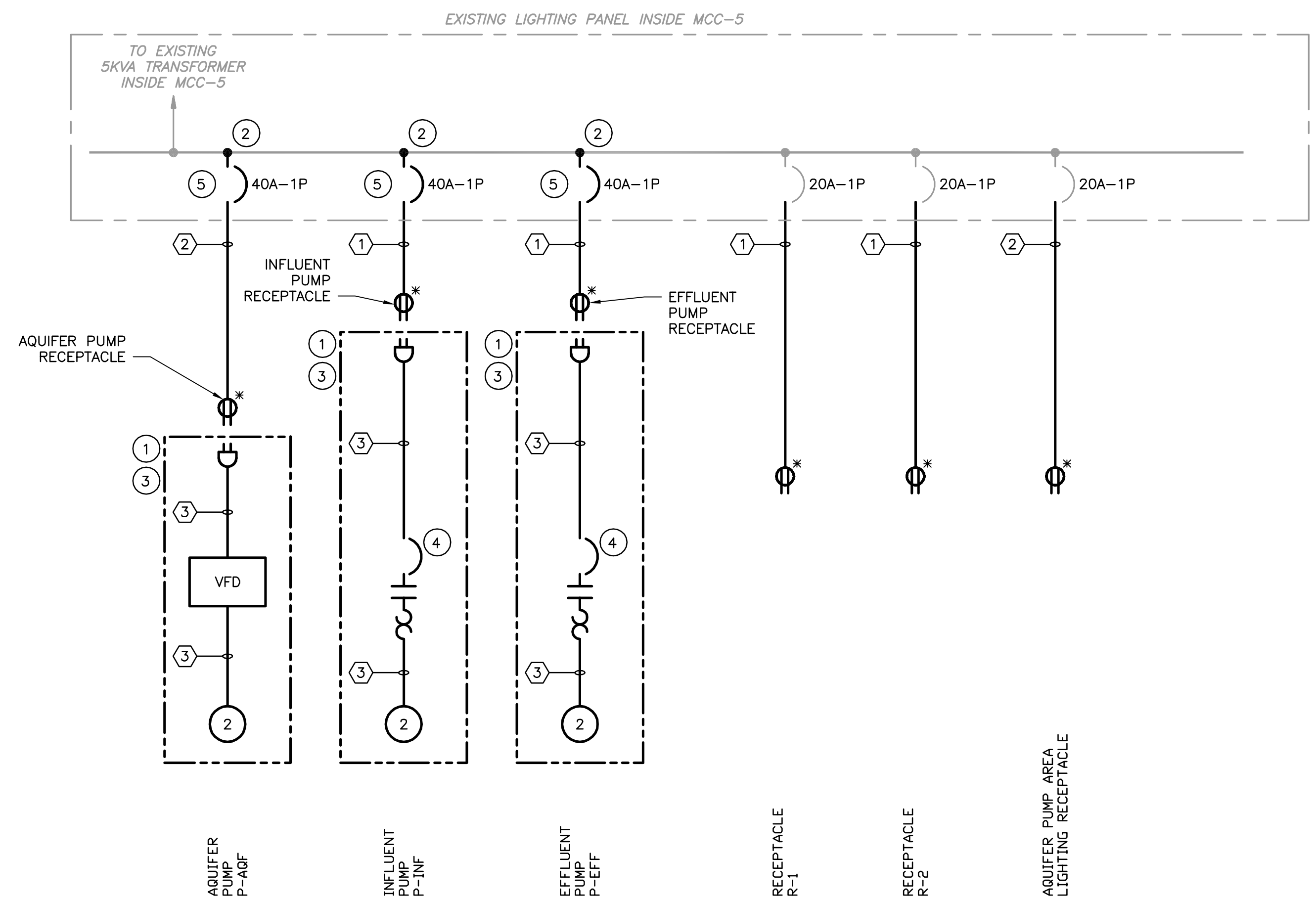
DESIGN-BUILD SUBMITTAL

KEY NOTES:

1. SEE SHEET P-2 FOR CONTROL STRATEGY.
2. COORDINATE WITH BREAKER MANUFACTURE TO SIZE LUGS FOR LOAD WIRES.
3. BY MANUFACTURE.
4. STARTER BY VENDOR.
5. REPLACE EXISTING 20A BREAKERS WITH NEW 40A BREAKERS INSIDE EXISTING LIGHTING PANEL IN EXISTING MCC-5.

LEGEND:

* DUPLEX RECEPTACLE, 20A, 120V, 3W, SINGLE PHASE
* WP – WEATHERPROOF & GFCI



SANTA SUSANA FIELD LABRATORY

SINGLE LINE DIAGRAM

N.T.S.

CONDUIT AND WIRE LEGEND
(NUMBERS REFERENCE THIS SHEET ONLY)

NO.	DESCRIPTION
1	3/4"C, 2#8, 1#10 GND
2	1"C, 2#6, 1#10 GND
3	MANUFACTURE CABLE

EXISTING MCC-5 LOAD COMPUTATION

LOADS	HP/KVA	AMPERE
6-P-1	7 HP	11
6-P-2	5 HP	7.6
P-102	10 HP	14
LIGHTING PANEL	5 KVA	10.4
SUBTOTAL AMPERE		43
25% LARGEST MOTOR		3.5
TOTAL CONNECT LOAD AMPERE		46.5

REV. NO.	DATE	DRWN	CHKD	REMARKS

DESIGNED BY: M. KOPEC
DRAWN BY: M. KOPEC
SHEET CHK'D BY: M. GOH
CROSS CHK'D BY: S. FUNDINGSLAND
APPROVED BY: F. YAO
DATE: SEPT 2015

CDM Smith
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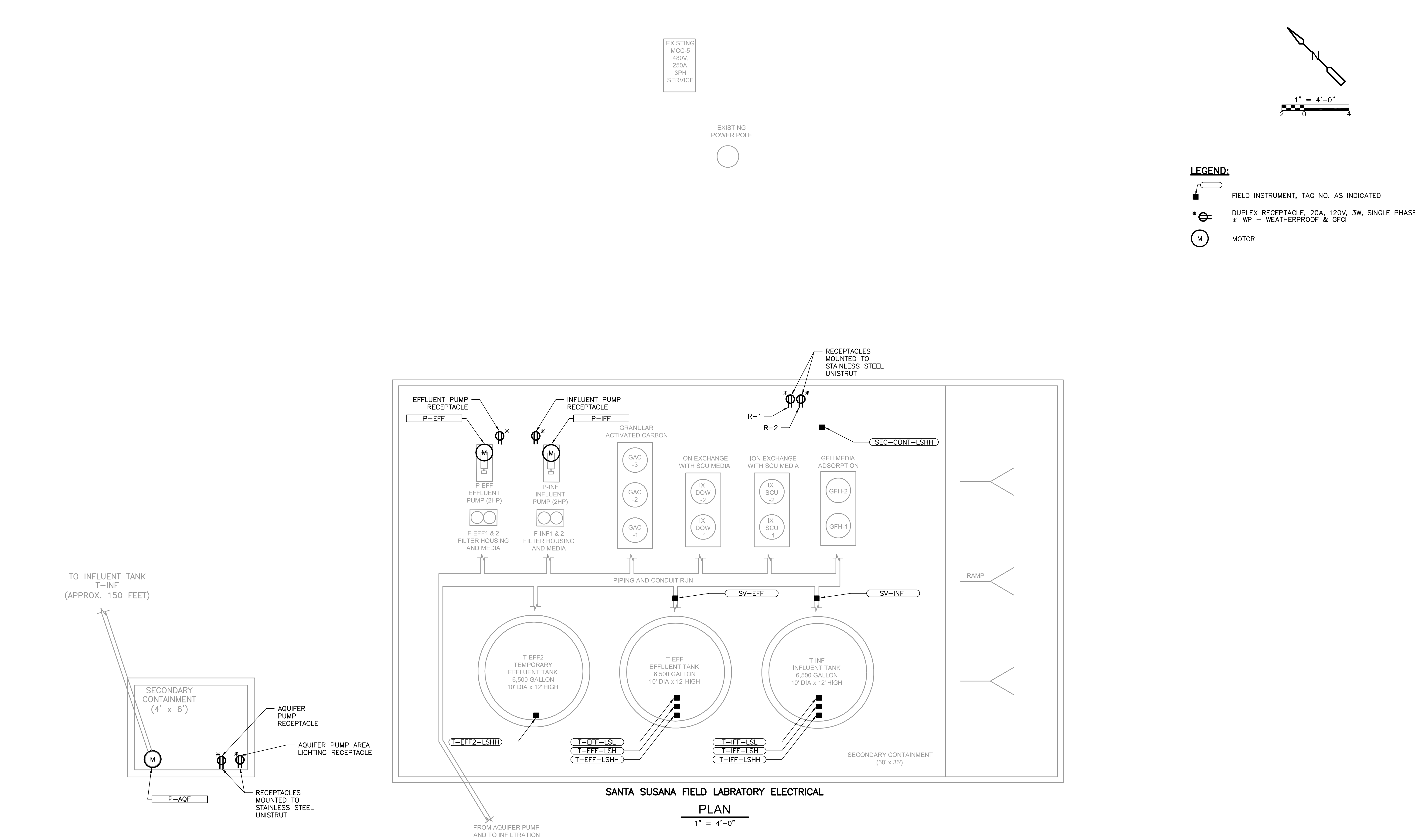
SANTA SUSANA FIELD LABORATORY
FORMER SODIUM DISPOSAL FACILITY
GROUNDWATER INTERIM MEASURE

GWIM IMPLEMENTATION
ELECTRICAL SINGLE LINE DIAGRAM

PROJECT NO. 128979.94489
FILE NAME:
SHEET NO. E-1

DESIGN-BUILD SUBMITTAL



SANTA SUSANA FIELD LABORATORY ELECTRICAL

PLAN

1" = 4'-0"

REV. NO.	DATE	DRWN	CHKD	REMARKS

DESIGNED BY: M. KOPEC
DRAWN BY: M. KOPEC
SHEET CHK'D BY: M. GOH
CROSS CHK'D BY: S. FUNDINGSLAND
APPROVED BY: F. YAO
DATE: SEPT 2015

CDM Smith
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SANTA SUSANA FIELD LABORATORY
FORMER SODIUM DISPOSAL FACILITY
GROUNDWATER INTERIM MEASURE

GWIM IMPLEMENTATION
ELECTRICAL POWER PLAN

PROJECT NO. 128979.94489
FILE NAME:
SHEET NO.
E-2

DESIGN-BUILD SUBMITTAL

Appendix C

Equipment Specifications

F-INF, F-EFF

Filter Housing and Media

CDM Smith

McMASTER-CARR. OVER 555,000 PRODUCTS

(562) 692-5911
(562) 695-2323 (fax)
la.sales@mcmaster.com
Text 75930

High-Flow Plastic Filter Bag Housing

2 Pipe Size, 70 gpm

In stock
$299.00 Each
51655K6

Pipe Size	2
Maximum Flow	70 gpm
Overall	
Diameter	7"
Height	30"
Maximum psi	100psi @ 110° F
Maximum Temperature	110° F
Additional Specifications	Standard
Related Product	Filter Bags

Designed for use in high-volume pipelines, polypropylene construction keeps these filter housings free from corrosion. They come with a polypropylene strainer basket that supports the filter bag. Filter bags are sold separately. Connections are NPT female.

Standard housing is blue. Strainer basket has 9/64" perforations. Cover seal is Buna-N.

GAC-1, -2 & -3 Evoqua Aquascrub Media

AQUACARB® S SERIES GRANULAR REACTIVATED CARBON AQUACARB® NS, AQUACARB® RS & AQUACARB® RSD CARBONS

FOR INDUSTRIAL AND REMEDIAL WATER TREATMENT

Description

AquaCarb® S Series carbons are produced through thermal reactivation of approved grades of spent carbon at one of our state-of-the-art ISO 14001 certified reactivation facilities. Through careful control of the residence time in the reactivation furnace, reactivation temperature, and reactivation gas composition, adsorbed contaminants on the spent carbon are removed and destroyed, and the carbon's internal pore structure is maintained as close to virgin condition as possible. AquaCarb® S Series reactivated carbons are pooled from a variety of sources, ensuring consistent product properties. The resulting carbon serves as an excellent economic alternative to virgin carbon for the removal of a broad range of organic contaminants from wastewater, process water, and groundwater streams.

Applications

Cost effective AquaCarb® S Series reactivated carbons have been demonstrated to provide excellent performance in a variety of liquid phase treatment applications, including the following:

- Removal of organic contaminants
- Pesticide removal
- Groundwater remediation
- Wastewater treatment
- Industrial process water treatment
- Biological activated carbon support

Quality Control

Evoqua's laboratories are fully equipped to provide complete quality control analysis using ASTM standard test methods in order to assure the consistent quality of all Westates® actived carbons.

Our technical staff offers hands-on guidance in selecting the most appropriate system, operating conditions and carbon to meet your needs. For more information contact your nearest Evoqua representative.

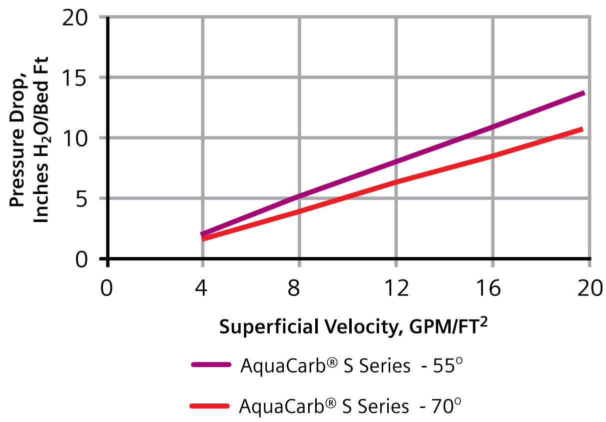
FEATURES AND BENEFITS:

- Reactivated carbons serve as an economical alternative to virgin carbon in many applications
- Use of reactivated carbons reduce the volume of spent carbon sent to landfill and encourages responsible usage of natural resources
- A detailed quality assurance program guarantees consistent quality from lot to lot and shipment to shipment
- Pooled reactivated carbons provide consistent properties and performance
- Reactivated carbons produced at ISO 14001 certified reactivation facilities, ensuring minimization of environmental liability and continued benchmarking against best practice standards for environmental management

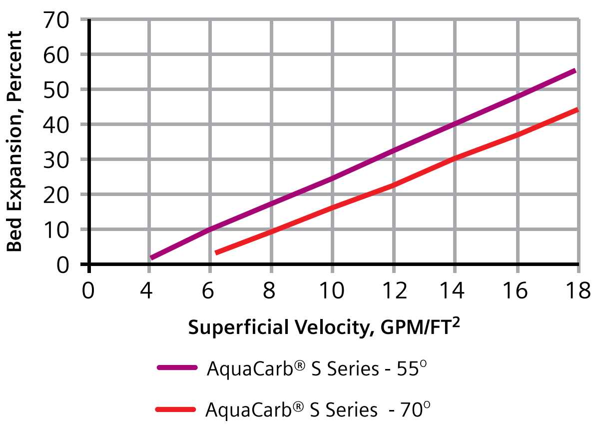
TYPICAL PROPERTIES

Parameter	AquaCarb® S Carbon
Carbon Type	Reactivated Coconut/Coal
Mesh Size, U.S. Sieve	8 x 30
Iodine No., mg I2/g	800 -1000
Apparent Density, g/cc	0.46 - 0.60
Moisture as Packed, Wt. %	2

Downflow Pressure Drop Through
A Backwashed and Stratified Bed (Typical)



Percent Bed Expansion During Backwash (Typical)



Safety Note: Under certain conditions, some compounds may oxidize, decompose or polymerize in the presence of activated carbon causing a carbon bed temperature rise that is sufficient to cause ignition. Particular care must be exercised when compounds that have a peroxide-forming tendency are being adsorbed. In addition the adsorption of VOCs will lead to the generation of heat within a carbon bed. These heats of reaction and adsorption need to be properly dissipated in order to fully assure the safe operation of the bed.

Wet activated carbon readily adsorbs atmospheric oxygen. Dangerously low oxygen levels may exist in closed vessels or poorly ventilated storage areas. Workers should follow all applicable state and federal safety guidelines for entering oxygen depleted areas.

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WATER TECHNOLOGIES

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GFH-1 & -2 Evoqua GFH Media for Arsenic removal

EVOQUA
WATER TECHNOLOGIES


GFH® GRANULAR FERRIC HYDROXIDE MEDIA

GFH® GRANULAR FERRIC HYDROXIDE MEDIA

A PROVEN, SAFE, AND SIMPLE SOLUTION TO ARSENIC REMOVAL CHALLENGES

Description

In 2002, the US Environmental Protection Agency (EPA) promulgated the final arsenic primary drinking water maximum contaminant level (MCL) of 10 micrograms per liter. In addition, some states have adopted even lower limits (5 micrograms per liter). Over the past decade, this regulation has prompted hundreds of municipalities to utilize numerous treatment technologies for the removal of arsenic. Among the various technologies available, the EPA identified adsorption with GFH Media from Evoqua Water Technologies as a Best Available Technology (BAT) for arsenic removal.

GFH Media is a specially designed adsorbent media based on granular ferric hydroxide. It is specifically designed for the removal of arsenic (arsenate (As+5) and arsenite (As+3)) from water and can remove other heavy metals as well. The arsenic removal requires no preconditioning or preoxidation. Applied in a downflow packed bed configuration, it is easily applied to municipal wellhead applications.

Applications

In addition to arsenic, GFH Media has been demonstrated to provide removal of several other contaminants, including:

- Phosphate
- Antimony
- Copper

System options

GFH Media can be placed into parallel or series pressure vessel systems depending on the removal requirement. To apply GFH Media, our Vantage® PTI Series systems are available in Simplex, Duplex, or Triplex configurations. These systems are pre-engineered, pre-assembled, and factory tested to minimize installation and startup time.

Service and Disposal options

For arsenic removal applications where the client cannot incur a capital expense for a treatment system, Evoqua offers integrated equipment and service combinations (temporary or permanent), thereby minimizing a plant's capital investment and reducing overall space requirements. Temporary installations are also available through our mobile fleet, providing the ultimate flexibility to add or remove treatment capacity as your business grows or compliance limits change. This option also saves valuable manufacturing space while minimizing your maintenance and installation requirements.

Once exhausted, spent GFH Media can be disposed of via landfill and classified as a non-hazardous waste after passing a TCLP test. Evoqua can provide full media exchange services and disposal assistance in GFH Media applications.

FEATURES AND BENEFITS

- ANSI / NSF 61 Certified for use in Potable Water Applications.
- Consistent removal of both arsenate and arsenite forms of arsenic, even during sudden changes in influent arsenic concentration.
- Applications fully supported by Evoqua laboratory facilities to evaluate and tailor specific solutions to each application
- Standard systems using GFH® Media are designed for flows from 1 to 5,000 gpm and higher. Compact designs that require minimal operator attention.
- Service based offerings reduce capital investment required.
- Full service capabilities for spent media exchange and disposal available.
- Low waste volume (<0.1% typical)
- High arsenic capacity resulting in long media bed life and reduced frequency of media exchange
- Does not impact water pH.

PHYSICAL PROPERTIES

Particle Size	10 x 70 mesh / 200 x 2000 mm
Bulk Density, backwashed (lb./ft^3)	64 – 79
Chemical Composition	b-FeOOH and Fe(OH)

OPERATING CONDITIONS

Operating pH Range	5.5 – 9.0
Recommended Contact Time	3.5 minutes minimum
Backwash Rate (gpm/ft^2)	10-12
Maximum Operating Temperature	140°F (*)

* temperature limit of standard equipment. Contact your representative for higher temperature applications.

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IX-DOW-1 & -2 Evoqua Dowex PSR-2 for perchlorate removal

CDM Smith

DOWEX™ PSR-2

A Strong Base Anion Exchange Resin Designed for the Selective Removal of Trace Contaminants from Potable Water

Product	Type	Matrix	Functional group
DOWEX™ PSR-2	Tri-n-butyl amine	Styrene-DVB, gel	Quatenary amine

Guaranteed Sales Specifications		Cl^- form
Total exchange capacity, min.	eq/L	0.65
	kgr/ft³ as $CaCO_3$	14.2
Water content	%	40.0 - 47.5
Bead size distribution†		
% on 16 mesh, max.	%	3
% through 40 mesh, max.	%	5
Whole uncracked beads, min.	%	95
Crush strength (>200 g/bead, min.)	%	90

Typical Physical and Chemical Properties		Cl^- form
Particle density	g/mL	1.10
Shipping weight**	g/L	670
	lbs/ft³	42

Recommended Operating Conditions

- Maximum operating temperature — 60°C (140°F)
- pH range — 0 - 14
- Service flow rate — 0.5 - 12 gpm/ft³
- Service linear velocity — 1.0 - 22 gpm/ft²
- Bed depth, min.:
  Single bed — 800 mm (2.6 ft)

† For additional particle size information, please refer to Particle Size Distribution Cross Reference Chart (Form No. 177-01775).

** As per the backwashed and settled density of the resin, determined by ASTM D-2187.

Typical Properties and Applications

DOWEX™ PSR-2 is a gellular strong base anion resin supplied in the Cl^- form. It is designed to offer the highest selectivity for trace contaminants such as nitrate and perchlorate, while it's gellular structure also achieves high total exchange capacity.

Applications include:

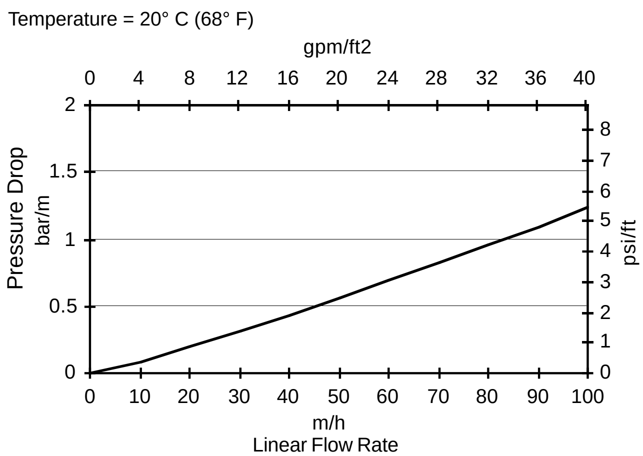
- Perchlorate retention and removal
- Gold recovery

This product has been certified under ANSI Standard 61.

Packaging

5 cubic feet fiber drums

Figure 1. Pressure Drop Data



For other temperatures use:

$P_T = P_{20°C} / (0.026\ T_{°C} + 0.48)$, where P ≡ bar/m
$P_T = P_{68°F} / (0.014\ T_{°F} + 0.05)$, where P ≡ psi/ft

DOWEX™ Ion Exchange Resins
For more information about DOWEX resins, call the Dow Water Solutions business:

North America:	1-800-447-4369
Latin America:	(+55) 11-5188-9222
Europe:	(+32) 3-450-2240
Pacific:	+60 3 7958 3392
Japan:	+813 5460 2100
China:	+86 21 2301 9000

http://www.dowwatersolutions.com

Warning: Oxidizing agents such as nitric acid attack organic ion exchange resins under certain conditions. This could lead to anything from slight resin degradation to a violent exothermic reaction (explosion). Before using strong oxidizing agents, consult sources knowledgeable in handling such materials.

Form No. 177-02120-0209

IX-SCU-1 & -2 Evoqua SCU Media for Metals Removal.pdf

SCU™ SPECIALTY TRACE METALS REMOVAL MEDIA

FOR REMOVAL OF TRANSITION METALS FROM INDUSTRIAL WASTEWATER, GROUNDWATER, AND STORMWATER RUNOFF

Description

SCU™ specialty media is a proprietary adsorbent which is similar in appearance to granular activated carbon or anthracite but with a higher density and particle hardness. It removes trace levels of various heavy metals from complex waters to levels not possible with standard ion exchange resins.

Ion exchange has historically been a proven technology to achieve metals discharge standards but in most cases has difficulty in achieving effluent levels below 25 ppb, depending on the contaminant and chemistry of the water. With many industries facing new, stricter metals discharge levels, Evoqua Water Technologies has developed SCU specialty media. This new class of adsorbent can routinely achieve effluent levels below 1 ppb for most metals and can achieve levels below 12 ppt (the current US regulation standard for discharge into the environment) for mercury.

Applications

SCU specialty media has been successfully used in a number of applications:

- Industrial Wastewater
- Groundwater Remediation
- Stormwater Runoff

Metals removed by SCU specialty media include the following:

- Cadmium
- Trivalent Chromium
- Copper
- Lead
- Mercury
- Nickel
- Zinc

Service and Disposal Options

To apply SCU specialty media, Evoqua offers integrated treatment alternatives which include the option of permanent or temporary exchange vessels/systems. Our service exchange approach integrates equipment and service combinations, thereby minimizing the customer's capital investment and reducing overall space requirements. Service exchange provides the ultimate flexibility to add or remove treatment capacity as your business grows or compliance limits change. This option also saves valuable manufacturing space while minimizing your maintenance and installation requirements.

Once exhausted, spent SCU specialty media can be transferred to Evoqua RCRA licensed central treatment and processing facility where both non-hazardous and hazardous wastes are treated in compliance with all state and federal guidelines and valuable metals are recycled into raw materials when possible.

FEATURES AND BENEFITS:

- Trace metals removal possible to ppb / ppt levels
- Applications fully supported by Evoqua laboratory facilities to evaluate and tailor specific solutions to each metals removal application
- Standard SCU™ specialty media system designs for flows from 1 to 5,000 gpm and higher
- SCU specialty media technology is simple to install and operate
- Service based offerings reduce capital investment required
- Full service capabilities for spent media exchange and disposal available

CHEMICAL PROPERTIES

Form (as shipped)	Irregularly shaped, granular
Typical metals capacity (lb./ft. ^{3})	1.5 - 2.5 lb. / cu. ft.

PHYSICAL PROPERTIES

Particle size	10 X 30 mesh / 600 X 2000 mm
Bulk density (lb./ft. ^{3})	39 – 45

OPERATING CONDITIONS

Operating pH range	5 to 11
Typical service flow rate (gpm/ft. ^{3})	1.0-2.2
Maximum operating temperature	120 º F

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P-AQF Aquifer Pump

CDM Smith

Electrical Submersible Pump Controller

geotech

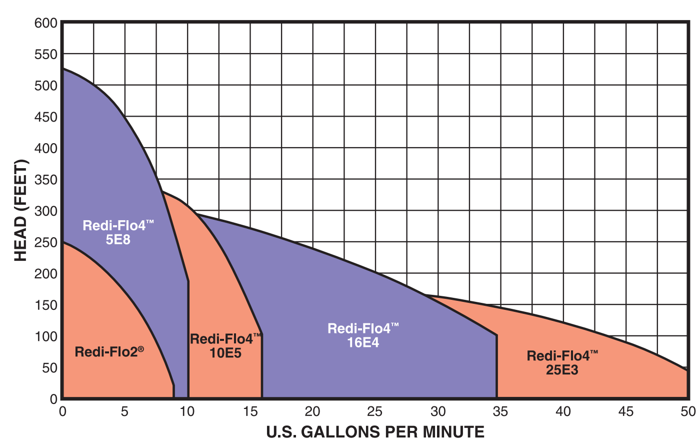
Grundfos Redi-Flo Variable Frequency Drive

The Redi-Flo Variable Frequency Drive (VFD) is designed to operate and protect the Redi-Flo2® and the Redi-Flo4™ Variable Performance Pumps. With the push of a button, an operator can precisely control the discharge flow rate from the pump from 50 GPM (189 LPM) to 100 milliliters per minute, to depths down to 524 feet (160m).

FEATURES

- **Precise Flow Control**
  The push button control pad provides greater control over the discharge flow rate for better accuracy and precision during sampling.
- **Wide Performance Range**
  Not just one performance curve, the Redi-Flo VFD covers a range of performances and can function at any point of operation within that range.
- **Dual Input Power Capability**
  Either 120V or 230V, single-phase AC input power is accommodated simply by changing the power cord terminations.
- **Dual Functionality**
  Easily switched to operate either the Redi-Flo2® or the Redi-Flo4™ Variable Performance Pumps.
- **NEMA 4R Enclosure**
  The NEMA 4R enclosure is designed for outdoor duty and is resistant to damage as a result of incidental exposure to rain.
- **Optimized Volts/Frequency Pattern**
  The Redi-Flo VFD V/Hz pattern is specially optimized to allow the most efficient operation of Redi-Flo2® and Redi-Flo4™ variable performance pumps.
- **Motor Protection**
  The Redi-Flo VFD will protect the Redi-Flo Variable Performance Pumps from adverse motor conditions such as, over- and under-voltage, over-current, and groundfault.

VFD shown with the Redi-Flo2® and Redi-Flo4™



Performance Curve for the Redi-Flo2® and Redi-Flo4™

CALL GEOTECH TODAY (800) 833-7958

Geotech Environmental Equipment, Inc.
2650 East 40th Avenue • Denver, Colorado 80205
(303) 320-4764 • **(800) 833-7958** • FAX (303) 322-7242
email: sales@geotechenv.com website: www.geotechenv.com

Electrical Submersible Pump Controller

geotech

Grundfos Redi-Flo Variable Frequency Drive

SPECIFICATIONS

Electric	
Input	115V± 10%/1 PH/48-62 Hz/23A 230V± 10%/1PH/48-62 Hz/23A
Output with 115V Input	1.5 kw/400 Hz/220V/3 PH/6.0A (RF2) 1.5 kw/80 Hz/230V/3 PH/6.5A (RF4)
Output with 230V Input	1.5 kw/400 Hz/220V/ 3 PH/6.0A (RF2) 1.5 kw/100 Hz/230V/ 3 PH/8.2A (RF4)
Acceleration Time (factory preset)	0 to 400 Hz: 3 seconds (RF2) 0 to 100 Hz: 3 seconds (RF4)
Deacceleration Time (factory preset)	400 to 0 Hz: 0 seconds (RF2) 100 to 0 Hz: 0 seconds (RF4)
Recommended Input Protection (115V)	Fuse, 1 each, 250V, 25A, UL Class RK1 or circuit breaker, 25A/300V/1P
Recommended Input Protection (230V)	Fuse, 2 each, 250V, 25A, UL Class RK1 or circuit breaker, 25A/300V/2P
Power Cord	SJOW, 14 AWG, 10' (3m) long
Minimum Frequency (factory preset)	115 or 230V 25 Hz
Maximum Frequency (factory preset)	115 or 230V 400 Hz (RF2) 115V 80Hz* (RF4) 230V 100 Hz (RF4) *Auto Frequency Limiting
Dimensions & Weight	
Dimensions	Protective Case – 17¾" L x 12½" W x 8" H (45cm L x 32cm W x 20cm H) VFD only – 13" L x 7¾" W x 7" H (33cm L x 20cm W x 18cm H)
Net Shipping Weight (VFD, Cord & Case)	35 lbs. (16 kg) VFD only – 18 lbs. (8 kg)
Operating Conditions VFD Only	
Ambient Temperature	14°F to 104°F (-10°C to 40°C)
Storage Conditions	
Ambient Temperature	-22°F to 149°F (-30°C to 65°C)
Relative Humidity	100%, Condensing
Protective Case Construction	
Case	High impact polyethylene
Trim	Aluminum
Lock	Cast drawbolt
Minimum Generator Size: (Redi-Flo2®/Redi-Flo4™)	
For Generators With Voltage Regulation	(2500 RF2/3400 RF4) Watts at 115/230 VAC, single phase
For Generators Without Voltage Regulation	(5000 RF2/6700 RF4) Watts at 115/230 VAC, single phase
Recommended For Optimal Performance	(4000 RF2/5400 RF4) Watts at 115/230 VAC, single phase w/voltage regulation

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(303) 320-4764 • **(800) 833-7958** • FAX (303) 322-7242
email: sales@geotechenv.com website: www.geotechenv.com

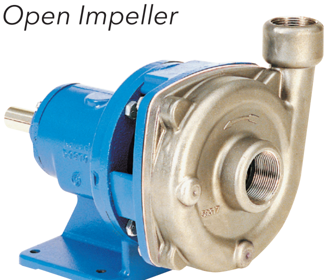
P-INF & P-EFF Influent and Effluent Pump

CDM Smith

End Suction – Stainless Steel

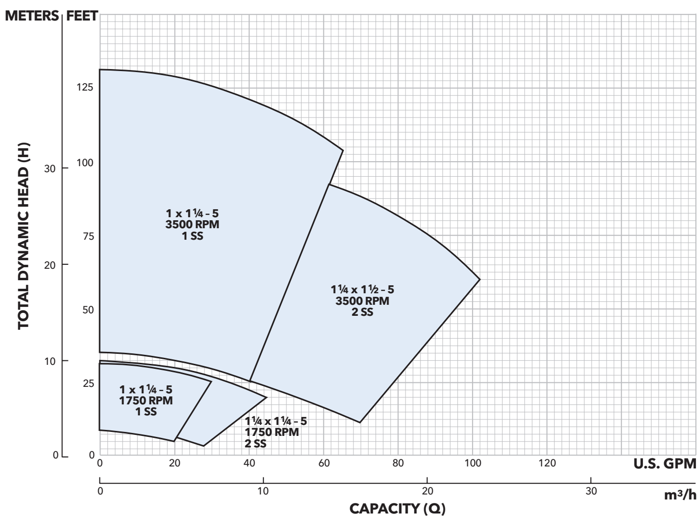
ICS/ICS-F

Investment Cast 316 Stainless Steel Open Impeller



ICS-F

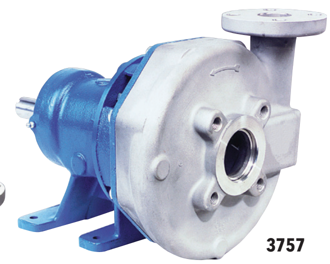
ICS



3657/3757

Investment Cast 316 Stainless Steel Enclosed Impeller

3657



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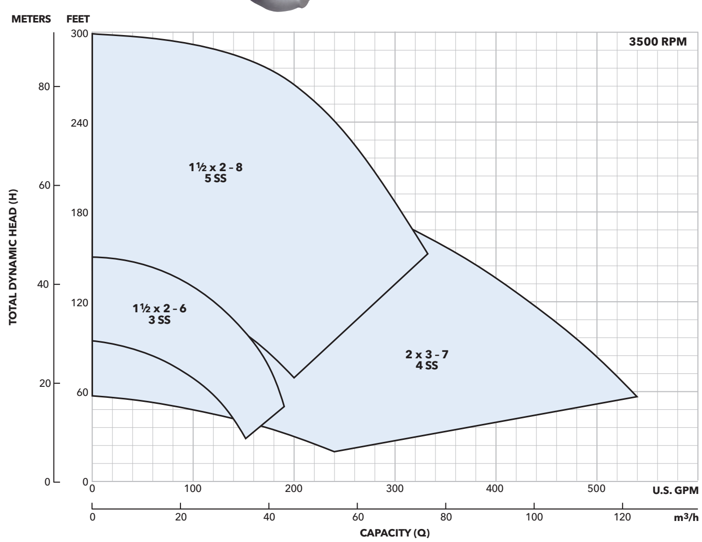
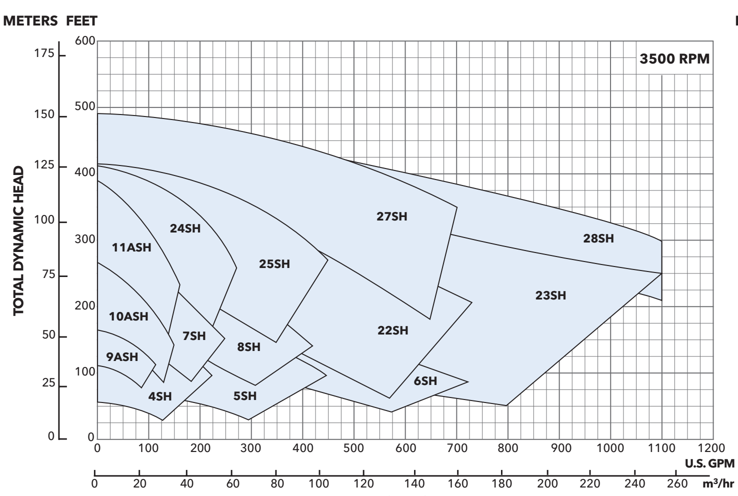
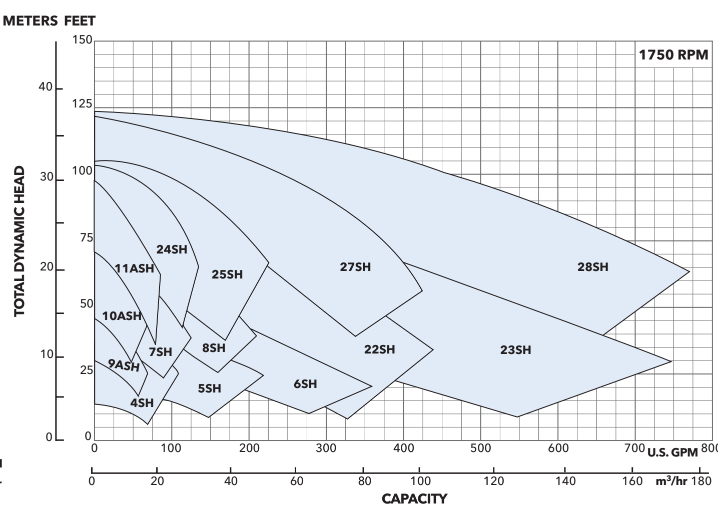


SSH

316L Stainless Steel Enclosed Impeller

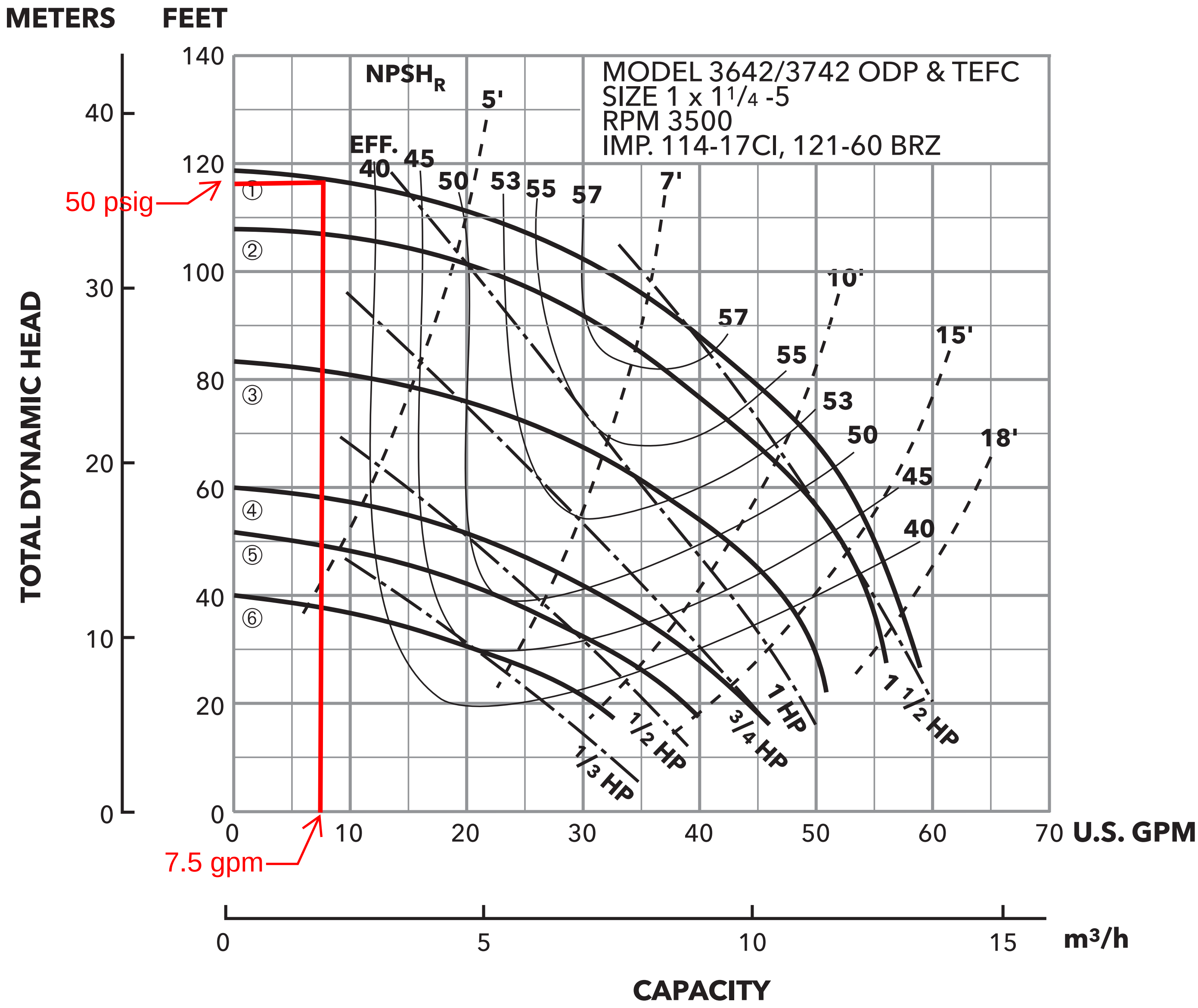




PERFORMANCE CURVE 1AI, 1BF, 1AB . . .

MOTOR SIZES AND IMPELLER DIAMETERS

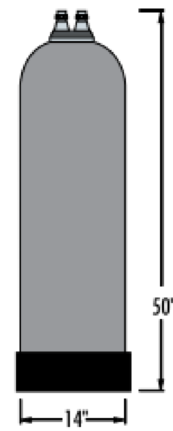
① 1½ HP ODP OR 2 HP TEFC	5⅜" DIA.	④ ½ HP ODP OR ¾ HP TEFC	3⅞" DIA.
② 1 HP ODP OR 1½ HP TEFC	5⅛" DIA.	⑤ ⅓ HP ODP OR ½ HP TEFC	3⁹⁄₁₆" DIA.
③ ¾ HP ODP OR 1 HP TEFC	4⁹⁄₁₆" DIA.	⑥ OPTIONAL TRIMMED IMPELLER	3³⁄₁₆" DIA.



Tank 3.6 Evoqua Tank Spec

Evoqua Water Technologies
10 Technology Drive Lowell, MA
01851-9926

Nominal Size (Ft^3):		3.6
Volume:	Ft^3	3.60
	Gal.	26.900
Dimensions:	Height w/base (In.)	46.4
	Height wo/base (In.)	45.8
	Diameter (In.)	14
	Dome Volume ($Ft.^3$)	0.24
	Dome Hole (inches)	4.5"
	Thread Style	Buttress
Material:	Shell Winding	FRP w/Epoxy
Tank Liner:	Seamless	ABS
		Polyethylene
Tank Base:		Rubber
		Polyethylene
Bumper Band		Rubber (3/16")
Exterior Color:		Pantone Cool Gray 8C
Labels:		**Evoqua** (with Serial Number)
Operating Specs:	Max Temperature	120-deg F
	Max Pressure	150-PSI
Tank Internals:	Outlet Diffuser	Noryl, ABS or PVC
	Inlet Diffuser	PP, ABS or PVC
	Riser Tube	1"-Sch-40 PVC, PP
External Fittings	Tank Adapter	4.5" Buttress, 3-Port (GF) Noryl, PVC
	Inlet Port	Male QD w/ 1.5" Acme Thread; w/ 1" MPT
	Outlet Port	Female QD w/ 1.5" Acme Thread; w/ 1" MPT
	Fill Port	Male QD w/ 1.5" Acme Thread; w/ 1" MPT
Industry Approved:	NSF Standard 44	
	UDT	
	WQA Standard S-100	



3.6 ft^3 (102 L)
10 GPM (36.2 LPM)

T-INF, T-EFF & TEFF2 6500 Gallon Storage Tank

CDM Smith

PRODUCT DATA SHEET

January, 2007

6500 GALLON POLY TANK

(Original Style and Total Drain)

GENERAL INFORMATION

This type of tank is not to be used for food applications. Potable water applications are generally not acceptable and must be reviewed by the Corporate office first for approval.

WEIGHTS AND MEASURES

» Capacity:	–	6500 gallons (nominal)
» Height‡:	–	10′-6″ (to top tangent line) 11′-11″ (to top of dome) 12′-4″ (to highest point on top lid)
» Diameter:	–	10′-0″ (nominal)
» Weight*:	–	Tank: 1700 lbs. – 1975 lbs. Pad: 400 lbs. - 450 lbs.

*Varies with origin of manufacture
‡ Does not include height of pad. Add four inches for pad thickness to determine heights from grade when pad is used.

DESIGN PARAMETERS

» Tank Material:	–	High Density Polyethylene
» Design Pressure:	–	0 psi – vented to atmosphere
» Design Vacuum:	–	0 psi – vented to atmosphere
» Spec. Gravity Limit:	–	Original Style – 1.65 Total Drain – 1.9
» Temp. Limit:	–	150° F
» Certification:	–	ASTM D1998 (not UL listed)

RESTRICTIONS

» Sulfuric Acid Storage:	–	• 80% concentration maximum • Use only tanks with equipment numbers ≥ 7376 • Previously repaired tank cannot be used (equipment number should have "W" at end) • 100° F maximum temperature • Top fill only • Top manway must be open during pneumatic filling of tank • Use flexible plumbing fixtures resistant to sulfuric acid

FEATURES

» Top Vent:	–	2″ PVC U-vent (two threaded street elbows)
» Manway:	–	Top mounted with 24″ opening (34 inch diameter screw-on cover)
» Valves:	–	3″ butterfly valve with PVC body and disc, Viton O-Ring seal and 316 SS stem.
» Ladder:	–	Top mounted bracket for ladder hook-up. Ladder is not permanently mounted to tank.
» Piping Connections:	–	Inlet – 3″ with butterfly valve Outlet – 3″ with butterfly valve Top – 4″ PVC adapter and PVC cap

MISCELLANEOUS

» Options:	–	Secondary containment berm

BAKERCORP™

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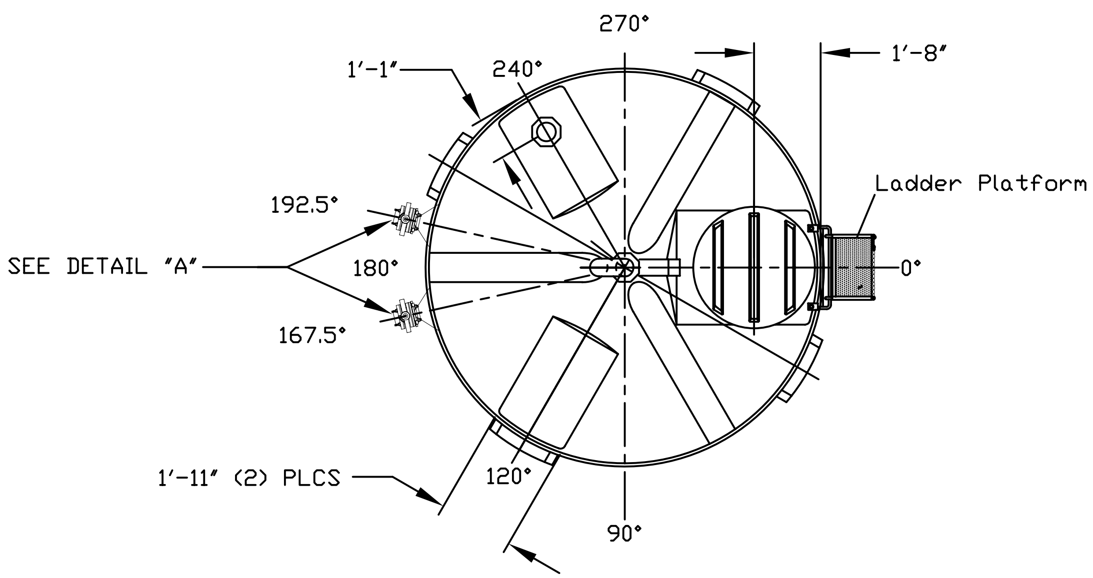
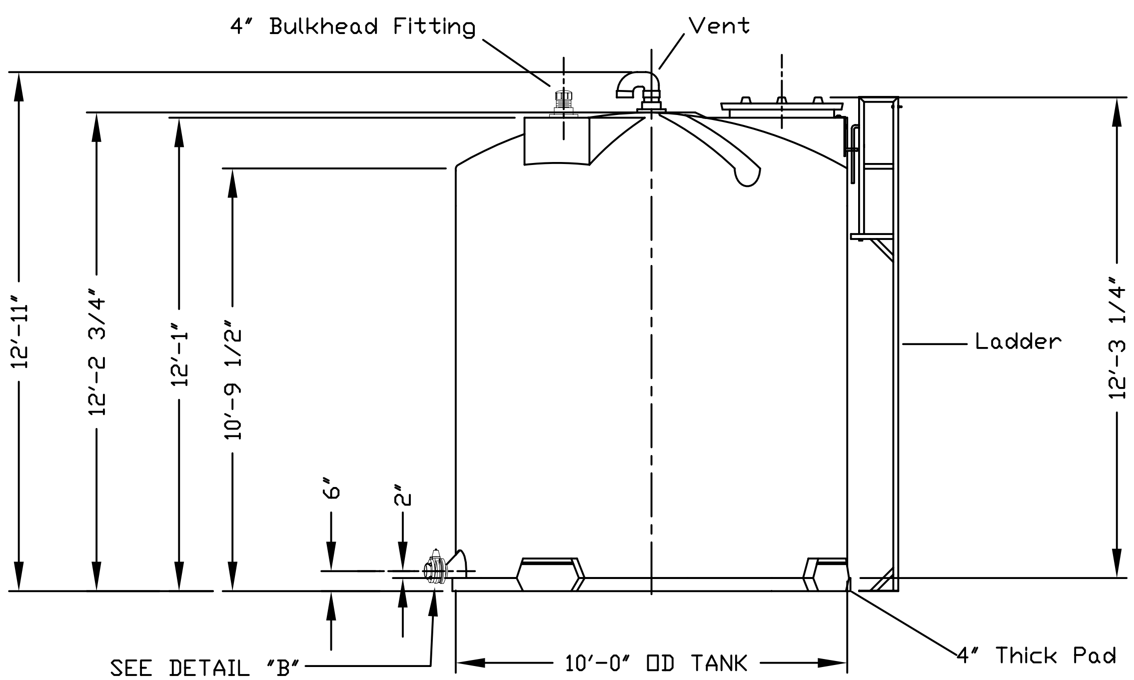
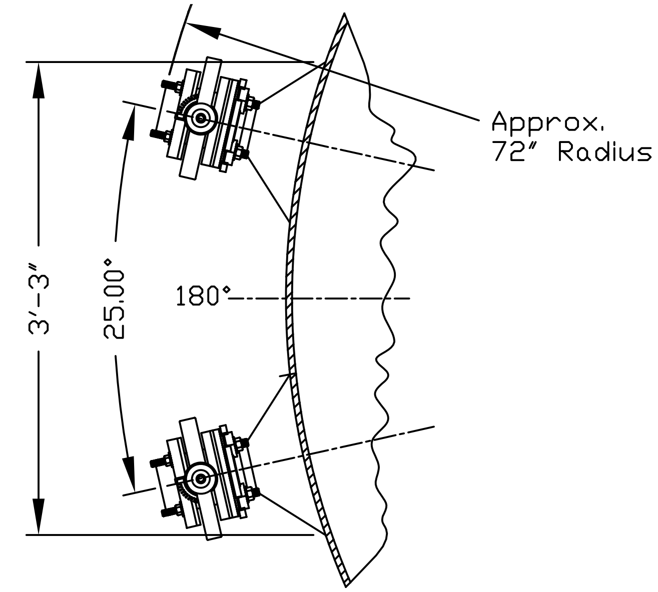
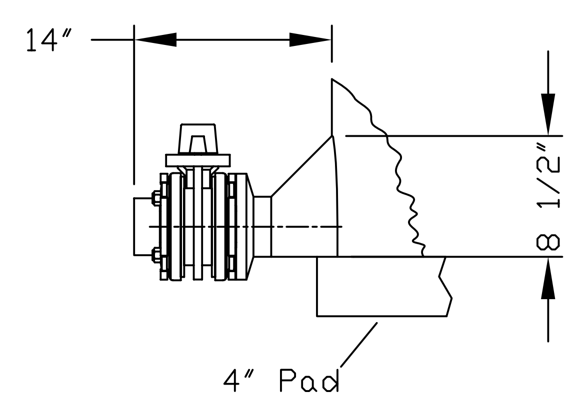






DETAIL "A"
(VALVE LAYOUT & CLEARANCE)
SCALE: NONE



DETAIL "B"
INTEGRALLY MOLDED FLANGED OUTLET (IMFO)
SCALE: NONE

SULFURIC ACID RESTRICTIONS

1. Do not store sulfuric acid above 80% concentration. For concentrations equal to or less than 80%, use tanks with equipment numbers equal to or greater than P7376. Do not use tanks with lower equipment numbers for sulfuric acid. Concentrations greater than 80% require Corporate approval.
2. Sulfuric acid must be less than 100 degrees to be stored in this tank.
3. Sulfuric acid must be filled through the top of the tank only.
4. Tank vent must always be open when storing sulfuric acid.

NOTES:
1. THIS IS A COMPUTER GENERATED DRAWING. DO NOT REVISE BY HAND.
2. DIMENSIONS WILL VARY ±3% DUE TO VARIATIONS IN MULTIPLE MOLDS & CONDITIONS PREVALENT DURING MANUFACTURE & USAGE.
3. DESIGN TANK WALL THICKNESS 1.9 SpG PRODUCT.
4. SEE DRAWING "BK65HUF", TITLED "BAKER 6500 GALLON STORAGE TANK TYPICAL FITTING INSTALLATION", FOR FITTING LOCATIONS.

SPECIFICATIONS:
1) Tank Weight: 1650 lbs.
2) Pad Weight: 450 lbs.
3) Tank Material: HDPE
4) Design Pressure: 0 psig
5) Vacuum Rating: Atmospheric only
6) Temperature limit: 150°F
7) Specific Gravity limit: Original Style - 1.65; Total Drain - 1.90

NOTES:
1. This drawing is a baseline representation for this model of tank. Variations between this drawing and the actual equipment in the field can and do exist, primarily with appurtenance locations, sizes and quantities. Consult your local BakerCorp representative if specific needs exist.
2. THIS TANK IS *NOT DESIGNED FOR TRANSPORTING LIQUIDS*. It should be moved only when empty..

BAKERCORP™ 3020 OLD RANCH PARKWAY SEAL BEACH, CA 90740-2751

REV.	DESCRIPTION	DATE	BY
G			
F			
E			
D	Revised dimensions	10/9/06	PJB
C	Added ladder & add'l dimensions	6/2/06	PJB
B	Fixed lineweights	7/12/05	Z.E.R
A	Added pad, valves, vent & bulkhead fitting.	3/10/05	PJB

SCALE: Do Not Scale	SIZE B	ORIGINAL DWG. DATE 05SEP02
DRAWN BY: P.J.B.	APPROVED BY: –	CAT/CLASS – –
TITLE 6500 GALLON POLY TANK		SHEET 1 OF 1
DRAWING NO. S-3-M0002-1-		REV. D

Appendix D

Technical Calculations

CDM Smith

Conveyance Piping Pressure Loss Calculations

CDM Smith

TECHNICAL CALCULATION

CDM Smith	CONVEYANCE PIPING PRESSURE LOSS	FSDF GWIM Implementation

Performed by	Mike Goh	Date	July 2015	Revision
Checked by	Steve Fundingsland	Date	July 2015	Rev 0
Checked by	Zoom Nguyen	Date	October 2015	Rev 1

1.0 Purpose/Objective

To estimate the pressure drop across conveyance piping.

2.0 References/Data Sources

- Drawing M-1.
- Manufacturer's Pressure drop information for PVC piping

3.0 Assumption

A flow rate of 1 gpm will be assumed as the maximum aquifer yield. A minimum flexible pipe size of 1" diameter will be used.

4.0 Calculations

With 1 gpm, the estimated pressure drop across 100 feet of PVC piping is less than 1 psig according to piping manufacture information.

5.0 Conclusion/Results

The following table is developed to estimate the total pressure loss across various lengths of piping.

Piping Length (Feet)	Pressure Drop (psig)
100	1
150	1.5
200	2
250	2.5
300	3

GAC Isotherm Calculations

CDM Smith

TECHNICAL CALCULATION

CDM Smith	GAC ISOTHERM	FSDF GWIM Implementation

Performed by	Mike Goh	Date	July 2015	Revision
Checked by	Steve Fundingsland	Date	July 2015	Rev 0
Checked by	Zoom Nguyen	Date	October 2015	Rev 1

1.0 Purpose/Objective

To estimate GAC usage.

2.0 References/Data Sources

Flow rates from Table 4-1 and Groundwater data from Table 4-2 of the GWIM Final Work Plan.

3.0 Assumption

GAC Aquascrub S media and a flow rate of 1 gpm will be used to model the isotherm.

4.0 Calculations

See attached Isotherm report.

Hence the usage for one GAC vessel is estimated at

$= 90\ lb - 5.6\ \#/day$

= 16 days

5.0 Conclusion/Results

Based on the carbon usage and size of vessel, it is expected that each GAC vessel will last approximately 16 days.

LIQUID PHASE ISOTHERM DESIGN PARAMETERS

Water Flow Rate 1.00000 gpm

LIQUID PHASE DESIGN

Component Name	Concentration	#GAC/1000 gallons of water
ETHANE,1,1,1-TRICHLORO- (TCA)	5868.0000 ppbw	2.4913
ETHENE,1,1-DICHLORO-	1034.0000 ppbw	0.9027
ETHENE,TRICHLORO- (TCE)	1842.0000 ppbw	0.3973
FREON 113	293.0000 ppbw	0.0266
XYLENE,m-	871.0000 ppbw	0.0698

Total Carbon Usage Estimated at Breakthrough

5.5983 #GAC/day

3.8877 #GAC/1000 gallons of water

The above carbon usage estimates are based on both experimental data as well as predictive models. Actual carbon usage rates observed at various stages of breakthrough depend on many factors, and may therefore differ from the above estimates. Please contact Westates Carbon Products for further assisitance.

LIQUID PHASE ISOTHERM DESIGN PARAMETERS

Water Flow Rate 1.00000 gpm

LIQUID PHASE DESIGN

Component Name	Concentration	Q [Wt %]	#GAC/1000 gallons of water	Suitability
ETHANE,1,1,1-TRICHLORO- (TCA)	5868.0000 ppbw	3.4365	1.4236	In Range
ETHENE,1,1-DICHLORO-	1034.0000 ppbw	1.6711	0.5158	In Range
ETHENE,TRICHLORO- (TCE)	1842.0000 ppbw	6.7638	0.2270	In Range
FREON 113	293.0000 ppbw	16.0646	0.0152	In Range
XYLENE,m-	871.0000 ppbw	18.2046	0.0399	In Range

Total Carbon Usage Estimated at Breakthrough

5.5983 #GAC/day

3.8877 #GAC/1000 gallons of water

(Both totals have been multiplied by a factor of 1.75)

The above carbon usage estimates are based on both experimental data as well as predictive models. Actual carbon usage rates observed at various stages of breakthrough depend on many factors, and may therefore differ from the above estimates. Please contact Westates Carbon Products for further assisitance.

Treatment System Pressure Loss Calculations

CDM Smith

TECHNICAL CALCULATION

CDM Smith	TREATMENT SYSTEM PRESSURE LOSS	FSDF GWIM Implementation

Performed by	Mike Goh	Date	July 2015	Revision
Checked by	Steve Fundingsland	Date	July 2015	Rev 0
Checked by	Zoom Nguyen	Date	October 2015	Rev 1

1.0 Purpose/Objective

To estimate the pressure drop across the equipment and treatment system.

2.0 References/Data Sources

- Mass Balance and Process Flow Diagram (PFD) in Drawing P-1.
- Pressure Drop Information for the 3.6 cu ft vessel

3.0 Assumption

A maximum flow rate of 7.5 gpm will be assumed.

4.0 Calculations

Calculating the individual losses and adding to obtain the maximum pressure loss across the system as shown on the following table.

Node (From –To)	Description	Pressure Loss Data	Qty	Units	Pressure Drop (psig)	Sum (psig)
2 - 3	GAC Treatment	Empirical *1	3	Vessel	2	6
3 - 4	Perchlorate Treatment	Empirical *2	2	Vessel	4	8
4 - 5	Metals Treatment	Empirical *1	2	Vessel	2	4
5 - 6	Arsenic Treatment	Empirical *1	2	Vessel	2	4
All	Misc piping and fittings inside compound	1" diameter flex hose *3	400	ft	0.01	4
-	Safety Factor	-	10%	-	-	2.6
TOTAL						**28.6**

*Note: *1 - The pressure loss values was based on vendor empirical data for these type of media*

**2 - Empirical data for Perchlorate media yield a higher pressure loss.*

**3 - From piping mfg data, 1" dia hose yields a deltaP of 1 psig per 100 ft*

5.0 Conclusion/Results

The estimated total Pressure Loss across the system is approximately 30 psig.

Influent and Effluent Tank Volume Calculations

CDM Smith

TECHNICAL CALCULATION

CDM Smith	STORAGE TANK VOLUME AND HOLDING TIME	FSDF GWIM Implementation

Performed by	Mike Goh	Date	July 2015	Revision
Checked by	Steve Fundingsland	Date	July 2015	Rev 0
Checked by	Zoom Nguyen	Date	October 2015	Rev 1

1.0 Purpose/Objective

To estimate the volume and holding time for the tanks.

2.0 References/Data Sources

- Flow rates from Table 4-1 of the GWIM Work Plan
- Drawing P-2.

3.0 Assumption / Parameters

- A maximum flow rate of 1 gpm will be assumed.
- A typical tank size from a vendor of 6500 gallon tank will be assumed.
- A minimum of 3-days holding time for system to operate over the weekend.

4.0 Calculations

The following calculations are performed in two parts (1. Estimate the minimum volume required and 2. Using a typical volume size estimate the holding time)

1. Using holding time, minimum volume required is
   = (3 days * 1440 mins in a day) *1 gpm
   = 4,320 volume (minimum)

2. Using a typical tank size from a tank vendor and time to reach storage capacity
   = 6500 gallons / 1 gallon per min / 1440 mins in a day
   = 4.5 days

5.0 Conclusion/Results

Each tank volume contains sufficient volume and exceeds the minimum holding time as specified.

Secondary Containment Volume Calculations

TECHNICAL CALCULATION

CDM Smith	SECONDARY CONTAINMENT VOLUME	FSDF GWIM Implementation

Performed by	Mike Goh	Date	July 2015	Revision
Checked by	Steve Fundingsland	Date	July 2015	Rev 0
Checked by	Zoom Nguyen	Date	October 2015	Rev 1

1.0 Purpose/Objective
To estimate the secondary containment volume.

2.0 References/Data Sources
- Flow rates from Table 4-1 of the GWIM Final Work Plan
- Drawing P-2.

3.0 Assumption
- The storage tanks are assumed to be doubled wall and not expected to leak into the secondary containment.
- A 50' long x 35' wide and 8" high secondary containment is assumed.

4.0 Procedures/Calculations
Secondary containment will be calculated using the total volume of the containment area minus the volume of the equipment they occupy.

Calculating the total containment area;
- Width x Length x Height of Berm = 35 feet x 50 feet x 8/12 foot
  = 1166.7 ft^3

Calculating the total footprint occupied by equipment;

Each tank takes a 10' in diameter footprint
- Volume of Tanks = Area of Tank *(PI x Radius^2)* x Height of Berm x Qty
  = 3.14 x 5 feet ^ 2 x 8/12 foot * Qty 3
  = 157.1 ft^3

Each 3.6 cuft treatment vessel takes a 18" x 18" (1.5 ft x 1.5 ft) footprint
- Volume of the treatment vessels = Qty 9 x (1.5 ft x 1.5 ft) x 8/12 foot of berm height
  = 13.5 ft^3

Each Pumps and Filters assembly takes a 3 ft x 4 ft footprint;
- Volume of Pumps and Filters assembly = Qty 2 x (3 ft x 4 ft) x 8/12 foot of berm height
  = 16 ft^3

Misc piping and conduits 2" in diameter (1" radius);
- Volume of Misc Piping = Area of piping x length inside containment.
  = 3.14 x 1/12 foot ^ 2 x 100 ft in length
  = 26.2 ft^3*

Total area occupied by equipment is 212.8 ft^3

Available Secondary containment volume

= total containment area - Total area occupied by equipment

= 1166.7 - 212.8 ft^3

= 953.9 ft^3* 7.48 gallon per ft^3

= **7135.2 gallons**

Using 110 percent containment capacity as a rule of thumb, verify if secondary containment volume exceeds and have "sufficient freeboard" over the capacity of all equipment when full excluding the double-wall storage tanks.

Estimate the volume of each major equipment components;

Equipment	Qty	Volume (ft^3)	Total Volume (ft^3)	Convert to Gallons (1 ft^3 = 7.48 gal)
Treatment Vessels	9	3.6	32.4	242.4
1" dia piping	200 ft	3.14 x 0.5/12ft^ 2	1	7.48
Pump and Filter	2	3.14 x 6/12ft^ 2	0.785	5.9
Misc	1	10% of total	3.5	26.2
		e	**37.7**	**282**

Percent freeboard = (Secondary Containment Vol - Equipment Vol) / Equipment Vol * 100%

= (7135.2 gal - 282 gal) / 282 gal * 100%

= 2430 %

5.0 Conclusion/Results

The available secondary containment volume meets the 110% rule and is significantly larger than the equipment volume.

Infiltration Trench Calculation

TECHNICAL CALCULATION

CDM Smith	INFILTRATION TRENCH	FSDF GWIM Implementation

Performed by	Mike Goh	Date	July 2015	Revision
Checked by	Steve Fundingsland	Date	July 2015	Rev 0
Checked by	Zoom Nguyen	Date	October 2015	Rev 1

1.0 Purpose/Objective

To estimate the volume of treated water that can be discharged into the infiltration trench assuming no infiltration occurring to surrounding soil.

2.0 References / Sources

- Drawing M-1 and refer to the Infiltration Trench.
- Drawing M-3 showing cross-section "B"
- Porosity of Geologic Materials, Freeze and Cherry (1997)

3.0 Assumption

- Trench length = 40 feet
- Quantity of infiltration trenches = 4
- Trench width = using 8 inches
- Trench height that will contain the pipe and crushed rock = 12 inches
- Perforated drain pipe = 3 inches (Corex drain pipe perforated)
- Crush rock = assume ½" diameter uniformity

4.0 Calculations

Performing calculation in multiple parts for one trench.

a) Calculating the backfill volume encased in crush rock under the native cover
= Width * Height * Length
$= \frac{8}{12} ft * \frac{12}{12}\ ft * 40$ ft
= 26.7 ft^3

b) Calculating the volume of the perforated pipe
= Area of pipe * pipe length
$= Pi * \left(\frac{\frac{Diameter}{2}}{12}\right)^2 * length$
$= 3.142 * \left(\frac{\frac{3}{2}}{12}\ ft\right)^2 * 40\ ft$
= 2 ft^3

c) Calculating the actual volume of crush rock minus the volume of pipe for all trenches
= Volume of trench backfill under native cover – Volume of pipe
= 26.7 –2 ft^3
= 24.7 ft^3

d) Calculating the void space of the actual rock backfill (*Using reference from Freeze and Cherry (1997), the porosity of gravel (crushed rock) ranges between 25% to 40%.)*
- Lower range = 24.7 ft^3 * 0.25 = 6.2 ft^3
- Higher range = 24.7 ft^3 * 0.40 = 9.9 ft^3

e) Adding the void space to the volume of piping
- Lower range = 6.2 ft^3 + 2 ft^3 = 8.2 ft^3
- Higher range = 9.9 ft^3 + 2 ft^3 = 11.9 ft^3

f) Converting the volume of void space and piping by multiply with 7.48 gallons
- Lower range = 8.2 ft^3 * 7.48 = 61.3 gallons
- Higher range = 11.9 ft^3 * 7.48 = 89.0 gallons

g) Calculating the total volume by multiplying with total number of trenches
- Lower range = 61.3 gallons * 4 = 245.2 gallons
- Higher range = 89.0 gallons* 4 = 356 gallons

5.0 Conclusion/Results

The estimated volume of treated water in gallons that can be discharged into the infiltration trenches for the system assuming no infiltration to surrounding soil ranges from approximately **245 to 356 gallons**.

Appendix E

CEQA Initial Study

CDM Smith

CALIFORNIA ENVIRONMENTAL QUALITY ACT
INITIAL STUDY

The Department of Toxic Substances Control (DTSC) has completed the following document for this project in accordance with the California Environmental Quality Act (CEQA) [Pub. Resources Code, div. 13, § 21000 et seq] and accompanying Guidelines [Cal. Code Regs., tit. 14, § 15000 et seq].

PROJECT TITLE: Former Sodium Disposal Facility Groundwater Interim Measure		CALSTARS CODING:
PROJECT ADDRESS: 5800 Woolsey Canyon Road	CITY: Canoga Park	COUNTY: Ventura
PROJECT SPONSOR: US Department of Energy	CONTACT: John Jones	PHONE: 805-416-0992

APPROVAL ACTION UNDER CONSIDERATION BY DTSC:

☐ Initial Permit Issuance ☐ Permit Renewal ☐ Permit Modification ☐ Closure Plan
☐ Removal Action Workplan ☐ Remedial Action Plan ☒ Interim Removal ☐ Regulations
☒ Other (specify): Implementation of FSDF GWIM

STATUTORY AUTHORITY:

☒ California H&SC, Chap. 6.5 ☐ California H&SC, Chap. 6.8 ☐ Other (specify):

DTSC PROGRAM/ ADDRESS: 8800 Cal Center Drive, Sacramento, CA 95826-3200	CONTACT: Roger Paulsen	PHONE: 916-255-3702

PROJECT DESCRIPTION:

Under the authority of Chapter 6.5 of the Health and Safety Code, the DTSC is currently overseeing investigative and remedial activities at the Santa Susana Field Laboratory. The Los Angeles Regional Water Quality Control Board is enforcing water discharge requirements related to treated groundwater per Order No. R4-2014-0187. The U.S. Department of Energy is proposing to install and operate a Groundwater Interim Measure (GWIM) treatment system at the Former Sodium Disposal Facility (FSDF) located within Area IV of the SSFL. The *Implementation Plan for the FSDF Groundwater Interim Measure* (CDM Smith, 2015) describes the proposed project.

Location

The SSFL is located approximately 29 miles northwest of downtown Los Angeles, California. The SSFL occupies approximately 2,850 acres of hilly terrain, with approximately 1,100 feet of topographic relief near the crest of the Simi Hills in Simi Valley (See Figure 1). Area IV of SSFL occupies approximately 900 acres of the western portion of SSFL, with the FSDF located in the western portion of Area IV (Figure 2).

The SSFL was established after World War II as a site to test engines and components for missiles, rockets, and spacecraft. Area IV of SSFL was used for nuclear power, conventional energy, liquid metals research, and laser development. During SSFL operations, a number of industrial solvents were released into the soil and groundwater. Currently, the SSFL is jointly owned by The Boeing Company (Boeing) and the federal government. Area IV of SSFL is owned by Boeing with portions of Area IV leased to DOE for energy and metals research.

Background

The SSFL is divided into four administrative areas (Areas I, II, III, and IV), and undeveloped land to the north and south (Figure 2). The FSDF GWIM in planned to be installed and operated by DOE on property owned by Boeing in the western portion of Area IV. The FSDF was used for the treatment of metal objects for the removal of sodium and potassium metals by placing the objects in one of two ponds. The land to the west and south of the FSDF was used for storage of wastes in drums. The FSDF ponds, drums, and impacted soils were removed through a series of actions in the 1990s.

The GWIM activities will occur within the footprint of the FSDF and soil removal areas, and within a gravel parking area used by Boeing to store surface water in large Baker Tanks. Existing monitoring wells will be used for groundwater extraction and possible reinjection. Extracted groundwater will be pumped to storage tanks and treated at the treatment unit. Treated water will be released into the subsurface using a horizontal piping installed nominally 4 feet below ground surface, 10 feet above the bedrock interface.

The proposed FSDF GWIM is designed to both remove a significant amount of trichloroethylene (TCE) contamination from the underlying aquifer and to refine the knowledge of the bedrock hydrology of the site, particularly in the identification of fracture zones harboring TCE contamination, and the ability to reduce TCE concentrations within those zones. Reinjection of treated groundwater near the extraction wells is intended to help flush contaminants to the direction of the extraction wells. Groundwater will also be treated for metals and perchlorate prior to release within the FSDF area.

Project Activities

The proposed FSDF GWIM activities are detailed in the *Implementation Plan FSDF GWIM* (CDM Smith, 2015). In summary the proposed FSDF GWIM activities are as follows:

- Hydrogeological characterization through video logging, step draw-down tests, packer testing, and sampling of existing FSDF wells to identify zones of contamination and candidate pumping wells
- Installation of GWIM treatment system with extracted water and treated water storage tanks
- Installation of treated water discharge trenches
- Installation of discharge piping from GWIM treated water storage tanks to discharge points
- Installation of extraction pumps in wells
- Installation of piping from extraction wells to GWIM storage tanks
- Initiation of pumping (nominal 0.5 gallons per minute) and filling of extracted water storage tank
- Performance testing of the treatment unit to ensure proper functions
- Batch treatment processing of extracted water and placement in treated water storage tanks
- Sampling of treated water to ensure it meets discharge standards
- Release of treated water to discharge points
- Measuring water level changes and water quality responses of adjacent monitoring wells
- Monitoring of infiltration response into the subsurface of the discharged treated water
- Operating system for 3 months

Field Schedule

The proposed FSDF GWIM project would be implemented at the project site according to the approximate schedule and durations:

- Site characterization: video logging, packer testing, step test, well sampling: Month 1 to Month 3 (2 months)
- Installation of GWIM treatment system: Month 3 (1 week)
- Installation of surface piping: Month 3 (1 week)
- Installation of trench infiltration system: Month 3 (1 week)
- System start up and testing: Month 4 (1 week)
- System operations: Month 4 to 6 (3 months)
- Monitoring well water level measuring and water quality sampling: Month 4 to 7 (4 months)

Site Characterization
Existing groundwater quality data for wells at the FSDF indicate that the TCE is primarily present in bedrock fractures. However the data are not clear as to what fractures mostly contribute to the TCE plume. To identify wells to be pumped and which fractures to target additional testing of the FSDF wells will be performed. Candidate bedrock pumping wells include Corehole-8, RD-21, RD-23, and RD-54A. Shallow well RS-54 would also be pumped when discharge re-saturates the alluvial soil/bedrock interface. For each well, the FLUTe system would be removed (if still installed), the well video logged to identify fractures, with zones of fractures being packer tested and sampled for the presence TCE.

Installation of GWIM System
The GWIM treatment unit consists of three treatment vessels: one containing granulated activated carbon to remove TCE, one with a resin to remove metals, and one with a resin to remove perchlorate. The system would have a single 6,500 gallon extracted groundwater storage tank and two 6,500 gallon treated groundwater storage tanks. The components would be modular to the extent practical, pre-manufactured by the subcontractor, and transported to the site on trucks. Once on the treatment unit site, the components would be linked using double-wall flexible piping. There is an existing electrical panel at the treatment unit site so power is readily available.

Installation of Surface Piping
All surface piping from the well heads to the treatment unit conveying extracted groundwater would be double lined and placed on the ground surface. Piping of treated groundwater to the discharge point would also be placed on ground surface.

Treated Water Discharge System
Treated water would be released into a subsurface discharge system consisting of gravel and perforated pipes installed in trenches about 10 feet above bedrock (about 4 feet below ground surface). Treated water would be piped to the discharge system to eventually percolate into the bedrock aquifer.

System Startup and Testing
System startup and testing involves first pumping potable water through the treatment unit to check for any leaks. Once leak detection has been completed, the pumping from the first well would be initiated at a nominal 0.5 gallons per minute (the rate will be determined prior to systems operations through the conduct of step drawdown test). Water levels from the pumping well would be monitored closely to ensure that the pumping rate can be maintained. Samples of the extracted water are to be analyzed per Order No. R4-2014-0187 for at least TDS, TSS, VOCs (TCE), metals, and perchlorate prior to any treatment

and following treatment to ensure treatment discharge concentrations are being met. If discharge limits are not met, then modifications of the system may be necessary. Treated water would be stored in a 6,500 gallon tank until sample results determine that discharge limits have been met.

Treated water meeting the discharge limits would then be piped to the discharge trenches and released underground using perforated piping. Water level responses above bedrock due to the treated water release are to be monitored. Also, monitoring would occur of the drainage downgradient of the FSDF for seeps or wet spots not present prior to the GWIM startup indicating a surface emergence of the treated water.

System Operations
Because the flow rate of 0.5 gallons per minute is too small to effectively pass the treatment vessels, the GWIM treatment system would be operated at a higher flow rate using a batch process basis. The treatment system would be operated during daylight hours only due to the high level of uncertainty regarding reinjection, and its location in the watershed. Each morning prior to restart the operator would verify that the system is working effectively and make adjustments as necessary.

Water would be pumped from the 6,500 gallon influent storage tank through the treatment unit at a rate of 5 gallons per minute (2,100 gallons capacity for a 7 hour operations shift). Only 720 gallons of groundwater can be extracted each 24 hour period so it is probable that the treatment system would not be operated every work day (operations will most likely occur on Monday, Wednesday and Friday). Treated water would be stored in an effluent tank until analytical data show it meets discharge limits. After permit compliance is met, the treated water can be released to the infiltration trenches at a nominal 1 gallon per minute from the storage tank.

During groundwater extraction and release, monitoring wells in the vicinity would be measured for water level changes and sampled for water chemistry changes. The wells targeted for measurement/sampling (depending on which well is used for pumping) include Corehole 8, RD-54A, RD-54B, RD-21, RD-22, RD-23, RD-33A, RD-33B, RD-50, and RD-91. Should the release of treated water recharge RS-54, RS-54 would also be sampled and considered for pumping.

ENVIRONMENTAL IMPACT ANALYSIS:

1. Aesthetics

Project Activities with a Potential Impact: Placement of treatment system, piping, and tanks on flat parking area would add a temporary feature visible primarily through foreground views.

Description of Baseline Environmental Conditions: The SSFL facility is located along the top crest of the Simi Hills. The FSDF site is located on flat terrain bordered by two linear bedrock features. The location has been subject to previous soil removal actions, is relatively flat, and slopes downward to the north. The treatment system will be placed on a gravel parking area that exhibits weedy vegetation along its fringes. The existing monitoring wells and proposed piping are within an area that has been subject to prior soil excavations and re-vegetation. The area above where the FSDF ponds were is backfilled. The area is surrounded by dirt roadways. Vegetation is a mixture of ruderal invasive plants and native plants. There are no distinguishing visual features of the project site, but the site is bordered on the east and west by bedrock outcrops that characterize the SSFL ridge. Disturbance of bedrock outcrops is not part of the proposed project.

Analysis as to whether or not project activities would:

a. Have a substantial adverse effect on a scenic vista.

Impact Analysis: There are no scenic vistas that allow public view of the project site. The site is located in a topographic depression within the Simi Hills crest and thus not visible to the public.

Conclusion:
☐ Potentially Significant Impact
☐ Potentially Significant Unless Mitigated
☒ Less Than Significant Impact
☐ No Impact

b. Substantially damage scenic resources, including, but not limited to, trees, rock outcroppings and historic buildings within a state scenic highway.

Impact Analysis: There are no scenic resources including trees, outcroppings or historic buildings that would be affected by the project. The site is not visible from a scenic highway (California Department of Transportation 2011).

Conclusion:
☐ Potentially Significant Impact
☐ Potentially Significant Unless Mitigated
☐ Less Than Significant Impact
☒ No Impact

c. Substantially degrade the existing visual character or quality of the site and its surroundings.

Impact Analysis: The most visible feature of the project would be the GWIM treatment system and tanks. The GWIM treatment system is temporary and would be located within an already disturbed area (gravel parking lot). The infiltration trench would be revegetated following installation. There would be no ground or vegetation disturbance for placement of the surface piping. The pipes would be partially hidden by existing vegetation. Digging of the infiltration trench would leave a linear feature that will eventually be re-vegetated. All project features would be primarily visible only from foreground views.

The project features would not be visible to the general public. The nearest residential areas, Runkle Canyon 5,000 feet to the northwest and Bell Canyon 6,000 feet to the southeast are at lower elevations and views of SSFL are blocked by higher elevations that border SSFL. At the end of the GWIM operations, all facilities would be removed including the surface piping from the wells and to the infiltration trench. Following removal of the treatment system and piping, natural re-vegetation of the impacted area would return the site to current conditions. There is no potential for substantial degradation of the project site or its surroundings.

Conclusion:
☐ Potentially Significant Impact
☐ Potentially Significant Unless Mitigated
☒ Less Than Significant Impact
☐ No Impact

d. Create a new source of substantial light or glare that would adversely affect day or nighttime views in the area.

Impact Analysis: All activities would occur in the day time. There would not be a need for introduction of new light sources at the site.

Conclusion:
☐ Potentially Significant Impact
☐ Potentially Significant Unless Mitigated
☐ Less Than Significant Impact
☒ No Impact

References Used:
California Department of Transportation. 2011. California Scenic Highway Program Mapping System. http://www.dot.ca.gov/hq/LandArch/scenic_highways/index.htm

2. Agricultural Resources

Project Activities with a Potential Impact: There are no agricultural resources at the project site.

Description of Baseline Environmental Conditions: There are no agricultural resources at the project site. Adjacent properties are used for cattle grazing, but the project site is fenced to prevent cattle access. SSFL is located in the unincorporated area of Ventura County and is not located within any specific plan area or other project area designated by the Ventura County General Plan (Ventura County 2013). The general plan designation for SSFL is open space, although it is zoned rural agriculture and open space. The land use is modified by a special use permit to allow industrial uses (Ventura County 2011).

Analysis as to whether or not project activities would:

a. Convert Prime Farmland, Unique Farmland, or Farmland of Statewide Importance (Farmland) as shown on the maps prepared pursuant to the Farmland Mapping and Monitoring Program of the California Resources Agency, to non-agricultural use.

Impact Analysis: There are no current agricultural uses at the project site. The project site, project vicinity, and surrounding areas are not located within designated prime, unique, or important farmland. Therefore, no impact to farmland designated by the California Resources Agency would occur as a result of project implementation.

Conclusion:
☐ Potentially Significant Impact
☐ Potentially Significant Unless Mitigated
☐ Less Than Significant Impact
☒ No Impact

b. Conflict with existing zoning or agriculture use, or Williamson Act contract.

Impact Analysis: The project site is subject to the Non-Coastal Zoning Ordinance (for structures and uses outside of the coastal zone) of Ventura County Planning Division and zoning is designated as RA-5ac (Rural Agricultural with a 5 acre minimum lot size). The SSFL site was granted a Special Use Permit by Ventura County in 1954 which allowed a variety of industrial activities. The purpose of the Rural Agricultural Zone is to provide for and maintain a rural setting where a wide range of agricultural uses are permitted while surrounding residential land uses are protected.

The project site is not located in an area designated for a Ventura County Area Plan and is not subject to a Land Conservation or Williamson Act contract, according to the County of Ventura Resource Management Agency maps (County of Venture Resource Management Agency 2014).

No existing or planned agricultural uses occur at the project site and use of the site is consistent with the Special Use Permit. No change in land use would occur as a result of the project. No impact would result.

Conclusion:
☐ Potentially Significant Impact
☐ Potentially Significant Unless Mitigated
☐ Less Than Significant Impact
☒ No Impact

c. Involve other changes in the existing environment which, due to their location or nature, could result in conversion of Farmland, to non-agricultural uses.

Impact Analysis: There are no current agricultural uses at the project site; therefore, there can be no conversion of farmlands.

Conclusion:

☐ Potentially Significant Impact
☐ Potentially Significant Unless Mitigated
☐ Less Than Significant Impact
☒ No Impact

References Used:

County of Ventura Resource Management Agency. 2014. Map of Lands Currently Under LCA Contract. (accessed on July 30, 2015, http://www.ventura.org/rma/planning/pdf/programs/lca/2014%20LCA%20Map.pdf)

Ventura County, 2011, Ventura County General Plan, Land Use Appendix, Ventura, California, June 28.

Ventura County, 2013, Ventura County General Plan (accessed on July 14, 2014, http://www.ventura.org/rma/planning/pdf/plans/Goals_Policies_and_Programs_10-22-13.pdf), Ventura, California, December 3.

3. Air Quality

Project Activities with a Potential Impact: There are no planned releases of atmospheric pollutants for the project. Groundwater pumps and the treatment system would be electrically powered. The treatment system is contained with no releases of volatiles. Transport of equipment and treatment media would be less than once per week.

Description of Baseline Environmental Conditions:
The project site is in the jurisdiction of the Ventura County Air Quality Control District. The climate of Ventura County is classified as Mediterranean and is characterized by mild winters and long warm summers with mild seasonal changes. Temperatures are typically moderated by sea breezes of the Pacific Ocean. The project site is affected by the frequent Santa Ana winds of the Traverse Ranges that on occasion raise temperatures dramatically.

Climate and meteorological data collected at Canoga Park (about 5 miles east of SSFL) and SSFL are used to describe the climatic conditions of the site (WRCC 2014). The average high and low temperatures in Canoga Park in July are about 95 and 57 degrees Fahrenheit, respectively. January's average high and low temperatures are about 68 and 39 degrees Fahrenheit, respectively. Winds at SSFL prevail from the northwest and southeast quadrants. These prevailing wind directions are in part due to the orientation of the slope of the terrain of SSFL, which in part forces winds upslope (blowing from the northwest) and downslope (blowing from the southeast). The number of days with precipitation varies substantially from year to year, resulting in a wide range of variability in annual precipitation totals. At Canoga Park, annual precipitation averages about 16.9 inches per year; the majority of rainfall occurs from late November through early April.

The federal Clean Air Act and the California Clean Air Act (CCAA) authorize the regulation of air quality by the USEPA and the California Air Resources Board (CARB), respectively. National Ambient Air Quality Standards (NAAQS) have been established for what are known as "criteria" pollutants and the state of California has established more stringent standards for these pollutants in the California Ambient Air Quality Standards (CAAQS). The criteria pollutants include nitrogen dioxide, carbon monoxide, sulfur oxides, ozone, particulate matter, and lead.

EPA designates all areas of the United States as having air quality better than (attainment) or worse than (nonattainment) the NAAQS. An area generally is in nonattainment for a pollutant if its NAAQS has been exceeded more than once per year. Former nonattainment areas that have attained the NAAQS are designated as maintenance areas. Presently, EPA categorizes Ventura County as in serious nonattainment of the 8-hour ozone standard and in attainment/unclassifiable for carbon monoxide, nitrogen dioxide, PM_{10}, $PM_{2.5}$, and lead (EPA 2014). CARB designates areas of the state that are in attainment or nonattainment of the CAAQS. An area is in nonattainment for a pollutant if its CAAQS have been exceeded more than once in 3 years. CARB currently designates Ventura County as in nonattainment for ozone and PM_{10} and in attainment for carbon monoxide, nitrogen dioxide, sulfur dioxide, $PM_{2.5}$, and lead (CARB 2014). The following table summarizes regional air quality for the project area.

Pollutant	California Standards	National Standards
Ozone	Nonattainment	Nonattainment
Carbon Monoxide	Attainment	Attainment

Nitrogen Oxides	Attainment	Attainment
Sulfur Oxides	Attainment	Attainment
Particulate Matter <10µm	Nonattainment	Attainment
Lead	Attainment	Attainment

The VCAPCD has recommended the following significance thresholds for development projects to address potential adverse air quality impacts: 25 pounds/day of ROC emissions and 25 pounds/day of NOx emissions.

Analysis as to whether or not project activities would:

a. Conflict with or obstruct implementation of the applicable air quality plan.

Impact Analysis:

The project would result in emissions from internal combustion engines due to vehicle trips of workers traveling to set up the GWIM and then daily to the site to operate the GWIM system and sample monitoring wells. Only 2 workers would be needed for the project. There would be also emissions from vehicles transporting the GWIM system to the site and chemicals and supplies for GWIM operations and to support well sampling. The two workers vehicles would operate on site an average of 1 hour each day. The vehicles transporting GWIM equipment would be on site for five days. The vehicle transporting chemicals and supplies would be on site 1 day a week and operate for 4 hours. The vehicle supporting sampling would be on site 3 days per week and operate 4 hours each day. Operations of the GWIM are anticipated to last 3 months (90 days). The operation of vehicles for the proposed activities would not release substantial emissions and net effect on regional air quality would not be significant.

Conclusion:
☐ Potentially Significant Impact
☐ Potentially Significant Unless Mitigated
☒ Less Than Significant Impact
☐ No Impact

b. Violate any air quality standard or contribute substantially to an existing or projected air quality violation.

Impact Analysis: Based on the vehicle operation hours and period of GWIM system operations, the project would not contribute to a significant quantity of any air pollutant, would not produce a continuing source of emissions, and would not contribute substantially to an existing or projected air quality violation.

Conclusion:
☐ Potentially Significant Impact
☐ Potentially Significant Unless Mitigated
☒ Less Than Significant Impact
☐ No Impact

c. Result in cumulatively considerable net increase of any criteria pollutant for which the project region is non-attainment under an applicable federal or state ambient air quality standard (including releasing emissions which exceed quantitative thresholds for ozone precursors).

Impact Analysis: Based on the vehicle operation hours and period of GWIM system operations, the project would not contribute to a significant quantity of any air pollutant. Also the emission levels would be well below significance thresholds so no net cumulative impact would occur and the impact of the project is not cumulatively considerable.

Conclusion:
☐ Potentially Significant Impact
☐ Potentially Significant Unless Mitigated
☒ Less Than Significant Impact
☐ No Impact

d. Expose sensitive receptors to substantial pollutant concentrations.

Impact Analysis: Sensitive receptors include, but are not limited to, hospitals, schools, daycare facilities, elderly housing, and convalescent facilities. These are areas where the occupants are more susceptible to the adverse effects of exposure to toxic chemicals, pesticides, and other pollutants. The proposed FSDS GWIM project site is located in the far western portion of Area IV of SSFL. It is located in a topographical depression surrounded by higher elevation. The nearest residential areas, Runkle Canyon 5,000 feet to the northwest and Bell Canyon 6,000 feet to the southeast are at lower elevations and views of SSFL are blocked by higher elevations that border SSFL. There are no sensitive receptors in proximity to the project site and the project would not result in “substantial pollutant concentrations.”

Conclusion:
☐ Potentially Significant Impact
☐ Potentially Significant Unless Mitigated
☐ Less Than Significant Impact
☒ No Impact

e. Create objectionable odors affecting a substantial number of people.

Impact Analysis: The project would not release odors.

Conclusion:
☐ Potentially Significant Impact
☐ Potentially Significant Unless Mitigated
☐ Less Than Significant Impact
☒ No Impact

f. Result in human exposure to Naturally Occurring Asbestos.

Impact Analysis: There is no naturally occurring asbestos at the project site. The project site is comprised of soil of Chatsworth formation sandstone and Santa Susana formation sandstone origin.

Conclusion:
☐ Potentially Significant Impact
☐ Potentially Significant Unless Mitigated
☐ Less Than Significant Impact
☒ No Impact

References Used:

CARB. 2014. Area Designations Maps/State and National (available at http://www.arb.ca.gov/desig/adm/adm.htm).

USEPA. 2014. *The Green Book Nonattainment Areas for Criteria Pollutants* (available at http://www.epa.gov/air/oaqps/greenbk/index.html).

WRCC (Western Region Climate Center), 2014, *Canoga Park Pierce College, California (041484) - Period of Record Monthly Climate Summary*, Period of Record: 7/ 1/1949 to 8/10/2011 (available at http://www.wrcc.dri.edu/cgi-bin/cliMAIN.pl?ca1484).

4. Biological Resources

Project Activities with a Potential Impact: The treatment system would be installed on a gravel parking lot. The piping and release system would be installed in an area of ruderal and native vegetation.

Description of Baseline Environmental Conditions: The FSDF is a more or less level site that was formerly disturbed. Portions of the site have been revegetated and portions remain disturbed. The disturbed habitat is in the northeastern portion of the site (within the proposed GWIM system location) and is mainly covered in gravel with sparse vegetation growing through the gravel. Species composition is mostly non-natives including tocalote (*Centaurea melitensis*), telegraphweed (*Heterotheca grandiflora*), summer mustard (*Hirschfeldia incana*) tree tobacco (*Nicotiana glauca*), red brome (*Bromus madratensis rubens*), with scattered individuals of native species including coyote brush (*Baccharis* *pilularis*) and narrow leaf milkweed (*Asclepias fascicularis*). There are some large coyote brush shrubs and tree tobacco plants along the border.

The southwestern portion of the site has been revegetated with a mix of species. The area is an open area dominated by native shrubs with both native and non-native grasses and herbaceous species in the understory. Coyote brush is dominant with coast goldenbush (*Isocoma menziesii*), coastal bush sunflower (*Encelia californica*), and deerweed (*Acmispon glabra*) also present. About seven planted coast live oak trees (*Quercus agrifolia*) (approximately 6 – 10 feet tall) are sparsely scattered throughout the area and there are a few larger trees along the edge of the site. No sensitive plant species, such as the Santa Susana tarplant (*Deinandra minthornii*) have been observed on the site (Tara Schoenwetter, Leidos, 2015).

Analysis as to whether or not project activities would:

a. Have a substantial adverse effect, either directly or through habitat modifications, on any species identified as a candidate, sensitive, or special status species in local or regional plans, policies, or regulations, or by the California Department of Fish and Game or U.S. Fish and Wildlife Service.

Impact Analysis: The project would not permanently modify habitat. Endangered, candidate, sensitive, and special status plant and animal species inhabit the vicinity. Pre-installation surveys would be conducted to ensure that endangered, candidate, sensitive, and/or special status plant and animal species are avoided during installation of pipes and the release system.

Conclusion:
☐ Potentially Significant Impact
☐ Potentially Significant Unless Mitigated
☒ Less Than Significant Impact
☐ No Impact

b. Have a substantial adverse effect on any riparian habitat or other sensitive natural community identified in local or regional plans, policies, regulations, or by the California Department of Fish and Game or U.S. Fish and Wildlife Service.

Impact Analysis: There is no riparian or sensitive natural community within the footprint of the project.

Conclusion:
☐ Potentially Significant Impact
☐ Potentially Significant Unless Mitigated
☐ Less Than Significant Impact
☒ No Impact

c. Have a substantial adverse effect on federally protected wetlands as defined by Section 404 of the Clean Water Act (including, but not limited to, marsh, vernal pool, coastal, etc.) through direct removal, filling, hydrological interruption, or other means.

Impact Analysis: There are no designated wetlands within the project footprint.

Conclusion:
☐ Potentially Significant Impact
☐ Potentially Significant Unless Mitigated
☐ Less Than Significant Impact
☒ No Impact

d. Interfere substantially with the movement of any native resident or migratory fish or wildlife species or with established native resident or migratory wildlife corridors, or impede the use of native wildlife nursery sites.

Impact Analysis: The SSFL property overall is part of a wildlife migratory corridor. The project would not interfere or prevent movement of wildlife as there is ample land to the north and south, and there would be no fencing to exclude movement through the project site.

Conclusion:
☐ Potentially Significant Impact
☐ Potentially Significant Unless Mitigated
☐ Less Than Significant Impact
☒ No Impact

e. Conflict with local policies or ordinances protecting biological resources, such as a tree preservation policy or ordinance.

Impact Analysis: The project would not involve removal of protected trees, plants, or animal species.

Conclusion:
☐ Potentially Significant Impact
☐ Potentially Significant Unless Mitigated
☐ Less Than Significant Impact
☒ No Impact

f. Conflict with the provisions of an adopted Habitat Conservation Plan, Natural Community Conservation Plan, or other approved local, regional, or state habitat conservation plan.

Impact Analysis: The project would not conflict with a Habitat Conservation Plan, Natural Community Conservation Plan. When completed, the project site will be allowed to return to existing conditions.

Conclusion:
☐ Potentially Significant Impact
☐ Potentially Significant Unless Mitigated
☐ Less Than Significant Impact
☒ No Impact

References Used:
Faulkner, D.K., 2010. Site Assessment for Quino Checkerspot Butterfly Santa Susana Field Laboratory (SSFL) Area IV, Ventura County, California. July 15.

Leidos, 2015. Jurisdictional Delineation of Waters of the United States and Wetlands on Area IV and the Northern Buffer Zone at the SSFL.

SAIC, 2009. Fall Biological Survey Report for Santa Susana Field Laboratory Area IV and Northern Buffer Zone. March

SAIC, 2010. California Red-legged Frog Habitat Site Assessment at Santa Susana Field Laboratory Area IV and Vicinity. March 25.

Padre Associates Inc. 2014. Brachiopad Vernal Pool Habitat Assessment for the Boeing SSFL.

Schoenwetter, Dr. Tara (Leidos). 2015, Personnel communication with John Wondolleck, CDM Smith, June

5. Cultural Resources

Project Activities with a Potential Impact: Installation of the release system could expose buried archaeological artifacts.

Description of Baseline Environmental Conditions: The SSFL property has historical significance to Native Americans. Several culturally relevant sites have been located in the vicinity of the project site. The site has been surveyed by registered archaeologists for the presence of artifacts or historical usage. Much of the project site has been previously disturbed: parking lot, soil removals, backfill using borrow soil from another portion of SSFL. The likelihood of any remaining archaeological resource of significance at the FSDF site is small. The project site lies within the Chatsworth formation characterized by sand stone out crops. This formation has not shown paleontological resources during past geologic reviews.

DOE's compliance with Section 106 of the National Historic Preservation Act (NHPA), including State Historic Preservation Officer (SHPO) consultation is ongoing. As part of NHPA compliance, DOE is consulting with the federally-recognized Santa Ynez Band of Chumash Indians and with whom DOE will also consult on a government-to-government basis as required by Executive Order 13175.

DOE is in the process of developing a programmatic agreement with the Office of Historic Preservation (including the SHPO), the Advisory Council on Historic Preservation (if they choose to participate), and the Santa Ynez Band of Chumash Indians; this agreement would establish standard operating procedures for DOE to address cultural resource issues. Until the programmatic agreement is finalized, DOE would continue to comply with Section 106, in accordance with existing regulations and accepted practices as detailed in 36 CFR Part 800, and would continue government-to-government consultation with the Santa Ynez Band of Chumash Indians.

The area of potential effects (APE) for archaeological, structural and traditional cultural resources includes all areas within the boundaries of Area IV and the NBZ at SSFL. As part of the Section 106 consultation process, SHPO has agreed with the APE defined by DOE (OHP (Office of Historic Preservation), 2015. Letter from C. Roland-Nawi, SHPO to J. Jones ETEC Director, February 25). Although the APE includes only Area IV and the NBZ, a record search included all of SSFL, and extended for a radius of 1 mile (1.6 kilometers) beyond the boundary of SSFL.

Area IV and the NBZ have been surveyed for the presence of archaeological resources. An extended phase 1 testing program is underway to determine NRHP eligibility of sites that are located where radionuclide or chemical remediation would be required; the testing results are expected to include the number of archaeological sites considered eligible for listing. There are no potentially eligible sites within the footprint of the FSDF GWIM action. No structures in Area IV or the NBZ are eligible for listing on the NRHP. SHPO has concurred with the structure eligibility findings; DOE is in consultation with SHPO regarding eligibility of the archaeological sites.[1]

Analysis as to whether or not project activities would:

a. Cause a substantial adverse change in the significance of a historical resource as defined in 15064.5.

Impact Analysis: There are no identified archaeological resources within the FSDF GWIM project footprint. However, as is with standard practice by DOE for any soil disturbance work in Area IV, a qualified archaeologist and Native American Monitor will be present during the laying of surface piping and digging of the infiltration ditch.

Conclusion:
☐ Potentially Significant Impact
☐ Potentially Significant Unless Mitigated
☐ Less Than Significant Impact
☒ No Impact

b. Cause a substantial adverse change in the significance of an archeological resource pursuant to 15064.5.

Impact Analysis: There are no identified archaeological resources within the FSDF GWIM project footprint. However, as is with standard practice by DOE for any soil disturbance work in Area IV, a qualified archaeologist and Native American Monitor will be present during the laying of surface piping and digging of the infiltration ditch.

Conclusion:
☐ Potentially Significant Impact
☐ Potentially Significant Unless Mitigated
☐ Less Than Significant Impact
☒ No Impact

c. Directly or indirectly destroy a unique paleontological resource or site or unique geologic feature.

[1] In addition to the number of NRHP-eligible archaeological sites, the results of the extended phase 1 testing is expected to include SHPO review of the previous agreement about the non-eligibility of structures.

Impact Analysis: There are no paleontological resources within the FSDF GWIM project footprint. The project would not involve excavation of adjacent area bedrock outcrops.

Conclusion:
☐ Potentially Significant Impact
☐ Potentially Significant Unless Mitigated
☐ Less Than Significant Impact
☒ No Impact

d. Disturb any human remains, including those interred outside of formal cemeteries.

Impact Analysis: There are no human burial sites identified within the SSFL property. Significant surface soil disturbances (digging, soil removals, backfill) have occurred at the project site. However, as is with standard practice by DOE for any soil disturbance work in Area IV, a qualified archaeologist and Native American Monitor will be present during the laying of surface piping and digging of the infiltration ditch.

Conclusion:
☐ Potentially Significant Impact
☐ Potentially Significant Unless Mitigated
☐ Less Than Significant Impact
☒ No Impact

References Used:

6. Geology and Soils

Project Activities with a Potential Impact: Installation of the infiltration gallery.

Description of Baseline Environmental Conditions: The project site location is mostly on disturbed soils including unpaved parking, excavated, and backfilled soils. Original soils were of sandstone origin from the Chatsworth bedrock formation. Fill soils were excavated from the adjacent Santa Susan formation, also of sandstone origin.

The Cretaceous Age (80 to 65 million years ago) Chatsworth Formation underlies about 80 percent of Area IV and consists primarily of over 6,000 feet of massive thick-bedded sandstone with lesser amounts of interbedded shale, siltstone, and conglomerate. The Chatsworth Formation is a deep-sea turbidite, a formation of sandstone interbedded with lesser amounts of shale and siltstone that was deposited by turbidity currents on the surface of a sand-rich submarine fan. In a submarine fan environment, turbidity currents transport sand from the continental shelf into the deep ocean basins along submarine canyons. These sands and silts were deposited from 600 feet to 3,000 feet below sea level during the late Cretaceous Epoch (from 65 to 100 million years ago). The sand was deposited on the surface of the submarine fan at the base of the continental slope. Submarine fans are typically subdivided into an inner, middle, and outer fan environment. Existing interpretations of the Chatsworth Formation beneath most of SSFL suggest that it was deposited in a middle fan environment. The Chatsworth Formation is divided into an upper and lower unit. The Lower Chatsworth Formation is exposed (or outcrops) only in the southeastern portion of SSFL. The Upper Chatsworth Formation is subdivided into upper and lower stratigraphic “packages” referred to as Sandstone 1 and Sandstone 2, respectively. These sandstone units are separated and bounded above and below by fine-grained units referred to as Shales 1, 2, and 3. Shale 1 lies at the top of the Lower Chatsworth Formation and Shale 3 lies at the top of Sandstone 2. Shale 2 separates Sandstone 1 from Sandstone 2. Area IV is primarily underlain by Sandstone 2 which comprises three coarser-grained members separated by two finer-grained members. These members from oldest to youngest are: Silvernale, Spa, Lower Burro Flats, ELV, and Upper Burro Flats (MWH 2009).

The SSFL Chatsworth Formation sandstone is composed primarily of quartz (27 to 44 percent), and feldspar (40 to 67 percent). Minor minerals include clays (6 to 9 percent), calcite (0 to 8 percent) and dolomite (0 to 1 percent). Other minerals include epidote, sphene, garnet, tourmaline, apatite, hornblende, tremolite, actinolite chlorite and biotite. Pyrite was also found throughout rock cores that were studied. The calcite and other carbonate minerals are the “cement” that holds the grains of quartz, feldspar and other minerals together. The siltstone members of the Chatsworth Formation contain 18 percent phyllosilicate minerals, mostly biotite and chlorite, and rock fragments (Loomer 2009; Hurley et al. 2009).

The pyrite, phyllosilicate and carbonate minerals are considered reactive because they can potentially impact the groundwater chemistry (oxidation-reduction potential) and can therefore be a factor in the fate of organic contaminants and perchlorate in the environment. Other studies (Hurley et al. 2009) have documented that the Chatsworth Formation contains a small amount, up to 0.37 weight percent, of solid phase organic matter. The highest weight percent of organic carbon was found in the fine-grained members (siltstone). As with the reactive minerals, the presence of organic carbon can impact the fate of organic contaminants in the environment as these contaminants can adsorb onto the carbon.

The Santa Susana Formation is only found at SSFL in the southern portions of Area IV and southwestern-most Area III, and is separated from the Chatsworth Formation by the Burro Flats Fault. The Santa Susana Formation is lower Eocene and Paleocene in age and according to *Geologic Map of the Calabasas Quadrangle* (Dibble 1992), comprises four mapped units (from youngest to oldest): Gray micaceous claystone and siltstone with few minor thin sandstone beds; Tan coherent fine grained sandstone that locally contains thin shell-beds and calcareous concretions; Tan, semi-friable bedded sandstone, locally pebbly (also defined as the Las Virgenes Sandstone Member); Gray to brown cobble conglomerate with smooth cobbles of quartzite, metavolcanic and granitic rocks in sandstone matrix that locally includes thin lenses of red clay; marine or nonmarine (also known as the Simi Conglomerate Member).

The uppermost (youngest) unit of the Santa Susana Formation outcrops in Area IV. The entire formation is as much as 3,280 feet thick.

Ventura County is in a seismically active area, but there are no known active faults that run through the project site (Jennings and Bryant 2010). Area IV is, however, susceptible to earthquakes due to movement along distant faults. Some slopes in the valleys in the NBZ and the north-facing slope of the hill in the southernmost part of Area IV have been identified as Earthquake-Induced Landslide Zones (California Geological Survey 1999). This designation is based on topography, geologic materials and structure, geotechnical data, rock strength data, and estimates of earthquake-related shaking.

Analysis as to whether or not project activities would:

a. Expose people or structures to potential substantial adverse effects, including the risk of loss, injury, or death involving: There are no people or structures in vicinity of project site. There is no active fault at the project site.

- Rupture of a known earthquake fault, as delineated on the most recent Alquist-Priolo Earthquake Fault Zoning Map issued by the State Geologist for the area or based on other substantial evidence of a known fault. (Refer to Division of Mines and Geology Special Publication 42):
- Strong seismic ground shaking.
- Seismic-related ground failure, including liquefaction.
- Landslides.

Impact Analysis:
While no known active faults run directly through the project site, the site is located in an area prone to seismic ground shaking. Additional people would be present on site as a result of the proposed FSDF GWIM project, so there is some increased likelihood that people would be subject to the effects of seismic ground shaking. However, this increased exposure to adverse effects associated with the rupture of a known earthquake fault, seismic shaking, or seismic related ground failure would be minimal. The project does not involve the construction of any building that would be subject to seismic shaking or related ground failure. The project does involve placement on ground surface one 6,500 gallon extracted groundwater tank and two 6,500 gallon treated groundwater tanks. The extracted groundwater tank will be placed within secondary containment to prevent release of water should piping be severed during a seismic event. The treatment facility will be situated above already impacted groundwater so threat to groundwater is minimal.

All activities are on relatively flat land; therefore, there is no potential for landslides.

Conclusion:
☐ Potentially Significant Impact
☐ Potentially Significant Unless Mitigated
☒ Less Than Significant Impact
☐ No Impact

b. Result in substantial soil erosion or the loss of topsoil.

Impact Analysis: The only soil disturbance activity is the installation of the infiltration channel. It will be installed, backfilled, and the disturbed area immediately stabilized to prevent any loss of top soil.

Conclusion:
☐ Potentially Significant Impact
☐ Potentially Significant Unless Mitigated
☒ Less Than Significant Impact
☐ No Impact

c. Be located on a geologic unit or soil that is unstable, or that would become unstable as a result of the project, and potentially result in on or off-site landslide, lateral spreading, subsidence, liquefaction or collapse.

Impact Analysis: The project location is flat and is not in an area of unstable soil.

Conclusion:

☐ Potentially Significant Impact
☐ Potentially Significant Unless Mitigated
☐ Less Than Significant Impact
☒ No Impact

d. Be located on expansive soil, as defined in Table 18-1-B of the Uniform Building Code (1994), creating substantial risks to life or property.

Impact Analysis: The project site is not in an area of expansive soil.

Conclusion:
☐ Potentially Significant Impact
☐ Potentially Significant Unless Mitigated
☐ Less Than Significant Impact
☒ No Impact

e. Have soils incapable of adequately supporting the use of septic tanks or alternative wastewater disposal systems where sewers are not available for the disposal of wastewater.

Impact Analysis: The project does not involve installation of septic systems or disposal of domestic wastes. Infiltration tests will be performed to identify the capacity of the sandstone materials to accept treated water.

Conclusion:
☐ Potentially Significant Impact
☐ Potentially Significant Unless Mitigated
☒ Less Than Significant Impact
☐ No Impact

References Used:
California Geolgical Survey, 1999, Seismic Hazard Mapping Program – Official Map of Calabasas Quadrangle.

Dibble, T. W. and H. E. Ehrenspeck. 1992. Geologic Map of the Calabasas Quadrangle, Los Angeles and Ventura Counties, California: Dibblee Geological Foundation, Map DF-37, Scale 1:24000.

Hurley, J. C., J. A. Cherry, and B. L. Parker. 2009. 20 Elements of the Santa Susana Field Laboratory Site Conceptual Model of Contaminant Transport, Site Conceptual Model Element 3-2, Draft, December 11.

Jennings, C. W., and W. A. Bryant, 2010, 2010 Fault Activity Map of California, California Geological Survey.

Loomer, D. 2009. Mineralogical Characterization of Drill Core Samples from the Santa Susana Field Laboratory, Ventura County, California, University of New Brunswick, April 9.

MWH. 2009. Draft Site-Wide Groundwater Remedial Investigation Report, Santa Susana Field Laboratory, Ventura County, California, December.

7. Greenhouse Gas Emissions

Project Activities with a Potential Impact: The following activities have the potential to impact greenhouse gas (GHG) emissions:

- Consumption of electricity, to operate water pumps, generated by burning fossil fuels
- Vehicle emissions for two workers commuting to the site, 5 days per week; vehicle emissions for once per week delivery of supplies; well sampling support

<u>Consumption of Electricity</u>

Operation of pumps to extract groundwater, to pump water through the treatment system, and to pump water to the infiltration trenches would consume electricity. The pumping of wells is expected to occur 24-hours per day; the operation of the GWIM treatment system 7 hours per day three days per week; and, the pumping of treated water 5 days per week. The GWIM operation is expected to last 3 months. The well pump would be a 2 horse power variable drive submersible low flow pump, the influent pump to the GWIM system would be a 2 horse power pump, the treated effluent pump would be a 2 horsepower pump.

<u>Vehicle Emissions</u>

The GWIM system would be operated by two workers who commute to the site 5 days per week. Their vehicles would be operational only during the commute hours. Once per week, a well support vehicle would be on site to raise/lower well pumps and to assist in well sampling. This vehicle would be operational 4 hours on site. Once per week, a supply truck would service treatment vessels and be operational 4 hours on site.

Description of Baseline Environmental Conditions:

GHGs are gases that trap heat in the atmosphere by absorbing infrared radiation. GHG emissions occur from natural processes and human activities. Water vapor is the most important and abundant GHG in the atmosphere. However, human activities produce only a small amount of the total atmospheric water vapor. The most common GHGs emitted from natural processes and human activities include carbon dioxide, methane, and nitrous oxide. The main source of GHGs from human activities is the combustion of fossil fuels, such as crude oil and coal. The most recent assessment of climate change impacts in California conducted by the State of California predicts that temperatures in California will increase between 4.1 and 8.6 degrees Fahrenheit by 2100, based on both low and high global GHG emission scenarios (California Energy Commission 2012). Predictions of long-term negative environmental impacts due to global warming include sea level rise; changing weather patterns, including increases in the severity of storms and droughts; changes to local and regional ecosystems, including the potential loss of species; and a substantial reduction in winter snowpack. In California, predictions of these effects include exacerbation of air quality problems; a reduction in municipal water supply from the Sierra snowpack; a rise in sea level that would displace coastal businesses and residences; an increase in wild fires; damage to marine and terrestrial ecosystems; and an increase in the incidence of infectious diseases, asthma, and other human health problems (California Energy Commission 2012).

Analysis as to whether or not project activities would:

a. Generate greenhouse gas emissions, either directly or indirectly, that may have a significant impact on the environment.

Impact Analysis: The project would involve two tractor-trailer rigs for installation of the treatment system, weekly trips of a tractor-trailer rig to replace treatment chemicals, and daily trips two personal vehicles for site workers. These vehicles would not produce a significant emission of greenhouse gases.

Conclusion:
☐ Potentially Significant Impact
☐ Potentially Significant Unless Mitigated
☒ Less Than Significant Impact
☐ No Impact

b. Conflict with an applicable plan, policy or regulation adopted for the purpose of reducing the emissions of greenhouse gases.

Impact Analysis: The project would not conflict with any plan, policy, or regulation intended to reduce greenhouse emissions. The objective of the proposed project is to remove accessible mass of TCE from the bedrock aquifer and to obtain data on aquifer properties for evaluation of the technology. At the end of the 3-month project the system may be dismantled or put in stand-by status pending the remedy decision. At the end of the project, GHG emissions would return to pre-project levels.

Conclusion:
☐ Potentially Significant Impact
☐ Potentially Significant Unless Mitigated
☒ Less Than Significant Impact
☐ No Impact

References Used:

California Energy Commission. 2012. Our Changing Climate 2012 – Vulnerability and Adaptation to the Increasing Risks from Climate Change in California: A Summary Report on the third Assessment from the California Climate Center, Publication number CEC-500-2012-007 (available at http://www.climatechange.ca.gov/adaptation/third_assessment/), July.

8. Hazards and Hazardous Materials

Project Activities with a Potential Impact:
The following activities would generate investigation-derived wastes:

- GWIM treatment media contains TCE, perchlorate, and metals. The treatment media would be transported off-site for reprocessing or disposal.
- Sampling of wells produce purge water containing VOCs, perchlorate, and metals. The purge water would be treated in the GWIM system.

Description of Baseline Environmental Conditions:

FSDF was used from 1956 to 1978 to clean metallic components and other materials (pipes, valves, tanks, and instruments) of alkali metals (sodium and potassium/sodium mixtures). In addition to sodium-contaminated materials, FSDF received chemical wastes, including chlorinated solvents (i.e., TCE), PCBs, metals such as mercury, and radionuclides (primarily cesium-137). The site was also used for the burning of "Santowax," an organic compound (a mixture of terphenyls) used as a heat transfer medium during thermal studies.

Various soil and debris removals at and in the vicinity of the FSDF ponds occurred from 1980 to 2000. In all, 14,000 cubic yards of soil were removed from the site, including 20 cubic yards of soil contaminated with cesium-137. Ultimately, the ponds were backfilled with soil from the Area IV borrow pit, and the site was hydroseeded and planted.

Impacted groundwater is found in weathered bedrock and alluvium (during rainy periods) and in the Chatsworth Formation groundwater. Groundwater at the FSDF location exhibits VOCs, perchlorate, and metals. Perchlorate and metals currently exist at drinking water standards. TCE is the most prevalent VOC.

Analysis as to whether or not project activities would:

a. Create a significant hazard to the public or the environment throughout the routine transport, use or disposal of hazardous materials.

Impact Analysis: The public does not have access to the site. All contaminated water would be piped, contained, and treated in a manner to protect the local environment. Transport of all materials would be through city streets to major freeways. There would be one anticipated trip of a tractor-trailer rig that would haul used treatment chemicals (activated carbon and resins) containing VOCs, metals, and perchlorate. The hauling of the used treatment chemicals will be per USDOT regulations. The activated carbon and resins would be treated and disposed of per RCRA regulations. The hauling of the chemicals would not create a significant hazard to the public.

Conclusion:
☐ Potentially Significant Impact
☐ Potentially Significant Unless Mitigated
☒ Less Than Significant Impact
☐ No Impact

b. Create a significant hazard to the public or the environment through reasonably foreseeable upset and accident conditions involving the release of hazardous materials into the environment.

Impact Analysis: The GWIM system would employ alarms and shut-off valves to prevent overfilling or spillage from tanks and vessels. The system would only be operated during daylight hours with personnel present during operations. The hauling of the used treatment chemicals would be in DOT approved vessels. The infrequent transport of the used treatment chemicals would not pose a significant hazard to the public or environment.

Conclusion:
☐ Potentially Significant Impact
☐ Potentially Significant Unless Mitigated
☒ Less Than Significant Impact
☐ No Impact

c. Emit hazardous emissions or handle hazardous or acutely hazardous materials, substances or waste within one-quarter mile of an existing or proposed school.

Impact Analysis: The treatment of extracted groundwater would be performed in a closed system. There would be no emissions of hazardous materials. There is no school or proposed school within ¼ mile of the project location.

Conclusion:
☐ Potentially Significant Impact
☐ Potentially Significant Unless Mitigated
☐ Less Than Significant Impact
☒ No Impact

d. Be located on a site which is included on a list of hazardous materials sites compiled pursuant to Government Code Section 65962.5 and, as a result, would it create a significant hazard to public or the environment.

Impact Analysis: The proposed activity is intended to reduce levels of contamination at an already contaminated location. The SSFL is subject to corrective action pursuant to Section 25187 of the Health and Safety Code, Consent Order for Corrective Action Docket Number P3-07/08-003. The site is on the Cortese list because it was issued a Clean Up and Abatement Order by the RWQCB pursuant to Water Code section 13304.

The proposed FSDF GWIM is being conducted with DTSC oversight to assess the effectiveness of pump and treatment of contaminated groundwater in the Chatsworth formation. All solid and liquid waste generated during the project activities would be properly contained, characterized, and disposed of at a permitted facility in accordance with applicable laws and regulations. All wastes would be containerized and secured from the general public and the environment. Hazardous materials would not be accessible to the general public. Best management practices will be implemented for all proposed project activities consistent with standard practices at the SSFL.

Conclusion:
☐ Potentially Significant Impact
☐ Potentially Significant Unless Mitigated
☒ Less Than Significant Impact
☐ No Impact

e. Impair implementation of, or physically interfere with, an adopted emergency response plan or emergency evacuation plan.

Impact Analysis: The project would not interfere with any emergency response or evacuation plan. The project is in a remote location away from any populated area.

Conclusion:
☐ Potentially Significant Impact
☐ Potentially Significant Unless Mitigated
☐ Less Than Significant Impact
☒ No Impact

References Used:
CDM Smith. 2015. Area IV Groundwater Remedial Investigation Work Plan.

9. Hydrology and Water Quality

Project Activities with a Potential Impact:

The objective of the project is to improve groundwater quality through removal of contaminant mass. Extracted groundwater will be treated to meet LARWQCB limits prior to release. Release of treated water at the location of extraction would not reduce aquifer volume, but will improve groundwater quality.

The hydrology of the drainage would not be impacted as no work would be performed within any drainage. Earth disturbance work to install the infiltration trenches has a potential for release of sediment during rainfall events. Best management practices will be followed to stabilize excavated soil replaced as part of installation of the infiltration trenches.

Description of Baseline Environmental Conditions:

Depth to groundwater in the Chatsworth formation below the FSDF site is approximately 100 feet below ground surface. The extent of TCE contamination at the FSDF site is reported in the Area IV Groundwater Remedial Investigation Work Plan (CDM Smith 2015). Groundwater beneath the FSDF exhibits the highest concentrations of TCE of any location in Area IV. Prior to aquifer pumping at FSDF in 1997, the maximum TCE concentration observed in this plume was 4,100 ppb. During and following pumping, TCE concentrations decreased, with a maximum concentration of 1,600 ppb reported in a sample collected in 2013.

There are no surface water features at the project site. Man-made and natural drainages start below the project site. The project location is above NPDES discharge point No.5. There are no surface water flows except during intense rainfall events.

Analysis as to whether or not project activities would:

a. Violate any water quality standards or waste discharge requirements.

Impact Analysis: Extracted groundwater containing VOCs, metals, and perchlorate would be treated to LA RWQCB waste discharge requirements and released back to groundwater at the project location. Authorization will be obtained to discharge under the LA RWQCB General Waste Discharge Requirements (WDR) for Groundwater Remediation at Petroleum Hydrocarbon Fuel and/or Volatile Organic Compound Impacted Sites (Order No. R4-2007-0019 and Resolution No. R07-001). The project would have a beneficial impact on groundwater quality. All GWIM operations will comply with the discharge and monitoring requirements specified in the authorization to discharge under the LA RWQCB WDRs.

Treated water would not be released to a stream and there would be no impact to surface water bodies.

Conclusion:
☐ Potentially Significant Impact
☐ Potentially Significant Unless Mitigated
☒ Less Than Significant Impact
☐ No Impact

b. Substantially deplete groundwater supplies or interfere substantially with groundwater recharge such that there would be a net deficit in aquifer volume or a lowering of the local groundwater table level (e.g., the production rate of pre-existing nearby wells would drop to a level which would not support existing land uses or planned uses for which permits have been granted).

Impact Analysis: Extracted groundwater would be treated and discharged at project location. The project would have a net zero change in groundwater volume within the project location.

Conclusion:
☐ Potentially Significant Impact
☐ Potentially Significant Unless Mitigated
☐ Less Than Significant Impact
☒ No Impact

c. Substantially alter the existing drainage pattern of the site or area, including through the alteration of the course of a stream or river, in a manner which would result in substantial erosion or siltation on or off-site.

Impact Analysis: The project would not change any drainage patterns. Project activities would avoid entering any visible drainage. Best management practices will be followed to prevent erosion or siltation of drainages.

Conclusion:
☐ Potentially Significant Impact
☐ Potentially Significant Unless Mitigated
☐ Less Than Significant Impact
☒ No Impact

d. Substantially alter the existing drainage pattern of the site or area, including through the alteration of the course of a stream or river, or substantially increase the rate or amount of surface runoff in a manner which would result in flooding on or off-site.

Impact Analysis: The project would not increase the rate or amount of surface water flow from the project site. The project would not involve soil compaction or placement of pavement that would increase runoff.

Conclusion:
☐ Potentially Significant Impact
☐ Potentially Significant Unless Mitigated
☐ Less Than Significant Impact
☒ No Impact

e. Create or contribute runoff water which would exceed the capacity of existing or planned storm water drainage systems or provide substantial additional sources of polluted runoff.

Impact Analysis: The project would not create or contribute from runoff from the project area. The project is upgradient from NPDES discharge point No. 5. Best management practices will be applied during installation of the infiltration gallery to prevent runoff impacting stormwater.

Conclusion:
☐ Potentially Significant Impact
☐ Potentially Significant Unless Mitigated

☒ Less Than Significant Impact
☐ No Impact

f. Otherwise substantially degrade water quality.

Impact Analysis: As stated above, the project would have a beneficial impact on groundwater quality. Best management practices will be applied during installation of the infiltration gallery to prevent stormwater water quality effects.

Conclusion:
☐ Potentially Significant Impact
☐ Potentially Significant Unless Mitigated
☒ Less Than Significant Impact
☐ No Impact

g. Place within a 100-flood hazard area structures which would impede or redirect flood flows.

Impact Analysis: The project location is not within a 100-year flood hazard area.

Conclusion:
☐ Potentially Significant Impact
☐ Potentially Significant Unless Mitigated
☐ Less Than Significant Impact
☒ No Impact

h. Expose people or structures to a significant risk of loss, injury or death involving flooding, including flooding as a result of the failure of a levee or dam.

Impact Analysis: The project does not involve construction or use of a levee or dam.

Conclusion:
☐ Potentially Significant Impact
☐ Potentially Significant Unless Mitigated
☐ Less Than Significant Impact
☒ No Impact

i. Inundation by sieche, tsunami or mudflow.

Impact Analysis: The project is at 1,100 feet elevation at the top of a ridge and is not in an area subject to sieche, tsunami, or mudflow.

Conclusion:
☐ Potentially Significant Impact
☐ Potentially Significant Unless Mitigated
☐ Less Than Significant Impact
☒ No Impact

References Used:
CDM Smith. 2015. Area IV Groundwater Remedial Investigation Work Plan.

10. Land Use and Planning

Project Activities with a Potential Impact: None of the project activities would conflict with land use plans or future land use.

Description of Baseline Environmental Conditions: SSFL is located in the unincorporated area of Ventura County and is not located within any specific plan area or other project area designated by the *Ventura County General Plan* (Ventura

County 2013). The general plan designation for SSFL is open space, although it is zoned rural agriculture and open space. The land use is modified by a special use permit to allow industrial uses (Ventura County 2011). The project location consists of an unpaved parking area and re-vegetated disturbed land.

Analysis as to whether or not project activities would:

a. Conflict with any applicable land use plan, policy, or regulation of an agency with jurisdiction over the project (including, but not limited to the general plan, specific plan, local coastal program, or zoning ordinance) adopted for the purpose of avoiding or mitigating an environmental effect.

   Impact Analysis: The project is temporary, consistent with current SSFL activities, and would not conflict with any plan.

   Conclusion:
   ☐ Potentially Significant Impact
   ☐ Potentially Significant Unless Mitigated
   ☐ Less Than Significant Impact
   ☒ No Impact

b. Conflict with any applicable habitat conservation plan or natural community conservation plan.

   Impact Analysis: There is no applicable habitat conservation plan or community conservation plan for the proposed project site. The project is temporary and does not change existing habitats.

   Conclusion:
   ☐ Potentially Significant Impact
   ☐ Potentially Significant Unless Mitigated
   ☐ Less Than Significant Impact
   ☒ No Impact

References Used:

Ventura County, 2011, Ventura County General Plan, Land Use Appendix, Ventura, California, June 28.

Ventura County, 2013, Ventura County General Plan (accessed on July 14, 2014, http://www.ventura.org/rma/planning/pdf/plans/Goals_Policies_and_Programs_10-22-13.pdf), Ventura, California, December 3.

11. Mineral Resources

Project Activities with a Potential Impact: The project does not involve mining or use of local mineral resources.

Description of Baseline Environmental Conditions:
There are no identified mineral resources within the project site.

Analysis as to whether or not project activities would:

a. Result in the loss of availability of a known mineral resource that would be of value to the region and the residents of the state.

   Impact Analysis: No mineral resources are known to occur at the project site.

   Conclusion:
   ☐ Potentially Significant Impact
   ☐ Potentially Significant Unless Mitigated
   ☐ Less Than Significant Impact

☒ No Impact

b. Result in the loss of availability of a locally-important mineral resource recovery site delineated on a local general plan, specific plan or other land use plan.

Impact Analysis: There are no identified mineral resources within the project site.

Conclusion:
☐ Potentially Significant Impact
☐ Potentially Significant Unless Mitigated
☐ Less Than Significant Impact
☒ No Impact

12. Noise

Project Activities with a Potential Impact: With the exception of the installation of the infiltration trenches, there would be no noise producing activities. Installation of the trenches would occur only during regular business hours (7 am to 6 pm). The trenches would take two days to install.

Description of Baseline Environmental Conditions: The project location is rural, open space, formerly industrial-use. Ambient noise levels are consistent with current land uses.

Analysis as to whether or not project activities would result in:

a. Exposure of persons to or generation of noise levels in excess of standards established in the local general plan or noise ordinance, or applicable standards of other agencies.

Impact Analysis: There are no sensitive noise receptors within a mile of the project location.

Conclusion:
☐ Potentially Significant Impact
☐ Potentially Significant Unless Mitigated
☐ Less Than Significant Impact
☒ No Impact

b. Exposure of persons to or generation of excessive groundbourne vibration or groundbourne noise levels.

Impact Analysis: The project does not involve ground vibrations. There are no occupied structures within 1,000 feet of the project area and no residences within a mile.

Conclusion:
☐ Potentially Significant Impact
☐ Potentially Significant Unless Mitigated
☐ Less Than Significant Impact
☒ No Impact

c. A substantial permanent increase in ambient noise levels in the vicinity above levels existing without the project.

Impact Analysis: The project would not involve a permanent increase in ambient noise levels.

Conclusion:
☐ Potentially Significant Impact
☐ Potentially Significant Unless Mitigated
☐ Less Than Significant Impact
☒ No Impact

d. A substantial temporary or periodic increase in ambient noise levels in the project vicinity above levels existing without the project.

Impact Analysis: There are no sensitive noise receptors within a mile of the project location.

Conclusion:
☐ Potentially Significant Impact
☐ Potentially Significant Unless Mitigated
☐ Less Than Significant Impact
☒ No Impact

13. Population and Housing

Project Activities with a Potential Impact: The project would not increase worker population, need for new housing, or additional government services.

Description of Baseline Environmental Conditions: The project site is currently open space in former industrial use area. There is no housing on the project site.

Analysis as to whether or not project activities would:

a. Induce substantial population growth in area, either directly (for example, by proposing new homes and businesses) or indirectly (for example, through extension of roads or other infrastructure).

Impact Analysis: The project involves two on-site workers. One of the workers currently works on site. Both workers would live in the region. The project does not substantially increase worker population or create a need for new housing.

Conclusion:
☐ Potentially Significant Impact
☐ Potentially Significant Unless Mitigated
☐ Less Than Significant Impact
☒ No Impact

b. Displace substantial numbers of existing housing, necessitating the construction of replacement housing elsewhere.

Impact Analysis: The project would occur in an open space, formerly industrial area and would not displace existing housing.

Conclusion:
☐ Potentially Significant Impact
☐ Potentially Significant Unless Mitigated
☐ Less Than Significant Impact
☒ No Impact

c. Displace substantial numbers of people, necessitating the construction of replacement housing elsewhere.

Impact Analysis: The project is on an unpopulated site and would not displace any people.

Conclusion:
☐ Potentially Significant Impact
☐ Potentially Significant Unless Mitigated
☐ Less Than Significant Impact
☒ No Impact

14. Public Services

Project Activities with a Potential Impact: None. The proposed project does not include any activities that are likely to impact public services. There is no need for use of or development of government services.

Description of Baseline Environmental Conditions:

There are existing power lines to project site to power pumps. The project would involve minimal amounts of potable water for system startup.

Analysis as to whether or not project activities would:

a. Result in substantial adverse physical impacts associated with the provision of new or physically altered government facilities, need for new or physically altered governmental facilities, the construction of which could cause significant environmental impacts, in order to maintain acceptable service ratios, response times or other performance objectives for any of the following public services: The project does not need any of these services.

- ❖ Fire protection
- ❖ Police protection
- ❖ Schools
- ❖ Parks
- ❖ Other public facilities

Impact Analysis: The project has minimal installation, limited operating activities and workers on site. There would be no impact on existing services.

Conclusion:
☐ Potentially Significant Impact
☐ Potentially Significant Unless Mitigated
☐ Less Than Significant Impact
☒ No Impact

15. Recreation

Project Activities with a Potential Impact: None. The project does not include any activities that would affect recreation.

Description of Baseline Environmental Conditions: There is no current recreation at SSFL.

Analysis as to whether or not project activities would:

a. Increase the use of existing neighborhood and regional parks or other recreational facilities such that substantial physical deterioration of the facility would occur or be accelerated.

Impact Analysis: The project would not result in any use of recreation facilities.

Conclusion:
☐ Potentially Significant Impact
☐ Potentially Significant Unless Mitigated
☐ Less Than Significant Impact
☒ No Impact

b. Include recreational facilities or require construction or expansion of recreational facilities which might have an adverse physical effect on the environment.

   Impact Analysis: The project has no need for existing or new recreation facilities.

   Conclusion:
   ☐ Potentially Significant Impact
   ☐ Potentially Significant Unless Mitigated
   ☐ Less Than Significant Impact
   ☒ No Impact

16. Transportation and Traffic

Project Activities with a Potential Impact: Vehicle trips required for the project include workers commute to project site, transport of treatment system (once to set up, once to remove), transport of treatment media, and transport of used media.

Description of Baseline Environmental Conditions: All traffic to the SSFL facility passes through a security gate at the entrance on the northeast corner of the site (the "Main Gate"). Vehicular access to SSFL and onsite roadways is restricted to operations of Boeing, DOE, and NASA, and their subcontractors, vendors, and visitors. Onsite roads do not serve public through-traffic. Paved roadways generally provide one lane of travel in each direction with limited shoulder area. Unpaved roadways generally provide a single lane of travel with no shoulder. Woolsey Canyon Road is the primary access road linking SSFL to the local collector road network. It is the only serviceable road for heavy truck traffic to and from SSFL. Woolsey Canyon Road is also used by homeowners living along the road. Valley Circle Boulevard is a two-lane collector street with a posted speed limit of 30 miles per hour located in Los Angeles County that intersects Woolsey Canyon Road, Roscoe Boulevard, Plummer Street, and Box Canyon Road. Roscoe Boulevard is an east-west collector street, which connects Valley Circle Boulevard with SR 27 (Topanga Canyon Boulevard). This road is a north-south route that connects with SR 118 (Ronald Reagan Freeway) to the north and U.S. Highway 101(Ventura Freeway) to the south. SR 27 (Topanga Canyon Boulevard) is generally a six-lane urban arterial roadway over this segment with a posted speed limit of 45 mph. Roscoe Boulevard is currently approaching unstable traffic flow and other local access and collector roads have average to good traffic flow. Traffic flow on SR 27 (Topanga Canyon Boulevard) operating at LOS F experiences considerable delays, as does U.S. Highway 101 (Ventura Freeway) (TRB 2010).

Analysis as to whether or not project activities would:

a. Cause an increase in traffic which is substantial in relation to the existing traffic load and capacity of the street system (i.e., result in a substantial increase in either the number of vehicle trips, the volume to capacity ratio on roads, or congestion at intersections).

   Impact Analysis: There would be two workers commuting to the site for 14 weeks. Transport of all materials would be through city streets to major freeways. There would be one anticipated weekly trip of a well sampling support rig. There would be one anticipated weekly trip of a tractor-trailer rig to haul used treatment chemicals (activated carbon and resins) containing VOCs, metals, and perchlorate. The limited number of vehicle trips required for the project would not affect existing traffic flow.

   Conclusion:
   ☐ Potentially Significant Impact
   ☐ Potentially Significant Unless Mitigated
   ☒ Less Than Significant Impact
   ☐ No Impact

b. Exceed, either individually or cumulatively, a level of service standard established by the country congestion management agency for designated roads or highway.

   Impact Analysis: There would be two workers commuting to the site for 14 weeks, one anticipated weekly trip of a well sampling support rig, and one anticipated weekly trip of a tractor-trailer rig to haul used treatment chemicals (activated carbon and resins) containing VOCs, metals, and perchlorate. The hauling of the used treatment chemicals will be per U.S. Department of Transportation regulations. The limited number of vehicle trips required for the project would not affect existing traffic flow, individually or cumulatively.

Conclusion:
☐ Potentially Significant Impact
☐ Potentially Significant Unless Mitigated
☒ Less Than Significant Impact
☐ No Impact

c. Substantially increase hazards due to a design feature (e.g., sharp curves or dangerous intersections) or incompatible uses (e.g., farm equipment).

Impact Analysis: The project does not involve the design of any roadways and would not increase hazards. Existing roadways would be used for all project activities. The steep grade and sharp turns down Woolsey Canyon Road are currently negotiable for passenger cars, trucks, and equipment that have traveled to the site since the late 1940s. Workers will follow posted speed limits to ensure safe transport.

Conclusion:
☐ Potentially Significant Impact
☐ Potentially Significant Unless Mitigated
☐ Less Than Significant Impact
☒ No Impact

d. Result in inadequate emergency access.

Impact Analysis: The project would not interfere with emergency access to SSFL or any location at SSFL.

Conclusion:
☐ Potentially Significant Impact
☐ Potentially Significant Unless Mitigated
☐ Less Than Significant Impact
☒ No Impact

e. Result in inadequate parking capacity.

Impact Analysis: There is adequate parking available for the two site workers.

Conclusion:
☐ Potentially Significant Impact
☐ Potentially Significant Unless Mitigated
☐ Less Than Significant Impact
☒ No Impact

f. Conflict with adopted policies, plans, or programs supporting alternative transportation (e.g., bus turnouts, bicycle racks).

Impact Analysis: There would be no conflict with adopted policies, plans or programs supporting alternative transportation. There is no alternative transportation to SSFL.

Conclusion:
☐ Potentially Significant Impact
☐ Potentially Significant Unless Mitigated
☐ Less Than Significant Impact
☒ No Impact

References Used:

TRB (Transportation Research Board). 2010. *Highway Capacity Manual 2010*, The National Academies, Washington, DC.

17. Utilities and Service Systems

Project Activities with a Potential Impact: The ½ to 3 horsepower pumps to extract groundwater and operate the treatment unit would require use of local electricity. The project would use a small amount of potable water as part of system start-up.

Description of Baseline Environmental Conditions: There is electrical power at the project location.

Analysis as to whether or not project activities would:

a. Exceed wastewater treatment requirements of the applicable Regional Water Quality Control Board.

Impact Analysis: The project will comply with LA RWQCB discharge requirements.

Conclusion:
☐ Potentially Significant Impact
☐ Potentially Significant Unless Mitigated
☒ Less Than Significant Impact
☐ No Impact

b. Require or result in the construction of new water or wastewater treatment facilities or expansion of existing facilities, the construction of which could cause significant environmental effects.

Impact Analysis: The project involves construction of a temporary, portable groundwater treatment system that has no other relationship with local or regional water or wastewater treatment facilities.

Conclusion:
☐ Potentially Significant Impact
☐ Potentially Significant Unless Mitigated
☐ Less Than Significant Impact
☒ No Impact

c. Require or result in the construction of new storm water drainage facilities or expansion of existing facilities, the construction of which could cause significant environmental effects.

Impact Analysis: The project uses existing storm water facilities. No new facilities are required and no changes in existing stormwater controls would be required.

Conclusion:
☐ Potentially Significant Impact
☐ Potentially Significant Unless Mitigated
☐ Less Than Significant Impact
☒ No Impact

d. Have sufficient water supplies available to serve the project from existing entitlements and resources, or are new or expanded entitlements needed.

Impact Analysis: The project does not require development of new water supplies or entitlements.

Conclusion:
☐ Potentially Significant Impact
☐ Potentially Significant Unless Mitigated
☐ Less Than Significant Impact

☒ No Impact

e. Result in determination by the wastewater treatment provider which serves or may serve the project that it has adequate capacity to serve the projects projected demand in addition to the providers existing commitments.

Impact Analysis: The project does not involve local or regional waste water treatment providers.

Conclusion:
☐ Potentially Significant Impact
☐ Potentially Significant Unless Mitigated
☐ Less Than Significant Impact
☒ No Impact

f. Be served by a landfill with sufficient permitted capacity to accommodate the projects solid waste disposal needs.

Impact Analysis: The project does not involve the use of landfills.

Conclusion:
☐ Potentially Significant Impact
☐ Potentially Significant Unless Mitigated
☐ Less Than Significant Impact
☒ No Impact

g. Comply with federal, state, and local statutes and regulations related to solid waste.

Impact Analysis: Groundwater treatment wastes (used carbon and resins) will be handled and disposed of per RCRA regulations by the treatment system vendor.

Conclusion:
☐ Potentially Significant Impact
☐ Potentially Significant Unless Mitigated
☒ Less Than Significant Impact
☐ No Impact

Mandatory Findings of Significance

Based on evidence provided in this Initial Study, DTSC makes the following findings:

a. The project ☐ has ☒ does not have the potential to degrade the quality of the environment, substantially reduce the habitat of a fish or wildlife species, cause a fish or wildlife population to drop below self-sustaining levels, threaten to eliminate a plant or animal community, reduce the number or restrict the range of a rare or endangered plant or animal, or eliminate important examples of the major periods of California history or prehistory.

b. The project ☐ has ☒ does not have impacts that are individually limited but cumulatively considerable. “Cumulatively considerable” means that the incremental effects of an individual project are considerable when viewed in connection with the effects of past projects, the effects of other current projects, and the effects of probable future projects.

c. The project ☐ has ☒ does not have environmental effects that will cause substantial adverse effects on human beings, either directly or indirectly.

Determination of Appropriate Environmental Document:

Based on evidence provided in this Initial Study, DTSC makes the following determination:

☒ The proposed project COULD NOT HAVE a significant effect on the environment. A **Negative Declaration** will be prepared.

☐ The proposed project COULD HAVE a significant effect on the environment. However, there will not be a significant effect in this case because revisions in the project have been made by or agreed to by the project proponent. A **Mitigated Negative Declaration** will be prepared.

☐ The proposed project MAY HAVE a significant effect on the environment. An **Environmental Impact Report** is required.

☐ The proposed project MAY HAVE a "potentially significant impact" or "potentially significant unless mitigated" impact on the environment, but at least one effect 1) has been adequately analyzed in an earlier document pursuant to applicable legal standards, and 2) has been addressed by mitigation measures based on the earlier analysis as described on attached sheets. An **Environmental Impact Report** is required, but it must analyze only the effects that remain to be addressed.

☐ The proposed project COULD HAVE a significant effect on the environment. However, all potentially significant effects (a) have been analyzed adequately in an earlier Environmental Impact Report or Negative Declaration pursuant to applicable standards, and (b) have been avoided or mitigated pursuant to that earlier Environmental Impact Report or Negative Declaration, including revisions or mitigation measures that are imposed upon the proposed project. Therefore, nothing further is required.

Certification:

I hereby certify that the statements furnished above and in the attached exhibits, present the data and information required for this initial study evaluation to the best of my ability and that the facts, statements and information presented are true and correct to the best of my knowledge and belief.

Preparer's Signature		Date
Preparer's Name	Preparer's Title	Phone #
Branch or Unit Chief Signature		Date
Branch or Unit Chief Name	Branch or Unit Chief Title	Phone #

ATTACHEMENT A

REFERENCES

Appendix F

Water Quality Control Plan Water Quality Objectives for Groundwater

CDM Smith

Water Quality Control Plan Water Quality Objectives for Groundwater

Groundwater and surface water quality objectives from the Water Quality Control Plan are presented in this Appendix.

Regional objectives for ground waters are found in Section 3, Water Quality Objectives, Water Quality Control Plan, Los Angeles Region (LARWQCB 2013). Since treated groundwater will be released into subsurface, regional objectives for ground waters apply and are presented as shown in the Water Quality Control Plan.

Bacteria

In ground waters used for domestic or municipal supply (MUN) the concentration of coliform organisms over any seven day period shall be less than 1.1/100 ml.

Chemical Constituents and Radioactivity

Ground waters designated for use as domestic or municipal supply (MUN) shall not contain concentrations of chemical constituents and radionuclides in excess of the limits specified in the following provisions of Title 22 of the California Code of Regulations which are incorporated by reference into this plan: Table 64431-A of Section 64431 (Inorganic chemicals), Table 64444-A of Section 64444 (Organic Chemicals), Table 64442 of Section 64442 (Gross Alpha Particle Activity, Radium-226, Radium-228, and Uranium), and Table 64443 of Section 64443 (Beta Particle and Photon Radioactivity). This incorporation by reference is prospective including future changes to the incorporated provisions as the changes take effect. (See Tables 3-8, 3-9, 3-12a, and 3-12b).

WQCP Table 3-8. The Maximum Contaminant Levels: Inorganic Chemicals (for MUN beneficial use) specified in Table 64431-A of Section 64431 of Title 22 of the California Code of Regulations as of February 2013.

Constituent	Unit	Maximum Contaminant Level
Aluminum	mg/L	1
Antimony	mg/L	0.006
Arsenic	mg/L	0.01
Asbestos	MFL*	7
Barium	mg/L	1
Beryllium	mg/L	0.004
Cadmium	mg/L	0.005
Chromium	mg/L	0.05
Cyanide	mg/L	0.15
Fluoride	mg/L	2
Mercury	mg/L	0.002
Nickel	mg/L	0.1

WQCP Table 3-8. The Maximum Contaminant Levels: Inorganic Chemicals (for MUN beneficial use) specified in Table 64431-A of Section 64431 of Title 22 of the California Code of Regulations as of February 2013.

Nitrate (as NO3)	mg/L	45
Nitrate + Nitrite (sum as nitrogen)	mg/L	10
Nitrite (as nitrogen)	mg/L	1
Perchlorate	mg/L	0.006
Selenium	mg/L	0.05
Thallium	mg/L	0.002

Source: Water Quality Control Plan (LARWQCB, 2013)

MFL = million fibers per liter; MCL for fibers >10 microns long

WQCP Table 3-9. The Maximum Contaminant Levels: Organic Chemicals (for MUN beneficial use) specified in Table 64444-A of Section 64444 of Title 22 of the California Code of Regulations as of February 2013.

Constituent	Unit	Maximum Contaminant Level
(a) Volatile Organic Chemicals (VOCs)		
Benzene	mg/L	0.001
Carbon Tetrachloride	mg/L	0.0005
1,2-Dichlorobenzene	mg/L	0.6
1,4-Dichlorobenzene	mg/L	0.005
1,1-Dichloroethane	mg/L	0.005
1,2-Dichloroethane	mg/L	0.0005
1,1-Dichloroethylene	mg/L	0.006
cis-1,2-Dichloroethylene	mg/L	0.006
trans-1,2-Dichloroethylene	mg/L	0.01
Dichloromethane	mg/L	0.005
1,2-Dichloropropane	mg/L	0.005
1,3-Dichloropropene	mg/L	0.0005
Ethylbenzene	mg/L	0.3
Methyl-tert-butyl ether	mg/L	0.013
Monochlorobenzene	mg/L	0.07
Styrene	mg/L	0.1
1,1,2,2-Tetrachloroethane	mg/L	0.001
Tetrachloroethylene	mg/L	0.005
Toluene	mg/L	0.15
1,2,4-Trichlorobenzene	mg/L	0.005
1,1,1-Trichloroethane	mg/L	0.2
1,1,2-Trichloroethane	mg/L	0.005
Trichloroethylene	mg/L	0.005
Trichlorofluoromethane	mg/L	0.15
1,1,2-Trichloro-1,2,2-Trifluoroethane	mg/L	1.2
Vinyl Chloride	mg/L	0.0005
Xylenes	mg/L	1.750*
(b) Non-Volatile Synthetic Organic Chemicals (SOCs)		
Alachlor	mg/L	0.002
Atrazine	mg/L	0.001
Bentazon	mg/L	0.018
Benzo(a)pyrene	mg/L	0.0002
Carbofuran	mg/L	0.018
Chlordane	mg/L	0.0001
2,4-D	mg/L	0.07
Dalapon	mg/L	0.2
Dibromochloropropane	mg/L	0.0002
Di(2-ethylhexyl)adipate	mg/L	0.4
Di(2-ethylhexyl)phthalate	mg/L	0.004
Dinoseb	mg/L	0.007

WQCP Table 3-9. The Maximum Contaminant Levels: Organic Chemicals (for MUN beneficial use) specified in Table 64444-A of Section 64444 of Title 22 of the California Code of Regulations as of February 2013.		
Diquat	mg/L	0.02
Endothall	mg/L	0.1
Endrin	mg/L	0.002
Ethylene Dibromide	mg/L	0.00005
Glyphosate	mg/L	0.7
Heptachlo	mg/L	0.00001
Heptachlor Epoxide	mg/L	0.00001
Hexachlorobenzene	mg/L	0.001
Hexachlorocyclopentadiene	mg/L	0.05
Lindane	mg/L	0.0002
Methoxychlor	mg/L	0.03
Molinate	mg/L	0.02
Oxamyl	mg/L	0.05
Pentachlorophenol	mg/L	0.001
Picloram	mg/L	0.5
Polychlorinated Biphenyls	mg/L	0.0005
Simazine	mg/L	0.004
Thiobencarb	mg/L	0.07
Toxaphene	mg/L	0.003
2,3,7,8-TCDD (Dioxin)	mg/L	$3x10^{-8}$
2,4,5-TP (Silvex)	mg/L	0.05

Source: Water Quality Control Plan (LARWQCB, 2013)

*MCL is for either a single isomer or the sum of the isomers.

WQCP Table: 3-12a. The Maximum Contaminant Levels (MCLs) and Detection Levels for Purposes of Reporting (DLRs): Gross Alpha Particle Activity, Radium-226, Radium-228, and Uranium (for MUN beneficial use) specified in Table 64442 of Section 64442 of Title 22 of the California Code of Regulations as of February 2013

Radionuclide	MCL (pCi/L)	DLR (pCi/L)
Radium-226 Radium-228	5 (combined radium-226 & -228)	1
Gross Alpha particle activity (excluding radon and uranium)	15	3
Uranium	20	1

WQCP Table: 3-12b. The Maximum Contaminant Levels (MCLs) and Detection Levels for Purposes of Reporting (DLRs): Beta particles and Photon Radioactivity (for MUN beneficial use) specified in Table 64443 of Section 64443 of Title 22 of the California Code of Regulations as of February 2013

Radionuclide	MCL	DLR (pCi/L)
Beta/photon emitters	4 millirem/year annual dose equivalent to the total body or any internal organ	Gross Beta particle activity: 4pCi/L
Strontium - 90	8 pCi/L (= 4 millirem/yr dose to bone marrow)	2 pCi/L
Tritium	20,000 pCi/L (= 4 millirem/yr dose to total body)	1,000 pCi/L

Source: Water Quality Control Plan (LARWQCB, 2013)

Mineral Quality

Numerical mineral quality objectives for individual groundwater basins are contained in Table 3-13.

WQCP Table 3-13. Water Quality Objectives for Selected Constituents in Regional Ground Waters a.

	Basin Number [b]	1994 Basin Name/Number	TDS (mg/L)	Sulfate (mg/L)	Chloride (mg/L)	Boron (mg/L)
Simi Valley	4-10	Confined Aquifers / 4-9	1200	600	150	1.5
San Fernando Valley	4-12	San Fernando Basin; West of Highway 405 / 4-12	800	300	100	1.5

Source: Water Quality Control Plan (LARWQCB, 2013)

[a.] Objectives for ground waters outside of the major basins listed on this table and outlined in Figure 1-9 have not been specifically listed. However, ground waters outside of the major basins are, in many cases, significant sources of water. Furthermore, ground waters outside of the major basins are either potential or existing sources of water for downgradient basins and, as such, objectives in the downgradient basins shall apply to these areas.

[b]. Basins are numbered according to Bulletin 118-Update 2003 (Department of Water Resources, 2003).

Nitrogen (Nitrate, Nitrite)

Groundwaters shall not exceed 10 mg/L nitrogen as nitrate-nitrogen plus nitrite-nitrogen (NO3-N + NO2-N), 45 mg/L as nitrate (NO3), 10 mg/L as nitrate-nitrogen (NO3-N), or 1 mg/L as nitrite-nitrogen (NO2-N).

Taste and Odor

Ground waters shall not contain taste or odor-producing substances in concentrations that cause nuisance or adversely affect beneficial uses.