John Hickman - Rancho Seco Groundwater Sampling

From: "Robert E. Jones" <RJones2@smud.org>
To: <jbh@nrc.gov>
Date: 04/17/2007 12:50 PM
Subject: Rancho Seco Groundwater Sampling

John,

Attached is the sampling procedure used for the groundwater monitoring at Rancho Seco in support of the LTP development. I've also am sending some information regarding the laboratory qualifications. I tried to find a copy of a NUPIC audit on the NUPIC site. There was an audit completed in August 2006, but I couldn't find the report on their website. There was some information regarding the audit that discussed a finding that was closed in Sept. 2006, but not the entire report.

Let me know if this is adequate for your needs and if you want me to submit something on the docket.

Thanks,
Bob Jones

<<Rancho Seco Groundwater Sampling SOP.DOC>> <<Sampling_Figures.pdf>>

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Subject:	Rancho Seco Groundwater Sampling
Creation Date	04/17/2007 12:48:40 PM
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Sampling Groundwater from Monitoring and Extraction Wells

1.0 PURPOSE

This standard operating procedure (SOP) establishes procedures for collecting groundwater samples from monitoring and extraction wells at Rancho Seco Nuclear Facility (Rancho Seco). The site location and the installed well locations are detailed in Figures 1 and 2 respectively. The type of monitoring well sample collection system discussed is the portable bailer/pump. Extraction well systems are sampled using procedures different than those used for monitoring well systems. The extraction well sampling procedures are discussed in Section 4.3.

This SOP will help ensure quality and consistency in sample collection procedures. These procedures may be used in conjunction with other documentation and recordkeeping procedures.

2.0 APPLICABILITY

This SOP is intended for personnel who participate in groundwater sampling, data review, and reporting activities at Rancho Seco.

3.0 TERMS AND DEFINITIONS

DO – Dissolved oxygen
DPM – Disintegrations per minute
GWMP – Groundwater Monitoring Program
NRC – Nuclear Regulatory Commission
OVM – Organic vapor meter
PPE – Personal protective equipment
psi – Pounds per square inch
redox – Reduction-oxidation
SOP – Standard operating procedure
VOC – Volatile organic compound
QA/QC – Quality assurance/quality control
U.S. EPA – U.S. Environmental Protection Agency

4.0 EQUIPMENT AND PROCEDURE DESCRIPTIONS

Groundwater sampling is performed to obtain samples representative of the groundwater surrounding the well screen. Use of consistent procedures and sample collection equipment ensures that

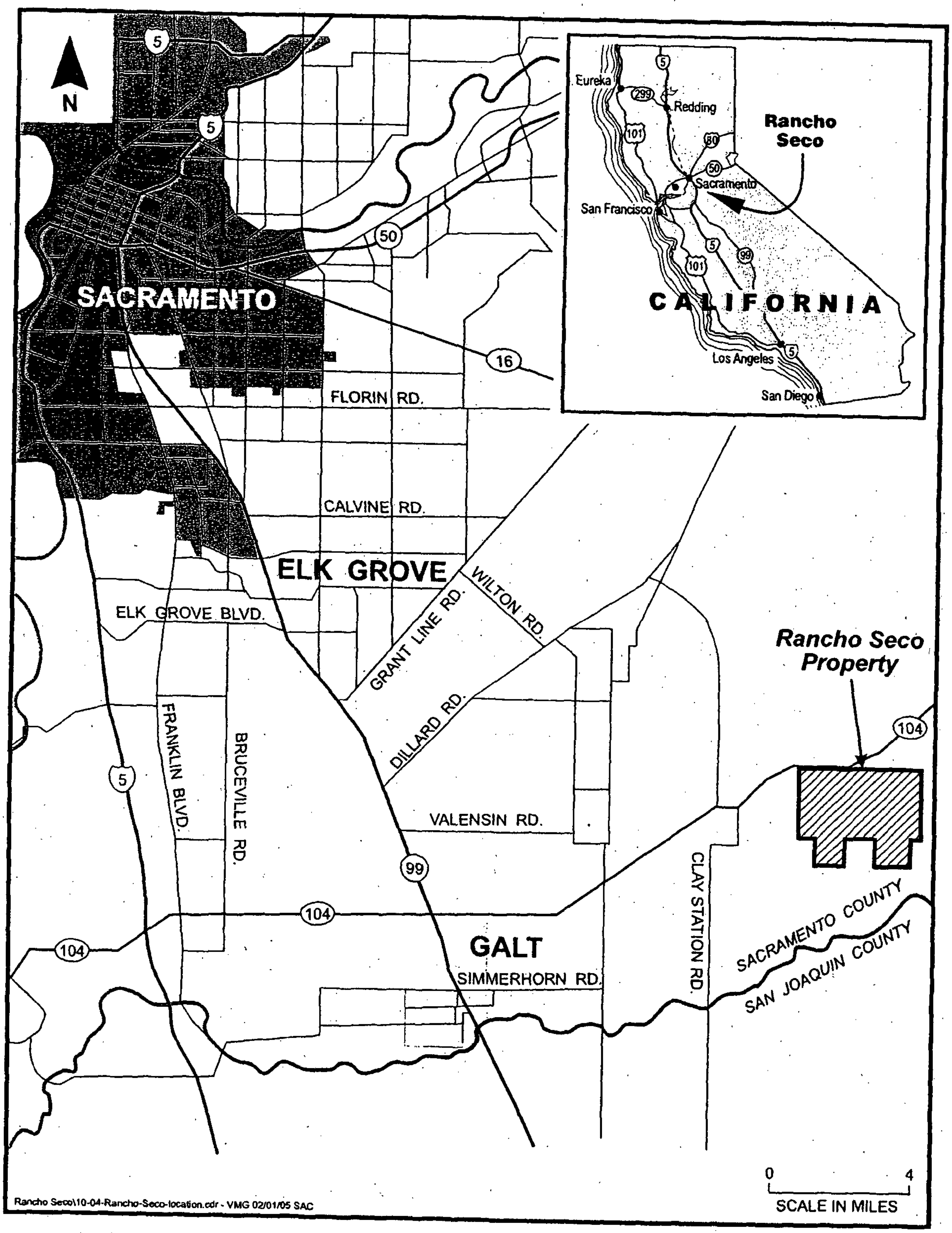

Figure 1.
Location of Rancho Seco Nuclear Generating Station

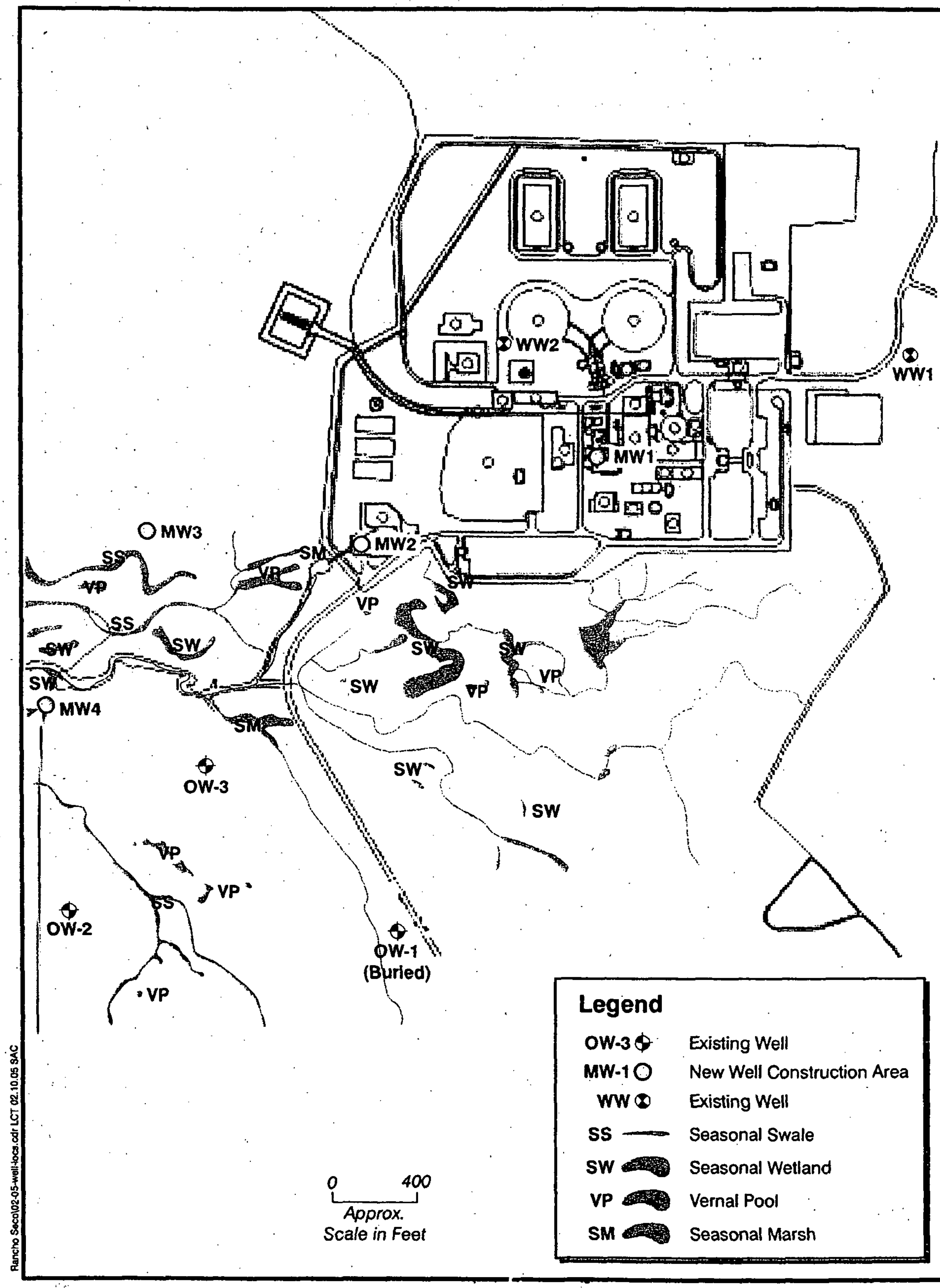

Figure 2. Locations of Wells ~~Installed~~ at Rancho Seco Nuclear Generating Station

the analytical results reflect the quality of the groundwater at a geographic location and a monitoring zone as accurately as possible.

4.1 Equipment

Rancho Seco wells are typically sampled using the system described below:

Bailer and Submersible Pump – An electric submersible pump and/or a Teflon® bailer are used to purge water and collect samples at wells not equipped with dedicated systems. The pump is typically used to purge the well while the bailer is used for sample collection. A flow control valve attachment on the bailer transfers the sample to the sample bottles; this minimizes sample agitation that could release volatile organic compounds (VOCs). Shallow wells with small water columns, or wells that produce insufficient volume to allow the use of a pump, are both purged and sampled with a bailer.

4.2 Procedures

General pre- and post-sampling procedures (e.g., planning, equipment decontamination) are discussed in Section 4.2.1. Quality assurance/quality control (QA/QC) sampling procedures are described in Section 4.2.2. The bailer/submersible pump sampling procedures are described in Section 4.2.3. Procedures generally adhere to the *Compendium of Superfund Field Operations* (U.S. Environmental Protection Agency [U.S. EPA], 1987).

Sample Planning

The following sections contain procedures that should be followed for groundwater collection using any type of system (dedicated delivery or portable bailer) and any type of analyte collected (VOC, inorganic species, or radionuclides).

Health and Safety

Project-specific health and safety plans will be followed during all field activities. During standard groundwater sampling activities, field personnel will wear personal protective equipment (PPE) at a minimum of level D (safety glasses, steel-toed boots, and nitrile/latex gloves). PPE requirements will be upgraded as necessary, in accordance with the project health and safety plan.

Staging Area

All necessary equipment and supplies will be gathered in the staging area and put onto sampling vehicles before sampling occurs. Non-consumable items include bailers, generators, water level meters, hoses, buckets, pH meters, conductivity meters, thermometers, multi-meters, and control boxes. Consumable items should be checked and restocked each day before sampling. Consumable items include sample containers (VOA bottles, plastic 250 mL, 500 mL, or 1-liter bottles, 1 L glass bottles, and others), labels, filters, gloves, monofilament line, calibration solutions, Ziploc® bags, ice, fuel for generators/air compressors, and black ball point pens. (For a complete list of equipment, refer to project-specific SOPs or project instructions.) Ensure that trip blanks are included in the sample cooler when VOCs are collected.

Initial Sampling Procedures

After arriving at the sampling site, the following steps should be performed.

1. Don appropriate PPE.

2. Validate ID of well, using a current monitoring well location map.

3. Calibrate meters, unless the meters do not require calibration at each well, i.e. many multi-parameter meters only require weekly or monthly calibration. Follow procedures in the respective meter's operating manuals.

4. Open well, allow it to "off-gas,".

5. Decontaminate equipment, purge well, and collect samples following procedures in Sections 4.2.1 through 4.3.

6. Collect QC samples (blanks, duplicates, or additional volume for laboratory spikes) as designated in the field sampling plan (FSP) or task instructions.

4.2.1 Equipment Decontamination Procedures

To decontaminate bailers (when disposable bailers are not used), submersible pumps, water level meters, and any other equipment that comes into direct contact with samples:

1. Rinse with ASTM II (deionized) water.

2. Rinse with hexane, then with reagent-grade methanol.

3. Rinse again with ASTM II water after solvents have dried.

submitting "blind" samples. The actual time of sample collection will be used during data validation to determine holding time compliance. Follow standard sampling procedures in Sections 4.2.3 through 4.3.

4.2.2.5 Matrix Spike/Matrix Spike (MS/MSD) Duplicates

A matrix spike/matrix spike duplicate (MS/MSD) sample is an exact duplicate of a normal sample taken. Sample ID labeling is identical to the original samples. Additional sample volume is collected for laboratory analysis QA/QC purposes. In the laboratory, the MS/MSD is prepared by spiking known concentrations of target analytes into the additional sample volume prior to sample preparation and analysis.

4.2.3 Sampling Procedures for the Bailer/Submersible Pump Systems

Well purging is an integral step in recovering samples representative of the quality of groundwater flowing through the monitoring zone. Each monitoring well sampled using dedicated (not low-flow) or bailer/submersible pump systems is purged immediately prior to sample collection, ensuring the sample is fresh monitoring zone groundwater rather than stagnant water that has been standing in the well casing.

Purging steps are as follows:

1. Prior to purging, calculate the minimum purge volume that must be collected (i.e., three wetted casing volumes) as follows:

   Minimum Purge Volume (gallons) = 3 x V

   where:

V	=	$3.14\, r^2 L \times 7.48$ gallons/ft^3
V	=	One wetted casing volume (gallons);
r	=	Inside radius of casing (feet); and
L	=	Height of water column in well (feet).

   The height of the water column in the well is determined by reading the depth to the top of water level (using a decontaminated water level meter) and subtracting this value from the total depth of the well.

   A 5-gallon bucket (or similar container of known capacity) is used to measure the amount of water removed from the well during purging. Elapsed time is noted as the container is filled,

4. Store and transport small pieces of equipment used for organic samples on decontaminated aluminum trays or wrap them in aluminum foil.

Clean, disposable gloves are worn during decontamination.

4.2.2 Quality Assurance/Quality Control (QA/QC) Sampling Procedures

Field QA/QC samples are used to assess the influence of sampling procedures, equipment, and handling on the reported analytical results.

4.2.2.1 Trip Blank

Trip blanks are taken by placing two 40-ml VOA bottles containing highly purified organic-free water into each cooler shipped to the laboratory (or in the number of coolers required to meet the frequency designated for the sampling effort) at the beginning of the sampling day. Handle trip blanks in the same manner as VOA bottles used for VOC sampling (Section 4.2.5.2).

4.2.2.2 Ambient Blank

Ambient blank samples are taken at the monitoring well site just prior to actual groundwater sampling. Fill 40-ml VOA bottles directly from a glass bottle containing ASTM II deionized water.

4.2.2.3 Equipment Blank

Equipment blank samples are obtained from a decontaminated bailer just prior to actual groundwater sampling.

1. Decontaminate bailer following procedures in Section 4.2.1, Equipment Decontamination Procedures.

2. Fill bailer with ASTM II water or radionuclide-free water.

3. Fill sample containers following directions in Sections 4.2.3 through 4.3.

4.2.2.4 Field Duplicates

A field duplicate is the second sample collected at the same time as the original sample. For some projects, field duplicate samples may be submitted to the laboratory as "double blind" samples. To maintain the anonymity of the field duplicate sample, a coded sample ID and a sampling time of 12:00 will be assigned. If the field duplicate sample is given the same sampling time as the original sample, the laboratory could easily determine the location of the duplicate sample, thus defeating the purpose of thereby allowing calculation of the discharge rate. The total amount of water purged from each well is recorded on the field sheets (Attachment A).

2. Position the bailer or pump near the middle of the screened interval (if feasible) to ensure that standing water is removed and fresh formation water is drawn into the well. Purged groundwater will be disposed of on the ground surface..

3. Purging is considered complete when the minimum purge volume has been collected <u>and</u> the pH, temperature, and conductivity have stabilized. The pH, temperature, and conductivity are considered stable when the variation in two successive readings does not exceed:

pH:	$< \pm 0.1$ pH unit
Temperature:	$< \pm 1.0$°C
Conductivity:	$< \pm 5\%$ change in microsiemens

If parameter stabilization has not occurred after three well volumes have been purged, continue purging and taking readings. Samples may be collected after a total of six wetted casing volumes have been removed from the well, even if readings have not stabilized.

Turbidity and oxidation-reduction (redox) potential will be measured and recorded during purging and sample collection, if specified in the FSP.

4. In low-yield wells that may be purged dry before three wetted casing volumes have been removed, the sample shall be collected when enough water has re-entered the well to obtain the volume of water needed for all sample containers. The time when the well is purged dry is recorded on the groundwater field sheets (Attachment A), as well as the volume of water removed prior to sampling.

4.2.4 Sample Collection and Handling Procedures

This section describes guidelines and procedures for the collection and handling of groundwater samples for radionuclides.

Sample Planning

Groundwater samples are collected in a prearranged priority so that collection and handling of samples occurs as efficiently as possible. Although the actual sample collection protocol will depend on the analytes of interest, general sample collection procedures must be consistent. Prior to using the bailer or collecting a sample from the discharge line, don new, clean disposable gloves to avoid cross-contamination. Samples for volatile constituents are collected first, to avoid loss of volatiles to the air, followed by inorganics and radionuclides.

During all sampling activities, position the support equipment so that any potential volatile organic sources, such as vehicles, gasoline-driven generators, or air compressors and fuel tanks, are downwind. Contamination caused by entrapment of volatile contaminants in the sample is thus avoided. Any potential VOC sources that are unavoidable are noted on the well purging log.

Sample Container Labeling

Label sample containers with sample I.D., location, date and time sample was taken, analyses to be performed, preservative, name of client, and the initials of the samplers. Use a black ball point pen when completing labels.

Sample Custody, Documentation, and Shipping

All custody, documentation, and shipping procedures will adhere to the specifications described in Section 6.0 of the QAPP (Sample Custody and Documentation).

4.2.4.1 Radionuclides

Groundwater is collected and analyzed for radionuclides in areas suspected of radioactive contamination. In order to prevent the spread of potential radioactive contamination, additional equipment, monitoring, and site control measures may be needed. The following screening equipment is used for groundwater collection for radionuclides analysis:

1. Zinc sulfide (ZnS) scintillation detector (alpha detector): An alpha particle detector attached to a survey meter OR

2. Geiger-Mueller counter with pancake probe (pancake probe): A Geiger-Mueller counter with a flat, round probe that is used to primarily detect beta radiation, and a portion of the gamma ray spectrum.

All instruments will be used and checked for performance following the guidelines in the Radiation Detection Instrument General Operation and Performance Check SOP, McAFB-038.

Sampling Procedures

As during any sampling activity, personnel must take the necessary health and safety precautions outlined in the applicable site-specific health and safety plan. Equipment which has come into contact with groundwater will be screened for radionuclides and decontaminated as necessary. The sampling procedures are as follows:

1. Collect groundwater in a non-preserved 1-liter plastic bottle.

2. If necessary to the analysis, within one hour after collecting the sample, filter through a cellulose nitrate 0.45-micron filter into a 1-liter plastic bottle preserved with 2 ml nitric acid (70%), using a peristaltic pump.

   A. Decontaminate the in-line filter holder by rinsing with a 10% nitric acid solution. When using a Geopump® system, attach the in-line filter holder to the Tygon® tubing and rinse both the tubing and filter holder.

   B. Follow with an ASTM II water rinse.

   C. Open the in-line filter holder and insert a 0.45-micron cellulose nitrate filter. Filter the 1 liter of non-preserved water from Step 1 into a preserved 1-liter plastic bottle. **If collecting a water sample for tritium analysis (Method E906), glass bottles without chemical preservatives should be used in Step 1 and Step 2.**

   D. After all water has been filtered, dry the filter by pumping air through the filter until it has sufficiently dried.

   E. Place filter in a labeled Ziploc® bag. The filter ID should correlate it to the water sample. Each 1-liter sample of water should have one corresponding filter. If more than one filter is needed to filter a liter of sample, submit additional filters in their own Ziploc® bag. Additional filter IDs should correlate to the water sample, but distinguish it from other filters. The purpose of the filter residue is to quantify the total radioactivity (if any) of the raw groundwater.

3. Place groundwater sample and filter in a cooler at 4°C.

Post-Collection Radiological Screening and Decontamination of Equipment

1. Screening of sampling equipment and radiological survey instruments may be conducted after use in radiologically contaminated areas. If possible, disposable sampling equipment and encapsulated instruments should be used at radiological sites.

   Screening levels for clearance of radioactive materials are presented in industry standard ANSI/HPS N13.12-1999, *Surface and Volume Radioactivity Standards for Clearance*. Values in Table 1 of ANSI/HPS N13.12, and presented in Attachment B, are total radioactivity levels without regard to the loose or removable radioactivity components.

2. Wipe with a clean moistened cloth all equipment that has come into contact with the groundwater. Dry bailers, pumps, pH meters, conductivity meters, thermometers, water level meters, and personal protective equipment.

3. Using appropriate radiation detection and measurement instrument(s), survey/screen all decontaminated equipment that has come into contact with the groundwater.

4. Radiological sampling equipment and field monitoring instruments will only be cleared for reuse if it is decontaminated to pre-use alpha/beta/gamma background radiation levels.

   Other equipment not used for radiological sampling or field measurement will be released for reuse if residual radioactivity is less than 50% of the surface screening decontamination levels presented in Table 1 of ANSI/HPS N13.12-1999 (Attachment B). Proceed to decontaminate according to standard chemical decontamination procedures in Section 4.2.1. Instrument readings can be converted to units of dpm/100 cm^2 following the equation in SOPs McAFB-046, Section 4.2.7, or McAFB-047, Section 4.2.2.

5. Equipment is considered contaminated if readings are above 50% of the surface screening levels cited in Table 1 of ANSI/HPS N13.12-1999 (Attachment B). The equipment must be decontaminated before leaving the site. An effort should be made to limit the amount of wastewater generated while decontaminating radioactive equipment. Where possible, equipment should be wiped with a cloth and re-screened. If readings are below 50% of the decontamination action levels, the equipment is considered no longer contaminated and can then be decontaminated for other potential contaminants following standard chemical decontamination procedures in Section 4.2.1.

Equipment destined for unconditional release or disposal and found to have residual radioactivity between 50% and 100% of the values in Attachment B, may be released by the Project Health Physicist without further decontamination on a case-by-case basis.

6. Screen wipe cloths for residual radioactivity and dispose as clean waste. If readings are less than 50% of the decontamination action levels of ANSI/HPS N13.12-1999 Table 1 (Attachment B). If readings are greater than 50% of these action levels, the wipe cloths are considered low-level radioactive waste.

7. Materials and equipment showing residual radioactivity greater than the values set forth in Table 1 of ANSI/HPS N13.12 (Attachment B), even after three successive decontamination attempts, can be disposed of as low-level radioactive waste. Equipment that would not cause cross-contamination of samples may be released for reuse within a radiologically controlled area with the approval of the Project Health Physicist on a case-by-case basis. Such material/equipment will be clearly marked to indicate that the items possess residual radioactivity greater than the screening levels in Table 1 of ANSI/HPS N13.12 (Attachment B) and are to be disposed of as low-level radioactive waste upon completion of use. All items classified as being radiologically contaminated or disposed of as low-level radioactive waste will be handled in accordance with applicable radioactive materials license conditions, issued by the State or NRC.

Sample Control

Although it is anticipated that all samples will be analyzed on-site at the Rancho Seco Nuclear Facility, the following protocols will be used when shipping samples off-site. In addition to all standard shipping procedures (Section 6.0 of this QAPP, Sample Custody and Documentation), the following procedures will be added when shipping samples for radiochemistry analyses. All samples for radiochemistry analyses should be shipped promptly. Additional sample shipping procedures will be in accordance with 49 CFR 173. Before a package containing samples for radiochemistry analyses is shipped, a swipe of the exterior of the shipping container will be performed. The purpose of the swipe sample is to assure that the package surface does not exceed Department of Transportation (DOT) radiation limits. A swipe sample is collected by rubbing filter paper with moderate pressure over a 300 cm^2 area on the package's lid or sides. This filter paper is then submitted to the lab for analysis, or screened using a fixed location instrument with an internal proportional counter. Maximum permissible limits shall be 2,200 dpm/100 cm^2 for beta-gamma emitting radionuclides, and 220 dpm/100 cm^2 for alpha emitting radionuclides (49 CFR 173.443 Table 11). Shipping restrictions for individual carriers should be checked to ensure compliance.

Analytical

The radiochemistry analyses performed on soil or water will be specified in individual field sampling plans. Samples collected for radiochemistry analyses will be sent to either the laboratory at the Rancho Seco Nuclear Facility or a laboratory either with a radioactive materials license issued by the Nuclear Regulatory Commission (NRC) or regulated under the jurisdiction of an NRC agreement state. Each laboratory will have sample screening guidelines and notification requirements that must be followed.

4.3 Water Supply Well System

A water supply well consists of a dedicated pump and piping for removing water from the ground and sending it to wherever needed. The water supply well system does not require standard sampling equipment such as portable pumps or bailers. Water supply wells are sampled by opening the flow control valve; only 3 gallons need to be purged from the well before sampling provided the well has been running continuously for five minutes prior to beginning the purge. When sampling from extraction wells, the following steps should be performed:

1. Don appropriate PPE, in accordance with the field sampling plan or task instructions.
2. Validate well ID, using a current map of base monitoring and extraction wells.
3. Calibrate pH meter and conductivity meters, if necessary, by following the procedures in the operating manual.
4. Open the flow control valve on the sampling port. Purge 3 gallons of water from the well, take water parameter readings each gallon (four readings total, including initial reading), and continue purging and readings until readings stabilize, if necessary.
5. Fill sample containers directly from the flow control valve. Follow procedures in Section 4.2.4.1 (for radionuclides).
6. Store samples in a cooler at 4°C.
7. Follow sample labeling, documentation, and handling procedures described in Section 4.2.4 (Sample Collection and Handling Procedures).

5.0 REFERENCES

American National Standard Institute, Inc., Health Physics Society (ANSI/HPS), 1999. *Surface and Volume Radioactivity Standards for Clearance.*

Interstate Technology and Regulatory Council (ITRC), 2002. *Recommendations for the Use of Polyethylene Diffusion Bag Samplers for the Long-Term Monitoring of Volatile Organic Compounds in Groundwater.*

Puls and Barcelona, 1995. *Low-Flow (Minimal Drawdown) Groundwater Sampling Procedures.*

Title 49, Code of Federal Regulations (CFR), Part 173

U.S. Environmental Protection Agency (U.S. EPA), 1987. *Compendium of Superfund Field Operations.*

U.S. Geologic Survey (USGS), 2001. *User's Guide for Polyethylene-Based Passive Diffusion Bag Samplers to Obtain Volatile Organic Compound Concentrations in Wells.*

6.0 ATTACHMENTS

Attachment A: Field Data Sheets
Attachment B: Screening Levels for Clearance (ANSI/HPS N13.12-1999, Table 1)

ATTACHMENT A

FIELD DATA SHEETS

URS

Water Sampling Data Sheet

Installation/Project: ______________________ Site ID: ______________________

Location ID: ______________________ Samplers: ______________________

Sample Date: ______________________ Sample Time: ______________________

Sample Method: ☐ *Grab* ☐ *Spigot* ☐ *Hydropunch* ☐ *Simulprobe* ☐ *Bailer*

Static Water Level: ______________________

Weather: ☐ *Sunny* ☐ *Cloudy* ☐ *Rainy* ☐ *Foggy* ☐ *Hazy* Temp (°F): ______ Wind Direction: ______

Comments: ______________________

Sample ID	Temp °C	pH	Conductivity (µhmos)	Comments

Samples Collected

METHOD:							
Container							
Preserv.							
Normal Sample							
Field Dup.							
MS/MSD							
Eqpt. Blank							

Samples Calibration Log

	Time	pH Readings Initial pH 7.0	pH 10.0	pH Readings Adjusted pH 7.0	pH 10.0
Post Check					

	Time	Conductivity Initial 700µs	Conductivity Adjusted 700µs
Post Check			

Rancho Seco Purge Log

Location: ____________________ **Purge Method:** ____________________

Purge Rate (GPM): ____________________ **Required Purge Volume:** ____________________

Sampler Initials: ____________________ **Water Level Meter #:** ____________________

Time	Volume Purged	Temp °C	pH	Conductivity	Turbidity	D.O. (ppm)	ORP	Comments

Site Calibration Log

pH Meter #:	Time	pH Readings Initial pH 7.0	pH 10.0	pH Readings Adjusted pH 7.0	pH 10.0
Post Check					

Turbidity Meter #:	
Initial (NTU)	Adjusted Reading (NTU)

Conductivity Meter #:	Time	Conductivity Initial 70µs	700µs	1410µs	Conductivity Adjusted 70µs	700µs	1410µs
Post Check							

D.O. Meter #:	
Diss. Oxy	
Initial	Adjusted

ATTACHMENT B

SCREENING LEVELS FOR CLEARANCE
(ANSI/HPS N13.12-1999, Table 1)

ATTACHMENT A

Screening Levels for Clearance (ANSI/HPS N13.12-1999, Table 1)			
Radionuclide Groups[a]	Screening Levels (S.I. Units)[b]	Surface Screening (Conventional Units)[b]	Volume Screening (Conventional Units)[b]
	(Bq/cm^2 or Bq/g)[c]	(dpm/100 cm^2)	(pCi/g)
Group 1 Radium, Thorium, and Transuranics: ^{210}Po, ^{210}Pb, ^{226}Ra, ^{228}Ra, ^{228}Th, ^{230}Th, ^{232}Th, ^{237}Np, ^{239}Pu, ^{240}Pu, ^{241}Am, ^{244}Cm, and associated decay chains[d], and others[a]	0.1	600	3
Group 2 Uranium and Selected High Dose Beta-Gamma Emitters: ^{22}Na, ^{54}Mn, ^{58}Co, ^{60}Co, ^{65}Zn, ^{90}Sr, ^{94}Nb, ^{106}Ru, ^{110m}Ag, ^{124}Sb, ^{134}Cs, ^{137}Cs, ^{152}Eu, ^{154}Eu, ^{192}Ir, ^{234}U, ^{235}U, Natural Uranium[e], and others[a]	1	6,000	30
Group 3 General Beta-Gamma Emitters: ^{24}Na, ^{36}Cl, ^{59}Fe, ^{109}Cd, ^{131}I, ^{129}I, ^{144}Ce, ^{198}Au, ^{241}Pu, and others[a]	10	60,000	300
Group 4[f] Other Beta-Gamma Emitters: ^{3}H, ^{14}C, ^{32}P, ^{35}S, ^{45}Ca, ^{51}Cr, ^{55}Fe, ^{63}Ni, ^{89}Sr, ^{99}Tc, ^{111}In, ^{125}I, ^{147}Pm, and others[a]	100	600,000	3,000

[a] To determine the specific group for radionuclides not shown, a comparison of the effective dose factors, by exposure pathway, listed in Table A.1 of NCRP Report No. 1231 (NCRP, 1996) for the radionuclides in question and the radionuclides in general groups above shall be performed and a determination of the proper group made, based on similarity of the factors.

[b] Rounded to one significant figure.

[c] The screening levels shown are used for either surface activity concentration (in units of Bq/cm^2), or volume activity concentration (in units of Bq/g). These groupings were determined based on similarity of the scenario modeling results, as described in Annex B (ANSI/HPS N13.12-1999).

[d] For decay chains, the screening levels represent the total activity (i.e., the activity of the parent plus the activity of all progeny) present.

[e] Where the Natural Uranium activity equals 48.9% from ^{238}U, plus 48.9% from ^{234}U, plus 2.25% from ^{235}U.

[f] Radionuclides were assigned to groups that were protective of 10 μSv/y (1.0 mrem/y) and were limited to four groups for ease of application, as discussed in Annex B (ANSI/HPS N12.13-1999).