

APPENDIX A
WORK PLAN INVESTIGATIVE APPROACH

This page intentionally left blank.

CONTENTS

A.1.0	INTRODUCTION	A-1
A.2.0	BOREHOLE 41-09-39 DECOMMISSIONING.....	A-2
A.2.1	REMOVAL OF KABIS SAMPLER	A-3
A.2.2	GROUNDWATER ANALYSES	A-3
A.2.3	TRACER INJECTION TEST	A-3
A.2.4	BOREHOLE GEOPHYSICAL SURVEYING ACTIVITIES	A-3
A.2.5	SIDEWALL SAMPLING BOREHOLE SEDIMENTS.....	A-4
A.2.6	REMOVAL OF THE OUTER TEMPORARY CASING	A-5
A.3.0	RESOURCE CONSERVATION AND RECOVERY ACT GROUNDWATER MONITORING WELL SEDIMENT SAMPLE ANALYSIS.....	A-7
A.4.0	INSTALLATION OF NEW BOREHOLE AT TANK SX-115	A-10
A.4.1	NEW BOREHOLE LOCATION.....	A-10
A.4.2	DRILLING AND SEDIMENT SAMPLING METHODS AND INTERVALS	A-10
A.4.3	BOREHOLE GEOPHYSICAL SURVEYING ACTIVITIES	A-14
A.4.4	GROUNDWATER SAMPLING ACTIVITIES.....	A-14
A.4.5	LABORATORY ANALYSIS	A-14
A.5.0	INSTALLATION OF SLANT BOREHOLE AT TANK SX-108	A-21
A.5.1	SLANT BOREHOLE LOCATION.....	A-21
A.5.2	DRILLING AND SEDIMENT SAMPLING METHODS AND INTERVALS	A-21
A.5.3	BOREHOLE GEOPHYSICAL SURVEYING	A-30
A.5.4	GROUNDWATER SAMPLING AND ANALYSIS	A-31
A.5.5	LABORATORY ANALYSES OF SX-108 SLANT BOREHOLE.....	A-31
A.6.0	NEAR-SURFACE CHARACTERIZATION.....	A-35
A.6.1	LOCATION	A-35
A.6.2	INVESTIGATIVE AND SAMPLING METHODS AND INTERVALS.....	A-35
A.6.2.1	Tank S-104 Site.....	A-37
A.6.2.2	Tank S-102 Site.....	A-37
A.6.2.3	Additional Pushes	A-38
A.6.3	GEOPHYSICAL SURVEYING ACTIVITIES.....	A-38
A.6.4	LABORATORY ANALYSES	A-38
A.7.0	REFERENCES	A-39

FIGURES

A.1.	Analytical Scheme for Analysis of Borehole 41-09-39 Samples	A-6
A.2.	Locations for the New Borehole and Resource Conservation and Recovery Act Groundwater Monitoring Wells.....	A-8
A.3.	Tank SX-115 Borehole Sampling Location.....	A-11
A.4.	New Borehole Sampling Strategy.....	A-13
A.5.	Tank SX-115 Borehole Subsample Analyses Strategy.....	A-17
A.6.	Tank SX-108 Soil Sampling Location.....	A-22
A.7.	Tank SX-108 Slant Borehole.....	A-28
A.8.	Tank SX-108 Slant Borehole Subsample Analyses Strategy	A-29
A.9.	Waste Management Area S-SX Shallow Soil Sampling Locations.....	A-36

TABLES

A.1.	Sample Number, Sample Interval, and Geologic Medium for Sampling During Decommissioning of Borehole 41-09-39 as Determined in the Data Quality Objectives Process	A-4
A.2.	Required Analyses on Resource Conservation and Recovery Act Well Sediment Samples.....	A-9
A.3.	Constituents and Methods for New Borehole Sediment Sample and Borehole 41-09-39 Decommissioning Sample Analyses	A-18
A.4.	Constituents and Methods for SX-108 Slant Borehole Sediment Sample Analyses and Near-Surface Characterization Samples	A-23
A.5.	Constituents and Methods for Organic Analysis of Borehole Sediment Samples.....	A-33

LIST OF TERMS

bgs	below ground surface
CHG	CH2M HILL Hanford Group, Inc.
DQO	data quality objectives
Ecology	Washington State Department of Ecology
PNNL	Pacific Northwest National Laboratory
RCRA	<i>Resource Conservation and Recovery Act of 1976</i>
WMA	waste management area

This page intentionally left blank.

A.1.0 INTRODUCTION

This appendix summarizes the two work plans for waste management area (WMA) S-SX: *Preliminary Site-Specific SST Phase 1 RFI-CMS Work Plan Addendum for WMA S-SX* (Henderson 1999) and *Site-Specific SST Phase 1 RFI/CMS Work Plan Addendum for WMA S-SX* (Rogers and Knepp 2000). The activities defined in the two work plans have been completed.

Both Henderson (1999) and Rogers and Knepp (2000) are intended to serve as guidelines for the work described and are designed to allow for changes depending on conditions encountered in the field. Any changes were recorded on the appropriate field documentation, memoranda, or letters. Any modifications that did occur are addressed in Appendix B.

The activities performed in accordance with the work plans were as follows:

- Borehole 41-09-39 sampling and decommissioning
- *Resource Conservation and Recovery Act of 1976* (RCRA) groundwater monitoring well sediment sampling and analyses
- Installation of new borehole (299-W23-19) at tank SX-115
- Installation and decommissioning of new slant borehole at tank SX-108
- Near-surface characterization in the S tank farm.

The following sections discuss these activities.

A.2.0 BOREHOLE 41-09-39 DECOMMISSIONING

Borehole 41-09-39 was driven to 40.1 m (131.5 ft) below ground surface (bgs) in December 1996 in the SX tank farm. A 17.8 cm (7 in.) outside diameter by 16.5 cm (6.5 in.) inside diameter well casing was placed from ground surface to 39.8 m (130.5 ft) bgs. The casing was initially closed at the bottom with a steel plug. The bottom plug was milled out and borehole 41-09-39 was extended to 69 m (225.3 ft) bgs in September 1997. A second 11.4 cm (4.5 in.) outside diameter by 9.8 cm (3.8 in.) inside diameter casing string was installed inside the 17.8 cm (7 in.) casing. The casing is 65 m (214 ft) in length by 11.4 cm (4.5 in.) outside diameter steel pipe, with a 3 m by 8.9 cm (10 ft by 3.5 in.) 0.010 slot stainless steel screen with a 0.3 m by 8.9 cm (1 ft by 3.5 in.) blank for a total length of 69 m (225 ft). There is no annular seal in either section of casing strings.

Borehole 41-09-39 decommissioning activities included sidewall sampling in the upper portion of the borehole; that is, 39.6 m (103 ft) bgs to surface. The lower portion of borehole 41-09-39 was sampled in 1997 and 1998. The following are the field activities executed as part of borehole 41-09-39 decommissioning:

- Removed Kabis sampler to support decommissioning
- Performed groundwater sampling and analysis before decommissioning
- Performed a tracer test that might clarify path, direction, and rate of groundwater flow
- Measured formation in the open borehole face as the casing is removed and measured temperature in the casing prior to removal to correlate sediment temperatures for future investigations
- Conducted borehole geophysical logging and analysis (moisture, neutron spectral gamma, and high-purity germanium analysis) to find indicated zones of contamination and stratigraphic correlation
- Sampled at intervals in the driven portion of the borehole to try to determine if drag-down from original drilling may be the cause of contamination found during geophysical analysis
- Obtained sediment samples to analyze for presence and concentration of contaminants and to evaluate alterations of the sediments from waste chemistry effects
- Obtained sediment samples to support preparation of the borehole geologic logs and stratigraphic and lithologic contact correlation with other boreholes
- Respond to the Washington State Department of Ecology (Ecology) and *Washington Administrative Code* requirements to decommission the borehole in a compliant manner.

The way some or all of the work was executed may have been modified because of field conditions; such modifications are acceptable per Henderson (1999). Any changes will be recorded on the appropriate field documentation, memoranda, or letters.

A.2.1 REMOVAL OF KABIS SAMPLER

The Kabis sampler is 10.2 cm (4 in.) in diameter and stuck at the top of the 7.6 cm (3 in.) well screen section (Johnson and Chou 1999). The sampler was removed using appropriate techniques. After removing the sampler; the 11.43 cm (4.5 in.) borehole casing was brushed and swabbed to improve the ability to gather high-purity germanium logging runs.

A.2.2 GROUNDWATER ANALYSES

The collection and analysis of groundwater samples from borehole 41-09-39 was completed before initiating the decommissioning activities described in Henderson (1999). Therefore, details of the groundwater analyses work are not addressed in this appendix. Information regarding groundwater analyses may be found in *RCRA Assessment Plan for Single-Shell Tank Waste Management Area at the Hanford Site* (Johnson and Chou 1999).

A.2.3 TRACER INJECTION TEST

The purpose of the tracer injection test was to measure direction and flow rate of the groundwater from the center of the SX tank farm to monitoring wells surrounding the tank farm. The tracer medium was sodium bromide powder dissolved in 15,140 L (4,000 gal) of water to obtain a 50 parts per million bromide solution. The well screen sections remain in the borehole to ensure that the hole stays open and to provide better control over the injection zone and the rate of injection for the tracer test. Removal of the screen could create downhole conditions that could prevent completion of tracer testing and complicate the decommissioning process. A variance request to leave the screen in the borehole was approved by Ecology.

A.2.4 BOREHOLE GEOPHYSICAL SURVEYING ACTIVITIES

Borehole 41-09-39 was geophysically surveyed in the lower portion prior to removal of the 11.43 cm (4 in.) casing and in the upper portion of the borehole prior to removal of the 17.8 cm (7 in.) casing to provide additional characterization information to supplement the sediment sampling data for the entire borehole. The following geophysical surveying techniques were used during borehole 41-09-39 decommissioning:

- Gross gamma logging to identify confining layers and for stratigraphic correlation
- Spectral gamma logging for measuring the distribution of selected radionuclides
- Neutron log for measuring the saturation distribution
- Neutron-enhanced spectral gamma logging for correlation of high-salt tank waste and moisture content with spectral gamma and neutron probes, respectively
- Infrared temperature gauge for measuring sediment temperature (this logging will be conducted both inside and outside the conductor casing for future correlation analysis).

The existing equipment and procedures for gross gamma and spectral gamma logging in use at the Hanford Site provide acceptable data through the various quality assurance measurements.

A.2.5 SIDEWALL SAMPLING BOREHOLE SEDIMENTS

Sixteen sidewall sample locations have been identified in accordance with the data quality objectives (DQO) process. Prior to sample collection, comparison of the geophysical surveys obtained from activities specified in Section A.2.4 to the surveys utilized in the DQO meeting was done to verify sample locations. If the geophysical surveys indicated movement of the gamma contamination or changes in moisture content, the sample horizons were adjusted with the concurrence of the CH2M HILL Hanford Group, Inc. (CHG) technical representative. The sample locations are identified in Table A.1. Three samples were taken in a 120° radial pattern at each sample horizon at the bottom of the 11.43 cm (4.5 in.) casing for a total of 48 aliquots. Samples were retrieved using a sidewall sampler.

Table A.1. Sample Number, Sample Interval, and Geologic Medium for Sampling During Decommissioning of Borehole 41-09-39 as Determined in the Data Quality Objectives Process

Sample Number	Sample Interval Below Ground Surface (ft) ^a	Geologic Medium
1	39.9 – 40.2 m (131 – 132)	Silt – Plio-Pleistocene unit
2	35.7 – 36.0 m (117 – 118)	Silty sand – Hanford formation
3	34.1 – 34.4 m (112 – 113)	Silty sand – Hanford formation
4	32.9 – 33.2 m (108 – 109)	Silty sand – Hanford formation
5	31.1 – 31.4 m (102 – 103)	Silty sand – Hanford formation
6	29.0 – 29.3 m (95 – 96)	Sandy gravel – Hanford formation
7	27.1 – 27.4 m (89 – 90)	Sandy gravel – Hanford formation
8	25.0 – 25.3 m (82 – 83)	Gravelly sand – Hanford formation
9	24.1 – 24.4 m (79 – 80)	Gravelly sand – Hanford formation
10	22.6 – 22.9 m (74 – 75)	Gravelly sand – Hanford formation
11	21.0 – 21.3 m (69 – 70)	Gravelly sand – Hanford formation
12	19.8 – 20.1 m (65 – 66)	Slightly silty sand – Hanford formation
13	18.6 – 18.9 m (61 – 62)	Slightly silty sand – Hanford formation
14	17.4 – 17.7 m (57 – 58)	Slightly silty sand – Hanford formation
15	13.7 – 14.0 m (45 – 46)	Gravelly sand – original backfill ^b
16	7.6 – 7.9 m (25 – 26)	Gravelly sand – original backfill ^b

^aSubject to change based on new geophysical surveying.

^bSample will be as a clean control.

If sampling the sidewall produced no sample or a limited sample collection as a result of sidewall collapse or poor retrieval as a result of field conditions, a split-spoon sample was to be collected if sidewall collapse occurs. If corrected sample volumes were small, another sample was to be attempted at an appropriate location above the first attempted sample location, unless interference for the next specified sample was a concern. See Appendix B for discussion of the events.

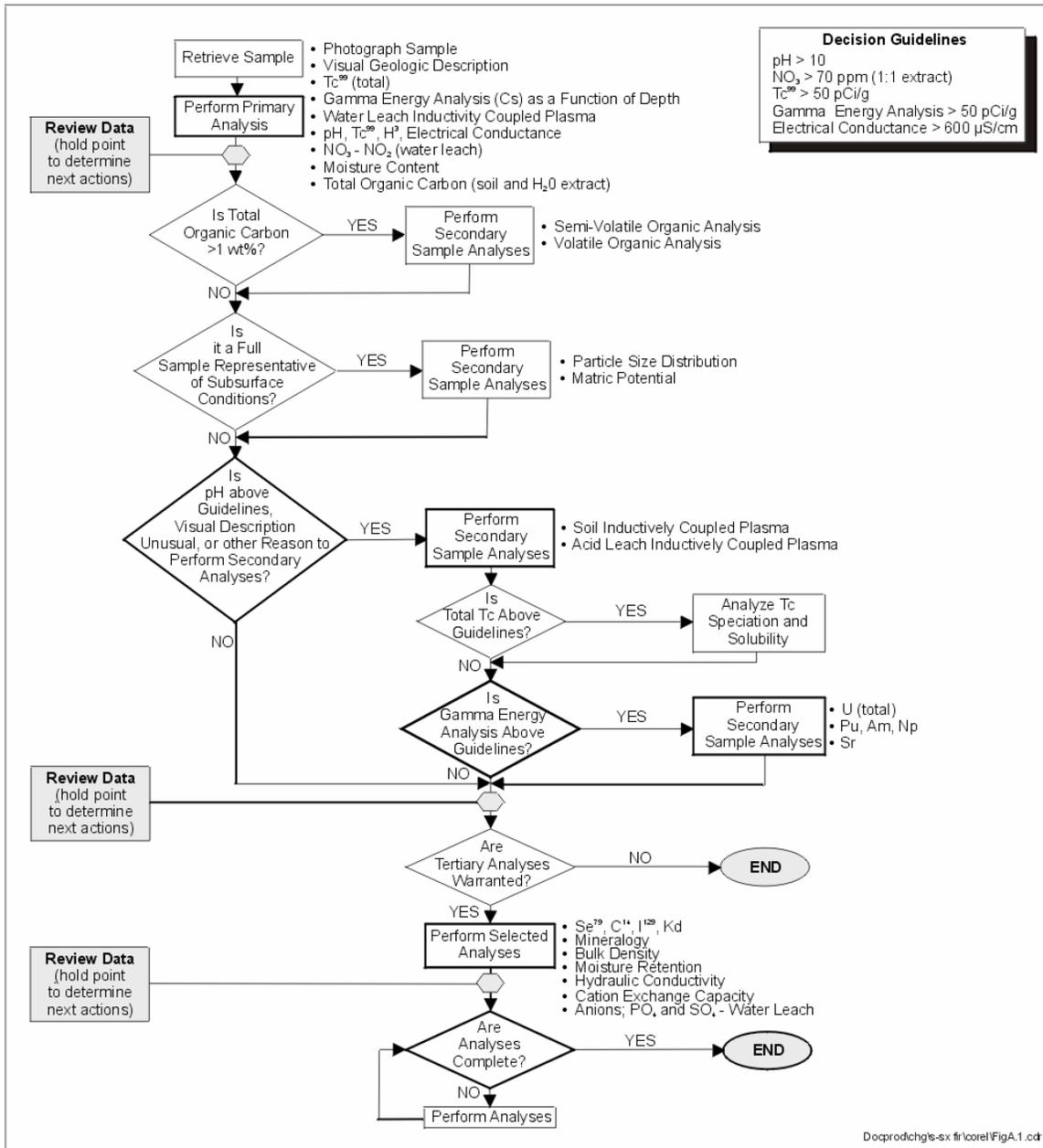
Once received at the laboratory, the samples underwent the analysis scheme identified in Figure A.1, using the analytical methods listed in Henderson (1999). This analysis event produced few samples with limited sample volume. Therefore, hold points were inserted into the process to allow the laboratory and CHG technical staff to collaborate and review data before each new round of analyses. See Appendix B for reports of the data review activities.

Based on the results of the primary analyses, spectral gamma surveys, and moisture content measurements performed during the field geophysical surveys and the geologic logging and field notes, geological technical experts, CHG technical staff, the laboratory technical staff, and decision-makers (Ecology and the U.S. Department of Energy) convened to determine what additional analyses should be conducted. Some of the determining criteria were to be the amount and integrity of the remaining sample, primary analytical results, and regulatory requirements. Based on these decisions, the secondary and tertiary analyses were to be performed. See Appendix B for report of the analyses performed.

A.2.6 REMOVAL OF THE OUTER TEMPORARY CASING

The total length of the 11.43 cm (4.5 in.) outside diameter casing removed is 63.4 m (208 ft). The casing shoe has a 13 cm (5 in.) outside diameter. Sediment sampling was conducted in 1997 from 39.6 m to 68.9 m (130 ft to 225 ft) bgs; therefore, no sampling was required in this interval. Abandonment of the interval is in compliance with “Minimum Standards for the Construction and Maintenance of Wells” (WAC 173-160) requirements. After the decommissioning, all steel casing in the borehole was removed and transferred to an appropriate disposal facility or a controlled decontamination facility.

Figure A.1. Analytical Scheme for Analysis of Borehole 41-09-39 Samples

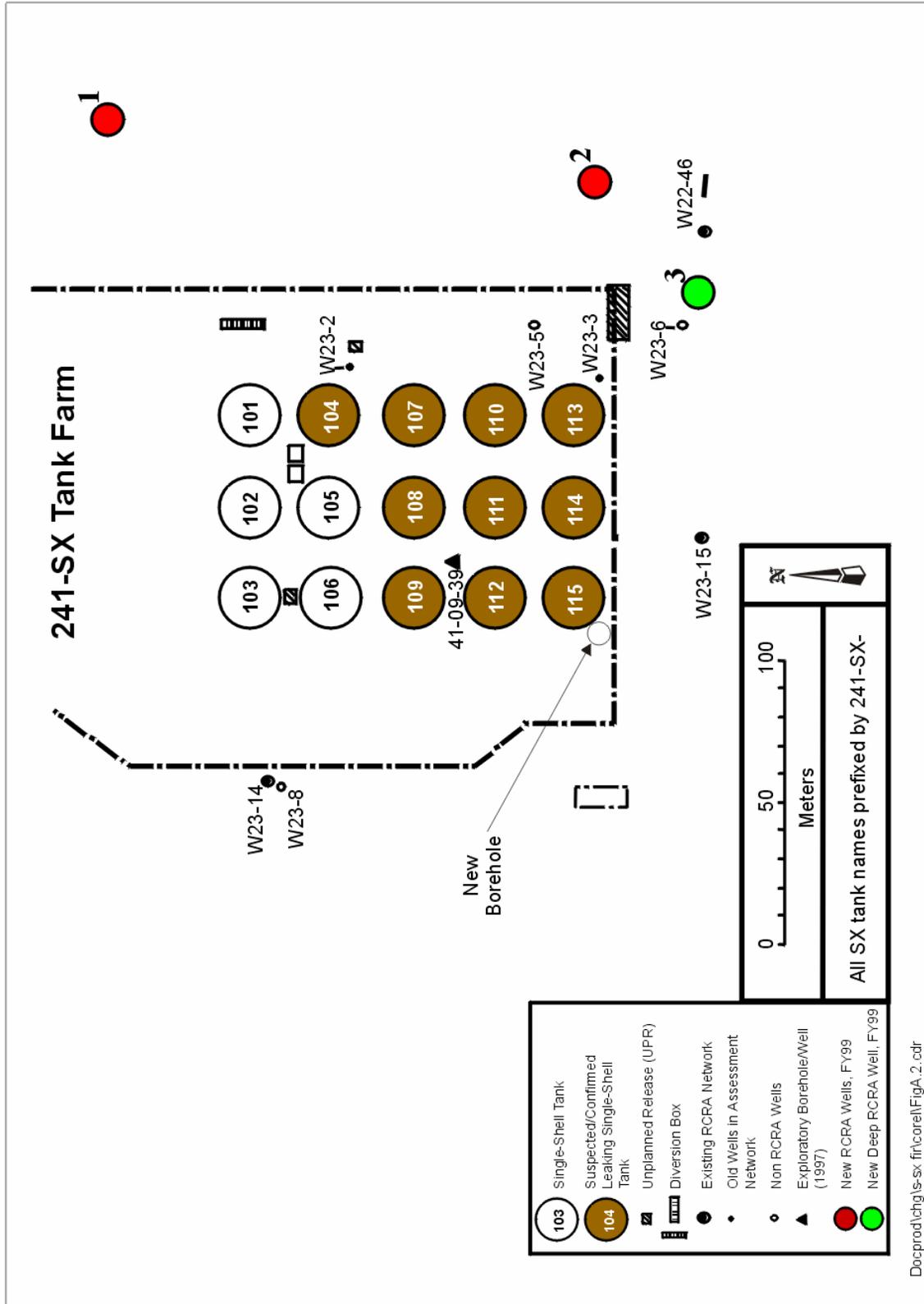


A.3.0 RESOURCE CONSERVATION AND RECOVERY ACT GROUNDWATER MONITORING WELL SEDIMENT SAMPLE ANALYSIS

Continuous split-spoon driven samples and drill cutting samples were collected in conjunction with the installation of three RCRA groundwater monitoring wells. The southern-most monitoring well is located about 50 m (164 ft) southeast of tank SX-113 (Figure A.2). From this well, continuous sediment split-spoon driven samples from about 6 m (20 ft) bgs to refusal (anticipated to be near the top of the Ringold Formation) were collected. Drill cuttings were collected from refusal to the total depth of the water table. The other two RCRA groundwater monitoring wells are located east of the S and SX tank farms. Drill cuttings were collected from these two wells. Selected portions of the driven samples and cuttings were analyzed for chemical and physical characteristics. A detailed description of the work associated with the installation of these monitoring wells has been developed and, once Ecology comments are incorporated, will supercede Johnson and Chou (1999). Only details associated with analysis of sediment split-spoon driven samples and cuttings are addressed in this appendix.

Continuous driven samples taken from the vadose zone during construction of one well (well 3 of Figure A.2), and the samples were made available for hydrologic properties analysis. The analyses required for this sample are listed in Table A.2. Samples for analysis were from each stratigraphic unit, stratigraphic contacts, weathered bedding structures, and lithologic facies changes.

Figure A.2. Locations for the New Borehole and Resource Conservation and Recovery Act Groundwater Monitoring Wells



**Table A.2. Required Analyses on Resource Conservation
and Recovery Act Well Sediment Samples**

Analysis/ Constituent	Preparation Method	Preparation Procedure Number	Analytical Method	Analytical Procedure Number*
PH	Water extract	Methods of Soil Analysis, Part 2; 62-1.3.2.2	Electrometric	Methods of Soil Analysis; 60-3.4
Particle size distribution	Bulk sediment	NA	Particle size distribution	ASTM D 422-63 ASTM D 854-83
Moisture content	Gravimetric	NA	Moisture content	PNL-MA-567-SA-7
Matric potential	Filter paper suction	NA	Matric potential	PNL-MA-567-SA-10
Bulk density	Gravimetric/volume	NA	Bulk density	PNL-MA-567-SA-8
Moisture retention	Bulk sediment	NA	Moisture retention	ASTM D 2325-68
Saturated hydraulic conductivity	Bulk sediment	NA	Saturated hydraulic conductivity	ASTM D 18.21 (draft in review) Methods of Soil Analysis, Part 2; 13-3.2 and 13-3.3
Anions	Water extract	Methods of Soil Analysis, Part 2; 62-1.3.2.2	IC ISE Colorimetric	PNL-ALO-212 US EPA Method 300.0A Orion-720a Hach procedure
Metals	Water extract Acid leach Fusion	Method of Soil Analysis, Part 2; 62-1.3.2.2 PNL-ALO-106 PNL-ALO-235	ICPMS	PNL-ALO-211
Cation exchange capacity	Bulk sediment	NA	Cation exchange capacity	Methods of Soil Analysis Part 2; 9-3.1

*The procedures are addressed in EPA (1983), EPA (1986), and ASTM (1998).

IC = ion chromatography.

ICPMS = inductively coupled plasma mass spectrometry.

ISE = ion selective electrode.

NA = not applicable.

A.4.0 INSTALLATION OF NEW BOREHOLE AT TANK SX-115

A new borehole labeled 299-W23-19 (well number B8809) was installed at tank SX-115. The following activities were conducted at the new borehole.

- Measured formation and casing temperature in the open borehole face after the casing was advanced and after cleaning the borehole during drilling for future correlation analysis.
- Conducted borehole geophysical surveying and analysis (moisture, neutron, gross gamma, spectral gamma and enhanced neutron spectral gamma analysis) for stratigraphic correlation and selected contaminant distribution.
- Performed spectral gamma logging and evaluated the potential use of microspheres to support attempt to determine the occurrence of dragdown during drilling.
- Obtained sediment samples to analyze for the presence and concentration of contaminants and to evaluate alterations of the sediments from waste chemistry effects.
- Obtained sediment samples to support preparation of the borehole geologic logs and stratigraphic and lithologic contact correlation with other boreholes in the WMA S-SX vicinity.

A.4.1 NEW BOREHOLE LOCATION

A new vertical borehole was drilled southwest of tank SX-115 within the SX tank farm. The location of the borehole is 3 m (10 ft) south of drywell 41-15-09 at coordinates Northing 134166.72 and Easting 566759.19, as is shown in Figure A.3. The boring extends from the surface to just below the water table, approximately 64 m (210 ft) bgs, to allow for groundwater sampling.

A.4.2 DRILLING AND SEDIMENT SAMPLING METHODS AND INTERVALS

The new borehole was advanced in conjunction with split-spoon sampling techniques through regions of interest with samples acquired in advance of the conductor casing installation. Then, the boring was cleaned out (i.e., drilled to expand the borehole diameter to approximately the drill pipe and conductor casing diameter while the conductor casing was being driven downward to the bottom of the last sample interval). The reverse-air circulation drill and drive method was used for this task because of the ease of drilling through gravels, cobbles, and boulders common to the area geology. Also, the quantity of drilling residuals (cuttings) is minimal with this technique, washout zones are significantly reduced or eliminated, and more representative formation and water samples can be obtained (Driscoll 1986) compared to previously used methods.

Air used in the drilling process had to be contained per the Washington State Department of Health. A Notice of Construction permit (DOE-RL 1999a) were acquired before drilling operations inside the tank farm. The drilling method complies with the requirements of the Washington State Department of Health for the Notice of Construction permit and other pertinent requirements and appropriate engineering systems to prevent the potentially contaminated air from being released to the environment.

Drilling was conducted using specifications and guidance in accordance with WAC 173-160. All waste was handled in accordance with the requirements of “Dangerous Waste Regulations” (WAC 173-303). The drilling and sampling techniques are based on minimizing the exposure of field personnel to both radiation and chemical pollutants, which is the application of as low as reasonably achievable principles in compliance with regulatory requirements.

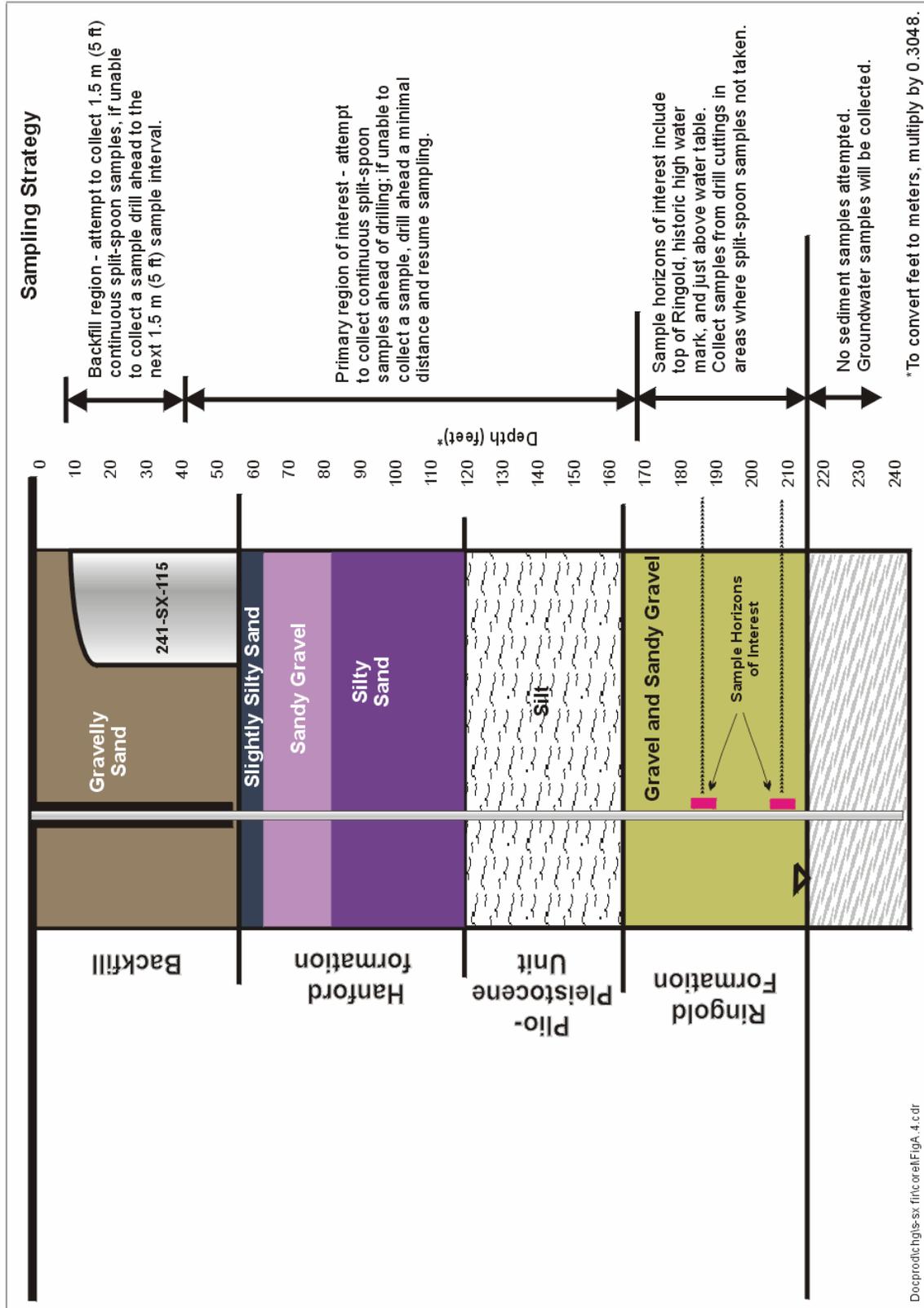
The new borehole was completed as a RCRA-compliant groundwater monitoring well after completion of the geophysical surveying. All temporary steel casing removed from the boring was surveyed and either decontaminated and released or transferred to an appropriate disposal facility. A 4-in. stainless steel casing and screen was permanently installed, and a flush mount surface protection/well seal was constructed. The well was completed in accordance with WAC 173-160 requirements to meet groundwater protection goals. Specific work steps for well completion were documented in the tank farm work package.

Borehole sampling was performed to define the depth of contamination. The borehole serves to establish the general lithology of the sediments lying below the site and to give indications of how radionuclides and other contaminants have migrated. It also provides sediment samples for determination of sediment chemistry and vadose zone properties.

There is some question as to the geographical extent of the effect of the Hanford Site operations on sediment quality. There are uncertainties as to the extent of the effect of the site activities; therefore, a background sample (i.e., above the base of the tank) was obtained from the drilling of the borehole at SX tank farm. As with all samples, this sample was field screened using alpha, beta, gross gamma, and spectral gamma scans. The results from this sample were evaluated and compared to data from onsite borings to determine whether there has been any significant impact on the sediment below WMA S-SX from the Hanford Site operations. Because the background sample was taken 9 m (30 ft) bgs, any surface contamination present in the drilling location is not expected to have altered the constituent results.

For the new borehole, split-spoon drive sampling began at 3 m (10 ft) bgs to allow for a limited open borehole and placement of a sealed surface casing to prevent air contamination from occurring. Drilling and sampling continued until groundwater was reached. Figure A.4 shows the sampling strategy for the new borehole. The boring extends to just below the water table to permit installation of the Kabis sampler for groundwater sampling in accordance with guidance from the Hanford Groundwater Program (Stewart 1997).

Figure A.4. New Borehole Sampling Strategy



A.4.3 BOREHOLE GEOPHYSICAL SURVEYING ACTIVITIES

Downhole spectral gamma or gross gamma geophysical logging was conducted to ascertain the gamma-emitting radionuclide concentrations and assess contaminant drag-down during advancement of the casing. The spectral gamma or gross gamma logging frequency was directed by CHG. The planning basis for spectral gamma or gross gamma logging frequency included logging every 6.1 to 9.2 m (20 to 30 ft) that the borehole was advanced. If the radiological screening performed by the site health physics technician indicated a zone of high contamination was penetrated, a log was to be run within 4.6 m (15 ft) of passing through that zone.

A full suite of geophysical logs was run any time the casing size was changed and at the completion of the borehole. This provided some flexibility and provided for logging on average every 2 days following Waste Management Northwest's planning basis of advancing the hole 3 m (10 ft) per day.

The following logging techniques were used for the new borehole:

- Gross gamma logging to support correlation of confining layers and stratigraphy
- Spectral gamma logging for measuring the distribution of selected radionuclides
- Neutron log for measuring the degree of saturation distribution
- Neutron-enhanced spectral gamma logging for correlation of high-salt tank waste and moisture content with spectral gamma and neutron probes, respectively
- Infrared temperature gauge for measuring sediment temperature.

The existing equipment and procedures for gross gamma and spectral gamma logging in use at the Hanford Site provide acceptable data (DOE-GJO 1995).

The borehole was decommissioned following completion of the groundwater sampling described in Section A.3.4. All steel casing was removed and transferred to an appropriate disposal facility or controlled decontamination facility, and each boring was pressure-grouted from the bottom up, using a Portland cement/bentonite slurry. The procedures comply with U.S. Environmental Protection Agency requirements and WAC 173-160.

A.4.4 GROUNDWATER SAMPLING ACTIVITIES

The sampling and analyses of groundwater was conducted by the Hanford Groundwater Program as described in Johnson and Chou (1999). The new borehole penetrated the groundwater table; therefore, samples of groundwater were collected and analyzed in accordance with guidance provided in the sampling plan for borehole 41-09-39 (Stewart 1997).

A.4.5 LABORATORY ANALYSIS

The following sections describe the laboratory analyses required for the samples collected from the new borehole. Samples for laboratory analysis were placed in appropriate containers and

properly preserved. All samples for laboratory analysis were transported under chain of custody in accordance with Henderson (1999).

Sediment Sample Analysis

After the split-spoon sediment samples and drill cutting samples were screened, these samples were transported to the Pacific Northwest National Laboratory (PNNL) Applied Geology and Geochemistry group for analysis. All material removed from the borehole was sent to the laboratory for possible future analysis. Samples are contained in airtight sample containers after their initial screening by the health physics technician and are kept under refrigeration. This process is used to retain sediment moisture in as close to field condition as possible. All samples were transported to the laboratory under refrigeration to further limit alteration of sediment moisture.

Sediment subsamples for laboratory analysis were defined by location in the sample after the field screening and geologic logging were completed and indication of contamination locations were identified. Approximately 22 sediment subsamples from the borehole were chosen for screening analysis. The following criteria were used to identify subsamples for laboratory analysis based on concurrence with Ecology.

- One background subsample taken at 9 m (30 ft) bgs.
- One subsample taken at 17 m (55 ft) bgs, at the level of the tank bottom.
- Two subsamples taken at the major lithology changes in the Hanford formation.
- One subsample taken at the Plio-Pleistocene unit and Hanford formation contact, and one subsample obtained at the Ringold Formation and Plio-Pleistocene unit contact.
- One subsample taken just above the water table in the capillary fringe zone.
- One subsample taken at the historic high water table at approximately 56 m (185 ft) bgs.
- Subsamples taken of any paleosols seen in the split-spoon drive samples.
- Subsamples taken in locations where elevated or altered gamma surveying or moisture content was measured during the geological and geophysical borehole logging process.
- At least one subsample taken every 3 m (10 ft) if samples have not already been taken, based on the above criteria to ensure continuous distribution and lithologic completeness.

Figure A.5 shows the subsamples identified for laboratory analyses. All subsamples underwent screening analyses, which consist of nitrate analysis by the colorimetric method, pH measurement, electrical conductance measurement, and gamma energy analysis. These analyses, along with the gamma surveying and moisture content measurements performed during the field geophysical surveys and the laboratory geologic logging, were used to determine the extent of further subsample analysis. Table A.3 identifies the full complement of analyses and their respective laboratory preparation and analytical methods. This paragraph and the remainder of

this section identifies which analyses were conducted on which subsample. If more than one preparation or analytical method is listed, the laboratory geochemistry staff determined which methods would produce the best results and provide the best understanding of the chemistry involved. For those methods that produce multiple constituents (i.e., inductively coupled plasma or volatile organic analysis), all constituents identified were reported. Regulatory hold times were met where appropriate.

Because the purpose of the new borehole analysis is to both gain an understanding of the nature and extent of contamination, the fate and transport of the contaminants in the vadose zone, and to produce RCRA-compliant data, the analysis of these subsamples consisted of two levels. The baseline level involved analysis of organic, inorganic, and radiochemical constituents in full conformance with *Hanford Analytical Services Quality Assurance Requirements Document* (DOE-RL 1998) and with no modifications to methods (as defined in DOE-RL 1998) without concurrence from the CHG technical representative and from Ecology. Substitutions and deviations to methods as defined in DOE-RL (1998) did not require concurrence from Ecology. The second level involved a research-type approach to the analyses. In this level, procedures could be modified or developed to gain a more comprehensive understanding of the dynamics involved. Although specific quality control criteria did not apply to this level, compliance with the other quality assurance requirements of DOE-RL (1998) still had to be met and research analysis had to be initiated only following review and approval of the activities by the CHG technical representative.

The background subsample, backfill – Hanford formation contact subsample, the two subsamples obtained at the Hanford formation and Plio-Pleistocene unit contact and the Plio-Pleistocene unit and Ringold Formation contact, and the subsample obtained just above the water table in the capillary fringe zone were analyzed for the constituents and properties identified in Table A.3. It was recognized before analysis that conditions could occur in which all of the analyses identified in Table A.3 are not warranted (e.g., limited potential for data). These occurrences were to be evaluated on a case-by-case basis. See Appendix B for discussion of what did occur.

The remaining subsamples were analyzed for specific constituents listed in Table A.3 depending on the results of the nitrate, electrical conductivity, and pH screening analyses. A review of the screening analyses results with technical representatives along with Ecology was conducted prior to performing additional analyses. Screening analysis may have been used to determine whether alternative analytical techniques with lower detection limits should be used for specific radionuclides of concern. The screening criteria and associated analytical requirements are identified as follows:

Figure A.5. Tank SX-115 Borehole Subsample Analyses Strategy

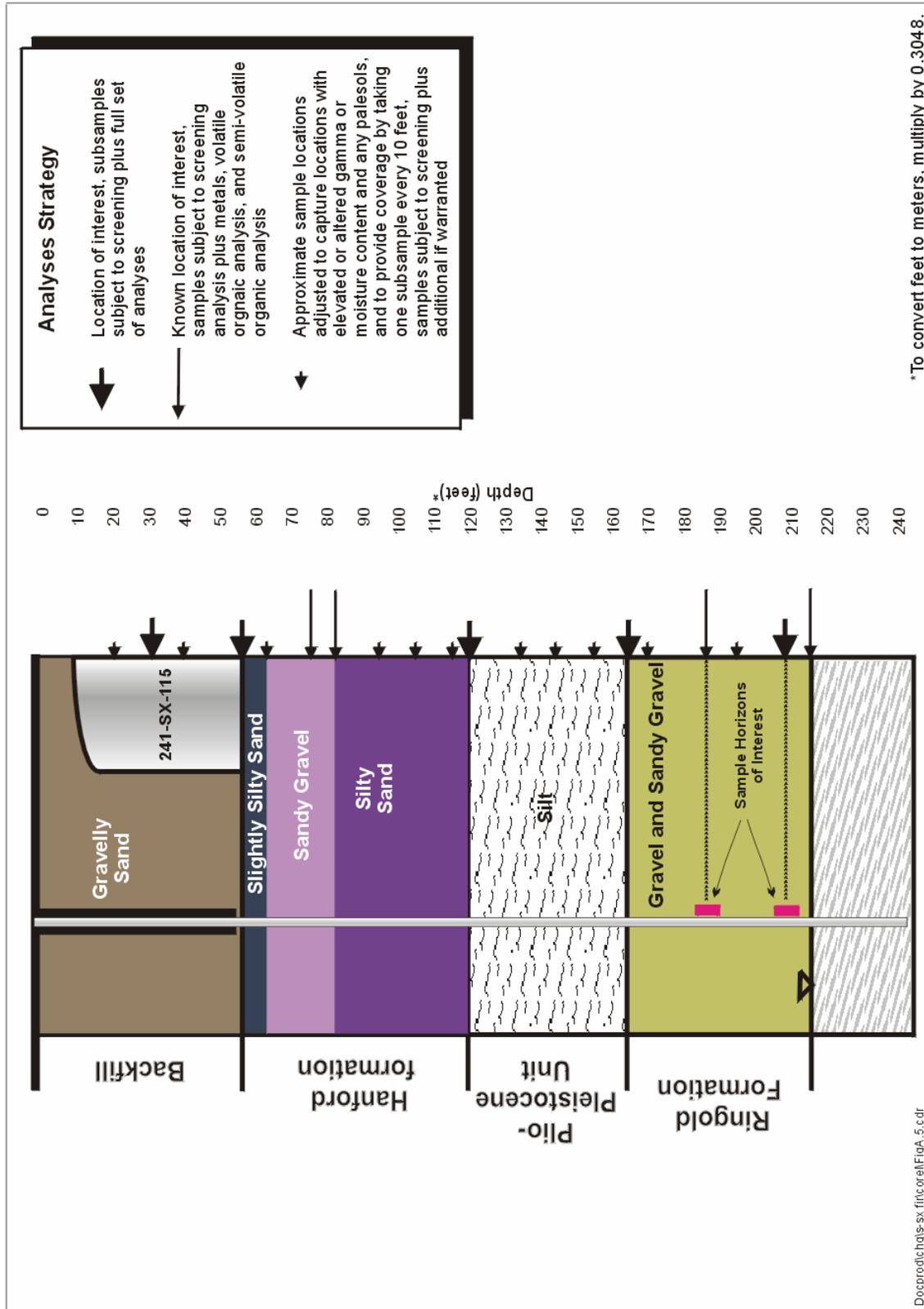


Table A.3. Constituents and Methods for New Borehole Sediment Sample and Borehole 41-09-39 Decommissioning Sample Analyses (2 Sheets)

Analysis/ Constituent	Preparation Method	Preparation Procedure Number	Analytical Method	Analytical Procedure Number^a
Cesium-137	Bulk sediment	NA	GEA	PNL-RRL-001
Carbon-14	Bulk sediment Water extract	NA Methods of Soil Analysis, Part 2; 62-1.3.2.2	Total combustion LSC method in review based on:	ASTM D 4129-82 PNL-ALO-476
Europium-152	Bulk sediment	NA	GEA	PNL-RRL-001
Neptunium-237 Plutonium-239 Plutonium-240 Americium-241	Acid leach Fusion	PNL-ALO-106 PNL-ALO-235	ICP-MS	PNL-ALO-211
Strontium-90	Acid leach Fusion	PNL-ALO-106 PNL-ALO-235	LSC	PNL-ALO-476
Cobalt-60	Bulk sediment	NA	GEA	PNL-RRL-001
Technetium-99	Acid leach Fusion	PNL-ALO-106 PNL-ALO-235	ICP-MS LSC	PNL-ALO-211 PNL-ALO-476
Hydrogen-3	Water extract	Methods of Soil Analysis, Part 2; 62-1.3.2.2	LSC	PNL-ALO-476
Iodine-129	Acid leach	PNL-ALO-106	ICP-MS	PNL-ALO-211
Selenium-79	b	b	b	b
Total uranium	Water extract Fusion	Methods of Soil Analysis, Part 2; 62-1.3.2.2 PNL-ALO-235	ICP-MS	PNL-ALO-211
Metals	Water extract Acid leach Fusion	Methods of Soil Analysis, Part 2; 62-1.3.2.2 PNL-ALO-106 PNL-ALO-235	ICP-MS	PNL-ALO-211
VOA	Bulk sediment	c	GC/MS	SW846-8260
SVOAs with TICs	Bulk sediment	c	CG/MS	SW846-8270
pH	Water extract	Methods of Soil Analysis, Part 2; 62-1.3.2.2	Electrometric	Methods of Soil Analysis; 60-3.4
Anions	Water extract	Methods of Soil Analysis, Part 2; 62-1.3.2.2	IC ISE Colorimetric	PNL-ALO-212 US EPA Method 300.0A Orion-720a Hach procedure
Cation exchange capacity	Bulk sediment	NA	Cation exchange capacity	Methods of Soil Analysis Part 2; 9-3.1

Table A.3. Constituents and Methods for New Borehole Sediment Sample and Borehole 41-09-39 Decommissioning Sample Analyses (2 Sheets)

Analysis/ Constituent	Preparation Method	Preparation Procedure Number	Analytical Method	Analytical Procedure Number^a
Particle size distribution	Bulk sediment	NA	Particle size distribution	ASTM D 422-63 ASTM D 854-83
Mineralogy	Bulk powder/clay	JEA-2, Rev. 0	XRD/SEM/TEM	JEA-3, Rev. 0
Electrical conductance	Water extract	Methods of Soil Analysis, Part 2; 62-1.3.2.2	Electrometric	PNL-MA-567-FA-2
Moisture content	Gravimetric	NA	Moisture content	PNL-MA-567-SA-7
Matric potential	Filter paper suction	N/A	Matric potential	PNL-MA-567-SA-10
Distribution coefficient	Bulk sediment	NA	Methods for determining radionuclide retardation factors, 1980	PNL-3349 USC-70
Bulk density	Gravimetric/volume	NA	Bulk density	PNL-MA-567-SA-8
Moisture retention	Bulk sediment	NA	Moisture retention	ASTM D 2325-68
Saturated hydraulic conductivity	Bulk sediment	NA	Saturated hydraulic conductivity	ASTM D18.21 (draft in review) Methods of Soil Analysis, Part 2; 13-3.2 and 13-3.3

^aThe procedures are addressed in EPA (1983), EPA (1986), and ASTM (1998).

^bProcedures for analysis of selenium-79 are being prepared; this analysis does not apply to the new borehole.

^cPreparation/extraction procedures for VOA and SVOA analysis will depend on the types of organic compounds present in the sediment.

GEA = gamma energy analysis.

IC = ion chromatography.

ISE = ion selective electrode.

LSC = liquid scintillation.

NA = not applicable.

SEM = scanning electron microscopy.

SVOA = semi-volatile organic analysis.

TEM = transmission electron microscopy.

TIC = tentatively identified compound.

TOC = total organic carbon.

VOA = volatile organic analysis.

XRD = x-ray diffraction.

- Gamma-emitting radioisotopes by gamma energy analysis
- Carbon-14
- Metals and radioisotopes by inductively coupled plasma mass spectrometry
- Tritium and strontium-90 by the liquid scintillation method
- Particle size distribution
- Volatile and semi-volatile organic analysis, including tentatively identified compounds.

A minimum of two subsamples collected within the Hanford formation were to be analyzed for volatile and semi-volatile organic compounds, including tentatively identified compounds and metals.

The data obtained from the above analyses were used to evaluate the location of contamination plumes in the sediment column. If isolated peaks or unusual results were found, additional subsamples from the archived drive sample may have been obtained and analyzed. The results of the above analyses were also used to determine if additional analyses are warranted.

Additional analyses were performed based on the judgement and expertise of the responsible PNNL geochemist, with concurrence from the CHG technical representative and Ecology.

The following analyses were considered for additional analyses:

- Cation exchange capacity
- Mineralogy
- Matric potential
- Distribution coefficient
- Bulk density
- Moisture retention
- Saturated hydraulic conductivity.

Table A.3 identifies the analyses and laboratory methods used for the sample analyses. For the chemical and radiological constituents, the preferred methods are those listed in *Test Methods for Evaluating Solid Waste, Physical/Chemical Methods* (EPA 1986) or the American Society for Testing and Materials standards (ASTM 1998). The requested constituents may have been analyzed by laboratory-specific procedures, provided that the procedures were validated and conform to DOE-RL (1998). Appendix B discusses the laboratory-specific procedures used. Both the EPA (1986) methods and the PNNL methods listed in Table A.3 are based on techniques from “Methods of Soil Analysis” (ASTM 1998). Therefore, these procedures should be comparable.

A.5.0 INSTALLATION OF SLANT BOREHOLE AT TANK SX-108

The following activities were conducted during installation of a slant borehole at tank SX-108.

- Conduct borehole geophysical surveying and analysis (moisture, neutron, gross gamma, spectral gamma and neutron-enhanced spectral gamma analysis).
- Obtain sediment samples to analyze for the presence and concentration of contaminants and to evaluate alterations of the sediments from waste chemistry effects.
- Obtain sediment samples to support preparation of the borehole geologic logs and stratigraphic and lithologic contact correlation with other boreholes/wells in the WMA S-SX vicinity.

A.5.1 SLANT BOREHOLE LOCATION

The slant borehole is located northwest of tank SX-108 extending under tank SX-108 within the SX tank farm. The location of the borehole is shown in Figure A.6.

A.5.2 DRILLING AND SEDIMENT SAMPLING METHODS AND INTERVALS

One of the primary constraints on sample collection from the 'hot' zone under tank SX-108 was the potential radiation level (greater than 500 mrem/h), which may have limited the sample volumes that could be brought to the surface. To reduce the uncertainties associated with placing a slant borehole beneath tank SX-108, a demonstration was conducted outside of the tank farms to evaluate the techniques for installing the borehole and collecting samples. This demonstration helped refine the borehole angle and the sample collection methods. The planning basis for the SX-108 slant borehole included the following.

- The borehole enters the ground at approximately the 11 o'clock position 12.2 m (40 ft) from the edge of the tank nominally 30° off vertical, heading directly underneath the center of the tank (toward the 5 o'clock position). A preliminary investigation of surface and subsurface interference identified this as a potentially viable location. The borehole depth was to be limited to the Plio-Pleistocene unit or to the maximum depth of contamination, whichever is greater.
- Driven samples were collected ahead of the casing. The samples were transported to the laboratory and analyzed for the contaminants of concern identified in Table A.4. Nominally, 10 horizons would be sampled based on the geophysical surveys or the need to provide depth coverage.

Figure A.6. Tank SX-108 Soil Sampling Location

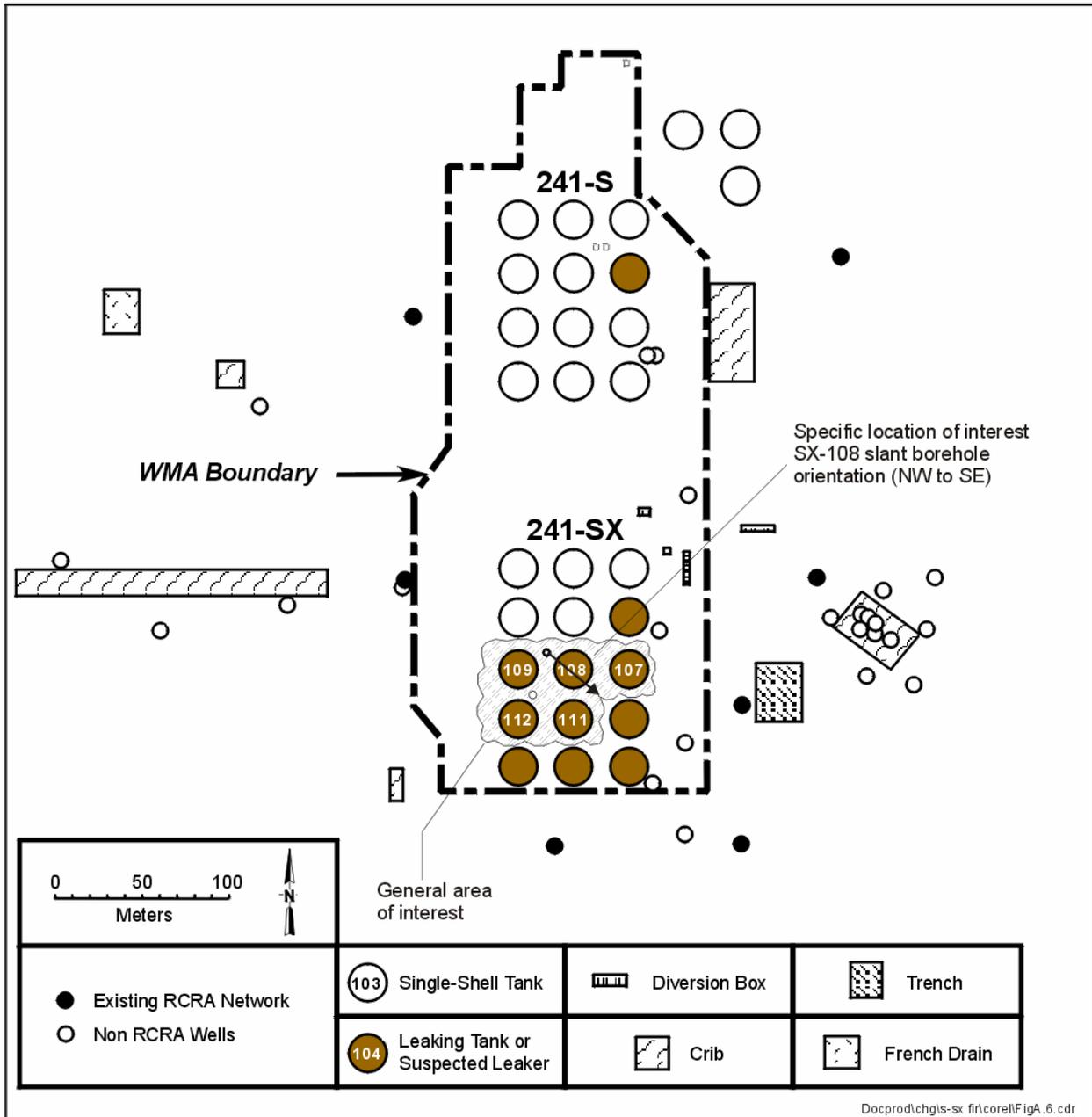


Table A.4. Constituents and Methods for SX-108 Slant Borehole Sediment Sample Analyses and Near-Surface Characterization Samples (4 Sheets)

Contaminants of Potential Concern	CAS #	Action Levels		Name/Analytical Technology ^a	Target Required Quantitation Limits				Precision Water (%)	Accuracy Water (%)	Precision Soil (%)	Accuracy Soil (%)
		RR ^c (pCi/g)	C/I ^c (pCi/g)		Water ^b Low Level (pCi/L)	Water ^b High Level (pCi/L)	Soil Other Low Level (pCi/g)	Soil Other High Level (pCi/g)				
Radionuclide												
Americium-241	14596-10-2	3.10E+01	2.10E+02	Americium isotopic - AEA	1	400	1	4,000	+20	70-130	+35	70-130
Carbon-14	14762-75-5	5.20E+00	3.31E+04	Carbon-14 - liquid scintillation	200		50	N/A	+20	70-130	+35	70-130
Cesium-137	10045-97-3	6.20E+00	2.50E+01	Gamma energy analysis	15	200	0.1	2,000	+20	70-130	+35	70-130
Cobalt-60	10198-40-0	1.40E+00	5.20E+00	Gamma energy analysis	25	200	0.05	2,000	+20	70-130	+35	70-130
Europium-152	14683-23-9	3.30E+00	1.20E+01	Gamma energy analysis	50	200	0.1	2,000	+20	70-130	+35	70-130
Europium-154	15585-10-1	3.00E+00	1.10E+01	Gamma energy analysis	50	200	0.1	2,000	+20	70-130	+35	70-130
Europium-155	14391-16-3	1.25E+02	4.49E+02	Gamma energy analysis	50	200	0.1	2,000	+20	70-130	+35	70-130
Neptunium-237	13994-20-2	2.50E+00	6.22E+01	Neptunium-237 - AEA	1		1	3,000	+20	70-130	+35	70-130
Nickel-63	13981-37-8	4.03E+03	3.01E+06	Nickel-63 - liquid scintillation	15	NA	30	N/A	+20	70-130	+35	70-130
Plutonium-238	13981-16-3	3.74E+01	4.73E+01	Plutonium isotopic - AEA	1	130	1	1,300	+20	70-130	+35	70-130
Plutonium-239/240	PU-239/240	3.39E+01	4.37E+02	Plutonium isotopic - AEA	1	130	1	1,300	+20	70-130	+35	70-130
Total radioactive strontium or strontium-90	SR-RAD or 10098-97-2	4.50E+00	2.50E+03	Total radioactive strontium or strontium isotopic - CPC	2	80	1	800	+20	70-130	+35	70-130
Technetium-99	14133-76-7	5.70E+00	4.10E+05	Technetium-99 - liquid scintillation	15	400	15	4,000	+20	70-130	+35	70-130
Thorium-232	TH-232	1.00E+00	5.10E+00	Thorium isotopic - AEA (pCi) ICPMS (mg)	1	0.002 mg/L	1	0.02 mg/Kg	+20	70-130	+35	70-130
Uranium-234	13966-29-5	1.60E+02	1.20E+03	Uranium isotopic - AEA (pCi) ICPMS (mg)	1	0.002 mg/L	1	0.02 mg/Kg	+20	70-130	+35	70-130
Uranium-235	15117-96-1	2.60E+01	1.00E+02	Uranium isotopic - AEA (pCi) ICPMS (mg)	1	0.002 mg/L	1	0.02 mg/Kg	+20	70-130	+35	70-130
Uranium-238	U-238	8.50E+01	4.20E+02	Uranium isotopic - AEA (pCi) ICPMS (mg)	1	0.002 mg/L	1	0.02 mg/Kg	+20	70-130	+35	70-130

Doc:\pub\ch\le-sx_fir\cont\TabA_4_1.cdr

Table A.4. Constituents and Methods for Slant Borehole Sediment Sample Analyses and Near-Surface Characterization Samples (4 Sheets)

Contaminants of Potential Concern	CAS #	Action Levels		Name/Analytical Technology ³	Target Required Quantitation Limits				Precision Water (%)	Accuracy Water (%)	Precision Soil (%)	Accuracy Soil (%)
		Method B (ug/Kg)	Method C (ug/Kg)		Water ^b Low Level (ug/L)	Water ^b High Level (ug/L)	Soil Other Low Level (ug/Kg)	Soil Other High Level (ug/Kg)				
PCBs	1336-36-3	5.00E+02	6.50E+04	PCBs - 303 ^b - GC	0.5	5	16.5	100	e	e	e	e
Cyanide	57-12-5	2.00E+04	2.00E+04	Total cyanide - 9010 - colorimetric	5	5	500	500	e	e	e	e
Lead	7439-92-1	3.53E+05	3.53E+05	Metals - 6010 - ICP	100	200	10,000	20,000	e	e	e	e
Lead	7439-92-1	3.53E+05	3.53E+05	Metals - 6010 - ICP(TRACE)	10	NA	1,000	NA	e	e	e	e
Mercury	7439-97-6	N/A	N/A	Mercury - 7470 - CVAA	0.5	5	N/A	N/A	e	e	e	e
Mercury	7439-97-6	3.30E+02	3.30E+02	Mercury - 7471 - CVAA	NA	NA	200	300	e	e	e	e
Nickel	7440-02-0	3.20E+04	7.00E+04	Metals - 6010 - ICP	40	40	4,000	4,000	e	e	e	e
Silver	7440-22-4	8.00E+03	1.00E+04	Metals - 6010 - ICP	20	20	2,000	2,000	e	e	e	e
Silver	7440-22-4	8.00E+03	1.00E+04	Metals - 6010 - ICP(TRACE)	5	NA	500	NA	e	e	e	e
Antimony	7440-36-0	3.20E+04	1.40E+06	Metals - 6010 - ICP	60	120	6,000	12,000	e	e	e	e
Antimony	7440-36-0	3.20E+04	1.40E+06	Metals - 6010 - ICP(TRACE)	10	NA	1,000	NA	e	e	e	e
Arsenic	7440-38-2	6.50E+03	6.50E+03	Metals - 6010 - ICP	100	200	10,000	20,000	e	e	e	e
Arsenic	7440-38-2	6.50E+03	6.50E+03	Metals - 6010 - ICP(TRACE)	10	NA	1,000	NA	e	e	e	e
Barium	7440-39-3	1.32E+05	2.45E+05	Metals - 6010 - ICP	200	200	20,000	20,000	e	e	e	e
Barium	7440-39-3	1.32E+05	2.45E+05	Metals - 6010 - ICP(TRACE)	5	NA	500	NA	e	e	e	e
Beryllium	7440-41-7	1.51E+03	1.51E+03	Metals - 6010 - ICP	5	10	500	1,000	e	e	e	e
Cadmium	7440-43-9	5.00E+02	5.00E+02	Metals - 6010 - ICP	5	10	500	1,000	e	e	e	e
Cadmium	7440-43-9	5.00E+02	5.00E+02	Metals - 6010 - ICP(TRACE)	5	NA	500	NA	e	e	e	e
Chromium (total)	7440-47-3	1.60E+06	3.50E+06	Metals - 6010 - ICP	10	10	1,000	2,000	e	e	e	e
Chromium (total)	7440-47-3	1.60E+06	3.50E+06	Metals - 6010 - ICP(TRACE)	10	NA	1,000	NA	e	e	e	e
Chromium VI	19540-29-9	8.00E+03	1.75E+04	Chromium (hex) - 7196 - colorimetric	10	4,000	500	200,000	e	e	e	e
Copper	7440-50-8	5.92E+04	1.30E+05	Metals - 6010 - ICP	25	25	2,500	2,500	e	e	e	e
Selenium	7782-49-2	5.00E+03	5.00E+03	Metals - 6010 - ICP	100	200	10,000	20,000	e	e	e	e
Selenium	7782-49-2	5.00E+03	5.00E+03	Metals - 6010 - ICP(TRACE)	10	NA	1,000	NA	e	e	e	e
Uranium (total)	7440-61-1	2.40E+05	1.05E+07	Uranium total - kinetic phosphorescence analysis	0.1	20	1,000	200	+,-20	70-130	+,-35	70-130

D:\epd\hgt\ssx_fir\coal\TbJA_4_2_cdr

Table A.4. Constituents and Methods for Slant Borehole Sediment Sample Analyses and Near-Surface Characterization Samples (4 Sheets)

Contaminants of Potential Concern	CAS #	Action Levels		Name/Analytical Technology ^a	Target Required Quantitation Limits				Precision Water (%)	Accuracy Water (%)	Precision Soil (%)	Accuracy Soil (%)
		Method B (ug/Kg)	Method C (ug/Kg)		Water ^b Low Level (ug/L)	Water ^b High Level (ug/L)	Soil Other Low Level (ug/Kg)	Soil Other High Level (ug/Kg)				
Ammonia-ammonium	7664-41-7	2.72E+07	5.95E+07	Ammonia - 350-N ^d	50	800,000	500	3,000,000	e	e	e	e
Phosphate	14265-44-2	N/A	N/A	Anions - 9056 -IC	500	15,000	5,000	40,000	e	e	e	e
Nitrate	14797-55-8	4.40E+06	4.40E+06	Anions - 9056 -IC	250	10,000	2,500	40,000	e	e	e	e
Nitrite	14797-65-0	3.30E+05	3.30E+05	Anions - 9056 -IC	250	15,000	2,500	20,000	e	e	e	e
Nitrate/nitrite as N	NO3*/NO2*-N	3.30E+05	3.30E+05	Nitrate/nitrite - 353-N ^d	75	NA	750	NA	e	e	e	e
Sulfate	14808-79-8	2.50E+07	2.50E+07	Anions - 9056 -IC	500	15,000	5,000	40,000	e	e	e	e
Chloride	16887-00-6	2.50E+07	2.50E+07	Anions - 9056 -IC	300	5,000	3,000	5,000	e	e	e	e
Fluoride	16984-48-8	9.60E+04	2.00E+05	Anions - 9056 -IC	500	5,000	5,000	5,000	e	e	e	e
Sulfides	18496-25-8	N/A	N/A	Sulfide - 9030 - colorimetric	500	NA	5,000	NA	e	e	e	e
Bromide	24959-67-9	N/A	N/A	Anions - 9056 -IC	250	NA	2,500	NA	e	e	e	e
pH		N/A	N/A	pH - 9045 - electrode	N/A	N/A	N/A	N/A	e	e	e	e
Total organic carbon/ total carbon	TOC/TC	N/A	N/A	ASTM D4129-S2 - total combustion/colorimetric	1 ppm	1 ppm	1 ppm	1 ppm	e	e	e	e
Cation exchange capacity	CEC	N/A	N/A	Cation exchange capacity/Methods of Soil Analysis Part 2, 9-3.1	N/A	N/A	N/A	N/A	f	f	f	f
Particle size distribution	N/A	N/A	N/A	Particle size distribution/ ASTM D 422-63, ASTM D 854-83	N/A	N/A	N/A	N/A	f	f	f	f
Mineralogy	N/A	N/A	N/A	XRD/SEM/TEM/JEA-3, Rev. 0	N/A	N/A	N/A	N/A	f	f	f	f
Electrical conductance	EC	N/A	N/A	Electrometric/ PNL-MA-567-FA-2	N/A	N/A	N/A	N/A	f	f	f	f
Moisture content	N/A	N/A	N/A	Moisture content/ PNL-MA-567-SA-7	N/A	N/A	N/A	N/A	f	f	f	f
Mebatic potential	N/A	N/A	N/A	Mebatic potential/ PNL-MA-567-SA-10	N/A	N/A	N/A	N/A	f	f	f	f
Distribution coefficient	K _d	N/A	N/A	Methods for determining radionuclide retardation factors, 1980/PNL-3349-USC-70	N/A	N/A	N/A	N/A	f	f	f	f
Bulk density	N/A	N/A	N/A	Bulk density/ PNL-MA-567-SA-3	N/A	N/A	N/A	N/A	f	f	f	f

Doc:\prod\lig\ss\sr\fit\ore\ITBIA_4_3.cnt

Table A.4. Constituents and Methods for Slant Borehole Sediment Sample Analyses and Near-Surface Characterization Samples (4 Sheets)

Contaminants of Potential Concern	CAS #	Action Levels		Name/Analytical Technology ^a	Target Required Quantitation Limits				Accuracy Water (%)	Precision Soil (%)	Accuracy Soil (%)
		Method B (ug/Kg)	Method C (ug/Kg)		Water ^b Low Level (ug/L)	Water ^b High Level (ug/L)	Soil Other Low Level (ug/Kg)	Soil Other High Level (ug/Kg)			
Moisture retention	9 ₁	N/A	N/A	Moisture retention/ ASTM D 2325-68	N/A	N/A	N/A	N/A	f	f	f
Saturated hydraulic conductivity	K _s	N/A	N/A	Saturated hydraulic conductivity/ASTM D 18.21 (draft in review)/Methods of Soil Analysis, Part 2, 13-3.2 and 13-3.3	N/A	N/A	N/A	N/A	f	f	f

Note: For the chemical and radiological constituents the preferred methods are those listed in *Test Methods for Evaluating Solid Waste, Physical/Chemical Methods* (EPA 1986) or *Standard Test Methods for Materials* (ASTM 1998).

^aWater values for sampling quality control (e.g. equipment blanks/runs) or drainable liquid (if recovered).

^bAll four digit numbers refer to *Test Methods for Evaluating Solid Waste* (EPA 1986).

^cValues from *Hanford Guidance for Radiological Cleanup* (WDOH 1997). Italicized values are calculated using the same parameters as the WDOH guidance.

^d*Methods for Chemical Analysis of Water and Wastes* (EPA 1983).

^ePrecision and accuracy requirements as identified and defined in the referenced U.S. Environmental Protection Agency procedures.

^fPrecision and accuracy for these measurements are not required because of the nature of the measurement.

AEA = alpha energy analysis.

N/A = not applicable.

ASTM = American Society for Testing and Materials.

NA = not available.

C/I = commercial industrial.

PCB = polychlorinated biphenyl.

CAS = chemical abstracts service.

ppm = parts per million.

CVAA = cold vapour atomic absorption.

RR = rural residential.

GC = gas chromatography.

SEM = scanning electron microscopy.

ICP = inductively coupled plasma mass spectrometry.

TEM = transmission electron microscopy.

IC = ion chromatography.

TOC/TC = total organic carbon/total carbon.

ICP = inductively coupled plasma mass spectrometry.

WDOH = Washington Department of Health.

ICPMS = inductively coupled plasma mass spectrometry.

XED = x-ray diffraction.

Doepfod\cigs-sx\file\coral\Tb1A_4_.cbr

Appropriate permits and compliance with the Notice of Construction permit (DOE-RL 1999a) were maintained during the drilling operations for inside the tank farm. The selected drilling method complies with the requirements of the Washington State Department of Health for the Notice of Construction permit and other pertinent requirements and appropriate engineering systems to prevent the possible contaminated air from being released to the environment.

Drilling was conducted using specifications and guidance in accordance with WAC 173-160. The technique for collecting sediment samples was a removable tip in conjunction with a split-spoon sampler that allowed driven samples to be collected ahead of the casing. The removable tip concept may have lead to contamination problems on the inside of the borehole casing and required the tip to be replaced with a new one each time it was removed and limited the ability to geophysical log the borehole. The split-spoon sampler that used was approximately 5 cm (2 in.) in diameter by 0.6 m (2 ft) long with a 10 cm (4 in.) diameter shielded lead casing around the sampler. The hole was 10 cm (4 in.) in diameter after the sample was collected, but only a 5 cm (2 in.) sample was collected and brought to the surface. The 0.6 m (2 ft) sample allowed for the depth of penetration to be beyond potential disturbed sediments below the end of the hole and brought sediments unable to be handled to the surface. This approach was demonstrated outside the tank farms prior to implementation inside the tank farms. This method collected enough sediment sample to be analyzed and provided the least amount of disturbance, therefore providing a sample that was as close as possible to being a representative sample.

There are backup approaches that could have been taken to collect sediment samples during casing extraction if collecting a split-spoon sample was found to be impractical. These options include using a sidewall sampling tool and scraping or under-reaming the hole and collecting the material with a split-spoon sampler. These backup approaches were not needed.

Contaminant dragdown during drilling and sampling activities is unavoidable and has been observed in recent sampling activities. Different drilling/sampling techniques impact dragdown to varying degrees. Because the objective of the characterization activities identified in the DQO is to safely sample in and below the 'hot' zone in a region of known leakage and not to tag the leading edge of a contaminant plume, the dragdown issue was a secondary concern.

The depth of the vadose zone boring was to the maximum depth of contamination.

Sediment Sampling Activities

For the SX-108 slant borehole, sediment sampling was conducted beginning at 16.7 m (55 ft) bgs and continued at discreet intervals of approximately 1.5 m (5 ft) until maximum depth of contamination or the Plio-Pleistocene unit was reached. Figures A.7 and A.8 show the slant borehole location and sampling strategy.

After the sediment samples were screened, these samples were transported to the PNNL Applied Geology and Geochemistry group for analysis. All material removed from the borehole was sent to the laboratory for possible future analysis. Samples were contained in airtight sample containers after their initial screening by the health physics technician and kept under refrigeration. This process is used to retain sediment moisture in as close to field condition as possible. All samples were transported to the laboratory under refrigeration to further limit alteration of sediment moisture.

Figure A.7. Tank SX-108 Slant Borehole

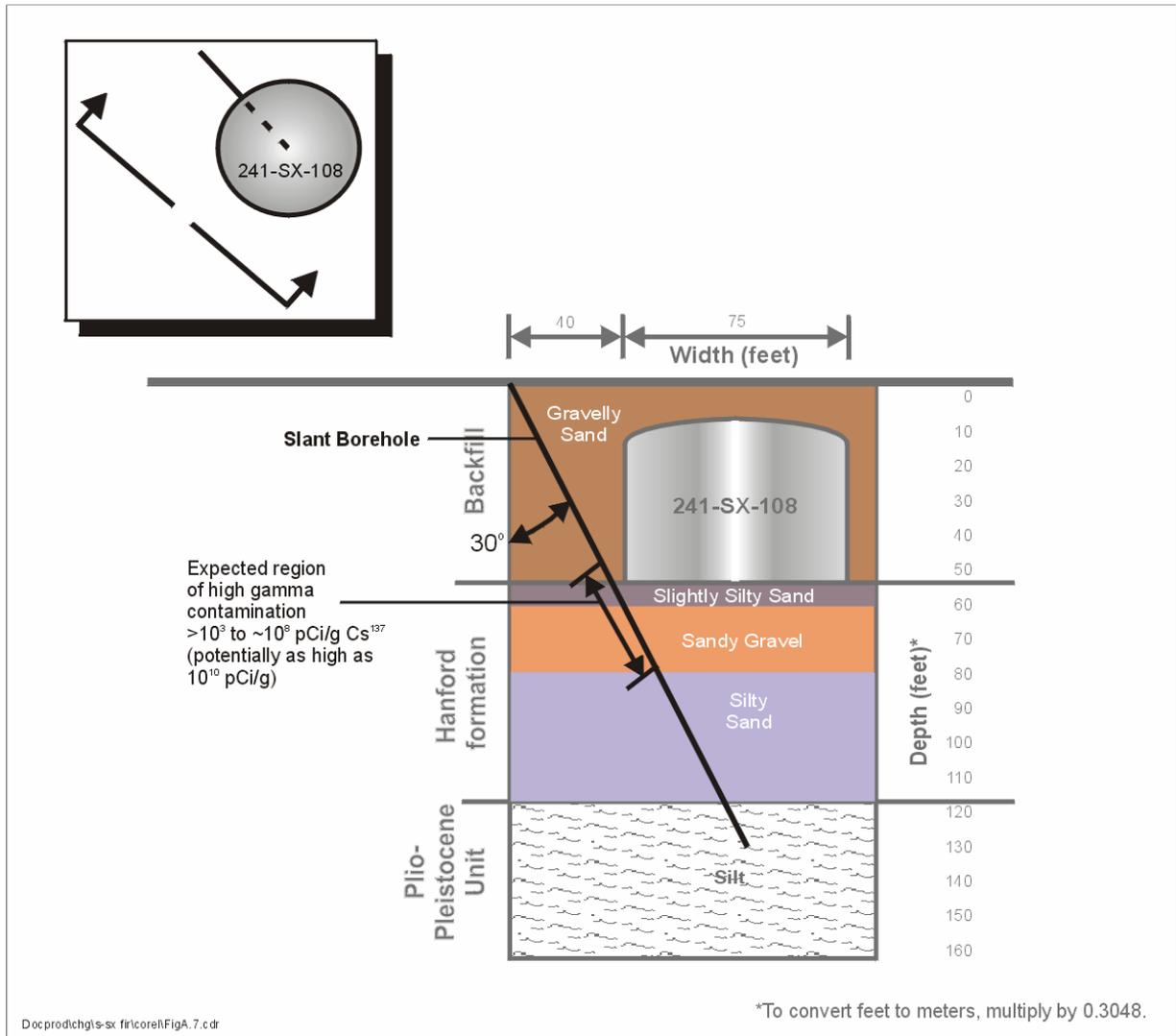
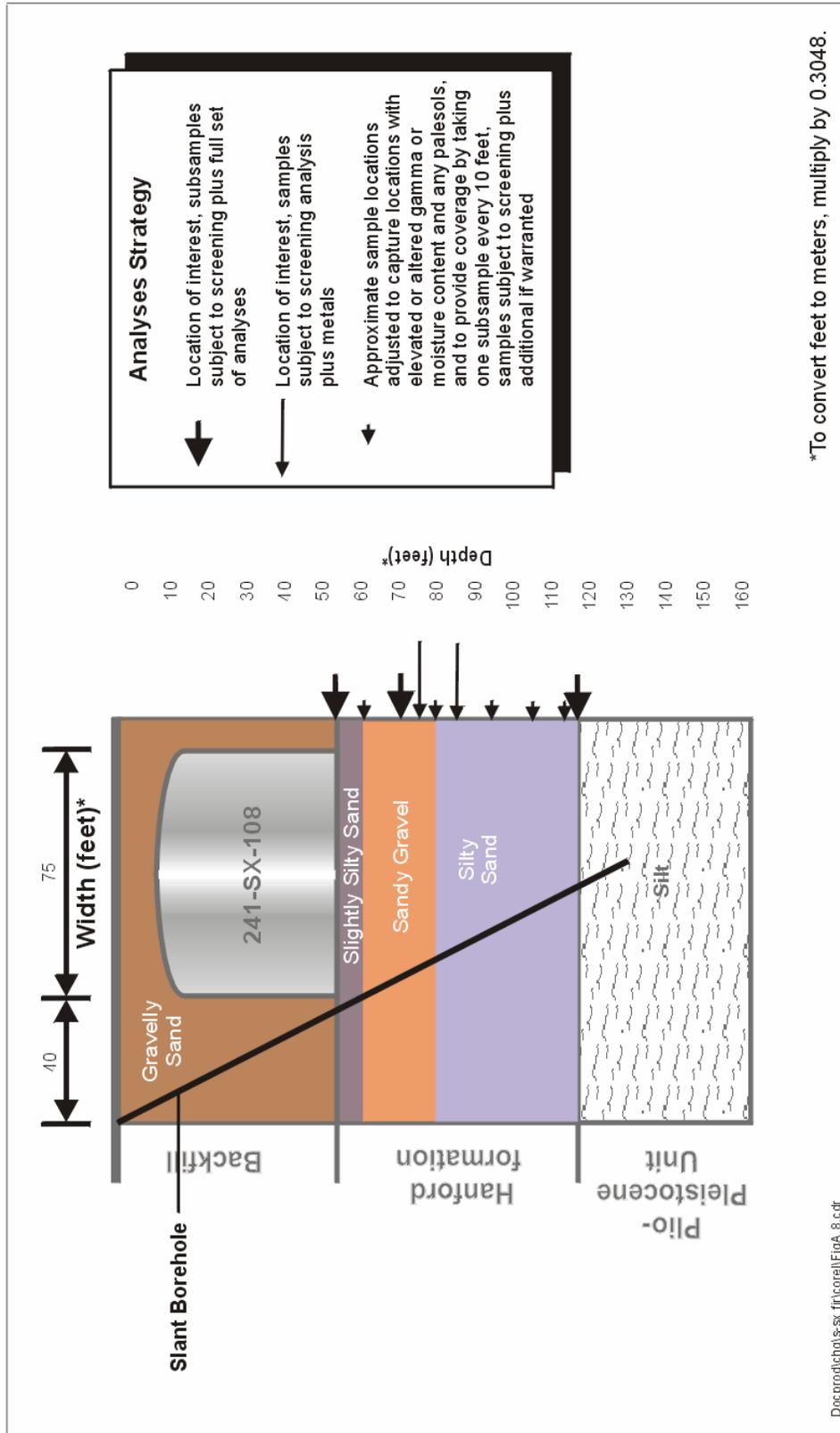


Figure A.8. Tank SX-108 Slant Borehole Subsample Analyses Strategy



Waste containing unknown, low-level mixed radioactive waste and/or hazardous waste contained, stored, and disposed of according with Appendix D of *Phase I RCRA Facility Investigation/Corrective Measures Study Work Plan for Single-Shell Tank Waste Management Areas* (DOE-RL 1999b) and specified in the quality assurance project plan (Appendix A of DOE-RL 1999b) and is documented in the field activity reports. Waste was disposed of in accordance with Appendix D of DOE-RL (1999b) and the waste acceptance criteria for the Mixed Waste Burial Grounds. All important information was recorded on field activity report forms per approved procedures. A field activity report form includes borehole number, site location drawings, drawing of the downhole tool strings, site personnel, sampling types and intervals, zones noted by the health physics technician as elevated in radiological contaminants, instrument readings and the depth represented by those readings, and specific information concerning borehole completion.

The SX-108 slant borehole was abandoned following completion of the geophysical surveying. All steel casing was removed and transferred to an appropriate disposal facility or controlled decontamination facility. The borehole was pressure-grouted from the bottom up, using a Portland cement/bentonite slurry or other appropriate material in accordance with WAC 173-160. Specific procedures for borehole abandonment were documented in the field work package. These procedures comply with U.S. Environmental Protection Agency requirements and WAC 173-160.

A.5.3 BOREHOLE GEOPHYSICAL SURVEYING

Based on sampling and construction methods, downhole spectral gamma or gross gamma geophysical logging was conducted to ascertain the gamma-emitting radionuclide concentrations. The spectral gamma or gross gamma logging frequency was directed by CHG.

A full suite of geophysical logs was run any time the casing size was changed and at the completion of the borehole. Because the sampling method involves pulling split-spoon samples up through the borehole, there was a high probability that the inner bore of the casing would become contaminated. Following completion of the sampling, the contamination levels were evaluated and a determination was made on the utility of geophysically logging the borehole.

The following logging techniques may have been used for the slant borehole:

- Gross gamma logging to support correlation of confining layers and stratigraphy
- Spectral gamma logging for measuring the distribution of selected radionuclides
- Neutron log for measuring the relative moisture content
- Neutron-enhanced spectral gamma logging for correlation of high-salt tank waste and moisture content with spectral gamma and neutron probes, respectively.

The existing equipment and procedures for gross gamma and spectral gamma logging in use at the Hanford Site provide acceptable data (DOE-GJO 1995).

A.5.4 GROUNDWATER SAMPLING AND ANALYSIS

No sampling of groundwater was conducted for the SX-108 slant borehole characterization effort.

A.5.5 LABORATORY ANALYSES OF SX-108 SLANT BOREHOLE

Sediment Sample Analysis

Geologic logging for the SX-108 slant borehole was conducted as it was for the borehole 41-09-39 extension. Specifically, once sample material from the slant borehole was received at the laboratory, it was geologically logged by an assigned geologist in general conformance with standard procedures. The assigned geologist photographed the samples and described the geologic structure, texture, and lithology of the recovered samples. Special attention was paid to the presence of contaminant alteration. If such a phenomenon were noted, that sample was noted; preserved for more detailed physical, chemical, and mineralogic analyses; and recorded in the laboratory notebook.

Sediment samples for laboratory analysis were defined by location in the sample after the field screening and geologic logging were completed, and indication of contamination locations were identified. Approximately 10 sediment samples from the borehole were chosen for screening analysis. Screening analyses consisted of the following:

- Nitrate
- Electrical conductivity
- Total organic carbon/total carbon
- pH.

The following criteria were used to identify samples for laboratory analysis based on concurrence with Ecology.

- One subsample was taken at approximately 17 m (55 ft) bgs, at or near the base of the tank.
- Subsamples were taken at the major lithology changes in the Hanford formation.
- One subsample was taken at the Plio-Pleistocene unit and Hanford formation contact.
- Subsamples were taken in locations where elevated or altered gamma surveying was measured during the geological and geophysical borehole logging process based on nearby geophysical drywell logging.
- At least one subsample was taken every 3 m (10 ft) if samples were not already taken, based on the above criteria to ensure continuous distribution and lithologic completeness.

Worker safety considerations have limited the collection of samples at certain intervals.

Figure A.8 shows the subsamples identified for laboratory analyses. A 1:1 water extract of all subsamples underwent screening analyses, which consist of nitrate analysis by the colorimetric

method, pH measurement, and electrical conductance measurement. In addition each subsample was directly measured for gamma emitters by gamma energy analysis. These analyses, along with the gamma surveying and moisture content measurements performed during the field geophysical surveys and the geologic logging, were used to determine the extent of further subsample analysis. Table A.4 identifies the full complement of analyses and their respective laboratory preparation and analytical methods. This paragraph and the remainder of this section identify which analysis was conducted on which sample. If more than one preparation or analytical method is listed, the laboratory geochemistry staff determined which methods would produce the best results and provide the best understanding of the chemistry involved. For those methods that produce multiple constituents (i.e., inductively coupled plasma), all constituents identified were reported. Every effort was made to meet regulatory holding times where appropriate.

Because the purpose of the slant borehole analysis was to gain an understanding of the nature and extent of contamination, the fate and transport of the contaminants in the vadose zone, and to produce RCRA-compliant data, the analysis of these subsamples consisted of two levels. The baseline level involved analysis of inorganic and radiochemical constituents in full conformance with DOE-RL (1998) and with no modifications to methods (as defined in DOE-RL 1998) without concurrence from the CHG technical representative and from Ecology. Substitutions and deviations to methods as defined by DOE-RL (1998) did not require concurrence from Ecology. The second level involved a research-type approach to the analyses. In this level, procedures may have been modified or developed to gain a more comprehensive understanding of the dynamics involved. Although specific quality control criteria do not apply to this level, compliance with an approved quality assurance plan provided by the primary laboratory was performed and research analysis was initiated following notification and approval of the activities by the CHG technical representative.

The backfill – Hanford formation contact sample, peak gamma concentration sample, and the sample obtained at the Hanford formation and Plio-Pleistocene unit contact were analyzed for the constituents and properties identified in Table A.4. It was recognized that conditions could occur when all of the analyses identified in Table A.4 were not warranted (e.g., limited potential for data). These occurrences were evaluated on a case-by-case basis.

One sample from at or near the base of the tank was analyzed for volatile organics identified in Table A.5.

**Table A.5. Constituents and Methods for Organic Analysis
of Borehole Sediment Samples**

Analysis/Constituent	Preparation Method	Preparation Procedure Number	Analytical Method	Analytical Procedure Number
VOA	Bulk Sediment	a	GC/MS	SW846-8260
SVOAs with TICs	Bulk Sediment	a	GC/MS	SW846-8270
PCBs ^b	Bulk Sediment	a	GC	GW846-8082

^a Preparation/extraction procedures for VOA and SVOA analysis will depend on the types of organic compounds present in the sediment.

^b Analyzed on selected samples collected from the near-surface characterization effort.

GC = gas chromatography.

MS = mass spectrometry.

PCB = polychlorinated biphenyl.

SVOA = semi-volatile organic analysis.

TIC = tentatively identified compounds.

VOA = volatile organic analysis.

The remaining samples were analyzed for specific constituents listed in Table A.4 depending on the results of the nitrate, electrical conductivity, total organic carbon/total carbon, and pH screening analyses. A review of the screening analyses results with technical representatives and Ecology was conducted prior to performing additional analyses. Screening analysis may have been used to determine whether alternative analytical techniques with lower detection limits were to be used for specific radionuclides of concern. The screening criteria and associated analytical requirements were identified as follows:

- Gamma-emitting radioisotopes by gamma energy analysis
- Metals and radioisotopes by inductively coupled plasma-mass spectrometry
- Tritium and strontium-90 by the liquid scintillation method
- Particle size distribution
- Carbon 14.

A minimum of two samples collected within the Hanford formation were analyzed for metals as identified in Table A.4.

The data obtained from the above analyses were used to evaluate the location of contamination plumes in the sediment column. The results of the above analyses were also used to determine if additional analyses are warranted. Additional analyses were performed based on the judgement and expertise of the responsible PNNL geochemist, with concurrence from the CHG technical representative and Ecology. The following analyses were performed as additional analyses:

- Cation exchange capacity
- Mineralogy
- Matric potential
- Distribution coefficient
- Bulk density

- Moisture retention
- Saturated hydraulic conductivity.

Tables A.4 and A.5 identify the analyses and laboratory methods used for the sample analyses. For the chemical and radiological constituents, the preferred methods are those listed in EPA (1986) or American Society for Testing and Materials standards (ASTM 1998). The requested constituents may have been analyzed by laboratory-specific procedures, provided that the procedures were validated and conform to DOE-RL (1998). Both the EPA (1986) methods and the PNNL methods listed in Tables A.4 and A.5 are based on techniques from “Methods of Soil Analysis” (ASTM 1998). Therefore, these procedures should be comparable. The detection limit, precision, and accuracy guidelines for the parameters of interest are listed in the DQO workbook for WMA S-SX (Ovink 1999).

A.6.0 NEAR-SURFACE CHARACTERIZATION

The following sections describe the near-surface characterization conducted in the S tank farm. These activities involved deployment of a truck-mounted, direct-push vehicle to collect the data.

A.6.1 LOCATION

Two areas have been identified as regions of interest for the Phase 1 characterization of the shallow vadose zone soil. These areas are within the north end of the S tank farm. The S tank farm areas of interest include:

- Unplanned release near diversion box 241-S-B
- East of tank S-104 near the fence (in the drainage path of the unplanned release that occurred in the SY tank farm and flowed into the S tank farm).

A.6.2 INVESTIGATIVE AND SAMPLING METHODS AND INTERVALS

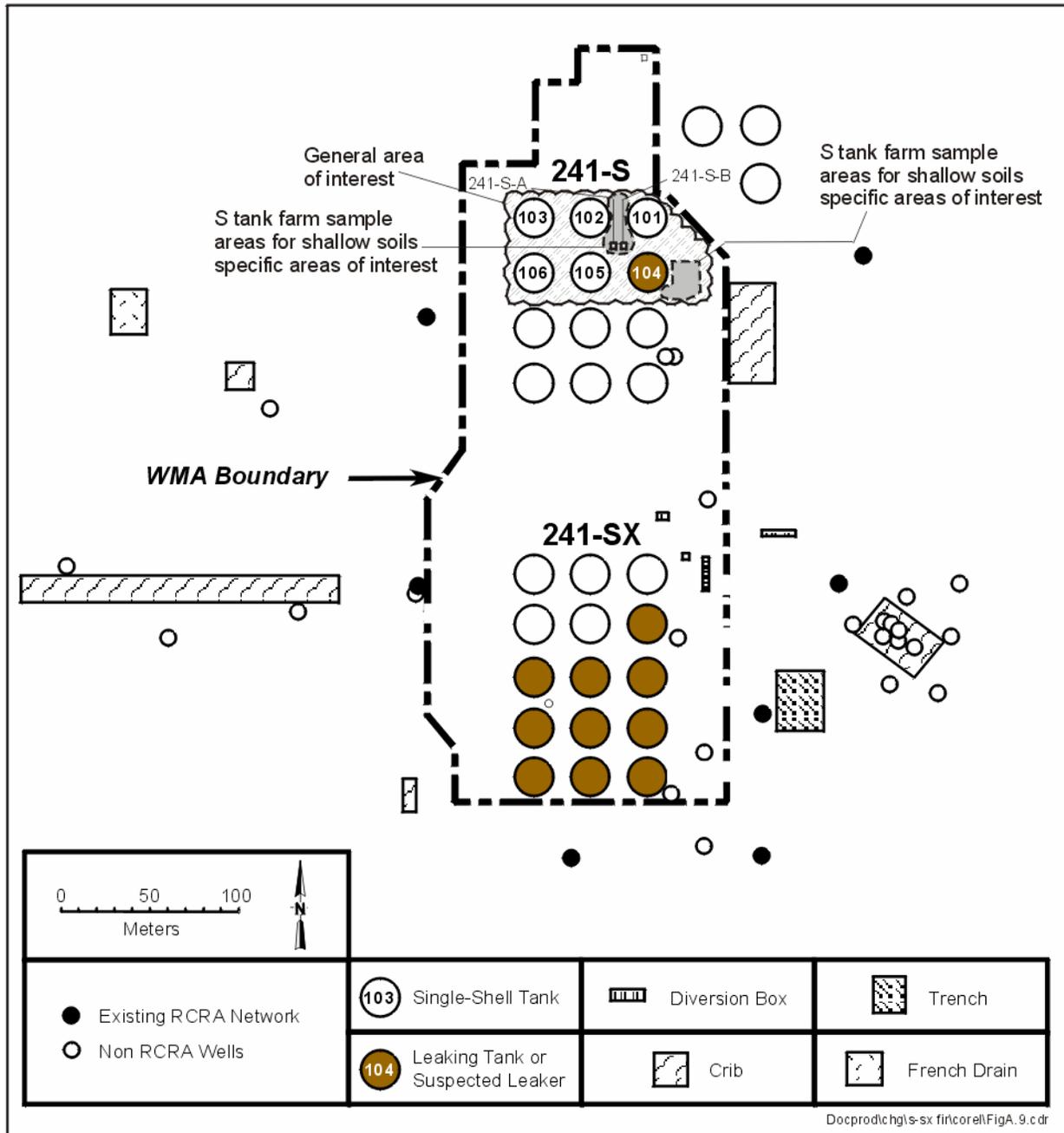
For the purpose of the DQO, the shallow investigation of 2 areas comprised collecting samples between the tank farm surface and approximately 16.7 m (55 ft) bgs using direct-push technology at 9 locations within either or both of these 2 areas (Figure A.9).

Shallow soil characterization was carried out using a truck-mounted cone penetrometer-based system. Specific sites cleared for access (underground piping and electrical services identified) and with an approved excavation permit were interrogated with a gross gamma/spectral gamma cone penetrometer probe. The depth of investigation was determined by the depth to which the probe could be advanced using a standard deployment truck. The probe was deployed using the gross gamma mode with the tool advanced at approximately 2 cm/sec (0.8 in./sec). If in the upper 5 m (15 ft) the downhole instrument indicated a potential cesium-137 concentration of 3.7 pCi/g or greater, logging was shifted to the spectral mode to determine the presence and level of concentration of cesium-137; below 5 m (15 ft) the threshold limit for spectral gamma determinations was 20 pCi/g. In zones where cesium-137 is present at concentrations greater than 20 pCi/g, spectral gamma readings were taken at 0.5 m (1.5 ft) intervals. In all cases, gross gamma measurements were to be taken while the probe was advanced.

The graphical log developed using the gross and spectral gamma measurements was used to select intervals to be sampled. The sampling push was made in a location no more than 0.7 m (2 ft) from the site of the gamma push. A single point sampler will be used to collect the required samples. Sampling intervals were selected from those horizons with a cesium-137 concentration of 20 pCi/g or greater. In the event that horizons were penetrated that would yield samples having a greater than 50 mrem/h dose rate at 30 cm (12 in.) (based on calculations using sampler size and cesium-137 concentration), a sample was collected from the first interval below the high rate zone having a dose rate of less than 50 mrem/h.

Two separate areas were characterized: the vicinity of tank S-102 and the vicinity of tank S-104. These two sites exhibit separate instances of cesium-137 in vadose zone drywells that may be indicative of near-surface sources. In addition, the region to the east of tank S-104 has potentially been impacted by a tank overfill event in the 241-SY double-shell tank farm. A total of nine push sites were identified. An average of four samples per site were collected.

Figure A.9. Waste Management Area S-SX Shallow Soil Sampling Locations



A.6.2.1 Tank S-104 Site

The highest recorded levels of cesium-137 contamination associated with the tank S-104 site are in borehole 40-04-05 in the southeast quadrant of the tank. Contamination was estimated at about 10^6 pCi/g at a depth of about 14 m (48 ft) bgs. Up to five sets of gamma probe and sampling pushes were conducted to investigate this site. The pushes included the following.

- Adjacent to the 40-04-05 drywell, between the drywell and the tank. This location was to ascertain if there is a vertical gradient between the push location and the identified elevation of contamination in 40-04-05 and to collect a sample from below the contaminated zone to determine if mobile contaminants are moving ahead of the cesium-137 hot spot.
- Adjacent to tank S-104 at the 5 o'clock position. This location was as close to the tank as the push-truck could be positioned within dome-load restrictions. The S tank farm tanks are constructed with a spare inlet port at this point. Experience in other farms has shown that these spare inlet ports are subject to failure if a tank is overfilled. This push tested the hypothesis that the contamination adjacent to the tank is due to an overfill event.
- Adjacent to the normal fill line at the 3 o'clock position. This location was within 3 to 4.5 m (10 to 15 ft) of the tank and as close to the fill line as safety considerations allow. This location was used to determine the horizontal and vertical extent of the contamination found in the 40-04-05 borehole.
- Adjacent to the S tank farm fence. This location was used to determine the impact to shallow soils due to the surface release and subsequent ponding that occurred in the SY tank farm.
- Midway between the previous two pushes. This location was only to be interrogated if positive determinations of contamination were found in one of the two previous pushes.

A.6.2.2 Tank S-102 Site

The highest recorded levels of cesium-137 contamination associated with the 241-S-102 site are in borehole 40-02-03 in the northeast quadrant of the tank. Contamination was estimated at about 10^6 pCi/g at a depth of about 6 m (20 ft) bgs. Four sets of gamma probe and sampling pushes were conducted to investigate this site. The pushes included the following.

- Adjacent to tank S-102, northwest of drywell 40-02-03. Because no contamination is detected in drywell 40-02-01, this push was used to determine the extent of contamination in a northwesterly direction from borehole 40-02-03. The push was situated about midway between the boreholes and as near the tank as safety considerations allow.
- Along the line projected between 40-02-01 and 40-02-03, north of the cascade line between tanks S-101 and S-102. This location provided information on the extent of contamination known to exist at 40-02-03 and assess the depth of movement of that contamination.

- Along the line projected between 40-02-01 and 40-02-03, south of the cascade line between tanks S-101 and S-102, and near the 241-S-A diversion box. This location provided information as to the extent and general direction of movement of contaminants for this site. In addition, the accumulation pit associated with the 241-S-A was assessed as a possible contributor to the contamination.
- Adjacent to the 241-S-B diversion box. The potential for contamination in this region related to operation of the 241-S-B accumulation pit was assessed.

A.6.2.3 Additional Pushes

Additional pushes have been made based on the information developed during the initial campaign or decisions of the River Protection Project Vadose Zone Project management. These additional pushes were determined based on the determined extent of contamination and (1) the availability of both the push truck and crew and (2) availability of budget and support personnel.

Any samples were transported to the laboratory and analyzed for the contaminants of concern identified in Table A.4. A detailed field work plan was prepared to identify the number and location of samples to be collected.

A.6.3 GEOPHYSICAL SURVEYING ACTIVITIES

Prior to sediment sampling using the direct push, downhole gross gamma and spectral gamma geophysical surveying was conducted to ascertain the gamma-emitting radionuclide concentration in the surrounding sediments. After each push with the direct-push or each borehole with the hollow-stem auger, decommissioning occurred.

A.6.4 LABORATORY ANALYSES

Laboratory analyses included radiological and chemical analyses of selected sediment samples. Physical and hydrologic analyses of selected sediment samples was performed.

Once received at the laboratory, these samples underwent analysis using the analytical methods listed in Table A.4. These analyses are sample-limited. Therefore, hold points were inserted into the process to allow the laboratory and CHG technical staff to collaborate and review data before each new round of analyses. Analyses were reprioritized based on the results of other measurements. See Appendix B for discussion of the analyses conducted.

Based on the results of the screening analyses identified in the SX-108 slant borehole, spectral gamma surveys performed during the field geophysical surveys, and the geologic logging and field notes, geological technical experts, CHG technical staff, the laboratory technical staff, and decision makers (Ecology and the U.S. Department of Energy) convened to determine what, if any, additional analyses were to be conducted. Some of the determining criteria were the amount and integrity of the remaining sample, screening analytical results, and regulatory requirements. Based on these decisions, additional analyses were performed.

A.7.0 REFERENCES

- ASTM, 1998, *Standard Test Methods for Materials*, American Society for Testing and Materials, West Conshohochen, Pennsylvania.
- DOE-GJO, 1995, *Vadose Zone Characterization at the Hanford Tank Farms, High-Resolution Passive Spectral Gamma-Ray Logging Procedures*, P-GJPO-1783, Rev. 1, U.S. Department of Energy, Grand Junction Projects Office, Grand Junction, Colorado.
- DOE-RL, 1998, *Hanford Analytical Services Quality Assurance Requirements Document*, DOE/RL-96-68, Rev. 2, U.S. Department of Energy, Richland Operations Office, Richland, Washington.
- DOE-RL, 1999a, *Notice of Construction for Tank Waste Remediation System Vadose Zone Characterization*, DOE/RL-99-34, Rev. 0, U.S. Department of Energy, Richland Operations Office, Richland, Washington.
- DOE-RL, 1999b, *Phase 1 RCRA Facility Investigation/Corrective Measures Study Work Plan for Single-Shell Tank Waste Management Areas*, DOE/RL-99-36, U.S. Department of Energy, Richland Operations Office, Richland, Washington.
- Driscoll, F. G., 1986, "Well Drilling Methods," *Groundwater and Wells 2nd Edition*, pp. 301-307, Johnson Division, St. Paul, Minnesota.
- EPA, 1983, *Methods for Chemical Analysis of Water and Wastes*, EPA 600/4-79/020, U.S. Environmental Protection Agency, Washington D.C.
- EPA, 1986, *Test Methods for Evaluating Solid Waste, Physical/Chemical Methods*, EPA SW-846, Office of Solid Waste, U.S. Environmental Protection Agency, Washington, D.C.
- Henderson, C. H., 1999, *Preliminary Site-Specific SST Phase 1 RFI/CMS Work Plan Addendum for WMA S-SX*, HNF-4380, Rev. 1B, Fluor Daniel Hanford, Inc., Richland, Washington.
- Johnson, V. G., and C. J. Chou, 1999, *RCRA Assessment Plan for Single-Shell Tank Waste Management Area S-SX at the Hanford Site*, PNNL-12114, Pacific Northwest National Laboratory, Richland, Washington.
- Ovink, R. W., 1999, *Data Quality Objectives Report for Waste Management Area S-SX*, HNF-5272, Rev. 0, Fluor Daniel Hanford, Inc., Richland, Washington.
- Raymond, J. E., and E. G. Shdo, 1966, *Characterization of Subsurface Contamination in the SX Tank Farm*, BNWL-CC-701, Battelle Northwest Laboratory, Richland, Washington.
- Resource Conservation and Recovery Act of 1976*, Public Law 94-580, 90 Stat. 2795, 42 USC 6901 et seq.

Rogers, P. M., and A. J. Knepp, 2000, *Site-Specific SST Phase I RFI/CMS Work Plan Addendum for WMA S-SX*, HNF-5085, Rev. 1, CH2M HILL Hanford Group, Inc., Richland, Washington.

Stewart, D. L., 1997, "Change Authorization #1: Work Order BE2822 and Sampling Plan for Borehole 41-09-39, Tank SX-109" (Letter to A. T. Broady, Fluor Daniel Hanford, Inc., December 23), Pacific Northwest National Laboratory, Richland, Washington.

WAC 173-160, "Minimum Standards for the Construction and Maintenance of Wells," *Washington Administrative Code*, as amended.

WAC 173-303, "Dangerous Waste Regulations," *Washington Administrative Code*, as amended.

WDOH, 1997, *Hanford Guidance for Radiological Cleanup*, WDOH/320-015, Rev. 1, Environmental Radiation Program, Washington Department of Health, Olympia, Washington.