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Limited Field Investigation Report for the 100-KR-1 Operable Unit

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EXECUTIVE SUMMARY

This report summarizes the data collection and analysis activities conducted during the 100-KR-1 source operable unit limited field investigation (LFI) and the associated qualitative risk assessment (QRA) and provides recommendations on the continued candidacy of high-priority sites for interim remedial measures (IRM). An IRM is intended to achieve remedies that are likely to lead to a final Record of Decision, and is not restricted to limited or short-term actions.

The data collection and analysis activities were conducted in accordance with the 100-KR-1 operable unit workplan (DOE-RL 1992a). The qualitative risk assessment was performed in accordance with the Hanford Site Baseline Risk Assessment Methodology (DOE-RL 1993a), and the recommendations incorporate the strategies of the Hanford Past-Practice Strategy (HPPS; Thompson 1991). The purpose is to provide a summary of site characterization activities, refine the conceptual exposure pathway model (as needed), identify chemical- and location-specific applicable or relevant and appropriate requirements (ARAR), provide a qualitative assessment of risks associated with the sites, and identify those sites that are candidates for an IRM.

The 100-KR-1 source operable unit encompasses an area of approximately 0.6 mi^2 and is located immediately adjacent to the Columbia River. In general, it contains facilities associated with disposal of cooling water effluent from the two reactors in the 100-K Area. All known and suspected areas of contamination were classified as high- or low-priority based on the collective knowledge of the operable unit managers (representatives from the U.S. Department of Energy, the U.S. Environmental Protection Agency, and the Washington Department of Ecology) during preparation of the 100-KR-1 workplan. High-priority sites were judged to pose sufficient risk(s) through one or more pathways to require evaluation for an IRM. Low-priority sites do not pose sufficient risk to require streamlined evaluation. In the 100-KR-1 operable unit, six facilities were identified as high-priority waste sites: the 116-K-1 crib, the 116-K-2 trench, the 116-K-3 outfall structure, the 116-KW-3 retention basin, the 116-KE-4 retention basin, and the process effluent pipelines. There are no low-priority sites in the 100-KR-1 operable unit.

Based on the workplan, four of the six sites were investigated during the LFI: the 100-K-1 crib, the 116-K-2 trench, the 116-KW-3 retention basin, and the 116-KE-4 retention basin. These sites were investigated using boreholes, testpits, field screening, geophysical surveys, and samples were submitted for laboratory analysis. All analytical data were validated.

Analytical results, field screening, and geophysical surveys all show that radiological contamination of vadose zone soils is the primary concern. The principal radionuclides found during the LFI include americium-241, cesium-137, cobalt-60, europium-152, europium-154, europium-155, plutonium-239/240, and strontium-90. In general, maximum concentrations of radionuclides were found in soil samples collected from the 116-K-2 trench. The contamination of soil in the 100-KR-1 operable unit by radionuclides is a result of disposal of reactor cooling water effluent to soil disposal sites (cribs and trenches) or leakage from basins and pipelines. Metal contamination (concentrations that exceed Hanford Site background concentrations) was found at the 116-K-2 trench, near the 116-KW retention basin, and near the 116-KE-4 retention basin. Metal contaminants included chromium, cobalt, copper, mercury, and zinc. None of the metal concentrations exceeded potential soil cleanup ARARs (Washington State Model Toxics Control Act [MTCA] Method B criteria). Semi-volatile organic compounds (benzo(a)anthracene, benzo(b)fluoranthene, and chrysene) were detected in surface soil samples from a testpit near the 116-KW-3 retention basin at concentrations that exceeded the MTCA Method B cleanup criteria.

No source for contamination of soil by semi-volatile organic compounds has been determined. Volatile organic compounds were detected in a number of samples, but at very low concentrations and are likely to be laboratory artifacts.

The remaining two high-priority sites (the 116-K-3 outfall structure and the process effluent pipelines) not investigated during the LFI were evaluated for continued IRM candidacy using information available from analogous facilities or historical data.

A QRA was performed for the high-priority sites. Conservative assumptions, such as highest reported contaminant levels from either the LFI or historical data base were used. The QRA provides estimates of risk to human and ecological health. Human health risks were estimated assuming either low- or high-frequency use and includes considerations such as the attenuation of external dose provided by layers of clean fill that overlie some of the sites. Ecological hazards were evaluated by considering external dose and the uptake and accumulation of contaminants in the food web. The QRA identified the major human health risk to be exposure to radionuclides. The major ecological health risk was found to be exposure to radionuclides and to metals.

The 100-KR-1 high-priority sites were recommended for continued candidacy for an IRM using the following criteria:

- If human and ecological risk estimates provided by the QRA for a low-frequency use exposure scenario showed a lifetime incremental cancer risk greater than 1E-04 or an environmental hazard quotient greater than 1
- If contaminants at a waste site exceed a chemical-specific ARAR
- If LFI results show that a site is a current source of groundwater contamination
- If the conceptual exposure assessment model of the site is found to be incomplete and additional data collection through limited field sampling is recommended
- The potential for natural attenuation of contaminants (e.g., radionuclide decay by the year 2018) may be a consideration for sites where risk is caused by external exposure to radionuclides with half-lives of 30 years or less.

Based on the criteria above, the 116-K-1 crib, 116-K-2 trench, the 116-KW-3 retention basin, the 116-KE-4 retention basin and the 116-K-3 outfall structure are recommended to remain candidates for an IRM. These sites show contamination that pose a risk to human or environmental health. In addition, the 116-K-2 trench poses a potential risk to groundwater due to chromium. The use of IRMs is warranted to minimize potential contaminant migration from these sites.

The recommendation for the process effluent pipelines is to defer them to final remedy selection. Historical data shows the process effluent pipelines are contaminated with radionuclides at concentrations that are a potential threat to human and environmental health. However, the contamination consists of scale on the inside of the pipe. Consequently, the contamination is contained within the pipe and is physically isolated from the environment. Because contaminant migration into the environment is minimized, the pipelines pose little or no risk. Therefore, an IRM will do little to mitigate specific contamination and is not justified. Consequently, remediation of the pipelines should be deferred to final remedy selection process for the operable unit.

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LIST OF ACRONYMS

ALARA	as low as reasonably achievable
ARAR	applicable or relevant and appropriate requirements
ASTM	American Society for Testing and Materials
BARCT	best available radionuclide control technology
bls	below land surface
CERCLA	*Comprehensive Environmental Response, Compensation and Liability Act*
CFR	Code of Federal Regulations
CLP	Contract Laboratory Program
CRDL	contract required detection limit
CRQL	contract required quantitation limit
DOE	U.S. Department of Energy
DOE-RL	U.S. Department of Energy, Richland Operations Office
Ecology	Washington State Department of Ecology
EHQ	environmental hazard quotient
EII	Environmental Investigation Instruction
EPA	U.S. Environmental Protection Agency
ERA	Expedited Response Action
GM	Geiger-Muller probe
HPPS	Hanford Past-Practice Strategy
HSBRAM	Hanford Site Baseline Risk Assessment Methodology
IAEA	International Atomic Energy Agency
ICR	lifetime incremental cancer risk
IDL	instrument detection limit
IRM	interim remedial measure
LFI	limited field investigation
MCL	maximum contaminant level
MTCA	*Washington State Models Toxics Control Act*
NOEL	no observable effect level
NPL	National Priorities List
NRC	U.S. Nuclear Regulatory Commission
OVM	organic vapor monitor
PCB	polychlorinated biphenyl
QRA	qualitative risk assessment
RCRA	*Resource Conservation and Recovery Act*
RCW	Regulatory Code of Washington
RFI/CMS	RCRA Facility Investigation/Corrective Measures Study
RI/FS	remedial investigation/feasibility study
ROD	Record of Decision
SARA	*Superfund Amendments and Reauthorization Act*
TAL	target analyte list
TBC	to-be-considered
TCL	target compound list
UTL	upper tolerance limit
VOC	volatile organic compound
WAC	Washington Administrative Code
WHC	Westinghouse Hanford Company
WL	Working Level

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1.0 INTRODUCTION

The Hanford Site near Richland, Washington was used by the U.S. Government to produce plutonium for nuclear weapons. The U.S. Department of Energy (DOE) currently manages the site which contains six operational areas. The U.S. Environmental Protection Agency (EPA) placed four of these six areas (the 100, 200, 300, and 1100 Areas) on the National Priorities List (NPL) in November 1989, under the *Comprehensive Environmental Response, Compensation and Liability Act* (CERCLA) of 1980. The *Hanford Federal Facility Agreement and Consent Order* (Tri-Party Agreement, Ecology et al. 1992) subdivided the individual operational areas into source and groundwater operable units based on waste disposal information, location, facility type, and other site characteristics.

Source operable units include facilities and unplanned release sites that are potential sources of hazardous substance contamination. The 100-KR-1 operable unit is a source operable unit within the 100 Area. Data collection and analysis activities conducted at the 100-KR-1 source operable unit during the limited field investigation (LFI) and the qualitative risk assessment (QRA) are summarized in this report. The purpose of the report is to evaluate available information and provide sufficient rationale to select sites for implementation of interim remedial measures (IRM).

1.1 SITE BACKGROUND

The Hanford Site is located in south-central Washington State (see Figure 1-1). The 100-K Area, located in the north-central part of the Hanford Site, was the site of two reactors that were used to produce plutonium.

1.1.1 The 100-KR-1 Operable Unit

Reactor operations in the 100-K Area released chemical and radioactive wastes to the soil, air, and water. For cleanup purposes, the 100-K Area has been divided into four operable units (see Figure 1-2). Three of the units are source operable units: 100-KR-1, 100-KR-2, and 100-KR-3. The fourth, 100-KR-4, is a groundwater operable unit that includes all groundwater, saturated soils, surface water, and aquatic biota potentially affected by operations in the 100-K Area. Groundwater monitoring wells for the 100-K Area are shown in Figure 1-3.

The 100-KR-1 operable unit covers an area of approximately 0.6 mi^2. The operable unit is located adjacent to the Columbia River, within Sections 5 and 6 of Township 13 N, Range 26 E, and Sections 31 and 32 of Township 14 N, Range 26 E. Figure 1-2 shows the facility layout of the 100-KR-1 source operable unit. The facilities located within the 100-KR-1 operable unit are associated with reactor cooling water effluent. These facilities include the 116-K-1 crib, the 116-K-2 trench, the 116-KW-3 and 116-KE-4 retention basins, the 116-K-3 outfall structure, and the process effluent pipelines.

1.1.2 The 100-KR-1 Operable Unit Conceptual Site Model

The conceptual site model for the 100-KR-1 operable unit was developed during the preparation of the remedial investigation/feasibility study (RI/FS) work plan (DOE-RL 1992a). The conceptual model as presented in the work plan addressed the following:

- structure and process of the waste sites
- source of contaminants
- type of contaminants
- nature and potential routes of contaminant migration
- known and potential human and environmental receptors.

The conceptual model is summarized below. Additional details can be found in the 100-KR-1 work plan.

In summary, the work plan identified the liquid waste disposal facilities (116-K-1 crib, 116-K-2 trench, 116-KW-3 and 116-KE-4 retention basins, 116-K-3 outfall structure, and the process effluent pipelines) associated with the reactor coolant effluent as the primary contaminant sources in the 100-KR-1 operable unit. In the past the process effluent, which was contaminated with radionuclides and hazardous chemicals, was discharged directly to the Columbia River and soil-specific retention areas (trenches and cribs) for disposal, or to nonspecific soil areas via leaks and spills.

Preliminary evaluation in the work plan of contaminant sources, release mechanisms, environmental transport media, and likely environmental receptors suggests that the most probable primary sources of contaminant releases to the 100-KR-1 operable unit environment are the process effluent facilities. While process effluents were once discharged directly into the Columbia River, the current mechanism of contaminant release is through infiltration from previously contaminated soils near the facilities into the underlying groundwater. This groundwater eventually discharges into the Columbia River where it can contaminate the sediments and has the potential to impose adverse impacts upon local biota. Of particular concern are impacts to sensitive and economically important fauna (e.g., salmon eggs and fry). Because there are no nearby residences, the most likely potential for current human exposure to 100-KR-1 operable unit contaminants is to onsite workers.

This conceptual model has been updated with data acquired through the LFI, and is presented in Chapter 5 of this report.

1.2 THE HANFORD PAST-PRACTICE STRATEGY AND THE 100-KR-1 LFI

1.2.1 Hanford Past-Practice Strategy

The signatories of the Tri-Party Agreement [DOE, EPA, and the Washington Department of Ecology (Ecology)] developed a new strategy to manage and implement past-practice investigations. The Hanford Past-Practice Strategy (Thompson 1991) was developed to enhance the efficiency of ongoing CERCLA RI/FS and *Resource Conservation and Recovery Act* (RCRA) facility investigation/corrective measures study (RFI/CMS) activities in the 100 Area of the Hanford Site. The objective of the HPPS is to expedite the ultimate goal of cleanup, by initiating and completing waste site cleanup through interim cleanup actions.

The HPPS focuses on reaching early decisions to initiate and complete cleanup projects by maximizing the use of existing data that are consistent with the data quality objectives, together with short-time-frame investigations, where necessary. As more data becomes available on contamination problems and associated risk, the details for longer-term investigations and studies are better defined. The effective use of existing data along with better management of uncertainty should reduce the number of sampling episodes and expedite treatability studies, feasibility studies, and cleanup actions, including expedited response actions (ERA) and IRMs.

The near-term strategy for decision-making in the HPPS and mitigating contamination problems at specific waste sites provides for three different pathways.

- The ERA pathway is used for abatement if conditions exist or are suspected that create an unacceptable current or future health or environmental risk and necessitate a rapid response to mitigate the problem.

- The IRM pathway without an LFI is appropriate if existing data are judged sufficient to develop a conceptual site model and perform a qualitative risk assessment. If necessary, a focused feasibility study will be conducted to select the IRM remedy.

- The LFI pathway is used to identify and gather the minimum additional data needed to formulate a conceptual site model and perform a QRA that would support an IRM or other decisions. The LFI is limited in scope and generally is not intended to support a final record of decision. Regardless of scope, however, the LFI is part of the RI/FS (or RFI/CMS) process and not a substitute for it.

Figure 1-4 summarizes the HPPS RI/FS process described above.

Although interim actions (ERA and IRM) may be used to mitigate specific contamination problems, the process of final remedy selection must be completed for the operable unit and the 100 Area NPL site to reach closure. The information obtained from the LFIs and interim actions may be sufficient to perform a risk assessment and to select the remedy for the operable unit. If the data are not sufficient, additional investigations and studies will be performed to the extent necessary to support the operable unit remedy selection. These investigations would be performed within the framework and process defined for RI/FS programs.

1.2.2 Application of the Hanford Past-Practice Strategy to the 100-KR-1 Operable Unit

Implementation of the HPPS to the 100-KR-1 operable unit began with the development of the *Remedial Investigation/Feasibility Study Work Plan for the 100-KR-1 Operable Unit, Hanford Site, Richland Washington* (DOE-RL 1992a). Following agreement on the past-practice strategy, the three parties re-scoped the 100 Area work plans with a bias toward IRMs and with the initial focus of the LFIs placed on the highest priority waste sites within each operable unit. The collective knowledge and judgment of the three parties together with information contained in existing work plans were used to classify all known and suspected areas of contamination into either high-priority or low-priority waste sites and the paths to be followed to implement the HPPS. The decisions made during joint meetings among the three parties are documented by meeting minutes that are part of the administrative record.

The high-priority waste sites in the 100-KR-1 operable unit were identified as follows:

- 116-K-1 crib
- 116-K-2 effluent trench
- 116-K-3 outfall structure
- 116-KW-3 retention basins
- 116-KE-4 retention basins
- process effluent pipelines.

Limited field investigations leading to IRMs were proposed for the 116-K-1 crib, the 116-K-2 effluent trench, the 116-KW-3 retention basin, and the 116-KE-4 retention basin. The remaining high-priority waste facilities in the 100-KR-1 operable unit (the 116-K-3 outfall structure and the process effluent pipelines) were recommended for remediation (IRM) using information gained from analogous sites. The knowledge gained from the characterization/remediation of other 100 Area analogous facilities will be applied toward remediation of the 116-K-3 outfall structure and the process effluent pipelines. At these sites, further characterization will be performed concurrently with remediation, using the observational approach. Table 1-1 contains a list of all 100 Area wide analogous facilities that are defined as facilities used in a similar manner and as part of a similar waste stream.

No low-priority facilities are currently identified within the 100-KR-1 operable unit. If any low-priority facilities are located by the source data compilation, any field investigations will be deferred until the cumulative risk assessment for the entire 100 Area.

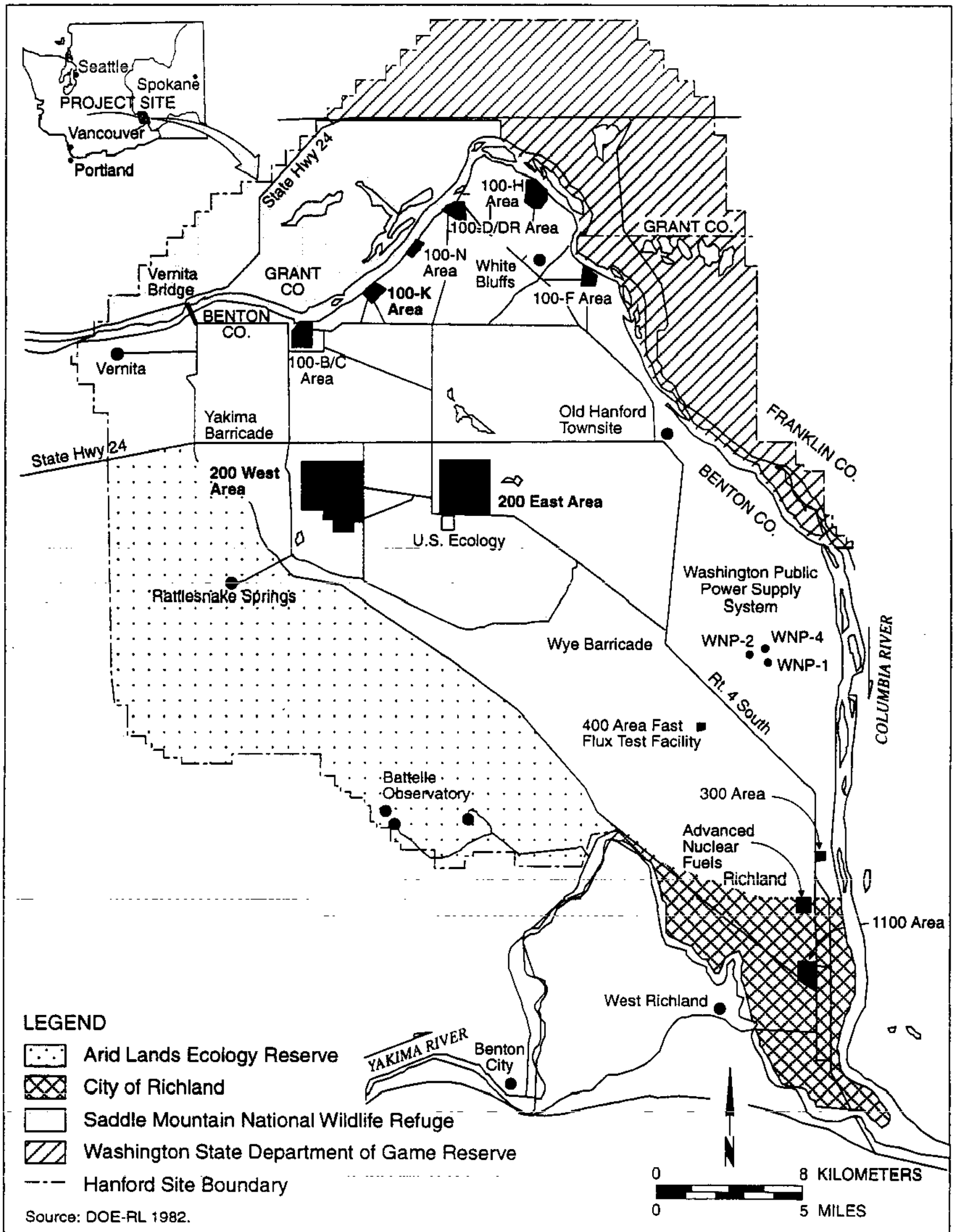

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Figure 1-1. Hanford Site.

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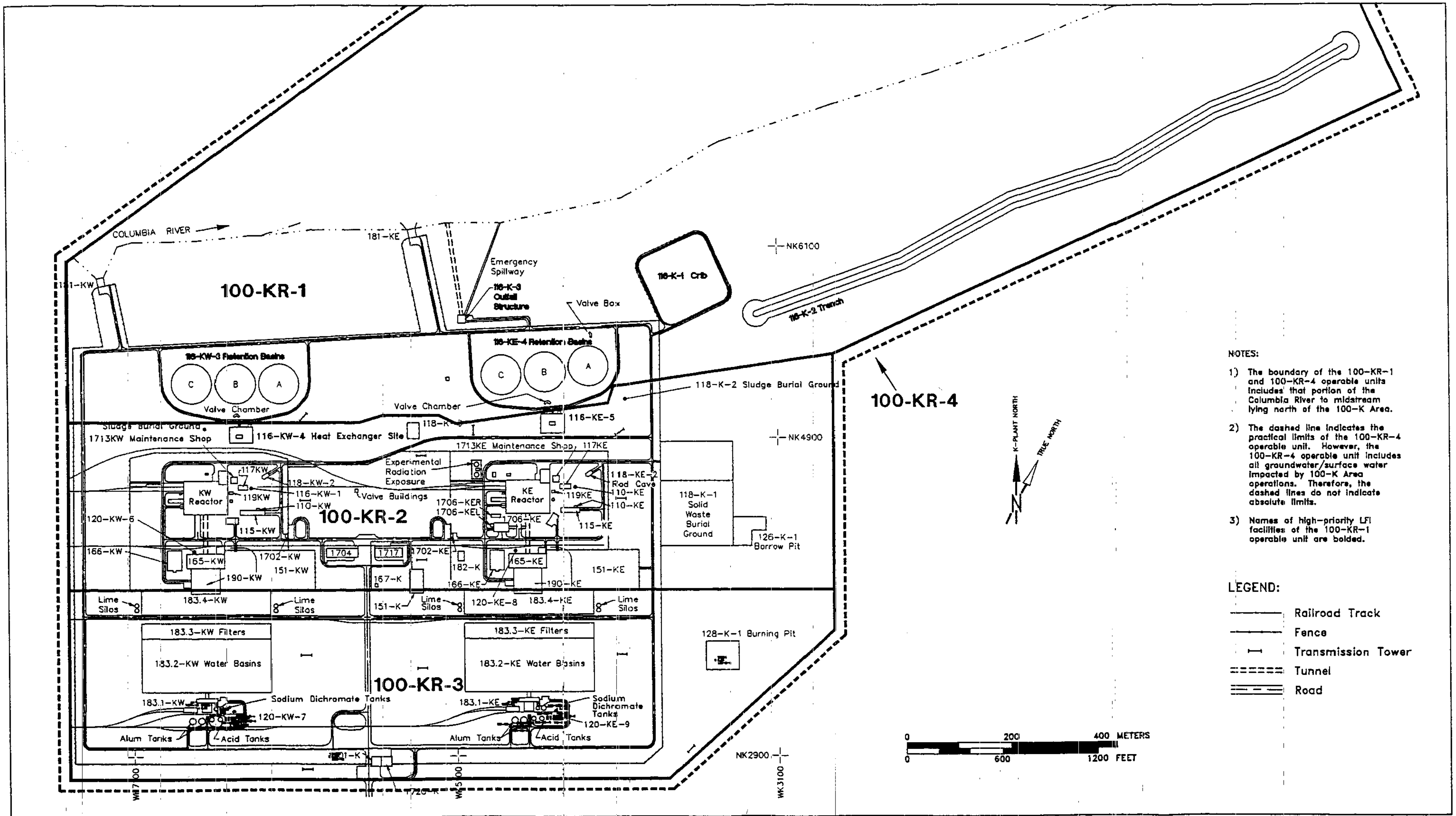

Figure 1-2. The 100-K Area Operable Units.

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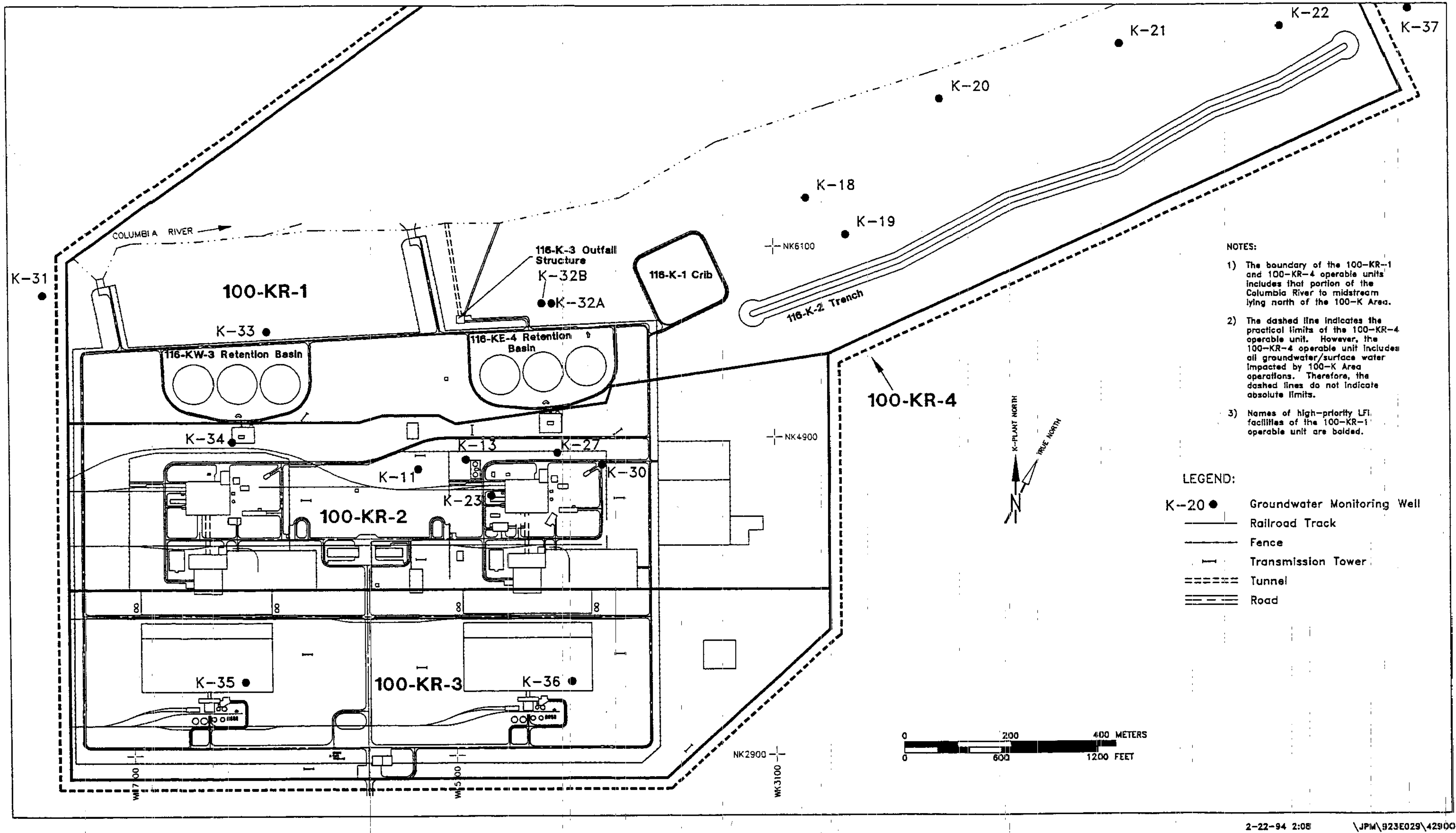

Figure 1-3. The 100-K Area Groundwater Monitoring Wells.

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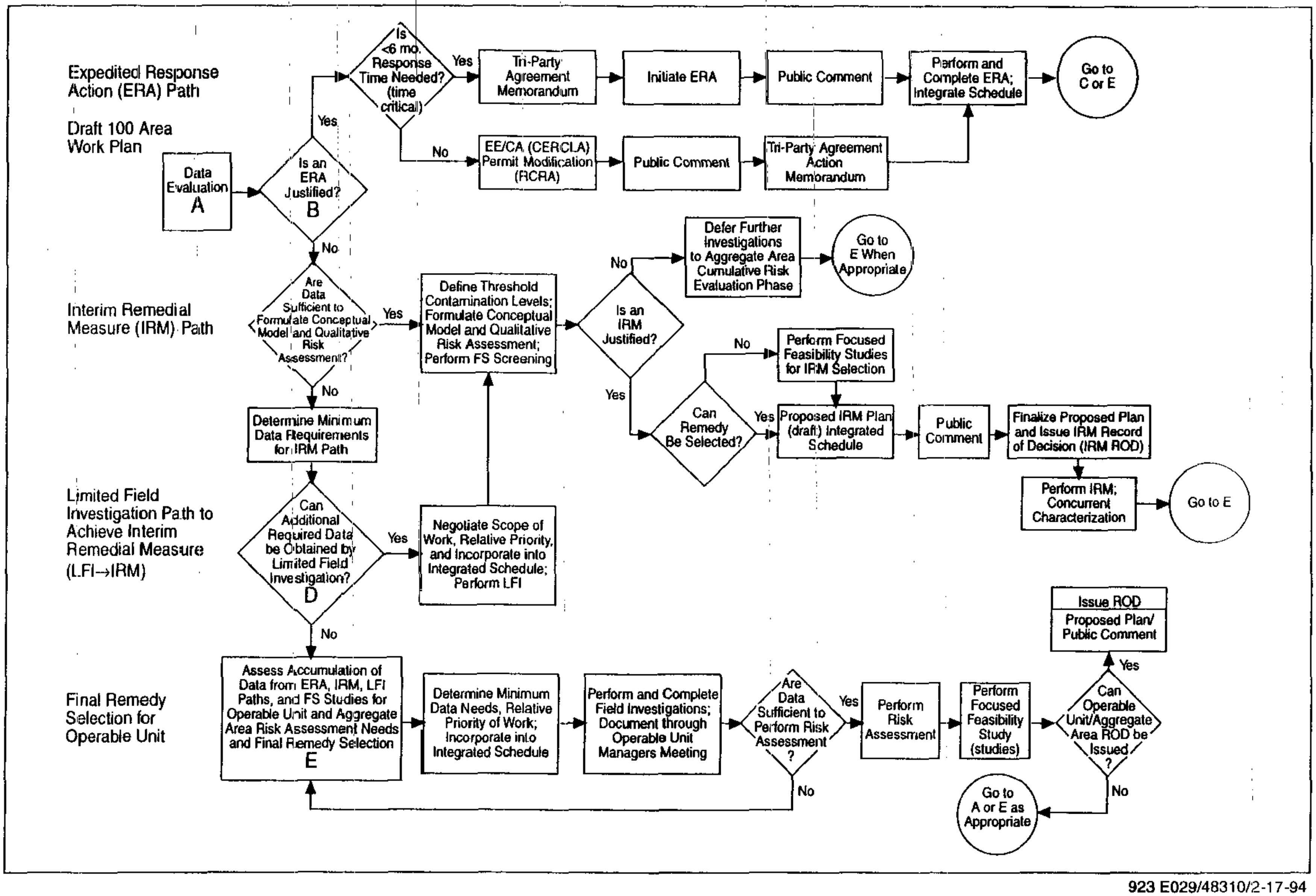

Figure 1-4. Hanford Past Practice Strategy Decision Flow Chart.

Table 1-1. 100-KR-1 Operable Unit Waste Sites and 100 Area Analogous Sites.

100-KR-1 Operable Unit Waste Sites	100-B/C Area	100-D/DR Area	100-H Area	100-F Area
116-K-1 effluent crib	116-B-1 116-C-1[a]	116-DR-1 116-DR-2	116-H-1	116-F-2
116-K-2 effluent trench	116-B-1 116-C-1[a]	116-DR-1 116-DR-2	116-H-1	116-F-2
116-K-3 outfall structure	116-B-7[b] 132-B-6[b] 132-C-2[b]	116-D-5 116-DR-5	116-H-5[b]	116-F-8[b]
116-KW-3 retention basins	116-B-11 116-C-5	116-D-7 116-DR-9	116-H-7	116-F-14
116-KE-4 retention basins	116-B-11 116-C-5	116-D-7 116-DR-9	116-H-7	116-F-14
Effluent discharge pipelines and valves	Effluent discharge pipelines and valves[b]	Effluent discharge pipelines and valves[b]	Effluent discharge pipelines and valves[b]	Effluent discharge pipelines and valves[b]

[a]A treatability study or technology demonstration is proposed.
[b]An IRM is proposed.

2.0 LIMITED FIELD INVESTIGATION ACTIVITIES

The LFI began the investigative phase of the RI for the high-priority sites identified in the 100-KR-1 RI/FS work plan (DOE-RL 1992a). The work plan divided the site characterization activities into 13 tasks. These tasks are listed in Table 2-1.

The LFI investigative activities (see Table 2-2) are discussed in greater detail in the following sections. Results of aggregate area investigations are summarized in the appropriate section below. Results of 100-KR-1 operable unit field investigation activities are discussed in Chapter 3.

2.1 SOURCE INVESTIGATION

A search of documents, photographs, and drawings from the 100-KR-1 operable unit was conducted to provide additional information about source units or potential source areas to focus subsequent investigative tasks (Stankovich 1992). Existing information on facilities within the 100-KR-1 operable unit was reviewed to more accurately and completely characterize potential sources of contamination and close data gaps identified in the 100-KR-1 RI/FS work plan (DOE-RL 1992a).

2.2 AGGREGATE AREA INVESTIGATIONS

2.2.1 Geology Investigation

Detailed results of the geology investigation for the 100-K area are contained in *Geology of the 100-K Area, Hanford Site, South Central Washington* (Lindberg 1993). In summary, the 100-K Area and vicinity is underlain (from oldest to youngest) by flows of the Columbia River Basalt Group with the intercalated Ellensburg Formation, the Ringold Formation, the Hanford formation, and scattered Holocene deposits. The Ringold Formation consists of semi-indurated clay, silt, fine- to coarse-grained sand, and pebble to cobble gravel grouped into five sediment facies associations that are defined on the basis of these lithologies, petrology, stratification, and pedogenic alteration.

The Hanford formation consists of three facies: (1) gravel-dominated (pebble-to-boulder gravel), (2) sand-dominated (fine- to coarse-grained sand), and (3) silt-dominated. These sediment types within the Hanford formation represent end members within a continuum of sediment types that were deposited by cataclysmic flood waters that drained out of glacial lake Missoula. Sharp distinctions among these sediments cannot always be made (Lindberg 1993). The Holocene surficial deposits consist of a thin veneer (< 16 ft) of silt, sand, and gravel deposited by a mix of eolian and alluvial processes.

Within the 100-K Area, basalt is encountered at depths greater than 500 ft below the surface. The Ringold Formation is exposed at the surface along the banks of the Columbia River and up to 1,200 ft away from the river (which includes much of the 100-KR-1 operable unit). Elsewhere, the Hanford formation covers the Ringold Formation in gradually increasing thickness up to the southern boundary of the 100-K Area, where the formation is approximately 120 to 130 ft thick. Holocene deposits in the 100-K Area are dominated by Columbia River deposits and eolian deposits. The Holocene deposits are not areally extensive.

Nearly the entire surface of the 100-K Area, with the exception of some locations along the steeply pitching river banks, has been disturbed by grading or excavation. Fill materials are largely composed of native materials. The extent of fill is greatest near the river bank terrace at berms established adjacent to the 116-KW-3 and 116-KE-4 retention basins, the 116-K-1 crib and local fill areas from washouts along the 116-K-2 trench.

2.2.2 Ecology Investigation

The 100 Area operable units, which cover a total of 4,532 ac, are topographically and environmentally similar. Each is situated along the Columbia River bank, with the reactor located on a high gravel terrace left by the recession of glacial floodwaters at the end of the Pleistocene Epoch. Shoreline areas grade from steep banks with narrow cobble beaches to broad, stepped, well-defined terraces with gently sloping beaches. The flood plain terraces consist of sand deposited during the Holocene Epoch and occur on at least two levels, one dating to the early or middle Holocene and another representing the later Holocene. Inland areas are broad flats broken only by stabilized dunes. The area from west of the 100-N Area to the western edge of the 100-D Area differs from this general pattern. In that vicinity are large, rounded gravel mounds (ripple marks) formed during catastrophic Pleistocene floods.

Ecological field investigations were conducted to:

- provide a description of the flora and fauna associated with the 100 Areas operable units with an emphasis on potentially significant pathways, and those species that have been classified as threatened, endangered, candidate, or monitor species by the state or federal government

- evaluate existing concentrations of contaminants in major species and pathways associated the 100 areas operable units (Landeen et al. 1993).

The field investigations concentrated on bird surveys, mammal and insect surveys, vegetation surveys, and sampling of various biota for radionuclides and inorganic waste constituents analysis. These investigations were completed in accordance with Appendix D-2 or the groundwater operable unit work plans (e.g., DOE-RL 1992b).

Comprehensive bird surveys were conducted at the 100-HR-3 and 100-BC-5 operable units during the winter, spring, summer, and fall of 1991 (Landeen et al. 1993). The main purposes were to verify existing species lists for the 100 Areas, to identify potentially significant pathways, and to verify and document species of special interest that use the operable units. Landeen et al. (1993) provides complete lists of birds identified during the surveys. No effort was made to quantify bird species inhabiting the operable units. Some common species reported near the reactors and along the shoreline and riparian zone include common nighthawk (*Chordeiles minor*), eastern and western kingbirds (*Tyrannus* and *Tyrannus verticalis*), willow flycatcher (*Empidonax traillii*), swallow spp., killdeer (*Charadrius vociferus*), American robin

(*Turdus migratorius*), gull spp.(*Laurus* spp.), American kestrels (*Falco sparverius*), black-billed magpie (*Pica pica*), common raven (*Corvus corax*), loggerhead shrike (*Lanius ludovicianus*), white-crowned sparrow (*Zonotrichia leucophrys*), mourning doves (*Zenaida macroura*), rock doves (*Columba livia*), quail (*Callipepla californica*), dark-eyed juncos (*Junco hyemalis*), house finch (*Carpodacus mexicanus*), horned larks (*Eremophila alpestris*), western meadowlark (*Sturnella neglecta*), red-winged blackbirds (*Agelaius phoeniceus*), European starling (*Sturnus vulgaris*), song sparrow (*Melospiza melodia*), house sparrow (*Passer domesticus*), bufflehead (*Bucephala albeola*), common merganser (*Mergus merganser*), great blue heron (*Ardea herodias*), American white pelican (*Erythrorhynchos pelecanus*), bald eagle (*Haliaeetus leucocephalus*), Canada goose (*Branta canadensis*), mallard (*Anas platyrhynchos*), American wigeon (*Anas americana*), northern shoveler (*Anas clypeata*), gadwall (*Anas strepera*), and redhead (*Aythya americana*).

Mammal species observed, including signs of animal activity such as burrowing, tracks, and scat, during field work activities (e.g., bird surveys, vegetation surveys, sampling, and general site reconnaissance) were recorded. No effort was made to quantify mammal species or inventory bat species, nor was trapping conducted to determine presence or absence of small mammal species. The most common mammals found in the 100 Areas are the mule deer (*Odocoileus hemionus*), coyote (*Canis latrans*), Great Basin pocket mouse (*Perognathus parvus*), jackrabbit (*Lepus californicus*), and cottontail rabbit (*Sylvilagus nuttalli*). A complete list of mammals known to inhabit the 100 Areas is provided in Landeen et al. (1993).

Harvester ant (*Pogonomyrmex owyheei*) colonies were also surveyed at individual waste sites because excavation of subsoils by these colonies represents a potential contaminant exposure pathway. Although harvester ant colonies were observed at several waste sites in the 100 Areas operable units, none were observed in waste sites of the 100-KR-1 operable unit (Landeen et al. 1993).

The plant communities within the 100 Area operable units are broadly described as riparian along the Columbia River and as a cheatgrass community in areas away from the shoreline (Landeen et al. 1993). The shoreline in the 100-K Area is characterized as gently sloping with areas of large boulders and areas of gently sloping mudflats on which Southern mudwort (*Limosella acaulis*) is found. Above the shoreline is a relatively broad riparian zone with several distinct vegetative zones. Near the water line the plant community is strongly dominated by reed canarygrass (*Phalaris arundinacea*). Above this zone is a Kentucky bluegrass (*Poa pratensis*) zone, a thickspike wheatgrass (*Agropyron dasytachyum*) zone, and a dryland cheatgrass (*Bromus tectorum*)/Sandberg's bluegrass (*Poa sandbergii*) community. The trees in the riparian zone, primarily elm (*Ulmus pumila*) and mulberry (*Morus alba*), are distributed in isolated clumps of five or six individuals. Beyond the riparian zone is a dryland, cheatgrass-dominated community that typifies much of the upland in the 100 Areas. A complete listing of species found in these communities is found in Landeen et al. (1993).

Ecological sampling was conducted in the 100 Areas and in and around the Columbia River adjacent to the 100 Areas. Biota and soil samples were collected from species and media with either a past history of documented contaminant uptake or an important position in the food web, such as reed canary grass, tree leaves, asparagus (*Asparagus officinalis*), coyote scat, raptor pellets, ant mounds, and small mammal burrows. These samples were analyzed for target analyte list (TAL) analytes and selected radionuclides. The results of these sample analyses have been compiled in Landeen et al. (1993). Other results of sampling by site-wide surveillance and facility monitoring programs that can be used in the evaluation of ecological contamination are presented in Weiss and Mitchell (1992).

Except for strontium-90 in tree leaves, Landeen et al. (1993) did not note any probable contamination in environmental samples collected from the 100-K Area. Samples of tree leaves collected near the 100-K reactors showed strontium-90 concentrations that ranged from <0.55 pCi/g to a maximum of 88 pCi/g. Concentrations of other analytes (inorganics and radionuclides) did not differ appreciably from collected control samples.

2.2.3 Cultural Resource Investigation

In compliance with Section 106 of the *National Historic Preservation Act* (16 USC 470 et seq.), Westinghouse Hanford Company (WHC) requested the Hanford Cultural Resources Laboratory conduct an archaeological survey of the 100 Area reactor compounds. This survey was conducted as part of a comprehensive review of 100 Area CERCLA operable units in support of CERCLA characterization activities. The work included a literature and records review and pedestrian survey of the project area following procedures set forth in the Hanford Cultural Resources Management Plan (PNL 1989).

Five prehistoric sites and a farmstead were identified in the 100-K Area during the survey (Chatters et al. 1992). All of these sites are located on terraces along the Columbia River. Three of the sites (45BN434, 45BN423, and 45BN424) are found in the 100-KR-1 operable unit. These sites are located downhill, to the north and to the west of the retention basins and the trench, and are adjacent to or intersected by radiation zones along the river floodplain. These sites are considered to be at high risk during CERCLA characterizations (Chatters et al. 1989). Evaluation of the significance for the identified sites is continuing.

2.3 100-KR-1 LFI SAMPLING AND FIELD ACTIVITIES

Field activities used to evaluate contamination at the high-priority sites identified in the work plan (DOE-RL 1992a) included cable-tool drilling of boreholes; backhoe excavations; field screening for evidence of volatile organics, chromium, and radionuclides: sampling for geology, physical properties, and analytical constituents; and borehole geophysical logging. The description of work (Green 1992) provided detailed guidance for these field activities. The LFI investigation activities for each waste site are summarized in Table 2-2.

2.3.1 Drilling and Excavations

Four boreholes were drilled at the 100-KR-1 operable unit to determine the nature and vertical extent of contamination associated with liquid waste disposal facilities: the 116-K-1 crib (borehole 116-K-1), 116-K-2 trench (borehole 116-K-2), 116-KW-3 retention basin (borehole 116-KW-3A), and 116-KE-4 retention basin (borehole 116-KE-4A). The location of the boreholes within each facility was chosen to represent the "worst case" contamination, such as near locations of effluent discharge to the facility or near the center of the facility if the discharge point could not be determined (see Figure 2-1). These boreholes were advanced using cable-tool drilling methods and sampled with split-spoon or core-barrel sampler. Target depths for the boreholes were established based on process knowledge and historical records. The maximum drilling and sampling depth was 5 ft below the water table (Green 1992). Boreholes were abandoned after all sampling and geophysical logging was completed.

Two test pits were excavated in the floodplain downgradient of each of the retention basin facilities (see Figure 2-1). At the 116-KW-3 retention basin, one test pit was excavated at the discharge end of each of two drainage culverts. At the 116-KE-4 retention basin, one test pit was excavated at the junction of the drainage ditches and one test pit was excavated at the base of the washed out areas between the retention basin and the drainage ditch. These test pits were used to provide a fast method for characterizing soil contamination in areas that received effluent runoff due to basin leakage. The test pits were excavated using a backhoe.

2.3.2 Screening

All material exhumed from either boreholes or test pits was field screened for evidence of volatile organic compounds (VOC) and radionuclides. The screening was used to assist in the selection of sample intervals and borehole total depths. The volatile organics were screened using an organic vapor monitor (OVM) that was used, maintained, and calibrated consistent with Environmental Investigations Instruction (EII) 3.2 and 3.4 (WHC 1988). Radionuclide screening was conducted using a portable scintillation counter per EII 3.4 (WHC 1988). The last sample interval was screened for chromium using a portable hexavalent chromium test kit. Screening results were recorded in logbooks as specified in EII 9.1 for boreholes and EII 1.5 for test pits (WHC 1988).

Prior to initiating drilling or excavation, a one-time background reading for VOCs and radionuclides was taken and recorded in the field logbook (or geologic log for boreholes), except background VOCs were not reported for the 116-K-1 borehole (see Section 3.2.1.2). Except for radionuclides in test pits, instrument backgrounds were measured on freshly disturbed surface soil, holding the instruments <1 inch from the soil. Radionuclide background for test pits was measured holding the scintillation counter at the approximate center of the test pit and approximately 3 ft above the ground.

Action levels were 5 ppm above background for VOCs and twice background for radionuclides. Chromium screening was for informational purposes only; therefore, an action level was not established.

2.3.3 Geophysical Logging

Three boreholes (116-K-2, 116-KE-4A, and 116-KW-3A) were logged using a spectral gamma-ray radiation logging system and one borehole (116-K-1) was logged using a gross-gamma ray system in accordance with EII 11.1 (WHC 1988). No geophysical logging was performed in the test pits. The objective of the borehole surveys was to identify the presence and species of man-made gamma-ray emitting radionuclides and the relative activity levels. The spectral gamma-ray radiation logging system identified gamma-ray emitting radionuclides, their concentration, and location in the borehole interval. The gross-gamma ray logging system only indicates the total radionuclide activity and its depth of occurrence and not the individual radioisotopes. Additional details on the methodology and limitations of the geophysical logging are presented in Appendix A.

2.3.4 Sampling

Four types of samples were collected: geologic samples (borehole), physical properties samples (borehole), analytical samples (borehole and test pits), and reference samples. Geologic samples were taken at 5 ft intervals, approximately, and at major stratigraphic changes for preparation of borehole logs.

Four samples for physical properties analyses were collected at borehole 116-KE-4A. The physical properties samples were collected at approximately 5 ft intervals. The primary objective for sample selection was to be representative of the principal soil types.

Analytical samples were collected from the boreholes and test pits in accordance with EII 5.2 (WHC 1988). One sample was collected from the surface soil at each borehole or test pit location prior to drilling or excavation. The remaining analytical samples were collected based on the following criteria.

- If drill cuttings or exposed material in the backhoe were greater than or equal to screening criteria (two times background for radionuclides or 5 ppm greater than background for VOCs), a sample was collected at that point and sampling continued at 5 ft intervals until two consecutive samples passed screening criteria.

- If drill cuttings or exposed material in the backhoe bucket are less than the screening criteria, a sample was collected at the maximum expected waste depth. Sampling continued at 5 ft intervals until two consecutive samples passed the screening criteria.

Samples from boreholes were collected using a split-spoon sampler. Samples from the test pits were collected directly from the middle of the backhoe bucket, away from the bucket sides, using hand tools and standard soil sampling techniques, as directed by EII 5.2 (WHC 1988).

Two samples were collected from a reference location (see Figure 2-1) in addition to the samples collected from the four boreholes and the four test pits. These reference samples were used to develop an operable unit specific control (see Section 3.1.1).

2.4 SAMPLE ANALYSES

Samples collected for chemical analysis were analyzed for the full suite of CERCLA Contract Laboratory Program (CLP) target compound list (TCL) and TAL constituents, together with certain specified anions that may be present, and radionuclides. Chemical analysis was conducted using CLP methods. Chemical analysis for non-CLP analytes (e.g., anions, nitrate/nitrite) were performed according to standard EPA methods. Radiochemistry analysis was performed according to laboratory specific procedures using common methodologies (e.g., gas proportional counting, alpha spectroscopy, gamma spectroscopy, etc.). Analytical methods, routine analytical detection and quantitation limits, and precision and accuracy specified for the methods are listed in Table QAPjP-1 of the Quality Assurance Project Plan in the work plan (DOE-RL 1992a).

Samples collected for physical properties were analyzed using American Society for Testing and Materials (ASTM) methods, except bulk density was analyzed using a method developed by the laboratory contractor. The analyzed parameters (and ASTM methods) were bulk density, particle size distribution (ASTM D422-63), moisture content (ASTM D2216), moisture retention (ASTM D2325-68, D3152-72), and saturated hydraulic conductivity (ASTM D2434-68).

2.5 DATA VALIDATION

Data validation was performed by a qualified independent participant contractor in compliance with the WHC *Sample Management Administration Manual* (WHC 1990). All data packages were assessed. The chemical and radiological analytical data were validated, but physical parameter data were not. Results of data validation are presented in separate reports (WHC 1993a, 1993b, 1993c, 1993d).

In addition to data validation, the data collected during the LFI were evaluated for use in the LFI and the QRA. This evaluation included (1) an inventory of all samples collected during the LFI, (2) data compilation and review, and (3) a review of laboratory and field (including trip and equipment) blanks. The sample inventory was conducted using multiple information sources including sample lists, borehole logs, sample tracking sheets, and sample location maps.

Laboratory and field blanks were used to evaluate each data set for common laboratory contaminants or sources other than media contamination. This review was conducted using the five and ten times rule as specified in Bleyler (1988) and Bechtold (1992). Detected concentrations of common laboratory contaminants (acetone, 2-butanone, methylene chloride, toluene, and common phthalate esters) had to be greater than 10 times their corresponding blank value. Detected concentrations of other contaminants had to be greater than five times their corresponding blank value to be considered valid.

One result of the data evaluation and validation process is the assignment of data qualifier letter codes to individual analytical results. The following qualifier letter codes were applied to data from the 100-KR-1 LFI investigation:

- "U" indicates that the analyte was analyzed for and not detected. The numerical value reported is the contract required detection limit (CRDL) or the contract required quantitation limit (CRQL). CRDLs apply to EPA CLP protocol analyses of inorganic constituents and to detection limits established by WHC for radionuclide analyses. CRQLs apply to EPA CLP protocol analyses of organic constituents. Sample quantitation limits and sample detection limits may be lower or higher than CRQLs or CRDLs, depending on instrumentation, matrix, and concentration factors.

- "J" indicates that the analyte was analyzed for and detected. The concentration reported is an estimate due to identified quality control deficiencies. For example, if the amount present is less than either the CRDL or CRQL, the concentration reported is considered an estimated value.

- "R" indicates that the data were rejected during validation because of quality assurance problems.

- "B" for organic data indicates the analyte was detected in the associated blank sample. For inorganic data, the flag indicates that the analyte was detected at a concentration between the instrument detection limit (IDL) and CRDL.

After data validation, the data compilation was done to verify that validation results were incorporated into the analytical database and that the data qualifiers were listed. Rejected data were assigned an "R" qualifier. If upon review of the rejected data, the reason for rejection was due to administrative concern (e.g., missing data sheets) and not because of major quality assurance/quality control deficiencies (e.g., technical concerns), the rejected data were considered usable for the LFI and the QRA. This is the only example for which rejected data were used in the LFI.

2.7 IDENTIFICATION OF APPLICABLE OR RELEVANT AND APPROPRIATE REQUIREMENTS

Section 121(d) of CERCLA, as amended by the *Superfund Amendments and Reauthorization Act of 1986*, required that fund-financed, enforcement, and federal facility remedial actions comply with applicable or relevant and appropriate requirements (ARARs) of federal environmental laws and more stringent, promulgated state environmental or facility siting laws.

Applicable requirements are defined in CERCLA as those cleanup standards, standards of control, and other substantive environmental protection requirements, criteria, or limitations promulgated under federal or state law that specifically address a hazardous substance, pollutant, contaminant, remedial action, location, or other circumstance at a CERCLA site. Relevant and appropriate requirements are defined in CERCLA as those cleanup standards, standards of control, and other substantive requirements, criteria, or limitations promulgated under federal or state environmental or facility siting laws, that while not "applicable" to a hazardous substance, pollutant contaminant, remedial action, location, or other circumstance at a CERCLA site, address problems or situations sufficiently similar to those encountered at the CERCLA site that their use is well suited to the particular site. Only those state standards that are identified in a timely manner and are more stringent than federal requirements may be applicable or relevant and appropriate.

In addition to ARARs, CERCLA also provides for the consideration of to-be-considered (TBC) materials, including nonpromulgated advisories or guidance documents, in determining necessary levels of protection of health or the environment.

Applicable or relevant and appropriate requirements may be further subdivided into the following categories.

- Chemical-specific requirements — health- or risk-based numerical values or methodologies that, when applied to site-specific conditions, result in the establishment or numerical values. If a chemical has more than one such requirement that is an ARAR, compliance should generally be with the most stringent requirement.

- Location-specific requirements — restrictions placed on the concentration of hazardous substances or the conduct of activities solely because they are in specific locations, such as wetlands or historic places.

- Action-specific requirements — technology- or activity-based requirements or limitations on actions taken with respect to hazardous wastes. These requirements are triggered by the particular remedial activities that are selected to accomplish a remedy.

Potential chemical- and location-specific ARARs are defined during the field investigation portion of the CERCLA process and refined in the feasibility study and proposed plan. Action-specific ARARs are generally defined during the phase I and II feasibility study and refined in detailed analysis in the proposed plan. Potential ARARs and TBCs in all categories are defined in the *100 Area Feasibility Study Phases 1 and 2* (DOE-RL 1992c). For purposes of this LFI, only the potential chemical- and location-specific ARARs are discussed. The potential ARARs are presented in Tables 2-3 through 2-8.

Potential chemical-specific ARARs for soils are limited to those levels for hazardous constituents prescribed in the Washington State Model Toxics Control Act (MTCA). Currently, MTCA has not defined levels for radionuclides. Additional soil limits are presented in Subpart S of RCRA for hazardous constituents and in DOE Order 5400.5 for radionuclides. These are considered TBCs for the 100 Area operable units. Potential chemical-specific ARARs for air emissions are also identified; however, these tend to be based on specific actions that have a tendency to increase releases to the air. Therefore, these are more appropriately addressed in the focused feasibility study. Potential chemical-specific ARARs are listed in Tables 2-3 and 2-4; TBCs are included in Table 2-5.

Potential location-specific ARARs are identified for the 100 Area because of the presence of threatened or endangered species and archaeological resources. In addition, potential location-specific ARARs based on possible impacts to wetlands and flood plains are included. These are included in Tables 2-6 and 2-7; TBCs are in Table 2-8.

The discussion of potential ARARs is intended to be a refinement of the ARARs discussion presented in the work plan. Additional evaluation of potential ARARs, especially those that are action-specific, will be done in the FS phase. Final ARARs will be determined in the Record Of Decision.

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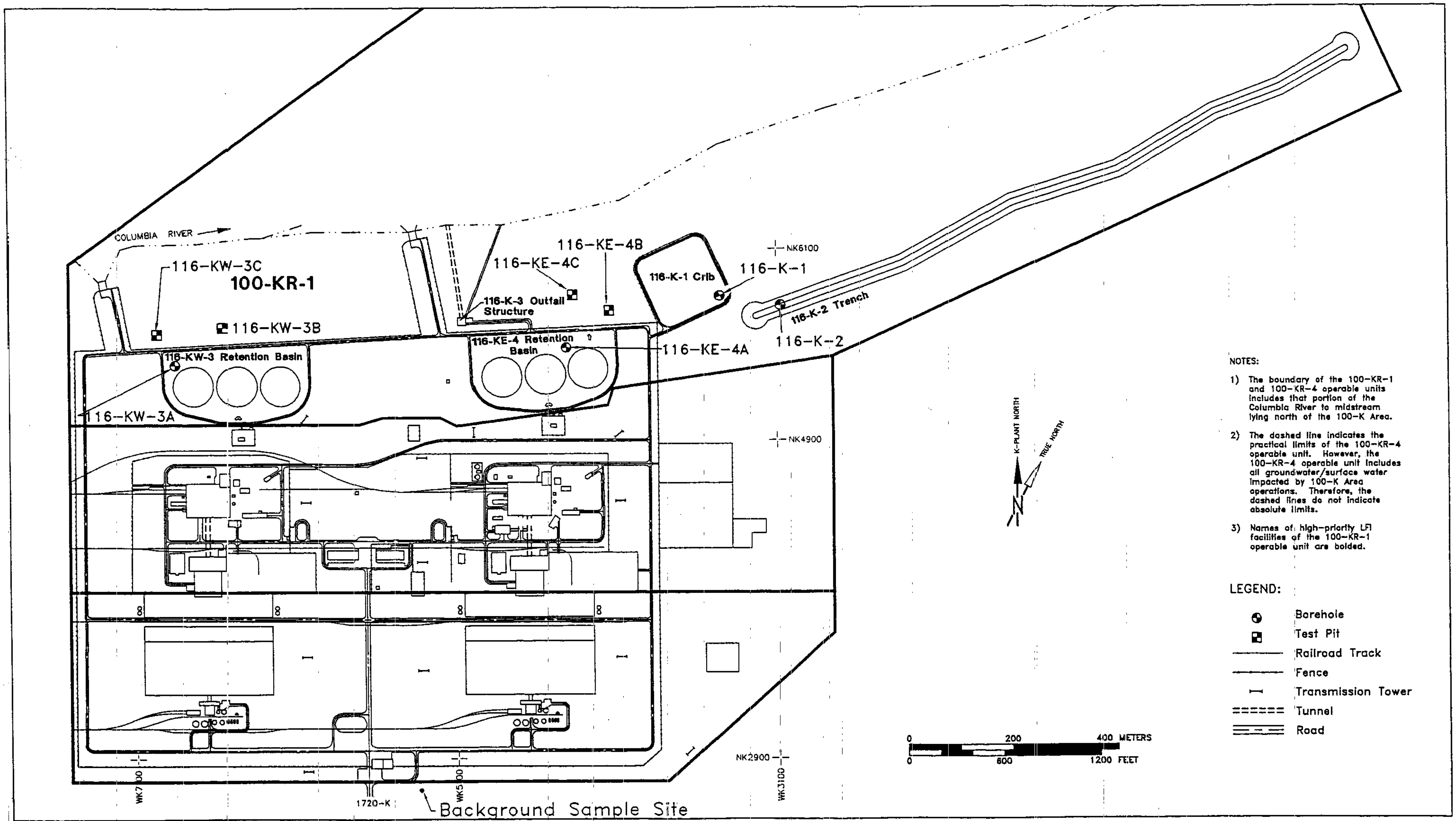

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Figure 2-1. The 100-KR-1 Borehole, Test Pit, and Background Sample Locations.

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Table 2-1. LFI Activities for the 100-KR-1 Operable Unit.

Task	Activity	Description
1	Project Management	Objectives are to direct and document project activities so that data and generated evaluations meet work plan goals and objectives.
2	Source Investigation	This task was conducted to identify sources, location, and potential contamination associated with high-priority sites.
3	Geologic Investigation	Compilation of geologic information for source and groundwater operable units was performed as part of the 100-KR-4 groundwater operable unit RI/FS.
4	Surface Water and Sediments Investigation	No surface water or sediments are included within the boundaries of the 100-KR-1 operable unit. This investigation is deferred to the 100-KR-4 groundwater operable unit.
5	Vadose Zone Investigation	The objective is to define the nature and vertical extent of contamination, relevant migration paths, and support selection of IRMs related to waste disposal facilities at the 100-KR-1 operable unit.
6	Groundwater Investigation	The groundwater investigation is being performed as part of the 100-KR-4 RI.
7	Air Investigation	Only routine health and safety air monitoring was conducted during investigation activities.
8	Ecological Investigation	The ecological investigation was conducted as an aggregate area investigation for the 100 Area.
9	Cultural Resource Investigation	The cultural resource investigation included a review of existing data on historic land uses, by Indian tribes and pioneer settlers, and a field survey.
10	Data Evaluation	Data generated during the LFI are being integrated, evaluated, and coordinated with FS activities.
11	Risk Assessment	A qualitative risk assessment that includes a human health and an environmental evaluation will be conducted during the LFI to support IRMs.
12	Verification of Contaminant- and Location-specific ARARs	Potential ARARs are identified in the LFI for verification by EPA and Ecology.
13	LFI Report	This interim report is prepared to summarize the characterization activities outlined above. The report also includes an assessment of the necessity for IRMs.

Table 2-2. LFI Investigation Activities for 100-KR-1 Operable Unit High-Priority Sites.

Site	Name - Size	Comments	LFI Investigative Approach
116-K-1	Crib 200 ft x 200 ft at its base, 400 ft x 400 ft at its surface	Received reactor coolant water from the 116-KE basin. Replaced by 116-K-2	B, C, F, G, H
116-K-2	Trench 4000 ft x 45 ft x 25 ft deep	Percolated cooling water effluent into the soil column	B, C, F, G, H
116-K-3	Outfall Structure 30 ft x 30 ft x 15 ft high	Collected reactor effluent discharge from the 116-KW-3 and 116-KE-4 basins.	A, N
116-KW-3	Retention basin 3 tanks each 250 ft in diameter and 29 ft high	Retained effluent cooling water for thermal cooling and decay of short-lived isotopes	B, C, F, G, H, T
116-KE-4	Retention basin 3 tanks each 250 ft in diameter and 25 ft high	Retained effluent cooling water for thermal cooling and decay of short-lived isotopes	B, C, F, G, H, P, T
Process Effluent Pipelines		Discharge system, includes lines from the reactors to the basins, and from the basins to the outfall structure	N

A = Analogous data reviewed
B = Vadose zone borehole - drilling, geologic logging, and sampling
C = Chemical and radionuclide analysis of samples
F = Field screening for radioactivity, volatile organic compounds, and hexavalent chromium
G = Borehole gamma-ray geophysical log
H = Historical data reviewed
N = No intrusive investigation
P = Physical properties analysis of samples
T = Test pits

Table 2-3. Potential Federal Chemical-Specific Applicable or Relevant and Appropriate Requirements for the 100-KR-1 Operable Unit. (sheet 1 of 3)

Description	Citation	A/ R&A	Requirements	Remarks
Atomic Energy Act of 1954, as amended	42 U.S.C. 2011 et seq.		Authorizes DOE to set standards and restrictions governing facilities used for research, development, and utilization of atomic energy.	
Radiation Protection Standards	40 CFR Part 191		Establishes standards for management and disposal of high-level and transuranic waste and spent nuclear fuel.	
Standards for Management and Storage	40 CFR §191.03	A	Requires that management and storage of spent nuclear fuel or high-level or transuranic radioactive wastes at all facilities for the disposal of such fuel or waste that are operated by the DOE and that are not regulated by the Commission or Agreement States shall be conducted in such a manner as to provide reasonable assurance that the combined annual dose equivalent to any member of the public in the general environment resulting from discharges of radioactive material and direct radiation from such management and storage shall not exceed 25 millirems to the whole body and 75 millirems to any critical organ.	Applicable to waste disposal of after November 18, 1985.
Nuclear Regulatory Commission Standards for Protection Against Radiation	10 CFR Part 20			
Radiation Dose Standards	10 CFR §§20.101-20.105	R&A	Sets specific radiation doses, levels, and concentrations for restricted and unrestricted areas.	May be relevant and appropriate, as radioactive materials in the 100 Area can contribute radiation doses, levels, and concentrations which could exceed the limits; however, Hanford is not an NRC-licensed facility.

Table 2-3. Potential Federal Chemical-Specific Applicable or Relevant and Appropriate Requirements for the 100-KR-1 Operable Unit. (sheet 2 of 3)

Description	Citation	A/ R&A	Requirements	Remarks
Safe Drinking Water Act	42 U.S.C. 300f et seq.		Creates a comprehensive national framework to ensure the quality and safety of drinking water.	
National Primary Drinking Water Regulations	40 CFR Part 141	R&A	Establishes maximum contaminant levels (MCL) and maximum contaminant level goals (MCLG) for organics, inorganic, and radioactive constituents. The MCL for combined radium-226 and radium-228 is 5 pCi/L.	Applicable to public water systems. Potential chemicals and radionuclides of concern may migrate to the drinking water supply as a result of remedial activities. Although federal MCLGs are not enforceable standards, they are potential ARARs under the Washington State Model Toxics Control Act when more stringent than other standards. See state ARARs. Although federal secondary drinking water standards are not enforceable, they are potential ARARs under the Washington State Model Toxics Control Act when more stringent than other standards. See state ARARs.
National Secondary Drinking Water Regulations	40 CFR Part 143	R&A	Controls contaminants in drinking water that primarily affect the aesthetic qualities relating to the public acceptance of drinking water.	
Solid Waste Disposal Act, as amended by the Resource Conservation and Recovery Act (RCRA)	42 U.S.C. 6901 et seq.		Establishes the basic framework for federal regulation of solid and hazardous waste.	
Groundwater Protection Standards	40 CFR §264.92 [WAC 173-303-645][1]	A	A facility shall not contaminate the uppermost aquifer underlying the waste management area beyond the point of compliance, which is a vertical surface located at the hydraulically downgradient limit of the waste management area that extends down into the uppermost aquifer underlying the regulated area. The concentration of certain chemicals shall not exceed background levels, certain specified maximum concentrations, or alternate concentration limits, whichever is higher.	Groundwater concentration limits in this section do not exceed 40 CFR 141, except for chromium which has a limit of 50 $\mu g/L$.

Table 2-3. Potential Federal Chemical-Specific Applicable or Relevant and Appropriate Requirements for the 100-KR-1 Operable Unit. (sheet 3 of 3)

Description	Citation	A/ R&A	Requirements	Remarks
Uranium Mill Tailings Radiation Control Act of 1978	Public Law 95-604, as amended			
Standards for Uranium and Thorium Mill Tailings	40 CFR 192		Establishes standards for control, cleanup, and management of radioactive materials from inactive uranium processing sites.	
Land Cleanup Standards	40 CFR §§192.10-192.12	R&A	Requires remedial actions to provide reasonable assurance that, as a result of residual radioactive materials from any designated processing site, the concentration of radium-226 in land averaged over any area of 100 square meters shall not exceed the background level by more than 5 pCi/g, averaged over the first 15 cm of soil below the surface, and 15 pCi/g, averaged over 15-cm-thick layers of soil more than 15 cm below the surface. In any habitable building, a reasonable effort shall be made during remediation to achieve an annual average (or equivalent) radon decay product concentration (including background) not to exceed 0.02 Working Level (WL). In any case, the radon decay product concentration (including background) shall not exceed 0.03 WL and the level of gamma radiation shall not exceed the background level by more than 20 microentegens per hour.	May be relevant and appropriate, as any radium-226 encountered during remediation did not result from uranium processing.
			Requires that when radionuclides other than radium-226 and its decay products are present in sufficient quality and concentration to constitute a significant radiation hazard from residual radioactive materials, remedial action shall reduce other residual radioactivity to levels as low as reasonably achievable (ALARA).	May be relevant and appropriate, as any radium-226 encountered during remediation did not result from uranium processing.
Implementation	40 CFR §§192.20-192.23	R&A		

*These are State of Washington regulatory citations which are equivalent to Title 40 Code of Federal Regulations, Parts 264 and 268 as stated in Washington Administrative Code 173-303.
*NOTE: A = Potentially applicable, R&A = Potentially relevant and appropriate.

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Table 2-4. Potential State Chemical-Specific Applicable or Relevant and Appropriate Requirements for the 100-KR-1 Operable Unit. (sheet 1 of 2)

Description	Citation	A/ R&A	Requirements	Remarks
Model Toxics Control Act (MTCA)	70.105D RCW		Requires remedial actions to attain a degree of cleanup protective of human health and the environment.	
Cleanup Regulations	WAC 173-340		Establishes cleanup levels and prescribes methods to calculate cleanup levels for soils, groundwater, surface water, and air.	
Groundwater Cleanup Standards	WAC 173-340-720	A	Requires that where the groundwater is a potential source of drinking water, cleanup levels under Method B must be at least as stringent as concentrations established under applicable state and federal laws, including the following: (A) Maximum contaminant levels established under the Safe Drinking Water Act and published in 40 CFR 141, as amended; (B) Maximum contaminant level goals for noncarcinogens established under the Safe Drinking Water Act and published in 40 CFR 141, as amended; (C) Secondary maximum contaminant levels established under the Safe Drinking Water Act and published in 40 CFR 143, as amended; and (D) Maximum contaminant levels established by the state board of health and published in Chapter 248.54 WAC, as amended.	Federal maximum contaminant level goals for drinking water (40 CFR Part 141) and federal secondary drinking water regulation standards (40 CFR Part 143) are potential ARARs under MTCA when they are more stringent than other standards. Method B cleanup levels are levels applicable to remediation at Hanford unless a demonstration can be made that method C (alternate cleanup levels) is valid.

Table 2-4. Potential State Chemical-Specific Applicable or Relevant and Appropriate Requirements for the 100-KR-1 Operable Unit. (sheet 2 of 2)

Description	Citation	A/ R&A	Requirements	Remarks
Soil Cleanup Standards	WAC 173-340-740	A	MTCA Method B concentration limits in milligrams per kilogram for potential contaminants in soils, sediments, and sludges are: Chromium 400 Cobalt N/L Copper 2,960 Mercury 24 Zinc 24,000 Acenapthene 4,800 Benzo(a)anthracene 0.137 Benzo(a)pyrene 0.137 Benzo(b)fluoranthene 0.137 Chrysene 0.137 Di-n-butylphthalate 8,000 Fluoranthene 3,200 Ideno(1,2,3-cd)pyrene 3,200 Methylene chloride 133 Phenanthrene N/L Pyrene 2,400 Tetrachloroethene 19.6 Toluene 16,000 Trichloroethene 90.9	
Washington State Department of Health	RCW 43.70			
Radiation Protection--Air Emissions	WAC 246-247		Establishes procedures for monitoring, control, and reporting of airborne radionuclide emissions.	
New and Modified Sources	WAC 246-247-070	A	Requires the use of best available radionuclide control technology (BARCT).	
Radiation Protection Standards	WAC 246-221		Establishes standards for protection against radiation hazards.	
Radiation dose to individuals in restricted areas	WAC 246-221-010	A	Specifies dose limits to individuals in restricted areas for hands and wrists, ankles and feet of 18.75 rem/quarter and for skin of 7.5 rem/quarter.	

A = Potentially applicable, R&A = Potentially relevant and appropriate

Table 2-5. Potential Chemical-Specific To-Be-Considered Guidance for the 100-KR-1 Operable Unit. (sheet 1 of 2)

Description	Citation	Requirements	Remarks
Model Toxics Control Act	70.105D RCW		
Cleanup Regulations	WAC 173-340	The State Department of Ecology is currently adapting the calculations in MTCA to be applicable to radioactive contaminants. These cleanup standards may become available prior to or during remediation.	
Solid Waste Disposal Act, as amended by RCRA	42 U.S.C. 6901 et seq.		
Criteria for Classification of Solid Waste Disposal Facilities and Practices	40 CFR §257.3-4	A facility or practice shall not contaminate an underground drinking water source beyond the solid waste boundary.	The courts or the state may establish alternate boundaries.
Corrective Action for Solid Waste Management Units	40 CFR 264 Subpart S, proposed	Establishes requirements for investigation and corrective action for releases of hazardous waste from solid waste management units.	
U.S. Department of Energy Orders			
Radiation Protection of the Public and the Environment	DOE 5400.5	Establishes radiation protection standards for the public and environment.	
Radiation Dose Limit (All Pathways)	DOE 5400.5, Chapter II, Section 1a	The exposure of the public to radiation sources as a consequence of all routine DOE activities shall not cause, in a year, an effective dose equivalent greater than 100 mrem from all exposure pathways, except under specified circumstances.	Pertinent if remedial activities are "routine DOE activities."
Radiation Dose Limit (Drinking Water Pathway)	DOE 5400.5, Chapter II, Section 1d	Provides a level of protection for persons consuming water from a public drinking water supply operated by DOE so that persons consuming water from the supply shall not receive an effective dose equivalent greater than 4 mrem per year. Combined radium-226 and radium-228 shall not exceed 5 pCi/mL and gross alpha activity (including radium-226 but excluding radon and uranium) shall not exceed 15 pCi/mL.	Pertinent if radionuclides may be released during remediation.

Table 2-5. Potential Chemical-Specific To-Be-Considered Guidance for the 100-KR-1 Operable Unit. (sheet 2 of 2)

Description	Citation	Requirements	Remarks
Residual Radionuclides in Soil	DOE 5400.5 Chapter IV, Section 4a	Generic guidelines for radium-226 and radium-228 are: • 5 pCi/g averaged over the first 15 cm of soil below the surface; and • 15 pCi/g averaged over 15-cm-thick layers of soil more than 15 cm below the surface. Guidelines for residual concentrations of other radionuclides must be derived from the basic dose limits by means of an environmental pathway analysis using specific property data where available. Procedures for these deviations are given in "A Manual for Implementing Residual Radioactive Material Guidelines" (DOE/CH-8901). Procedures for determination of "hot spots," "hot-spot cleanup limits," and residual concentration guidelines for mixtures are in DOE/CH-8901. Residual radioactive materials above the guidelines must be controlled to the required levels in 5400.5, Chapter II and Chapter IV.	Residual concentrations of radioactive material in soil are defined as those in excess of background concentrations averaged over an area of 100 m^2.

Table 2-6. Potential Federal Location-Specific Applicable or Relevant and Appropriate Requirements for the 100-KR-1 Operable Unit.

Description	Citation	A/ R&A	Requirements	Remarks
Archaeological and Historical Preservation Act of 1974	16 U.S.C. 469	A	Requires action to recover and preserve artifacts in areas where activity may cause irreparable harm, loss, or destruction of significant artifacts.	Applicable when remedial action threatens significant scientific, prehistorical, historical, or archaeological data.
Endangered Species Act of 1973	16 U.S.C. 1531 et seq.		Prohibits federal agencies from jeopardizing threatened or endangered species or adversely modifying habitats essential to their survival.	
Fish and Wildlife Services List of Endangered and Threatened Wildlife and Plants	50 CFR Parts 17, 222, 225, 226, 227, 402, 424	A	Requires identification of activities that may affect listed species. Actions must not threaten the continued existence of a listed species or destroy critical habitat.	Requires a consultation with the Fish and Wildlife Service to determine if threatened or endangered species could be impacted by activity.
Historic Sites, Buildings, and Antiquities Act	16 U.S.C. 461	A	Establishes requirements for preservation of historic sites, buildings, or objects of national significance. Undesirable impacts to such resources must be mitigated.	
National Historic Preservation Act of 1966, as amended.	16 U.S.C. 470 et seq.	A	Prohibits impacts on cultural resources. Where impacts are unavoidable, requires impact mitigation through design and data recovery.	Applicable to properties listed in the National Register of Historic Places, or eligible for such listing. B reactor is listed on the Register.
Wild and Scenic Rivers Act	16 U.S.C. 1271	A	Prohibits federal agencies from recommending authorization of any water resource project that would have a direct and adverse effect on the values for which a river was designated as a wild and scenic river or included as a study area.	The Hanford Reach of the Columbia River is under study for inclusion as a wild and scenic river.

A = Potentially applicable, R&A = Potentially relevant and appropriate

Table 2-7. Potential State Location-Specific Applicable or Relevant and Appropriate Requirements for the 100-KR-1 Operable Unit.

Description	Citation	A/ R&A	Requirements	Remarks
Habitat Buffer Zone for Bald Eagle Rules	RCW 77.12.655			
Bald Eagle Protection Rules	WAC 232-12-292	A	Prescribes action to protect bald eagle habitat, such as nesting or roost sites, through the development of a site management plan.	Applicable if the areas of remedial activities include bald eagle habitat.
Regulating the Taking or Possessing of Game	RCW 77.12.040			
Endangered, Threatened, or Sensitive Wildlife Species Classification	WAC 232-12-297	A	Prescribes action to protect wildlife classified as endangered, threatened, or sensitive, through development of a site management plan.	Applicable if wildlife classified as endangered, threatened, or sensitive are present in areas impacted by remedial activities.

A = Potenitally applicable, R&A = Potentially relevant and appropriate

Table 2-8. Potential Location-Specific To-Be-Considered Guidance for the 100-KR-1 Operable Unit.

Description	Citation	Requirements	Remarks
Floodplains/Wetlands Environmental Review	10 CFR Part 1022	Requires federal agencies to avoid, to the extent possible, adverse effects associated with the development of a floodplain or the destruction or loss of wetlands.	Pertinent if remedial activities take place in a floodplain or wetlands.
Protection and Enhancement of the Cultural Environment	Executive Order 11593	Provides a direction to federal agencies to preserve, restore, and maintain cultural resources.	Pertains to sites, structures, and objects of historical, archaeological, or architectural significance.
Hanford Reach Study Act	PL 100-605	Provides for a comprehensive river conservation study. Prohibits the construction of any dam, channel, or navigation project by a federal agency for 8 years after enactment. New federal and non-federal projects and activities are required, to the extent practicable, to minimize direct and adverse effects on the values for which the river is under study and to utilize existing structures.	This law was enacted November 4, 1988.

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3.0 LIMITED FIELD INVESTIGATION RESULTS

This chapter summarizes results from field investigations at the 100-KR-1 operable unit. The following types of data are presented in the discussions of high-priority sites:

- Site location, size, characteristics, history, expected contaminants, and results of historical sampling activities
- Geologic data obtained during the site investigation
- Results of field screening conducted during sample collection
- Borehole geophysical logging results for gamma-ray emitting radionuclides
- Results of laboratory analyses for TCL and TAL analytes, specific anions, radionuclides, and physical properties (data validation qualifier codes are included in analytical data appendices)
- Data applicable to potential groundwater impacts from liquid waste disposal facilities in the 100-KR-1 operable unit obtained from the LFI of the 100-KR-4 groundwater operable unit.

3.1 BACKGROUND SOIL SAMPLING

Background sampling is used to identify radiological, inorganic, and organic constituents in the soil that occur naturally or as a result of widespread anthropogenic sources. The characterization of background soil constituent concentrations has been conducted both on a 100-K Area project-specific basis and on a Hanford Site-wide basis. The results of both of these characterization efforts are presented below.

3.1.1 Operable Unit Specific Control

The 100-KR-1 operable unit project-specific control was determined based on two samples collected from surface soil from a single site located outside the 100-K Area along the southern boundary (see Figure 2-1). These control samples were analyzed for the same constituents as the LFI samples collected from boreholes or test pits at the high-priority waste sites. Results of detected analytes are summarized in Table 3-1. The analytical results for the operable unit control samples were used to derive the 95th percentile assuming a lognormal (see Table 3-2) distribution for comparative purposes with the Hanford Site background (see Section 3.1.2). The data on operable unit control distributions are presented for informational purposes only. However, it should be noted that the only radionuclides detected in the control samples are either naturally occurring or have a wide-spread occurrence because of atmospheric fallout from nuclear weapons testing. The activities of cesium-137 and uranium-238 are less than average activities found in off-site soils (PNL 1990). Consequently, it is assumed these background samples have not been affected by operable unit disposal practices. In the absence of Hanford Site Background data on radionuclides, it is appropriate to use operable unit specific control samples to qualitatively identify those radionuclides with an origin other than past disposal practices.

3.1.2 Hanford Site Background

The range in natural composition of soils at the Hanford Site has been recently characterized (DOE-RL 1993b). The characterization effort involved the determination of the types and concentrations of non radioactive analytes that exist naturally in soils across the Hanford Site. In addition, physical properties and factors that might affect the natural soil chemical composition, as determined by regulatory protocols, were also characterized.

The Hanford Site-wide approach for determining background is based on the premise that all waste sites are part of a common sequence of vadose zone sediments, and the basic characteristics that control the chemical composition of vadose zone sediments are similar throughout the site. This approach has the advantage of providing a single, consistent set of data for assessing the nature and extent of contamination.

Background concentrations were determined using the 95% ($\alpha = 0.05$) upper tolerance limit (UTL) for a lognormal distribution (DOE-RL 1993b). The UTL is the 95% upper confidence limit for the 95th percentile of the distribution and serves as a statistically significant estimate of the upper population limit of background concentrations. The Hanford Site background UTLs for inorganic analytes are presented in Table 3-2.

3.1.3 Identification of Contaminants of Potential Interest

Concentrations of inorganic constituents detected in LFI samples or reported in historical reports are screened against their Hanford Site background 95% UTL. If a concentration exceeds this value, then the inorganic constituent is considered a contaminant and is evaluated further. Organic and radionuclide analytes detected in either historical or LFI samples from the operable unit are considered contaminants and are carried through the LFI evaluation regardless of background.

3.2 LFI RESULTS AT HIGH-PRIORITY WASTE SITES

3.2.1 116-K-1 Crib

The 116-K-1 crib is a 20 ft deep, excavated percolation basin 200 by 200 ft at its base and 400 by 400 ft at its surface. The basin was designed to receive reactor coolant water from the 116-KE retention basin and the 116-KW retention basin during reactor outages. It failed to percolate adequately and was replaced by the 116-K-2 trench. The 116-K-1 crib overflowed at least once, resulting in direct discharge to the river. It is believed that 1E+07 gal of effluent was disposed of at this site (Stenner et al. 1988). There is conflicting information, however, concerning the number of times cooling water effluent was discharged to this basin (DOE-RL 1992a). Additionally, an estimated 88 lb of sodium dichromate that was added to the cooling water process to inhibit corrosion of the circulation system was disposed of in the crib (Stenner et al. 1988).

The 116-K-1 crib has been backfilled with earth and capped with a 1 ft layer of gravel (DOE-RL 1993c). The depth of fill was not reported. In 1990, a visual site inspection showed that the crib is enclosed by a cyclone fence and posted with radiation signs (DOE-RL 1992a).

A single borehole was drilled inside the basin at this site during the LFI (see Figure 2-1). Based on this borehole, the surficial soil at the 116-K-1 crib is a sandy gravel to a depth of 9.5 ft below land surface (bls). The log for the 116-K-1 borehole notes that the top 9 ft is fill. It is unknown if this fill was placed during construction of the site, as opposed to backfill after closure of the facility. The lithology changes to sand at 9.5 to 17 ft bls. At 17 ft the lithology changes to silty sandy gravel to a depth of 26 ft, the total depth of the borehole. A hardpan of unknown character was noted in the borehole log at a depth of 17 ft bls. Hard drilling conditions resulted in no sample recovery at that depth.

Historical and LFI information is summarized in Figure 3-1.

3.2.1.1 Historical Data. Dorian and Richards (1978) collected 16 samples from 5 locations in and around the 116-K-1 crib and surrounding area. Analytical results are presented in Appendix B. During sampling, radiation along the bottom of the crib averaged approximately 1,000 cpm with localized contamination present up to 10,000 cpm.

3.2.1.2 LFI Data. Five depth intervals were sampled from borehole 116-K-1, which was located within the basin area (see Figure 2-1). The samples were collected at depths between 0 to 1 ft, 4 to 6 ft, 10 to 12 ft, 19 to 21 ft, and 24 to 26 ft. These samples were analyzed for radionuclides, semivolatile and volatile organics, polychlorinated biphenyls (PCB), pesticides and metals.

Screening. Field screening for VOCs was performed using an OVM photoionization detector. Area and site background VOC values were not reported in the borehole logs. However, monitoring did take place throughout drilling and remained at <0.1 ppm.

Radioactivity was monitored during field work using a Ludlum portable scintillation detector. Area background registered 2,120 cpm γ. Site background was reported to be 1,900 cpm γ and 0 cpm β, however, it was reported that the β probe was not working. Gamma measurements generally ranged from 2,000 cpm to 3,000 cpm throughout drilling, except for between 4 to 6 ft where it reached 8,000 cpm.

The site was also tested for hexavalent chromium at the bottom of the borehole, 26 ft. The sample tested negative for hexavalent chromium.

Sample Analysis. Five samples were collected and submitted for chemical and radionuclide analysis from the 116-K-1 vadose zone borehole. Samples were taken at intervals from 0 to 1 ft, 4 to 6 ft, 10 to 12 ft, 19 to 21 ft, and 24 to 26 ft. Concentrations of detected analytes are presented in Table 3-3.

Toluene was the only VOC detected in the sample from the 0 to 1 ft range (see Table 3-3) at the 116-K-1 crib.

No metals or inorganic compounds exceeded the Hanford Site background 95% ($\alpha = 0.05$) UTL.

The following radionuclides were detected in the 116-K-1 crib: americium-241, cesium-137, cobalt-60, europium-152, europium-154, plutonium-238, plutonium-239/240, potassium-40, radium-226, strontium-90, thorium-228, thorium-232, uranium-233/234, and uranium-238. Maximum radionuclide concentrations generally occurred in the 4 to 6 ft range (sample BO7HG3, see Table 3-3).

Geophysical logging. A scheduling conflict prevented the use of the spectral gamma-ray system from surveying the borehole at this waste management site. Instead, a gross-gamma system was used. This survey detected a maximum of 4,600 counts per second (cps) at a depth of 4 ft (see Appendix A for details).

3.2.1.3 Groundwater Assessment. Monitoring well 199-K-30 is located upgradient of the 116-K-1 crib and monitoring well 199-K-18 is down gradient (Figure 1-3). Based on preliminary information contained in the 100-KR-4 LFI (DOE-RL 1993d), only tritium, carbon-14, arsenic, beryllium, and chromium were detected in the groundwater at concentrations in excess of risk-based levels. Of these constituents only tritium and chromium were detected in the down gradient well. The tritium concentration was lower in the downgradient well than in the upgradient well. The tritium isopleths showed the tritium plume emanating from near the KE reactor rather than from the 116-K-1 Crib. Chromium concentrations in groundwater samples from the down gradient well were higher than groundwater concentrations in the upgradient well. However, based on chromium concentration isopleths, it appears the chromium concentrations emanate from the 116-K-2 trench rather than the 116-K-1 crib.

3.2.1.4 Conclusions. The only organic compound detected in samples collected at the 116-K-1 site was toluene. Historical records do not indicate that this contaminant was disposed of in the 100-KR-1 operable unit. No inorganic contaminants were detected in concentrations exceeding the Hanford Site background 95% UTL. Historical data for organic and inorganic, non-radionuclide constituents are not available for comparison.

LFI test results revealed the presence of radionuclides in all samples collected from the borehole, with the maximum concentrations generally occurring in the 4 to 6 ft interval. This is consistent with historical information in Dorian and Richards (1978), which showed the maximum radionuclide concentrations in the crib were found in the upper 5 ft. Historical data, LFI test results, geophysical logging, and screening data together show that maximum radionuclide concentrations are found near the surface. The lack of significant concentrations at depth indicate that the facility was probably not used extensively. It is possible that contaminated fill material was used for backfilling. Consequently, the contamination at 4 to 6 ft may be an artifact rather than evidence of contamination due to effluent disposal.

3.2.2 116-K-2 Trench

The 116-K-2 trench was excavated in 1955 to replace the 116-K-1 crib. It was designed to percolate cooling water effluent into the soil column. The trench is approximately 4,000 by 45 ft and 25 ft deep. In 1971, the sides and bottom of the trench were covered (except the end where effluent entered the trench) with a layer of dirt and was later backfilled to grade.

This site received discharges from all contaminated floor drains from the reactor buildings and approximately 500 gal/min basin overflow from the KE and KW reactors (DOE-RL 1993c). Leakage through butterfly valves in the retention basins added an estimated 10,000 to 20,000 gal/min of waste. Other inflows to the trench are thought to include dummy decontamination waste, process-cooling water, 500 gal/min of metal storage basin flow, and some special disposal (DOE-RL 1993c). Chemical compounds that were dissolved in these effluents and disposed of in the trench include an estimated 661,000 lbs of sodium dichromate, 1,100 lbs of copper sulfate, 22,000 lbs of sulfuric acid, and at least 22,000 lbs of sulfamic acid (Stenner et al. 1988). According to Stenner et al. (1988), a total of 8E+10 gallons of effluent was deposited at this site.

Several washout areas were created during the reactor operation along the north side of the trench. Extensive seepage occurred through the north side of the unit due to the higher elevation of the trench relative to the area between it and the Columbia River. Surface contamination extended several hundred feet on the north side of the unit. In 1977, the area was covered with up to a few feet of soil and gravel (DOE-RL 1993c).

A single borehole (116-K-2) was drilled at the influent end of the trench (see Figure 2-1). Borehole logs from the 116-K-2 trench show a sandy gravel soil that extends from 0 to 23 ft bls. No soil samples were recoverable between 6.0 to 10.0 ft due to large cobbles and boulders. The lithology changes to a silty sandy gravel between 23.0 and 25.5 ft and then changes back to a sandy gravel from 25.5 to 26.0 ft. At 26.0 ft, the lithology is silty sandy gravel that extends to 27.0 ft. The lithology becomes sandy gravel from 27.0 to 29.0 ft and then changes to silty sandy gravel to the bottom of the borehole at 30.0 ft bls. The borehole logs indicate that the top 25.5 ft of soil is fill.

Historical and LFI information are summarized in Figure 3-2.

3.2.2.1 Historical Data. Dorian and Richards (1978) investigated the area inside the 116-K-2 trench by collecting 46 samples from 14 locations. Radionuclide activity levels measured in sample holes ranged from less than 200 up to 12,000 cpm with a Geiger-Muller (GM) probe.

The area outside the 116-K-2 trench was investigated with 29 samples from 17 locations. Surface contamination (0 to 2 ft) was identified approximately 150 ft north of the trench in a former washout area. Surface contamination in these washout areas had direct GM readings from 500 to 3,000 cpm. In 1977, this contamination was covered with a few feet of soil and gravel (Dorian and Richards 1978). Analytical results of the Dorian and Richards study are presented in Appendix B.

3.2.2.2 LFI Data. Five depth intervals were sampled from within the basin area. The depth intervals were 0 to 1 ft, 18 to 20 ft, 22.5 to 24.3 ft, 26 to 27.5 ft, and 29 to 30 ft. These samples were analyzed for radionuclides, semi-volatile and volatile organics, polychlorinated biphenyls (PCBs), pesticides and metals.

Screening. Field screening for VOCs was performed using an OVM photoionization detector. Area background readings for VOCs before the start of drilling was 0.0 ppm. This level remained constant throughout drilling.

Radioactivity screening was monitored during field work using a Ludlum portable scintillation detector. Site background using the scintillation detector was 2,100 cpm γ and 75 cpm β. Screening measurements for γ- and β-radiation ranged from 1,700 cpm to a maximum of 280,000 cpm and 50 cpm to a maximum of 12,000 cpm, respectively. Minimum count rates were detected at the surface and at the bottom of the borehole. The maximum count rate for both γ- and β-radiation was detected at a depth of 18 ft bls. The zone of radiation extended from 17 to 26 ft bls.

The site was tested for hexavalent chromium at depths of 26.0 ft and 29.0 ft bls. Hexavalent chromium was undetected (<500 ppb).

Sample Analysis. Five samples were collected from the 116-K-2 trench and submitted for chemical and radionuclide analysis. Samples were taken between 0 to 1 ft, 18 to 20 ft, 22.5 to

24.3 ft, 26 to 27.5 ft, and 29 to 30 ft. Analytical results of detected analytes are summarized in Table 3-4.

Methylene chloride, tetrachloroethane, toluene, and trichloroethane were detected in the 116-K-2 trench. Methylene chloride was detected in all collected samples. Concentrations ranged from 1 to 3 µg/kg, with the maximum occurring in the 18 to 20 ft bls interval. Tetrachloroethane, toluene, and trichloroethane were only found in one or two samples and the maximum concentrations were also found in the sample collected from the 18 to 20 ft interval (see Table 3-4).

Inorganic contaminants for the 116-K-2 site whose concentrations exceed the Hanford Site background UTL included chromium, copper, mercury, and zinc. The maximum concentrations for all of these contaminants were all found in the 18 to 20 ft sample interval (see Table 3-4). Copper concentrations exceeded background screening to the bottom of the borehole.

The following radionuclides were detected in the 116-K-2 trench: americium, carbon-14, cesium-137, cobalt-60, europium-152, europium-154, europium-155, plutonium-238, plutonium-239/240, potassium-40, radium-226, strontium-90, thorium-232, uranium-233/234, and uranium-238. Maximum radionuclide concentrations were generally found in the 18 to 20 ft sample interval. Below the zone of maximum concentration (18 to 20 ft bls), the concentrations of radionuclides decreased significantly. At the bottom of the borehole (30 ft bls) most radionuclides were undetectable or equal to concentrations observed in the background samples (see Table 3-4).

Geophysical Logging. Man-made radionuclides identified during the spectral gamma-ray survey of borehole 116-K-2 are cesium-137, cobalt-60, europium-152, and europium-154. Cesium-137 was detected in the borehole survey from 16 to 26.7 ft. The maximum activity occurred from 17.5 to 20 ft and exceeded 200 pCi/g. Cobalt-60 and europium-152 were both detected in the borehole from 15 to 25.5 ft at an activity exceeding 200 pCi/g. Europium-154 was detected in the survey from 15.5 to 24 ft. The maximum activity occurred at 18.5 ft and exceeded 200 pCi/g. It is noted in the borehole survey report (Appendix A) that the calculated values for cobalt-60 activity reach unusually high values for Hanford soils.

3.2.2.3 Groundwater Assessment. There are five wells down gradient of the 116-K-2 trench: 199-K-18, 199-K-20, 199-K-21, 199-K-22, and 199-K-37. There are no upgradient wells identified for this facility. These wells show that there is a chromium plume emanating from the 116-K-2 trench. No other contaminants of concern identified by the 100-KR-4 LFI (DOE-RL 1993d) show elevated concentrations in the groundwater beneath the 116-K-2 trench.

3.2.2.4 Conclusions. The organic compounds methylene chloride, tetrachloroethane, toluene, and trichloroethane were detected at trace levels (<10 µg/kg) in samples from the 116-K-2 site. Maximum organic compound concentrations were detected in the 18 to 20 ft sample interval. Only methylene chloride was detected (1 µg/kg) in a surface soil sample (0 to 1 ft). Historical records do not indicate these contaminants were disposed of in the 100-KR-1 operable unit and no source for these contaminants has been identified.

Chromium, copper, mercury, and zinc were all detected at concentrations that exceeded the Hanford Site background 95% ($\alpha = 0.05$) UTL and are considered contaminants of potential interest. The maximum concentration of these contaminants was found in the 18 to 20 ft sample interval. Contaminant concentrations decreased with depth, and except for copper, did not exceed the Hanford Site background UTL at the bottom of the borehole. Historical data for organic and inorganic non radionuclide constituents are not available for comparison.

LFI test results show maximum concentrations of radionuclides in the 18 to 20 ft sample interval. At the bottom of the borehole, most radionuclides were either undetected or similar in magnitude with concentrations in operable unit specific-samples samples. This is comparable with historical data presented in Dorian and Richards (1978), field screening results, and geophysical logging.

3.2.3 116-KW-3 Retention Basin

The 116-KW-3 retention basin is a significant waste site for the 100-K Area. The retention basin consists of three above ground tanks constructed of welded carbon steel plate, and each is 250 ft in diameter and 29 ft high. All tanks are mounted on reinforced-concrete foundations at ground surface. The inlet structure to each tank consists of a 72 inch diameter pipe leading to an outlet chute that discharges at the bottom of the basin. The 116-KW-3 retention basin was used from 1955 to 1971 to retain effluent cooling water, allowing for thermal cooling of circulated water and decay of short-lived isotopes before release to the Columbia River.

During operation, the retention basin frequently developed leaks. According to DOE-RL (1993c), leakage rates through butterfly valves could have been as high as 5,000 to 10,000 gal/min. The first indications of large leaks occurred before 1965 when extensive ponding reportedly developed between the basins and the road directly to the north. To prevent this ponding, 2 to 3 ft of fill was placed in this area. Cooling water that leaked from the basins flowed overland and under the road by way of culvert. Because the basins were less than 1000 ft from the shorelines, it was a common occurrence for leaked effluent to reach the Columbia River.

In 1971, the basin was deactivated, pipe entrances were covered for wildlife control, and the walls were washed down. According to DOE-RL (1993c), 4 ft of soil was placed at the bottom of the basin.

A single borehole (116-KW-3A) was drilled in the basin. According to the borehole log, the 116-KW-3 basin consists of at least 24 ft of fill. The soil is stratified as follows. From 0 to 2.5 ft bls, the soil is sandy gravel. At 2.5 ft the lithology changes to a slightly silty gravely sand that extends to 3 ft. From 3 to 3.5 ft the lithology changes to silt. The lithology changes to slightly silty gravely sand between 3.5 to 7 ft. From 7 to 14 ft. the lithology is sandy gravel and from 14 to 24 ft bls the lithology is silty sandy gravel. No in situ material was sampled during drilling.

Historical and LFI information is summarized in Figures 3-3, 3-4, and 3-5.

3.2.3.1 Historical Data. Dorian and Richards (1978) collected 10 samples from 6 locations inside and adjacent to the 116-KW-3 basin. The average GM reading was 2,000 cpm for samples of soil taken in fill material along the bottom of the basin. Predominant radionuclides present in the soil column as a result of cooling water leaks and waste disposal were tritium, cobalt-60, nickel-63, strontium-90, cesium-137, europium-152, europium-154, and europium-155 (Dorian and Richards 1978). A full list of radionuclide sample results is located in Appendix B (see Table B-6).

Twenty-three samples were also collected outside the 116-KW-3 basin. Two samples were generally collected from each location: one at the surface and one from 5 to 25 ft below the surface. Soil contamination in the area surrounding the retention basin had GM readings from 500 to 1,500 cpm. The 116-KW-3 waste site had a total radionuclide inventory of 3.9 Ci.

3.2.3.2 LFI Data. LFI samples were collected adjacent to the basin on the north side (see Figure 2-1). A single borehole was drilled to determine the nature and vertical extent of contamination beneath the tanks. Outside the basin, two test pits were dug to examine soil contamination due to effluent leakage during basin operation.

Three samples were collected from the borehole at depths from 0 to 1 ft, 17 to 19 ft, and 22 to 24 ft. These samples were analyzed for radionuclides, semi-volatile and volatile organics, PCBs, pesticides and metals.

Two test pits located outside the basin were sampled at the surface (0 to 6 in), 10 ft, 15 ft and 20 ft. One duplicate sample was collected from each test pit, therefore a total of five samples were collected from each pit. These samples were analyzed for metals, volatile and semi-volatile organics, pesticides, PCBs, radionuclides and total activity.

Screening. Field screening for VOCs during borehole drilling was performed using an OVM photoionization detector. VOC area background was 0.0 ppm and remained constant throughout drilling.

Radioactivity was monitored during drilling using a Ludlum portable scintillation detector. Area background was reported at 2,230 cpm γ and 30 cpm β, while site background registered at 3,000 cpm γ and <1 cpm β. Screening measurements during drilling for γ-radiation and β-radiation ranged from 2,000 to 3,000 cpm and <1 to 10 cpm, respectively.

The 116-KW-3 site was tested for hexavalent chromium at a depth of 24 ft. Hexavalent chromium testing was negative.

The test pit excavations were also monitored during on-site activities for volatile organics and radioactivity with the OVM and the GM, respectively. The readings remained below detection throughout digging.

Sample Analysis. Detected analytes for samples collected from the borehole are shown in Table 3-5. Detected analytes for samples collected from the test pits are shown in Tables 3-6 and 3-7.

Organics detected in samples from the borehole included di-n-butylphthalate, tetrachloroethane, and toluene. Maximum concentrations for di-n-butylphthalate and tetrachloroethane were found in the surface sample (0 to 1 ft bls). The maximum concentration for toluene was found in the deepest sample at 22 to 24 ft bls (see Table 3-5).

The samples from test pit 116-KW-3B showed organic contamination from benzo(a)anthracene, benzo(a)pyrene, benzo(b)fluoranthene, chrysene, fluoranthene, indeno(1,2,3-cd)pyrene, phenanthrene, pyrene, and toluene. These contaminants were found only in the sample collected from the surface (see Table 3-6). Toluene was the only organic contaminant found in the samples from test pit 116-KW-3C. It too was only found in the surface sample (see Table 3-7).

The only inorganic analyte in samples from either the borehole or the test pits found above the Hanford Site Background UTL was cobalt. The cobalt concentrations in the sample from 10 ft bls in test pit 116-KW-3B exceeded the UTL (see Tables 3-5, 3-6, and 3-7).

The following radionuclides were detected in either the borehole or the test pits: cesium-137, cobalt-60, europium-152, europium-154, potassium-40, radium-226, strontium-90, thorium-228, thorium-232, uranium-233/234, uranium-235, and uranium-238 (see Tables 3-5, 3-6, and 3-7). In the borehole, most radionuclides were distributed uniformly with depth and only europium-152 was present at concentrations that differed appreciably from the operable unit background (see Table 3-2).

In the test pits, maximum concentrations were typically found at the surface. Cesium-137, cobalt-60, europium-152, europium-154, strontium-90, thorium-228, uranium-233/234, uranium-235, and uranium-238 differed appreciably from concentrations observed at the operable unit background (see Table 3-2).

Geophysical Logging. The spectral gamma-ray survey of borehole 116-KW-3A detected no man-made radionuclides. The total gamma activity did not exceed 140 cps. Details are shown in Appendix A.

3.2.3.3 Groundwater Assessment. Well 199-K-34 is upgradient of the 116-KW-3 basin and well 199-K-33 is down gradient. The LFI for the 100-KR-4 operable unit (DOE-RL 1993d) shows that carbon-14 was the only contaminant of potential concern with groundwater concentrations greater in the down gradient well than in the upgradient well. All other contaminants were either not detected or had lower concentrations in the down gradient well than in the upgradient well. The 116-KW-3 retention basin does not appear to have a significant impact on groundwater at this time.

3.2.3.4 Conclusions. A number of organic compounds (benzo(a)anthracene, benzo(a)pyrene, benzo(b)fluoranthene, chrysene, di-n-butylphthalate, fluoranthene, indeno(1,2,3-cd)pyrene, phenanthrene, pyrene, tetrachloroethane, and toluene) were detected in the surface soil in and around the 116-KW-3 basin. The origin of these compounds is uncertain. There is no record of the use of these compounds in the reactor effluent.

Cobalt (inorganic metal) was detected in concentrations exceeding the Hanford Site background 95% UTL in a single sample from 10 ft bls at the 116-KW-3B test pit. Therefore, cobalt is considered a contaminant of potential interest.

LFI test results show the presence of radionuclides at all depth intervals in the boreholes and test pits. Concentrations were generally greater near the surface. Below 15 ft, however, radionuclide concentrations were generally detected at concentrations equal to or less than the concentrations detected in operable unit specific control samples (Tables 3-1 and 3-2).

Data collected during the LFI together with historical data show that there is widespread contamination in the surface soils around the 116-KW-3 retention basin. This contamination is likely the result of the basin leakage during operation. Based on sample data (historical and LFI), screening, and geophysical logging, the contamination has not migrated to significant depths. The horizontal extent of contamination has not been defined during the LFI.

3.2.4 116-KE-4 Retention Basin

The 116-KE-4 retention basin is a significant waste site for the 100-K Area. The 116-KE-4 retention basin was used from 1955 to 1971. Like the 116-KW-3 retention basin, it was used to retain effluent cooling water, allowing for thermal cooling of circulated water and decay of short-lived isotopes before release to the Columbia River. The basin consists of three above ground tanks constructed of welded carbon steel plate and each is 250 ft in diameter. Tanks at the 116-KE-4 retention basin are 25 ft high. All tanks are mounted on reinforced-concrete foundations at ground surface. The inlet structure to each tank consists of a 72 inch diameter pipe leading to an outlet chute that discharges at the bottom of the basin.

During operation, this retention basin also frequently developed leaks. According to DOE-RL (1993c), leakage rates through butterfly valves could have been as high as 5,000 to 10,000 gal/min. As with the 116-KW-3 retention basin, the first indications of large leaks occurred before 1965 when extensive ponding reportedly developed between the basins and the road directly to the north. To prevent this ponding, 2 to 3 ft of fill was placed in this area. Cooling water that leaked from the basins flowed overland and under the road by way of culvert. Because the basin was less than 1,000 ft from the shorelines, it was a common occurrence for leaked effluent to reach the Columbia River.

In 1971, the basins were deactivated, pipe entrances were covered for wildlife control, and the walls were washed down. According to DOE-RL (1993c), 4 ft of soil was placed at the bottom of the basin.

The 116-KE-4 site consists of about 16.5 ft of poorly sorted, silty, sandy gravel fill. In situ material from 16.5 to 22.5 ft is also silty, sandy gravel but has fewer small cobbles and more very fine pebbles, sand, and silt.

Historical and LFI information is summarized on Figures 3-6, 3-7, and 3-8.

3.2.4.1 Historical Data. Thirteen samples from 6 locations were collected inside the 116-KE-4 basin. The average GM reading was 2,000 cpm for samples of soil taken in fill material along the bottom of the basins. Predominant radionuclides present in the soil column as a result of cooling water leaks and waste disposal are tritium, cobalt-60, nickel-63, strontium-90, cesium-137, europium-152, europium-154, and europium-155 (Dorian and Richards 1978). Sample results are shown in Appendix B.

Eighteen samples from 12 locations were also collected outside the 116-KE-4 basin. Two samples were generally collected from each location: one at the surface and one from 5 to 20 ft below the surface. Soil contamination in the area surrounding the retention basin had GM readings from 500 to 1,500 cpm. The 116-KE-4 waste site has a total radionuclide inventory of 6.2 Ci. Eighty percent of the total radionuclide inventory is thought to be contained within the soil adjacent to the basins (DOE-RL 1992a).

3.2.4.2 LFI Data. LFI samples were collected adjacent to the tanks and outside the basins downhill of the basins. Adjacent to the retention basin, a single borehole was drilled to determine the nature and vertical extent of contamination beneath the tanks. Outside the basins, two test pits were dug to examine soil contamination due to effluent leakage during basin operation.

Borehole samples for chemical analysis were collected from within the basin area from depths of 0 to 1 ft, 15 to 17 ft, and 20 to 22 ft. These samples were analyzed for radionuclides, semivolatile and volatile organics, PCBs, pesticides and metals. Borehole samples were also collected from 4 to 6, 10 to 12, 13 to 15, and 18 to 20 ft for analysis of physical properties (bulk density, particle-size distribution, moisture content, moisture retention, saturated and unsaturated hydraulic conductivity).

Test pits located outside the basin were sampled at the surface (0 to 6 in.), 5 ft, 10 ft, 15 ft, and 20 ft. These samples were analyzed for metals, volatile and semi-volatile organics, pesticides, PCBs, radionuclides and total activity.

Screening. Field screening for VOCs during borehole drilling was performed using an OVM photoionization detector. Area and site background for VOCs was 0.0 ppm and remained constant throughout drilling.

Radioactivity was monitored during drilling using a Ludlum portable scintillation detector. Area background was recorded to be 2,100 cpm γ, while site background was detected at 6,000 cpm γ. Background β radiation was not reported. Screening measurements for γ-radiation ranged from 1,000 to 1,200 cpm throughout drilling. Screening measurements for β-radiation ranged from 0 to 150 cpm.

The 116-KE-4 site was also tested for hexavalent chromium at depths between 22.0 and 22.5 ft. Hexavalent chromium tests were negative.

The test pit area was monitored during on-site activities for volatile organics and radioactivity with the OVM and the GM, respectively. The readings remained below detection throughout excavation.

Sample Analysis. Four samples from three depth increments (one duplicate) at the 116-KE-4A borehole and five samples from four depth increments (one duplicate) at the 116-KE-4B and the 116-KE-4C test pits were analyzed for chemicals and radionuclides. Detected analytes in the borehole and test pits are presented in Tables 3-8, 3-9, and 3-10.

Organics detected in samples from the borehole were benzo(a)anthracene, benzo(b)fluoranthene, fluoranthene, pyrene, and toluene (see Table 3-8). Benzo(a)anthracene, benzo(b)fluoranthene, fluoranthene, and pyrene were found only in one sample collected at the 0 to 1 ft interval but not its duplicate. Toluene was detected in the 20 to 22 ft sample interval. Acenapthene was detected in a surface sample collected at the 116-KE-4B test pit (see Table 3-9).

No metals or inorganic compounds were detected in samples from the 116-KE-4A borehole or the 116-KE-4C test pit in concentrations above the Hanford Site background 95% UTL (see Table 3-2). In test pit 116-KE-4B, chromium was detected in the surface at a concentration of 85.1 mg/kg (see Table 3-8), which exceeds the background UTL.

Radionuclides detected at the borehole were cesium-134, cesium-137, cobalt-60, europium-152, europium-154, europium-155, plutonium-239/240, potassium-40, radium-226, strontium-90, thorium-228, thorium-232, uranium-233/234, and uranium-238 (see Table 3-8). Radionuclides detected in test pit 116-KE-4B were cesium-137, cobalt-60, europium-152, europium-154, plutonium-238, potassium-40, radium-226, strontium-90, thorium-228, thorium-232, uranium-233/234, and uranium-238 (see Table 3-9). Radionuclides detected in test pit 116-KE-4C were cesium-137, cobalt-60, europium-152, potassium-40, radium-226, thorium-228, thorium-232, uranium-233/234, and uranium-238 (see Table 3-10). Maximum concentrations for the radionuclides in the borehole and the test pits were generally found in samples collected at or near the surface. At the bottom of the borehole or the test pits, the radionuclide concentrations were either not detected or were not appreciably different from concentrations detected at the background sample site, except that cesium-134 was detected in the borehole at 20 ft bls.

Four split spoon samples were taken in conjunction with the 100-KR-1 LFI for physical property analysis. The samples were analyzed as described in Section 2.4. The results will be used to support the 100 Area-wide physical properties report to be issued at a later date. Results for bulk density, porosity, moisture content, and moisture retention are shown in Table 3-11. Saturated hydraulic conductivity and unsaturated hydraulic conductivity analysis have not been completed.

Samples were collected from vadose borehole 116-KE-4A from 4 to 6 ft, 10 to 12 ft, 13 to 15 ft, and 18 to 20 ft bls. These samples were described in the field as silty sandy gravel with 30% to 45% gravel, 45% to 50% sand, and 10% to 25% silt (fines). Laboratory analysis or particle size showed 49% to 73% gravel, 22% to 42% sand, and 5% to 9% fines.

Geophysical Logging. The gamma-ray survey of borehole 116-KE-4A detected potassium-40, uranium, and thorium at levels that are typical of naturally occurring radionuclides in local sediments. The only man-made radionuclide detected was cesium-137, which was detected at several discontinuous depths throughout the survey. An activity level of less than 0.2 pCi/g occurred at 2.5, 5.5, 9.0 to 9.5, 12.5, and 14.5 ft. This activity approaches the minimum detection level for the 80 second survey time. Details of the gamma-ray geophysical logging are shown in Appendix A.

3.2.4.3 Groundwater Assessment. Wells 199-K-27 and 199-K-30 are upgradient of the 116-KE-4 retention basin, and well 199-K-32A is down gradient. The LFI for the 100-KR-4 operable unit (DOE-RL 1993d) shows no contaminants of potential concern with groundwater concentrations greater in the down gradient well than in the upgradient wells. The 116-KE-4 retention basin does not appear to have a significant impact on groundwater at this time.

3.2.4.4 Conclusions. Organic compounds benzo(a)anthracene, benzo(b)fluoranthene, fluoranthene, pyrene, toluene, and acenapthene were detected in samples from the 116-KE-4 site. Historical records do not indicate these contaminants were disposed of on this site or used in the reactor effluent. Their source is unknown. Chromium was the only inorganic compound detected in and around the 116-KE-4 retention basin at concentrations that exceeded the Hanford Site background UTL. It was detected in the surface soil.

LFI test results show the presence of radionuclides at all depth intervals in the boreholes and test pits. However, concentrations were generally greater near the surface. Below 15 ft, radionuclides were generally detected at concentrations equal to or less than the concentrations detected in operable unit specific control samples (Table 3-1 and 3-2).

Data collected during the LFI together with historical data show that there is widespread contamination in the surface soils around the 116-KE-4 retention basin. This contamination is likely the result of the basin leakage during operation. Based on sample data (historical and LFI), screening, and geophysical logging, the contamination has not migrated to significant depths but extends 10 to 20 feet below the surface. The horizontal extent of contaminated soils was not defined during the LFI.

3.2.5 116-K-3 Outfall Structure

The 116-K-3 outfall structure consists of an open, reinforced concrete water box, approximately 30 by 30 ft wide and 15 ft high. The structure is 10 ft above grade and 20 ft below grade. The outfall structure collected reactor effluent discharge from the 116-KW-3 and the 116-KE-4 retention basins. Waste from the structure was discharged to the center of the Columbia River through a steel pipeline. The structure could also discharge to the river through an emergency overflow spillway.

No investigation of local geology has been conducted; however, it is expected that the unit is underlain by sands and gravels similar to those encountered at other sites in the 100-KR-1 operable unit. No historical or recent sampling has been conducted at the site.

3.2.5.1 LFI Data. The 100-KR-1 did not include a field investigation of the 116-K-3 outfall structure. Therefore data are not available for soil concentrations of organic, inorganic, and radionuclide constituents; field screening for VOC and radiological contamination, or geophysical borehole logs.

3.2.5.2 Groundwater Assessment. The unit is located adjacent to the river and there are no down gradient wells in the vicinity of the site. Consequently, no assessment of impacts to groundwater by this site can be made.

3.2.5.3 Conclusions. No site-specific information exists to evaluate contamination at the 116-K-3 outfall structure. Therefore, analogous sites will be used to determine likely contamination. Analogous sites to the 116-K-3 outfall structure are identified in Table 1-1. Of these sites, only the 116-D-5 outfall structure and the 116-DR-5 outfall structure have been examined by an LFI. The 100-DR-1 LFI (DOE-RL 1993e) did not identify any metals above the Hanford Site UTL. Several organic compounds were identified including trichloroethane, bis(2-ethylhexyl)phthalate, butylbenzyl phthalate, and dieldrin. No source for these compounds was identified. The only radionuclides detected at 116-D-5 were carbon-14, potassium-40, radium-226, and thorium-228. No man-made radionuclides were detected. At the 116-DR-5 outfall structure, historical information identified radiological contamination in surface samples and carbon-14, uranium-235, plutonium-239, and americium-241 were detected in a borehole. Based on the information from analogous sites, it is possible that there is contamination remaining at the 116-K-3 outfall structure.

3.2.6 Process Effluent Pipelines

The discharge system includes effluent lines from 116-KE-4 and 116-KW-3 retention basins to the 116-K-3 outfall structure, 116-K-1 crib, and 116-K-2 trench. Effluent discharge pipelines and valves may have developed leaks during their periods of operation.

No investigation of local geology has been conducted; however, it is expected that the unit is underlain by sands and gravels similar to those encountered at other sites in the 100-KR-1 operable unit. No historical or recent sampling has been conducted at the site.

3.2.6.1 Historical Investigations. Three of the four analogous sites for the process effluent pipelines, listed in Table 1-1 were characterized during a recent study (Beckstrom and Steffes 1986). Testing consisted of radiological characterization of direct and smear surveys of sample pipe sections, isotopic analyses of scrapings taken from the interior section of the pipes and isotopic analyses of the loose scale and sediment from the pipe located near the shore. No contamination was found on the exterior of any pipe, therefore, the contact dose rate was zero. Radioactive material was located on the interior surface and in the loose scale from inside the pipe (see Table 3-12). The contact dose rate on the interior surface was less than 1 mrem/hr. The predominant isotopes found in the lines were europium-152 and europium-154. The concentrations in the scrapings were higher than the concentrations in sediment inside the pipe (Beckstrom and Steffes 1986). Contamination appears to be associated with rust and sediments held within the pipes.

3.2.6.2 LFI Data. The 100-KR-1 did not include a field investigation of the process effluent pipelines. Therefore, data are not available for soil concentrations of organic, inorganic, and radionuclide constituents; field screening for VOC and radiological contamination, or geophysical borehole logs.

3.2.6.3 Groundwater Assessment. Because of the extensive nature of the process effluent pipelines across the site and their proximity to other waste sites, no assessment of impacts to groundwater can be made. It can be assumed that leaks/unplanned releases that may have occurred in the past in the pipelines may have been a contributor of contaminants to the groundwater.

3.2.6.4 Conclusions. No site specific information exists to evaluate contamination at the process effluent pipelines. However, three of the four analogous sites identified in Table 1-1 have been examined. A study at these analogous sites (Beckstrom and Steffes 1986) shows contact rate on the exterior of the pipe was zero, while on the inside it was <1 mrem/hr. Radionuclide contamination exists as scale on the inside of the pipe. Because there is no contamination on the exterior of the pipes, the immediate risk for contaminant migration is minimal. Note that potential soil contamination due to pipeline leakage has not been specifically evaluated. Soil contamination can be evaluated during remediation using the observational approach.

3.3 DATA QUALITY OBJECTIVES

Data quality objectives for the 100-KR-1 LFI, including the decision types, the data uses and needs, and a data collection program, were established in the 100-KR-1 RI/FS work plan and associated quality assurance project plan (DOE-RL 1992a). The overall project objective was to produce data for one or more of the project purposes:

- Confirm or revise the conceptual exposure assessment models for specific waste sites and/or areas of contaminated environmental media
- Support a qualitative risk assessment
- Support development and evaluation of IRMs
- Support the quantitative baseline risk assessment for the operable unit

- Support the ARARs evaluation
- Support development, evaluation, and selection of a final remedial alternative.

To fulfill these objectives, the workplan established a data collection program using a streamlined approach with a bias for action as outlined in the HPPS. This approach focused on using a limited amount of new data at high-priority sites together with historical or analogous site data to evaluate the need for IRMs with the intention to use the observational approach during remedial measure implementation to complete any additional characterization needed to define the extent of contamination.

To ensure that data are sufficient to fulfill project data quality objectives, the data collected during the LFI are evaluated against relevant precision, accuracy, representativeness, completeness, and comparability (PARCC) parameters. Precision and accuracy goals are met by using methods specified in the workplan with maximum detection or quantitation limit values and maximum acceptable ranges for accuracy and precision. Representativeness is achieved by collecting samples at locations and sampling depth or intervals that are specified in descriptions of work for the LFI activities. Objectives for completeness of this LFI require that contractually or procedurally established requirements for precision and accuracy be met for at least 90 percent of the total number of requested determinations. A failure to meet the completeness criteria will be documented and evaluated during the data validation process. The use of approved analytical procedures, reporting techniques, and units as specified in the quality assurance project plan will facilitate comparability of data sets.

The LFI data reported in this report were collected and analyzed in accordance with the workplan (DOE-RL 1992a) and description of work (Green 1992). No discrepancies were noted in the data validation reports (WHC 1992 a,b,c,d). Therefore, the data are judged to meet the PARCC parameters and have been used accordingly to satisfy project objectives and are judged adequate to meet data quality objectives for the 100-KR-1 LFI. The LFI and historical data all show similar radiological contaminants and similar concentrations. Therefore, the historical data are considered to be sufficiently accurate to provide additional information on extent of contamination. The LFI data together with historical data are sufficiently complete to make IRM decisions and for other data uses.

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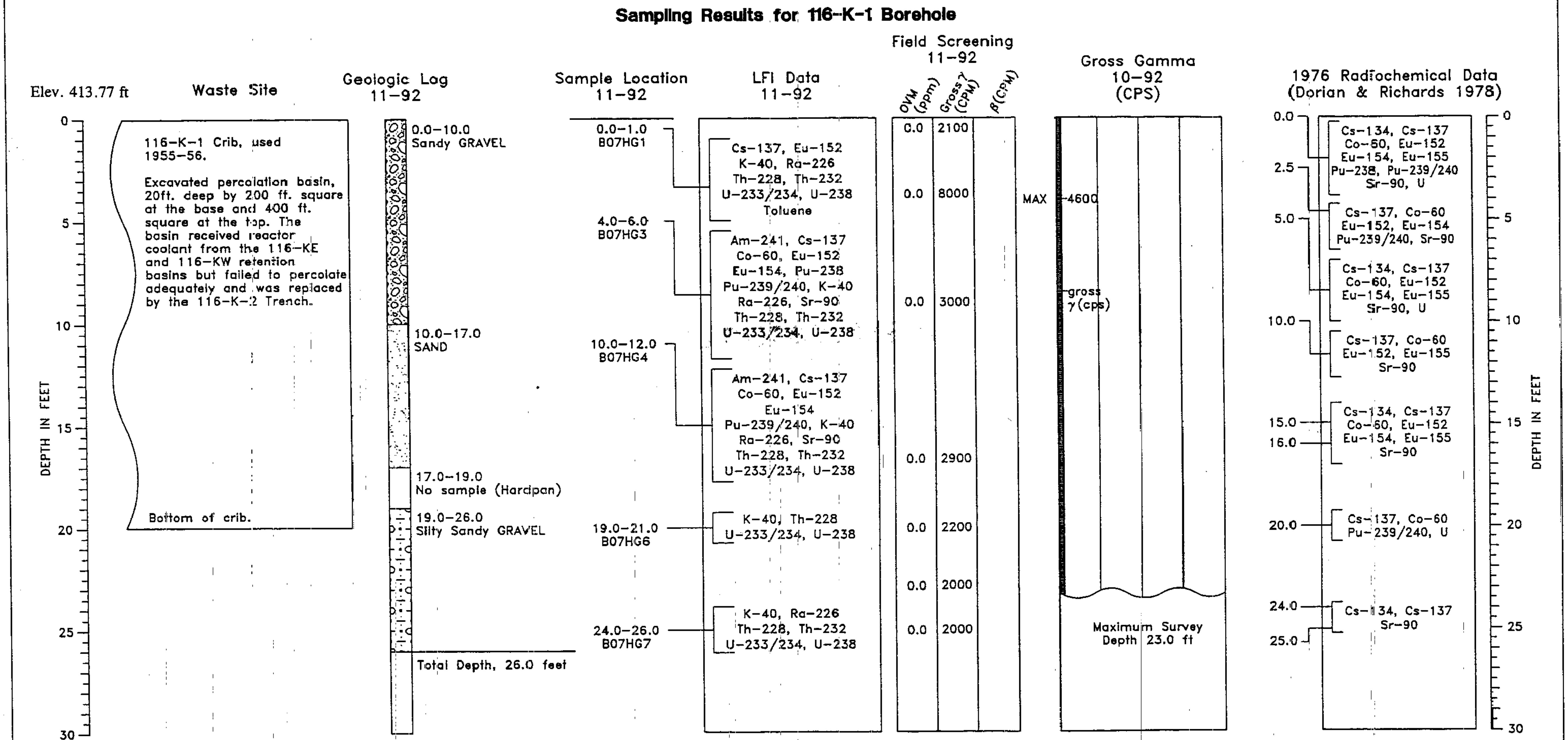

NOTES:

LFI Data – Analytical lab results for all inorganic constituents greater than 95% upper threshold limits and all detected organic compounds and radionuclides are shown.

Field Screening – Action levels for volatile organic compounds (VOC) was 10ppm and for Gross Gamma (γ) radiation was twice background. All Gross γ radiation was below background (1900cpm γ).

Borehole log indicated the depth interval of Fill was 0 to 9.5 ft. bgs.

Only a gross gamma survey was conducted in this borehole.

1976 Radiochemical Data – All radionuclides found in samples from the corresponding depth intervals are shown.

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Figure 3-1. Summary Diagram for the 116-K-1 Borehole.

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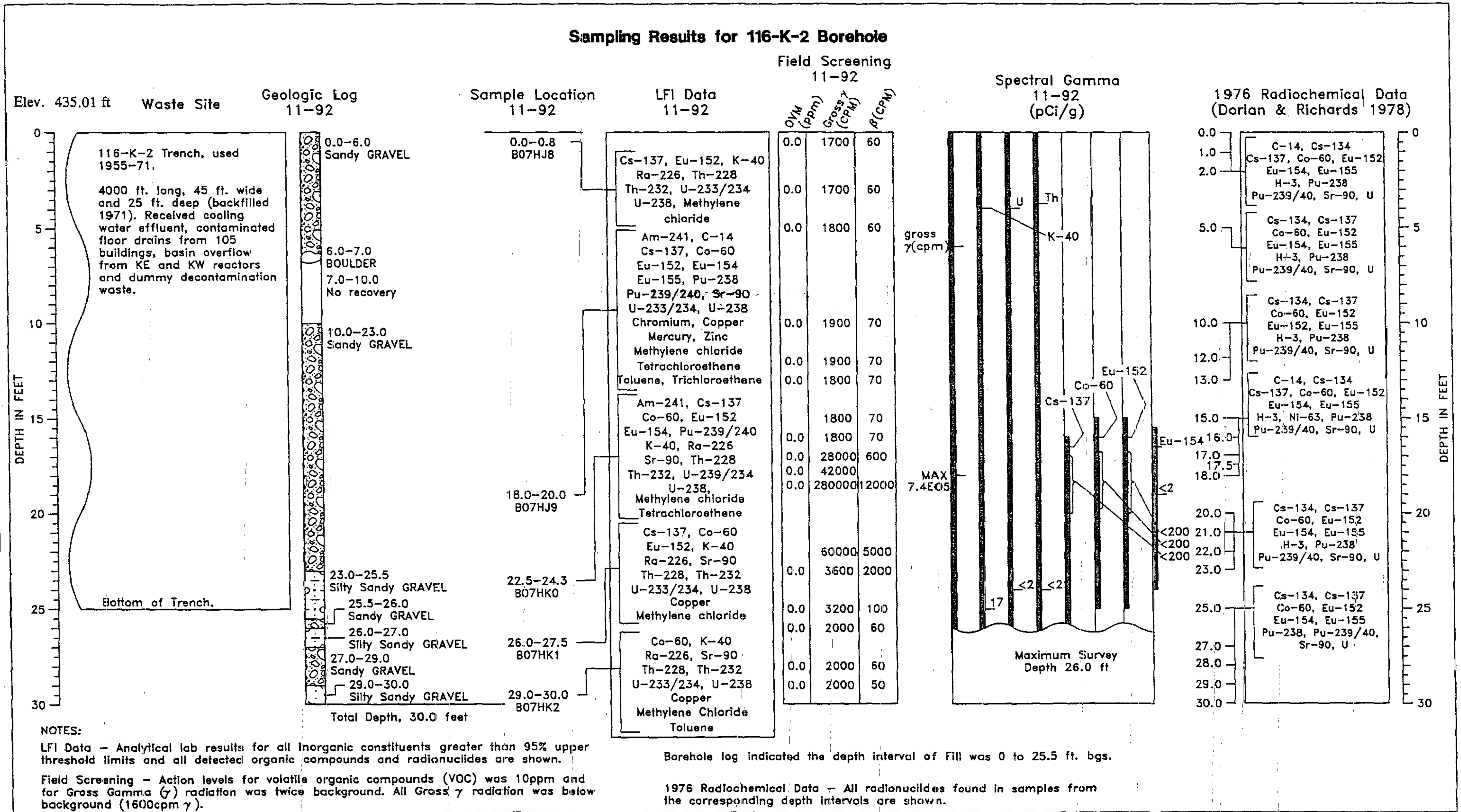

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Figure 3-2. Summary Diagram for the 116-K-2 Borehole.

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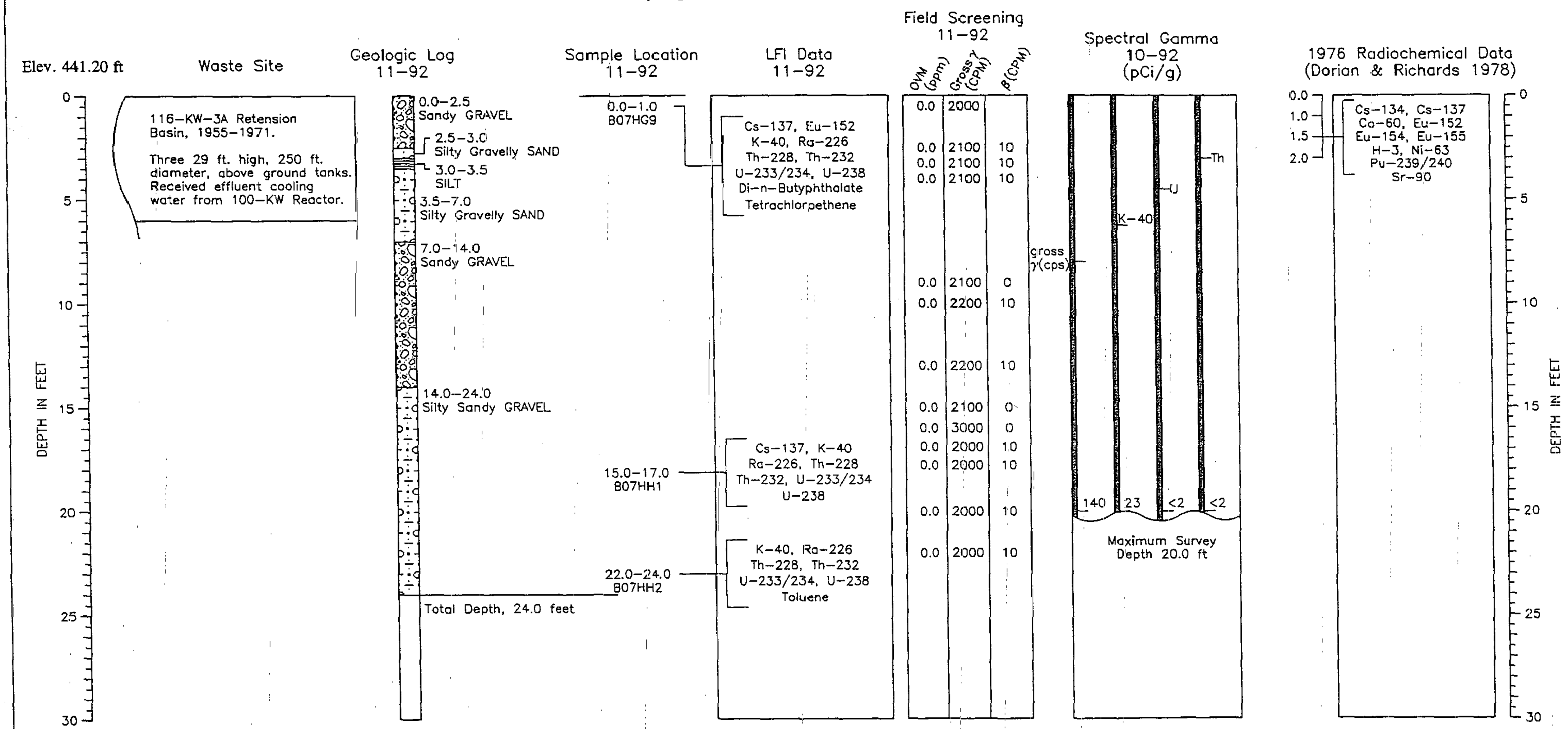
Sampling Results for 116-KW-3A Borehole



NOTES:

LFI Data — Analytical lab results for all inorganic constituents greater than 95% upper threshold limits and all detected organic compounds and radionuclides are shown.

Field Screening — Action levels for volatile organic compounds (VOC) was 10ppm and for Gross Gamma (γ) radiation was twice background. All Gross γ radiation was below background (3000cpm γ).

Borehole log indicated the depth interval of Fill was 0 to 24 ft. bgs.
No manmade radionuclides were detected in the borehole survey.

1976 Radiochemical Data — All radionuclides at the corresponding depth intervals are shown. Samples were collected in material described as Fill.

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Figure 3-3. Summary Diagram for the 116-KW-3A Borehole.

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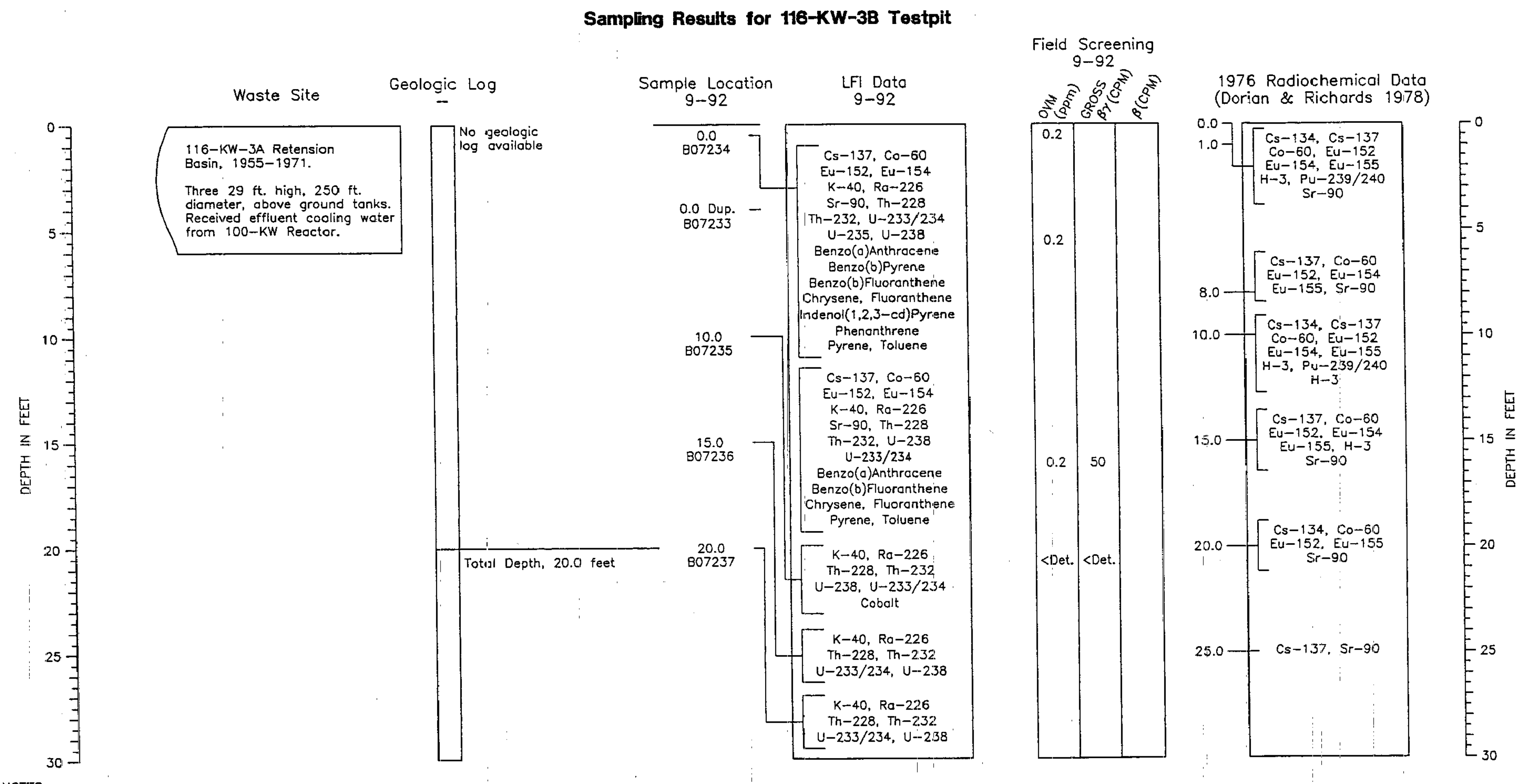

NOTES:

LFI Data — Analytical lab results for all inorganic constituents greater than 95% upper threshold limits and all detected organic compounds and radionuclides are shown.

Field Screening — Action levels for volatile organic compounds (VOC) was 10ppm and for Gross Beta Gamma ($\beta\gamma$) radiation was twice background. All Gross $\beta\gamma$ radiation was below background (50cpm $\beta\gamma$).

Borehole Spectral/Gamma Log — No geophysical survey was performed.

1976 Radiochemical Data — All radionuclides found in samples from the corresponding depth intervals are shown. Sample locations are located outside of the basin.

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Figure 3-4. Summary Diagram for the 116-KW-3B Testpit.

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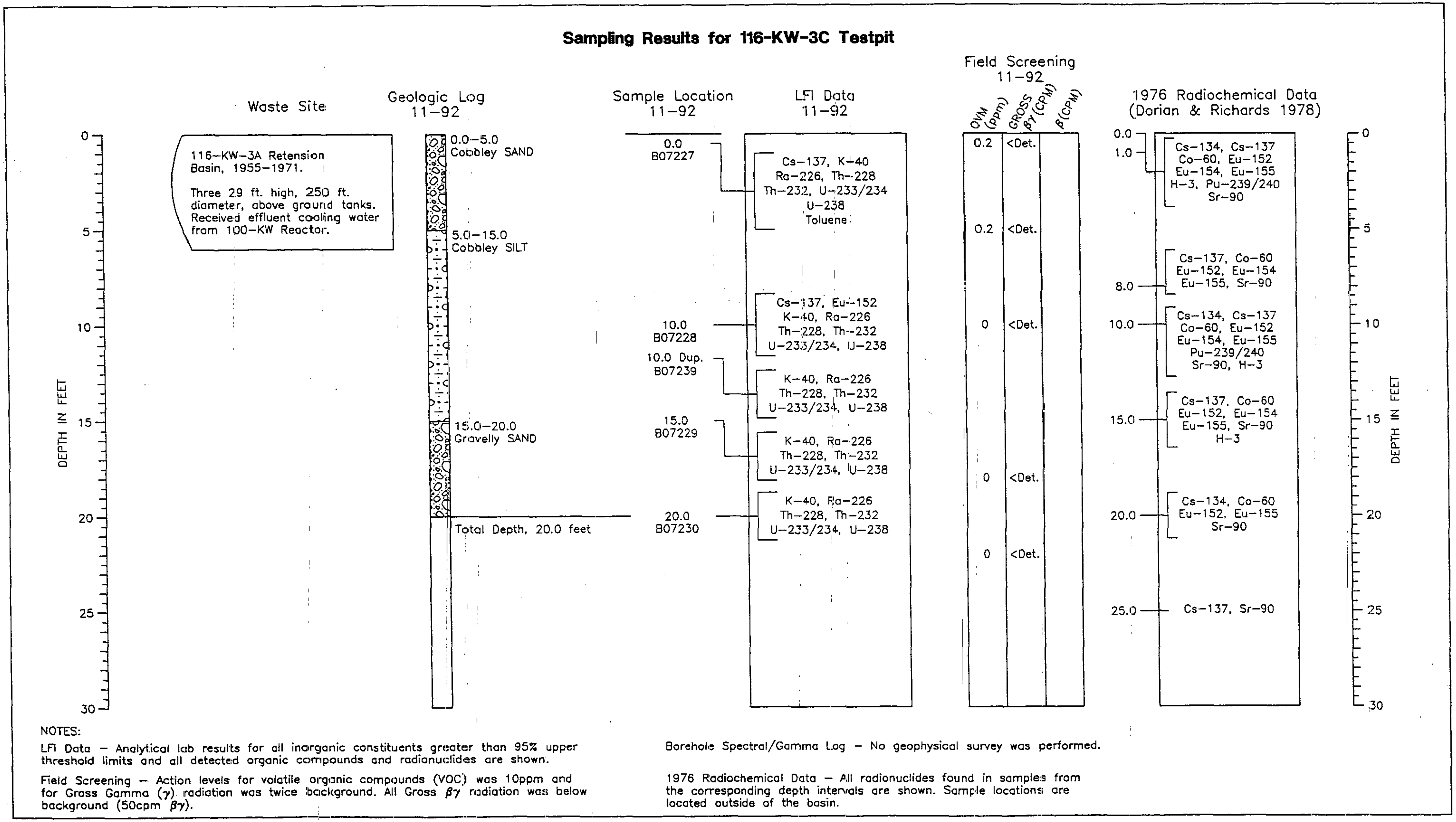

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Figure 3-5. Summary Diagram for the 116-KW-3C Testpit.

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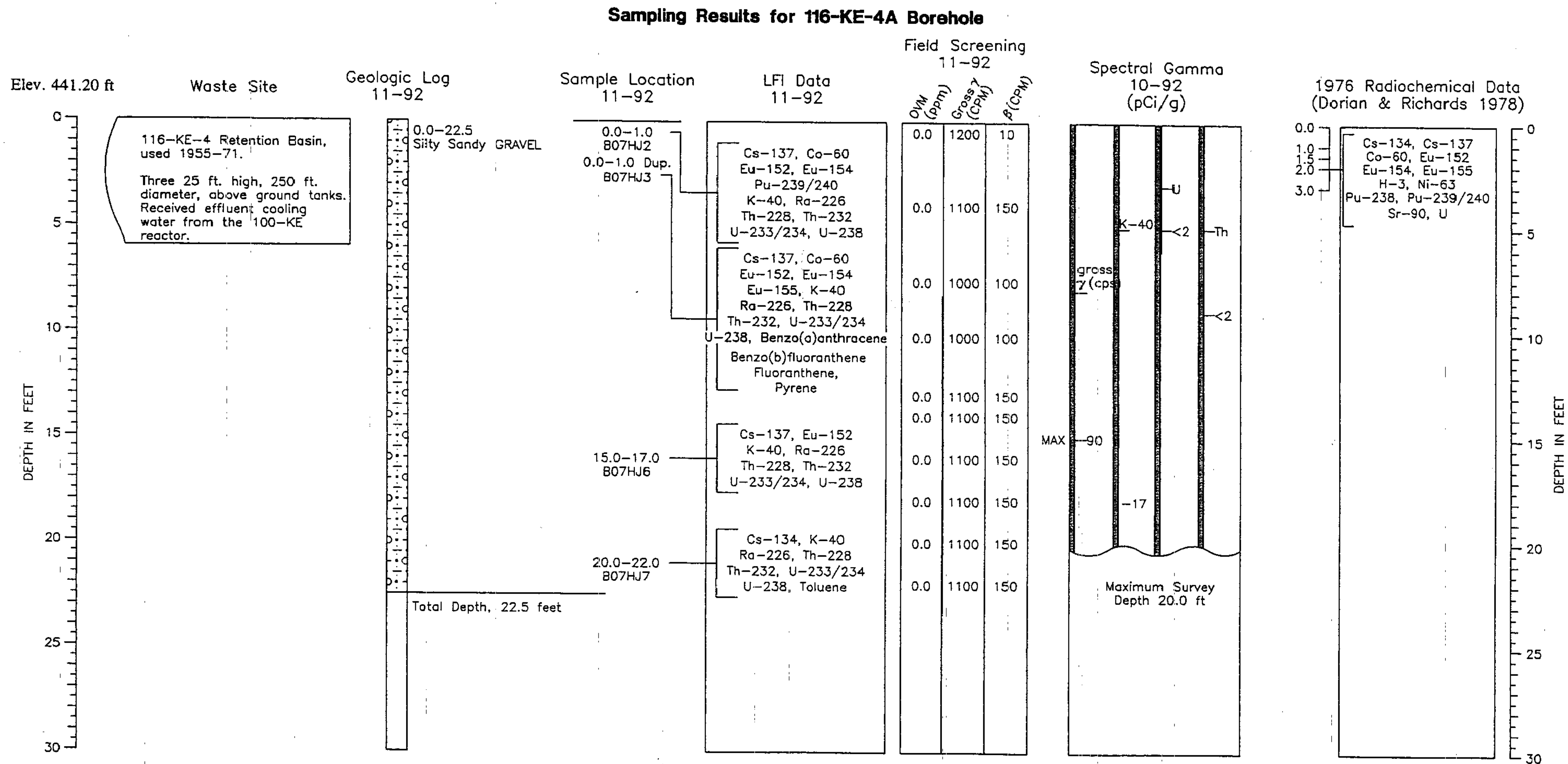

NOTES:

LFI Data – Analytical lab results for all inorganic constituents greater than 95% upper threshold limits and all detected organic compounds and radionuclides are shown.

Field Screening – Action levels for volatile organic compounds (VOC) was 10ppm and for Gross Gamma (γ) radiation was twice background. All Gross γ radiation was below background (2100cpm γ).

Borehole log indicated the depth interval of Fill was 0 to 16.5 ft. bgs.

Cs-137 was the only manmade radionuclide detected in the borehole survey, activity was < 0.2 pCi/g, and was not plotted.

1976 Radiochemical Data – All radionuclides found in samples from the corresponding depth intervals are shown. Samples collected in material described as Fill.

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Figure 3-6. Summary Diagram for the 116-KE-4A Borehole.

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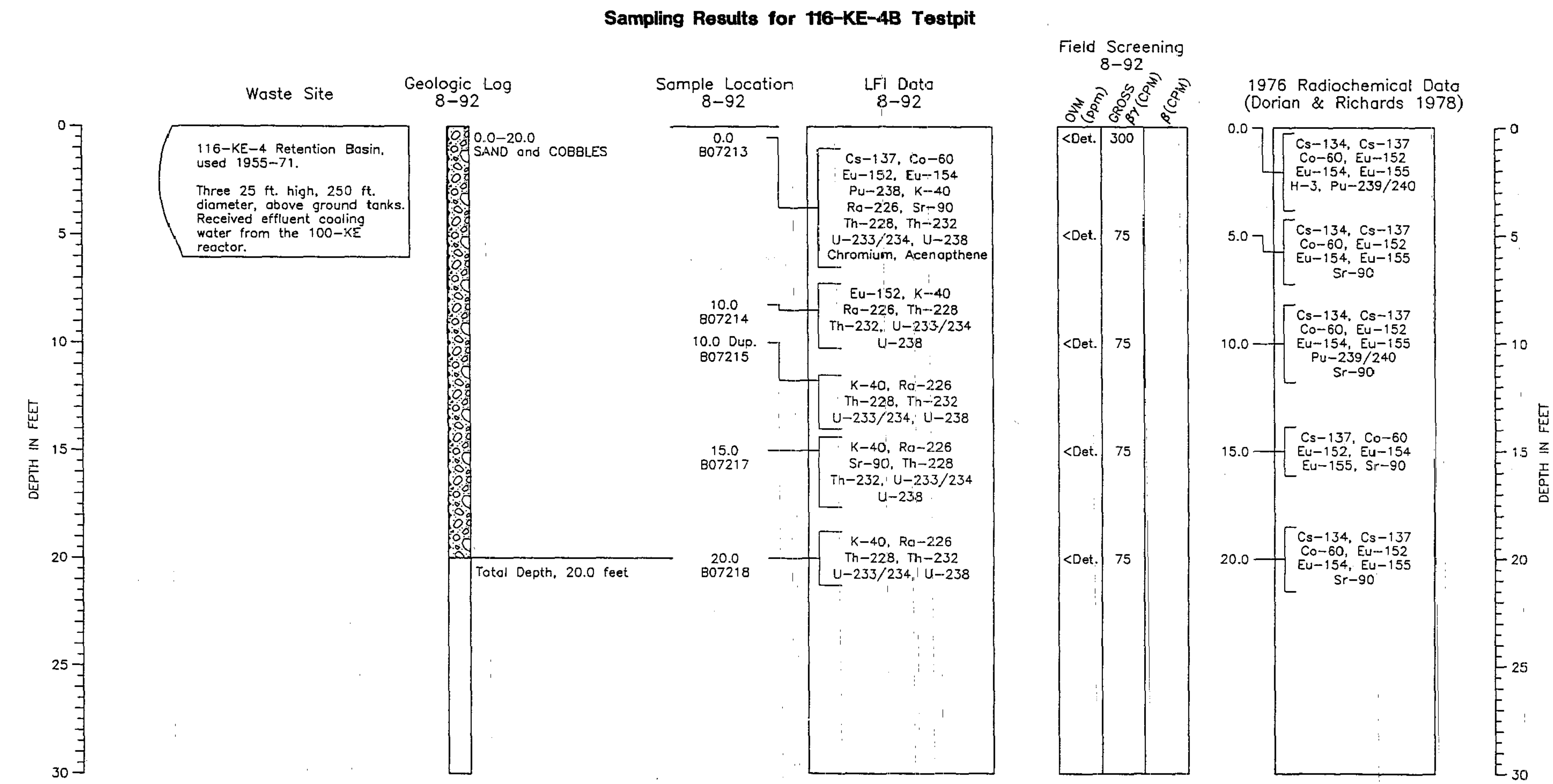

NOTES:

LFI Data – Analytical lab results for all inorganic constituents greater than 95% upper threshold limits and all detected organic compounds and radionuclides are shown.

Field Screening – Action levels for volatile organic compounds (VOC) was 10ppm and for Gross Gamma (γ) radiation was twice background.

Borehole Spectral/Gamma Log – No geophysical survey was performed.

1976 Radiochemical Data – All radionuclides found in samples from the corresponding depth intervals are shown. Sample locations are located outside of the basin.

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Figure 3-7. Summary Diagram for the 116-KE-4B Testpit.

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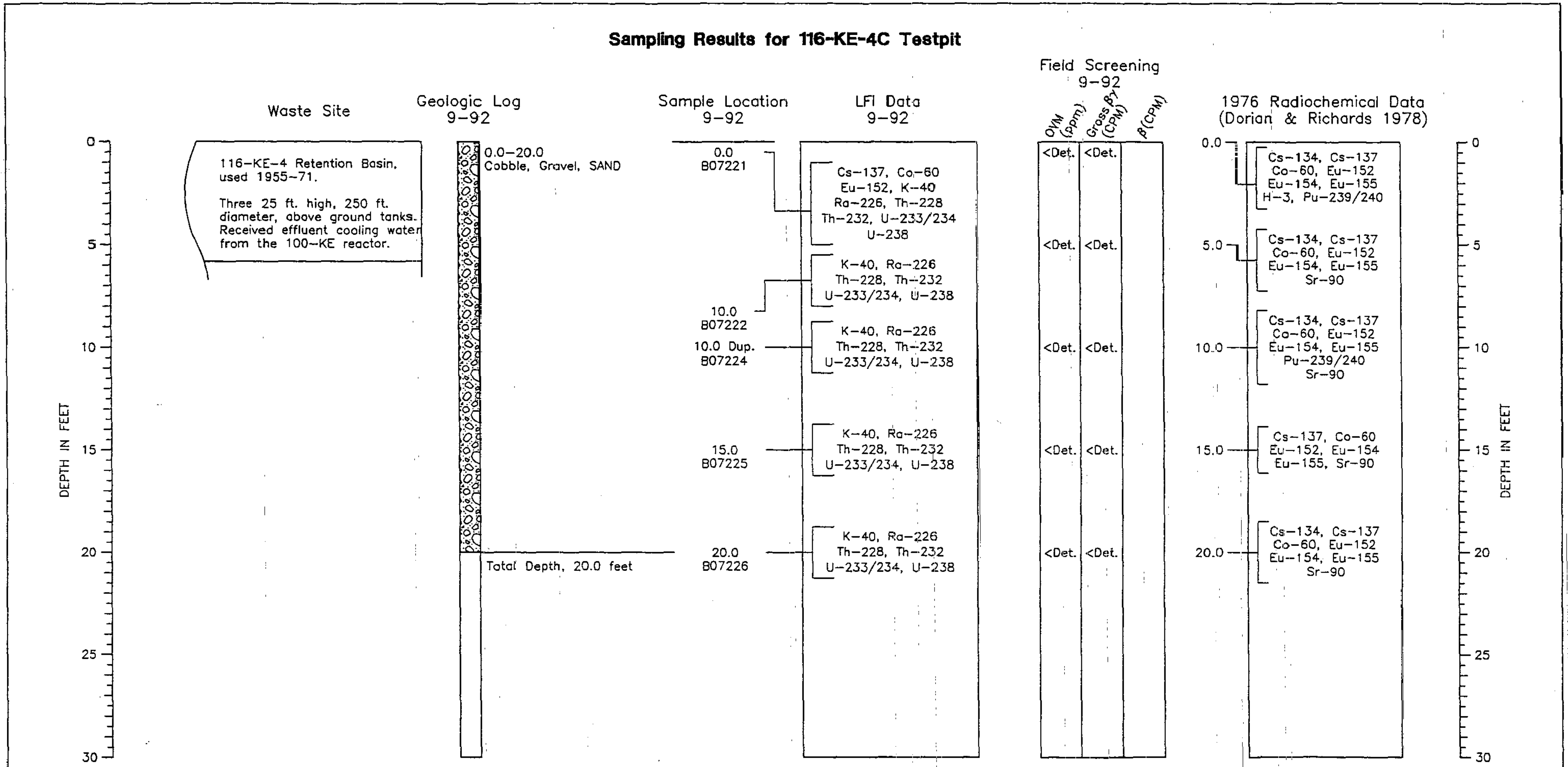

NOTES:

LFI Data – Analytical lab results for all inorganic constituents greater than 95% upper threshold limits and all detected organic compounds and radionuclides are shown.

Field Screening – Action levels for volatile organic compounds (VOC) was 10ppm and for Gross Gamma (γ) radiation was twice background. All Gross βγ radiation was below background (<75cpm βγ).

Borehole Spectral/Gamma Log – No geophysical survey was performed.

1976 Radiochemical Data – All radionuclides at the corresponding depth intervals are shown. Sample locations are located outside of the basin.

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Figure 3-8. Summary Diagram for the 116-KE-4C Testpit.

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Table 3-1. Analytes Detected in Operable Unit Control Samples.

Sample Number (depth)	BO7HG1 (0 ft)	BO7HK3 (0 ft)
Radionuclides	pCi/g	pCi/g
Cesium-134	ND	0.052
Cesium-137	0.46	0.067
Gross Beta	12.0	15.0
Potassium-40	11.0	12.0
Radium-226	0.39	0.58
Thorium-228	0.72	0.78
Thorium-232	0.60	0.85
Uranium-233/234	0.46	0.40
Uranium-238	0.32	0.63
Inorganics	mg/kg	mg/kg
Aluminum	5,480	8,030
Arsenic	<1.90	1.90B
Barium	63.3J	78.6
Beryllium	0.54	0.44B
Chromium	≤6.7	9.00
Cobalt	8.30	10.7
Copper	11.7	12.7
Iron	16,400	20,100
Lead	6.40	<5.4
Magnesium	<2,870	3,580
Manganese	306	366
Nickel	8.10	8.70
Nitrate-Nitrite (mg-N/kg)	3.71	ND
Potassium	<911	1,470
Silver	<1.2	1.10B
Vanadium	42.0	44.9
Zinc	37.0J	39.7
Organics	ug/kg	ug/kg
Toluene	29.0	ND
ND = not detected		

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Table 3-2. Operable-Unit Specific Control and Site-Wide Background. (Page 1 of 2)

	Local Control			Hanford Site Background				
Analyte	$\bar{X}$	S	95% Distribution[a]	$\bar{X}^b$	S^b	N^b	95% Distribution[c]	95% UTL[d]
Inorganics (mg/kg)								
Aluminum	6,755	1,803	11,448	8,302	3,225	119	13,621	15,082
Antimony	<3.2			<15.2	--	65		
Arsenic	1.43	0.67	2.94	4.2	1.66	117	7.63	9.0
Barium	71.0	10.8	95.9	94.5	32	119	155.9	174.6
Beryllium	0.49	0.071	0.65	1.1	0.34	117	1.58	1.8
Cadmium	<0.3	--		<0.7	--	117		
Calcium	<3470	---		11,311	9,577	119	21,012	24,642
Chromium	6.2	4.0	15.2	11.3	6.09	119	24.13	28.2
Cobalt	9.5	1.7	13.58	12	3.01	118	17.58	18.9
Copper	12.2	0.7	13.9	15.8	5.3	119	25.3	27.9
Iron	18,250	2,616	24,838	24,584	5,822	119	35,746	38,246
Lead	4.6	2.6	10.7	6.2	3.47	119	12.61	14.9
Magnesium	2,508	1,517	6,411	5,250	1,588	119	7,970	8,760
Manganese	336	42.4	439	384	93.1	119	548	583
Mercury	<0.06	--		0.3	0.44	118	0.61	1.3
Nickel	8.4	0.4	9.43	13.2	4.96	119	22.16	24.7
Potassium	963	717	2,578	1,414	604	117	2,676	3,090
Selenium	<0.82			<5	--	98		
Silver	0.85	0.35	1.69	1.5	1.22	117	1.48	2.1
Sodium	<175	--		480	787	117	969	1,393
Thallium	<0.33	--		<3.7	--	118		
Vanadium	43.5	2.1	48.7	58.3	19.9	119	96.7	106.5
Zinc	38.4	1.9	43.0	52.6	13.1	119	74.7	78.9
Radionuclides (pCi/g)								
Cesium-137	0.26	0.28	0.91	NR	NR	--	NR	NR
Potassium-40	11.5	0.71	13.3	NR	NR	--	NR	NR
Radium-226	0.49	0.13	0.84	NR	NR	--	NR	NR
Thorium-228	0.75	0.042	0.86	NR	NR	--	NR	NR
Thorium-232	0.73	0.18	1.2	NR	NR	--	NR	NR
Uranium-233/234	0.43	0.042	0.53	NR	NR	--	NR	NR

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Table 3-2. Operable-Unit Specific Control and Site-Wide Background. (Page 2 of 2)

Local Control				Hanford Site Background				
Analyte	$\bar{X}$	S	95% Distribution[a]	$\bar{X}$[b]	S[b]	N[b]	95% Distribution[c]	95% UTL[d]
Uranium-238	0.48	0.22	1.0	NR	NR	--	NR	NR

Source: DOE-RL 1993b

[a] 95th percentile of the data for a lognormal distribution of the population estimate.

[b] Mean ($\bar{X}$), standard deviation (S) and sample size (N).

[c] 95th percentile of the data for a lognormal distribution, except copper and magnesium, which are based on a Weibull distribution.

[d] 95% upper confidence limit of the 95th percentile of the data distribution.

NR = not reported

Table 3-3 Analytes Detected in Samples from the 116-K-1 Borehole.

Sample Number	B07HG1	BO7HG3	BO7HG4	BO7HG6	BO7HG7
Depth Interval	0-1 ft	4-6 ft	10-12 ft	19-21 ft	24-26 ft
Radionuclides	pCi/g	pCi/g	pCi/g	pCi/g	pCi/g
Americium-241	ND	1.7	0.047 J	ND	ND
Cesium-137	0.34	150	3.5	ND	ND
Cobalt-60	ND	15	0.58	ND	ND
Europium-152	0.09J	76	4.3	ND	ND
Europium-154	ND	12	0.74	ND	ND
Plutonium-238	ND	0.19J	ND	ND	ND
Plutonium-239/240	ND	2.4J	0.07J	ND	ND
Potassium-40	10	17	13	9.6	13
Radium-226	0.47	0.57	0.42	ND	0.44
Strontium-90	ND	3.9	5.4	ND	ND
Thorium-228	0.66	0.8	0.64	0.6	0.65
Thorium-232	0.77	0.74	0.46	ND	0.74
Uranium-233/234	0.49	0.61	0.35	0.29J	0.38
Uranium-238	0.64	0.57	0.54	0.2J	0.44
Inorganics	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg
Aluminum	5,010	5,450	4,730	3,800	4,180
Arsenic	ND	2.7	ND	ND	ND
Barium	57.8J	60.4J	59.6J	46J	50.1J
Beryllium	ND	ND	0.62	ND	0.52
Chromium	ND	13J	10J	9.3J	11.1J
Cobalt	9.3	7.5	5.4	3.8	3.7
Copper	14.7	27.3	10.6	11	20.1
Iron	18,800	16,500	12,700	8,840	8,080
Magnesium	3,810	4,430	4,180	ND	ND
Manganese	298	281	238	185	170
Mercury	ND	0.31	ND	ND	ND
Nickel	7.7	10.7	9.8	6.7	7.3
Nitrate/Nitrite (mg-N/kg)	18.6	ND	ND	ND	ND
Vanadium	41.7	37.1	22.7	14.9	15.9
Zinc	35.1J	43.8J	28.5J	24.3J	24.1J
Organics	ug/kg	ug/kg	ug/kg	ug/kg	ug/kg
Toluene	2	ND	ND	ND	ND

J = estimated value
ND = not detected

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Table 3-4. Analytes Detected in Samples From the 116-K-2 Borehole. (sheet 1 of 2)

Sample Number	BO7HJ8	BO7HJ9	BO7HK0	BO7HK1	BO7HK2
Depth Interval	0-1 ft	18-20 ft	22.5-24.3 ft	26-27.5 ft	29-30 ft
Radionuclides	pCi/g	pCi/g	pCi/g	pCi/g	pCi/g
Americium-241	ND	13	0.08	ND	ND
Carbon-14	ND	11J	ND	ND	ND
Cesium-137	0.014	1,900	17	0.14	ND
Cobalt-60	ND	370	22	1.6	0.077
Europium-152	0.12	1,600	23	0.4	ND
Europium-154	ND	250	3.2	ND	ND
Europium-155	ND	15	ND	ND	ND
Plutonium-238	ND	2.1	ND	ND	ND
Plutonium-239/240	ND	44	0.077	ND	ND
Potassium-40	12	ND	14	13	12
Radium-226	0.49	ND	0.48	0.5	0.44
Strontium-90	ND	15	3.5	2.1	2.5
Thorium-228	1.1	ND	0.82	0.69	0.85
Thorium-232	0.71	ND	0.82	0.58	0.48
Uranium-233/234	0.54	0.81	0.61	0.35	0.48
Uranium-238	0.36	0.46	0.43	0.56	0.34
Inorganics	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg
Aluminum	7,430	5,900	6,450	6,330	5,680
Arsenic	2.5	2.1	1.5	1.4B	1.4B
Barium	63	58.2	74.7	64.5	122
Beryllium	0.68	0.37	0.44	0.23B	0.58B
Chromium	11.2	153	21.7	17.2	14.9
Cobalt	10.1	7.8	7.5	5.8B	6.1B
Copper	18.6	44.9	ND	37.8	30.7
Iron	21,000	17,000	13,900	11,600	12,700
Magnesium	5,050	4,290	4,350	3,760	3,810
Manganese	309	229	297	249	284
Mercury	ND	3.9	ND	0.13	ND
Nickel	11.3	14	10.7	9.1	10.1
Nitrate/Nitrite (mg-N/kg)	ND	4.42J	ND	ND	ND
Potassium	1,550	ND	1,240	1,180	1,220
Silver	ND	ND	ND	0.86B	1.5B
Vanadium	42	39.4	26.3	25.8	23.3
Zinc	44.5J	143J	63.6J	39	35.5

Table 3-4. Analytes Detected in Samples From the 116-K-2 Borehole. (sheet 2 of 2)

Sample Number	BO7HJ8	BO7HJ9	BO7HK0	BO7HK1	BO7HK2
Depth Interval	0-1 ft	18-20 ft	22.5-24.3 ft	26-27.5 ft	29-30 ft
Organics	**ug/kg**	**ug/kg**	**ug/kg**	**ug/kg**	**ug/kg**
Methylene Chloride	**1J**	**3J**	**2J**	**2J**	**2J**
Tetrachloroethene	**ND**	**4J**	**3J**	**ND**	**ND**
Toluene	**ND**	**5J**	**ND**	**ND**	**5J**
Trichloroethene	**ND**	**2J**	**ND**	**ND**	**ND**

Note: Shaded values exceed Hanford Site UTL (Table 3-2).
J = estimated value
B = For organics, analyte detected in blank sample, for inorganics, analyte was detected at a concentration between IDL and CRDL.
ND = not detected

Table 3-5. Analytes Detected in Samples From the 116-KW-3A Borehole.

Sample Number	BO7HG9	BO7HH1	BO7HH2
Depth Interval	0-1 ft	17-19 ft	22-24 ft
Radionuclides	pCi/g	pCi/g	pCi/g
Cesium-137	0.2	0.64	ND
Europium-152	0.29	ND	ND
Potassium-40	9.9	9.5	13
Radium-226	0.42	0.39	0.49
Thorium-228	0.69	0.5	0.64
Thorium-232	0.57	0.45	0.68
Uranium-233/234	0.54	0.34	0.44
Uranium-238	0.43	0.42	0.33
Inorganics	mg/kg	mg/kg	mg/kg
Aluminum	6,420	6,110	5,740
Arsenic	3.2	1.8B	2.2B
Barium	69.6	67.1	50.9
Beryllium	0.77B	ND	0.2B
Chromium	8	10.9	11.3
Cobalt	11.5	6.9B	5.4B
Copper	21.2	20.7	11.3
Iron	23,200	13,400	11,100
Lead	14.8	ND	ND
Magnesium	5,170	3,900	3,660
Manganese	359	246	210
Nickel	9.2	10.8	10.7
Nitrate/Nitrite (mg-n/kg)	ND	3.03	ND
Potassium	1,230	1,110	1,060
Thallium	ND	ND	0.32
Vanadium	49.9	33.1	26.9
Zinc	52.3	31.2	27.2
Organics	ug/kg	ug/kg	ug/kg
Di-n-Butylphthalate	44BJ	ND	ND
Tetrachloroethene	4J	ND	ND
Toluene	ND	ND	2J

Note: analyte detect in blank
J = estimated value
B = For organics, analyte detected in blank sample, for inorganics, analyte was detected at a concentration between IDL and CRDL.
ND = not detected

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Table 3-6. Analytes Detected in Samples Collected from 116-KW-3B Test Pit.
(sheet 1 of 2)

Sample Number	BO7234	BO7233	BO7235	BO7236	BO7237
Depth	0 ft	0 ft	10 ft	15 ft	20 ft
Radionuclides	pCi/g	pCi/g	pCi/g	pCi/g	pCi/g
Cesium-137	12	11	ND	ND	ND
Cobalt-60	0.89	1.1	ND	ND	ND
Europium-152	7.8	8.8	ND	ND	ND
Europium-154	1.1	1.2	ND	ND	ND
Potassium-40	12	11	14	15	16
Radium-226	0.5	0.6	0.63	0.86	0.85
Strontium-90	0.84J	1.1	ND	ND	ND
Thorium-228	0.81	0.86	1.1	1.2	1.7
Thorium-232	0.56	0.56	0.96	1.1	1.4
Uranium-233/234	17	0.6	0.7	0.74	1
Uranium-235	1.7	ND	ND	ND	ND
Uranium-238	17	0.48	0.53	0.91	0.73
Inorganics	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg
Aluminum	6,370	7,370	9,860	7,990	7,960
Arsenic	1.9	1.9B	1.9B	4	4.1
Barium	64.6	66.7	90.4	75.8	65.4
Beryllium	0.39B	0.58B	0.6B	0.47B	0.53B
Chromium	17.8	16.3	14.8	16.8B	17.2
Cobalt	10.4	10.1	90.4B	7.5	7.3B
Copper	16.7	18.3	15.3	13.2	11.8
Fluoride	ND	3	3	ND	ND
Iron	20,100	18,800	20,300	16,300	16,100
Lead	8.2	11.3	6.5	ND	ND
Magnesium	4,500	4,610	4,300	6,070	6,360
Manganese	305	308	368	292	262
Mercury	0.11	0.2	0.06B	0.06B	ND
Nickel	10.4	10.7	11.8	15.2	15.7
Nitrate/Nitrite (mg-N/kg)	18.8	9.18	ND	ND	2.91
Phosphate	14	15	14	ND	ND
Potassium	1,510	1,620	1,990	1,610	1,080
Silver	1.1B	ND	0.95B	0.84B	0.98B
Vanadium	47	43.2	44	33	33.9
Zinc	58.1	59.4	52.4	ND	39.7

Table 3-6. Analytes Detected in Samples Collected from 116-KW-3B Test Pit.
(sheet 2 of 2)

Sample Number	BO7234	BO7233	BO7235	BO7236	BO7237
Depth	0 ft	0 ft	10 ft	15 ft	20 ft
Organics	**ug/kg**	**ug/kg**	**ug/kg**	**ug/kg**	**ug/kg**
Benzo(a)anthracene	370	170J	ND	ND	ND
Benzo(a)pyrene	130J	ND	ND	ND	ND
Benzo(b)fluoranthene	340	160J	ND	ND	ND
Chrysene	310J	170J	ND	ND	ND
Fluoranthene	980	270J	ND	ND	ND
Indeno(1,2,3-cd)pyrene	45J	ND	ND	ND	ND
Phenanthrene	390	ND	ND	ND	ND
Pyrene	750	220J	ND	ND	ND
Toluene	11	5J	ND	ND	ND

Note: Sample B07233 is a duplicate of B0723A
Shaded values exceed Hanford Site UTL
B = for organics, analyte detected in blank sample, for inorganics, analyte was detected at a concentration between IDL and CRDL.
J = estimated value
ND = not detected

Table 3-7. Analytes Detected in Samples Collected from 116-KW-3C Test Pit.

Sample Number	BO7227	BO7228	BO7239	BO7229	BO7230
Depth	0 ft	10 ft	10 ft	15 ft	20 ft
Radionuclides	pCi/g	pCi/g	pCi/g	pCi/g	pCi/g
Cesium-137	0.19J	0.22J	ND	ND	ND
Europium-152	ND	0.42	ND	ND	ND
Potassium-40	12	14	13	12	12
Radium-226	0.51J	0.68J	0.65	0.54	0.53
Thorium-228	0.97J	1.3J	1.1	0.97	1
Thorium-232	0.71	0.96	0.88	0.95	0.92
Uranium-233/234	0.51	0.65	0.6	0.59	0.63
Uranium-238	0.42	0.61	0.59	0.5	0.62
Inorganics	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg
Aluminum	5,440	7,060	7,560	7,550	5,650
Arsenic	ND	ND	3.5	ND	ND
Barium	70.7J	62.7J	59.9J	62.9J	58.3J
Beryllium	0.5	ND	ND	0.71	ND
Chromium	ND	13.1	13.8	14.3	10.5
Cobalt	10.6	7.3	8.1	8	5.8
Copper	19.8	15.3	21.8	19.9	16.6
Fluoride	ND	ND	ND	ND	3J
Iron	19,600	14,300	16,700	15,800	10,500
Lead	14.8	ND	ND	ND	7.6J
Magnesium	4,330	5,210	5,970	5,290	3,670
Manganese	356	259	274	283	217
Nickel	10	14.3	15.9	14.8	12
Potassium	1,090	1,420	1,500	1,320	1,160
Vanadium	41.4	29.5	35.1	30.4	19.5
Zinc	46.7	36.9	38	38	26.9
Organics	ug/kg	ug/kg	ug/kg	ug/kg	ug/kg
Toluene	4	ND	ND	ND	ND

Note: Sample B07239 is a duplicate of sample B07228.
J = estimated value
ND = not detected

Table 3-8. Analytes Detected in Samples Collected from 116-KE-4A Borehole.

Sample Number	BO7HJ2	BO7HJ3	BO7HJ6	BO7HJ7
Depth Interval	0-1 ft	0-1 ft	15-17 ft	20-22 ft
Radionuclides	pCi/g	pCi/g	pCi/g	pCi/g
Cesium-134	ND	ND	ND	0.056
Cesium-137	1.3	1.5	0.35	ND
Cobalt-60	1	0.46	ND	ND
Europium-152	7	6.4	0.47	ND
Europium-154	1.2	1.1	ND	ND
Europium-155	ND	0.16	ND	ND
Plutonium-239/240	0.03J	ND	ND	ND
Potassium-40	10	12	11	16
Radium-226	0.48	0.5	0.44	0.5
Thorium-228	0.72	0.66	0.74	0.66
Thorium-232	0.77	0.47	0.78	0.77
Uranium-233/234	0.5	0.55	0.39	0.44
Uranium-238	0.56	0.55	0.45	0.32
Inorganics	mg/kg	mg/kg	mg/kg	mg/kg
Aluminum	5,430	6,430	6,260	5,570
Barium	60.6	68.7	65.8	60.4
Beryllium	ND	0.39	ND	ND
Chromium	9.5	10.3	12.4	11.1
Cobalt	11.3	12.7	8.7	6.1
Copper	22.3	20.3	14.8	12
Iron	22,700	25,500	17,100	11,900
Lead	6.4	6.2	ND	ND
Magnesium	4,390	4,970	3,930	3,580
Manganese	303	417	266	213
Mercury	ND	0.06J	ND	ND
Nickel	8.3	9.6	8.1	9.5
Potassium	ND	1,120	ND	1130
Silver	ND	0.79	ND	ND
Vanadium	48.9	58.8	42.4	27.5
Zinc	44	50.8	35.2	28.1
Organics	ug/kg	ug/kg	ug/kg	ug/kg
Benzo(a)anthracene	ND	53J	ND	ND
Benzo(b)fluoranthene	ND	46J	ND	ND
Fluoranthene	ND	62J	ND	ND
Pyrene	ND	67J	ND	ND
Toluene	ND	ND	ND	2J

Note: Sample B07HJ3 is a duplicate of sample B07HJ2.
J = estimated value
ND = not detected

Table 3-9. Analytes Detected in Samples Collected from 116-KE-4B Test Pit.

Sample Number	BO7213	BO7214	BO7215	BO7217	BO7218
Depth Interval	0 ft	10 ft	10 ft	15 ft	20 ft
Radionuclides	pCi/g	pCi/g	pCi/g	pCi/g	pCi/g
Cesium-137	2.1	ND	ND	ND	ND
Cobalt-60	2.7	ND	ND	ND	ND
Europium-152	21	0.071J	ND	ND	ND
Europium-154	2.9	ND	ND	ND	ND
Plutonium-238	0.054	ND	ND	ND	ND
Potassium-40	13	12	12	13	13
Radium-226	0.47	0.41	0.04	0.42	0.38
Strontium-90	1.7	ND	ND	0.81J	ND
Thorium-228	0.67	0.75	0.85	0.8	0.66
Thorium-232	0.69	0.54	0.7	0.69	0.77
Uranium-233/234	0.4	0.37	0.21J	0.41	0.46
Uranium-238	0.33	0.41	0.4	0.51	0.41
Inorganics	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg
Aluminum	7,660	4,590	5,720	4,960	5,040
Barium	55.7	36.7	38.4	36.6	34.5
Beryllium	0.34	ND	ND	ND	ND
Chromium	85.1	8.8	10.4	9.3	9.3
Cobalt	8.9	4.8	4.6	4.4	4.8
Copper	18	16.6	18	14.7	19.2
Iron	17,400	8,260	9,510	8,620	8,730
Lead	7.2	ND	ND	ND	ND
Magnesium	4,650	ND	3,430	3,300	ND
Manganese	240	163	167	139	159
Nickel	11.7	9.8	10.8	9	10.1
Potassium	1,470	ND	ND	1,140	ND
Vanadium	45	14.5	17.8	15.9	15.6
Zinc	46.9J	23.6J	26.4J	26J	24.1J
Organics	ug/kg	ug/kg	ug/kg	ug/kg	ug/kg
Acenapthene	99J	ND	ND	ND	ND

Note: Sample B07215 is a duplicate of sample B07214.
Shaded values exceed Hanford Site UTL.
J = estimated value
ND = not detected

Table 3-10. Analytes Detected in Samples Collected from 116-KE-4C Test Pit.

Sample Number	BO7221	BO7222	BO7224	BO7225	BO7226
Depth	0 ft	10 ft	10 ft	15 ft	20 ft
Radionuclides	pCi/g	pCi/g	pCi/g	pCi/g	pCi/g
Cesium-137	1.3	ND	ND	ND	ND
Cobalt-60	0.47	ND	ND	ND	ND
Europium-152	1.2	ND	ND	ND	ND
Potassium-40	15	13	13	13	14
Radium-226	0.77	0.53	0.53	0.43	0.43
Thorium-228	1.2	0.92	0.65	0.83	0.81
Thorium-232	1.1	0.73	0.73	0.68	0.7
Uranium-233/234	0.66	0.45	0.32	0.47	0.41
Uranium-238	0.6	0.42	0.39	0.42	0.35
Inorganics	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg
Aluminum	8,150	5,430	5,790	4,860	4,950
Arsenic	2.2	0.84	0.68	ND	ND
Barium	67	38.1	56	37.5	31.1
Beryllium	0.43	0.12	ND	ND	ND
Chromium	21.7	10.1	21	8.5	8.7
Cobalt	10.2	4.9	5.8	4.5	4.3
Copper	16	17	14.8	14.4	14.8
Iron	20,700	10,100	11,100	9,160	8,950
Lead	6.2	ND	ND	ND	ND
Magnesium	6,040	3,480	4,350	ND	ND
Manganese	325	168	129	158	163
Mercury	0.07J	ND	ND	0.37J	0.42J
Nickel	14.4	9.4	11.4	8.7	8.8
Nitrate/Nitrite (mg-N/kg)	7.24J	ND	ND	ND	ND
Potassium	1,340	ND	1,450	ND	ND
Vanadium	45.7	20.3	22.3	17.2	17.2
Zinc	48.3J	27.4J	29.2J	24.5J	25J

Note: Sample B07224 is a duplicate of sample B07222.
J = estimated value
ND = not detected.

Table 3-11. Physical Properties of Samples Collected from 116-KE-4 Borehole.

Sample Number	BO7LK2	BO7LK3	BO7LK4	BO7LK5
Depth	4-6 ft	10-12 ft	13-15 ft	18-20 ft
Particle Size Distribution				
% Gravel	49.1	73.3	50.0	59.0
% Sand	41.8	21.7	41.2	33.4
% Fines (silt + clay)	9.1	5.0	8.8	7.6
Bulk Density (g/cm^3)	2.01	1.82	2.03	2.08
Porosity (%)	27.1	NR	25.9	23.43
Moisture Content (%)	4.49	NR	3.86	2.46
% Moisture Retention				
11 cm tension	12.55	5.67	12.04	10.50
35.5 cm tension	12.21	5.37	11.88	10.58
99 cm tension	10.13	4.32	10.04	7.49
500 cm tension	6.62	2.98	6.64	3.76
1000 cm tension	5.58	2.40	5.59	3.31
2040 cm tension	4.44	1.80	4.35	2.33
7,140 cm tension	3.39	1.39	3.04	1.39
10,200 cm tension	3.04	1.27	2.65	1.20

NR = not reported

Table 3-12. Process Effluent Pipeline Characterization Data.

Site	Sample	Isotopic Analysis		Activity Level (Beta-Gamma)	
		Isotope	pCi/g	Direct cpm/probe***	Technical Smear cpm/200 cm^2
100-C	Pipeline section inner surface			33,000	6,700
	Loose scale*	Co-60 Eu-152 Eu-154 Eu-155	150 3,400 580 51		
	Pipe scrapings**	Co-60 Eu-152 Eu-154 Eu-155	600 7,700 1,300 150		
100-DR	Pipe section inner surface			33,000	6,700
	Loose scale	Co-60 Cs-137 Eu-152 Eu-154 Eu-155	150 25 1,700 310 16		
	Pipe scrapings	Co-60 Cs-137 Eu-152 Eu-154 Eu-155	670 28 7,000 1,200 83		
100-F	Pipe section inner surface			20,000	10,000
	Loose scale	Co-60 Eu-152 Eu-154 Eu-155	120 6,500 1,000 73		
	Pipe scrapings	Co-60 Eu-152 Eu-154 Eu-155	330 12,000 1,900 93		

Source: Beckstrom and Steffes (1986)
* Loose scale samples were taken from sediment lying in the underwater pipe.
** Pipe scrapings were taken from the inner surface of the cut pipe section after removal from the river.
***Nominal efficiency for the P-11 Probe used for these results is 10%.

4.0 QUALITATIVE RISK ASSESSMENT OF THE 100-KR-1 OPERABLE UNIT

This chapter provides a summary of the methods and results of the QRA that was performed for the high-priority waste sites in the 100-KR-1 operable unit (WHC 1993e). Details concerning the selection of contaminants of potential concern, exposure and toxicity assessments, the risk characterization and the uncertainty analysis may be found in the QRA for the 100-KR-1 operable unit (WHC 1993e).

4.1 QUALITATIVE RISK ASSESSMENT PROCESS

The QRA is an evaluation of risk for a predefined set of human and ecological exposure scenarios. The QRA is not intended to replace or be a substitute for a baseline risk assessment. Consequently, the QRA is streamlined to consider only two human health scenarios (frequent and occasional use) with four exposure pathways (soil ingestion, fugitive dust inhalation, inhalation of volatile organics, and external radiation exposure) and a limited ecological evaluation. The use of these scenarios and pathways was agreed to by the 100 Area Tri-Party Unit Managers (December 21, 1992, and February 8, 1993). Future waste site risk estimates considering the decay of radionuclides to the year 2018 and the effect on external radiation exposure from shielding provided from current soil and gravel covers are also presented. Frequent and occasional use exposures (residential and recreational exposure scenarios, respectively) and Great Basin pocket mouse habitat are assumed at the site in order to provide a conservative estimate of risk. However, since the 100-KR-1 operable unit is not used for residential or recreational purposes currently, and because of the uncertainty associated with Great Basin pocket mouse exposure at the site, actual risks at the site may be lower than estimated in the QRA.

4.1.1 Approach

The QRA is conducted using the Hanford Site Baseline Risk Assessment Methodology (HSBRAM) (DOE-RL 1993a) as guidance and
consists of the following:

- An evaluation of the data sources and/or process information
- Identification of maximum constituent concentrations, where data is available
- A human health risk evaluation
- An ecological risk evaluation.

Key factors that contribute to uncertainty throughout the risk assessment process are also identified.

4.1.2 Guidelines Used in the Qualitative Risk Assessment

The following guidelines were agreed to by the Tri-Party Unit Managers prior to performing the QRA.

- Site-wide soil background concentration data are used to screen inorganic constituents.
- Historical radionuclide concentrations (without considering daughter products) are decayed to 1992.
- The maximum contaminant concentration within the upper 15 ft of soil, either from historical or LFI data, is used to estimate risk in the QRA.
- Two scenarios, frequent use and occasional use, are evaluated in the human health section of the QRA.
- For the human health exposure assessment, the pathways evaluated in the QRA are soil ingestion, fugitive dust inhalation, inhalation of volatile organics, and external radiation exposure.
- Ecological scenarios are evaluated using the Great Basin pocket mouse because it is a key component of the Hanford area food chain and a biological endpoint with a range similar in size to the dimensions of most individual waste sites.

Several other guidelines are used in the QRA. The data collection during the LFI for the operable unit followed a known process and therefore the data are considered to be of high quality. Historical data (e.g., Dorian and Richards 1978) are considered to be of medium quality because the data were not validated and documentation was less rigorous. Where historical data do not specify uranium isotopes, uranium-238 is evaluated because it represents >99% of natural uranium. Chromium is assumed to be present as chromium (VI) because it provides the most conservative evaluation and chromium was not speciated during analysis. Nickel in the soil environment is not considered carcinogenic because the pyrolytic activity that generates the carcinogenic form of nickel was not present in the operable unit. If toxicity factors are not available for a constituent, surrogate factors are generally not used unless specifically noted.

The qualitative risk estimations are grouped into high (lifetime incremental cancer risk [ICR] > 1E-02), medium (ICR > 1E-04 to 1E-02), low (ICR 1E-06 to 1E-04), and very low (ICR< 1E-06) risk categories. A frequent-use scenario is evaluated in 2018 to ascertain potential future risks associated with each waste site after additional radionuclide decay. For the current occasional-use scenario, the effect of radiation shielding by the upper 6 ft of soil on the external exposure risk at each waste site is evaluated.

For the ecological risk assessment, metals are assumed to be completely bioavailable for uptake by vegetation. The identified concentrations are assumed to be uniformly distributed over the site, biologically active, and available for transport. Environmental hazard quotients (EHQ) for ecological exposure to radionuclides are based on an exposure limit of 1 rad/day (DOE Order 5400.5) and the no observable effect level (NOEL) dose.

4.2 HUMAN HEALTH QUALITATIVE RISK ASSESSMENT

The QRA provides estimates of risk that might occur under frequent-use or occasional-use scenarios based on the best available knowledge of current contaminant conditions, but it does not represent actual risks since neither frequent-use nor occasional-use of high priority sites currently occurs.

4.2.1 Overview of the Human Health Risk Evaluation Process

The frequent-use and occasional-use scenarios are evaluated using residential and recreational exposure parameters respectively, from DOE-RL (1993a). Frequent-use is addressed for current (1992) and future (2018) contaminant concentrations. Air inhalation of volatile organics is eliminated from this analysis because volatile organics are not present above preliminary risk-based screening levels in the soil at any waste site. Therefore, inhalation of volatile organics is not a likely exposure pathway for this operable unit. For the soil ingestion and external exposure pathways, maximum sample concentrations from the upper 15 ft of soil are used. For the fugitive dust inhalation pathway, maximum contaminant concentrations in the upper 15 ft of soil are used in conjunction with a particulate emission factor. This factor relates contaminant concentrations in the soil to concentrations of respirable particles in the air due to fugitive dust emissions. Quantification of exposures is conducted using Section 2.3 of DOE-RL (1993a).

The external exposure pathway is also evaluated for the current occasional-use scenario while considering the effect of shielding by existing soil cover. In this evaluation, only radionuclides detected in the upper 6 ft of soil are considered as contributors to external radiation exposure. These external exposure risks are considered to be more representative of current site conditions where activities in a contaminated zone are controlled.

Section 2.3 of DOE-RL (1993a) contains the general procedures followed in the QRA for toxicity assessment. The toxicity assessment in the QRA involves the selection of slope factors and reference doses for contaminants of potential concern and includes sufficient toxicity information on contaminants of potential concern to assist project managers in reaching decisions on IRMs.

Risk characterization for the individual waste sites differs depending on the type and amount of data available for the specific waste site. Risk characterization is conducted in accordance with Section 2.4 of DOE-RL (1993a). The risk characterization for each site is performed by calculating contaminant-specific ICRs and HQs and then summing contaminant-specific risks to obtain a risk estimate for the waste site.

For sites where sampling data are not available to calculate ICRs and HQs, the risk characterization consists of a qualitative discussion of the site, the potential threat posed by the site, and the confidence in the information available to assess the threat. Risk estimates from analogous sites are used, where appropriate, to qualitatively determine possible contaminants and potential risk levels.

4.2.2 Results of the Human Health QRA

An overview of the human health QRA and associated uncertainties for the 100-KR-1 QRA are summarized in the following sections.

Information summarized in Tables 4-1, 4-2 and 4-3 for the human health QRA includes:

- Data availability and confidence in data
- The qualitative risk estimation
- The risk-driving contaminants for the frequent-use and occasional-use scenarios
- The risk-driving pathways for the frequent-use and occasional-use scenarios

The risk-driving contaminants for both the frequent-use and occasional-use scenarios are generally radionuclides and the primary risk-driving pathway is usually the external exposure pathway.

The high-priority waste sites listed in Table 4-2 of the 100-KR-1 work plan (DOE-RL 1992a) are evaluated in the QRA. Where LFI data were not collected, historical data were used in the risk assessment. Where sampling data were not available, risk estimates from analogous waste sites (if any) were considered in evaluating the potential risk from the waste site.

Based on the QRA, the high-priority waste sites within the 100-KR-1 operable unit are all grouped in high, medium, and low risk categories as shown in Table 4-3.

The 100-KR-1 operable unit waste sites with data are categorized in the frequent-use scenario in 1992 as follows:

- High human health risk potential
  - 116-K-1 crib
  - 116-K-2 trench (inside trench soils)
  - 116-KW-3 retention basin (inside and outside basin soils)
  - 116-KE-4 retention basin (inside basin soils and inlet chute scale)
- Medium human health risk potential
  - 116-K-2 trench (outside trench soils)
  - 116-KE-4 retention basin (outside basin soils).

The 100-KR-1 operable unit waste sites with data are categorized in the occasional-use scenario in 1992 as follows:

- High human health risk potential
  - 116-KE-4 retention basin (inside basin inlet chute scale)

- Medium human health risk potential
  - 116-K-1 crib
  - 116-K-2 trench (inside trench soils)
  - 116-KW-3 retention basin (inside and outside basin soils)
  - 116-KE-4 retention basin (inside and outside basin soils)

- Low human health risk potential
  - 116-K-2 trench (outside trench soils).

The 100-KR-1 operable unit waste sites with data are categorized in the frequent-use scenario in 2018 as follows:

- High human health risk potential
  - 116-K-1 crib
  - 116-K-2 trench (inside trench soils)
  - 116-KE-4 retention basin (inside basin soils)
  - 116-KE-4 retention basin (inside basin inlet chute scale)

- Medium human health risk potential
  - 116-K-2 trench (outside trench soils)
  - 116-KW-3 retention basin (inside and outside basin soils)
  - 116-KE-4 retention basin (outside basin soils).

The risks, both carcinogenic and non-carcinogenic, presented in this QRA are deterministic estimates given multiple assumptions about exposure, toxicity, and variables. Consequently, uncertainty exists for the evaluation of the contaminants, the exposures, the toxicities, and the risk characterization for the QRA. This uncertainty is discussed more extensively in the following sections.

4.2.3 Summary of Key Uncertainties in the Human Health Risk Assessment

In general, the QRA is based on a limited data set. Uncertainties are associated with both the contaminants identified for each waste site and the concentrations of the contaminants. Collected samples may not be representative of conditions throughout the waste site, and historical data may not accurately represent current conditions. Confidence in the contaminant identification and concentrations is therefore rated medium. Because the samples may not be completely representative of the site risks may be overestimated or underestimated. The use of maximum concentrations from a conservatively-biased sampling scheme could result in an overestimation of risk. The collection of limited numbers of samples could result in an underestimation of risks.

Uncertainty exists with respect to the identification of specific contaminants. Where the isotope of uranium is not specified, uranium is evaluated as uranium-238. The slope factors for the various uranium isotopes differ slightly from one another, resulting in slightly different risks if each is evaluated separately. The valence state of chromium identified in the QRA samples was not known. For the risk estimate, the most toxic form was assumed (Cr VI). Therefore, inhalation risks are overestimated if chromium exists as the less toxic form (Cr III).

External exposure slope factors are appropriate for a uniform contaminant distribution, infinite in depth and areal extent (i.e., an infinite slab source), with no clean soil cover. For high-energy gamma emitters (e.g., cobalt-60 and cesium-137), the assumption of an infinite slab source can only be satisfied if these radionuclides extend to nearly 6 ft below ground surface and over a distance of a few hundred meters or more. If the site being evaluated is smaller than this, or if the site has a clean soil cover, use of external exposure slope factors is likely to provide risk estimates that are unrealistic.

When there is a high degree of uncertainty associated with the information used to determine toxicity, there is less confidence in the assessment of the risk associated with exposure. The primary sources of these uncertainties include the following:

- Use of information on dose-response effects from high-dose exposure scenarios to predict effect at low-dose exposure scenarios
- Use of animal dose-response data to predict effects in humans
- Use of short-term exposure data to extrapolate to long-term exposure, or vice versa
- Use of dose-response information from a homogeneous animal or healthy human population to predict the effects that may occur in the general population where there are varying sensitivities to different contaminants.

Uncertainty in the risk characterization also results from summing ICRs and HQs across contaminants and pathways, a process which gives equal weight to toxicity information derived from different sources or species. Exposures to multiple contaminants may result in additive effects or effects that are greater or less than additive.

4.3 ECOLOGICAL QUALITATIVE RISK ASSESSMENT

The purpose of the qualitative ecological risk assessment is to estimate the ecological risks from existing contaminant concentrations in the 100-KR-1 operable unit to the Great Basin pocket mouse.

The 100-KR-1 operable unit is a terrestrial waste unit. The approach consistent with the objective of the QRA is to assess the dose to the Great Basin pocket mouse. The mouse is used as the indicator receptor because its home range is comparable to the size of most waste sites and could receive most of its dose from a waste site. This allows a risk comparison between waste sites.

Contaminants found in the soil at waste sites within the 100-KR-1 operable unit include radioactive and nonradioactive elements. For nonradioactive elements, ecological effects are evaluated from uptake from the soil by plants and by accumulation of these elements through the foodweb. Radioactive elements have ecological effects resulting from their presence in the abiotic environment (external dose) and from ingestion (e.g., dose from contaminated food consumption), resulting in a total body burden. Total daily doses to an organism can be estimated as the sum of doses (weighted by energy of radiation) received from all radioactive elements ingested, residing in the body, and available in the organism's environment.

Radiological dose calculation methodology as reviewed by Baker and Soldat (1992), were applied in the QRA.

The radiological dose an organism receives is usually expressed as rad/day. Exposure can result from both external environmental radiation and internal radiation from body burden. External dose is less than 1% of the total dose (internal and external); therefore, external dose to an animal as small as a pocket mouse, at this site, can be ignored (Appendix D of DOE-RL 1993a). Internal exposure includes both body burden (contaminants that are taken into the body from all pathways) and dose from recent food consumption which is still in the gut. All exposure pathways are added in determining total organism dose.

The assessment and measurement endpoint is the health and mortality, respectively, of the Great Basin pocket mouse. This is consistent with the objective of the qualitative ecological risk assessment. The dose to the pocket mouse is used to screen the level of risk of an individual waste site. For radionuclides, mouse dose is compared to 1 rad/day (Order DOE 5400.5; IAEA 1992). For nonradiological contaminants, dose is compared to toxicity values.

Risk is evaluated for the Great Basin pocket mouse based on a two-step accumulation model (e.g., soil-to-plant and plant-to-mouse) operated on a waste-site-by-waste-site basis, since each waste site approximates the size of the Great Basin pocket mouse home range. Because of the lack of site-specific data other than soil, it is assumed the receptor spends some fraction of its life in the site, obtains all its food from the site when present, and all consumed food is contaminated.

For nonradiological constituents, concentrations estimated in mice were compared to reported benchmark or potentially toxic concentrations. For radiological constituents, concentrations in mice are converted to dose. Total dose for all radionuclides is compared to published effect levels and regulatory standards where available.

The major route of contaminants to plants is assumed to be direct uptake from soil. Ingestion of vegetation is assumed to be a major route of exposure to the mouse for both nonradiological and radiological constituents. For radionuclides, the exposure pathway considered uptake from contaminated food resulting in internal exposure. For both radiological and nonradiological contaminants, the dose is based on receptor whole-body concentrations. Metals are assumed to be completely bioavailable for uptake by vegetation, which is consistent with the objectives of the QRA.

4.3.1 Results of the Ecological Evaluation

A qualitative ecological evaluation is completed for radiological constituents for the 100-KR-1 operable unit. Soils along the 116-K-2 Disposal Trench and inside, adjacent, and outside the 116-KW-3 Basin exceeded the 1 rad/day benchmark with an EHQ >1. For sites where the total dose is greater than one, strontium-90 exceeds the EHQ by itself and is the primary dose contributor (see Table 4-4). Strontium-90 is present in the upper soil level (0 - 6 ft) of 116-K-2 and 116-KW-3 and is therefore available to the mouse.

For nonradiological constituents, the 116-KE-4 Basin (outside only) exceeded the concentration corresponding to the NOEL for chromium (see Table 4-5).

4.3.2 Summary of Key Uncertainties in the Ecological Evaluation

The uncertainty in contaminant concentrations for the ecological evaluation is related to the accuracy of the data. For the QRA, uncertainty exists in both contaminants identified and exposure concentrations. As for the human health assessment, the maximum contaminant concentration is used.

The QRA models the potential exposure of wildlife suspected to be present in or near the waste site. The issues of concern with regard to ecological risk assessment (particularly qualitative) are the uncertainties in using an assortment of environmental variables in risk modeling. This begins with the source term. If this number is not realistic, no amount of modeling will overcome this deficiency. For example, in the case of the QRAs, the maximum reported waste concentration is used as the source term no matter how deep this concentration was found.

Generally, site-specific organisms (e.g., pocket mouse) are identified as being associated with a site, but little if any data may exist concerning transfer of contaminants to site specific organisms. Often, it is necessary to use biological trophic transfer information for related species.

A significant source of uncertainty in the exposure scenario is the assumption that the waste site is uniformly contaminated, and in the case of the mouse, all foodstuff is assumed to be contaminated. No provision is made for dilution of contaminated foodstuff by non-contaminated foodstuff. It was also assumed that contaminants were not passed through the gut but completely retained (100% absorption efficiency).

To complete the QRA for the 100-KR-1 operable unit it is necessary to use data from surrogate organisms (e.g., white-tailed mouse) in place of the pocket mouse since no site data are available for this organism. This contributes to overall QRA uncertainty. In addition, transfer coefficients used to model uptake of contaminants from soil to plants are not Hanford specific, the approach does not consider whether roots of a plant actually grow deep enough to contact a contaminant, and the model does not account for reduced concentrations from plant to seed (it was assumed the seed concentration is the same as the plant). The pocket mouse food consumption rate is generalized; seasonal behavior (hibernation) that can reduce internal exposure and body burden is not considered.

Uncertainty associated with wildlife toxicity values is significant, particularly for non radiological contaminants. The approach used in the QRA tends to build conservatism into the toxicity value.

Table 4-1. Summary of Data Availability and Data Confidence (for sites where data are available).

Waste Site	Summary of Data Availability and Data Confidence[a]				
	Historical Data[b]	LFI Data[b]	Data from the same Medium[c]	Confidence in Contaminant Identification	Confidence in Contaminant Concentrations
Sites with LFI data and historical data					
116-K-1 Crib	R	R,O	Yes	medium	medium
116-K-2 Trench	R	R,I,O	Yes	medium	medium
116-KW-3 Retention Basins	R	R,I,O	Yes	medium	medium
116-KE-4 Retention Basins	R	R,I,O	Yes	medium	medium

\- = Not applicable
[a] Summary of inorganics are screened against Hanford Site Background Levels.
[b] R = radionuclide, I = inorganic, O = organic contaminant
[c] LFI and Historical Data are from the same medium (e.g., both from soil) or from different media (e.g., soil and sludge).

Table 4-2. Human Health Data and Risk Assessment Summary (for sites where only process knowledge is available).

Site	Disposal Information	Suspected Risk-Driving Contaminants	Description and Notes	Qualitative Risk Rating[a]	Rationale for Rating
116-K-3 Outfall structure	Unknown volume of treated process effluent from all other waste sites within the 100-KR-1 operable unit.	Cesium-137, cobalt-60, europium-152, and europium-154	Reinforced concrete building, measuring 30 x 30 x 15 ft, with two 84 in. steel effluent lines and a concrete lined overflow spillway (the spilling has been removed and disposed).	Medium	116-D-5 outfall structure in the 100-DR-1 operable unit has a high risk estimate.
Effluent Discharge Pipelines and Valves	Pumped water from the KE and KW reactors from 1955 to 1971.	Cesium-137, cobalt-60, europium-152, and europium-154	100-KR-1 operable unit pipeline system which conveyed effluent to the 5 other wastes sites.	Medium	100-BC-1 operable unit process effluent pipelines have a high risk estimate.

[a] Rating is qualitative based on process information, analogous site information, and site-specific information such as size, potential contaminants, and location of contaminations as indicated under rationale column, but the 100-KR-1 sites are rated medium because of the uncertainty associated with assuming that conditions are identical between similar waste sites at different operable units in the 100 Area.

Table 4-3. Human Health Risk Assessment Summary (for sites where data are available).

Waste Site	Human Health Risk Assessment Summary				
	Frequent-Use Scenario			Occasional-Use Scenario	
	Qualitative Risk Estimation		Risk Driving Contaminant[a] (and pathway[b])	Qualitative Risk Estimation (1992)	Risk Driving Contaminant[a] (and pathway [b])
	1992	2018			
Sites with LFI and historical data					
116-K-1 Crib	High	High	R(O,I,E)	Medium	R (E)
116-K-2 Effluent Trench	High	High	R(O,I,E)	High	R (O,I,E)
116-KW-3 Retention Basins	High	High	R(O,I,E) O(I)	Medium	R (I,E) O(I)
116-KE-4 Retention Basins	High	High	R(O,I,E) I(In)	High[c]	R (O,I,E)

- = Not applicable
[a] R = radionuclide, O = organic, I = inorganic contaminant
[b] O = oral, In = inhalation, E = external exposure pathways
[c] Based on exposure to inlet chute scale, not on soils inside and outside the 116-KE-4 retention basin.

Table 4-4. Environmental Hazard Quotients Summary for Radionuclides by Waste Site.

Waste Site	Dose Rate Exceeds EHQ of 1
116-K-1 Effluent Crib	No
116-K-2 Trench	Yes
116-KW-3 Basin	Yes
116-KW-3 Basin (Outside)	Yes
116-KE-4 Basin	No
116-KE-4 Basin (Outside)	No

Table 4-5. Environmental Hazard Quotient Summary for Non-Radiological Contaminants which Exceed Hanford Background by Waste Site.

Contaminants	Dose Rate Exceeds EHQ of 1[a]
116-K-1 Crib toluene	 No
116-K-2 Effluent Trench methylenechloride	 No
116-KW-3 Retention Basin (Inside) tetrachloroethane	 No
116-KW-3 Retention Basin (Outside)[b] cobalt, toluene, pyrene, fluoranthene	 Yes No
116-KE-4 Retention Basin (Inside)	NA[c]
116-KE-4 Retention Basin (Outside)[d] chromium acenapththene	 Yes No

a EHQ based on no observable effect level.
b Data from test pits 116-KW-3B or 116-KW-3C.
c All contaminants below Hanford Background values (DOE-RL 1993C)
d Data from test pits 116-KE-4B or 115-KE-4C.

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5.0 RECOMMENDATIONS

The primary purpose of the LFI report is to recommend those high-priority sites that should remain candidates for the IRM path and those high-priority sites that can be eliminated from IRM consideration. Sites that are eliminated from the IRM path are addressed in the final remedy selection process.

5.1 HIGH-PRIORITY SITE IRM EVALUATION CRITERIA

The 100-KR-1 high-priority sites were evaluated using the following criteria to identify those sites where continued IRM candidacy is recommended:

- the 100-KR-1 QRA (WHC 1993e)
- the assessment of the waste site conceptual model
- an evaluation of site-specific contaminant impact on groundwater
- identification of sites where natural attenuation by the year 2018 may reduce risks and mitigate contamination
- identification of ARAR exceedance for vadose zone contaminants.

5.1.1 Qualitative Risk Assessment

The QRA provides risk estimates for human health and for adverse ecological effects. Human health risks for high-priority sites were developed in the QRA using two scenarios: high-frequency use and low-frequency use. The low-frequency use risk values were used to evaluate the continued candidacy of high-priority sites for IRMs. Based on the ICR, the qualitative risk estimates presented in Table 5-1 are grouped into high ($ICR > 1E\text{-}02$), medium ($1E\text{-}04 < ICR \le 1E\text{-}02$), low ($1E\text{-}06 < ICR \le 1E\text{-}04$), and very low ($ICR \le 1E\text{-}06$) risk categories. Sites that pose a medium or high risk to human health under the low-frequency use scenario are recommended to continue as IRM candidates.

Environmental hazard quotients are from the qualitative ecological risk assessment that was performed in the QRA. Sites that have an EHQ rating greater than 1 for potentially adverse ecological impacts are recommended to continue as IRM candidates.

5.1.2 Conceptual Model

The conceptual model for the waste site includes sources of contamination, types of contaminants, nature and extent of contamination in each affected media, known and potential routes of migration, known or potential human and environmental receptors, and the general understanding of the site structure/process. This information was included in the 100-KR-1 work plan (DOE-RL 1992a) and has been revised using data obtained during the LFI. Information on contaminant sources, types of contaminants, nature and extent of contamination in affected media, and general understanding of site/structure was discussed for each waste site in Chapter 3. Figure 5-1 presents the known and potential routes of migration and known or potential human and environmental receptors for the operable unit. The conceptual model is judged adequate for all sites addressed in this report.

5.1.3 Current Impact on Groundwater

The probability of current impact on groundwater is evaluated for each site by comparing groundwater contaminant concentrations from monitoring wells located upgradient and down gradient of each specific site, where wells are available. Groundwater concentrations of carbon-14, tritium, and chromium in upgradient and down gradient wells are compared. Groundwater contaminant concentrations in down gradient wells that are higher than in upgradient wells indicate current impact to groundwater. Sites that are impacting groundwater are recommended to continue as IRM candidates.

5.1.4 Potential for Natural Attenuation

The potential for radioactive contaminants at a site to be reduced by natural attenuation, i.e., radioactive decay by the year 2018, may be a consideration at sites where radionuclides with half-lives of 30 years or less are the primary contaminant and external exposure is the only pathway. Sites with excess risk, i.e., greater than 1E-06, attributed to radionuclides with half-lives of 30 years or less (e.g., cobalt-60, cesium-137, europium-152, and europium-154) have potential for natural reduction of risk through radioactive decay. Natural attenuation is not a consideration for sites contaminated by metals, by radionuclides with a half-life greater than 30 years, or when there are multiple radionuclide exposure pathways.

5.1.5 Applicable or Relevant and Appropriate Requirements

The MTCA Method B concentrations are potential ARARs for soil contamination as identified in Section 2.7. The MTCA Method B limits are used because they represent a conservative, standardized approach for source units. Table 2-4 lists the MTCA Method B limits for organic compounds or those metals that exceeded the Hanford Site UTL. Sites that have soil concentrations that exceed this potential chemical-specific ARAR are recommended to continue as IRM candidates.

5.2 HIGH-PRIORITY SITE IRM RECOMMENDATIONS

The final selection of IRM sites and priority of action are decisions left to the Tri-Party Agreement signatories. Factors that may be considered in the selection and prioritization of IRM sites include:

- impact of IRM actions in relation to the 100 Area Environmental Impact Statement, e.g., disposition of the reactors

- access control
- relation to the IRM Program Plan recommendations
- land use
- point of compliance
- time of compliance
- feasibility
- bias-for-action
- threat to human health and the environment.

The high-priority sites recommended to continue as IRM candidates are identified in Table 5-1. For those sites that are recommended for an IRM, the next step is to evaluate remedial alternatives in a focused feasibility study. Sites deferred to final remedy selection will be evaluated in the final feasibility study. The recommendations for the sites are discussed below.

5.2.1 116-K-1 Crib

The 116-K-1 crib is recommended as a candidate for an IRM because there is surficial contamination that poses a medium risk for a low-frequency use exposure scenario to human health. The EHQ is less than 1. The historical and LFI data show that the contamination is largely confined to the surface [<12 ft], which correlates with limited usage of the site for reactor effluent disposal. None of the detected organic constituents or the inorganic constituents above background exceeded MTCA level B criteria (see Table 2-4). The conceptual model of the site is adequate to conduct an IRM.

5.2.2 116-K-2 Trench

The 116-K-2 trench is recommended as a candidate for an IRM because the human health risks are high for a low-frequency use exposure scenario, the EHQ is greater than 1, and there is groundwater monitoring data to show the site is apparently impacting groundwater. Groundwater monitoring wells down gradient of the site show chromium is emanating from the site. None of the detected organic constituents or the inorganic constituents above background exceeded MTCA level B criteria (see Table 2-4). The source for organic contaminants detected in the LFI samples was not expected given the historical use of the site for reactor effluent disposal. It is possible they are a result of laboratory contamination. The conceptual model of the site is adequate to conduct an IRM.

5.2.3 116-KW-3 Retention Basin

The 116-KW-3 retention basin is recommended as a candidate for an IRM because the human health risk is medium for a low-frequency use exposure scenario, the EHQ is greater than 1, and there are constituents that exceed MTCA level B criteria. Benzo(a)anthracene, benzo(b)fluoranthene, and chrysene exceed MTCA level B criteria (see Table 2-4). The origin of these organic chemicals is unknown. Radiological contamination was found to extend from the retention basin along the floodplain toward the river. This contamination was due to the leakage that occurred during basin operation. The horizontal extent of this contamination was not defined during the LFI. The conceptual model for the site is generally complete, except for the origin of the organic chemicals and the horizontal extent of contamination. Further review of historical records is recommended to identify the possible use of organic chemicals at the site or in the operable unit. The horizontal extent of contamination does not need to be defined during the LFI. The IRM process can use the observational approach to identify contamination during remedial measures implementation.

5.2.4 116-K-KE-4 Retention Basin

The 116-KE-4 retention basin is recommended as a candidate for an IRM because the human health risk is high for a low-frequency use exposure scenario and the EHQ is greater than 1. There is no evidence of impact to groundwater from this facility. None of the detected organic constituents or the inorganic constituents above background exceeded MTCA level B criteria (see Table 2-4). Radiological contamination was found to extend from the retention basin along the floodplain toward the river. This contamination was due to the leakage that occurred during basin operation. The horizontal extent of this contamination was not defined during the LFI. The conceptual model for the site, except the horizontal extent of contamination, is generally complete. The horizontal extent of contamination does not need to be defined during the LFI. The IRM process can use the observational approach to identify contamination during remedial measures implementation.

5.2.5 116-K-3 Outfall Structure

The 116-K-3 outfall structure is recommended as a candidate for an IRM because the human health risk is medium for a low-frequency use exposure scenario (environmental health was not evaluated). There is no evidence of impact to groundwater. Based on LFI data from analogous facilities (116-D-5 and 116-DR-5 outfall structures), there is a possibility that the 116-K-3 outfall structure is contaminated with radionuclides. Although there is no data for the 116-K-3 outfall structure, the IRM can use the observational approach during remedial measure implementation to identify the horizontal and vertical extent of contamination.

5.2.6 Process Effluent Pipelines

The process effluent pipelines are not recommended for continued IRM candidacy. Although there is contamination within the pipes that could pose a risk to human health, the contamination exists as scale that has minimal opportunity for migration into the environment. In addition, the radionuclides detected in the scale have half-lives of 30 year or less. Therefore, there is the potential for natural attenuation of radionuclide contamination. Because there is little opportunity for contaminant migration, an IRM is not justified. Instead, the process effluent pipelines should be deferred to the final remedy selection process for the operable unit.

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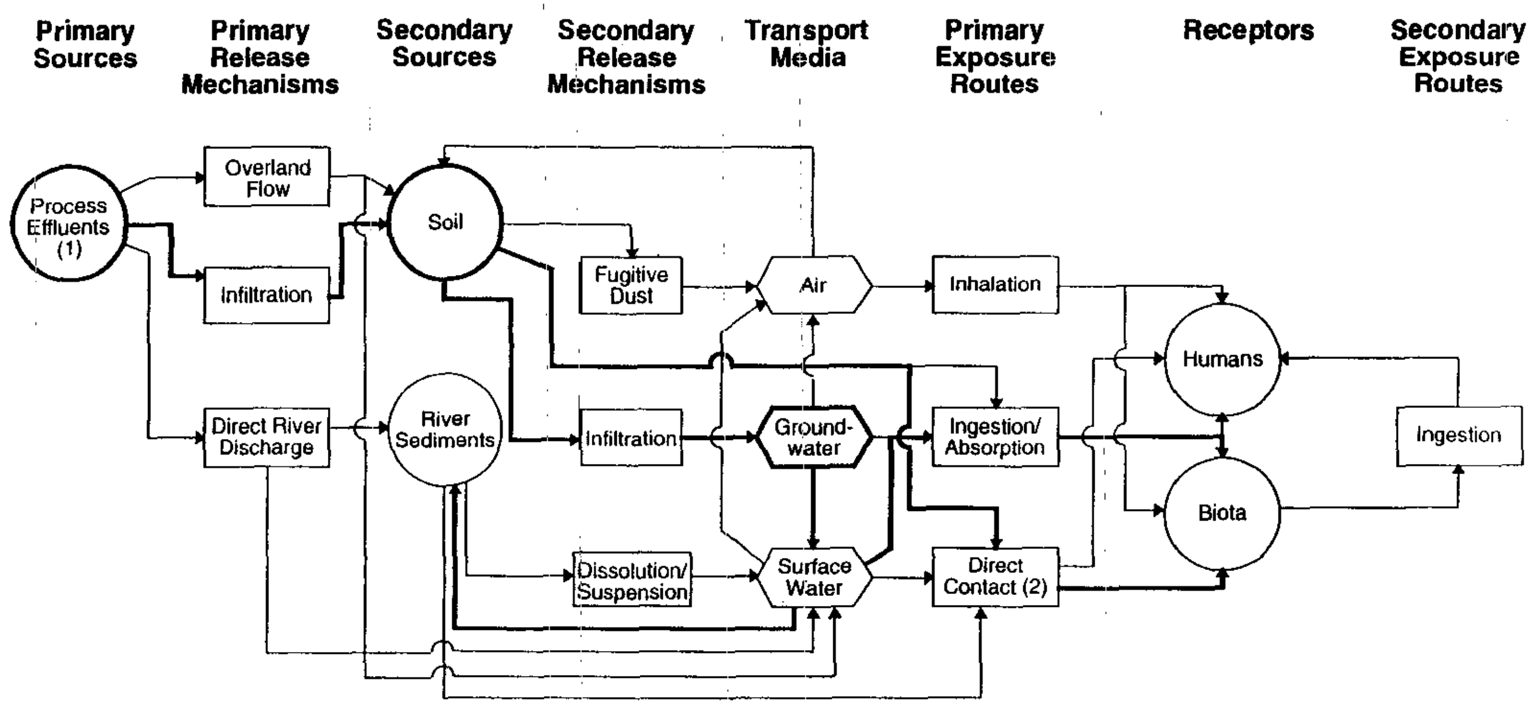

(1) Includes all facilities that received process effluents, including pipelines, basins, cribs, trenches, french drains, and outfall structures.

(2) Includes exposure to radiation.

LEGEND:
→ Potential Exposure Pathway
→ Potential Primary Exposure Pathway
○ ⬭ Primary contaminant sources and known contaminated media

923 E029/47301/2-17-94

Figure 5-1. Contaminant Exposure Pathway for the 100-KR-1 Operable Unit.

Table 5-1. Summary and IRM Recommendations for 100-KR-1 High-Priority Sites.

Waste Site	Qualitative Risk Assessment		Conceptual Model	Exceeds ARARs	Probable Groundwater Impact	Natural Attenuation by 2018	IRM Candidate
	Low - frequency scenario	EHQ > 1					
116-K-1 Crib	Medium	No	Adequate	No	No	No	Yes
116-K-2 Trench	High	Yes	Adequate	No	Yes	No	Yes
116-KW-3 Retention Basin	Medium	Yes	Adequate	Yes	No	No	Yes
116-KE-4 Retention Basin	High	Yes	Adequate	No	No	No	Yes
116-K-3 Outfall Structure	Medium	Not evaluated	Adequate	Unknown	No	Unknown	Yes
Process Effluent Pipelines	Medium	Not evaluated	Adequate	Unknown	Unknown	Yes	No

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APPENDIX A

GAMMA-RAY
GEOPHYSICAL LOGGING

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Westinghouse Hanford Company **Internal Memo**

From: Geosciences Function 81230-93-009
Phone: 6-0940 H6-06
Date: March 4, 1993
Subject: SPECTRAL GAMMA-RAY LOG REPORT OF RADIONUCLIDE SURVEYS ACQUIRED FOR 100-KR-1 OPERABLE UNIT

To: N. M. Naiknimbalkar H6-02

cc: A. D. Krug H6-02
J. R. Brodeur H6-06
J. W. Fassett H6-06
C. J. Koizumi H6-06
J. E. Meisner H6-06
R. K. Price H6-06
R. R. Thompson L4-96
KRF:RKP File/LB

9413222.0625

Attached is a report for three boreholes surveyed with the spectral gamma-ray logging truck in the 100-KR-1 Operable Unit. The spectral gamma-ray logs were collected with the Radionuclide Logging System (RLS) high purity germanium passive gamma-ray logging probe and showed the presence of gamma emitting man-made radionuclides in two of the three boreholes. A fourth borehole was logged with the gross-gamma equipment operated by PNL. This borehole had elevated gamma activity which indicated the presence of man-made contamination even though the radionuclide could not be identified or the activity level determined.

Questions about the technical material in the report should be directed to R. K. Price on 376-9148 or C. J. Koizumi on 376-9534 of the Geosciences staff.

K. R. Fecht
Manager

dyl

Attachment

RLS Passive Spectral Gamma-Ray Borehole Survey Report

Report Date:	March 3, 1993		
Project:	100-KR-1 Operable Unit		
Boreholes:	116-K-1 10/15/92 (logged by PNL Gross-Gamma system)		
	116-K-2 11/13/92		
	116-KE-4A 10/02/92		
	116-KW-3A 10/22/92		
Calibration Date:	November 1991		
Logging Engineers:	R. V. Cram,	S. E. Kos,	J. P. Kiesler
Analyst:	R. K. Price,	J. P. Kiesler,	W. F. Nicaise

9413222.0626

Introduction

Logging with the high resolution, high purity germanium (HPGe) passive spectral gamma-ray system has been completed for three of the four requested boreholes. The fourth borehole was logged with the Gross-Gamma system operated by PNL when the RLS encountered a scheduling conflict which required it to investigate a tank leak. A summary of the boreholes included in this report are presented in Table 1 and Table 2 below. Table 1 contains the survey date, maximum survey depth and maximum depth at which each man-made radionuclide was identified. Table 2 contains the maximum decay activity and corresponding depth for each man-made radionuclide.

The objective of the borehole surveys was to identify the presence and species of man-made gamma-ray emitting radionuclides and the relative activity levels. The graphs of the decay activities (concentrations) versus depth for both man-made radionuclides and the natural radionuclides are presented for each survey. Decay activities are reported in pico-curies per gram (pCi/g) of sample.

The contents of the report are limited to the description of the survey results for each borehole logged. Details of the following: equipment configuration, calibration, logging procedures, casing and water correction factors, spectra analysis software, and data management have been excluded. The details of the excluded topics are described in the papers cited at the end of this report.

100-KR-1 Operable Unit Borehole Geophysics Project Review

Observations of the RLS borehole surveys included in this report are summarized below. This review does not necessarily include all the information that can be gleaned from the spectral gamma-ray survey data.

Table 1: Summary of Maximum Radionuclide Depths from RLS Log Surveys of 100-KR-1 Operable Unit

Borehole ID	Survey Date	Survey Depth[1]	Cesium-137 Depth[2]	Cobalt-60 Depth[2]	Europium-152 Depth[2]	Europium-154 Depth[2]
116-K-1	10/15/92	23'	PNL Survey[3] Maximum 4600 counts per second at 4 feet			
116-K-2	11/13/92	27'	27'[4]	26'	26'	24'
116-KE-4A	10/02/92	20'	14'	-	-	-
116-KW-3A	10/22/92	20'	-	-	-	-

[1]Maximum survey depth
[2]Maximum depth were radionuclide was identified
[3]Scheduling conflict prevented RLS from surveying the borehole. PNL acquired a Gross-Gamma survey.
[4]Maximum depth of borehole survey

Table 2: Summary of Maximum Radioactivity from RLS Log Surveys of 100-KR-1 Operable Unit

Borehole ID	Cesium-137 pCi/g[1]	Ft	Cobalt-60 pCi/g[1]	Ft	Europium-152 pCi/g[1]	Ft	Europium-154 pCi/g[1]	Ft
116-K-1	PNL Survey							
116-K-2	> 200	20	> 200	19	>5000	19	> 200	20
116-KE-4A	< 1	14	-		-		-	
116-KW-3A	-		-		-		-	

[1]Maximum decay activity observed for radionuclide. Maximum depth of reported activity.

COBALT: The highest concentration of cobalt-60 for any borehole surveyed by the RLS at Hanford was recorded in 116-K-2. The activity appeared to exceed 1000 pCi/g.

RADIONUCLIDE MIGRATION: Discharge fluids with low salt content generally permit cesium-137 to be absorbed by the soils very quickly after being discharged. Cobalt-60 generally is much more mobile than cesium and migrates to the ground-water relatively quickly. The migration rate of europium (Eu-152 and Eu-154) is generally intermediate to that of cesium and cobalt. The distribution profile for cesium, cobalt and europium in borehole 116-K-2 indicate that very little migration has occured since the contaminants were introduced to the soils.

EQUIPMENT CALIBRATION: The borehole surveys presented in this report have all been analysed using the calibration data acquired in November 1991. Calculation of the calibration factors used in data reduction depended on the calibration data and on nuclear data (half lives, branching ratios, number of gammas per decay) for the particular nuclide. All of the nuclear data were taken from Erdtmann and Soyka, Die Gamma-Linien der Radionuklide (The Gamma Rays of the Radionuclides), Verlag Chemie GMBh Weinheim, Deutchland, 1979.

Borehole Survey Report

The report for each borehole survey by the RLS contains three types of information. The contents of each information type are described below. The borehole survey reports are presented in the same order as they are listed in Table 1.

1. A single page log header form is first. The form is titled "RLS Spectral Gamma-Ray Borehole Survey Log Header" and summarizes the borehole and survey information.

   The form contains the borehole name, coordinates, and elevation.

   Borehole environment information is next and includes casing parameters and water depth (if present). These are the parameters used for data reduction.

   RLS survey information is presented third and includes the logging engineers name, date, file names, logging mode, and survey depths.

   The survey data reduction information follows and includes calibration date and calibration report number, analyst names and analysis date. A single line is present for analysis notes and man-made radionuclides encountered.

2. Radionuclide activity responses versus depth, i.e., data plots, are plotted on one or more pages. A uniform depth scale of 20 feet/inch is used for all plots. Four plot tracks are presented for uniformity. The experimental uncertainties in the computed radionuclide activities are

not presented on the data plots at this time.

The "Total Gamma" is the count rate for all gamma-rays detected by the RLS detector with no discrimination of gamma-ray energy. The "Total Gamma" is equivalent to the gross gamma log commonly used by some organizations at Hanford. The count rate data values are plotted on two linear scales. The scale of the narrow line is 0 to 1000 c/s. The scale of the wide line is 0 to 100,000 c/s.

The remaining plot tracks contain the results of the spectra gamma-ray analysis. The computed data values are generally plotted on two linear scales. The scale of the narrow line is given at the top of the plot and is 0 to 50 pCi/g. The scale of the wide line is given at the bottom of the plot and is 0 to 5000 pCi/g.

The natural radionuclide activities if presented will be plotted on a separate graph. The Gross Gamma is plotted with a maximum linear scale of 500 cps. The natural radionuclides (potassium, uranium and thorium) are plotted in the three remaining tracks.

3. The analysis notes follow as the third type of information reported for each spectral gamma-ray survey. The notes contain descriptions of the borehole conditions and possible limitations of the plotted results. The depth ranges where each radionuclide was encountered and the maximum activities are reported.

Limitations to the Radioelement Analyses

Several limitations of the borehole survey equipment, calibration, and data acquisition objectives follow.

The logging cable supporting the borehole detector, supplying electrical power, recieving voltage signals for each detected gamma-ray, and permitting the liquid-nitrogen cooled detector to be submerged in water was specially fabricated for the RLS system. The recorded depth of the detector is estimated to be accurate to 98.5 percent, with a precision (repeatability) of 99 percent. Comparisons with drilling measurements, other logging equipment, and secondary measuring systems have verified the accuracy. An upgrade in the logging cable and measuring system is being investigated.

The standard logging configuration optimizes the counting system for detecting low decay activities of radioelements. The RLS has frequently detected man-made radioelement activities of 0.3 pCi/g for nuclides with gamma-rays having energies greater than 500 keV and number of gammas per decay at greater than 50 percent. The maximum decay activity the RLS has detected is about 10,000 pCi/g in this standard configuration.

The alternate logging configuration employs a lead shield and changes the counting system to maximize the count rate. Configuring the counting system to maximize the count rate compromises its ability to detect radioelements at low decay activities (concentrations). The RLS has frequently detected man-made radioelement activities exceeding 33,000 pCi/g in this shielded configuration. The alternate logging configuration was not employed for the surveys included in this report due to hole size restrictions.

Borehole environment correction factors have been determined for steel casing and water in the borehole. Correction factors for other borehole configurations have not been investigated. Borehole configurations for which no correction is available include: (1) grout between multiple casing strings, (2) formation seals containing bentonite, sand, or grout behind the casing, and (3) drilling mud remaining inside the borehole during logging. The calculated decay activity for manmade radionuclides will be underestimated for boreholes with these configurations.

Energy dependent casing corrections have been established for steel casing thicknesses up to 0.40 inches. Corrections for casings of different materials and/or cumulative thicknesses greater than 0.40 inches have not been calculated and therefore cannot be used in the data reduction.

The calibration data were recorded with the detector centered in calibration zones that are uniform in density, water content, and gamma-ray source material. The dimensions of each zone are large enough that the detector always responded as though surrounded by a medium of infinite extent. Therefore, the use of the calibration results to calculate nuclide activity carries the assumption that the nuclides in the logged formation are also distributed in thick uniform layers.

Gamma-ray sources are not normally distributed in the earth in thick uniform layers. Source inhomogeneities are reflected to some degree by the fluctuations in the amplitudes of the log traces. A factor called the vertical spacial resolution quantifies the correlation between (1) the intensity of the log fluctuation and the depth interval over which it extends, and (2) the intensity of the corresponding gamma-ray source and the thickness of the zone in which the source is embedded. The vertical spatial resolution of the RLS HPGe logging system is scheduled for investigation.

Radionuclide decay activities are determined from the net area of the gamma-ray peaks. Radioelements such as strontium-90 which do not emit a gamma-ray when they decay will not be identified or quantified by the spectra analysis performed for this report. The decay of strontium-90 results in a high energy beta particle that can excite surrounding elements to emit photon radiation that can be identified by the HPGe detector. This type of radiation is called bremsstrahlung radiation. A method to obtain estimates of the concentrations of strontium-90 is under consideration.

Conclusion

The RLS has completed surveys for three boreholes associated with 100-KR-1 Operable Unit. Significant quantities of man-made radionuclides were identified in 116-K-2. Trace amounts of cesium-137, less than 0.2 pCi/g, were recorded in borehole 116-KE-4A. No man-made radionuclides were detected in borehole 116-KW-3A. The PNL gross-gamma logging system acquired a survey of borehole 116-K-1 due to scheduling conflicts with the RLS spectral-gamma system. The maximum count rate activity recorded in 116-K-1 was 4600 cps.

The decay activity for the natural radionuclides, KUT, have been computed by the data reduction program and were presented in this report.

Cited Reports

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Westinghouse Hanford Company
RLS Spectral Gamma-Ray Borehole Survey Log Header

Project: 100-KR-1

Borehole	116-KW-3A			
Coordinates	______ N	______ W	Feet	(Plant 100 Area)
Elevation	______.___ ft		Top of casing	(Plant 100 Area)

Borehole Environment Information

Borehole fluid depth None (ft) from zero (0.0) depth reference of log

Casing size (in.)	Casing thickness (in.)	Top depth (ft)	Base depth (ft)
8	0.33	0	24

RLS Passive Spectral Gamma Survey Information

Logging Engineers R. V. Cram J. P. Kiesler
Log depth reference at zero (0.0) depth is ground level

Log Date	Archive file names	Log mode speed	Depth interval (ft) Top	Base	Incr
Oct. 22, 92	H116KW3A\A268	MSA 80sec RT	0	20	0.5

MSA: Move-Stop-Acquire
RT: Real time

Calibration and Analysis Information

RLS Calibration Date: Nov. 21, 1991
Calibration Report: WHC-SD-EN-TRP-001

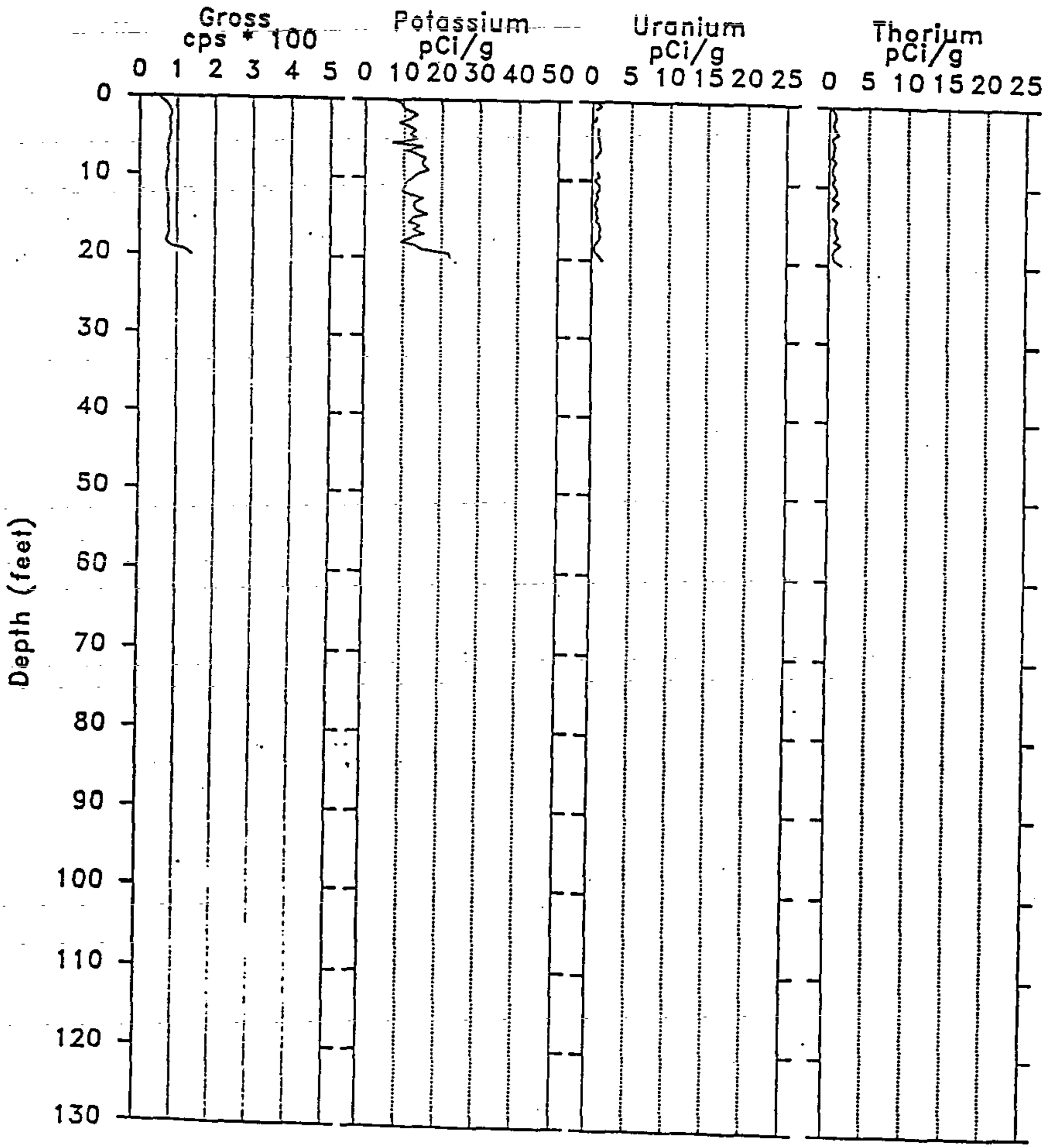
Analyst Names: J. P. Kiesler ______________
Analysis Date: Nov. 24, 1992

Analysis Notes: ______________
Radionuclides Identified: No man made nuclides detected

RLS Spectral Gamma-Ray Borehole Survey

Project: 100-KR-1
Borehole : 116-KW-3A

Log Date : Oct 22, 1992
Anal Date: Nov 24, 1992



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RLS Borehole Survey Report

Borehole: 116-KW-3A Project: 100-KR-1

Casing	Depth: 24'	Size: 8"	Thickness: 0.33"
Water	Depth: none		
Survey	Depth: 0 - 20'	Date: 10/22/92	

General Notes:
The Potassium, uranium and thorium activities are typical of naturally occurring radioelements in the local sediments.

The calculated potassium activities vary between about 6 and 23 pCi/g for the logged interval. The uranium and thorium activities are less than 2 pCi/g over the logged interval. The activity variations are within the statistical uncertainties of the measurements.

The total gamma activity did not exceed 140 cps in the borehole survey.

Man-made Radionuclides:
No man-made Radionuclides were detected in the borehole survey.

Westinghouse Hanford Company
RLS Spectral Gamma-Ray Borehole Survey Log Header

Project: 100-KR-1

Borehole	116-KE-4A			
Coordinates	N	W	Feet	(Plant 100 Area)
Elevation	. ft		Top of casing	(Plant 100 Area)

Borehole Environment Information

Borehole fluid depth None (ft) from zero (0.0) depth reference of log

Casing size (in.)	Casing thickness (in.)	Top depth (ft)	Base depth (ft)
8	0.33	0	22

RLS Passive Spectral Gamma Survey Information

Logging Engineers R. V. Cram S. E. Kos
Log depth reference at zero (0.0) depth is ground level

Log Date	Archive file names	Log mode speed	Depth interval (ft) Top	Base	Incr
Oct. 02, 92	H116KE4A\A273	MSA 80sec RT	0	20	0.5

MSA: Move-Stop-Acquire
RT: Real time

Calibration and Analysis Information

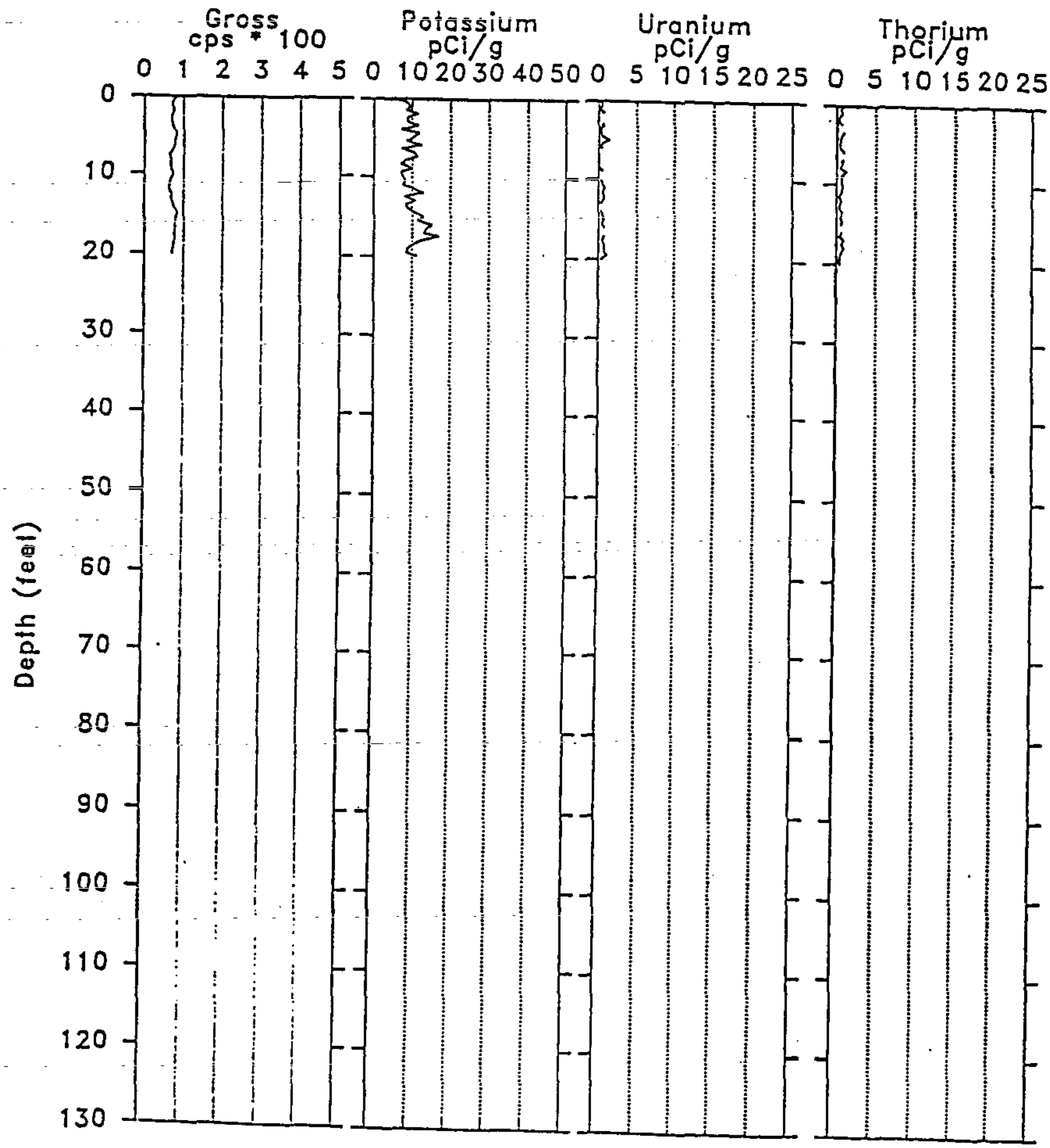
RLS Calibration Date: Nov. 21, 1991
Calibration Report: WHC-SD-EN-TRP-001

Analyst Names: J. P. Kiesler
Analysis Date: Nov. 24, 1992

Analysis Notes:
Radionuclides Identified: Cs-137 discontinuous near detection level

RLS Spectral Gamma-Ray Borehole Survey

Project: 100-K Reactor — Log Date : Nov 02, 1992
Borehole : 116-KE-4A — Anal Date: Nov 24, 1992



RLS Borehole Survey Report

Borehole: 116-KE-4A Project: 100-KR-1

Casing	Depth: 22'	Size: 8"	Thickness: 0.33"
Water	Depth: none		
Survey	Depth: 0 - 20'	Date: 11/02/92	

General Notes:
The Potassium, uranium and thorium activities are typical of naturally occurring radioelements in the local sediments.

The calculated potassium activities vary between about 3 and 17 pCi/g for the logged interval. The uranium and thorium activities are less than 2 pCi/g over the logged interval. The activity variations are within the statistical uncertainties of the measurements.

The total gamma activity did not exceed 90 cps in the borehole survey.

Man-made Radionuclides:
Cesium (Cs-137) was indicated at several discontiuous depths in the survey. The activity level was less than 0.2 pCi/g which is approaching the minimum detection level for the 80 second survey time. The cesium activity was not plotted. The depths where cesium was indicated are 2.5, 5.5, 9.0-9.5, 12.5 and 14.5 feet.

Westinghouse Hanford Company
RLS Spectral Gamma-Ray Borehole Survey Log Header

Project: 100 KR - 1

Borehole	116-K-2			
Coordinates	NA N	NA W	Feet	(Hanford 100 Area)
Elevation	NA	ft	Top of casing	(Hanford 100 Area)

Borehole Environment Information

Borehole liquid depth none (ft) from zero (0.0) depth reference of log

Casing size (in.)	Casing thickness (in.)	Top depth (ft)	Base depth (ft)
8	0.322	0	26

RLS Passive Spectral Gamma Survey Information

Logging Engineers R. V. Cram S. E. Kos
Log depth reference at zero (0.0) depth is ground level

Log Date	Archive file names	Log mode speed	Depth interval (ft) Top	Base	Incr
Nov 13, 1992	H116K02\A281	MSA 80sec RT	0	26	0.5
		Station 300sec	26.7 ft		

MSA: Move-Stop-Acquire
RT: Real time

Calibration and Analysis Information

RLS Calibration Date: Nov. 21, 1991
Calibration Report: WHC-SD-EN-TRP-001

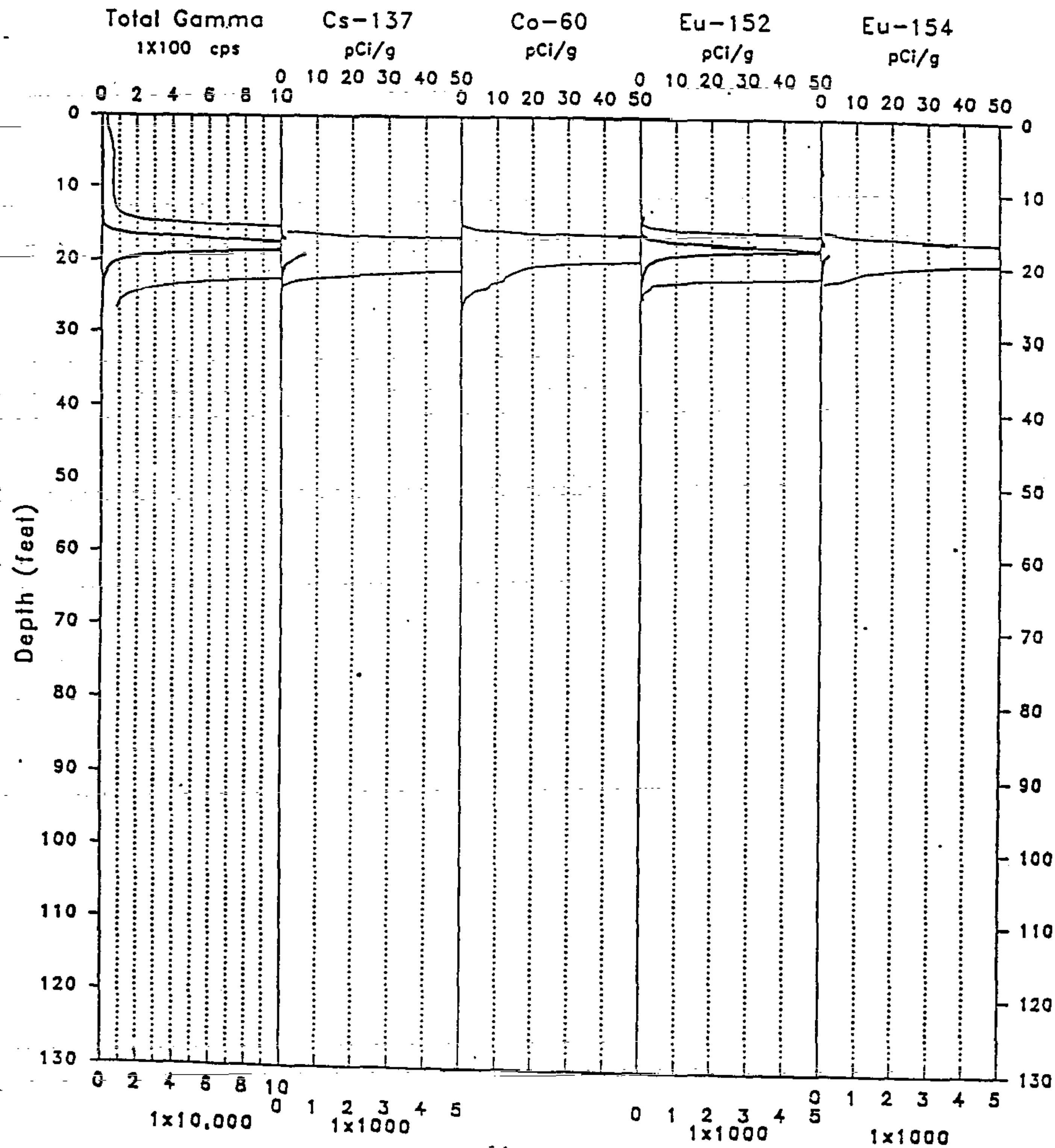
Analyst Names: W. F. Nicaise
Analysis Date: Jan. 15, 1993

Analysis Notes:
Radionuclides Identified: Cs-137, Co-60, Eu-152, Eu-154

RLS Spectral Gamma-Ray Borehole Survey

Project: 100 KR-1
Borehole: 116-K-2

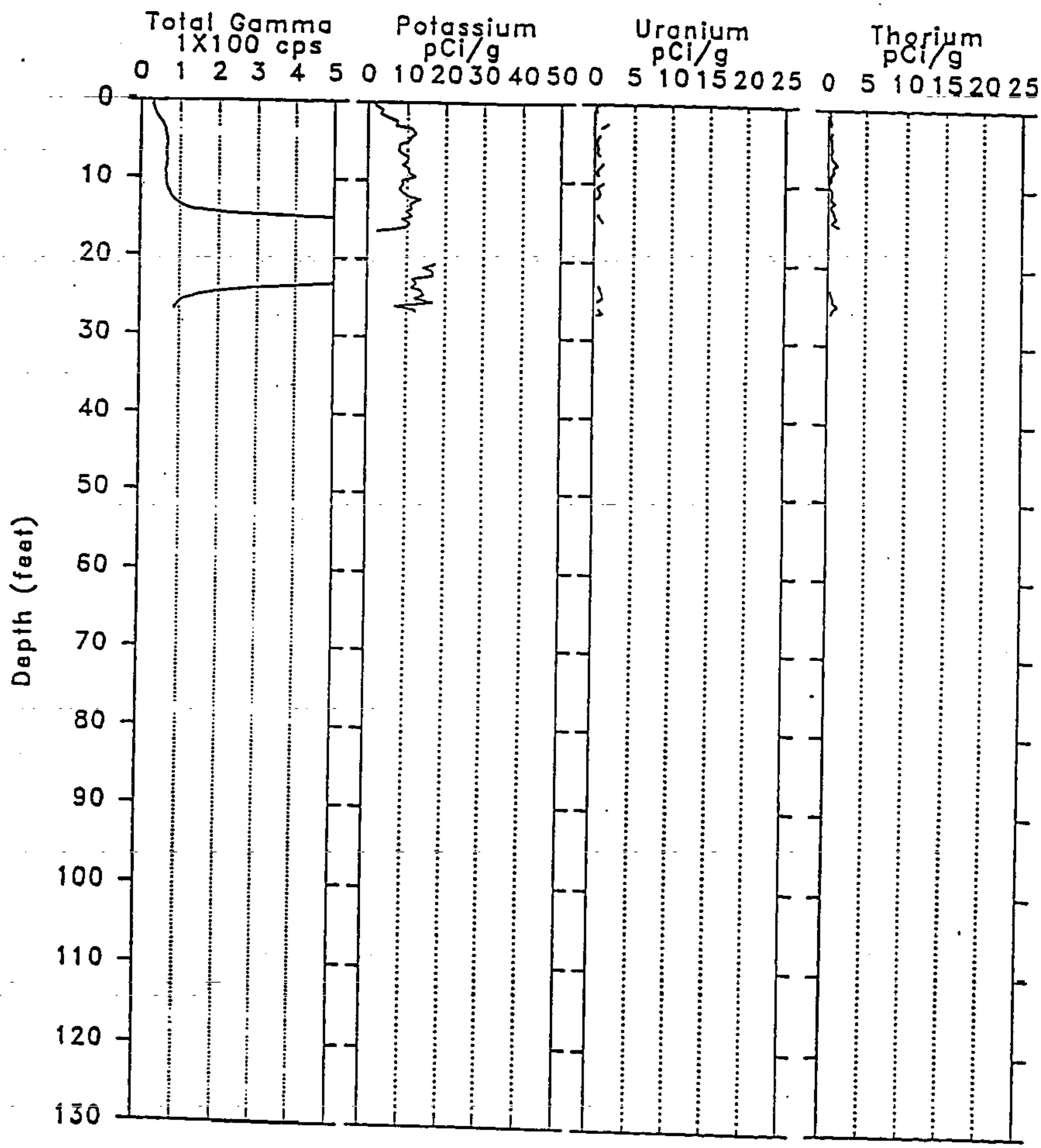
Log Date: Nov 13, 1992
Anal. Date: Feb 02, 1993



RLS Spectral Gamma-Ray Borehole Survey

Project: 100 KR-1
Borehole : 116-K-2

Log Date : Nov 13, 1992
Anal Date: Feb 02, 1993



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RLS Borehole Survey Report

Borehole: 116-K-2

Casing	Depth: 28'	Size: 8"	Thickness: 0.322"
Water	Depth: NA		
Survey	Depth: 0 - 26'	Date: 11/13/92	
	Stations: 26.7 ft		

General Notes:
The well was monitored at fixed intervals from 0 to 26 feet in 0.5 foot increments for real time counting intervals of 80 seconds. A spectrum was also acquired for 300 seconds at 26.7 feet. The total gamma count rate has a maximum of 7.4 E05 cps which occurs at a depth of 18 feet. The depth at which this maximum occurs coincides with the depth of activity maxima for the man-made radionuclides Cs-137, Co-60, Eu-152, and Eu-154. The activities of the naturally occurring radionuclides potassium, uranium, and thorium are within their normal ranges for Hanford soils.It should be noted that the calculated values for Cobalt-60 activity reaches unusually high values for Hanford soils.

Man-made Radionuclides:
Cesium (Cs-137) was detected from 16 to 26.7 feet. The activity exceeded 200 pCi/g from 17.5 to 20 feet.

Cobalt (Co-607) was detected from 15 to 25.5 feet. The activity exceeded 200 pCi/g from 17 to 19 feet.

Europium (Eu-152) was detected from 15 to 25.5 feet. The activity exceeded 200 pCi/g from 17 to 20 feet.

Europium (Eu-154) was detected from 15.5 to 24 feet. The activity exceeded 200 pCi/g at 18.5 feet.

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APPENDIX B
AVAILABLE HISTORICAL DATA FOR 100-KR-1 HIGH PRIORITY SITES

Dorian, J.J., and V.R. Richards, 1978, *Radiological Characterization of the Retired 100 Areas*, UNI-946, United Nuclear Industries, Richland, Washington

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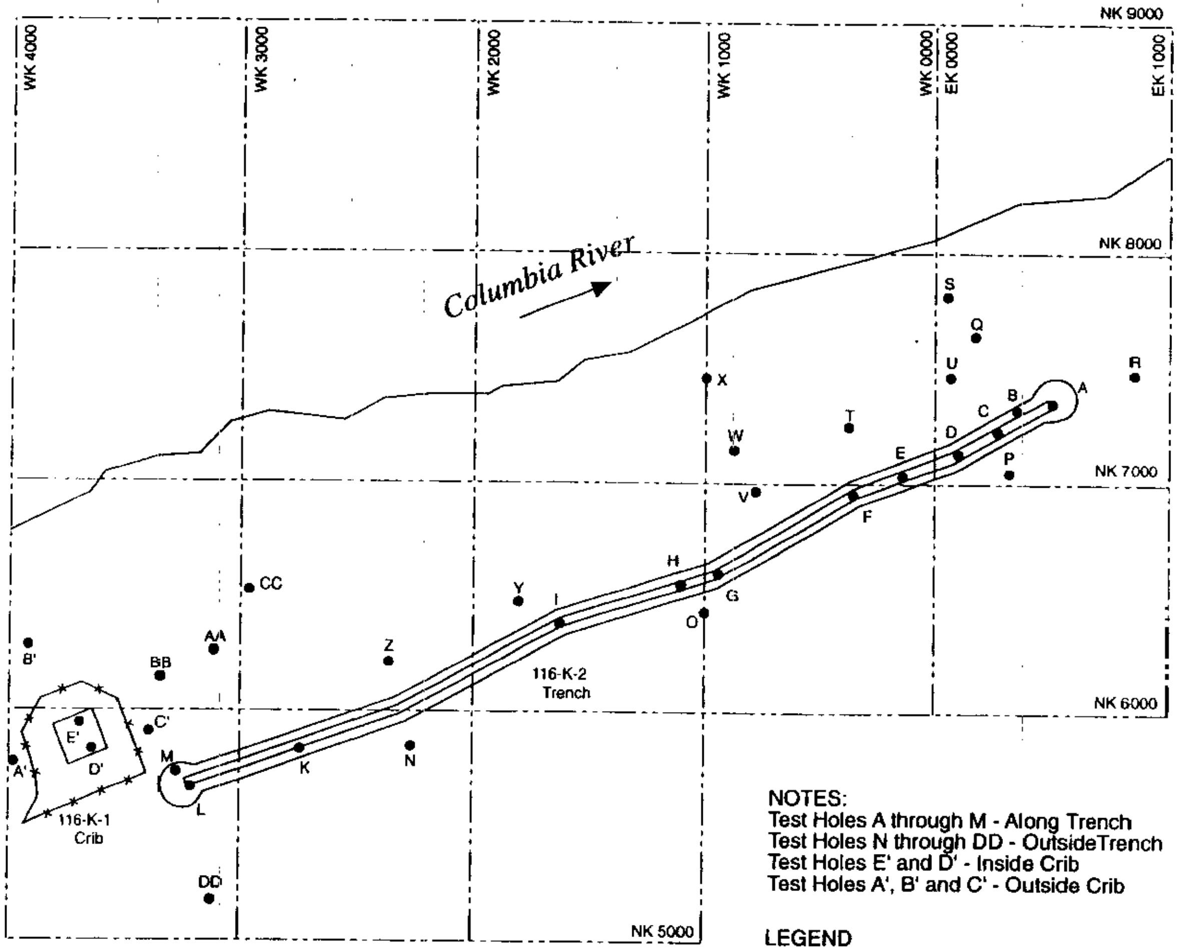


Trench and Crib Sample Hole Data

Trench Points

Hole	North	East	Elev (FT)
A	7344.07	493.73	427.15
B	7306.35	342.20	*
C	7200.94	241.08	428.11
D	7109.82	72.57	428.19
E	7107.50	-163.87	432.51
F	6950.14	-350.98	441.27
G	6596.24	-961.02	426.89
H	6544.75	-1122.38	427.59
I	6383.03	-1615.15	429.14
J	6007.33	-2313.53	434.30
K	5831.20	-2748.11	433.29
L	5670.02	-3221.84	433.40
M	5724.76	-3274.07	442.90
N	5845.30	-2275.39	442.25
O	6441.98	-1006.84	435.60
P	7049.12	313.20	434.71
Q	7632.32	165.32	411.90
R	7471.93	842.79	437.15
S	7813.41	48.70	405.61
T	7236.49	-381.24	416.17
U	7461.27	61.72	405.81
V	6957.16	-785.22	420.75
W	7133.90	-879.42	419.83
X	7443.60	-1001.93	414.46
Y	6460.41	-1799.47	426.48
Z	6204.70	-2359.54	423.84
AA	6242.68	-3108.48	404.53
BB	6133.12	-3342.05	409.00
CC	6532.98	-2965.27	398.18
DD	5170.29	-3137.24	450.98

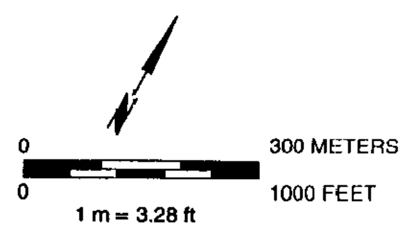
Crib Points

Hole	North	East	Elev (FT)
A'	5782.15	-3976.20	421.77
B'	6283.34	-3912.69	404.50
C'	5914.15	-3411.34	430.05
D'	5837.86	-3635.41	430.17
E'	5941.70	-3687.14	420.88

* Elevation not reported

NOTES:
Test Holes A through M - Along Trench
Test Holes N through DD - OutsideTrench
Test Holes E' and D' - Inside Crib
Test Holes A', B' and C' - Outside Crib

LEGEND
H ● Sample Location
—x—x— Fence



Source: Dorian and Richards 1978.

923 E029/47573/2-17-94

Figure B-1. Location of Soil Samples from the 116-K-1 Crib and 116-K-2 Trench.

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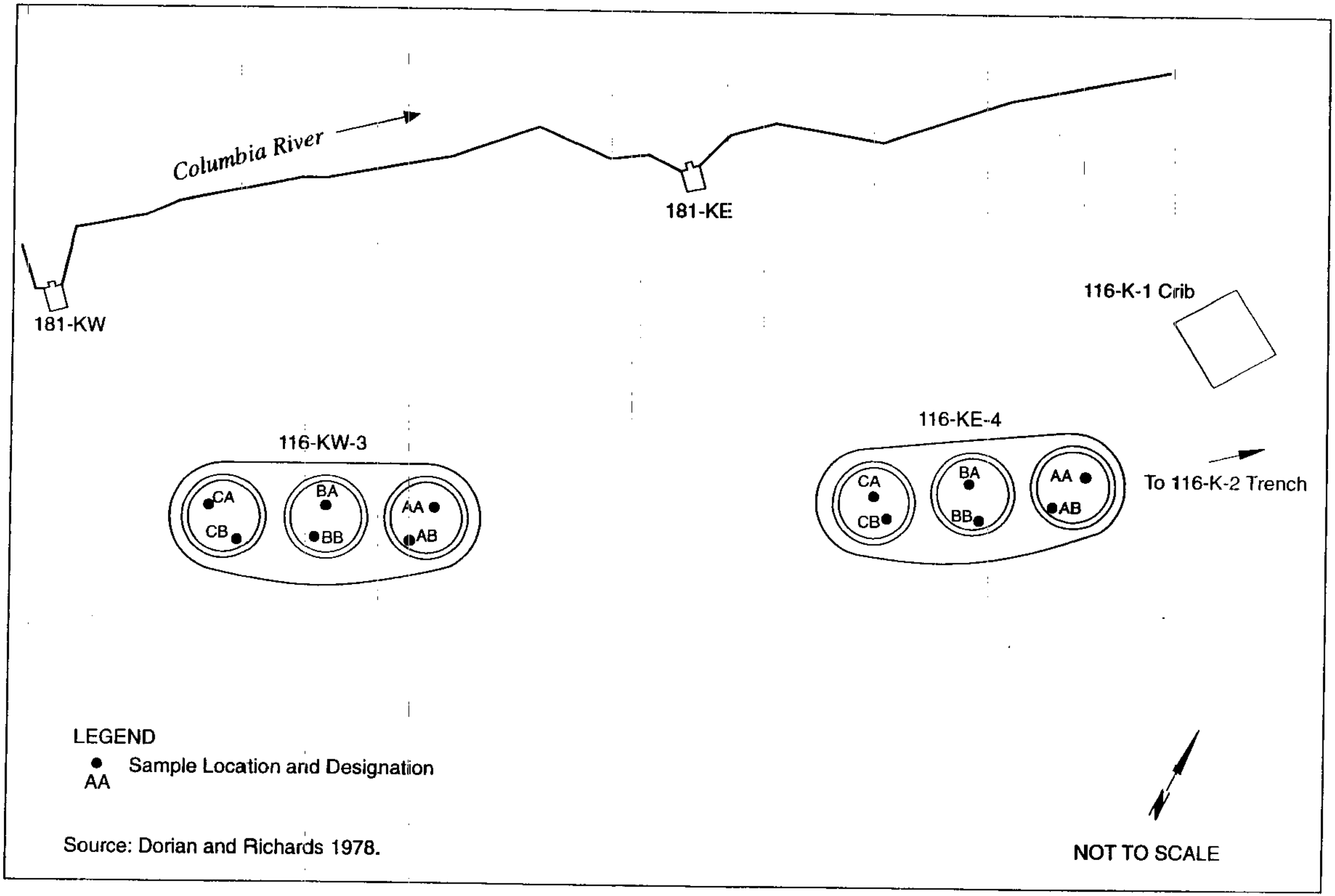

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Figure B-2. Sample Locations Inside the 116-KW-3 and 116-KE-4 Retention Basins.

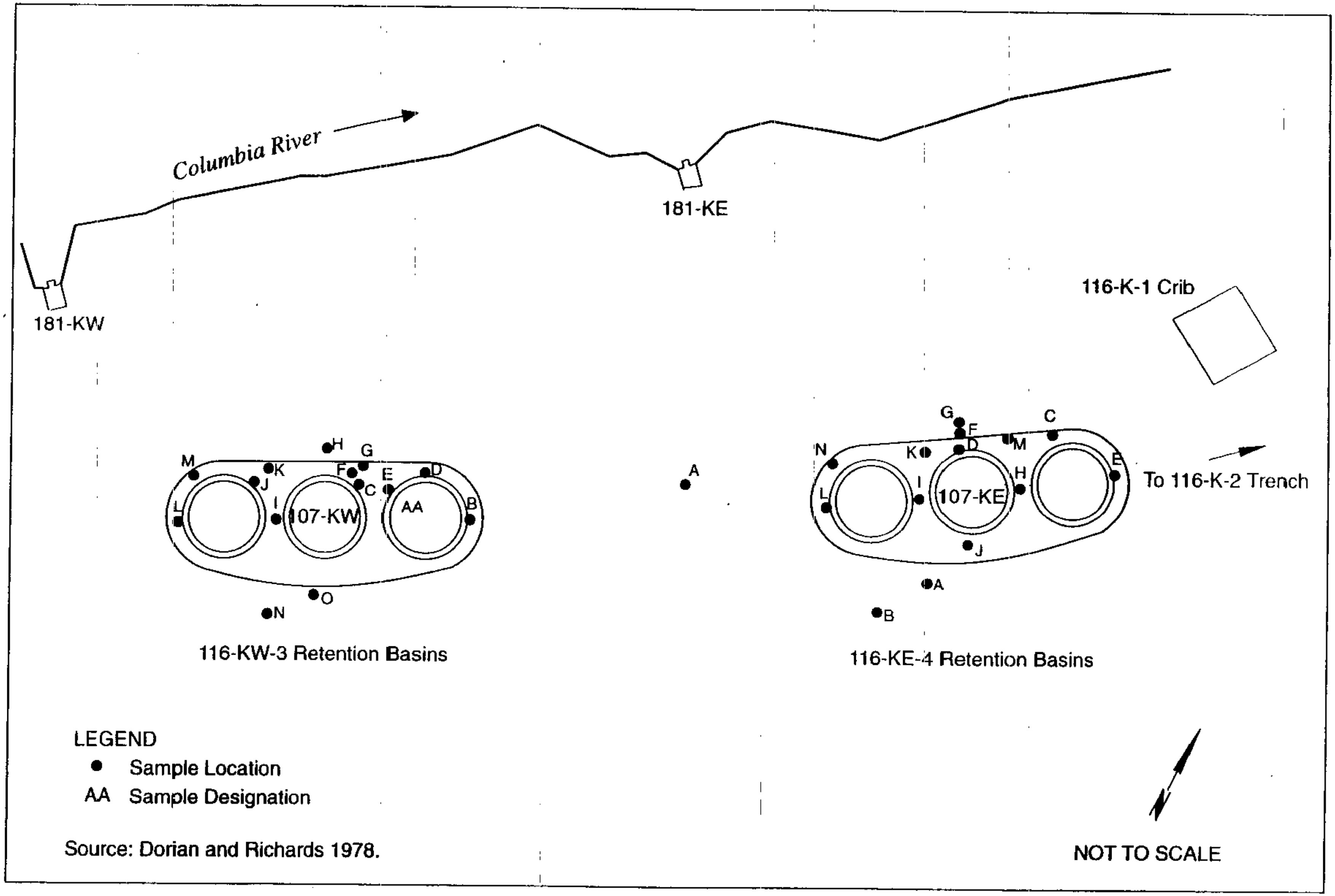

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Figure B-3. Test Hole Locations for Soil Samples Outside the 116-KW-3 and 116-KE-4 Retention Basins.

Table B-1. Radionuclide Concentration (pCi/g) in Holes at 116-K-1 Crib.

Sample Location	Depth (ft)	Pu-238	Pu-239/240	Sr-90	H-3	P-11/Scaler c/m	Eu-152	Co-60	Eu-154	Cs-134	Cs-137	Eu-155	U
A	0	NR	NR	*	NR	<200/5	*	*	*	*	*	*	NR
	5	NR	NR	9.1×10^{-2}	NR	<200/20	*	1.5×10^{-1}	*	*	1.7×10^{-1}	*	2.2×10^{-1}
	15	NR	NR	5.6×10^{-1}	NR	<200/Bkg	9.7×10^{-1}	6.4×10^{-1}	6.4×10^{-1}	4.5×10^{-2}	*	*	NR
B	5	NR	NR	3.7×10^{-2}	NR	<200/30	*	5.8×10^{-2}	*	*	3.9×10^{-2}	*	NR
	15	NR	NR	2.5×10^{-2}	NR	<200/10	*	*	*	*	*	*	NR
	20	*	3.2×10^{-3}	*	NR	<200/30	*	5.4×10^{-2}	*	*	4.5×10^{-2}	*	1.4×10^{-1}
C	0	*	*	1.3×10^{-1}	NR	<200/25	4.3×10^{-1}	9.1×10^{-1}	2.4×10^{-1}	*	6.5×10^{-1}	1.6×10^{-1}	1.1×10^{-1}
	15	NR	NR	2.9×10^{-2}	NR	<200/20	*	*	*	*	4.6×10^{-2}	1.7×10^{-1}	NR
	25	NR	NR	2.6×10^{-2}	NR	<200/5	*	*	*	3.3×10^{-2}	5.2×10^{-2}	*	NR
D	0	4.8×10^{-1}	4.4×10^{0}	1.0×10^{1}	NR	2,500	4.2×10^{2}	3.1×10^{2}	1.7×10^{2}	6.4×10^{0}	7.7×10^{2}	1.4×10^{1}	NR
	5	NR	NR	6.3×10^{0}	NR	1,000	1.3×10^{2}	1.5×10^{2}	5.2×10^{1}	4.0×10^{0}	4.4×10^{2}	4.4×10^{0}	NR
	10	NR	NR	7.2×10^{0}	NR	<200/90	3.0×10^{-1}	3.6×10^{-1}	*	*	6.6×10^{-1}	1.5×10^{-1}	NR
	16	NR	NR	7.9×10^{0}	NR	<200/30	*	*	*	*	*	1.8×10^{-1}	NR
E	0	*	2.5×10^{-1}	2.8×10^{0}	NR	300	3.7×10^{1}	3.0×10^{1}	1.3×10^{1}	2.3×10^{-1}	3.4×10^{1}	5.7×10^{-1}	NR
	2-1/2	*	1.8×10^{-1}	5.9×10^{0}	NR	<200/40	1.1×10^{0}	9.7×10^{-1}	4.1×10^{-1}	*	5.9×10^{-1}	*	NR
	24	*	*	1.0×10^{0}	NR	<200/Bkg.	*	*	*	*	3.8×10^{-2}	*	NR

Notes: Sample locations shown in Figure B-1.
NR = not reported
* = less than detection limit

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Table B-2. Radionuclide Concentration (pCi/g) in Sample Holes Drilled Along 116-K-2 Trench Concentration. (sheet 1 of 2)

Sample Location	Depth (ft)	Pu-238	Pu-239/240	Sr-90	H-3	P-11/Scaler c/m	Eu-152	Co-60	Eu-154	Cs-134	Cs-137	Ni-63	Eu-155	U	C-14
A	5	3.1×10^{-1}	7.6×10^{0}	2.5×10^{1}	NR	1,500	*	*	*	*	*	NR	NR	NR	NR
2A	5	*	*	NR	NR	<200/30	9.7×10^{-1}	2.4×10^{-1}	2.5×10^{1}	*	1.1×10^{-1}	NR	*	NR	NR
	15	2.4×10^{-1}	2.1×10^{0}	1.8×10^{1}	1.5×10^{-1}	1,000	5.8×10^{2}	1.8×10^{2}	1.7×10^{2}	1.3×10^{0}	1.1×10^{2}	NR	9.3×10^{0}	2.5×10^{-1}	NR
	20	*	3.0×10^{-1}	5.7×10^{0}	NR	<200/100	8.6×10^{-1}	8.6×10^{-1}	9.3×10^{-1}	*	2.6×10^{1}	NR	5.2×10^{-1}	NR	NR
B	0	1.9×10^{-1}	2.5×10^{0}	6.2×10^{0}	2.7×10^{2}	1,500	6.0×10^{2}	2.7×10^{2}	2.5×10^{2}	5.6×10^{0}	1.2×10^{2}	NR	6.5×10^{1}	3.1×10^{-1}	NR
	5	*	*	1.6×10^{0}	NR	<200/15	2.2×10^{-1}	1.0×10^{-1}	*	*	*	NR	*	NR	NR
	10	*	*	2.7×10^{-1}	NR	<200/25	3.4×10^{0}	1.5×10^{0}	1.1×10^{0}	*	5.9×10^{-1}	NR	1.4×10^{-1}	2.4×10^{-1}	NR
C	15	4.0×10^{0}	1.3×10^{2}	2.3×10^{2}	1.4×10^{1}	12,000	4.4×10^{4}	1.3×10^{3}	1.7×10^{4}	5.3×10^{2}	4.8×10^{2}	5.1×10^{3}	9.5×10^{2}	2.1×10^{0}	3.2×10^{1}
	17-1/2	2.8×10^{-1}	1.1×10^{1}	4.4×10^{1}	NR	2,000	5.8×10^{2}	3.1×10^{2}	1.4×10^{2}	2.8×10^{0}	4.5×10^{2}	NR	3.7×10^{0}	NR	NR
	20	*	1.6×10^{0}	1.4×10^{1}	NR	400	1.6×10^{2}	9.9×10^{1}	6.1×10^{1}	9.7×10^{-1}	5.7×10^{1}	NR	1.3×10^{1}	NR	NR
	25	3.0×10^{-1}	4.9×10^{0}	3.7×10^{1}	NR	2,500	1.2×10^{3}	2.7×10^{2}	4.5×10^{2}	2.3×10^{0}	2.3×10^{2}	NR	5.7×10^{1}	NR	NR
	28	*	5.4×10^{-1}	1.4×10^{1}	NR	600	1.4×10^{2}	5.0×10^{1}	4.7×10^{1}	5.5×10^{-1}	6.5×10^{1}	NR	2.1×10^{1}	NR	NR
D	5	1.4×10^{-2}	1.2×10^{-1}	6.8×10^{-1}	NR	<200/10	6.6×10^{0}	4.6×10^{0}	2.8×10^{0}	6.7×10^{-2}	2.8×10^{0}	NR	3.8×10^{-1}	NR	NR
	15	4.3×10^{-1}	1.3×10^{-1}	5.7×10^{1}	2.7×10^{1}	2,000	1.6×10^{3}	7.3×10^{2}	6.6×10^{2}	2.1×10^{1}	3.9×10^{2}	NR	1.8×10^{2}	4.1×10^{-1}	NR
	20	*	8.1×10^{0}	1.1×10^{1}	NR	300	1.5×10^{1}	4.1×10^{0}	7.7×10^{-1}	8.6×10^{-2}	7.2×10^{0}	NR	9.3×10^{-1}	NR	NR
	28	*	*	6.3×10^{0}	NR	<200/10	9.0×10^{-1}	3.3×10^{-1}	*	*	2.5×10^{-1}	NR	*	NR	NR
E	0	*	*	4.8×10^{-1}	NR	<200/40	2.9×10^{0}	2.2×10^{2}	1.5×10^{0}	*	1.2×10^{0}	NR	2.8×10^{-1}	NR	NR
	12	1.2×10^{0}	2.1×10^{1}	3.0×10^{1}	8.1×10^{1}	5,000	2.2×10^{3}	7.4×10^{2}	7.4×10^{2}	2.8×10^{1}	9.2×10^{2}	NR	2.3×10^{2}	5.5×10^{-1}	NR
	16	3.0×10^{-1}	4.0×10^{0}	6.7×10^{0}	NR	900	3.5×10^{2}	1.1×10^{2}	1.2×10^{2}	1.1×10^{0}	1.9×10^{2}	NR	4.0×10^{0}	NR	NR
	20	*	3.7×10^{-1}	4.4×10^{0}	NR	250	2.9×10^{1}	3.8×10^{1}	1.1×10^{1}	6.5×10^{-1}	6.9×10^{1}	NR	*	NR	NR
	25	*	2.6×10^{-1}	6.2×10^{0}	NR	<200/50	6.9×10^{0}	4.6×10^{0}	2.0×10^{0}	1.3×10^{-1}	1.3×10^{1}	NR	9.6×10^{-1}	NR	NR
F	0	*	2.0×10^{-1}	2.3×10^{-1}	NR	<200/80	4.7×10^{0}	2.5×10^{0}	*	*	1.6×10^{0}	NR	NR	NR	NR
	12	*	2.0×10^{0}	4.7×10^{0}	2.2×10^{0}	800	2.8×10^{2}	1.8×10^{2}	8.2×10^{1}	9.0×10^{-1}	3.4×10^{2}	NR	5.6×10^{0}	2.6×10^{-1}	NR
	20	*	6.1×10^{-1}	7.4×10^{0}	NR	<200/100	5.8×10^{1}	4.1×10^{1}	1.8×10^{1}	5.3×10^{-1}	1.7×10^{2}	NR	8.2×10^{-1}	NR	NR
G	0	1.6×10^{-2}	*	7.6×10^{-2}	NR	<200/55	*	1.5×10^{-1}	*	6.2×10^{-2}	6.4×10^{-1}	NR	2.7×10^{-1}	NR	NR
3G	19	3.7×10^{-1}	7.1×10^{0}	1.5×10^{1}	5.5×10^{1}	1,500	1.1×10^{3}	5.0×10^{2}	3.4×10^{2}	3.4×10^{0}	7.1×10^{2}	NR	2.6×10^{1}	5.8×10^{-1}	NR
	25	*	2.4×10^{0}	4.8×10^{0}	NR	650	2.8×10^{2}	1.3×10^{2}	1.1×10^{2}	9.0×10^{0}	6.2×10^{2}	NR	2.9×10^{1}	NR	NR
	29	*	7.8×10^{-1}	4.2×10^{0}	NR	500	9.3×10^{1}	7.2×10^{1}	3.2×10^{1}	1.1×10^{0}	1.0×10^{2}	NR	5.5×10^{0}	NR	NR
H	0	*	*	3.3×10^{-1}	NR	<200/85	7.8×10^{0}	5.1×10^{0}	4.0×10^{0}	1.7×10^{-1}	3.1×10^{0}	NR	1.0×10^{0}	NR	NR
	13	2.1×10^{0}	2.8×10^{1}	2.0×10^{1}	2.5×10^{1}	2,000	1.7×10^{3}	5.4×10^{2}	5.3×10^{2}	1.7×10^{1}	7.2×10^{2}	NR	1.9×10^{2}	7.1×10^{-1}	NR
	15	*	4.2×10^{0}	7.6×10^{0}	NR	500	8.7×10^{1}	4.8×10^{1}	2.9×10^{1}	2.9×10^{-1}	9.3×10^{1}	NR	1.1×10^{0}	NR	NR
	18	*	9.4×10^{-1}	1.6×10^{0}	NR	400	1.2×10^{2}	1.2×10^{2}	3.9×10^{1}	1.6×10^{0}	1.2×10^{2}	NR	6.3×10^{0}	NR	NR
	21	*	*	1.9×10^{0}	NR	<200/15	5.8×10^{-1}	7.8×10^{1}	4.4×10^{-1}	*	8.2×10^{0}	NR	3.1×10^{-1}	NR	NR

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Table B-2. Radionuclide Concentration (pCi/g) in Sample Holes Drilled Along 116-K-2 Trench Concentration. (sheet 2 of 2)

Sample Location	Depth (ft)	Pu-238	Pu-239/240	Sr-90	H-3	P-11/Scaler c/m	Eu-152	Co-60	Eu-154	Cs-134	Cs-137	Ni-63	Eu-155	U	C-14
I	15	*	*	3.5×10^{-2}	NR	<200/20	2.7×10^{-1}	9.0×10^{-2}	*	*	1.5×10^{-1}	NR	8.8×10^{-2}	NR	NR
	17	8.7×10^{-1}	2.0×10^{1}	3.3×10^{1}	1.3×10^{2}	3,000	3.0×10^{3}	8.4×10^{2}	9.9×10^{2}	1.1×10^{1}	9.5×10^{2}	NR	3.8×10^{1}	1.2×10^{-1}	NR
	19	*	*	3.0×10^{0}	NR	500	2.9×10^{1}	2.1×10^{2}	1.1×10^{1}	*	*	NR	3.6×10^{-1}	NR	NR
	23	*	*	3.4×10^{0}	NR	<200/20	3.3×10^{0}	2.0×10^{0}	1.4×10^{0}	4.2×10^{-2}	1.7×10^{0}	NR	3.1×10^{-1}	NR	NR
K	0	*	*	3.5×10^{-2}	NR	<200/40	*	*	*	*	7.1×10^{-2}	NR	2.0×10^{-1}	NR	NR
	22	6.4×10^{-1}	1.3×10^{1}	1.9×10^{1}	9.1×10^{1}	3,000	3.8×10^{3}	2.2×10^{3}	1.4×10^{3}	1.5×10^{1}	3.0×10^{3}	NR	1.4×10^{2}	4.5×10^{-1}	NR
	27	9.0×10^{-2}	1.4×10^{0}	2.6×10^{0}	NR	1,000	2.2×10^{2}	1.7×10^{2}	8.3×10^{1}	1.0×10^{0}	1.0×10^{2}	NR	1.1×10^{1}	NR	NR
	30	*	1.9×10^{-1}	2.0×10^{0}	NR	<200	6.1×10^{0}	4.4×10^{1}	*	*	2.6×10^{0}	NR	*	NR	NR
L	0	*	*	2.1×10^{-1}	NR	<200/30	*	*	3.1×10^{-1}	4.9×10^{-2}	*	NR	1.2×10^{-1}	NR	NR
	17	*	1.1×10^{0}	3.5×10^{0}	2.2×10^{1}	<200/130	2.3×10^{1}	1.1×10^{2}	1.2×10^{1}	1.7×10^{-1}	2.4×10^{1}	NR	3.7×10^{0}	4.2×10^{-1}	NR
M	0	*	3.6×10^{-1}	5.5×10^{-2}	MR	<200/40	*	1.4×10^{-1}	5.6×10^{-1}	*	1.3×10^{-1}	NR	*	NR	NR
	17	*	*	1.3×10^{0}	2.8×10^{0}	<200/150	4.0×10^{-1}	1.1×10^{-1}	*	4.7×10^{-2}	5.7×10^{-2}	NR	1.8×10^{-1}	1.9×10^{-1}	NR
	20	*	6.3×10^{-1}	9.3×10^{-1}	NR	<200/25	3.7×10^{-1}	9.3×10^{-2}	4.4×10^{-1}	*	2.9×10^{-2}	NR	*	NR	NR

Sample locations shown in Figure B-1.
* less than detection limit
NR = not reported

Table B-3. Radionuclide Concentrations (pCi/g) in Holes Drilled Outside of 116-K-2

Sample	No.	Pu-238	Pu-239/240	Sr-90	H-3	P-11/Scaler c/m	Eu-152	Co-60	Eu-154	Cs-134	Cs-137	Eu-155	U
N	10	*	*	*	$5.7x10^{-1}$	<200/10	$4.0x10^{-1}$	$8.2x10^{-2}$	*	*	$7.3x10^{-2}$	*	$1.9x10^{-1}$
P	5	*	*	$5.5x10^{-2}$	$2.9x10^{0}$	<200/20	$7.9x10^{-1}$	2.9x10-1	*	$7.5x10^{-2}$	$1.8x10^{-1}$	$3.6x10^{-1}$	$2.6x10^{-1}$
	15	*	*	$2.2x10^{-2}$	NR	<200/10	*	*	*	*	$4.0x10^{-2}$	$2.5x10^{-1}$	NR
	30	*	*	$5.8x10^{-1}$	NR	<200/10	*	*	$1.9x10^{-1}$	*	*	$5.8x10^{-2}$	NR
Q	0	*	*	$3.1x10^{-1}$	NR	<200/25	$5.1x10^{0}$	$1.9x10^{0}$	1.9x100	*	$8.8x10^{-1}$	$3.5x10^{-1}$	NR
	20	*	*	*	$1.0x10^{0}$	<200/10	$1.7x10^{-1}$	$7.8x10^{-2}$	*	$7.0x10^{-2}$	$5.6x10^{-2}$	*	$3.0x10^{-1}$
R	5	*	*	$2.5x10^{-1}$	$9.1x10^{-1}$	<200/25	$5.6x10^{-1}$	$1.0x10^{-1}$	*	$4.9x10^{-2}$	$7.8x10^{-1}$	*	$3.6x10^{-1}$
	15	*	*	*	NR	<200/10	$2.3x10^{-1}$	$7.2x10^{-2}$	*	*	$3.9x10^{-2}$	*	NR
S	0	*	*	$4.6x10^{-1}$	$1.0x10^{0}$	<200/25	$2.1x10^{-1}$	$5.1x10^{-2}$	*	*	*	$2.0x10^{-1}$	$2.2x10^{-1}$
	18	*	*	$1.6x10^{-1}$	NR	<200/10	*	*	*	$4.0x10^{-2}$	$3.6x10^{-2}$	$1.8x10^{-1}$	NR
T	15	*	$1.9x10^{-1}$	$1.6x10^{-1}$	$1.7x10^{0}$	<200/10	$5.7x10^{-1}$	*	*	$5.3x10^{-2}$	*	*	$1.6x10^{-1}$
U	0	*	*	$9.7x10^{-2}$	$5.5x10^{-1}$	<200/20	*	$5.1x10^{-2}$	*	*	$6.9x10^{-2}$	*	$2.7x10^{-1}$
V	0-1	*	*	$2.0x10^{0}$	$2.7x10^{-1}$	250	$1.6x10^{1}$	$3.5x10^{0}$	$5.9x10^{0}$	$5.1x10^{-2}$	$2.8x10^{0}$	$4.9x10^{-1}$	$1.7x10^{-1}$
	0-2	*	*	$2.2x10^{0}$	$2.3x10^{0}$	600	$1.3x10^{2}$	$6.1x10^{1}$	$5.3x10^{1}$	$2.1x10^{0}$	$9.7x10^{1}$	$1.5x10^{1}$	$2.8x10^{-1}$
	5	*	*	$1.9x10^{0}$	NR	<200/15	$4.7x10^{-1}$	$1.4x10^{-1}$	*	*	$3.5x10^{-2}$	$1.5x10^{-1}$	NR
	15	*	*	$6.7x10^{-1}$	NR	<200/20	$3.7x10^{-1}$	$4.8x10^{-2}$	*	*	*	*	NR
Y	-	*	*	$2.1x10^{-1}$	$1.9x10^{0}$	<200/25	*	$1.2x10^{-1}$	*	$3.3x10^{-2}$	$5.4x10^{-1}$	*	$2.1x10^{-1}$
	15	*	*	$1.9x10^{0}$	NR	<200/20	*	*	*	*	*	*	NR
	25	*	*	$2.8x10^{0}$	NR	<200/10	$3.1x10^{-1}$	$1.1x10^{-1}$	*	*	$1.1x10^{0}$	$2.2x10^{-1}$	NR
Z	0	*	*	$7.0x10^{-1}$	NR	<200/20	$1.3x10^{0}$	$1.3x10^{0}$	$1.2x10^{0}$	$5.0x10^{-2}$	$6.5x10^{-1}$	*	NR
	20	*	*	$4.5x10^{0}$	NR	<200/30	*	$4.3x10^{-2}$	*	*	*	$3.4x10^{-1}$	$1.3x10^{-1}$
	25	*	*	$4.2x10^{0}$	NR	<200/15	*	*	*	*	*	$2.8x10^{-1}$	NR
AA	18	*	*	$5.1x10^{-1}$	NR	<200/20	*	*	*	*	*	*	$1.2x10^{-1}$
BB	20	*	*	$2.2x10^{-2}$	$2.4x10^{0}$	<200/10	*	*	*	*	*	*	1.5x10-1
CC	15	*	*	$3.1x10^{-1}$	$3.9x10^{0}$	<200/10	*	*	*	*	*	*	$1.8x10^{-1}$
	20	*	*	$2.6x10^{-2}$	$1.4x10^{1}$	<200/15	$7.2x10^{-1}$	*	$7.2x10^{-1}$	*	*	*	$1.2x10^{-1}$
DD	0	*	*	$2.7x10^{-1}$	$8.5x10^{-1}$	<200/20	$1.5x10^{0}$	$1.6x10^{0}$	$1.5x10^{0}$	$1.6x10^{0}$	$3.3x10^{-1}$	*	$3.1x10^{-1}$
	10	*	*	*	NR	<200/15	*	*	*	*	*	$3.3x10^{-1}$	NR
	20	*	*	$2.8x10^{-2}$	NR	<200/5	*	$3.5x10^{-2}$	*	$3.5x10^{-2}$	*	*	NR

Notes: V 0-1 surface sample from cleared area around sample hole
V 0-2 surface sample from outside cleared area
Sample locations shown on Figure B-1
* = less than detection limit
NR = not reported

Table B-4. Radionuclide Concentration (pCi/g) in Samples of 116-KE Retention Basin Fill.

Sample Location	Depth (ft)	Pu-238	Pu-239/240	Sr-90	H-3	P-11/Scaler c/m	Eu-152	Co-60	Eu-154	Cs-134	Cs-137	Eu-155	U	Ni-63
AA	0	*	*	6.7×10^{-2}	NR	<200/40	6.9×10^{-1}	1.1×10^{0}	4.9×10^{-1}	9.7×10^{-2}	1.6×10^{-1}	1.6×10^{0}	NR	NR
	3	*	1.9×10^{-1}	6.0×10^{0}	2.1×10^{0}	<200/160	6.6×10^{1}	2.0×10^{1}	2.4×10^{1}	*	1.6×10^{0}	5.3×10^{0}	NR	NR
AB	0	NR	NR	7.6×10^{-2}	NR	<200/20	4.2×10^{0}	1.8×10^{-1}	1.3×10^{0}	3.1×10^{-2}	1.3×10^{-1}	3.4×10^{-1}	NR	NR
	2	*	1.8×10^{-1}	6.9×10^{-1}	7.6×10^{-1}	<200/200	1.0×10^{2}	8.4×10^{0}	3.7×10^{1}	*	1.9×10^{-1}	4.4×10^{0}	NR	NR
BA	1	NR	NR	1.6×10^{-1}	NR	<200/30	3.4×10^{-1}	1.2×10^{-1}	*	8.8×10^{-2}	1.4×10^{-1}	1.7×10^{0}	NR	NR
	1-1/2	6.2×10^{-1}	4.6×10^{0}	1.6×10^{-1}	*	<200/150	6.5×10^{1}	8.0×10^{0}	3.2×10^{1}	7.3×10^{-1}	1.7×10^{0}	1.5×10^{1}	NR	NR
BB	1-1/2	*	*	1.9×10^{-1}	*	<200/150	6.4×10^{1}	5.2×10^{0}	2.5×10^{1}	*	3.3×10^{-1}	3.9×10^{0}	NR	NR
CA	0	*	*	3.7×10^{-2}	NR	<200/20	1.6×10^{0}	1.4×10^{-1}	8.5×10^{-1}	*	1.4×10^{-1}	1.6×10^{0}	NR	NR
	2	*	9.8×10^{-1}	1.3×10^{1}	6.0×10^{0}	800	1.8×10^{2}	1.8×10^{2}	7.7×10^{1}	*	6.2×10^{0}	1.1×10^{1}	NR	NR
CB	0	NR	NR	3.6×10^{-2}	NR	400	1.2×10^{1}	3.9×10^{-1}	4.8×10^{0}	*	9.4×10^{-2}	1.5×10^{0}	NR	NR
	1	*	*	3.2×10^{-1}	NR	400	3.5×10^{0}	2.6×10^{0}	2.3×10^{0}	*	7.8×10^{-2}	6.3×10^{-1}	NR	NR
	2	NR	NR	9.2×10^{-2}	NR	<200/20	3.8×10^{0}	3.8×10^{0}	2.7×10^{0}	*	1.5×10^{-1}	2.7×10^{0}	NR	NR
	2-1/2	*	1.1×10^{0}	7.9×10^{0}	1.7×10^{1}	5,000	6.4×10^{2}	1.2×10^{3}	5.8×10^{2}	1.3×10^{1}	2.7×10^{1}	2.7×10^{2}	4.2×10^{-2}	6.1×10^{0}
Scale from bottom of the inlet chute 107-KE		9.4×10^{-1}	1.2×10^{1}	4.8×10^{0}	1.1×10^{2}		5.0×10^{4}	7.7×10^{3}	1.7×10^{4}	1.8×10^{2}	7.9×10^{3}	NR	1.6×10^{0}	NR

Sample locations shown in Figure B-2.
* = less than analytical detection limit
NR = not reported

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Table B-5. Radionuclide Concentrations (pCi/g) Sample Holes Drilled Outside of 116-KE Retention Basin.

Sample Location	Depth (ft)	Pu-238	Pu-239/240	Sr-90	H-3	P-11/Scaler c/m	Eu-152	Co-60	Eu-154	Cs-134	Cs-137	Eu-155
C	0	*	*	$3.9x10^{-1}$	NR	<200/70	$1.2x10^{1}$	$5.5x10^{0}$	$5.2x10^{0}$	*	$5.2x10^{-1}$	$4.7x10^{-1}$
D	0	*	*	$1.2x10^{0}$	NR	<200/80	$1.4x10^{1}$	$8.8x10^{1}$	$5.2x10^{0}$	*	$2.4x10^{1}$	$1.3x10^{0}$
E	5	*	*	$3.0x10^{-1}$	NR	<200/50	$2.3x10^{1}$	$1.2x10^{1}$	$7.8x10^{0}$	$2.0x10^{-1}$	$1.3x10^{0}$	$2.7x10^{0}$
F	0	*	*	$8.8x10^{-1}$	NR	<200/40	$9.4x10^{0}$	$7.9x10^{0}$	$4.3x10^{0}$	*	$3.9x10^{0}$	$6.0x10^{-1}$
	5	*	*	$4.5x10^{-1}$	NR	<200/30	$3.5x10^{0}$	$3.3x10^{0}$	$1.3x10^{0}$	*	$2.3x10^{0}$	$1.4x10^{-1}$
G	15	NR	NR	$1.2x10^{-1}$	NR	<200/25	$3.6x10^{-1}$	$1.4x10^{-1}$	*	*	$3.7x10^{-2}$	$2.0x10^{-1}$
H	0	*	*	$4.4x10^{-1}$	*	<200/50	$2.5x10^{1}$	$8.4x10^{0}$	$8.3x10^{0}$	*	$1.4x10^{0}$	$2.1x10^{0}$
	5	NR	NR	$4.3x10^{-1}$	NR	<200/25	$1.9x10^{0}$	$8.6x10^{-1}$	$8.1x10^{-1}$	*	$4.1x10^{-1}$	$2.7x10^{-1}$
I	0	*	*	$2.8x10^{-1}$	$5.3x10^{-1}$	<200/30	$5.5x10^{0}$	$6.5x10^{-1}$	$2.0x10^{0}$	$8.2x10^{-2}$	$1.9x10^{-1}$	$4.6x10^{-1}$
J	0	*	*	$1.6x10^{0}$	$1.3x10^{0}$	<200/100	$2.9x10^{1}$	$1.7x10^{1}$	$1.2x10^{1}$	*	$3.6x10^{0}$	$6.8x10^{-1}$
	15	NR	NR	$1.8x10^{-1}$	NR	<200/15	$1.1x10^{-1}$	$1.0x10^{-1}$	*	*	$3.4x10^{-2}$	$1.1x10^{-1}$
K	0	*	*	$7.4x10^{-1}$	NR	<200/25	$5.9x10^{0}$	$2.7x10^{0}$	$2.4x10^{0}$	$6.9x10^{-2}$	$7.4x10^{-1}$	$1.5x10^{0}$
L	0	*	*	$3.2x10^{-1}$	*	<200/30	$2.2x10^{0}$	$3.7x10^{-1}$	$9.6x10^{-1}$	$6.8x10^{-2}$	$3.4x10^{-1}$	$2.8x10^{-1}$
M	10	*	*	$4.3x10^{-1}$	NR	400	$2.8x10^{1}$	$3.3x10^{1}$	$1.1x10^{1}$	*	$9.2x10^{0}$	$1.1x10^{1}$
	10	*	$2.1x10^{-1}$	$2.3x10^{0}$	*	400	$6.2x10^{1}$	$4.1x10^{1}$	$2.5x10^{1}$	$5.2x10^{-2}$	$4.0x10^{1}$	$1.3x10^{0}$
	20	*	*	$1.1x10^{0}$	NR	<200/50	$1.3x10^{0}$	$6.6x10^{-1}$	$1.1x10^{0}$	$1.0x10^{-1}$	$2.3x10^{1}$	$7.5x10^{-1}$
N	0	*	$1.2x10^{-2}$	$1.9x10^{0}$	*	<200/60	$3.8x10^{1}$	$1.3x10^{1}$	$1.3x10^{1}$	*	$1.2x10^{1}$	$2.2x10^{0}$
	15	NR	NR	$1.8x10^{-1}$	NR	<200/30	$5.6x10^{-1}$	$2.3x10^{-1}$	$2.0x10^{-1}$	*	$1.5x10^{1}$	$1.0x10^{0}$

Notes: Sample locations shown in Figure B-1.
NR = not reported
* = less than detection limit

Table B-6. Radionuclide Concentration (pCi/g) in Samples of 116-KW Retention Basin Fill.

Sample Location	Depth (ft)	Pu-238	Pu-239/240	Sr-90	H-3	P-11/Scaler c/m	Eu-152	Co-60	Eu-154	Cs-134	Cs-137	Eu-155	Ni-63
AA	1-1/2	*	*	1.8×10^{-2}	5.7×10^{0}	200	1.1×10^{1}	2.3×10^{1}	6.1×10^{0}	1.3×10^{-1}	3.0×10^{-1}	2.1×10^{0}	NR
	2	*	2.1×10^{-1}	2.9×10^{-1}	5.5×10^{-1}	5,000	5.6×10^{2}	1.3×10^{3}	3.4×10^{2}	8.2×10^{0}	8.8×10^{0}	5.0×10^{1}	8.8×10^{2}
AB	1	NR	NR	*	NR	<200/40	2.7×10^{0}	1.8×10^{0}	1.4×10^{0}	4.6×10^{-2}	7.0×10^{-2}	5.4×10^{-1}	NR
	2	*	4.3×10^{-1}	1.8×10^{-1}	1.5×10^{0}	1,000	2.1×10^{2}	1.9×10^{2}	3.9×10^{1}	*	9.7×10^{-1}	3.5×10^{2}	NR
BA	1-1/2	*	*	9.2×10^{-1}	NR	<200/60	5.4×10^{0}	1.4×10^{1}	7.2×10^{-1}	*	1.9×10^{-1}	4.0×10^{-1}	NR
	2	*	8.3×10^{0}	7.9×10^{1}	1.7×10^{0}	3,000	6.7×10^{2}	5.3×10^{2}	2.0×10^{2}	*	3.0×10^{1}	1.6×10^{1}	NR
BB	1-1/2	NR	NR	NR	NR	<200/40	1.5×10^{0}	1.1×10^{0}	5.5×10^{-1}	*	1.5×10^{-1}	*	NR
	2	*	1.2×10^{0}	3.3×10^{0}	1.3×10^{0}	3,000	5.3×10^{2}	9.0×10^{2}	3.1×10^{2}	*	4.1×10^{0}	2.8×10^{1}	NR
CA	1-1/2	*	6.7×10^{-1}	1.2×10^{0}	6.0×10^{-1}	600	1.3×10^{2}	9.9×10^{1}	1.3×10^{2}	*	7.3×10^{-1}	*	NR
CB	2	*	1.1×10^{0}	1.2×10^{1}	NR	NR	1.1×10^{3}	1.0×10^{3}	6.6×10^{2}	5.3×10^{0}	1.8×10^{1}	3.6×10^{2}	NR

Notes: Sample locations shown in Figure B-1.
NR = not reported
* = less than detection limit

Table B-7. Radionuclide Concentrations (pCi/g) Sample Holes Drilled Outside of 116-KW Retention Basin.

Sample Location	Depth (ft)	Pu-238	Pu-239/240	Sr-90	H-3	P-11/Scaler c/m	Eu-152	Co-60	Eu-154	Cs-134	Cs-137	Eu-155
B	0	*	*	6.9×10^{-1}	4.9×10^{-1}	<200/50	2.0×10^{1}	1.1×10^{1}	1.0×10^{1}	5.0×10^{-1}	2.0×10^{0}	4.3×10^{0}
	25	*	*	2.6×10^{-1}	NR	<200/25	*	*	*	*	4.3×10^{-2}	*
C	0	*	*	2.1×10^{-1}	*	<200/50	1.5×10^{1}	2.4×10^{0}	4.3×10^{0}	*	5.3×10^{-1}	9.6×10^{-1}
	20	NR	NR	*	NR	<200/30	*	*	*	*	*	*
D	0	*	*	6.9×10^{-1}	*	<200/80	2.2×10^{1}	1.2×10^{1}	1.1×10^{1}	2.1×10^{-1}	3.8×10^{0}	4.5×10^{0}
	10	NR	NR	1.8×10^{-1}	NR	<200/25	2.2×10^{0}	1.0×10^{0}	5.1×10^{-1}	4.1×10^{-2}	7.6×10^{-1}	2.8×10^{-1}
E	0	*	3.5×10^{-1}	1.4×10^{-1}	4.3×10^{-1}	<200/40	6.8×10^{0}	3.6×10^{0}	3.2×10^{0}	5.9×10^{-2}	2.0×10^{0}	1.3×10^{0}
	20	NR	NR	*	NR	<200/20	4.8×10^{-1}	4.1×10^{-2}	*	*	*	*
F	0	*	*	3.0×10^{-2}	NR	<200/40	3.5×10^{0}	2.6×10^{0}	4.3×10^{0}	5.9×10^{-2}	3.7×10^{-1}	1.5×10^{0}
	15	NR	NR	*	NR	<200/15	*	3.7×10^{-2}	*	*	*	1.7×10^{-1}
G	0	*	*	4.0×10^{-1}	*	<200/50	1.1×10^{1}	6.0×10^{0}	4.9×10^{0}	*	1.1×10^{0}	1.8×10^{0}
	8	NR	NR	5.4×10^{-2}	NR	<200/30	1.1×10^{0}	4.8×10^{-1}	7.0×10^{-1}	*	1.6×10^{-1}	2.9×10^{-1}
H	0	*	*	9.8×10^{-1}	*	<200/50	6.3×10^{0}	1.1×10^{1}	1.3×10^{1}	1.5×10^{-1}	2.8×10^{0}	6.9×10^{0}
	20	NR	NR	3.9×10^{-2}	NR	<200/25	*	4.4×10^{-2}	*	4.3×10^{-2}	*	1.0×10^{-1}
I	0	*	*	1.3×10^{-1}	NR	<200/25	3.4×10^{0}	1.2×10^{0}	1.3×10^{0}	*	7.3×10^{-1}	2.8×10^{-1}
J	0	*	1.4×10^{-1}	1.5×10^{0}	*	<200/60	2.1×10^{1}	8.9×10^{0}	6.4×10^{0}	*	3.1×10^{0}	2.7×10^{-1}
K	0	*	*	1.8×10^{0}	NR	5,000	8.1×10^{2}	1.0×10^{1}	1.8×10^{2}	1.9×10^{0}	6.9×10^{0}	5.7×10^{2}
	10	*	1.0×10^{-1}	1.9×10^{0}	*	<200/50	1.6×10^{1}	7.6×10^{0}	7.1×10^{0}	2.5×10^{-1}	5.3×10^{0}	2.3×10^{0}
L	1	*	5.2×10^{-1}	7.8×10^{-1}	4.3×10^{-1}	600	1.3×10^{2}	5.0×10^{1}	3.3×10^{1}	*	2.8×10^{1}	2.6×10^{2}
	10	*	2.3×10^{-1}	2.7×10^{0}	1.1×10^{0}	<200/140	5.4×10^{1}	2.2×10^{1}	1.8×10^{1}	*	1.5×10^{1}	1.2×10^{0}
M	0	*	3.2×10^{0}	3.8×10^{1}	7.8×10^{0}	800	5.6×10^{2}	2.6×10^{2}	2.4×10^{2}	3.9×10^{0}	2.4×10^{2}	2.4×10^{1}
N	0	NR	NR	1.1×10^{0}	NR	<200/15	1.3×10^{0}	3.6×10^{-1}	3.0×10^{-1}	*	2.6×10^{0}	1.2×10^{-1}
	15	*	*	1.1×10^{0}	3.2×10^{1}	<200/25	9.4×10^{-1}	2.1×10^{-1}	2.1×10^{-1}	*	4.3×10^{0}	1.7×10^{-1}

Notes: Sample locations shown in Figure B-1.
NR = not reported
* = less than detection limit

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APPENDIX C

Results of Physical Properties Samples from 116-KE-4 Borehole

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116-KE-4A Borehole
5.0 to 5.5 ft bgs
Sample BO7LK2

SAMPLE NO.	3-0567
Contact	R.F. Raidl
Well No.	116-KE-4A
Operable Unit	100-KR-1
HEIS No.	B07LK2
Depth	5.0 - 5.5

TEMPE CELLS	Sample #	3-0567 1 Bar Drying Curve								
tension in cm	N/A	N/A	3.5	7.3	11	21.5	35.5	49	74.5	99
error in tension value +/-			0.5	0.5	1	2	5	2	5	2
container number	MC-1	TC-26	TC-26	TC-26	TC-26	TC-26	TC-26	TC-26	TC-26	TC-26
weight of container/ring,+wet sample	171.52	557.84	575.55	575.85	575.70	575.35	575.15	574.49	572.78	571.78
weight of container/ring,+ dry sample	171.06	557.28	555.33	555.33	555.33	555.33	555.33	555.33	555.33	555.33
weight of moisture	0.46	0.56	20.22	20.52	20.37	20.02	19.82	19.16	17.45	16.45
weight of container and ring	62.74	424.95	424.83	424.83	424.83	424.83	424.83	424.83	424.83	424.83
weight of dry sample	108.78	132.33	130.50	130.50	130.50	130.50	130.50	130.50	130.50	130.50
moisture content % by wt.	0.42%		15.49%	15.72%	15.61%	15.34%	15.19%	14.68%	13.37%	12.60%
moisture content % by vol.			12.46%	12.64%	12.55%	12.33%	12.21%	11.80%	10.75%	10.13%
date measured			2/26/93	3/1/93	3/2/93	3/3/93	3/4/93	3/5/93	3/8/93	3/9/93
temperature deg. C			24	23	24	25	22	25	23	24
volume of brass ring, cm^3	68.26									

TEMPE CELLS	Sample #	3-0567 1 Bar Drying Curve						
tension in cm	200.3	300	500	700	850	1000	N/A	N/A
error in tension value +/-	5	2	20	20	20	20		
container number	TC-26	TC-26	TC-26	TC-26	TC-26	TC-26	TC-26	MC-1
weight of container/ring,+wet sample	568.65	567.20	566.08	565.40	564.64	564.39	564.37	202.23
weight of container/ring,+ dry sample	555.33	555.33	555.33	555.33	555.33	555.33	555.33	193.23
weight of moisture	13.32	11.87	10.75	10.07	9.31	9.06	9.04	9.00
weight of container and ring	424.83	424.83	424.83	424.83	424.83	424.83	424.83	62.74
weight of dry sample	130.50	130.50	130.50	130.50	130.50	130.50	130.50	130.49
moisture content % by wt.	10.20%	9.09%	8.23%	7.71%	7.13%	6.94%	6.92%	6.90%
moisture content % by vol.	8.20%	7.31%	6.62%	6.20%	5.73%	5.58%	5.57%	
date measured	3/10/93	3/11/93	3/12/93	3/15/93	3/16/93	3/17/93		3/18/93
temperature deg. C	25	23	23	24	25	23		26
volume of brass ring, cm^3	68.26							

SAMPLE BULK DENSITY = 1.91 g/cm³

FIELD BULK DENSITY = 2.01 g/cm³

FRACTION LESS THAN 2 mm = 0.40

Cell wt. before cleanup = 424.71 grams

Cell wt. after cleanup = 424.84 grams

424.83 Average of all 3

TEMPE CELLS	Sample #	3-0567 1 Bar Wetting Curve							
tension in cm	N/A	N/A	1000	1000	1000	1000	1000	1000	1000
error in tension value +/-			20	20	20	20	20	20	20
container number	MC-1	TC-1	TC-1	TC-1	TC-1	TC-1	TC-1	TC-1	TC-1
weight of container/ring,+wet sample	171.52	557.46	561.86	563.67	563.75	563.80	563.85	563.95	563.88
weight of container/ring,+ dry sample	171.06	556.91	557.50	557.50	557.50	557.50	557.50	557.50	557.50
weight of moisture	0.46	0.55	4.36	6.17	6.25	6.30	6.35	6.45	6.38
weight of container and ring	62.74	425.71	426.00	426.00	426.00	426.00	426.00	426.00	426.00
weight of dry sample	108.78	131.20	131.50	131.50	131.50	131.50	131.50	131.50	131.50
moisture content %	0.42%		3.32%	4.69%	4.75%	4.79%	4.83%	4.90%	4.85%
moisture content % by vol.			2.67%	3.77%	3.82%	3.85%	3.88%	3.94%	3.90%
date measured			2/25/93	2/26/93	3/1/93	3/2/93	3/3/93	3/4/93	3/5/93
temperature deg. C			22	23	22	24	25	22	22
volume of brass ring, cm^3	68.26								

TEMPE CELLS	Sample #	3-0567 1 Bar Wetting Curve							
tension in cm	1000	700	500	300	202	104.5	69	54.5	31
error in tension value +/-	20	20	20	20	20	20	5	2	2
container number	TC-1	TC-1	TC-1	TC-1	TC-1	TC-1	TC-1	TC-1	TC-1
weight of container/ring,+wet sample	563.84	564.09	564.64	565.68	566.94	569.74	571.71	572.77	574.34
weight of container/ring,+ dry sample	557.50	557.50	557.50	557.50	557.50	557.50	557.50	557.50	557.50
weight of moisture	6.34	6.59	7.14	8.18	9.44	12.24	14.21	15.27	16.84
weight of container and ring	426.00	426.00	426.00	426.00	426.00	426.00	426.00	426.00	426.00
weight of dry sample	131.50	131.50	131.50	131.50	131.50	131.50	131.50	131.50	131.50
moisture content %	4.82%	5.01%	5.43%	6.22%	7.18%	9.31%	10.81%	11.61%	12.81%
moisture content % by vol.	3.88%	4.03%	4.37%	5.00%	5.77%	7.48%	8.69%	9.34%	10.30%
date measured	3/8/93	3/9/93	3/10/93	3/11/93	3/12/93	3/15/93	3/16/93	3/17/93	3/18/93
temperature deg. C	23	23	24	22	23	23	26	23	26
volume of brass ring, cm^3	68.26								

Cell wt. before cleanup = 426.06 grams
Cell wt. after cleanup = 425.56 grams
425.78 Average of all 3

TEMPE CELLS	Sample #	3-0567 1 Bar Wetting Curve				
tension in cm	24.0	10.0	6.3	2.5	N/A	N/A
error in tension value +/-	3	2	2	1		
container number	TC-1	TC-1	TC-1	TC-1	TC-1	MC-9
weight of container/ring,+wet sample	574.91	576.11	576.33	576.73	576.72	211.36
weight of container/ring,+ dry sample	557.50	557.50	557.50	557.50	557.50	192.24
weight of moisture	17.41	18.61	18.83	19.23	19.22	19.12
weight of container and ring	426.00	426.00	426.00	426.00	426.00	60.89
weight of dry sample	131.50	131.50	131.50	131.50	131.50	131.35
moisture content %	13.24%	14.15%	14.32%	14.62%	14.62%	14.56%
moisture content % by vol.	10.64%	11.38%	11.51%	11.76%	11.75%	
date measured	3/19/93	3/22/93	3/23/93	3/24/93		3/25/93
temperature deg. C	25	23	25	24		25
volume of brass ring, cm^3	68.26					

BULK DENSITY = 1.93

KETTLES	Sample #	3-0567 15 Bar Drying Curve							
tension in Bars	0.5	0.5	0.7	0.7	1.0	1.0	2.0	2.0	3.0	3.0
error in tension value +/-	20	20	20	20	20	20	20	20	20	20
container number	BA1	BA2	BA1	BA2	BA1	BA2	BB1	BB2	BB1	BB2
weight of container/ring,+wet sample	55.74	59.20	55.77	59.14	55.51	59.00	55.48	57.90	55.33	57.78
weight of container/ring,+ dry sample	53.83	57.24	53.96	57.28	53.78	57.21	54.03	56.32	53.95	56.30
weight of moisture	1.91	1.96	1.81	1.86	1.73	1.79	1.45	1.58	1.38	1.48
weight of container and ring	27.93	30.36	27.93	30.36	27.93	30.36	27.89	27.57	27.89	27.57
weight of dry sample	25.90	26.88	26.03	26.92	25.85	26.85	26.14	28.75	26.06	28.73
moisture content %	7.37%	7.29%	6.95%	6.91%	6.69%	6.67%	5.55%	5.50%	5.30%	5.15%
date measured	3/18/93	3/18/93	3/12/93	3/12/93	3/23/93	3/23/93	3/12/93	3/12/93	3/18/93	3/18/93
temperature deg. C	27	27	24	24	25	25	24	24	27	27

KETTLES						
tension in Bars	5.0	5.0	7.0	7.0	10.0	10.0
error in tension value +/-	20	20	100	100	100	100
container number	BB1	BB2	BC1	BC2	BC1	BC2
weight of container/ring,+wet sample	55.17	57.57	60.29	59.39	60.08	59.22
weight of container/ring,+ dry sample	53.91	56.20	59.06	58.18	58.99	58.13
weight of moisture	1.26	1.37	1.23	1.21	1.09	1.09
weight of container and ring	27.89	27.57	30.30	29.12	30.30	29.12
weight of dry sample	26.02	28.63	28.76	29.06	28.69	29.01
moisture content %	4.84%	4.79%	4.28%	4.16%	3.80%	3.76%
date measured	3/23/93	3/23/93	3/12/93	3/12/93	3/18/93	3/18/93
temperature deg. C	25	25	24	24	27	27

Water Potential Data for CX-2 Samples		
Sample No.	3-0567A	3-0567
Container Number	BC1	BC1
Aw Reading	0.689	0.986
Temperature °C	23.8	24.7
Water Potential, Bars	509.9	19.4
Can ID No	BA1	BA2
Can + Soil Wet wt., g	36.73	39.66
Can + Soil Dry wt., g	36.59	39.38
Can Tare wt., g	27.93	30.36
Weight of Water, g	0.14	0.28
Dry Weight of Sample, g	8.66	9.02
Moisture Content, wt. %	1.62%	3.10%
date measured	4/5/93	4/5/93

9413222.0659

POINTS SELECTED FOR PLOTTING Sample # 3-0567

container number	TC-26	TC-26	TC-26	TC-26	TC-26	TC-26	TC-26	TC-26	TC-26	TC-26	TC-26
Tension in cm	3.50E+00	7.30E+00	1.10E+01	2.15E+01	3.55E+01	4.90E+01	7.45E+01	9.90E+01	2.00E+02	3.00E+02	5.00E+02
Tempe Drying Curve	12.46%	12.64%	12.55%	12.33%	12.21%	11.80%	10.75%	10.13%	8.20%	7.31%	6.62%
Kettle/CX-2 Drying Curve											
Tempe Wetting Curve											
date measured	2/26/93	3/1/93	3/2/93	3/3/93	3/4/93	3/5/93	3/8/93	3/9/93	3/10/93	3/11/93	3/12/93

container number	TC-26	TC-26	TC-26	BA1	BB1	BB1	BC1	BC1	BC1	BC1	TC-1
tension in cm	7.00E+02	8.50E+02	1.00E+03	1.02E+03	2.04E+03	3.06E+03	7.14E+03	1.02E+04	1.97E+04	5.20E+05	1.00E+03
Tempe Drying Curve	6.20%	5.73%	5.58%								
Kettle/CX-2 Drying Curve				5.37%	4.44%	4.20%	3.39%	3.04%	2.50%	1.30%	
Tempe Wetting Curve											3.88%
date measured	3/15/93	3/16/93	3/17/93	3/23/93	3/12/93	3/18/93	3/12/93	3/18/93	4/5/93	4/5/93	3/8/93

container number	TC-1	TC-1	TC-1	TC-1	TC-1	TC-1	TC-1	TC-1	TC-1	TC-1	TC-1
tension in cm	7.00E+02	5.00E+02	3.00E+02	2.02E+02	1.05E+02	6.90E+01	5.45E+01	3.10E+01	2.40E+01	1.00E+01	6.30E+00
Tempe Drying Curve											
Kettle/CX-2 Drying Curve											
Tempe Wetting Curve	4.03%	4.37%	5.00%	5.77%	7.48%	8.69%	9.34%	10.30%	10.64%	11.38%	11.51%
date measured	3/9/93	3/10/93	3/11/93	3/12/93	3/15/93	3/16/93	3/17/93	3/18/93	3/19/93	3/22/93	3/23/93

container number	TC-1
tension in cm	2.50E+00
Tempe Drying Curve	
Kettle/CX-2 Drying Curve	
Tempe Wetting Curve	11.76%
date measured	3/24/93

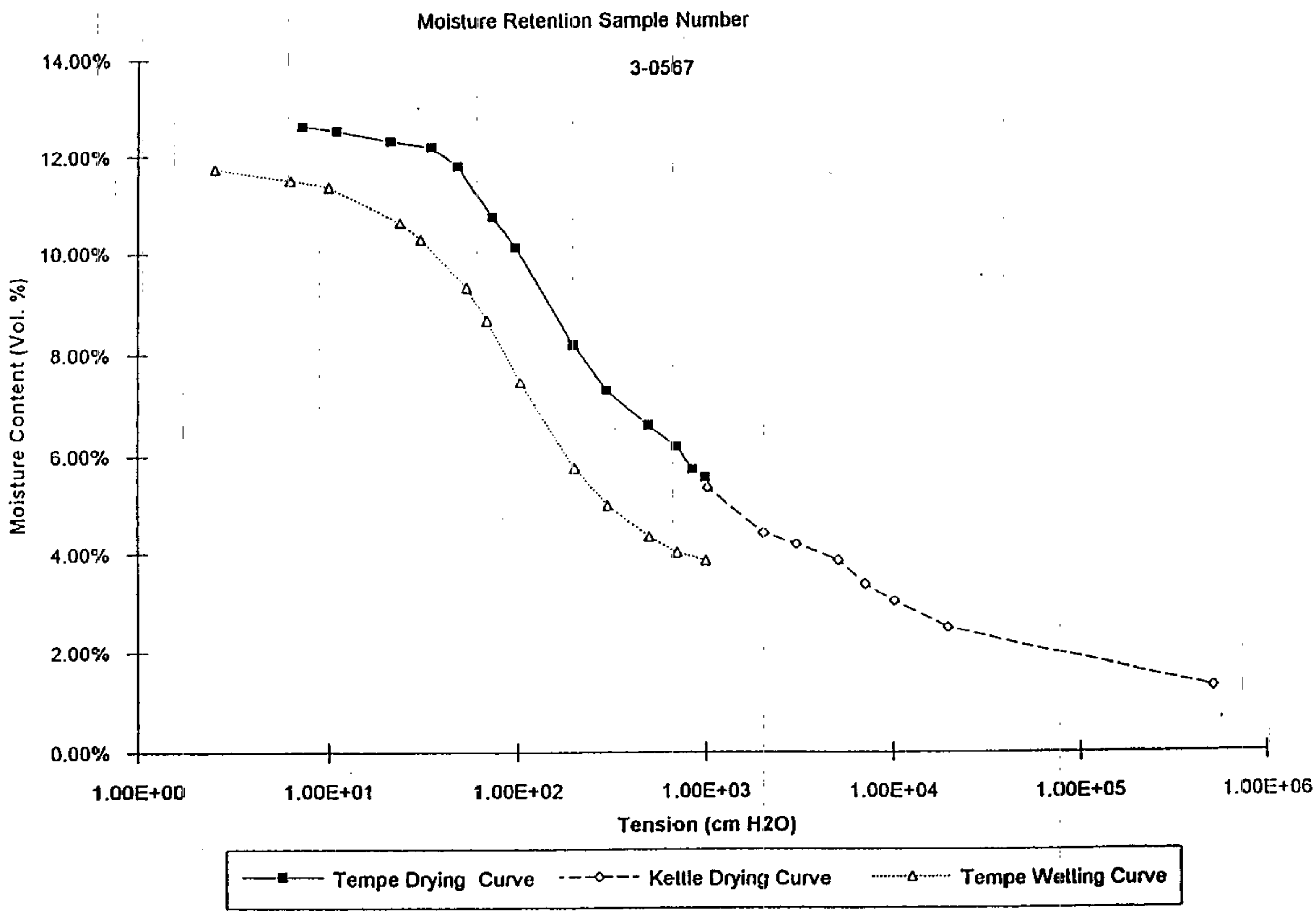
Kettle data points were converted from gravimetric to volumetric by multiplying by the field Bulk Density
And the fraction of fines (less than 2mm).

Bulk Density = 2.01 g/cm³

Fraction of fines = 0.40

Points from kettle are enclosed by the double outline

Points from CX-2 are enclosed by the single outline


Moisture Retention Sample Number
3-0567
14.00%
12.00%
10.00%
8.00%
6.00%
4.00%
2.00%
0.00%
Moisture Content (Vol. %)
1.00E+00
1.00E+01
1.00E+02
1.00E+03
1.00E+04
1.00E+05
1.00E+06
Tension (cm H2O)
Tempe Drying Curve
Kettle Drying Curve
Tempe Wetting Curve

MOISTURE RETENTION DATA SHEET

SAMPLE NO. 3-0567 | Page ____ of ____

Tested By:	R.M. Shaller	Date	2/25/93		
Procedure No:	17	Rev.	0	Date Issued	2/25/90
Test Plan No:	N/A	Rev.	N/A	Date Issued	N/A
Pressure Cell No.	TC-26	Calibration Due Date	N/A		
Gauge:	GEL - 2026	Calibration Due Date	1/27/94		
Thermometer:	GEL - 12	Calibration Due Date	N/A		
Balance:	GEL - 3315	Calibration Due Date	5/18/93		
Gauge:	GEL - 2040	Calibration Due Date	6-17-93		
:	GEL -	Calibration Due Date			

(1) Tension units = cm	N/A	N/A	3.5	7.3	11	21.5	35.5	49	74.5	99	200.3	300	500
(2) Container/Ring Number	MC-1	TC-26	TC-26	TC-26	TC-26	TC-26	TC-26	TC-26	TC-26	TC-26	TC-26	TC-26	TC-26
(3) Wt. of Container and Wet Sample, g	171.52	557.84	575.55	575.85	575.70	575.35	575.15	574.49	572.78	571.78	568.65	567.20	566.08
(4) Wt. of Container and Dry Sample, g	171.06												
(5) Container Tare Wt., g	62.74	424.95											
(6) Temperature			24	23	24	25	22	25	23	24	25	23	23
(7) Date			2/26/93	3/1/93	3/2/93	3/3/93	3/4/93	3/5/93	3/8/93	3/9/93	3/10/93	3/11/93	3/12/93

(1) Tension units = cm	700	850	1000	N/A	N/A								
(2) Container/Ring Number	TC-26	TC-26	TC-26	TC-26	MC1								
(3) Wt. of Container and Wet Sample, g	565.40	564.64	564.39	564.37	202.23								
(4) Wt. of Container and Dry Sample, g					193.23								
(5) Container Tare Wt., g				* 424.71	62.74								
(6) Temperature	24	25	23		26								
(7) Date	3/15/93	3/16/93	3/17/93		3/18/93								

REMARKS
Operable Unit 100-KR-1
* Tempe Drying Curve (0 to 1 Bar)
Cleaned Tare Wt. 424.84

All data are acurately and completely recorded. The test operator was trained and used calibrated instruments

Checked By: J F Relyea Date: 4-19-93

MOISTURE RETENTION DATA SHEET

SAMPLE NO. 3-0567 Page ____ of ____

Tested By:	R.H. Shailer	Date	2/24/93
Procedure No:	17	Rev. 0	Date Issued 2/25/90
Test Plan No:	N/A	Rev. N/A	Date Issued N/A
Pressure Cell No.	TC-1	Calibration Due Date	N/A
Gauge:	GEL - 2029	Calibration Due Date	1/27/94
Thermometer:	GEL - 12	Calibration Due Date	N/A
Balance:	GEL - 3315	Calibration Due Date	5/18/93
Gauge:	GEL - 2045	Calibration Due Date	7-31-93
:	GEL -	Calibration Due Date	

(1) Tension units = cm	NA	NA	1000	1000	1000	1000	1000	1000	1000	1000	700	500	300
(2) Container/Ring Number	MC-1	TC-1	TC-1	TC-1	TC-1	TC-1	TC-1	TC-1	TC-1	TC-1	TC-1	TC-1	TC-1
(3) Wt. of Container and Wet Sample, g	171.52 ~~160.27~~	557.46	561.86	563.67	563.75	563.80	563.85	563.95	563.88	563.84	564.09	564.64	565.68
(4) Wt. of Container and Dry Sample, g	RMS 2/24/93 171.06												
(5) Container Tare Wt., g	62.74	425.71											
(6) Temperature			22	23	22	24	25	22	22	23	23	24	22
(7) Date			2/25/93	2/26/93	3/1/93	3/2/93	3/3/93	3/4/93	3/5/93	3/8/93	3/9/93	3/10/93	3/11/93

(1) Tension units = cm	202	104.5	69	54.5	31	24	10	6.3	2.5	NA	NA		
(2) Container/Ring Number	TC-1	TC-1	TC-1	TC-1	TC-1	TC-1	TC-1	TC-1	TC-1	TC-1	MC-9		
(3) Wt. of Container and Wet Sample, g	566.94	569.24	571.71	572.77	574.34	574.91	576.11	576.33	576.73	576.72	211.36		
(4) Wt. of Container and Dry Sample, g											192.24		
(5) Container Tare Wt., g										*426.06	60.89		
(6) Temperature	23	23	26	23	26	25	23	25	24		25		
(7) Date	3/12/93	3/15/93	3/16/93	3/17/93	3/18/93	3/19/93	3/22/93	3/23/93	3/24/93		3/25/93		

REMARKS

Operable Unit 100-KR-1

Tempe Wetting Curve (0 to 1 Bar)

*Cleaned Tare 425.56

All data are acurately and completely recorded. The test operator was trained and used calibrated instruments

Checked By: J F Relyea Date: 4-19-93

MOISTURE RETENTION DATA SHEET

SAMPLE NO. 3-0567 Page 1 of 3

Tested By:	R.M. Shailer	Date 3/8/93	
Procedure No:	17	Rev. 0	Date Issued 2/25/90
Test Plan No:	N/A	Rev. N/A	Date Issued
Pressure Cell No.	KETTLE PK05-01	Calibration Due Date	N/A
Gauge:	GEL - 2038	Calibration Due Date	6/17/93
Thermometer:	GEL - 12	Calibration Due Date	N/A
Balance:	GEL - 3315	Calibration Due Date	5/18/93
Gauge:	GEL -	Calibration Due Date	
:	GEL -	Calibration Due Date	

.5 .5 .7 .7 1 1

(1) Tension units = cm	.5	.5	.7	.7	1	1									
(2) Container/Ring Number	1-1 BA1	1-2 BA2	1-1 BA1	1-2 BA2	1-1 BA1	1-2 BA2									
(3) Wt. of Container and Wet Sample, g	55.74	59.20	55.77	59.14	55.51	59.20									
(4) Wt. of Container and Dry Sample, g	53.83	57.24	53.96	57.28	53.78	57.21									
(5) Container Tare Wt., g	27.93	30.36	27.93	30.36	27.93	30.36									
(6) Temperature	27	27	24	24	25	25									
(7) Date	3/18/93	3/18/93	3/22/93	3/22/93	3/23/93	3/23/93									

(1) Tension units = cm															
(2) Container/Ring Number															
(3) Wt. of Container and Wet Sample, g															
(4) Wt. of Container and Dry Sample, g															
(5) Container Tare Wt., g															
(6) Temperature															
(7) Date															

REMARKS
operable unit
100-KR-1

KETTLE DRYING CURVE (0.5 to 1.0 BARs)

All data are acurately and completely recorded. The test operator was trained and used calibrated instruments

Checked By: J F Relyea Date: 4-19-93

MOISTURE RETENTION DATA SHEET

SAMPLE NO. 3-0567

Tested By:	K.M. Shailer	Date	3/8/93
Procedure No:	17	Rev.	0
Test Plan No:	N/A	Rev.	N/A
Pressure Cell No.	KETTLE PK05-02	Calibration Due Date	
Gauge:	GEL - 2052	Calibration Due Date	7/2/93
Thermometer:	GEL - 12	Calibration Due Date	N/A
Balance:	GEL - 3315	Calibration Due Date	5/18/93
Gauge:	GEL - 2034	Calibration Due Date	4/3/93
:	GEL -	Calibration Due Date	

Date Issued 2/25/90
Date Issued

2 2 3 3 5 5

(1) Tension units = cm	2	2	3	3	5	5							
(2) Container/Ring Number	3-1 BB1	3-2 BB2	3-1 BB1	3-2 BB2	3-1 BB1	3-2 BB2							
(3) Wt. of Container and Wet Sample, g	55.48	57.90	55.33	57.78	55.17	57.57							
(4) Wt. of Container and Dry Sample, g	54.63	56.32	53.95	56.30	53.91	56.20							
(5) Container Tare Wt., g	27.89	27.57	27.89	27.57	27.89	27.57							
(6) Temperature	24	24	27	27	25	25							
(7) Date	3/12/93	3/12/93	3/18/93	3/18/93	3/23/93	3/23/93							

(1) Tension units = cm													
(2) Container/Ring Number													
(3) Wt. of Container and Wet Sample, g													
(4) Wt. of Container and Dry Sample, g													
(5) Container Tare Wt., g													
(6) Temperature													
(7) Date													

REMARKS

KETTLE DRYING CURVE (2.0 to 5.0 BARs)

Operable Unit
100-KR-1

All data are acurately and completely recorded. The test operator was trained and used calibrated instruments

Checked By: J F Relyea Date: 4-19-93

MOISTURE RETENTION DATA SHEET

SAMPLE NO. 3-0567 Page 3 of 3

Tested By:	R.M. Shailer	Date	3/8/93
Procedure No:	17	Rev. 0	Date Issued 2/25/90
Test Plan No:	N/A	Rev. N/A	Date Issued
Pressure Cell No.	KETTLE PK15-02	Calibration Due Date	
Gauge:	GEL - 2038	Calibration Due Date	6/17/93
Thermometer:	GEL - 12	Calibration Due Date	N/A
Balance:	GEL - 3315	Calibration Due Date	5/18/93
Gauge:	GEL -	Calibration Due Date	
:	GEL -	Calibration Due Date	

	7	7	10	10									
(1) Tension units = cm	7	7	10	10									
(2) Container/Ring Number	5-1 BC1	5-2 BC2	5-1 BC1	5-2 BC2									
(3) Wt. of Container and Wet Sample, g	60.39	59.37	60.08	59.22									
(4) Wt. of Container and Dry Sample, g	59.06	58.18	58.99	58.13									
(5) Container Tare Wt., g	30.30	29.12	30.30	29.12									
(6) Temperature	24	24	27	27									
(7) Date	3/12/93	3/12/93	3/18/93	3/18/93									

(1) Tension units = cm													
(2) Container/Ring Number													
(3) Wt. of Container and Wet Sample, g													
(4) Wt. of Container and Dry Sample, g													
(5) Container Tare Wt., g													
(6) Temperature													
(7) Date													

REMARKS KETTLE DRYING CURVE (7.0 to 15.0 BARS)

Operable Unit
100-KR-1

All data are accurately and completely recorded. The test operator was trained and used calibrated instruments

Checked By: J F Relyea Date: 4-19-93

CX-2 WATER ACTIVITY DATA SHEET

Tested By: K.M. Shailer   Date 4/5/93   Page 1 of 2

Procedure No: GEL-33   Rev. 0   Date Issued 3/23/93
Test Plan No: ______   Rev. ______   Date Issued ______

Equipment	GEL No.	Calibration Due Date
Balance	3315	5/18/93
Thermometer		

Equipment	GEL No.	Calibration Due Date
Balance		
Thermometer		

Linear Offset Data	Pretest Verification					Post Test / Periodic Verification				
Type of Salt	DI H_2O									
Salt Conc. (Molal)/(Sat.)	Sat	LiCl	NaCl	KCl						
Aw Reading	.999	.114	.755	.846						
Temperature °C	24.0	24.0	24.4	24.5						
Aw Standard at 20°C										

Water Potential Data for Samples

Sample No.	3-0567A	3-0567	3-0568A	3-0568	3-0569A	3-0569	3-0570A	3-0570	3-0571A	3-0571
Container Number	BC1	BC1	BC3	BC3	BC5	BC5	BC7	BC7	BC9	BC9
Aw Reading	.689	.986	.844	.984	.756	.981	.641	.892	.835	.900
Temperature °C	23.8	24.7	24.6	24.5	24.7	24.6	24.9	25.1	25.3	25.4
Water Potential, Bars										

Moisture Content for Water Potential Samples

Can ID No	BA1	BA2	BA3	BA4	BA5	BA6	BA7	BA8	BA9	BA10
Can + Soil Wet wt., g	36.73	39.66	39.04	37.24	39.15	36.40	35.57	38.79	41.53	38.90
Can + Soil Dry wt., g	36.57	39.38	38.90	37.03	39.10	36.28	35.46	38.60	41.47	38.82
Can Tare wt., g	27.93	30.36	25.67	27.84	30.37	27.49	27.72	28.09	30.32	27.71
Weight of Water, g										
Dry Weight of Sample, g										
Moisture Content, wt. %										

REMARKS

All data are accurate and completely recorded. The test operator was trained and used calibrated instruments.

Checked By: Arlen F Relyea   Date: 4-19-93

GEL 16 ☒ GEL 17 ☒ GEL 19 ☒ GEL ☐
☒ ☒ .0 ☒ 14 ☒

GEOTECHNICAL ENGINEERING LABORATORY
GEL-07 SIEVE AND HYDROMETER ANALYSIS

Sample No. 3-0567

Page 1 of 5

GEL-07 SIEVE ANALYSIS

Date 2-12-93 Calibration Due Date 4-25-93 Balance:

Sample Description SAND & GRAVEL Sieve Time 10 (min)

Reduced By: ☒ Splitting ☐ Quartering ☐ Stockpile

Sieve Size	Sample Weight	Cumulative Wt. Retained	Cumulative % Retained	Cumulative % Passed	Tested By
2	2210.7	0	0	100	LD Bruggeman
1 1/2	↓	183.7	8.3	91.7	
3/4		626.0	28.3	71.7	
3/8		872.5	39.5	60.5	
4		1084.8	49.1	50.9	
10	↓	1326.7	60.0	40.0	
40	202.2	101.3	50.1	20.0	
60		122.3	60.5	15.8	
100		135.2	66.9	13.3	
200	↓	156.0	77.2	9.1	

Remarks:

GEL-07 HYDROMETER ANALYSIS

Date

Balance: Calibration Due Date

Thermometer: Calibration Due Date

Hydrometer: Calibration Due Date

WEIGHT OF SAMPLE

Wt. Container + Soil (g) Specific Gravity of Sample

Wt. Container (g) % Passing No. 10 Sieve %

Wt. Soil (g) A = W = K =

COMPOSITE CORRECTION

1st Reading at °C

2nd Reading at °C

Date	Clock Time	Elapsed Time (min)	Hydrometer Reading	Hydrometer with Composite Correction	Temperature (°C)	Soil in Suspension (%)	Particle Diameter (mm)	Tested By
		2.0						
		5.0						
		15.0						
		30.0						
		60.0						
		250.0						
		1440.0						

NOT APPLICABLE

Remarks:

Tests Checked By R.T. McIntosh Date 2/16/93

9413222.0667

GEL 16 ☒
GEL 17 ☒
GEL 19 ☒
GEL ☐

GEOTECHNICAL ENGINEERING LABORATORY
GEL-14, GEL-16, GEL-19

Sample No. 3-0567

Page 5 of 5

GEL-14 SOIL MOISTURE

Balance: 3304 Calibration Due Date 4-25-93 Tested By LD Bruggem

Thermometer: 0018 Calibration Due Date 9-17-93

Date	Wet Wt. + Can	Dry Wt. + Can	Tare Wt.	Moisture	Dry Wt. Soil	% Moisture	Calculated By
2/8/93	633.63	609.09	63.08	24.54	546.01	4.49	LD Bruggem

Remarks:

GEL-16 BULK DENSITY-POROSITY

DETERMINATION NO.			1	
Pan No.:	Mold: ☒ Plastic ☐ Metal	Length:	15.24	
Sample Volume, V, cc			1087.07	
Wt. of Sample & Mold, g			2615.3	
Wt. of Mold, g			328.9	
Wet Wt. of Sample, g			2286.4	
Wet Density of Sample, γ m, g/cc			2.10	
Water Content % Dry Weight			4.49	
Dry Density, g/cc γ d			2.01	
Dry weight of Sample, g, Ws			2188.15	
*Void Ratio, e			0.3712	
**Porosity, n, %			27.07	

Tested By LD Bruggem

$$W_s = \frac{\text{Wet Wt.}}{1 + \%\ \text{Dry Wt.}}$$

$$\text{*Void Ratio, } e = \frac{\text{Avg. Sp. Gr. x Vol.}}{W_s} - 1$$

$$\text{**Porosity, } n, \% = \left(\frac{e}{1+e}\right) 100$$

Remarks: SpG 2.76

GEL-19 CALCIUM CARBONATE

Vessel No. 5650 Tested By LD Bruggeman

Balance No. 3304 Date Due 4-25-93

Sample Weight 8.0 (g)

Sample Pressure 0.4 (psi) $\%CaCO_3$ <1.0 Per Gram

Remarks:

Tests Checked By: R.J. McIntosh Date 2/16/93

BD-6000-797 (04/92)

116-KE-4A Borehole
10.5 to 12.0 ft bgs
Sample B07LK3

SAMPLE NO.	3-0570
Contact	R.F. Raidl
Well No.	116-KE-4A
Operable Unit	100-KR-1
HEIS No.	B07LK3
Depth	10.5 - 12.0

TEMPE CELLS	Sample #	3-0570	1 Bar Drying Curve							
tension in cm	N/A	N/A	3.5	7.3	11	21.5	35.5	49	74.5	99
error in tension value +/-			0.5	0.5	1	2	5	2	5	2
container number	MC-4	TC-29	TC-29	TC-29	TC-29	TC-29	TC-29	TC-29	TC-29	TC-29
weight of container/ring,+wet sample	167.19	561.11	581.06	581.34	581.04	580.59	579.92	579.07	577.20	576.00
weight of container/ring,+ dry sample	166.71	560.50	559.90	559.90	559.90	559.90	559.90	559.90	559.90	559.90
weight of moisture	0.48	0.61	21.16	21.44	21.14	20.69	20.02	19.17	17.30	16.10
weight of container and ring	61.05	426.29	425.60	425.60	425.60	425.60	425.60	425.60	425.60	425.60
weight of dry sample	106.14	134.21	134.30	134.30	134.30	134.30	134.30	134.30	134.30	134.30
moisture content % by wt.	0.45%		15.76%	15.96%	15.74%	15.41%	14.91%	14.27%	12.88%	11.99%
moisture content % by vol.			5.68%	5.75%	5.67%	5.55%	5.37%	5.14%	4.64%	4.32%
date measured			2/26/93	3/1/93	3/2/93	3/3/93	3/4/93	3/5/93	3/8/93	3/9/93
temperature deg. C			24	23	24	25	22	25	23	24
volume of brass ring, cm^3	68.26									

TEMPE CELLS	Sample #	3-0570	1 Bar Drying Curve				
tension in cm	200.3	300	500	700	850	1000	N/A	N/A
error in tension value +/-	5	2	20	20	20	20		
container number	TC-29	TC-29	TC-29	TC-29	TC-29	TC-29	TC-29	MC-4
weight of container/ring,+wet sample	573.47	572.35	570.99	569.84	569.37	568.84	568.81	204.16
weight of container/ring,+ dry sample	559.90	559.90	559.90	559.90	559.90	559.90	559.90	195.28
weight of moisture	13.57	12.45	11.09	9.94	9.47	8.94	8.91	8.88
weight of container and ring	425.60	425.60	425.60	425.60	425.60	425.60	425.60	61.06
weight of dry sample	134.30	134.30	134.30	134.30	134.30	134.30	134.30	134.22
moisture content % by wt.	10.10%	9.27%	8.26%	7.40%	7.05%	6.66%	6.63%	6.62%
moisture content % by vol.	3.64%	3.34%	2.98%	2.67%	2.54%	2.40%	2.39%	
date measured	3/10/93	3/11/93	3/12/93	3/15/93	3/16/93	3/17/93		3/18/93
temperature deg. C	25	23						26
volume of brass ring, cm^3	68.26							

SAMPLE BULK DENSITY = 1.97 g/cm³

FIELD BULK DENSITY = 1.82 g/cm³

FRACTION LESS THAN 2 mm = 0.20

Cell wt. before cleanup = 425.57 grams

Cell wt. after cleanup = 426.38 grams

426.08 Average of all 3

TEMPE CELLS	Sample #	3-0570 1 Bar Wetting Curve							
tension in cm	N/A	N/A	1000	1000	1000	1000	1000	1000	1000
error in tension value +/-			20	20	20	20	20	20	20
container number	MC-4	TC-4	TC-4	TC-4	TC-4	TC-4	TC-4	TC-4	TC-4
weight of container/ring,+wet sample	167.19	557.84	561.24	562.93	563.49	563.51	563.50	563.62	563.54
weight of container/ring,+ dry sample	166.71	557.23	557.50	557.50	557.50	557.50	557.50	557.50	557.50
weight of moisture	0.48	0.61	3.74	5.43	5.99	6.01	6.00	6.12	6.04
weight of container and ring	61.05	421.54	421.70	421.70	421.70	421.70	421.70	421.70	421.70
weight of dry sample	106.14	135.69	135.80	135.80	135.80	135.80	135.80	135.80	135.80
moisture content %	0.45%		2.75%	4.00%	4.41%	4.43%	4.42%	4.51%	4.45%
moisture content % by vol.			0.99%	1.44%	1.59%	1.59%	1.59%	1.62%	1.60%
date measured			2/25/93	2/26/93	3/1/93	3/2/93	3/3/93	3/4/93	3/5/93
temperature deg. C			22	23	22	24	25	22	22
volume of brass ring, cm^3	68.26								

TEMPE CELLS	Sample #	3-0570 1 Bar Wetting Curve							
tension in cm	1000	700	500	300	202	104.5	69	54.5	31
error in tension value +/-	20	20	20	20	20	20	5	2	2
container number	TC-4	TC-4	TC-4	TC-4	TC-4	TC-4	TC-4	TC-4	TC-4
weight of container/ring,+wet sample	563.50	563.92	564.52	565.60	566.90	569.46	571.28	572.55	574.17
weight of container/ring,+ dry sample	557.50	557.50	557.50	557.50	557.50	557.50	557.50	557.50	557.50
weight of moisture	6.00	6.42	7.02	8.10	9.40	11.96	13.78	15.05	16.67
weight of container and ring	421.70	421.70	421.70	421.70	421.70	421.70	421.70	421.70	421.70
weight of dry sample	135.80	135.80	135.80	135.80	135.80	135.80	135.80	135.80	135.80
moisture content %	4.42%	4.73%	5.17%	5.96%	6.92%	8.81%	10.15%	11.08%	12.28%
moisture content % by vol.	1.59%	1.70%	1.86%	2.15%	2.49%	3.17%	3.66%	3.99%	4.42%
date measured	3/8/93	3/9/93	3/10/93	3/11/93	3/12/93	3/15/93	3/16/93	3/17/93	3/18/93
temperature deg. C	23	23	24	22	23	23	26	23	26
volume of brass ring, cm^3	68.26								

Cell wt. before cleanup = 421.70 grams
Cell wt. after cleanup = 421.12 grams
421.62 Average of all 3

TEMPE CELLS	Sample #	3-0570 1 Bar Wetting Curve				
tension in cm	24.0	10.0	6.3	2.5	N/A	N/A
error in tension value +/-	3	2	2	1	0.5	
container number	TC-4	TC-4	TC-4	TC-4	TC-4	MC-12
weight of container/ring,+wet sample	574.86	575.93	576.26	576.63	576.63	215.26
weight of container/ring,+ dry sample	557.50	557.50	557.50	557.50	557.50	196.24
weight of moisture	17.36	18.43	18.76	19.13	19.13	19.02
weight of container and ring	421.70	421.70	421.70	421.70	421.70	60.55
weight of dry sample	135.80	135.80	135.80	135.80	135.80	135.69
moisture content %	12.78%	13.57%	13.81%	14.09%	14.09%	14.02%
moisture content % by vol.	4.61%	4.89%	4.98%	5.08%	5.08%	
date measured	3/19/93	3/22/93	3/23/93	3/24/93		3/25/93
temperature deg. C	25	23	25	24		25
volume of brass ring, cm^3	68.26					

BULK DENSITY = 1.99

KETTLES	Sample #	3-0570 15 Bar Drying Curve								
tension in Bars	0.5	0.5	0.7	0.7	1.0	1.0	2.0	2.0	3.0	3.0
error in tension value +/-	20	20	20	20	20	20	20	20	20	20
container number	BA7	BA8	BA7	BA8	BA7	BA8	BB7	BB8	BB7	BB8
weight of container/ring,+wet sample	51.50	54.39	51.58	54.41	51.35	54.13	52.13	54.47	52.07	54.36
weight of container/ring,+ dry sample	50.08	52.81	50.16	52.87	49.98	52.61	50.98	53.19	50.94	53.15
weight of moisture	1.42	1.58	1.42	1.54	1.37	1.52	1.15	1.28	1.13	1.21
weight of container and ring	27.72	28.09	27.72	28.09	27.72	28.09	27.77	27.87	27.77	27.87
weight of dry sample	22.36	24.72	22.44	24.78	22.26	24.52	23.21	25.32	23.17	25.28
moisture content %	6.35%	6.39%	6.33%	6.21%	6.15%	6.20%	4.95%	5.06%	4.88%	4.79%
date measured	3/18/93	3/18/93	3/12/93	3/12/93	3/23/93	3/23/93	3/12/93	3/12/93	3/18/93	3/18/93
temperature deg. C	27	27	24	24	25	25	24	24	27	27

KETTLES						
tension in Bars	5.0	5.0	7.0	7.0	10.0	10.0
error in tension value +/-	20	20	100	100	100	100
container number	BB7	BB8	BC7	BC8	BC7	BC8
weight of container/ring,+wet sample	51.96	54.26	63.93	62.36	63.65	62.25
weight of container/ring,+ dry sample	50.90	53.11	62.68	61.17	62.52	61.16
weight of moisture	1.06	1.15	1.25	1.19	1.13	1.09
weight of container and ring	27.77	27.87	30.35	30.32	30.35	30.32
weight of dry sample	23.13	25.24	32.33	30.85	32.17	30.84
moisture content %	4.58%	4.56%	3.87%	3.86%	3.51%	3.53%
date measured	3/23/93	3/23/93	3/12/93	3/12/93	3/18/93	3/18/93
temperature deg. C	25	25	24	24	27	27

Water Potential Data for CX-2 Samples

Sample No.	3-0570A	3-0570
Container Number	BC7	BC7
Aw Reading	0.641	0.892
Temperature °C	24.9	25.1
Water Potential, Bars	611.1	157.1
Can ID No	BA7	BA8
Can + Soil Wet wt., g	35.57	38.79
Can + Soil Dry wt., g	35.46	38.60
Can Tare wt., g	27.72	28.09
Weight of Water, g	0.11	0.19
Dry Weight of Sample, g	7.74	10.51
Moisture Content, wt. %	1.42%	1.81%
date measured	4/5/93	4/5/93

POINTS SELECTED FOR PLOTTING — Sample # 3-0570

container number	TC-29	TC-29	TC-29	TC-29	TC-29	TC-29	TC-29	TC-29	TC-29	TC-29	TC-29
Tension in cm	3.50E+00	7.30E+00	1.10E+01	2.15E+01	3.55E+01	4.90E+01	7.45E+01	9.90E+01	2.00E+02	3.00E+02	5.00E+02
Tempe Drying Curve	5.68%	5.75%	5.67%	5.55%	5.37%	5.14%	4.64%	4.32%	3.64%	3.34%	2.98%
Kettle/CX-2 Drying Curve											
Tempe Wetting Curve											
date measured	2/26/93	3/1/93	3/2/93	3/3/93	3/4/93	3/5/93	3/8/93	3/9/93	3/10/93	3/11/93	3/12/93

container number	TC-29	TC-29	TC-29	BA7	BB7	BB7	BC7	BC7	BC7	BC7	TC-4
tension in cm	7.00E+02	8.50E+02	1.00E+03	1.02E+03	2.04E+03	3.06E+03	7.14E+03	1.02E+04	1.60E+05	6.23E+05	1.00E+03
Tempe Drying Curve	2.67%	2.54%	2.40%								
Kettle/CX-2 Drying Curve				2.23%	1.80%	1.74%	1.39%	1.27%	0.65%	0.51%	
Tempe Wetting Curve											1.59%
date measured	3/15/93	3/16/93	3/17/93	3/23/93	3/12/93	3/18/93	3/12/93	3/18/93	4/5/93	4/5/93	3/8/93

container number	TC-4	TC-4	TC-4	TC-4	TC-4	TC-4	TC-4	TC-4	TC-4	TC-4	TC-4
tension in cm	7.00E+02	5.00E+02	3.00E+02	2.02E+02	1.05E+02	6.90E+01	5.45E+01	3.10E+01	2.40E+01	1.00E+01	6.30E+00
Tempe Drying Curve											
Kettle/CX-2 Drying Curve											
Tempe Wetting Curve	1.70%	1.86%	2.15%	2.49%	3.17%	3.66%	3.99%	4.42%	4.61%	4.89%	4.98%
date measured	3/9/93	3/10/93	3/11/93	3/12/93	3/15/93	3/16/93	3/17/93	3/18/93	3/19/93	3/22/93	3/23/93

container number	TC-4
tension in cm	2.50E+00
Tempe Drying Curve	
Kettle/CX-2 Drying Curve	
Tempe Wetting Curve	5.08%
date measured	3/24/93

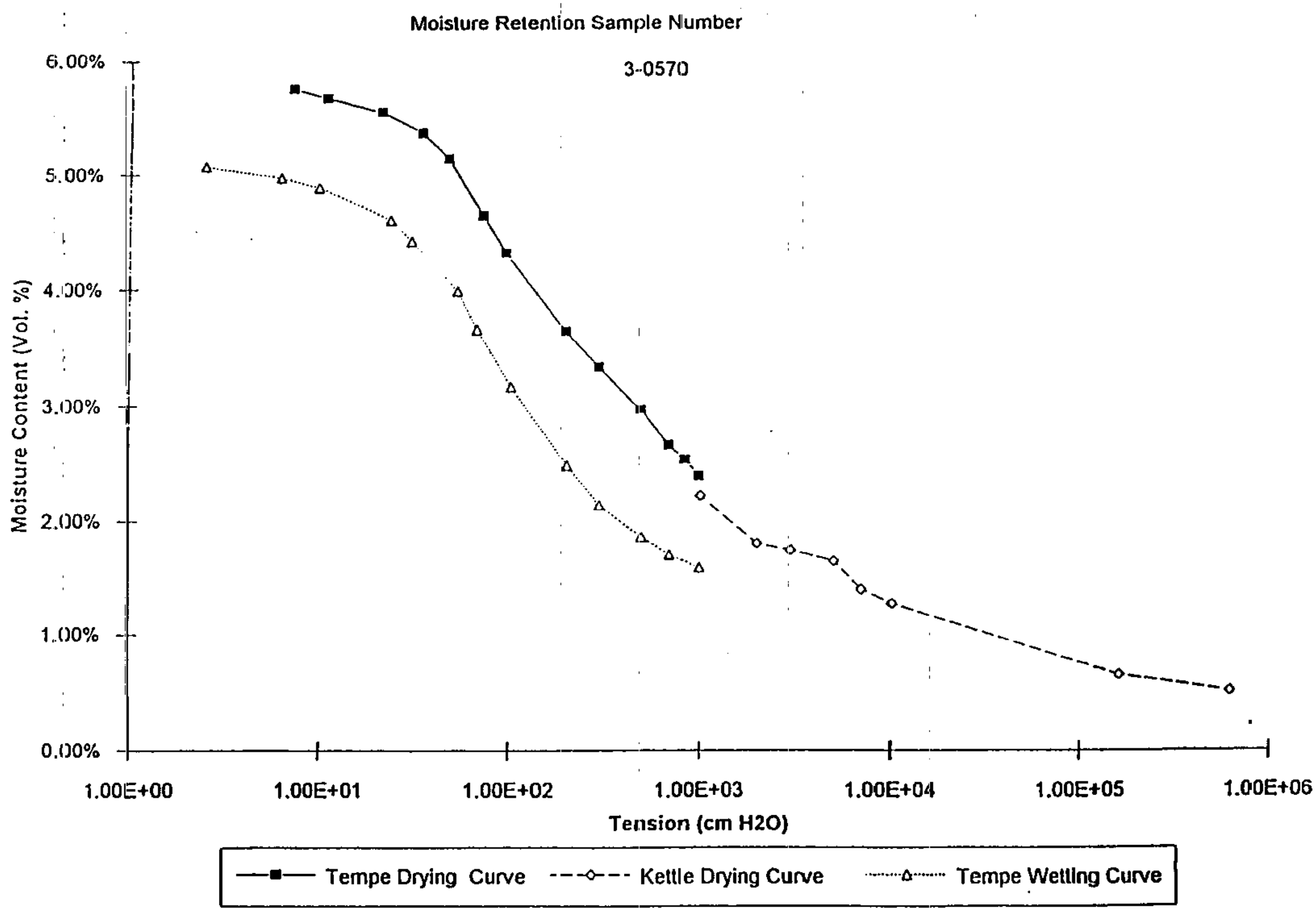
Kettle data points were converted from gravimetric to volumetric by multiplying by the field Bulk Density
And the fraction of fines (less than 2mm).

Bulk Density = 1.82 g/cm³

Fraction of fines = 0.20

Points from kettle are enclosed by the double outline

Points from CX-2 are enclosed by the single outline


Moisture Retention Sample Number
3-0570
Moisture Content (Vol. %)
6.00%
5.00%
4.00%
3.00%
2.00%
1.00%
0.00%
1.00E+00
1.00E+01
1.00E+02
1.00E+03
1.00E+04
1.00E+05
1.00E+06
Tension (cm H2O)
Tempe Drying Curve
Kettle Drying Curve
Tempe Wetting Curve

MOISTURE RETENTION DATA SHEET

SAMPLE NO. 3-0570 Page ____ of ____

Tested By:	R.M. Shailer	Date	2/25/93
Procedure No:	17	Rev.	0
		Date Issued	2/25/90
Test Plan No:	N/A	Rev.	N/A
		Date Issued	N/A
Pressure Cell No.	TC-29	Calibration Due Date	N/A
Gauge:	GEL - 2026	Calibration Due Date	1/27/94
Thermometer:	GEL - 12	Calibration Due Date	N/A
Balance:	GEL - 3315	Calibration Due Date	5/18/93
Gauge:	GEL - 2046	Calibration Due Date	6-17-93
:	GEL -	Calibration Due Date	

(1) Tension units = cm	NA	NA	3.5	7.3	11	21.5	35.5	49	74.5	99	200.3	300	500
(2) Container/Ring Number	mc-4	TC-29	TC-29	TC-29	TC-29	TC-29	TC-29	TC-29	TC-29	TC-29	TC-29	TC-29	TC-29
(3) Wt. of Container and Wet Sample, g	167.19	561.11	581.66	581.34	581.04	580.59	578.92	578.07	577.20	576.00	573.47	572.35	570.99
(4) Wt. of Container and Dry Sample, g	166.71												
(5) Container Tare Wt., g	61.05	426.29											
(6) Temperature			24	23	24	25	22	25	23	24	25	23	23
(7) Date			2/26/93	3/1/93	3/2/93	3/3/93	3/4/93	3/5/93	3/8/93	3/9/93	3/10/93	3/11/93	3/12/93

(1) Tension units = cm	700	850	1000	NA	NA								
(2) Container/Ring Number	TC-29	TC-29	TC-29	TC-29	mc-4								
(3) Wt. of Container and Wet Sample, g	569.84	569.37	568.84	568.91	204.16								
(4) Wt. of Container and Dry Sample, g					195.28								
(5) Container Tare Wt., g				* 425.57	61.06								
(6) Temperature	24	25	23		26								
(7) Date	3/15/93	3/16/93	3/17/93		3/18/93								

REMARKS

Tempe Drying Curve (0 to 1 Bar)

Operable Unit 100-KR-1

* Cleaned Tare Wt. 426.38

All data are acurately and completely recorded. The test operator was trained and used calibrated instruments

Checked By: J. F. Relyea Date: ~~4-16-93~~ 4-19-93 JR

MOISTURE RETENTION DATA SHEET

SAMPLE NO. 3-0570 Page ____ of ____

Tested By:	R.H. Shaller	Date	2/24/93
Procedure No:	17	Rev. 0	Date Issued 2/25/90
Test Plan No:	N/A	Rev. N/A	Date Issued N/A
Pressure Cell No.	TC-4	Calibration Due Date	N/A
Gauge:	GEL - 2029	Calibration Due Date	1/27/94
Thermometer:	GEL - 12	Calibration Due Date	N/A
Balance:	GEL - 3315	Calibration Due Date	5/18/93
Gauge:	GEL - 2045	Calibration Due Date	7/31/93
:	GEL -	Calibration Due Date	

(1) Tension units = cm	NA	NA	1000	1000	1000	1000	1000	1000	1000	1000	700	500	300
(2) Container/Ring Number	MC-4	TC-4	TC-4	TC-4	TC-4	TC-4	TC-4	TC-4	TC-4	TC-4	TC-4	TC-4	TC-4
(3) Wt. of Container and Wet Sample, g	167.19	557.84	561.24	562.93	563.49	563.51	563.50	563.62	563.59	563.50	563.92	564.52	565.60
(4) Wt. of Container and Dry Sample, g	166.71												
(5) Container Tare Wt., g	61.05	421.54											
(6) Temperature			22	23	22	24	25	22	22	23	23	24	22
(7) Date			2/25/93	2/26/93	3/1/93	3/2/93	3/3/93	3/4/93	3/5/93	3/8/93	3/9/93	3/10/93	3/11/93

(1) Tension units = cm	202	104.5	69	54.5	31	24	10	6.3	2.5	NA	NA		
(2) Container/Ring Number	TC-4	TC-4	TC-4	TC-4	TC-4	TC-4	TC-4	TC-4	TC-4	TC-4	MC-12		
(3) Wt. of Container and Wet Sample, g	566.90	569.46	571.28	572.55	574.17	574.86	575.93	576.26	576.63	576.63	215.26		
(4) Wt. of Container and Dry Sample, g											196.24		
(5) Container Tare Wt., g										*421.70	60.55		
(6) Temperature	23	23	26	23	26	25	23	25	24		25		
(7) Date	3/12/93	3/15/93	3/16/93	3/17/93	3/18/93	3/19/93	3/22/93	3/23/93	3/24/93		3/25/93		

REMARKS

Operable Unit
100-KR-1

Tempe Wetting Curve (0 to 1 Bar)

* Cleaned Tare
421.12

All data are acurately and completely recorded. The test operator was trained and used calibrated instruments

Checked By: J F Relyea Date: 4-19-93

9413222.0677

MOISTURE RETENTION DATA SHEET

SAMPLE NO. 3-0570 Page 1 of 3

Tested By:	B.M. Shaiker	Date	3/8/93
Procedure No:	17	Rev. 0	Date Issued 2/25/90
Test Plan No:	N/A	Rev. N/A	Date Issued
Pressure Cell No.	KETTLE PK05-01	Calibration Due Date	N/A
Gauge:	GEL - 2038	Calibration Due Date	6/17/93
Thermometer:	GEL - 12	Calibration Due Date	N/A
Balance:	GEL - 3315	Calibration Due Date	5/18/93
Gauge:	GEL -	Calibration Due Date	
:	GEL -	Calibration Due Date	

.5 .5 .7 .7 1 1

(1) Tension units = cm	.5	.5	.7	.7	1	1								
(2) Container/Ring Number	1-7 BA7	1-8 BA8	1-7 BA7	1-8 BA8	1-7 BA7	1-8 BA8								
(3) Wt. of Container and Wet Sample, g	51.50	54.39	51.58	54.41	51.35	54.13								
(4) Wt. of Container and Dry Sample, g	50.08	52.81	50.16	52.87	49.98	52.61								
(5) Container Tare Wt., g	27.72	28.09	27.72	28.09	27.72	28.09								
(6) Temperature	27	27	24	24	25	25								
(7) Date	3/18/93	3/18/93	3/12/93	3/12/93	3/23/93	3/23/93								

(1) Tension units = cm														
(2) Container/Ring Number														
(3) Wt. of Container and Wet Sample, g														
(4) Wt. of Container and Dry Sample, g														
(5) Container Tare Wt., g														
(6) Temperature														
(7) Date														

REMARKS

KETTLE DRYING CURVE (0.5 to 1.0 BARs)

operable Unit
100-KR-1

All data are acurately and completely recorded. The test operator was trained and used calibrated instruments

Checked By: J F Relyea Date: 4-19-91

MOISTURE RETENTION DATA SHEET

SAMPLE NO. 3-0570

Tested By:	K. M. Shailer	Date	3/8/93
Procedure No:	17	Rev. 0	Date Issued 2/25/90
Test Plan No:	N/A	Rev. N/A	Date Issued
Pressure Cell No.	KETTLE PK05-02	Calibration Due Date	
Gauge:	GEL - 2052	Calibration Due Date	7/2/93
Thermometer:	GEL - 12	Calibration Due Date	N/A
Balance:	GEL - 3315	Calibration Due Date	5/18/93
Gauge:	GEL - 2034	Calibration Due Date	4/3/93
:	GEL -	Calibration Due Date	

	2	2	3	3	5	5							
(1) Tension units = cm	2	2	3	3	5	5							
(2) Container/Ring Number	3-7 BB7	3-8 BB8	3-7 BB7	3-8 BB8	5-7 BB7	5-8 BB8							
(3) Wt. of Container and Wet Sample, g	52.13	54.47	52.07	54.36	51.96	54.26							
(4) Wt. of Container and Dry Sample, g	50.98	53.19	50.94	53.15	50.90	53.11							
(5) Container Tare Wt., g	27.77	27.87	27.77	27.87	2777	27.87							
(6) Temperature	24	24	27	27	25	25							
(7) Date	3/12/93	3/12/93	3/18/93	3/18/93	3/23/93	3/23/93							

(1) Tension units = cm													
(2) Container/Ring Number													
(3) Wt. of Container and Wet Sample, g													
(4) Wt. of Container and Dry Sample, g													
(5) Container Tare Wt., g													
(6) Temperature													
(7) Date													

REMARKS

KETTLE DRYING CURVE (2.0 to 5.0 BARs)

Operable Unit
100-KR-1

All data are acurately and completely recorded. The test operator was trained and used calibrated instruments

Checked By: J F Relyea Date: 4-19-93

MOISTURE RETENTION DATA SHEET

SAMPLE NO. 3-0570 Page 3 of 3

Tested By:	R. M. Shaiker	Date 3/8/93		
Procedure No:	17	Rev. 0	Date Issued	2/25/90
Test Plan No:	N/A	Rev. N/A	Date Issued	
Pressure Cell No.	KETTLE PK15-02	Calibration Due Date		
Gauge:	GEL - 2038	Calibration Due Date	6/17/93	
Thermometer:	GEL - 12	Calibration Due Date	N/A	
Balance:	GEL - 3315	Calibration Due Date	5/10/93	
Gauge:	GEL -	Calibration Due Date		
:	GEL -	Calibration Due Date		

7 7 10 10

(1) Tension units = cm	7	7	10	10									
(2) Container/Ring Number	5-7 BC7	5-8 BC8	5-7 BC7	5-8 BC8									
(3) Wt. of Container and Wet Sample, g	63.93	62.36	63.65	62.25									
(4) Wt. of Container and Dry Sample, g	62.68	61.17	62.52	61.16									
(5) Container Tare Wt., g	30.35	30.32	30.35	30.32									
(6) Temperature	24	24	27	27									
(7) Date	3/12/93	3/12/93	3/18/93	3/18/93									

(1) Tension units = cm													
(2) Container/Ring Number													
(3) Wt. of Container and Wet Sample, g													
(4) Wt. of Container and Dry Sample, g													
(5) Container Tare Wt., g													
(6) Temperature													
(7) Date													

REMARKS KETTLE DRYING CURVE (7.0 to 15.0 BARs)

Operable Unit
100-KR-1

All data are acurately and completely recorded. The test operator was trained and used calibrated instruments

Checked By: J. J. Relyea Date: 4-19-93

CX-2 WATER ACTIVITY DATA SHEET

Tested By: K.M. Shailer Date 4/5/93 Page 1 of 2

Procedure No: GEL-33 Rev. 0 Date Issued 3/23/93
Test Plan No: ______ Rev. ______ Date Issued ______

Equipment	GEL No.	Calibration Due Date
Balance	3315	5/18/93
Thermometer		

Equipment	GEL No.	Calibration Due Date
Balance		
Thermometer		

Linear Offset Data	Pretest Verification					Post Test / Periodic Verification				
Type of Salt	DIH2O									
Salt Conc. (Molal)/(Sat.)	Sat	LiCl	NaCl	KCl						
Aw Reading	.999	.114	.755	.846						
Temperature °C	24.0	24.0	24.4	24.5						
Aw Standard at 20°C										

Water Potential Data for Samples

Sample No.	3-0567A	3-0567	3-0568A	3-0568	3-0569A	3-0569	3-0570A	3-0570	3-0571A	3-0571
Container Number	BC1	BC1	BC3	BC3	BC5	BC5	BC7	BC7	BC9	BC9
Aw Reading	.689	.986	.844	.984	.756	.981	.641	.892	.835	.900
Temperature °C	23.8	24.7	24.6	24.5	24.7	24.6	24.9	25.1	25.3	25.4
Water Potential, Bars										

Moisture Content for Water Potential Samples

Can ID No	BA1	BA2	BA3	BA4	BA5	BA6	BA7	BA8	BA9	BA10
Can + Soil Wet wt., g	36.73	39.66	39.04	37.24	39.15	36.40	35.57	38.79	41.53	38.90
Can + Soil Dry wt., g	36.57	39.38	38.90	37.03	39.10	36.28	35.46	38.60	41.47	38.82
Can Tare wt., g	27.93	30.36	25.67	27.84	30.37	27.49	27.72	28.09	30.32	27.71
Weight of Water, g										
Dry Weight of Sample, g										
Moisture Content, wt. %										

REMARKS

All data are accurate and completely recorded. The test operator was trained and used calibrated instruments.

Checked By: John Kelyen Date: 4-19-93

GEL 07 ☒ GEL 09 ☒ GEL 10 ☒ GEL 14 ☒ GEL 16 ☒ GEL 17 ☒ GEL 19 ☒ GEL ☐

GEOTECHNICAL ENGINEERING LABORATORY
GEL-07 SIEVE AND HYDROMETER ANALYSIS

Sample No. 3-0570
Page 1 of 5

GEL-07 SIEVE ANALYSIS

Date 2-12-93 Calibration Due Date 4-25-93 Balance: 33/0

Sample Description Fractured Cobble, Gravel, Sand Sieve Time 10 (m

Reduced By: ☒ Splitting ☐ Quartering ☐ Stockpile

Sieve Size	Sample Weight	Cumulative Wt. Retained	Cumulative % Retained	Cumulative % Passed	Tested By
4 / 3	1721.1	0 / 902.1	0 / 52.4	100 / 47.6	LD Bruggeman
1½	↓	960.7	55.8	44.2	
3/4		1046.8	60.8	39.2	
3/8		1156.4	67.2	32.8	
4		1261.0	73.3	26.7	
10	↓	1380.8	80.2	19.8	
40	166.1	82.1	49.7	9.9	
60	↓	97.4	58.6	8.2	
100		108.0	65.0	6.9	
200	↓	123.7	74.5	5.0	

Remarks:

GEL-07 HYDROMETER ANALYSIS

Date ______

Balance: ______ Calibration Due Date ______

Thermometer: ______ Calibration Due Date ______

Hydrometer: ______ Calibration Due Date ______

WEIGHT OF SAMPLE

Wt. Container + Soil ______ (g)

Wt. Container ______ (g)

Wt. Soil ______ (g)

Specific Gravity of Sample ______

% Passing No. 10 Sieve ______ %

A = ______ W = ______ K = ______

COMPOSITE CORRECTION

1st Reading ______ at ______ °C

2nd Reading ______ at ______ °C

Date	Clock Time	Elapsed Time (min)	Hydrometer Reading	Hydrometer with Composite Correction	Temperature (°C)	Soil In Suspension (%)	Particle Diameter (mm)	Tested By
		2.0						
		5.0						
		15.0						
		30.0						
		60.0						
		250.0						
		1440.0						

Remarks:

Tests Checked By R.Y. McIntosh Date 2/18/93

BD-6000-796 (04/92)

116-KE-4A Borehole
13.0 to 15.0 ft bgs
Sample B07LK4

SAMPLE NO.	3-0568
Contact	R.F. Raidl
Well No.	116-KE-4A
Operable Unit	100-KR-1
HEIS No.	B07LK4
Depth	13.0 - 15.0

TEMPE CELLS	Sample #	3-0568 1 Bar Drying Curve								
tension in cm	N/A	N/A	3.5	7.3	11	21.5	35.5	49	74.5	99
error in tension value +/-			0.5	0.5	1	2	5	2	5	2
container number	MC-2	TC-27	TC-27	TC-27	TC-27	TC-27	TC-27	TC-27	TC-27	TC-27
weight of container/ring,+wet sample	161.54	557.90	577.83	578.19	578.00	577.76	577.70	577.05	575.36	574.42
weight of container/ring,+ dry sample	161.23	557.48	556.50	556.50	556.50	556.50	556.50	556.50	556.50	556.50
weight of moisture	0.31	0.42	21.33	21.69	21.50	21.26	21.20	20.55	18.86	17.92
weight of container and ring	60.84	421.70	421.70	421.70	421.70	421.70	421.70	421.70	421.70	421.70
weight of dry sample	100.70	135.78	134.80	134.80	134.80	134.80	134.80	134.80	134.80	134.80
moisture content % by wt.	0.31%		15.82%	16.09%	15.95%	15.77%	15.73%	15.24%	13.99%	13.29%
moisture content % by vol.			11.95%	12.15%	12.04%	11.91%	11.88%	11.51%	10.57%	10.04%
date measured			2/26/93	3/1/93	3/2/93	3/3/93	3/4/93	3/5/93	3/8/93	3/9/93
temperature deg. C			24	23	24	25	22	25	23	24
volume of brass ring, cm^3	68.26									

TEMPE CELLS	Sample #	3-0568 1 Bar Drying Curve						
tension in cm	200.3	300	500	700	850	1000	N/A	N/A
error in tension value +/-	5	2	20	20	20	20		
container number	TC-27	TC-27	TC-27	TC-27	TC-27	TC-27	TC-27	MC-2
weight of container/ring,+wet sample	571.86	570.04	568.36	567.19	566.90	566.47	566.42	205.89
weight of container/ring,+ dry sample	556.50	556.50	556.50	556.50	556.50	556.50	556.50	196.00
weight of moisture	15.36	13.54	11.86	10.69	10.40	9.97	9.92	9.89
weight of container and ring	421.70	421.70	421.70	421.70	421.70	421.70	421.70	60.85
weight of dry sample	134.80	134.80	134.80	134.80	134.80	134.80	134.80	135.15
moisture content % by wt.	11.39%	10.04%	8.80%	7.93%	7.72%	7.40%	7.36%	7.32%
moisture content % by vol.	8.60%	7.59%	6.64%	5.99%	5.83%	5.59%	5.56%	
date measured	3/10/93	3/11/93	3/12/93	3/15/93	3/16/93	3/17/93		3/18/93
temperature deg. C	25	23	23	24	25	23		26
volume of brass ring, cm^3	68.26							

SAMPLE BULK DENSITY = 1.97 g/cm³

FIELD BULK DENSITY = 2.03 g/cm³

FRACTION LESS THAN 2 mm = 0.37

Cell wt. before cleanup = 423.85 grams

Cell wt. after cleanup = 424.9 grams

423.48 Average of all 3

TEMPE CELLS	Sample #	3-0568 1 Bar Wetting Curve							
tension in cm	N/A	N/A	1000	1000	1000	1000	1000	1000	1000
error in tension value +/-			20	20	20	20	20	20	20
container number	MC-2	TC-2	TC-2	TC-2	TC-2	TC-2	TC-2	TC-2	TC-2
weight of container/ring,+wet sample	161.54	562.46	567.38	568.53	568.71	568.73	568.76	568.87	568.73
weight of container/ring,+ dry sample	161.23	562.05	562.40	562.40	562.40	562.40	562.40	562.40	562.40
weight of moisture	0.31	0.41	4.98	6.13	6.31	6.33	6.36	6.47	6.33
weight of container and ring	60.84	430.39	430.60	430.60	430.60	430.60	430.60	430.60	430.60
weight of dry sample	100.70	131.66	131.80	131.80	131.80	131.80	131.80	131.80	131.80
moisture content %	0.31%		3.78%	4.65%	4.79%	4.80%	4.83%	4.91%	4.80%
moisture content % by vol.			2.85%	3.51%	3.62%	3.63%	3.64%	3.71%	3.63%
date measured			2/25/93	2/26/93	3/1/93	3/2/93	3/3/93	3/4/93	3/5/93
temperature deg. C			22	23	22	24	25	22	22
volume of brass ring, cm^3	68.26								

TEMPE CELLS	Sample #	3-0568 1 Bar Wetting Curve							
tension in cm	1000	700	500	300	202	104.5	69	54.5	31
error in tension value +/-	20	20	20	20	20	20	5	2	2
container number	TC-2	TC-2	TC-2	TC-2	TC-2	TC-2	TC-2	TC-2	TC-2
weight of container/ring,+wet sample	568.71	569.23	570.06	571.64	573.47	576.56	578.29	579.31	580.52
weight of container/ring,+ dry sample	562.40	562.40	562.40	562.40	562.40	562.40	562.40	562.40	562.40
weight of moisture	6.31	6.83	7.66	9.24	11.07	14.16	15.89	16.91	18.12
weight of container and ring	430.60	430.60	430.60	430.60	430.60	430.60	430.60	430.60	430.60
weight of dry sample	131.80	131.80	131.80	131.80	131.80	131.80	131.80	131.80	131.80
moisture content %	4.79%	5.18%	5.81%	7.01%	8.40%	10.74%	12.06%	12.83%	13.75%
moisture content % by vol.	3.62%	3.91%	4.39%	5.29%	6.34%	8.11%	9.10%	9.69%	10.38%
date measured	3/8/93	3/9/93	3/10/93	3/11/93	3/12/93	3/15/93	3/16/93	3/17/93	3/18/93
temperature deg. C	23	23	24	22	23	23	26	23	26
volume of brass ring, cm^3		68.26							

Cell wt. before cleanup = 430.59 grams

Cell wt. after cleanup = 430.19 grams

430.49 Average of all 3

TEMPE CELLS	Sample #	3-0568 1 Bar Wetting Curve				
tension in cm	24	10.0	6.3	2.5	N/A	N/A
error in tension value +/-	3	3	2	2	0.5	
container number	TC-2	TC-2	TC-2	TC-2	TC-2	MC-10
weight of container/ring,+wet sample	580.94	581.86	582.03	582.32	582.30	212.03
weight of container/ring,+ dry sample	562.40	562.40	562.40	562.40	562.40	192.27
weight of moisture	18.54	19.46	19.63	19.92	19.90	19.76
weight of container and ring	430.60	430.60	430.60	430.60	430.60	60.52
weight of dry sample	131.80	131.80	131.80	131.80	131.80	131.75
moisture content %	14.07%	14.76%	14.89%	15.11%	15.10%	15.00%
moisture content % by vol.	10.62%	11.15%	11.25%	11.41%		
date measured	3/19/93	3/22/93	3/23/93	3/24/93		3/25/93
temperature deg. C	25	23	25	24		25
volume of brass ring, cm^3	68.26					

BULK DENSITY = 1.93

KETTLES	Sample #	3-0568 15 Bar Drying Curve								
tension in Bars	0.5	0.5	0.7	0.7	1.0	1.0	2.0	2.0	3.0	3.0
error in tension value +/-	20	20	20	20	20	20	20	20	20	20
container number	BA3	BA4	BA3	BA4	BA3	BA4	BB3	BB4	BB3	BB4
weight of container/ring,+wet sample	60.88	57.13	60.77	57.03	60.57	56.82	57.96	56.62	57.79	56.47
weight of container/ring,+ dry sample	58.40	54.91	58.46	54.96	58.35	54.83	56.32	55.02	56.32	55.02
weight of moisture	2.48	2.22	2.31	2.07	2.22	1.99	1.64	1.60	1.47	1.45
weight of container and ring	28.67	27.84	28.67	27.84	28.67	27.84	27.62	27.52	27.62	27.52
weight of dry sample	29.73	27.07	29.79	27.12	29.68	26.99	28.70	27.50	28.70	27.50
moisture content %	8.34%	8.20%	7.75%	7.63%	7.48%	7.37%	5.71%	5.82%	5.12%	5.27%
date measured	3/18/93	3/18/93	3/12/93	3/12/93	3/23/93	3/23/93	3/12/93	3/12/93	3/18/93	3/18/93
temperature deg. C	27	27	24	24	25	25	24	24	27	27

KETTLES						
tension in Bars	5.0	5.0	7.0	7.0	10.0	10.0
error in tension value +/-	20	20	100	100	100	100
container number	BB3	BB4	BC3	BC4	BC3	BC4
weight of container/ring,+wet sample	57.59	56.31	59.61	58.99	59.36	58.75
weight of container/ring,+ dry sample	56.20	54.95	58.43	57.89	58.33	57.80
weight of moisture	1.39	1.36	1.18	1.10	1.03	0.95
weight of container and ring	27.62	27.52	29.28	30.50	29.28	30.50
weight of dry sample	28.58	27.43	29.15	27.39	29.05	27.30
moisture content %	4.86%	4.96%	4.05%	4.02%	3.55%	3.48%
date measured	3/23/93	3/23/93	3/12/93	3/12/93	3/18/93	3/18/93
temperature deg. C	25	25	24	24	27	27

Water Potential Data for CX-2 Samples

Sample No.	3-0568A	3-0568
Container Number	BC3	BC3
Aw Reading	0.844	0.984
Temperature °C	24.5	24.5
Water Potential, Bars	232.7	22.1
Can ID No	BA3	BA4
Can + Soil Wet wt., g	39.04	37.24
Can + Soil Dry wt., g	38.90	37.03
Can Tare wt., g	28.67	27.84
Weight of Water, g	0.14	0.21
Dry Weight of Sample, g	10.23	9.19
Moisture Content, wt. %	1.37%	2.29%
date measured	4/5/93	4/5/93

POINTS SELECTED FOR PLOTTING Sample # 3-0568

container number	TC-27	TC-27	TC-27	TC-27	TC-27	TC-27	TC-27	TC-27	TC-27	TC-27	TC-27
Tension in cm	7.30E+00	1.10E+01	2.15E+01	3.55E+01	4.90E+01	7.45E+01	9.90E+01	2.00E+02	3.00E+02	5.00E+02	7.00E+02
Tempe Drying Curve	12.15%	12.04%	11.91%	11.88%	11.51%	10.57%	10.04%	8.60%	7.59%	6.64%	5.99%
Kettle/CX-2 Drying Curve											
Tempe Wetting Curve											
date measured	3/1/93	3/2/93	3/3/93	3/4/93	3/5/93	3/8/93	3/9/93	3/10/93	3/11/93	3/12/93	3/15/93

container number	TC-27	TC-27	BA3	BA3	BA3	BB3	BB3	BC3	BC3	BC3	BC3
tension in cm	8.50E+02	1.00E+03	5.10E+02	7.14E+02	1.02E+03	2.04E+03	3.06E+03	7.14E+03	1.02E+04	2.26E+04	2.37E+05
Tempe Drying Curve	5.83%	5.59%									
Kettle/CX-2 Drying Curve			6.25%	5.81%	5.61%	4.35%	3.92%	3.04%	2.65%	1.73%	1.03%
Tempe Wetting Curve											
date measured	3/16/93	3/17/93	3/18/93	3/12/93	3/23/93	3/12/93	3/18/93	3/12/93	3/18/93	4/5/93	4/5/93

container number	TC-2	TC-2	TC-2	TC-2	TC-2	TC-2	TC-2	TC-2	TC-2	TC-2	TC-2
tension in cm	1.00E+03	7.00E+02	5.00E+02	3.00E+02	2.02E+02	1.05E+02	6.90E+01	5.45E+01	3.10E+01	2.40E+01	1.00E+01
Tempe Drying Curve											
Kettle/CX-2 Drying Curve											
Tempe Wetting Curve	3.62%	3.91%	4.39%	5.29%	6.34%	8.11%	9.10%	9.69%	10.38%	10.62%	11.15%
date measured	3/8/93	3/9/93	3/10/93	3/11/93	3/12/93	3/15/93	3/16/93	3/17/93	3/18/93	3/19/93	3/22/93

container number	TC-2	TC-2
tension in cm	6.30E+00	2.50E+00
Tempe Drying Curve		
Kettle/CX-2 Drying Curve		
Tempe Wetting Curve	11.25%	11.41%
date measured	3/23/93	3/24/93

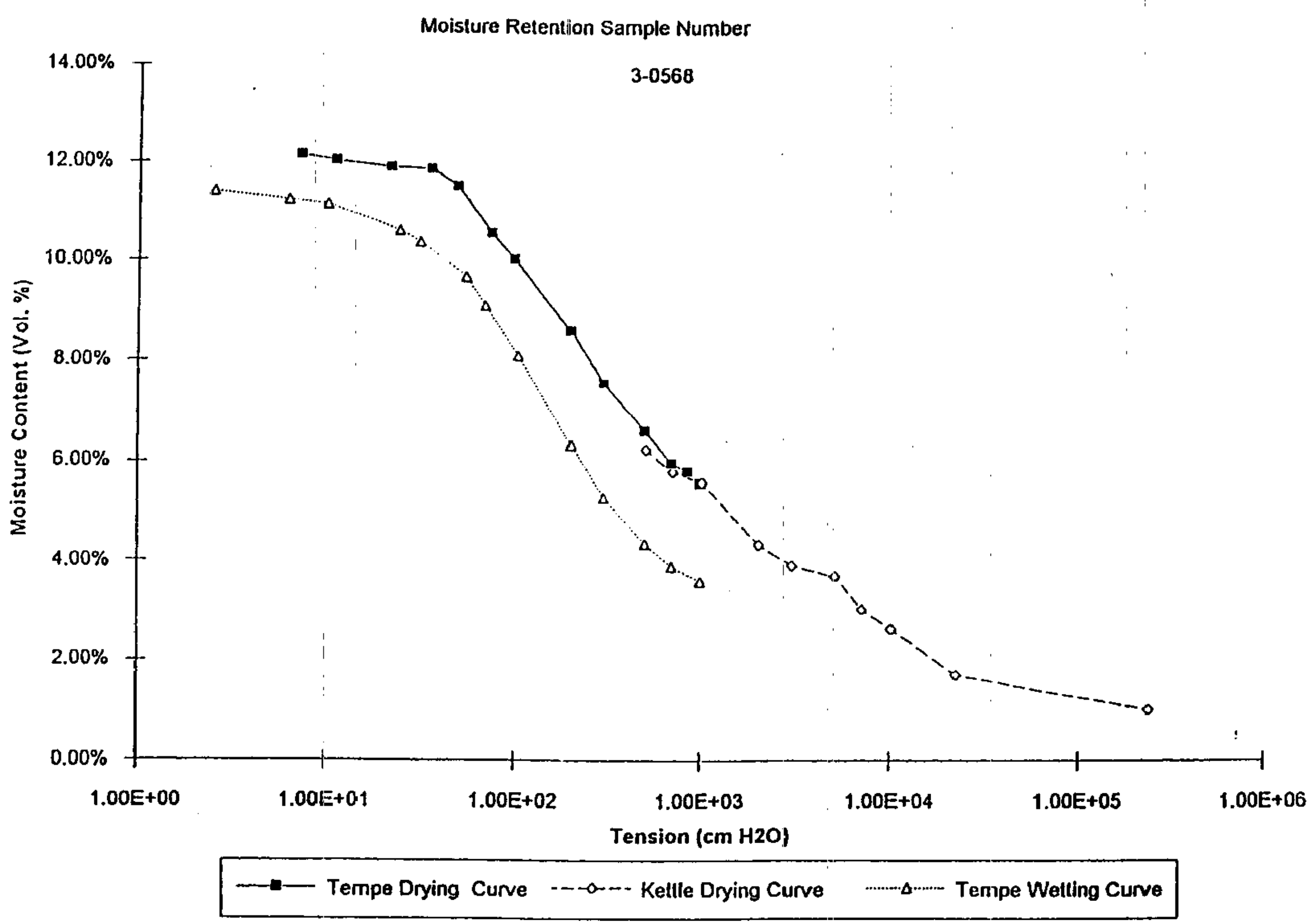
Kettle data points were converted from gravimetric to volumetric by multiplying by the field Bulk Density
And the fraction of fines (less than 2mm).

Bulk Density = 2.03 g/cm^3
Fraction of fines = 0.37

Points from kettle are enclosed by the double outline

Points from CX-2 are enclosed by the single outline

9413222.0688



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MOISTURE RETENTION DATA SHEET

SAMPLE NO. 3-0568 Page ____ of ____

Tested By: R.M. Shailer Date 2/25/93
Procedure No: 17 Rev. 0 Date Issued 2/25/90
Test Plan No: N/A Rev. N/A Date Issued N/A
Pressure Cell No. TC-27 Calibration Due Date N/A
Gauge: GEL - 2026 Calibration Due Date 1/27/94
Thermometer: GEL - 12 Calibration Due Date N/A
Balance: GEL - 3315 Calibration Due Date 5/18/93
Gauge: GEL - 2046 Calibration Due Date 6-17-93
: GEL - Calibration Due Date

(1) Tension units = cm	N/A	N/A	3.5	7.3	11	21.5	35.5	49	74.5	99	200.3	300	500
(2) Container/Ring Number	MC-2	TC-27	TC-27	TC-27	TC-27	TC-27	TC-27	TC-27	TC-27	TC-27	TC-27	TC-27	TC-27
(3) Wt. of Container and Wet Sample, g	161.54	557.96	577.83	578.19	578.00	577.76	577.20	577.05	575.36	574.42	571.86	570.04	568.36
(4) Wt. of Container and Dry Sample, g	161.23												
(5) Container Tare Wt., g	60.54	421.70											
(6) Temperature			24	23	24	25	22	25	23	24	25	23	23
(7) Date			2/26/93	3/1/93	3/2/93	3/3/93	3/4/93	3/5/93	3/9/93	3/9/93	3/10/93	3/11/93	3/12/93

(1) Tension units = cm	700	850	1000	N/A	N/A								
(2) Container/Ring Number	TC-27	TC-27	TC-27	TC-27	MC-2								
(3) Wt. of Container and Wet Sample, g	567.19	566.90	566.47	566.42	205.87								
(4) Wt. of Container and Dry Sample, g					196.00								
(5) Container Tare Wt., g				* 423.85	60.85								
(6) Temperature	24	25	23		26								
(7) Date	3/15/93	3/16/93	3/17/93		3/18/93								

REMARKS Tempe Drying Curve (0 to 1 Bar)
Operable Unit 100-KR-1
* Cleaned Tare Wt. 424.90

All data are acurately and completely recorded. The test operator was trained and used calibrated instruments

Checked By: J F Relyea Date: 4-19-93

MOISTURE RETENTION DATA SHEET

SAMPLE NO. 3-0568 Page ______ of ______

Tested By:	R.M. Shailer	Date	2/24/93
Procedure No:	17	Rev. 0	Date Issued 2/25/90
Test Plan No:	N/A	Rev. N/A	Date Issued N/A
Pressure Cell No.	TC-2	Calibration Due Date	N/A
Gauge:	GEL - 2029	Calibration Due Date	1/27/94
Thermometer:	GEL - 12	Calibration Due Date	N/A
Balance:	GEL - 3315	Calibration Due Date	5/18/93
Gauge:	GEL - 2015	Calibration Due Date	7/31/93
:	GEL -	Calibration Due Date	

(1) Tension units = cm	NA	NA	1000	1000	1000	1000	1000	1000	1000	1000	700	500	300
(2) Container/Ring Number	MC-2	TC-2	TC-2	TC-2	TC-2	TC-2	TC-2	TC-2	TC-2	TC-2	TC-2	TC-2	TC-2
(3) Wt. of Container and Wet Sample, g	161.54	562.46	567.38	568.53	568.71	568.73	568.76	568.87	568.73	568.71	569.23	570.06	571.64
(4) Wt. of Container and Dry Sample, g	161.23												
(5) Container Tare Wt., g	60.84	430.39											
(6) Temperature			22	23	22	24	25	22	22	23	23	24	22
(7) Date			2/25/93	2/26/93	3/1/93	3/2/93	3/3/93	3/4/93	3/5/93	3/8/93	3/9/93	3/10/93	3/11/93

(1) Tension units = cm	202	164.5	69	54.5	31	24	10	6.3	2.5	NA	NA		
(2) Container/Ring Number	TC-2	TC-2	TC-2	TC-2	TC-2	TC-2	TC-2	TC-2	TC-2	TC-2	MC-10		
(3) Wt. of Container and Wet Sample, g	573.47	576.56	578.29	579.31	580.52	580.94	581.86	582.03	582.32	582.30	212.03		
(4) Wt. of Container and Dry Sample, g											192.27		
(5) Container Tare Wt., g										* 430.59	60.52		
(6) Temperature	23	23	26	23	26	25	23	25	24		25		
(7) Date	3/12/93	3/15/93	3/16/93	3/17/93	3/18/93	3/19/93	3/22/93	3/23/93	3/24/93		3/25/93		

REMARKS

Operable Unit 100-KR-1

Tempe Wetting Curve (0 to 1 Bar)

* Corrected Tare 430.19

All data are acurately and completely recorded. The test operator was trained and used calibrated instruments

Checked By: J F Relyea Date: 4-19-93

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MOISTURE RETENTION DATA SHEET

SAMPLE NO. 3-0568 Page 1 of 3

Tested By: K.M. Shailer Date 3/8/93
Procedure No: 17 Rev. 0 Date Issued 2/25/90
Test Plan No: N/A Rev. N/A Date Issued
Pressure Cell No. KETTLE PK05-01 Calibration Due Date N/A
Gauge: GEL - 2038 Calibration Due Date 6/17/93
Thermometer: GEL - 12 Calibration Due Date N/A
Balance: GEL - 3315 Calibration Due Date 5/18/93
Gauge: GEL - Calibration Due Date
: GEL - Calibration Due Date

	.5	.5	.7	.7	1	1							
(1) Tension units = cm	.5	.5	.7	.7	1	1							
(2) Container/Ring Number	1-3 BA3	1-4 BA4	1-3 BA3	1-4 BA4	1-3 BA3	1-4 BA4							
(3) Wt. of Container and Wet Sample, g	60.88	57.13	60.77	57.03	60.57	56.82							
(4) Wt. of Container and Dry Sample, g	58.40	54.91	58.46	54.96	58.35	54.83							
(5) Container Tare Wt., g	28.67	27.84	28.67	27.84	28.67	27.84							
(6) Temperature	27	27	24	24	25	25							
(7) Date	3/18/93	3/18/93	3/12/93	3/12/93	3/23/93	3/23/93							

(1) Tension units = cm													
(2) Container/Ring Number													
(3) Wt. of Container and Wet Sample, g													
(4) Wt. of Container and Dry Sample, g													
(5) Container Tare Wt., g													
(6) Temperature													
(7) Date													

REMARKS KETTLE DRYING CURVE (0.5 to 1.0 BARs)
operable limit
100-KR-1

All data are acurately and completely recorded. The test operator was trained and used calibrated instruments

Checked By: J.F. Relyea Date: 4-19-93

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MOISTURE RETENTION DATA SHEET

SAMPLE NO. 3-0568 Page 2 of 3

Tested By:	K. M. Shailer	Date	3/8/93	
Procedure No:	17	Rev. 0	Date Issued 2/25/90
Test Plan No:	N/A	Rev. N/A	Date Issued
Pressure Cell No.	KETTLE PK05-02	Calibration Due Date	
Gauge:	GEL - 2052	Calibration Due Date	7/2/93
Thermometer:	GEL - 12	Calibration Due Date	N/A
Balance:	GEL - 3315	Calibration Due Date	5/18/93
Gauge:	GEL - 2034	Calibration Due Date	4/3/93
:	GEL -	Calibration Due Date	

	2	2	3	3	5	5							
(1) Tension units = cm	2	2	3	3	5	5							
(2) Container/Ring Number	3-3 BB3	3-4 BB4	3-3 BB3	3-4 BB4	3-3 BB3	3-4 BB4							
(3) Wt. of Container and Wet Sample, g	57.76	56.62	57.79	56.47	57.59	56.31							
(4) Wt. of Container and Dry Sample, g	56.32	55.02	56.32	55.02	56.20	54.45							
(5) Container Tare Wt., g	27.62	27.52	27.62	27.52	27.62	27.52							
(6) Temperature	24	24	27	27	25	25							
(7) Date	3/12/93	3/12/93	3/18/93	3/18/93	3/23/93	3/23/93							

(1) Tension units = cm													
(2) Container/Ring Number													
(3) Wt. of Container and Wet Sample, g													
(4) Wt. of Container and Dry Sample, g													
(5) Container Tare Wt., g													
(6) Temperature													
(7) Date													

REMARKS KETTLE DRYING CURVE (2.0 to 5.0 BARS)

Ceramic Unit
100-KR-1

All data are accurately and completely recorded. The test operator was trained and used calibrated instruments

Checked By: J. F. Relyea Date: 4-19-93

MOISTURE RETENTION DATA SHEET

SAMPLE NO. 3-0568 Page 3 of 3

Tested By: R.M. Shailer
Procedure No: 17
Test Plan No: N/A
Pressure Cell No. KETTLE PK15-02
Gauge: GEL - 2038
Thermometer: GEL - 12
Balance: GEL - 3315
Gauge: GEL -
: GEL -

Date 3/8/93
Rev. 0 Date Issued 2/25/90
Rev. N/A Date Issued
Calibration Due Date
Calibration Due Date 6/17/93
Calibration Due Date N/A
Calibration Due Date 5/18/93
Calibration Due Date
Calibration Due Date

7 7 10 10

(1) Tension units = cm	7	7	10	10									
(2) Container/Ring Number	5-3 BC3	5-4 BC4	5-3 BC3	5-4 BC4									
(3) Wt. of Container and Wet Sample, g	59.61	58.99	59.36	58.75									
(4) Wt. of Container and Dry Sample, g	58.43	57.87	58.33	57.80									
(5) Container Tare Wt., g	29.28	30.50	29.28	36.50									
(6) Temperature	24	24	27	27									
(7) Date	3/12/93	3/12/93	3/18/93	3/18/93									

(1) Tension units = cm													
(2) Container/Ring Number													
(3) Wt. of Container and Wet Sample, g													
(4) Wt. of Container and Dry Sample, g													
(5) Container Tare Wt., g													
(6) Temperature													
(7) Date													

REMARKS KETTLE DRYING CURVE (7.0 to 15.0 BARS)

Operable Unit
100-KR-1

All data are acurately and completely recorded. The test operator was trained and used calibrated instruments

Checked By: D F Relyea Date: 4-19-93

CX-2 WATER ACTIVITY DATA SHEET

Tested By: K. M. Shailer Date 4/5/93 Page 1 of 2

Procedure No: GEL-33 Rev. 0 Date Issued 3/23/93
Test Plan No: Rev. Date Issued

Equipment	GEL No.	Calibration Due Date
Balance	3315	5/18/93
Thermometer		

Equipment	GEL No.	Calibration Due Date
Balance		
Thermometer		

Linear Offset Data	Pretest Verification					Post Test / Periodic Verification				
Type of Salt	DIH2O									
Salt Conc. (Molal)/(Sat.)	Sat	LiCl	NaCl	KCl						
Aw Reading	.999	.114	.755	.846						
Temperature °C	24.0	24.0	24.4	24.5						
Aw Standard at 20°C										

Water Potential Data for Samples

Sample No.	3-0567A	3-0567	3-0568A	3-0568	3-0569A	3-0569	3-0570A	3-0570	3-0571A	3-0571
Container Number	BC1	BC1	BC3	BC3	BC5	BC5	BC7	BC7	BC9	BC9
Aw Reading	.689	.986	.844	.984	.756	.981	.641	.892	.835	.900
Temperature °C	23.8	24.7	24.6	24.5	24.7	24.6	24.9	25.1	25.3	25.4
Water Potential, Bars										

Moisture Content for Water Potential Samples

Can ID No	BA1	BA2	BA3	BA4	BA5	BA6	BA7	BA8	BA9	BA10
Can + Soil Wet wt., g	36.73	39.66	39.04	37.24	39.15	36.40	35.57	38.79	41.53	38.90
Can + Soil Dry wt., g	36.57	39.38	38.90	37.03	39.00	36.28	35.46	38.60	41.47	38.82
Can Tare wt., g	27.93	30.36	28.67	27.84	30.37	27.49	27.72	28.09	30.32	27.71
Weight of Water, g										
Dry Weight of Sample, g										
Moisture Content, wt. %										

REMARKS

All data are accurately and completely recorded. The test operator was trained and used calibrated instruments.

Checked By: John F Relyea Date: 4-19-93

GEL 09 ☒ GEL 17 ☒
GEL 10 ☒ GEL 19 ☒
GEL 14 ☒ GEL ☐

GEOTECHNICAL ENGINEERING LABORATORY
GEL-07 SIEVE AND HYDROMETER ANALYSIS

Sample No. 3-0268
Page 1 of 5

GEL-07 SIEVE ANALYSIS

Date 2-12-93 Calibration Due Date 4-25-93 Balance: 3310

Sample Description SAND, GRAVEL Sieve Time 10 (min)

Reduced By: ☒ Splitting ☐ Quartering ☐ Stockpile

Sieve Size	Sample Weight	Cumulative Wt. Retained	Cumulative % Retained	Cumulative % Passed	Tested By
2	2213.1	0	0	100	LD Bruggeman
1½	↓	164.7	7.4	92.6	
3/4		535.0	24.2	75.8	
3/8		844.1	38.1	61.9	
4		1106.5	50.0	50.0	
10		1389.7	62.8	37.2	
40	180.9	86.5	47.8	19.4	
60	↓	106.6	58.9	15.3	
100		120.4	66.6	12.4	
200		137.9	76.2	8.8	

Remarks:

GEL-07 HYDROMETER ANALYSIS

Date ______ Balance: ______ Calibration Due Date ______

Thermometer: ______ Calibration Due Date ______

Hydrometer: ______ Calibration Due Date ______

WEIGHT OF SAMPLE

Wt. Container + Soil ______ (g) Specific Gravity of Sample ______

Wt. Container ______ (g) % Passing No. 10 Sieve ______ %

Wt. Soil ______ (g) A = ______ W = ______ K = ______

COMPOSITE CORRECTION

1st Reading ______ at ______ °C

2nd Reading ______ at ______ °C

Date	Clock Time	Elapsed Time (min)	Hydrometer Reading	Hydrometer with Composite Correction	Temperature (°C)	Soil in Suspension (%)	Particle Diameter (mm)	Tested By
		2.0						
		5.0						
		15.0						
		30.0						
		60.0						
		250.0						
		1440.0						

NOT APPLICABLE

Remarks:

Tests Checked By R. T. McIntosh Date 2/16/93

BD-6000-796 (04/92)

116-KE-4A Borehole
18.0 to 20.0 ft bgs
Sample B07LK5

9413222.0698

SAMPLE NO.	3-0569
Contact	R.F. Raidl
Well No.	116-KE-4A
Operable Unit	100-KR-1
HEIS No.	B07LK5
Depth	18.0 - 20.0

TEMPE CELLS	Sample #	3-0569	1 Bar Drying Curve							
tension in cm	N/A	N/A	3.5	7.3	11	21.5	35.5	49	74.5	99
error in tension value +/-			0.5	0.5	1	2	5	2	5	2
container number	MC-3	TC-28	TC-28	TC-28	TC-28	TC-28	TC-28	TC-28	TC-28	TC-28
weight of container/ring,+wet sample	163.76	557.82	579.44	579.33	579.26	579.21	579.43	579.25	574.23	573.00
weight of container/ring,+ dry sample	163.55	557.55	557.37	557.37	557.37	557.37	557.37	557.37	557.37	557.37
weight of moisture	0.21	0.27	22.07	21.96	21.89	21.84	22.06	21.88	16.86	15.63
weight of container and ring	61.02	427.83	427.67	427.67	427.67	427.67	427.67	427.67	427.67	427.67
weight of dry sample	102.74	129.72	129.70	129.70	129.70	129.70	129.70	129.70	129.70	129.70
moisture content % by wt.	0.20%		17.02%	16.93%	16.88%	16.84%	17.01%	16.87%	13.00%	12.05%
moisture content % by vol.			10.58%	10.53%	10.50%	10.47%	10.58%	10.49%	8.08%	7.49%
date measured			2/26/93	3/1/93	3/2/93	3/3/93	3/4/93	3/5/93	3/8/93	3/9/93
temperature deg. C			24	23	24	25	22	25	23	24
volume of brass ring, cm^3	68.26									

TEMPE CELLS	Sample #	3-0569	1 Bar Drying Curve					
tension in cm	200.3	300	500	700	850	1000	N/A	N/A
error in tension value +/-	5	2	20	20	20	20		
container number	TC-28	TC-28	TC-28	TC-28	TC-28	TC-28	TC-28	MC-3
weight of container/ring,+wet sample	569.73	567.04	565.22	564.47	LEAKER	LEAKER	566.24	199.70
weight of container/ring,+ dry sample	557.37	557.37	557.37	557.37	557.37	557.37	557.37	190.79
weight of moisture	12.36	9.67	7.85	7.10	-557.37	-557.37	8.87	8.91
weight of container and ring	427.67	427.67	427.67	427.67	427.67	427.67	427.67	61.03
weight of dry sample	129.70	129.70	129.70	129.70	129.70	129.70	129.70	129.76
moisture content % by wt.	9.53%	7.46%	6.05%	5.47%			6.84%	6.87%
moisture content % by vol.	5.93%	4.64%	3.76%	3.40%			12.99%	
date measured	3/10/93	3/11/93	3/12/93	3/15/93	3/16/93	3/17/93		3/18/93
temperature deg. C	25	23						26
volume of brass ring, cm^3	68.26							

SAMPLE BULK DENSITY = 1.90 g/cm³

FIELD BULK DENSITY = 2.08 g/cm³

FRACTION LESS THAN 2 mm = 0.30

Cell wt. before cleanup = 427.43 grams

Cell wt. after cleanup = 427.75 grams

427.67 Average of all 3

9413222.0699

TEMPE CELLS	Sample #	3-0569 1 Bar Wetting Curve							
tension in cm	N/A	N/A	1000	1000	1000	1000	1000	1000	1000
· error in tension value +/-			20	20	20	20	20	20	20
container number	MC-3	TC-3	TC-3	TC-3	TC-3	TC-3	TC-3	TC-3	TC-3
weight of container/ring,+wet sample	163.76	550.20	552.89	553.98	554.21	554.27	554.25	554.30	554.22
weight of container/ring,+ dry sample	163.55	549.93	550.60	550.60	550.60	550.60	550.60	550.60	550.60
weight of moisture	0.21	0.27	2.29	3.38	3.61	3.67	3.65	3.70	3.62
weight of container and ring	61.02	417.43	418.10	418.10	418.10	418.10	418.10	418.10	418.10
weight of dry sample	102.74	132.50	132.50	132.50	132.50	132.50	132.50	132.50	132.50
moisture content %	0.20%		1.73%	2.55%	2.72%	2.77%	2.75%	2.79%	2.73%
moisture content % by vol.			1.07%	1.59%	1.69%	1.72%	1.71%	1.74%	1.70%
date measured			2/25/93	2/26/93	3/1/93	3/2/93	3/3/93	3/4/93	3/5/93
temperature deg. C			22	23	22	24	25	22	22
volume of brass ring, cm^3	68.26								

TEMPE CELLS	Sample #	3-0569 1 Bar Wetting Curve							
tension in cm	1000	700	500	300	202	104.5	69	54.5	31
error in tension value +/-	20	20	20	20	20	20	5	2	2
container number	TC-3	TC-3	TC-3	TC-3	TC-3	TC-3	TC-3	TC-3	TC-3
weight of container/ring,+wet sample	554.20	554.64	555.35	556.95	558.83	562.41	564.18	564.91	566.01
weight of container/ring,+ dry sample	550.60	550.60	550.60	550.60	550.60	550.60	550.60	550.60	550.60
weight of moisture	3.60	4.04	4.75	6.35	8.23	11.81	13.58	14.31	15.41
weight of container and ring	418.10	418.10	418.10	418.10	418.10	418.10	418.10	418.10	418.10
weight of dry sample	132.50	132.50	132.50	132.50	132.50	132.50	132.50	132.50	132.50
moisture content %	2.72%	3.05%	3.58%	4.79%	6.21%	8.91%	10.25%	10.80%	11.63%
moisture content % by vol.	1.69%	1.90%	2.23%	2.98%	3.86%	5.54%	6.37%	6.72%	7.23%
date measured	3/8/93	3/9/93	3/10/93	3/11/93	3/12/93	3/15/93	3/16/93	3/17/93	3/18/93
temperature deg. C	23	23	24	22	23	23	26	23	26
volume of brass ring, cm^3	68.26								

Cell wt. before cleanup = 418.11 grams

Cell wt. after cleanup = 417.62 grams

417.72 Average of all 3

TEMPE CELLS	Sample #	3-0569 1 Bar Wetting Curve				
tension in cm	24.0	10.0	6.3	2.5	N/A	N/A
error in tension value +/-	3	2	2	1	0.5	
container number	TC-3	TC-3	TC-3	TC-3	TC-3	MC-11
weight of container/ring,+wet sample	566.63	567.75	568.07	568.38	568.37	210.36
weight of container/ring,+ dry sample	550.60	550.60	550.60	550.60	550.60	192.72
weight of moisture	16.03	17.15	17.47	17.78	17.77	17.64
weight of container and ring	418.10	418.10	418.10	418.10	418.10	60.27
weight of dry sample	132.50	132.50	132.50	132.50	132.50	132.45
moisture content %	12.10%	12.94%	13.18%	13.42%	13.41%	13.32%
moisture content % by vol.	7.52%	8.05%	8.20%	8.35%	8.34%	
date measured	3/19/93	3/22/93	3/23/93	3/24/93		3/25/93
temperature deg. C	25	23	25			25
volume of brass ring, cm^3	68.26		BULK DENSITY = 1.94			

KETTLES	Sample #	3-0569 15 Bar Drying Curve								
tension in Bars	0.5	0.5	0.7	0.7	1.0	1.0	2.0	2.0	3.0	3.0
error in tension value +/-	20	20	20	20	20	20	20	20	20	20
container number	BA5	BA6	BA5	BA6	BA5	BA6	BB5	BB6	BB5	BB6
weight of container/ring,+wet sample	57.46	55.30	57.49	55.34	57.31	55.17	54.62	54.84	54.51	54.71
weight of container/ring,+ dry sample	56.03	53.85	56.07	53.91	55.94	53.78	53.68	53.86	53.66	53.81
weight of moisture	1.43	1.45	1.42	1.43	1.37	1.39	0.94	0.98	0.85	0.90
weight of container and ring	30.37	27.49	30.37	27.49	30.37	27.49	28.41	27.85	28.41	27.85
weight of dry sample	25.66	26.36	25.70	26.42	25.57	26.29	25.27	26.01	25.25	25.96
moisture content %	5.57%	5.50%	5.53%	5.41%	5.36%	5.29%	3.72%	3.77%	3.37%	3.47%
date measured	3/18/93	3/18/93	3/12/93	3/12/93	3/23/93	3/23/93	3/12/93	3/12/93	3/18/93	3/18/93
temperature deg. C	27	27	24	24	25	25	24	24	27	27

KETTLES						
tension in Bars	5.0	5.0	7.0	7.0	10.0	10.0
error in tension value +/-	20	20	100	100	100	100
container number	BB5	BB6	BC5	BC6	BC5	BC6
weight of container/ring,+wet sample	54.38	54.57	56.31	57.43	56.17	57.31
weight of container/ring,+ dry sample	53.60	53.76	55.73	56.82	55.68	56.78
weight of moisture	0.78	0.81	0.58	0.61	0.49	0.53
weight of container and ring	28.41	27.85	29.23	30.17	29.23	30.17
weight of dry sample	25.19	25.91	26.50	26.65	26.45	26.61
moisture content %	3.10%	3.13%	2.19%	2.29%	1.85%	1.99%
date measured	3/23/93	3/23/93	3/12/93	3/12/93	3/18/93	3/18/93
temperature deg. C	25	25	24	24	27	27

Water Potential Data for CX-2 Samples

Sample No.	3-0569A	3-0569
Container Number	BC5	BC5
Aw Reading	0.756	0.981
Temperature °C	24.7	24.6
Water Potential, Bars	384.1	26.3

Can ID No	BA5	BA6
Can + Soil Wet wt., g	39.15	36.40
Can + Soil Dry wt., g	39.10	36.28
Can Tare wt., g	30.37	27.49
Weight of Water, g	0.05	0.12
Dry Weight of Sample, g	8.73	8.79
Moisture Content, wt. %	0.57%	1.37%
date measured	4/5/93	4/5/93

9413222.0701

POINTS SELECTED FOR PLOTTING Sample # 3-0569

container number	TC-28	TC-28	TC-28	TC-28	TC-28	TC-28	TC-28	TC-28	TC-28	TC-28	TC-28
Tension in cm	7.30E+00	1.10E+01	2.15E+01	3.55E+01	4.90E+01	7.45E+01	9.90E+01	2.00E+02	3.00E+02	5.00E+02	7.00E+02
Tempe Drying Curve	10.53%	10.50%	10.47%	10.58%	10.49%	8.08%	7.49%	5.93%	4.64%	3.76%	3.40%
Kettle/CX-2 Drying Curve											
Tempe Wetting Curve											
date measured	3/1/93	3/2/93	3/3/93	3/4/93	3/5/93	3/8/93	3/9/93	3/10/93	3/11/93	3/12/93	3/15/93
container number	BA5	BA5	BA5	BB5	BB5	BC5	BC5	BC5	BC5	TC-3	TC-3
tension in cm	5.10E+02	7.14E+02	1.02E+03	2.04E+03	3.06E+03	7.14E+03	1.02E+04	2.69E+04	3.92E+05	1.00E+03	7.00E+02
Tempe Drying Curve											
Kettle/CX-2 Drying Curve	3.44%	3.40%	3.31%	2.33%	2.12%	1.39%	1.20%	0.85%	0.36%		
Tempe Wetting Curve										1.69%	1.90%
date measured	3/18/93	3/12/93	3/23/93	3/12/93	3/18/93	3/12/93	3/18/93	4/5/93	4/5/93	3/8/93	3/9/93
container number	TC-3	TC-3	TC-3	TC-3	TC-3	TC-3	TC-3	TC-3	TC-3	TC-3	TC-3
tension in cm	5.00E+02	3.00E+02	2.02E+02	1.05E+02	6.90E+01	5.45E+01	3.10E+01	2.40E+01	1.00E+01	6.30E+00	2.50E+00
Tempe Drying Curve											
Kettle/CX-2 Drying Curve											
Tempe Wetting Curve	2.23%	2.98%	3.86%	5.54%	6.37%	6.72%	7.23%	7.52%	8.05%	8.20%	8.35%
date measured	3/10/93	3/11/93	3/12/93	3/15/93	3/16/93	3/17/93	3/18/93	3/19/93	3/22/93	3/23/93	3/24/93
container number											
tension in cm											
Tempe Drying Curve											
Kettle/CX-2 Drying Curve											
Tempe Wetting Curve											
date measured											

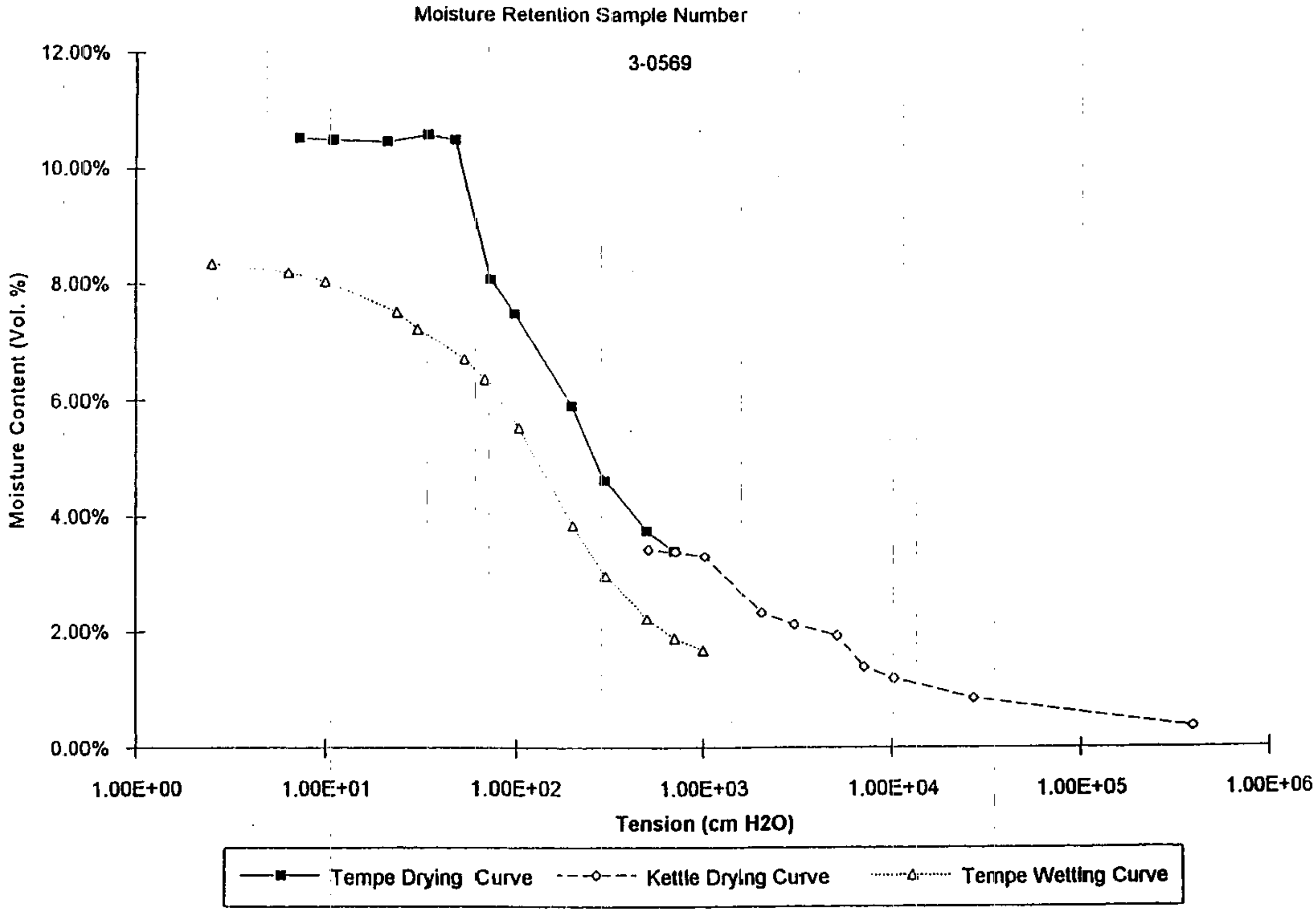
Kettle data points were converted from gravimetric to volumetric by multiplying by the field Bulk Density And the fraction of fines (less than 2mm).

Bulk Density = 2.08 g/cm³

Fraction of fines = 0.299

Points from kettle are enclosed by the double outline

Points from CX-2 are enclosed by the single outline


Moisture Retention Sample Number
3-0569
Moisture Content (Vol. %)
12.00%
10.00%
8.00%
6.00%
4.00%
2.00%
0.00%
1.00E+00
1.00E+01
1.00E+02
1.00E+03
1.00E+04
1.00E+05
1.00E+06
Tension (cm H2O)
Tempe Drying Curve
Kettle Drying Curve
Tempe Wetting Curve

MOISTURE RETENTION DATA SHEET

SAMPLE NO. 3-0569 Page ____ of ____

Tested By:	R.M. Shailer	Date	2/25/93
Procedure No:	17	Rev. 0	Date Issued 2/25/90
Test Plan No:	N/A	Rev. N/A	Date Issued N/A
Pressure Cell No.	TC-28	Calibration Due Date	N/A
Gauge:	GEL - 2026	Calibration Due Date	1/27/94
Thermometer:	GEL - 12	Calibration Due Date	N/A
Balance:	GEL - 3315	Calibration Due Date	5/18/93
Gauge:	GEL - 2046	Calibration Due Date	6-17-93
:	GEL -	Calibration Due Date	

(1) Tension units = cm	NA	NA	3.5	7.3	11	21.5	35.5	49	74.5	99	200.3	300	500
(2) Container/Ring Number	MC-3	TC-28	TC-28	TC-28	TC-28	TC-28	TC-28	TC-28	TC-28	TC-28	TC-28	TC-28	TC-28
(3) Wt. of Container and Wet Sample, g	163.76	557.82	579.44	579.33	579.26	579.21	579.43	579.25	574.23	573.00	569.73	567.04	565.22
(4) Wt. of Container and Dry Sample, g	163.55												
(5) Container Tare Wt., g	61.02	427.83											
(6) Temperature			24	23	24	25	22	25	23	24	25	23	23
(7) Date			2/26/93	3/1/93	3/2/93	3/3/93	3/4/93	3/5/93	3/8/93	3/9/93	3/10/93	3/11/93	3/12/93

(1) Tension units = cm	700	850	NA	NA									
(2) Container/Ring Number	TC-28	TC-28	TC-28	MC-3									
(3) Wt. of Container and Wet Sample, g	564.47		566.24	199.70									
(4) Wt. of Container and Dry Sample, g				190.79									
(5) Container Tare Wt., g		Leaked 9 gms	*427.43	61.03									
(6) Temperature	24	25		26									
(7) Date	3/15/93	3/16/93		3/18/93									

REMARKS Tempe Drying Curve (0 to 1 Bar)

Operable Unit * Checked Tare Wt. 427.75

100-KR-1

All data are acurately and completely recorded. The test operator was trained and used calibrated instruments

Checked By: J F Relyea Date: 4-19-93

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MOISTURE RETENTION DATA SHEET

SAMPLE NO. 3-0519 Page ____ of ____

Tested By: R.M. Shailer Date 2/24/93
Procedure No: 17 Rev. 0 Date Issued 2/25/90
Test Plan No: N/A Rev. N/A Date Issued N/A
Pressure Cell No. TC-3 Calibration Due Date N/A
Gauge: GEL - 2029 Calibration Due Date 1/27/94
Thermometer: GEL - 12 Calibration Due Date N/A
Balance: GEL - 3315 Calibration Due Date 5/18/93
Gauge: GEL - 2045 Calibration Due Date 7/31/93
: GEL - Calibration Due Date

(1) Tension units = cm	NA	NA	1000	1000	1000	1000	1000	1000	1000	1000	700	500	300
(2) Container/Ring Number	MC-3	TC-3	TC-3	TC-3	TC-3	TC-3	TC-3	TC-3	TC-3	TC-3	TC-3	TC-3	TC-3
(3) Wt. of Container and Wet Sample, g	163.76	550.20	552.89	553.98	554.21	554.27	554.25	554.30	554.22	554.20	554.64	555.35	556.95
(4) Wt. of Container and Dry Sample, g	163.55												
(5) Container Tare Wt., g	61.02	417.43											
(6) Temperature			22	23	22	24	25	22	22	23	23	24	22
(7) Date			2/25/93	2/26/93	3/1/93	3/2/93	3/3/93	3/4/93	3/5/93	3/8/93	3/9/93	3/10/93	3/11/93

(1) Tension units = cm	202	104.5	69	54.5	31	24	10	6.3	2.5	NA	NA		
(2) Container/Ring Number	TC-3	TC-3	TC-3	TC-3	TC-3	TC-3	TC-3	TC-3	TC-3	TC-3	MC-11		
(3) Wt. of Container and Wet Sample, g	558.83	562.41	564.18	564.91	566.01	566.63	567.75	568.07	568.38	568.37	210.36		
(4) Wt. of Container and Dry Sample, g											192.72		
(5) Container Tare Wt., g										* 418.11	60.27		
(6) Temperature	23	23	26	23	26	25	23	25	24		25		
(7) Date	3/12/93	3/15/93	3/16/93	3/17/93	3/18/93	3/19/93	3/22/93	3/23/93	3/24/93		3/25/93		

REMARKS

Tempe Wetting Curve (0 to 1 Bar)

operable unit 100-KR-1

* Cleaned Tare 417.62

All data are acurately and completely recorded. The test operator was trained and used calibrated instruments

Checked By: [illegible signature] Date: 4-19-92

MOISTURE RETENTION DATA SHEET

SAMPLE NO. 3-0569 Page 1 of 3

Tested By: R. M. Shailer Date 3/8/93
Procedure No: 17 Rev. 0 Date Issued 2/25/90
Test Plan No: N/A Rev. N/A Date Issued
Pressure Cell No. KETTLE PK05-01 Calibration Due Date N/A
Gauge: GEL - 2038 Calibration Due Date 6/17/93
Thermometer: GEL - 12 Calibration Due Date N/A
Balance: GEL - 3315 Calibration Due Date 5/18/93
Gauge: GEL - Calibration Due Date
: GEL - Calibration Due Date

.5 .5 .7 .7 1 1

(1) Tension units = cm	.5	.5	.7	.7	1	1							
(2) Container/Ring Number	1-5 BA5	1-6 BA6	1-5 BA5	1-6 BA6	1-5 BA5	1-6 BA6							
(3) Wt. of Container and Wet Sample, g	57.46	55.30	57.49	55.34	57.31	55.17							
(4) Wt. of Container and Dry Sample, g	56.63	53.85	56.07	53.91	55.94	53.78							
(5) Container Tare Wt., g	30.37	27.49	30.37	27.49	30.37	27.49							
(6) Temperature	27	27	24	24	25	25							
(7) Date	3/18/93	3/18/93	3/12/93	3/12/93	3/23/93	3/23/93							

(1) Tension units = cm													
(2) Container/Ring Number													
(3) Wt. of Container and Wet Sample, g													
(4) Wt. of Container and Dry Sample, g													
(5) Container Tare Wt., g													
(6) Temperature													
(7) Date													

REMARKS KETTLE DRYING CURVE (0.5 to 1.0 BARs)
Operable Unit
100-KR-1

All data are acurately and completely recorded. The test operator was trained and used calibrated instruments

Checked By: J. F. Relyea Date: 4-19-93

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Draft A

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MOISTURE RETENTION DATA SHEET

SAMPLE NO. 3-0569

Tested By: K.M. Shailer
Procedure No: 17
Test Plan No: N/A
Pressure Cell No. KETTLE PK05-02
Gauge: GEL - 2052
Thermometer: GEL - 12
Balance: GEL - 3315
Gauge: GEL - 2034
: GEL -

Date 3/8/93
Rev. 0 Date Issued 2/25/90
Rev. N/A Date Issued
Calibration Due Date
Calibration Due Date 7/2/93
Calibration Due Date N/A
Calibration Due Date 5/18/93
Calibration Due Date 4/3/93
Calibration Due Date

	2	2	3	3	5	5							
(1) Tension units = cm	2	2	3	3	5	5							
(2) Container/Ring Number	3-5 BB5	3-6 BB6	3-5 BB5	3-6 BB6	3-5 BB5	3-6 BB6							
(3) Wt. of Container and Wet Sample, g	54.62	54.84	54.51	54.71	54.38	54.57							
(4) Wt. of Container and Dry Sample, g	53.68	53.86	53.66	53.81	53.60	53.76							
(5) Container Tare Wt., g	28.41	27.85	28.41	27.85	28.41	27.85							
(6) Temperature	24	24	27	27	25	25							
(7) Date	3/12/93	3/12/93	3/18/93	3/18/93	3/23/93	3/23/93							

(1) Tension units = cm													
(2) Container/Ring Number													
(3) Wt. of Container and Wet Sample, g													
(4) Wt. of Container and Dry Sample, g													
(5) Container Tare Wt., g													
(6) Temperature													
(7) Date													

REMARKS KETTLE DRYING CURVE (2.0 to 5.0 BARs)

Operable Unit
100-KR-1

All data are acurately and completely recorded. The test operator was trained and used calibrated instruments

Checked By: J.F. Relyea Date: 4-19-93

MOISTURE RETENTION DATA SHEET

SAMPLE NO. 3-0569

Tested By:	K. M. Shaiker	Date	3/8/93
Procedure No:	17	Rev. 0	Date Issued 2/25/90
Test Plan No:	N/A	Rev. N/A	Date Issued
Pressure Cell No.	KETTLE PK15-02	Calibration Due Date	
Gauge:	GEL - 2038	Calibration Due Date	6/17/93
Thermometer:	GEL - 12	Calibration Due Date	N/A
Balance:	GEL - 3315	Calibration Due Date	5/18/93
Gauge:	GEL -	Calibration Due Date	
:	GEL -	Calibration Due Date	

	7	7	10	10										
(1) Tension units = cm	7	7	10	10										
(2) Container/Ring Number	5-5 BC5	5-6 BC6	5-5 BC5	5-6 BC6										
(3) Wt. of Container and Wet Sample, g	56.31	57.43	56.17	57.31										
(4) Wt. of Container and Dry Sample, g	55.73	56.82	55.68	56.78										
(5) Container Tare Wt., g	29.23	30.17	29.23	30.17										
(6) Temperature	24	24	27	27										
(7) Date	3/12/93	3/12/93	3/18/93	3/18/93										

(1) Tension units = cm														
(2) Container/Ring Number														
(3) Wt. of Container and Wet Sample, g														
(4) Wt. of Container and Dry Sample, g														
(5) Container Tare Wt., g														
(6) Temperature														
(7) Date														

REMARKS

KETTLE DRYING CURVE (7.0 to 15.0 BARS)

Operable Unit 100-KR-1

All data are acurately and completely recorded. The test operator was trained and used calibrated instruments

Checked By: J F Relyea Date: 4-19-93

CX-2 WATER ACTIVITY DATA SHEET

Tested By: K. M. Shailer Date 4/5/93 Page 1 of 2

Procedure No: GEL-33 Rev. 0 Date Issued 3/23/93
Test Plan No: Rev. Date Issued

Equipment	GEL No.	Calibration Due Date
Balance	3315	5/18/93
Thermometer		

Equipment	GEL No.	Calibration Due Date
Balance		
Thermometer		

Linear Offset Data	Pretest Verification					Post Test / Periodic Verification				
Type of Salt	DI H_2O									
Salt Conc. (Molal)/(Sat.)	Sat	LiCl	NaCl	KCl						
Aw Reading	.999	.114	.755	.846						
Temperature °C	24.0	24.0	24.4	24.5						
Aw Standard at 20°C										

Water Potential Data for Samples

Sample No.	3-0567A	3-0567	3-0568A	3-0568	3-0569A	3-0569	3-0570A	3-0570	3-0571A	3-0571
Container Number	BC1	BC1	BC3	BC3	BC5	BC5	BC7	BC7	BC9	BC9
Aw Reading	.689	.986	.844	.984	.756	.991	.641	.892	.835	.900
Temperature °C	23.8	24.7	24.6	24.5	24.7	24.6	24.9	25.1	25.3	25.4
Water Potential, Bars										

Moisture Content for Water Potential Samples

Can ID No	BA1	BA2	BA3	BA4	BA5	BA6	BA7	BA8	BA9	BA10
Can + Soil Wet wt., g	36.73	39.66	39.04	37.24	39.15	36.40	35.57	38.79	41.53	38.90
Can + Soil Dry wt., g	36.59	39.38	38.90	37.03	39.10	36.28	35.46	38.60	41.47	38.82
Can Tare wt., g	27.93	30.36	28.67	27.84	30.37	27.49	27.72	28.09	30.32	27.71
Weight of Water, g										
Dry Weight of Sample, g										
Moisture Content, wt. %										

REMARKS

All data are accurately and completely recorded. Test operator was trained and used calibrated instruments.

Checked By: John F. Relyea Date: 4-19-93

GEL 07 ☒	GEL 16 ☒
GEL 09 ☒	GEL 17 ☒
GEL 10 ☒	GEL 19 ☒
GEL 14 ☒	GEL ☐

GEOTECHNICAL ENGINEERING LABORATORY
GEL-07 SIEVE AND HYDROMETER ANALYSIS

Sample No. 3-0569

Page 1 of 5

GEL-07 SIEVE ANALYSIS

Date 2-12-93 Calibration Due Date 4-25-93 Balance: 3310

Sample Description cobble, gravel, sand, silt Sieve Time 10 (min)

Reduced By: ☒ Splitting ☐ Quartering ☐ Stockpile

Sieve Size	Sample Weight	Cumulative Wt. Retained	Cumulative % Retained	Cumulative % Passed	Tested By
~~3 1/2~~ 3	1849.3	~~0~~ 556.8	~~0~~ 30.1	~~100~~ 69.9	[signature]
3/4		717.5	38.8	61.2	
3/8		876.8	47.4	52.6	
4		1090.2	59.0	41.0	
10		1296.3	70.1	29.9	
40	197.1	84.2	42.7	17.1	
60		110.7	56.2	13.1	
100		127.6	64.7	10.5	
200		147.0	74.6	7.4	

Remarks:

GEL-07 HYDROMETER ANALYSIS

Date

Balance: Calibration Due Date

Thermometer: Calibration Due Date

Hydrometer: Calibration Due Date

WEIGHT OF SAMPLE

Wt. Container + Soil (g)

Wt. Container (g)

Wt. Soil (g)

Specific Gravity of Sample

% Passing No. 10 Sieve %

A = W = K =

COMPOSITE CORRECTION

1st Reading at °C

2nd Reading at °C

Date	Clock Time	Elapsed Time (min)	Hydrometer Reading	Hydrometer with Composite Correction	Temperature (°C)	Soil in Suspension (%)	Particle Diameter (mm)	Tested By
		2.0						
		5.0						
		15.0						
		30.0						
		60.0						
		250.0						
		1440.0						

NOT APPLICABLE

Remarks: NA

Tests Checked By [signature] Date 2/16/93

BD-6000-796 (04/92)

GEL 16 [X] GEL 17 [X] GEL 19 [X] GEL [ ]

GEOTECHNICAL ENGINEERING LABORATORY
GEL-14, GEL-16, GEL-19

Sample No. 3-0529
Page 5 of 5

GEL-14 SOIL MOISTURE

Balance: 3304 Calibration Due Date 4-25-93 Tested By LD Bruggeman
Thermometer: 0018 Calibration Due Date 9-17-93

Date	Wet Wt. + Can	Dry Wt. + Can	Tare Wt.	Moisture	Dry Wt. Soil	% Moisture	Calculated By
2-11-92	488.88	478.65	62.16	10.23	416.49	2.46	LD Bruggeman

Remarks:

GEL-16 BULK DENSITY-POROSITY

DETERMINATION NO.	1	
Pan No.: Mold: [X] Plastic [ ] Metal Length:	11.75	
Sample Volume, V, cc	837.95 (~~2098~~)	
Wt. of Sample & Mold, g	2098.5	
Wt. of Mold, g	316.9	
Wet Wt. of Sample, g	1781.6	
Wet Density of Sample, γ m, g/cc	2.13	
Water Content % Dry Weight	2.46	
Dry Density, g/cc γ d	2.08	
Dry weight of Sample, g, Ws	1738.82	
*Void Ratio, e	0.3060	
**Porosity, n, %	23.43	

Tested By LD Bruggeman

$$W_s = \frac{\text{Wet Wt.}}{1 + \%\ \text{Dry Wt.}}$$

$$\text{*Void Ratio, } e = \frac{\text{Avg. Sp. Gr.} \times \text{Vol.}}{W_s} - 1$$

$$\text{**Porosity, } n, \% = \left(\frac{e}{1+e}\right) 100$$

Remarks: 372.1 ~~304~~ 0 403 2-9 grs of Road top (At 1032 +10) to fill void SpG = 2.71

GEL-19 CALCIUM CARBONATE

Vessel No. 5650 Tested By LD Bruggeman

Balance No. 3304 Date Due 2-10-93

Sample Weight 8.0 (g)

Sample Pressure 0.2 (psi) $\%CaCO_3$ <1.0 Per Gram

Remarks:

Tests Checked By: R.T. McIntosh Date 2/16/93

BD-6000-797 (04/92)