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MAR 04 1996

Mr. Steve M. Alexander
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Dear Mr. Alexander:

TRANSMITTAL OF PRELIMINARY SCREENING OF 100-NR-2 GROUNDWATER STRONTIUM-90 REMEDIATION ALTERNATIVES AND PRELIMINARY 1301-N/1325-N LIQUID WASTE DISPOSAL FACILITY (LWDF) CHARACTERIZATION DATA

Enclosed for your information you will find one copy each of the following summaries, "Preliminary Screening of 100-NR-2 Groundwater Strontium-90 Remediation Alternatives" and "Preliminary 1301-N/1325-N LWDF Characterization Data." These summaries were prepared in support of the recently developed 100 N Area Consolidated Remedial Action Strategy. The information provided in these summaries are presented to assist the U.S. Department of Energy, Richland Operations Office, the State of Washington Department of Ecology, and the U.S. Environmental Protection Agency in making a decision on the future of the N-Springs Expedited Response Action (ERA).

The Strontium-90 summary (Enclosure 1) identifies and discusses remediation alternatives suitable for the treatment of Strontium-90 in the N Area groundwater. It conducts a preliminary screening of these alternatives and produces a short list of alternatives to be considered in the detailed analysis performed as part of the NR-1 and NR-2 Corrective Measures Study. The summary addresses various specific methods to deal with institutional controls, in situ treatment, impermeable barriers, hydraulic controls, and pump and treat.

The crib characterization summary (Enclosure 2) presents preliminary data for the activities associated with the limited field investigation (LFI) of the 1301-N and 1325-N LWDFs. The data is considered preliminary, because final deliverables have not been received nor validated, and interpreted. Data are presented on the drilling, sampling, and geophysical logging of the three new characterization boreholes and the geophysical logging of four existing wells.

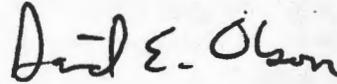
Mr. Steve M. Alexander

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If you have any questions, please contact me on 376-7326.

Sincerely,



David E. Olson, Project Manager
N Area Remedial Actions

Enclosures

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Attachment 1

Preliminary Screening of 100-NR-2 Groundwater Strontium-90 Remediation Alternatives

Remedial Action Objectives

There are two principal remedial action objectives that may be applied to groundwater at N-Springs: exposure pathway reduction or elimination and concentration reduction. Exposure pathway reduction requires the control of human and ecological receptors to prevent ingestion or contact with groundwater contaminated with strontium-90 (^{90}Sr). Concurrently, this objective may be achieved by containing or otherwise preventing migration of groundwater to environments where inadvertent contact with human or ecological receptors may occur. This remedial action objective may be met at Operable Unit 100-NR-2 by institutional controls and reduction or elimination of ^{90}Sr flux to the Columbia River.

Reduction of ^{90}Sr concentration in groundwater as a remedial action objective is not directly linked to human and ecological risk reduction, but is indirectly linked as the source concentration for fate and transport modeling of exposure assessments. As applied to Operable Unit 100-NR-2, reduction of ^{90}Sr concentration will result in a reduced flux of ^{90}Sr to the Columbia River. This objective may be achieved through pump and treat or in situ options for ^{90}Sr removal.

Remediation Alternatives

Institutional Controls

Access Control

Controlling site access involves temporary or permanent physical restrictions to prevent or reduce exposure to site contaminants. Possible methods of controlling access to contaminated sites include signs, entry control, artificial or natural barriers, and active surveillance. Measures to be used depend on specific site conditions, demography and proximity of the local population, and the degree of hazard associated with contamination at the site. Implementation and maintenance costs increase as the level of protection increases.

Advantages of access control are that it provides some protection of human health, is relatively simple to implement, and implementation does not require contact with contaminated media. A disadvantage of access control is that it does not effectively achieve standard measures of performance such as containment, removal, destruction, or treatment of contaminants. In addition, continual monitoring is required.

Groundwater Use Restriction

Groundwater use restriction involves legal prohibitions on well construction and use within a contaminated area or specific aquifer. Use restriction is designed to limit exposure which may pose a threat to human health and to prohibit offsite extraction of groundwater which could increase contaminant migration.

Regulatory agencies in charge of groundwater quality, well construction, and well registration are likely to be involved with groundwater restriction efforts. Such restriction is accomplished through deed restrictions which prohibit the installation or use of a well and institutional restrictions administered by a regional groundwater authority. The restrictions may be imposed for the duration of a groundwater cleanup or may be permanent.

Advantages of groundwater use restriction are low cost, some human health protection, simple implementation, and construction does not require contact with contaminated media. A disadvantage of groundwater use restriction is that it does not effectively achieve any of the standard measures of performance such as containment, removal, destruction, or treatment of contaminants. Continual groundwater monitoring is required to ensure that restrictions continue to cover the extent of contamination.

In situ Treatment

Permeable/Treatment Barrier Wall

Sorption technologies rely on attractive forces that exist between fluid phase contaminant molecules and molecules of a solid sorbent material. These attractive forces bind the contaminant to the solid phase and reduce the mobility of the contamination. Sorption involves several mechanisms including physical adsorption, chemisorption, ion exchange, and hydrophobic bonding. Physical adsorption occurs between the dissolved contaminant and the sorbent surface due to weak atomic and molecular forces (e.g., Van der Waal forces). Chemisorption is a chemical reaction between the contaminant and the surface of the sorbent and is typified by a much stronger adsorption energy than occurs with physical adsorption. Ion exchange is the exchange of cations and anions in the aqueous phase with counterions on the sorbent. Hydrophobic bonding results from a substantial incompatibility between the solute and the solvent.

Typical adsorbent material includes activated carbon, agricultural residues, clays, zeolites, glauconitic greensand, and limestone. Activated carbon is generally used for the removal of organic compounds, however it may be used to immobilize certain heavy metals such as trivalent and hexavalent chromium. Clays adsorb cations and thus adsorb many dissolved metals and a number of cationic organic materials including certain pesticides and herbicides. Zeolites and glauconitic greensands are high surface area cation exchange materials and are used to remove a

number of heavy metal and radionuclide cations. Crushed limestone and lime are used to neutralize acidic groundwater and to adsorb or coprecipitate metal cations such as iron, cadmium and chromium.

The effectiveness of various adsorbents is measured by isotherms which relate how contamination will be distributed between the aqueous phase and the solid surface. These isotherms are often fitted to theoretical equations. An useful equation is the Freundlich isotherm which has the form: $C_s = (K)(C_e)^n$. Here, C_s is the mass of contaminant adsorbed to the solid surface per mass of solid, C_e is the mass of contaminant per volume of water in equilibrium with the solid, K is a partition coefficient reflecting the extent of sorption, and n is a dimensionless constant between 0.7 and 1.2. If n is close to 1, the equation is approximated as $C_s = (K_d)(C_e)$ where K_d is the sorbent/water distribution coefficient. This approximate equation is often used to estimate the mobility of contaminants in the environment. A K_d value of zero indicates that the contaminant has no tendency to adsorb to the solid and will be highly mobile and likely to spread. High K_d values indicate that the contaminant strongly adsorbs to the solid material and is relatively immobile. In situ sorbent technologies decrease contaminant mobility (increase the effective K_d) through the mixture of sorbents with soil.

Permeable treatment beds are constructed by digging trenches and backfilling with a mixture of soil and one or more adsorbents. Trench excavation may require shoring and, because the trench will intersect the water table, dewatering is required during excavation. Groundwater removed during excavation may require treatment. The bed is placed downgradient of the contaminant plume and natural groundwater flow carries contamination through the bed. Bed permeability is constructed to match the surrounding soil. Bed size depends on specific characteristics of the contaminated groundwater. It must be long enough and deep enough to intercept and treat the entire contaminated plume unless funnel and gate systems are employed. Bed thickness depends groundwater flow velocity and the required contact time for effective treatment.

A permeable barrier wall has several advantages over other in situ treatment methods. As a passive technique, no continuous maintenance or pumping is required, hence operation is unobtrusive. Over time, the permeable barrier wall is relatively inexpensive as there are no ongoing operating costs. After construction is complete, the wall is inherently safe as contaminated groundwater is not pumped to the surface. This technology is a permanent solution as the treatment zone can be designed to immobilize radionuclides until they decay to acceptable levels. After installation, terrain overlying the permeable barrier wall can be relandscaped and revegetated to reflect the natural surroundings.

A disadvantage of a permeable barrier wall is that the sorption media may become fully loaded with contaminants and competing ions and lose its adsorption capability. In addition, permeable treatment beds may clog with precipitates. Consequently, the permeable bed could require periodic removal and treatment/replacement.

This technology is currently planned for a treatability test at N-Springs. The purpose of the test is to demonstrate in a field application the effectiveness of a permeable/treatment barrier wall in mitigating the flux of strontium-90 into the Columbia River.

Electrokinetics

Electrokinetic separation uses a direct current electric field to achieve separation of contaminants and water from soil and sludge by causing groundwater and contaminants to flow between electrodes. Electrokinetics includes a number of electrokinetic phenomena associated with the flow of direct current electricity through a soil-water electrolyte system. These include the movement of electricity (current flow), ions (ionic drift), charged particles (electrophoresis), and water (electroosmosis). Hazardous waste applications of the technology center on ion drift and electroosmosis to achieve dewatering and the enhanced extraction of contaminants. The term electroosmosis is most often used to describe the technology.

Electroosmotic flow is made possible because most soil particles acquire a negative surface charge when in contact with water and other polar liquids. Positively-charged ions in the water are attracted to soil particles to neutralize the charge, creating an "electric double layer." When an electric field is applied to the soil, a static force is applied to the double layer causing the positively-charged layer to migrate toward the cathode. As the layer moves, it drags water that is farther away from the soil surfaces in the same direction. In addition, the electrical field applies a force to cations and anions in the water causing them to undergo ionic drift in opposite directions. Water and cations are collected and removed from the soil at the cathode using an extraction well. Conversely, anions in the water will migrate toward the anode and may be extracted. If there are no means for recharging water, the soil becomes dewatered, making continued ionic separation impossible. However, by providing recharge from either an aquifer or an injection well, electroosmosis can be used to separate ionic species from unsaturated soil. One potential advantage of this technology is that less water must be extracted to achieve decontamination than required for conventional extraction.

Electrokinetic separation using electroosmosis is applicable to soil and sludge with hydraulic conductivities less than 10^{-5} cm/sec. Often, these low permeability soils are not amenable to more conventional extraction methods. Specifically, this technology is potentially applicable to clay soils with hydraulic conductivities from 10^{-4} cm/sec to less than 10^{-7} cm/sec. In soil with higher hydraulic conductivity, electrokinetic separation may be employed to induce ion migration to the electrodes and enhance ion extraction in pump-induced extraction well systems.

Electrokinetic separation is at the demonstration stage of development. Power consumption may be a major consideration in the economic feasibility of the procedure. The technology can cause significant and potentially undesirable changes in soil chemistry including mineral dissolution, precipitation of secondary minerals, and a change in soil pH. In addition, electrolysis of water at

the cathode will generate hydrogen gas. Further treatment is required for contaminated groundwater extracted at the electrodes to separate toxic ions from solution prior to disposal.

Phosphate Treatment

Bench-scale studies are presently being performed to evaluate the effectiveness of in situ phosphate treatment and the optimum employment technology. Near the end of bench-scale studies, enough information should be available to begin detailed project planning in preparation for field activities. The feasibility of using phosphate compounds for large scale remediation of heavy metals in soils and groundwater is being evaluated in the bench scale studies. Laboratory tests indicate that phosphate minerals and compounds efficiently at precipitate ^{90}Sr into insoluble forms. These insoluble complexes are stable and immobile over a wide range of physical and chemical conditions.

The potential for use of phosphates for remedial action will be investigated in two phases. Phase one is the bench-scale testing program to determine optimum concentration of phosphate compounds needed to precipitate ^{90}Sr and to determine solubility and stability of the precipitated compounds. Parallel laboratory tests will investigate the effect that phosphate materials have on hydraulic conductivity. Phase two includes pilot-scale implementation of phosphate remediation techniques in the field using knowledge gained from the bench-scale tests. The pilot-scale test will investigate stabilizing ^{90}Sr in situ by precipitating these elements from groundwater. This will be accomplished by constructing a permeable phosphate "curtain." Injection of phosphatic materials directly into the aquifer is an alternative option.

The permeable phosphate curtain will be placed into the upper portion of the aquifer with an augering system. This will minimize local disturbances associated with trenching. The curtain will be approximately 200 feet long, 4 feet wide, and 60 feet deep. After installation, the permeable curtain will precipitate heavy minerals from groundwater and retain those minerals in a nonsoluble form. As an option, phosphate materials may be introduced into the aquifer by injection through wells, where the phosphate will permeate the aquifer and precipitate any heavy metals present. If proved effective, either or both of these methods may be used for groundwater treatment as alternatives to groundwater pump and treat.

Impermeable Barriers

Barrier Walls

Vertical cutoff walls are a containment technology that places a low permeability barrier in the groundwater aquifer to control the movement of groundwater and associated contaminants. These barriers may be constructed downgradient from the groundwater plume to contain contaminated groundwater emanating from the site, or upgradient from the plume to divert groundwater flow away from the site. In some cases, the entire plume may be encircled by the

barrier to minimize any further interaction with uncontaminated portions of the aquifer. Containment technologies as a group are applicable to a wide range of contaminants and reduce worker and short-term public risk because the contaminated media are not handled.

There are several methods of vertical cutoff wall construction. The type of barrier chosen depends on the size and shape of the required wall, the aquifer soil type, local material availability, wall permeability specifications, and required design life. Contaminants and groundwater composition can also limit material choices. General categories of vertical cutoff walls include *soil-bentonite slurry walls*, *cement-bentonite slurry walls*, *soil mixed walls*, *jet grout barriers*, *metal sheet piles*, and *cryogenic barriers*.

Soil-Bentonite Slurry Wall

The soil-bentonite slurry wall is an excavation and replacement technology where the excavated soil is continually replaced with a bentonite slurry. The slurry serves to maintain trench stability and creates a low-permeability filter cake on the trench walls to prevent large fluid losses into the adjacent ground. As excavation continues at one end of the wall, the other end is backfilled with excavated trench soil that has been treated as necessary to ensure sufficient fines content. If the excavated soil is not suitable for backfill due to a large particle size or the nature of contamination, an alternate fill material is used. The permeability of the composite trench will generally be 1×10^{-6} cm/sec to 1×10^{-7} cm/sec. Wall depths of 50 feet or less are usually excavated with backhoes, while depths of 50 to 200 feet are excavated with clamshell digging equipment. Excavations range from two to four feet in width. Whenever the design requires that the slurry trench be keyed into an underlying impervious zone, a keyway two to three feet deep is constructed. The completed slurry trench is usually topped with a compacted soil cap.

Cement-Bentonite Slurry Wall

The cement-bentonite slurry wall is similar to the soil-bentonite wall except that the excavated trench is backfilled with a cement and bentonite mixture. This mixture gels and sets as a result of the cement content and provides the barrier with strengths equal to or exceeding the existing soil. This increased strength allows walls to be constructed on sites with higher amounts of topographic relief, difficult soil conditions, or nearby structures. Construction of cement-bentonite slurry walls do not make use of the excavated trench soil and this soil becomes a spoil which must be disposed.

Soil-Mixed Wall

Soil-mixed walls use crane-mounted single or multiple shaft augers to mix soil and an engineered slurry. As the auger is advanced through the soil, slurry material is pumped through the hollow auger shaft and injected into the soil at the pilot bit. Slurry is continuously injected as the auger penetrates the soil. Once the desired depth is reached, the auger is removed while continuing to rotate and further mix the soil. The completion of one penetration leaves a column

of solidified material with a diameter approximately equal to the diameter of the original auger. After completing the column, the auger is moved and a new column is formed adjacent to and slightly overlapping the previous column. The process is repeated until a wall is constructed.

Jet Grout Barrier

Jet grout barriers are constructed by drilling a small diameter hole (approximately 5 cm) to the design depth using a downward jet of air or water pumped through a drill pipe. Slurry material is then pumped out laterally through jets located near the bottom of the drill pipe at pressures as high as 6000 psi. The drill pipe is rotated continuously and drawn up at a predetermined rate. The solidification agent exiting the jets mixes with the soil and forms a cylindrical column of solidified soil. The diameter of the column is a function of soil strength, soil composition, jetting pressure, processing rate, rotational speed, jet nozzle diameter, and slurry density. Once the column diameter is determined, placement of subsequent drill holes at a spacing slightly less than the column radius allows the second column to join the unset material in the previous column. Continuing this pattern creates the subsurface wall.

Sheet Pile Cutoff Wall

Sheet pile cutoff walls consists of interlocked metal sheet piles 18 to 24 inches wide (typical). The piles are interlocked at the surface and driven into the ground with vibratory or impact pile drivers a few feet at a time over the entire length of the wall. This process is repeated until the piles are driven to the desired depth. Sheet pile systems are available that allow the interlocked joint to be grouted to provide a low permeability barrier. Rocky or dense soils limit the applicability of this type of cutoff wall as pile driving is difficult and excessive driving force can damage the piles.

Cryogenic Barrier

Cryogenic, or frozen soil, barriers are formed by recirculating a chilled brine or refrigerant through an array of closely spaced wells. As the soil surrounding and between the wells cools and freezes, water in the voids freezes and expands, effectively creating an impermeable barrier. This process has been marketed at Hanford by RKK, Ltd. of Arlington, Washington.

The CRYOCELL® process, developed by RKK, involves the placement of two rows of steel pipe into the soil. Within the barrier, a series of perforated pipe casing are placed at 15 to 20 foot intervals. These injection pipes are used to optimize soil moisture and to provide a place to insert temperature monitoring devices. In addition, the pipes enable subsurface sampling (in the event of contaminant intrusion into the barrier), provide a means to selectivity thaw frozen soil, and allow for continual real-time air pressure monitoring and verification of barrier formation.

Typically, freeze pipes are standard 6 inch Schedule 40 PVC well casing with integral 3 inch return pipes to facilitate a closed loop flow of the refrigerant. Typical refrigerants include

aqueous ammonia for above-ground systems and brine for below-ground systems. All freeze pipes are connected via a manifold and supplied with a steady flow of refrigerant to uniformly cool the pipes and carry heat out of the ground. The establishment of a complete barrier can be carried out quickly with large scale temporary refrigeration equipment. After formation, the cryogenic barrier can be maintained with a modest refrigeration plant.

As the soil temperature reaches the design point of -35°F, compression strength ratings exceed those of concrete. Once fully formed, the barrier reaches its design thickness of 35 to 75 feet. Barrier temperature is controlled similar to a refrigerator. Sensors monitor the internal temperature and pressure of the wall. Electromagnetic imaging and ground penetrating radar can provide real-time, full spectrum monitoring and analysis of a contained site. If required, a computer software program adjusts refrigerant flow.

Hydraulic Control

Hydraulic containment is a technology that utilizes extraction wells to control the horizontal movement of groundwater and associated contaminants. When extraction wells are used in a purely containment strategy, the goal is to pump the minimum amount of water that will prevent further migration of the contaminant plume. Hydraulic containment may be used if natural decay mechanisms (e.g. radioactive decay or natural biodegradation) can reduce the amount of contamination in reasonable lengths of time.

Containment strategies that use extraction wells attempt to remove enough water upgradient from the waste site to reduce the hydraulic gradient through the site to zero. The strategy is also used to intercept contaminated water entering an adjacent body of water or aquifer or to maintain contamination within a site boundary. Hydraulic control using extraction wells is most often coupled with pump and treat technology. Treated groundwater is often returned to the contaminated plume. This technique, however, may create unwanted dispersion of contamination. The amount of water that must be pumped and the number of wells required depends on the natural gradient at the site, the hydraulic conductivity of the soil, and the dimensions of the plume. Extraction wells used for hydraulic control are frequently used in combination with vertical cutoff walls or other contaminant or diversion devices to control groundwater movement. The existing N-Springs Expedited Response Action pump and treat is effective as a hydraulic control mechanism.

Hydraulic control may also be achieved by pumping uncontaminated water into the ground, creating a mound of groundwater. The groundwater mound will alter the subsurface flow regime and will function similar to an impermeable barrier wall.

Pump and Treat Alternatives

Ion Exchange

Ion exchange is a proven separations process whereby ionic species, primarily inorganics, are concentrated into a secondary waste stream. Ion exchange resins act as insoluble acids or bases, having functional groups which take on a positive or negative charge in solution. Negatively-charged resins sorb cations, and the process is referred to as cation exchange; anion exchange is accomplished with positively-charged resins. These charged groups "hold on" to counter-ions through weak ionic bonds. Co-ions compete for these functional sites, hence their relative distribution in solution and on the resin depends on their bulk concentration and their relative affinity. The ion exchange process takes advantage of the competition between co-ions to exchange contaminant ions onto the resin and remove them from the waste stream.

Ion exchange is a reversible process, allowing resins to be regenerated and reused. Considerations in choosing regeneration or disposal of exchange resins include cost, waste management, and effluent requirements. For small applications, regeneration may not be cost effective, and the resin is packaged and disposed. Regeneration produces an aqueous waste stream which has implications for overall site waste management. Treatment objectives may call for extremely low effluent concentrations that can be accomplished practically with only virgin resin, making regeneration a non-viable option.

Ion exchange is a competitive process—exchange kinetics and equilibrium partitioning between the resin and the bulk liquid depend on the solid and liquid concentrations of all competing ions. Distribution coefficients, K_d , are commonly used to characterize the equilibrium capacity of a resin for a particular ion, and are defined as the equilibrium ratio of solid phase concentration (mg/g) to liquid phase concentration (mg/ml) for that ion. When a specific contaminant is very dilute relative to competing ions, it will occupy a small fraction of the exchange sites, and K_d will be largely independent of that contaminant's liquid phase concentration. In this regime, resin capacity is underutilized for that contaminant. At the other extreme, where a specific contaminant is very concentrated relative to competing ions, most exchange sites will be occupied by that contaminant, and solid phase concentration is independent of liquid phase concentration. Here, resin capacity is fully utilized. A common situation where resin capacity is underutilized is in the treatment of groundwater where naturally occurring minerals, such as calcium, sodium, and magnesium, can be present at concentrations orders of magnitude higher than the contaminant ions and, therefore, dominate the exchange sites of the resin.

Ion exchange is normally a fixed or fluidized bed process utilizing highly porous pellets, beads, or granulated resins. The most significant process differences occur in process configuration and operation. Mixed beds of anion and cation exchangers can be used to accomplish removal of both cations and anions within the same bed. After initially saturating the resin with innocuous exchange ions, a contaminated stream is directed through the ion exchange column, where

contaminants exchange with co-ions on the resin, producing a clean stream. A contaminant concentration profile develops within the bed, forming a concentration front that moves through the bed and emerges as a breakthrough curve. The shape of the front is largely determined by the selectivity of the resin for the contaminant over the exchange ion. A contaminant with higher affinity will form a self-sharpening front, while lower affinity will cause a dispersive, broadening front. The front speed is largely dictated by the resin capacity and the bulk flow rate. Typically, a bed is taken out of service when the effluent concentration reaches a predetermined level. Resin utilization can be improved by running multiple beds in series, and taking beds out of service only when they are completely spent. Resins have different affinities for different ions; the least selective contaminant will emerge first, and that contaminant will dictate the frequency of bed replacement.

Membrane Technologies

Membrane processes utilize selective semipermeable membranes to separate a contaminated aqueous waste stream into a dilute and a concentrate stream. When a driving force is applied, the membrane preferentially allows components of a fluid mixture or solution to permeate through the membrane, while rejecting passage of other components. The driving force can be pressure, concentration gradient, or electrochemical potential. A major advantage of membranes is that there is no net increase in volume. Membranes have few moving parts and are simple to operate. However, membranes are susceptible to fouling, and retention or removal of contaminants is rarely 100%. In many cases, the dilute stream may require further treatment. Therefore, membrane technology can rarely meet all remedial or treatment objectives, but may play a role in the overall remedial strategy.

The flow capacity of membranes is limited by the flux through the membrane, which is directly related to the driving force. Hence, the total capacity of a membrane device is constrained by the amount of active membrane surface area and membrane devices are designed to maximize the available surface area. The simplest configuration is a plate and frame arrangement, where flat membranes, separated by spacers, are alternated with impermeable layers. Feed is introduced on one side of the flat membranes and permeate is collected on the other side. The stream remaining on the feed side of the membrane is called the concentrate, retentate or reject. Alternately, the flat sheet membrane can be rolled into a cylindrical, spiral wound configuration. Membranes are also fabricated into tubes or hollow fibers, and assembled into devices resembling shell-and-tube heat exchangers. The feed may be introduced to the bore or the shell side of the tubes, with the permeate collected on the other. The performance of a membrane device is characterized by recovery, defined as the ratio of permeate flow rate to feed flow rate.

Process options applicable to inorganic radionuclides for membrane separations includes *reverse osmosis* and *ultrafiltration and microfiltration*.

Reverse osmosis utilizes a pressure driving force to selectively transport water through a membrane while retaining particulates, organic contaminants, and ions, thereby achieving

volume reduction of the primary stream. The pressure driving force must overcome the natural osmotic pressure generated by the concentration difference across the membrane. The membranes typically have broad pore size distribution, including a few large "defect holes" which prevents absolute retention of even large proteins and bacteria. Reverse osmosis membranes utilize a combination of size exclusion and physical forces to accomplish retention and achieve separation. Effectiveness for individual contaminants is a combination of size, shape, and chemical characteristics. Although small organic molecules and selected inorganics are not effectively retained, high molecular weight organic molecules and most inorganic ions are 90% rejected or better.

The pore sizes of *ultrafiltration and microfiltration* membranes are generally much larger than the pores of reverse osmosis membranes, and allow free passage of ions and small molecules. The driving force is again pressure, and retention is based solely on exclusion by size, shape, and flexibility. Ultrafiltration is capable of retaining organic molecules with molecular weights greater than 500 and particles larger than 0.001 to 0.01 micron, while microfiltration generally rejects particles greater than 0.1 micron. Filtration membranes can be made with very narrow pore size distributions, thus retention curves as a function of particle size can be very sharp. The process has been successfully applied to heterogeneous colloidal suspensions which are difficult to separate using other technologies. Ultrafiltration is a well developed technology and is commercially available.

Precipitation

Precipitation is a separation process that removes soluble contaminants from contaminated water. Remedial applications of this technology usually involve removal of dissolved toxic metals and radionuclides, but occasionally this process is required as a pretreatment for reducing water hardness (calcium and magnesium) to prevent scaling in downstream processes. Removal of dissolved contaminants requires two steps. The first step reduces contaminant solubility and generates a solid precipitate while the second step removes the precipitate using a solids/liquid separation process. Chemical precipitation is used widely in wastewater treatment and is a low cost, proven technology. Although the chemicals used are readily available and inexpensive, precipitation generates large secondary waste volumes, and is limited in achieving low effluent concentrations.

Reducing contaminant solubility is usually accomplished by the addition of a chemical precipitant that reacts with the contaminant to form an insoluble compound. The most common types of chemical precipitation for waste water treatment are *hydroxide precipitation, sulfide precipitation, and carbonate precipitation*. Other types of precipitation can be used for specific contaminants.

Hydroxide precipitation, using calcium or sodium hydroxide to remove metals as metal hydroxides, is the most common method for treating wastewaters. *Sulfide precipitation* has several possible advantages over hydroxide precipitation. The solubilities of many metallic

sulfide compounds are significantly lower than corresponding hydroxide compounds, allowing lower effluent concentrations. Common sulfides used in this process include sodium sulfide, sodium hydrosulfide, and ferrous sulfide. The potential drawbacks associated with sulfide precipitation include the possible formation of toxic hydrogen sulfide gas at pH values below 8 and the presence of excess sulfide in the effluent that may require subsequent treatment. These considerations generally require that sulfide precipitation occur in a closed system and sulfide additions are carefully controlled to minimize excess sulfide.

Some metals including cadmium and lead can be precipitated as a *carbonate*. This process does not reduce effluent concentrations lower than achievable by hydroxide precipitation, but has the advantages of lower operating pH levels and production of a higher density precipitate that is easier to separate. Sodium carbonate is a common additive for carbonate precipitation.

The overall precipitation process may require several steps depending on the type of influent. If the wastewater is contaminated with oils or large quantities of suspended solids, pretreatment with oil-water separation or filtration prior to adding chemical precipitants may be necessary. In addition, high levels of complexing agents can limit the effectiveness of precipitation and wastes may require pretreatment to remove or destroy the complexing agent prior to precipitation.

After pretreatment, the waste water and chemical precipitants are combined in a stirred tank to form solid precipitates. The precipitation process can generate very fine particles that are held in suspension by electrostatic surface charges. These surface charges cause clouds of counter-ions to form around the particles, giving rise to repulsive forces that prevent aggregation and reduce the effectiveness of subsequent solid-liquid separation processes. Therefore, chemical coagulants are often added to overcome the repulsive forces and allows agglomeration into larger particles which are easier to separate. The three main types of coagulants are: inorganic electrolytes (such as alum, lime, ferric chloride, and ferrous sulfate) that reduce the size of the counter-ion clouds, organic polymers that promote flocculation through hydrogen bonding and electrostatic forces, and synthetic polyelectrolytes with anionic or cationic functional groups that promote agglomeration. Precipitation/flocculation is followed by a solid-liquid separation process. The complete precipitation process generates a treated aqueous effluent and a sludge containing the separated metals. Ion exchange and membrane processes are sometimes used to polish the treated effluent if lower concentrations levels are required. Sludges are often treated with solidification/stabilization technologies prior to disposal.

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Attachment 2

Preliminary 1301-N/1325-N LWDF Characterization Data

This summary presents preliminary data, available to date, for the activities associated with the limited field investigation (LFI) of the 1301-N and 1325-N Liquid Waste Disposal Facilities (LWDFs). Because the final data deliverables have not been received, this data is considered "preliminary." Once all the data have been received, validated, reviewed, and interpreted, they will be presented in a LFI report and used in a qualitative risk assessment for the 1301-N and 1325-N sites. A discussion of the data received to date is provided below.

The field activities consisted of drilling, sampling, and geophysical logging of three characterization boreholes: B2536, B2537, and B2539. In addition, four existing wells were geophysically logged: 199-N-35, 199-N-45, 199-N-67, and Pacific Northwest National Laboratory's research well # 1. Borehole B2536 was drilled within the 1301-N crib, while boreholes B2537 and B2539 were drilled immediately adjacent to the 1301-N trench and 1325-N crib, respectively. The borings were drilled to groundwater using the cable-tool drill method. The drilling was done by Water Development Hanford under the supervision of a Bechtel Hanford field superintendent. Field activities were supported by an IT Hanford geologist and sampler. The field characterization began on November 6, 1995, and was completed on January 11, 1996, when concrete pads around the temporary well casings were installed.

All work was conducted in accordance with the *Description of Work (DOW) for Vadose Zone Characterization of the 1301-N and 1325-N Liquid Waste Disposal Facilities (DOE/RL-94-104)*. Two sampling methods, split spoon sample collection and grab sample collection, were used to collect borehole soil samples. The recommended sample collection depths presented in the DOW are shown in Figure 1. The analyses required for these samples are presented in Table 1. In addition to collecting soil samples, geophysical logging was performed as indicated in Table 1.

A split spoon sampler was used to collect discrete soil samples at targeted sampling depths for chemical, radiological, and physical properties analyses. These samples were analyzed by Quanterra for metal and radionuclide contaminants of concern. A subsample was submitted to the Westinghouse Hanford Company (WHC) 222-S Laboratory for radionuclide screening. Split spoon soil samples were also analyzed for physical properties by the WHC Geotechnical Laboratory and Southwest Research Institute (SRI). In addition, grab samples were collected directly from the cable-tool drive barrel at 3 m (10 ft) intervals for radiological screening and limited physical property analyses. Chemical, radiological, physical properties, and geophysical logging results are provided as attachments:

- Borehole Summary Sheets
- 222-S Laboratory Radiological Screening Data
- Quanterra Chemical and Radiological Data
- Borehole Geophysical Logs
- Physical Properties Results

These results will be reviewed and revised as new data becomes available and is validated. The new data will then be reported in the 1301-N/1325-N LFI report.

Draft summary sheets for each borehole (Attachment A) provide sample locations and numbers, general lithology, and well construction information. The remarks column of the summary sheet contains sample identification numbers to correlate with radiological, chemical, and physical properties data in other attachments.

Soil samples were collected for radiological screening analysis by the WHC 222-S Laboratory to provide quick turnaround information to assist selection of supplementary sample intervals, support sample packaging, and shipment to off-site laboratories. The information was also used to upgrade and/or downgrade site health and safety documentation during drilling. Because of the inherent limitations associated with quick turnaround time analyses, the results given here should be used judiciously for other purposes.

The table in Attachment B is a summary of gamma energy analysis, ^{90}Sr , total alpha, total beta, and plutonium results for all three boreholes. Soil samples were analyzed for plutonium when total alpha activity exceeded 20 pCi/gm. A total of 31 samples was submitted for analysis.

Soil samples were collected and submitted to Quanterra Laboratory for chemical and radiological analysis in accordance with the DOW. Preliminary, non-validated data for boreholes B2536, B2537, and B2539 are found in Attachment C. This data is currently in the validation process. A total of 20 samples was submitted for analysis.

Geophysical logging of each borehole casing string was performed by Schlumberger, Inc. and WHC. Spectral gamma, neutron moisture, and gamma density sondes were run by Schlumberger in each borehole. WHC ran high-purity germanium spectral gamma (HPGE) and neutron moisture sondes. For comparison, spliced logs, at the same scale for each borehole, are presented in Attachment D. Additionally, WHC ran HPGE in four existing wells and neutron in three of those wells. These results are included in Attachment D. The logs include the following:

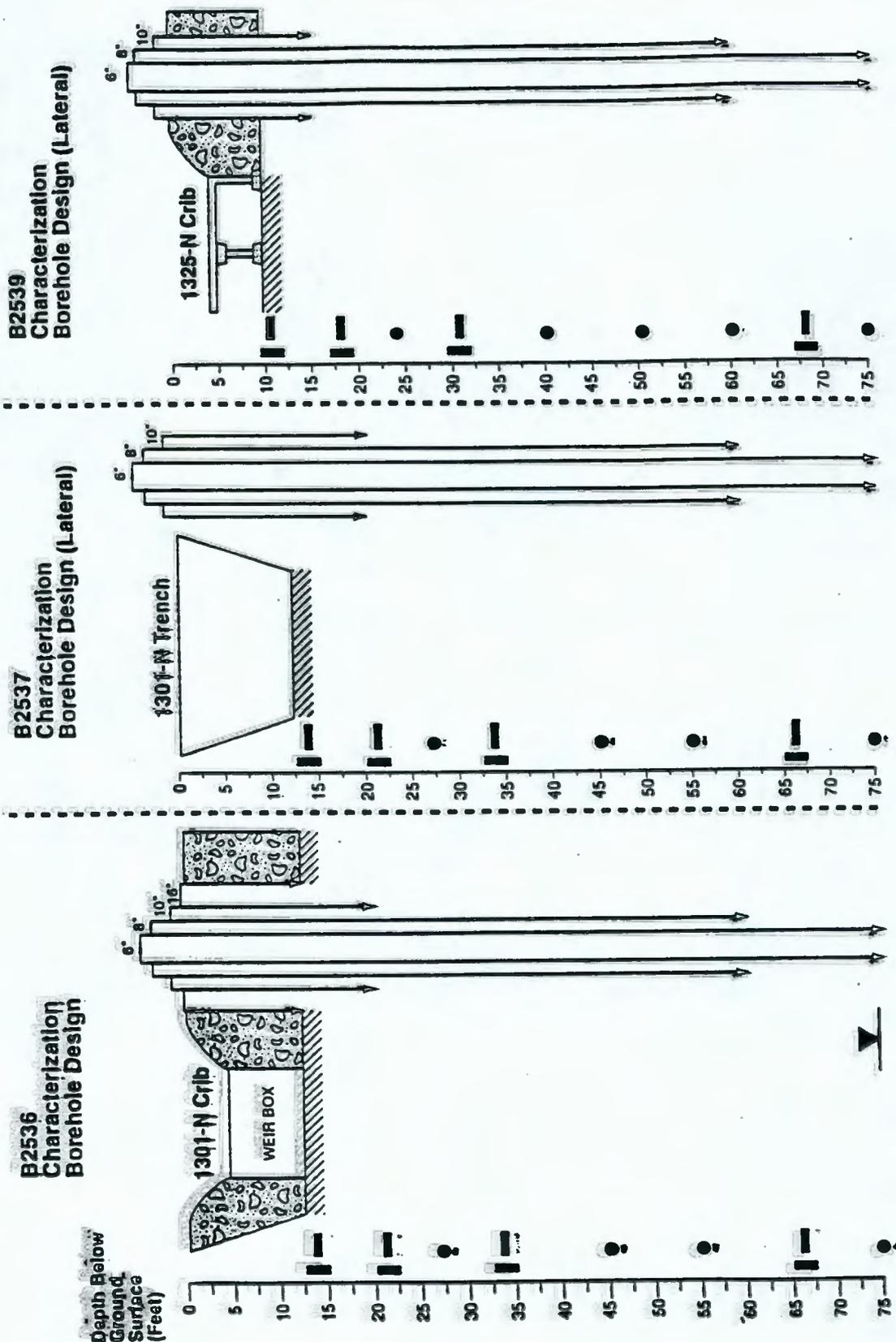
gross gamma	WHC
cesium-137	WHC
cobalt-60	WHC
potassium-40	WHC
uranium	WHC
thorium	WHC
neutron moisture	Schlumberger
bulk density for information only	Schlumberger.

Soil samples were collected from boreholes B2537 and B2539 for physical properties testing. The WHC Geotechnical Engineering Laboratory analyzed samples from borehole B2537 for

moisture content, porosity, bulk density, particle size distribution, and saturated hydraulic conductivity. Samples from borehole B2539 and the remaining moisture retention samples from F32537 were shipped to SRI for analyses because the WHC laboratory facility was closed. However, no data has yet been received from SRI. Laboratory results received to date from WHC are presented in Attachment E.

Again, it is important to state that the data in the attachments have not been subjected to validation, review, or interpretation; therefore, they are preliminary and incomplete. Once all project data have been received, the information will be incorporated in the LFI report.

Figure 1. Sample Collection Intervals for Boreholes



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Table 1. Analytical Methods, Analytical Parameters, Detection Limits, and Precision and Accuracy Requirements (3 sheets)

	Analytical Category	Analytical Parameters	Analytical Method	Detection Limit	Container Type/Volume or Mass	Maximum Holding Time	
Split-Spoon Samples	Metals	Cadmium Chromium Lead Nickel	SW-846; Method 6010 ICP - Metals	1.0 ppm	amber glass 40 mL	6 months	
	Radionuclides	Strontium-90		Sr-02 ^a	1.0 pCi/g	amber glass 60 mL	6 months
		Alpha Spectrometry Uranium-233/234 Uranium-238 Plutonium-238 Plutonium-239/240		ASTM D 3084 ^b	0.6 pCi/g (for all parameters)		
		Gross alpha		Water 901.1 Soil ^c	7.0 pCi/g		
		Gross beta		Water 901.1 Soil ^c	8.0 pCi/g		
		Gamma Spectrometry Potassium-40 Manganese-54 Cobalt-60 Ruthenium-106 Cesium-134 Cesium-137 Cerium-134 Europium-154 Europium-155 Radium-226 Thorium-228 Thorium-232		Water 901.1 Soil ^c	10.0 pCi/g 0.25 pCi/g 0.05 pCi/g 1.5 pCi/g 0.25 pCi/g 0.25 pCi/g 0.75 pCi/g 0.75 pCi/g 0.75 pCi/g 4.5 pCi/g 0.6 pCi/g 0.6 pCi/g		
	Offsite Shipping Requirements	For less than detectable rad samples: total activity only		222-S Laboratory Liquid Scintillation	50.0 pCi/g	20 mL	6 months
		For Radioactive Samples: Gross alpha Gross beta Gamma emitters Strontium-90		222-S Laboratory Methods	1.0 pCi/g 4.0 pCi/g 0.05 pCi/g 1.0 pCi/g		

Table 1. Analytical Methods, Analytical Parameters, Detection Limits, and Precision and Accuracy Requirements (3 sheets)

	Analytical Category	Analytical Parameters	Analytical Method	Detection Limit	Container Type/Volume or Mass	Maximum Holding Time
Split-Spoon Samples	Physical Properties	Moisture Content	ASTM D2216 (GEL-14)	N/A	moisture tin (sealed) 400 g	N/A
		Moisture Retention	ASTM D2325 ASTM D3152 (GEL-18)	N/A	one 6-in. capped split-spoon liner	N/A
		Bulk Density/Porosity	ASTM D2937 ASTM D4564 (GEL-14)	N/A		
		Permeability	ASTM D2434 (GEL-09)	N/A		
		Particle Size Distribution	ASTM D422 (GEL-07)	N/A	depends on grain size, one 6-in. capped split-spoon liner minimum	N/A
Grab Samples	Radionuclides	Strontium-90	Sr-02 ^a	1.0 pCi/g	amber glass 40 mL	6 months
		Gross Alpha	Gas Proportional	7.0 pCi/g		
		Gross Beta	Gas Proportional	8.0 pCi/g		
		Gamma Spectrometry Potassium-40 Manganese-54 Cobalt-60 Ruthenium-106 Cesium-134 Cesium-137 Cerium-134 Europium-154 Europium-155 Radium-226 Thorium-228 Thorium-232	Gamma Spectrometry	0.05 pCi/g (for all parameters)		
	Physical Properties	Moisture Content	ASTM D2216 (GEL-14)	N/A	moisture tin (sealed) 400 g	N/A
		Particle Size Distribution	ASTM D422 (GEL-07)	N/A	double-wrapped plastic bag; 1 kg minimum	N/A

Table 1. Analytical Methods, Analytical Parameters, Detection Limits, and Precision and Accuracy Requirements (3 sheets)

	Analytical Category	Analytical Parameters	Analytical Method	Detection Limit	Container Type/Volume or Mass	Maximum Holding Time
Geophysical Logging	Radionuclides	Gamma Spectrometry Uranium-233 Uranium-234 Uranium-238 Plutonium-238 Plutonium-239 Plutonium-240	RLS	150.0 pCi/g 300.0 pCi/g 25.0 pCi/g 1.6 nCi/g 20.0 nCi/g 85.0 nCi/g	N/A	N/A
		Gamma Spectrometry Potassium-40 Manganese-54 Cobalt-60 Ruthenium-106 Cesium-134 Cesium-137 Cerium-134 Europium-154 Europium-155 Radium-226 Thorium-228 Thorium-232	RLS	2.0 pCi/g 1.0 pCi/g 1.0 pCi/g 5.0 pCi/g 1.0 pCi/g 1.0 pCi/g 5.0 pCi/g 1.0 pCi/g 10.0 pCi/g 5.0 pCi/g 5.0 pCi/g 1.0 pCi/g		
	Physical Properties	Moisture Content	Neutron Moisture Logging	2% VFW		

^aMethods specified are from the *EML Procedures Manual* (Chieco et al. 1990)

^bMethod specified is from the *1993 Annual Book of ASTM Standards* (ASTM 1993).

^cMethod shall be based on the specified water method, modified to allow measurement of the parameter of interest in a soil sample, and shall be submitted for Bechtel Hanford, Inc. review and approval prior to use.

ASTM - American Society of Testing and Materials

GEL-## - Westinghouse Hanford Company Geotechnical Engineering Laboratory

N/A - Not Applicable

RLS - Radionuclide Logging System

VFW - Volume Fraction Water

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ATTACHMENT A

BOREHOLE SUMMARY SHEETS FOR B2536, B2537 and B2529

Project: 1301-N/1325-N LWDF Drilling Well No: B2536 Page 1 of 2

Date Started: 11-28-95 Date Completed: 12-8-95 Total Depth: 76.00 Static Water Level: 75.00

Logged By: D. C. Weekes Checked By: Surface Elevation: 463.44 Casing Elevation: 463.92

Drilling Co: Water Development Hanford Co Driller: M. Wrasplr/G. Howell Northing: 149685.11 Easting: 571462.35

Drilling Method: Cable tool Drilling Equipment: Bucyrus Erle 22W

Screen: NA

Filter Pack: NA

Permanent Casing: Temporary Casing: 16" 0-9', 10" 0-16.2', 8" 0-76.2'

Comments: Characterization borehole through 1301-N Crib (see DOE/RL-94-104) elevation is in FEET NAVD88, Northing and Easting are in meters WCS83(1991)S

Elev'n (Feet) Depth (Feet)	Casing Strings (inches)	Well Construction	Sample	Interval	Remarks	Lithology	Gross Gamma Log	Sieve Analysis				% CaCO3 -----E	% Moist ———●	Red Cnt pCi/g
								clay	silt	sand	gravel			
460	18					0-9 Sandy GRAVEL: BACKFILL not logged by geologist								
450	10		CH	9.8 11.0 13.0	BOGLF4 222S, BOGL88 QUAN, AR BOGLF5 222S, BOGL89 QUAN, AR	9-28 Silty Sandy GRAVEL								
440	8			22.5 23.0	BOGLF7 222S, BOGL90 MT, AR									
430			CH	28.8 30.0	BOGLF6 222S, BOGLF8 222S DUP, BOGL91 QUAN, BOGL92 QUAN DUP BOGL93 MT, AR	28-38 Gravelly SAND								
				35.5 36.0	AR									
40				39.5 40.0	BOGLF9 222S, AR	38-42 Sandy GRAVEL Hanford-Ringold Contact at 42 ft								
420				44.5		42-48 Silty Sandy GRAVEL: BASALT-POOR								

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Elev'n (Feet) Depth (Feet)	Casing Strings (inches)	Well Construction	Sample	Interval	Remarks	Lithology	Gross Gamma Log	Sieve Analysis				% CaCO3	Rad Cnt pCi/g
								clay	silt	sand	gravel	% Moist	
				45.0	AR								
50				49.5		48-52 Gravelly SAND							
				50.0	BOGLG0 222S, AR								
410				53.5		52-55 Silty Sandy GRAVEL							
				54.0	AR								
				58.0		55-76 Sandy GRAVEL							
				59.0	BOGLG1 222S, BOGL95 QUAN, AR								
400				68.5									
				69.0	BOHIV6 222S, AR								
390				73.5									
				74.0	AR								
						Water at 75 ft TD = 76 ft							
80													
380													
90													
370													
100													
360													

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Project: 1301-N/1325-N LWDF Drilling Well No: B2537 Page 1 of 2

Date Started: 11-6-95 Date Completed: 11-16-95 Total Depth: 75.00 Static Water Level: 72.00
 Logged By: DC Weekes Checked By: Surface Elevation: 460.15 Casing Elevation: 460.29
 Drilling Co: Water Development Co. Driller: G. Howell/M. Wasplr Northing: 149812.50 Easting: 571541.51
 Drilling Method: Cable tool Drilling Equipment: Bucyrus-Erie 22W

Screen: NA

Filter Pack: NA

Permanent Casing: Temporary Casing: 10" 0-36.4', 8" 0-70.8'

Comments: Characterization borehole next to 1301-N Trench (see DOE/RL-94-104) elevation is in FEET NAVD88, location in METERS WCS83/91S

Elev'n (Feet)	Casing Strings (inches)	Well Construction	Sample	Interval	Remarks	Lithology	Gross Gamma Log	Sieve Analysis clay silt sand gravel fines	% CaCO3 -----E	% Moist -----●	Red-Gnt pEig moist. wt %
10	10					0-8 Silty Sandy GRAVEL: BACKFILL					
10						8-14 Silty GRAVEL					
15.0						14-14.5 Sand Lens					
15.5					BOGL72 PH	14.5-21 Silty Sandy GRAVEL					4.03
16.5					BOGLD2 222S,						
17.5					BOGL71 QUAN						2.98
18.0					BOGLD5 222S, BOGL76 PH, AR						
20						21-27 SAND (f-v)					
23.5											
24.0					BOGLD3 222S,						
24.5					BOGLD4 222S DUP,						8.88
25.0					BOGL73 QUAN,						
27.5					BOGL76 QUAN DUP	27-32 Sandy GRAVEL					3.83
28.0					BOGL74 PH						
30					AR						
32.0					BOGLD6 222S,						
32.5					BOGL77 PH, AR	32-39 Silty Sandy GRAVEL					2.6
32.5					BOGLD7 222S,						
32.5					BOGL78 PH, AR						
35.5											
36.0					AR	Henford-Ringold Contact at 39 ft					
40						39-50 Silty Sandy GRAVEL: BASALT-POOR					
42.5											
43.0					BOGLD8 222S,						
43.5					BOGLB1 QUAN						8.48

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Elev'n (Feet) Depth (Feet)	Casing Strings (inches)	Well Construction	Sample	Interval	Remarks	Lithology	Gross Gamma Log	Sieve Analysis				% CeCO3 = - - - - E	Red-Cat. - pCtg moisture wt %
								clay	silt	sand	gravel		
-410 50				44.0	BOGL80 PH, AR								2.84
				46.5	BOGLD9 222S,								
-400 60				47.0	BOGL82 PH, AR	50-59 SAND (f-vf)							4.27
				51.5									
				52.0	BOGLF0 222S, BOGL83 PH, AR								
				56.6									
-400 60				57.0	AR	59-62 Sandy GRAVEL							4.93
				59.0									
				59.5	BOGLF1 222S, BOGL84 PH, AR								
				62.3									
				62.8	AR								
-390 70				63.3	BOGL85 PH	62-66.5 Silty Sandy GRAVEL							2.77
				63.8	BOGLF2 222S, BOGL86 QUAN								
				66.5									
				68.5	BOGLF3 222S, BOGL87 PH, AR								
-390 70				69.0		66.5-68.5 SAND: vc-m. thin bed							3.2
						66.6-72.5 Silty Sandy GRAVEL							
-380 80						Water at 72 ft							
						TD = 72.5 ft							
-370 80													
-360 100													

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Project: 1301-N/1325-N LWDF Drilling		Well No: B2539		Page 1 of 2
Date Started: 12-19-95	Date Completed: 12-28-95	Total Depth: 64.64	Static Water Level: 63.00	
Logged By: DC Weekes	Checked By:	Surface Elevation: 453.84	Casing Elevation: 454.85	
Drilling Co: Water Development Hanford Co	Driller: M. Wraspir/G. Howell	Northing: 149630.62	Easting: 571898.17	
Drilling Method: Cable tool		Drilling Equipment: Bucyrus-Erie 22W		
Screen: NA				
Filter Pack: NA				
Permanent Casing:		Temporary Casing: 10" 0-21', 8" 0-64.64'		
Comments: Characterization borehole next to 1325-N Crib (see DOE/RL-94-104) elevation is in FEET NAVD88, Northing and Easting in meters WCS83(1991)S				

Elev'n (Feet) Depth (Feet)	Casing String (Inches)	Well Construction	Sample	Interval	Remarks	Lithology	Gross Gamma Log	Sieve Analysis				% CaCO3	Rad Cnt pCi/g
								clay	silt	sand	gravel		
450	10					0-2.5 Sandy GRAVEL: new backfill 2.5-8 Sandy GRAVEL: old backfill							
10				9.0 9.5 10.0 10.5 11.0 12.0	BOHIV7 222S,BOGL97 QUAN,BOGL96 MT ONLY,AR BOGL98 PH,BOHIV8 222S,BOGL99 QUAN,AR	8-10 Silty Sandy GRAVEL 10-44 Sandy GRAVEL							
440				17.5 18.0 19.0	BOGLB0 PH,BOHIV9 222S,BOGLB1 QUAN,AR								
430				24.5 25.0 26.0	BOGLB2 PH,BOHIW1 222S,BOHIW2 222S DUP,BOGLB3 QUAN,BOGLB4								
30				29.5 30.0	QUAN DUP AR BOHIW3								
420				34.5 35.0	222S,BOGLB5 PH,AR AR								
40				39.5 40.0 41.0	BOGLB7 PH,BOHIW4 222S,BOGLB6 QUAN,AR	HANFORD/RINGOLD CONTACT AT 44 FT							
410				44.5		44-64.5 Silty Sandy GRAVEL							

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Elev'n (Feet) Depth (Feet)	Casing Strings (inches)	Well Construction	Sample	Interval	Remarks	Lithology	Gross Gamma Log	Sieve Analysis				Rad Cnt pCi/g
								clay	silt	sand	gravel	
				45.0	AR							
50				49.5 50.0	BOHIW5 222S,BOGLB9 PH							
400			54.5 55.0	AR								
60			60.0 60.5 61.5	BOH5N9 222S,BOGLC1 PH,AR								
390					WATER AT 63 FT TD = 64.5 ft							
70												
380												
80												
370												
90												
360												
100												
350												

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ATTACHMENT B

222-S LABORATORY DATA FOR B2536, B2537 and B2539

1301-N/1325-N Analytical Screening Data from the 222-S Laboratory (Page 1 of 4)

Borehole: Sample ID: Depth (ft): Date: Units:	B2536								
	B0GGC3*	B0GLF4	B0GLF5	B0GLF7	B0GLF6	B0GLF8 (Dup)	B0GLF9	B0GLG0	B0GLG1
	N/A	9-11	11-13	23	28-30	28-30	40	50	57-59
	8/25/95	11/29/95	11/30/95	12/5/95	12/5/95	12/5/95	12/6/95	12/6/95	12/8/95
	pCi/g	pCi/g	pCi/g	pCi/g	pCi/g	pCi/g	pCi/g	pCi/g	pCi/g
Actinium-228	NR	NR	NR	NR	NR	NR	NR	NR	NR
Americium-241	17,300	856	1,130	NR	NR	NR	NR	NR	NR
Bismuth-214	NR	NR	NR	NR	NR	NR	NR	NR	NR
Cerium-144	NR	456 U	402 U	11.2 U	6.5 U	NR	2.51 U	1.17 U	2.44 U
Cesium-134	NR	97.9 U	87.8 U	2.61	0.282 U	0.225 U	0.097 U	0.076 U	0.144 U
Cesium-137	102,000	12,100	15,100	2,790	5.81	5.69	0.143 U	NR	0.41 U
Cobalt-60	56,300	107,000	132,000	23.9	5.82	5.25	1.2	0.786	1.15
Europium-154	11,800	1,030	1,370	0.978 U	0.557 U	0.567 U	0.286 U	0.294 U	0.524 U
Europium-155	4,120	355	304	5.55 U	2.01 U	1.85 U	0.716 U	0.332 U	0.703 U
Gross Alpha	13,900	941	38,200	2.52 U	2.18 U	3.39 U	1.44 U	0.968 U	1.96 U
Gross Beta	305,000	63,700	60,600	4,310	2,810	2,490	1,680	145	124
Lead-214	NR	NR	NR	NR	NR	NR	NR	NR	NR
Manganese-54	NR	140 U	127 U	0.568 U	0.265 U	0.258 U	0.097 U	0.105 U	0.241 U
Plutonium-238	NR	NR	222 U	NR	NR	NR	NR	NR	NR
Plutonium-239	12,700	NR	689	NR	NR	NR	NR	NR	NR
Potassium-40	NR	422 U	457 U	0.11	7.02 U	NR	11.6	2.05	16.9
Radium-224	NR	NR	NR	NR	NR	NR	NR	NR	NR
Radium-226	NR	1,410 U	1,260 U	45 U	6.77 U	9.28 U	3.36 U	2.07 U	4.94 U
Ruthenium-106	NR	1,930 U	1,740 U	29 U	4.81 U	4.69 U	1.85 U	1.76 U	3.52 U
Strontium-90	92,299	3,250	12,600	1,170	1,550	1,350	1,080	188	63.1
Thorium-228	NR	5,270 U	4,650 U	152	54.2 U	50.4	19.9 U	8.84 U	20.6 U

* Sample was collected from soil precipitate scraped off a boulder that was removed from the base of the crib.

U - Undetected at specified detection limits

NR - Not Requested

N/A - Not Applicable

Dup - Duplicate

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1301-N/1325-N Analytical Screening Data from the 222-S Laboratory (Page 2 of 4)

Borehole: Sample ID: Depth (ft): Date: Units:	B2537								
	B0H1V6	B0GLD2	B0GLD5	B0GLD3	B0GLD4 (Dup)	B0GLD6	B0GLD7	B0GLD8	B0GLD9
	69	14.5-16.5	18	23-25	23-25	28	32.5	42-44	47
	12/8/95	11/9/95	11/9/95	11/10/95	11/10/95	11/10/95	11/10/95	11/15/95	11/15/95
	pCi/g	pCi/g	pCi/g	pCi/g	pCi/g	pCi/g	pCi/g	pCi/g	pCi/g
Actinium-228	NR	NR	NR	NR	NR	NR	NR	NR	NR
Americium-241	NR	NR	NR	NR	NR	NR	NR	NR	NR
Bismuth-214	NR	NR	NR	NR	NR	NR	NR	NR	NR
Cerium-144	2.45 U	66.7 U	107 U	22 U	15.5 U	12 U	6.89 U	7.42 U	9.32 U
Cesium-134	0.161 U	5.54 U	17.1	1.5 U	1.32 U	0.962 U	0.622 U	0.536 U	0.808 U
Cesium-137	0.421 U	3,200	15,700	108	84.9	24.1	1.34 U	1.73 U	2.27 U
Cobalt-60	70.9	522	3,300	10.4	14.2	3.53	0.999 U	0.832 U	0.976 U
Europium-154	0.49 U	9.05 U	18.3 U	3.99 U	3.64 U	2.2 U	1.61 U	2.24 U	3.11 U
Europium-155	0.697 U	16.1 U	24.1 U	6.09 U	4.21 U	3.18 U	1.66 U	1.98 U	2.12 U
Gross Alpha	2.77	1.4	51.1	1.33 U	1.45 U	1.31 U	1.38 U	1.02 U	1.86 U
Gross Beta	123	2,280	17,600	2,690	2,770	435	228	80.9	34.8
Lead-214	NR	NR	NR	NR	NR	NR	NR	NR	NR
Manganese-54	18.3 U	5.05 U	9.49 U	1.35 U	0.978 U	0.943 U	0.591 U	0.589 U	0.969 U
Plutonium-238	NR	NR	11.2	NR	NR	NR	NR	NR	NR
Plutonium-239	NR	NR	73.7	NR	NR	NR	NR	NR	NR
Potassium-40	17	43.1 U	43.3 U	48.4 U	13 U	35.4 U	15.7 U	27.1 U	35.2 U
Radium-224	NR	NR	NR	NR	NR	NR	NR	NR	NR
Radium-226	4.53 U	121 U	200 U	36.1 U	27.1 U	20.8 U	11.7 U	12.9 U	16.2 U
Ruthenium-106	3.36 U	109 U	184 U	31.4 U	16.1 U	20 U	10.6 U	12.6 U	14.4 U
Strontium-90	54.6	139	785	1,410	1,380	195	119	24.6	4.33
Thorium-228	18.2 U	427 U	651 U	165 U	115 U	81 U	51.7 U	48.9 U	63.5 U

* Sample was collected from soil precipitate scraped off a boulder that was removed from the base of the crib.

U - Undetected at specified detection limits

NR - Not Requested

N/A - Not Applicable

Dup - Duplicate

9615492.7047

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130J-N/1325-N Analytical Screening Data from the 222-S Laboratory (Page 3 of 4)

Borehole: Sample ID: Depth (ft): Date: Units:	B2537				B2539			
	B0GLF0	B0GLF1	B0GLF2	B0GLF3	B0H1V7	B0H1V8	B0H1V9	B0H1W1
	52	59.5	62-63.5	69	8-10	10-12	17-19	24-26
	11/15/95	11/15/95	11/16/95	11/16/95	12/19/95	12/20/95	12/20/95	12/22/95
	pCi/g							
Actinium-228	NR	NR	NR	NR	NR	0.866	NR	NR
Americium-241	NR	NR	NR	NR	6.51	NR	NR	NR
Bismuth-214	NR	NR	NR	NR	NR	0.65	0.59	NR
Cerium-144	10.1 U	11.1 U	8.47 U	7.54 U	5.29 U	2.29 U	1.57 U	5.79 U
Cesium-134	0.688 U	0.855 U	0.827 U	0.463 U	0.478 U	0.105 U	0.0917 U	0.402 U
Cesium-137	1.7 U	2.52 U	2.06 U	1.86 U	371	0.211 U	0.14 U	0.498 U
Cobalt-60	1.37 U	1.77 U	0.983 U	0.604 U	225	3.83	1.65	1.73
Europium-154	3.76 U	3.74 U	1.92 U	2.41 U	1.05 U	0.332 U	0.287 U	1.2 U
Europium-155	2.68 U	2.62 U	2.21 U	1.8 U	1.37 U	0.677 U	0.448 U	1.05 U
Gross Alpha	2.46 U	1.53 U	1.65	1.47 U	5.26	0.969	1.15 U	0.981
Gross Beta	20	537	272	74	2,440	1,610	579	346
Lead-214	NR	NR	NR	NR	NR	1.09	0.788	NR
Manganese-54	0.988 U	0.876 U	0.719 U	0.765 U	1.11	0.13 U	0.109 U	0.417 U
Plutonium-238	NR							
Plutonium-239	NR							
Potassium-40	12.6 U	25.1 U	16.6 U	30 U	10.1	9.18	6.56	17.9 U
Radium-224	NR							
Radium-226	21.8 U	20.3 U	14.7 U	14.1 U	9.32 U	3.28 U	2.29 U	10 U
Ruthenium-106	18.9 U	17.6 U	15.8 U	13.6 U	9.29 U	2.07 U	1.67 U	7.23 U
Strontium-90	138	239	24.7	129	1,080	866	331	193
Thorium-228	75.4 U	74.6 U	61.7 U	50.4 U	36.5 U	18.2 U	12 U	27.6 U

* Sample was collected from soil precipitate scraped off a boulder that was removed from the base of the crib.

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Dup - Duplicate

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1301-N/1325-N Analytical Screening Data from the 222-S Laboratory (Page 4 of 4)

Borehole: Sample ID: Depth (ft): Date: Units:	B2539				
	B0H1W2 (Dup)	B0H1W3	B0H1W4	B0H1W5	B0H5N9
	24-26	30	39-41	50	59-61.5
	12/22/95	12/22/95	12/27/95	12/27/95	12/28/95
	pCi/g	pCi/g	pCi/g	pCi/g	pCi/g
Actinium-228	NR	NR	0.794	0.85	0.866
Americium-241	NR	NR	NR	NR	NR
Bismuth-214	NR	NR	0.709	0.929	0.846
Cerium-144	3.33 U	3.02 U	0.936 U	1.03 U	1.05 U
Cesium-134	0.185 U	0.241 U	0.0763 U	0.0843 U	0.0904 U
Cesium-137	0.415 U	0.512 U	0.14 U	0.151 U	0.144 U
Cobalt-60	1.95	2.78	0.542	1.25	1.42
Europium-154	0.654 U	0.681 U	0.264 U	0.34 U	0.311 U
Europium-155	1.05 U	0.826 U	0.264 U	0.293 U	0.288 U
Gross Alpha	1.42 U	0.912	1.45 U	1.15	0.997 U
Gross Beta	319	228	30.5	11.3	42.3
Lead-214	NR	NR	0.787	1.62	1.16
Manganese-54	0.209 U	0.246 U	0.089 U	0.1 U	0.11 U
Plutonium-238	NR	NR	NR	NR	NR
Plutonium-239	NR	NR	NR	NR	NR
Potassium-40	7.19	6.38 U	9.86	13 U	13.8
Radium-224	20.5	NR	NR	NR	NR
Radium-226	4.83 U	5.23 U	1.77 U	2.01 U	1.98 U
Ruthenium-106	4.08 U	3.99 U	1.42 U	1.6 U	1.76 U
Strontium-90	147	127	2.34	4.61	18.1
Thorium-228	28.3 U	22.9 U	7.23 U	7.82 U	8.16 U

* Sample was collected from soil precipitate scraped off a boulder that was removed from the base of the crib.

U - Undetected at specified detection limits

NR - Not Requested

N/A - Not Applicable

Dup - Duplicate

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ATTACHMENT C

QUANTERRA DATA FOR B2536, B2537 and B2539

1301-N/1325-N Analytical Data from the Quanterra Laboratory (Page 1 of 3)

Borehole: Sample ID: Depth (ft): Date:	B2536						B2537		
	B0GL88	B0GL89	B0GL91	B0GL92 (Dup)	B0GL94(EB)	B0GL95	B0GL71	B0GL73	B0GL75 (Dup)
	9.0-11.0 11/29/95	11.0-13.0 11/30/95	28.0-30.0 12/5/95	28.0-30.0 12/5/95	N/A 12/8/95	57.0-59.0 12/8/95	14.5-16.5 11/9/95	23-25 11/10/95	23-25 11/10/95
Radionuclides (pCi/g)									
Americium-241	1,110	1,050	NR	NR	NR	NR	6.55	NR	NR
Cerium-144	-130	62.9	-0.57	0.0968	-0.103	-0.0378	-0.638	0.163	0.259
Cesium-134	31.1	4.84	-0.01	-0.0459	-0.00734	-0.0177	5.28	-0.0578	-0.0252
Cesium-137DA	15,800	12,500	2.46	6.01	0.0116	0.0144	6,770	44.3	65.8
Cobalt-58	-120	-100	0.0383	-0.00793	-0.0553	0.0116	-0.559	-0.00341	-0.0123
Cobalt-60	139,000	120,000	4.96	5.57	-0.00425	1.29	1,200	7.1	9.2
Europium-152	2.85	71.7	0.0936	-0.207	0.0453	0.0341	0.833	0.00937	0.0632
Europium-154	990	807	0.155	0.147	-0.0017	0.0133	8.17	0.178	0.232
Europium-155	207	141	0.0209	0.133	0.0359	0.0133	2.36	0.013	0.112
Gross Alpha	1,980	2,530	7.43	6.43	3.62	6.61	30.1	7.69	7.6
Gross Beta	128,000	131,000	4,480	5,120	2.88	293	5,750	3,790	2,740
Iron-59	-40	142	-0.284	-0.0398	-0.0956	0.0729	0.221	-0.127	0.0766
Potassium-40	879	55.4	9.33	9.93	0.488	15.7	13.7	16.1	15.8
Manganese-54	56.8	19.3	0.0983	0.047	-0.0116	0.0357	0.936	0.0565	0.0493
Plutonium-238	226	465	-0.00126	0.00823	-0.000822	0.00339	1.17	0.105	0.0862
Plutonium-239/40	1,590	3,340	0.023	0.0708	0.00472	-0.00156	12.6	0.0211	0.301
Radium-224DA	NR	NR	NR	0.552	0.0857	0.435	NR	0.772	0.903
Radium-226	NR	NR	NR	NR	NR	NR	1.54	0.599	0.808
Radium-226DA	104	25	0.346	0.369	0.189	0.365	NR	NR	NR
Radium-228	NR	NR	NR	NR	NR	NR	NR	NR	NR
Radium-228DA	NR	NR	NR	NR	NR	0.562	NR	NR	0.59
Ruthenium-106DA	103	-425	0.403	-0.203	-0.0924	-0.146	0.378	-0.271	-0.159
Strontium-90	9,560	19,700	1,530	1,310	0.0771	50	768	1430	1,740
Thorium-228DA	35.5	144	0.47	0.402	0.179	0.462	0.744	0.883	1.08
Thorium-232DA	62.2	-156	1.08	0.388	NR	0.624	-1.13	NR	1.12
Uranium-234	10.5	5.12	41.4	0.479	0.0347	0.302	0.111	0.407	1
Uranium-235	0.677	-0.672	0.0227	0.00386	0.00388	0.0193	-0.111	0.0762	0.104
Uranium-238	-0.226	9.99	0.363	0.441	0.0127	0.364	1.74	0.343	0.842
Inorganics (mg/Kg)									
Cadmium	0.46 B	0.73	0.37 B	0.47 B	0.08 U	0.19	0.35 U	0.36 U	0.36 U
Chromium	45.7	57.7	8	12.7	0.23 B	12.4	22.2	18.5	20.4
Lead	6.3	21.9	1.3	1.2	0.1 U	1.5	0.57	0.69	0.76
Nickel	16.7	15.7	5	7.5	0.4 U	13.8	13.1	9.3	9.8

U = The concentration is undetected at the specified detection limit.

B = The concentration reported is less than the contract required detection limit (CRDL) but greater than the instrument detected limit (IDL).

-- = Analytical data not yet available.

NR = Not requested

EB = Equipment Blank

DA (Daughters) = Actual gamma lines are measured from a daughter isotope with assumed equilibrium with the reported parent.

Negative radionuclide results = Radioactive results are measured as decay counts (e.g. counts per/minute).

An average background count subtraction is applied, which may be more than the specific sample count, therefore a negative result is possible.

N/A = Not Applicable.

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1301-N/1325-N Analytical Data from the Quanterra Laboratory (Page 2 of 3)

Borehole: Sample ID: Depth (ft): Date:	B2537			B2539					
	BOGL81	BOGL86	BOGL79(EB)	BOGL97	BOGL99	BOGLB1	BOGLB3	BOGLB4 (Dup)	BOGLB6
	42-44 11/15/95	62-63.5 11/16/95	11/15/95	8-10 12/19/95	10-12 12/20/95	17-19 12/20/95	24-26 12/22/95	24-26 12/22/95	39-41 12/27/95
Radionuclides (pCi/g)									
Americium-241	NR	NR	NR	14.2	NR	NR	NR	NR	NR
Cerium-144	-0.0552	-0.0879	0.0565	2.36	-0.079	-0.176	-0.0485	-0.131	-0.0915
Cesium-134	0.0237	-0.037	-0.0188	0.633	-0.0107	-0.00192	-0.0138	-0.0137	0.0031
Cesium-137DA	0.00704	-0.0205	0.0135	573	0.522	0.143	0.0587	0.0337	0.00348
Cobalt-58	0.0425	0.0158	-0.0118	0.268	-0.03	-0.0036	0.00897	0.00889	-0.0391
Cobalt-60	0.547	0.535	-0.0278	379	4.51	4.51	1.57	1.43	5.46
Europium-152	-0.0682	-0.00833	-0.0386	-0.315	-0.116	-0.0339	2.05	0.703	0.216
Europium-154	0.0979	-0.0225	0.00875	2.86	0.00621	0.106	0.164	0.129	0.0456
Europium-155	-0.00806	0.109	-0.0316	2.02	0.0156	0.0136	0.0912	-0.0231	0.0212
Gross Alpha	9.33	2.9	2.99	39.8	6.69	5.7	5.52	6.8	5.79
Gross Beta	132	328	2.14	3170	2450	808	530	491	64
Iron-59	-0.219	0.0356	-0.0121	0.236	-0.135	-0.0845	-0.131	-0.127	0.0867
Potassium-40	10.9	18.6	5.68	12.5	9.01	9.62	8.03	7.93	8.62
Manganese-54	-0.0179	-0.00807	0.00963	2.74	-0.000466	-0.0106	0.00315	0.0234	0.00878
Plutonium-238	-0.00376	0	-0.00608	3.81	0	0.0751	0	0.0142	-0.00257
Plutonium-239/40	-0.00376	-0.00416	-0.00187	24.1	0.385	0.15	0.0246	-0.00228	0
Radium-224DA	0.462	0.415	0.115	NR	0.353	0.422	0.473	0.477	0.535
Radium-226	0.5	0.524	0.258	NR	NR	NR	NR	NR	NR
Radium-226DA	NR	NR	NR	1.58	0.322	0.368	0.415	0.304	0.358
Radium-228	NR	NR	NR	NR	NR	NR	NR	NR	NR
Radium-228DA	0.814	NR	NR	NR	NR	0.481	NR	NR	NR
Ruthenium-106DA	0.0126	-0.13	-0.145	2.44	0.178	0.205	0.153	-0.162	0.245
Strontium-90	57.9	144	0.274	1340	1230	401	226	200	27.7
Thorium-228DA	0.748	0.635	0.185	0.535	0.409	0.42	0.406	0.498	0.574
Thorium-232DA	0.596	0.822	0.27	-0.167	NR	0.622	0.504	0.136	0.682
Uranium-234	0.534	0.398	0.0433	1.36	0.451	0.727	0.642	0.354	0.348
Uranium-235	0.0324	0.0268	-0.00146	-0.21	0.0846	0.0333	-0.00422	0.00763	0.0169
Uranium-238	0.487	0.48	0.0892	0.776	0.564	0.44	0.435	0.531	0.5
Inorganics (mg/Kg)									
Cadmium	0.35 U	0.09 U	0.08 U	0.36 U	0.36 U	0.35 U	0.35 U	0.35 U	0.09 U
Chromium	27.3	13	0.12 B	8.9	6.2	3.2	5	3.6	1.7
Lead	0.21 B	0.63	0.1 U	2.7	1.9	1.7	1.6	1.7	1.2
Nickel	14.5	12.5	0.4 U	8.5	7.4	4.6	3.3	4.3	3.4

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An average background count subtraction is applied, which may be more than the specific sample count, therefore a negative result is possible.

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1301-N/1325-N Analytical Data from the Quanterra Laboratory (Page 3 of 3)

Borehole:	B2539	
Sample ID:	BOGLC0	BOGLB8 (EB)
Depth (ft):	59.5-61.5	
Date:	12/28/95	12/27/95
Radionuclides (pCi/g)		
Americium-241	NR	NR
Cerium-144	-0.173	-0.0309
Cesium-134	-0.0296	-0.0113
Cesium-137DA	-0.0148	-0.00721
Cobalt-58	0.00725	-0.013
Cobalt-60	1.48	-0.00818
Europium-152	0.00186	0.0472
Europium-154	0.0676	-0.00481
Europium-155	-0.0203	-0.00461
Gross Alpha	4.53	-0.906
Gross Beta	60.5	1.53
Iron-59	-0.0488	0.0232
Potassium-40	12.4	4.19
Manganese-54	0.0152	0.0205
Plutonium-238	0.00589	-0.00105
Plutonium-239/40	0.0103	-0.00105
Radium-224DA	0.627	0.125
Radium-226	NR	NR
Radium-226DA	0.34	0.116
Radium-228	NR	NR
Radium-228DA	0.434	NR
Ruthenium-106DA	0.0541	-0.00963
Strontium-90	16	-0.013
Thorium-228DA	0.567	0.304
Thorium-232DA	0.616	0.134
Uranium-234	0.454	0.0509
Uranium-235	0.0291	0.00324
Uranium-238	0.418	0.0278
Inorganics (mg/Kg)		
Cadmium	0.36 U	0.08 U
Chromium	12.2	0.24 B
Lead	3.2	0.1 U
Nickel	11.9	0.4 U

U = The concentration is undetected at the specified detection limit.

B = The concentration reported is less than the contract required detection limit (CRDL) but greater than the instrument detected limit (IDL).

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EB = Equipment Blank

DA (Daughters) = Actual gamma lines are measured from a daughter isotope with assumed equilibrium with the reported parent.

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An average background count subtraction is applied, which may be more than the specific sample count, therefore a negative result is possible.

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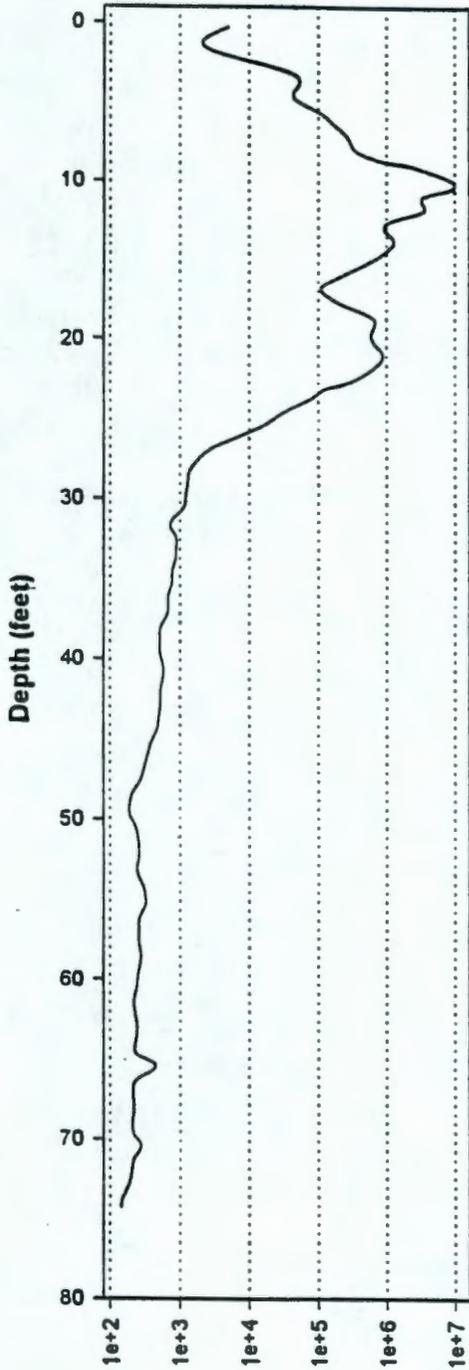
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ATTACHMENT D

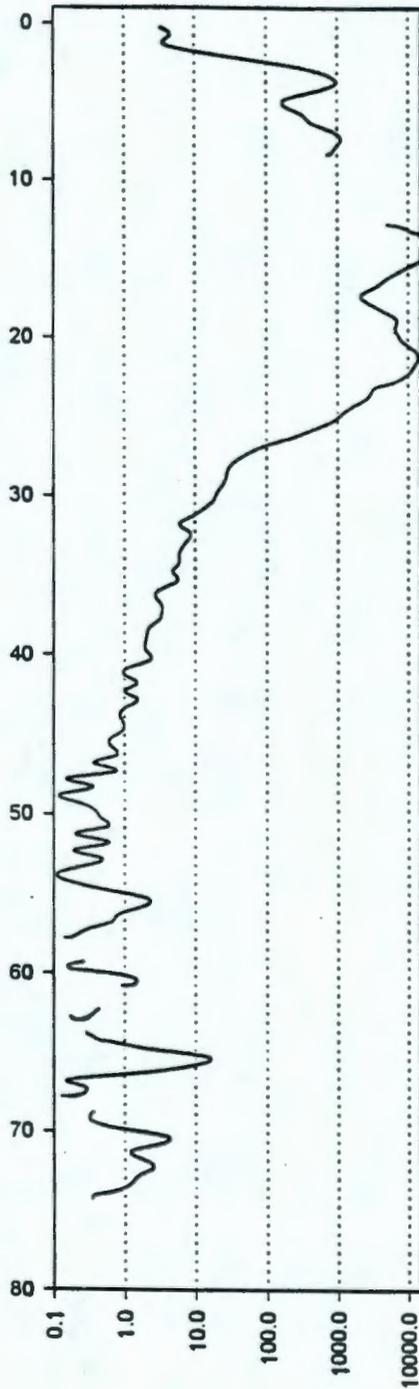
**BOREHOLE GEOPHYSICAL LOGS FOR B2536, B2537, B2539,
199-N-35, 199-N-45, 199-N-67 and PNNL RESEARCH WELL #1**

Geophysics - B2536

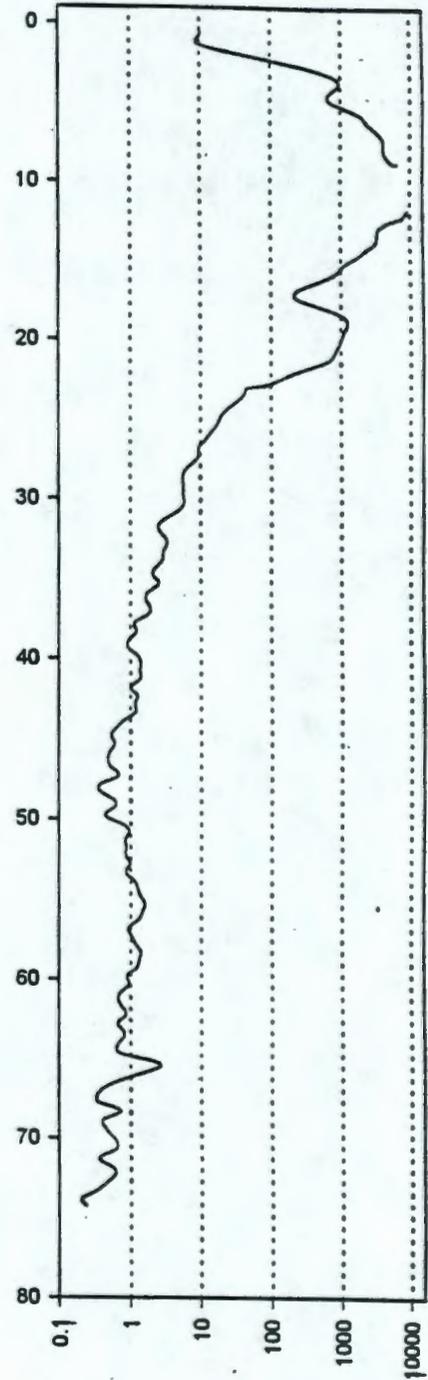
Gross Gamma
(CPS (normalized))



Cesium-137
(pCi/g)



Cobalt-60
(pCi/g)

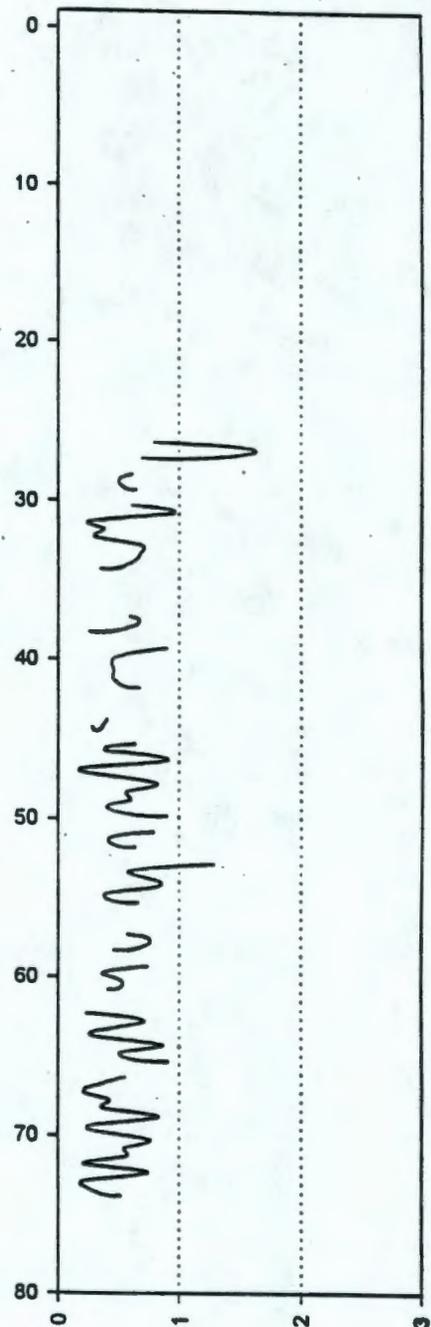
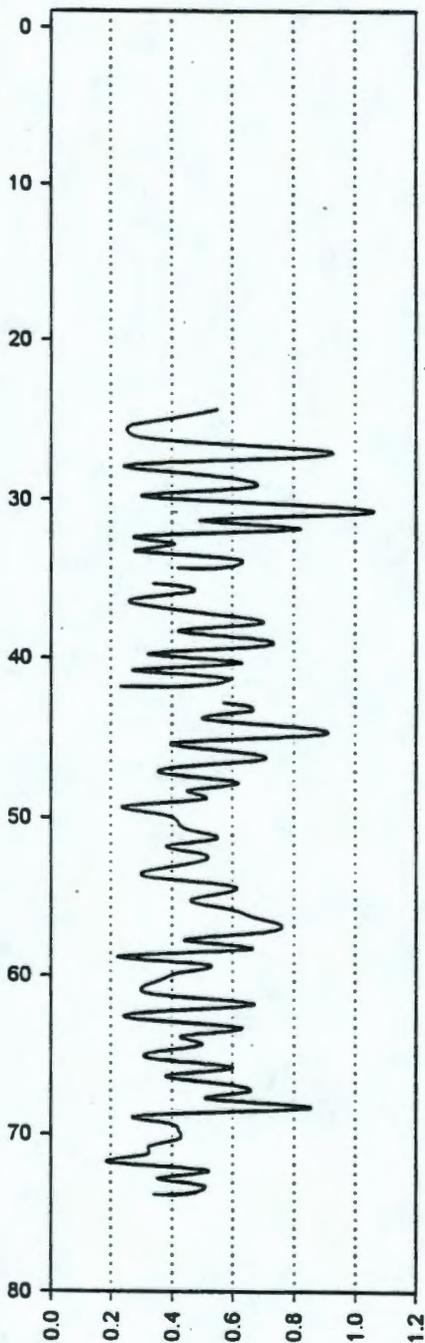
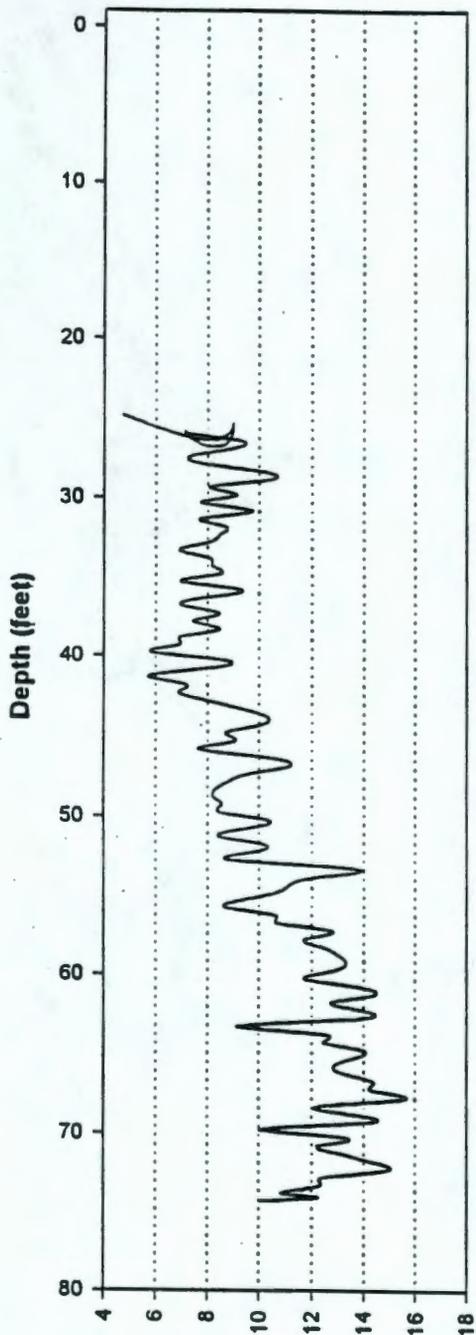


Geophysics - B2536

Potassium-40
(pCi/g)

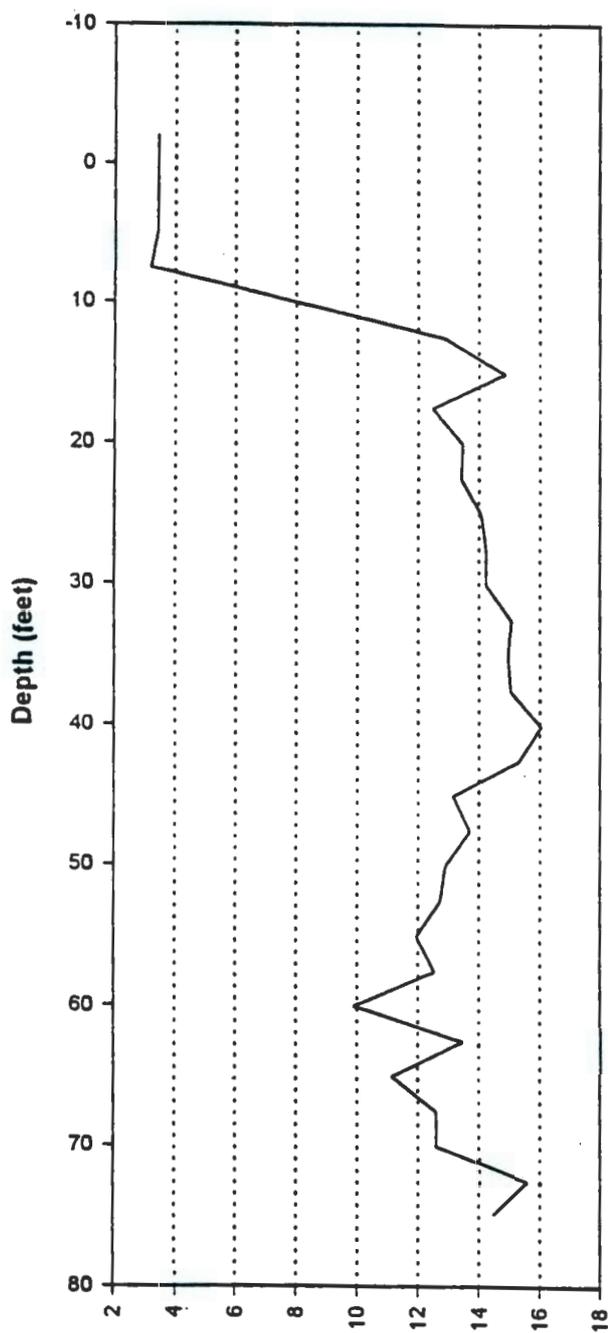
Uranium
(pCi/g)

Thorium
(pCi/g)

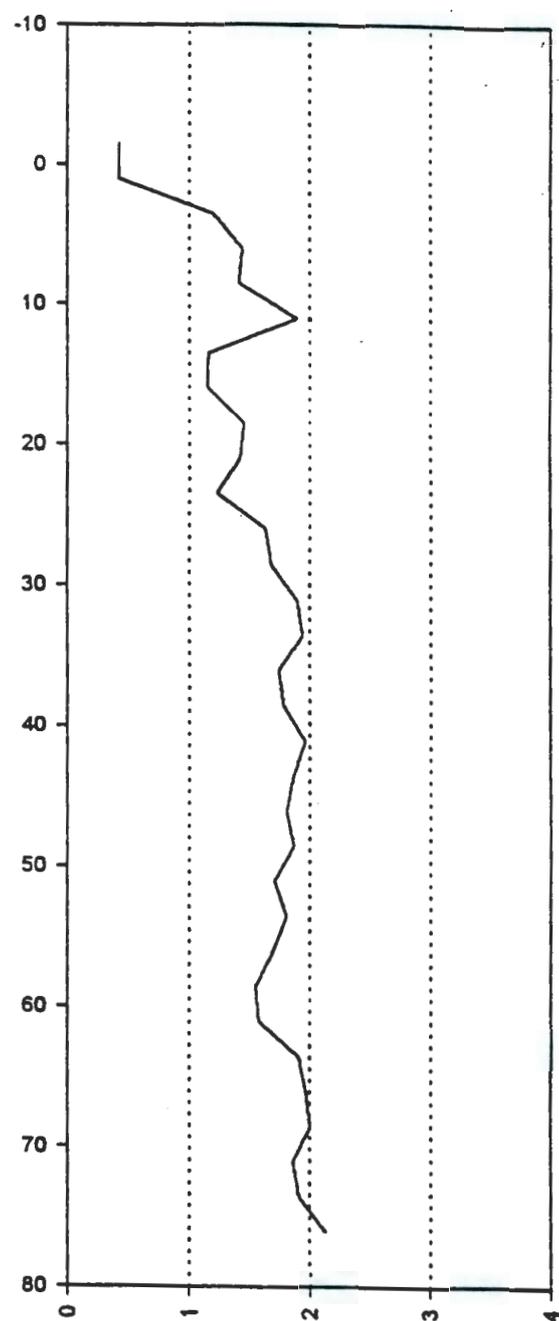


Geophysics - B2536

Neutron Moisture (vol. %)

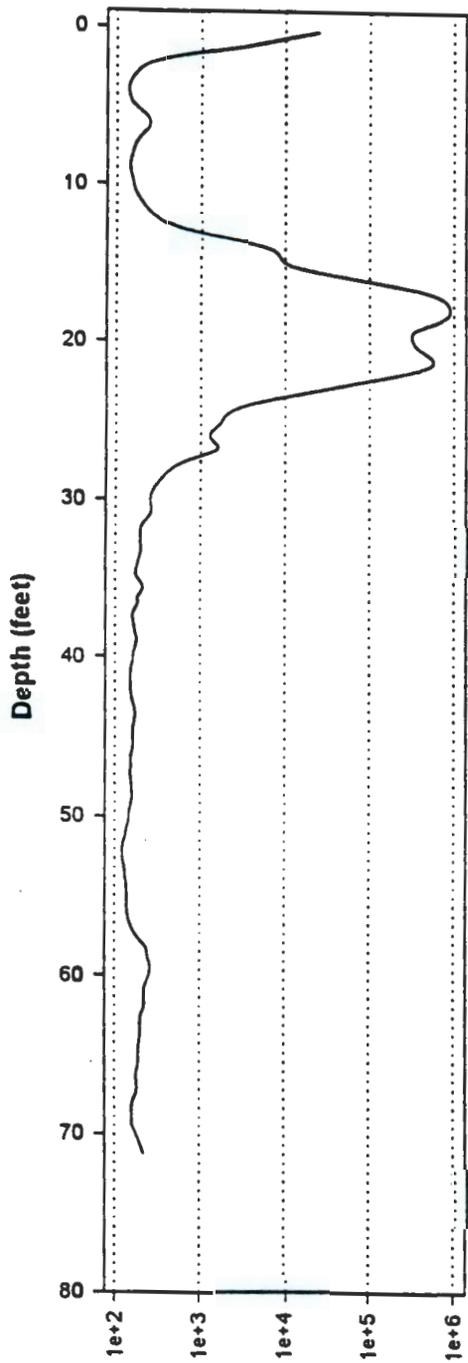


Bulk Density (g/cc)

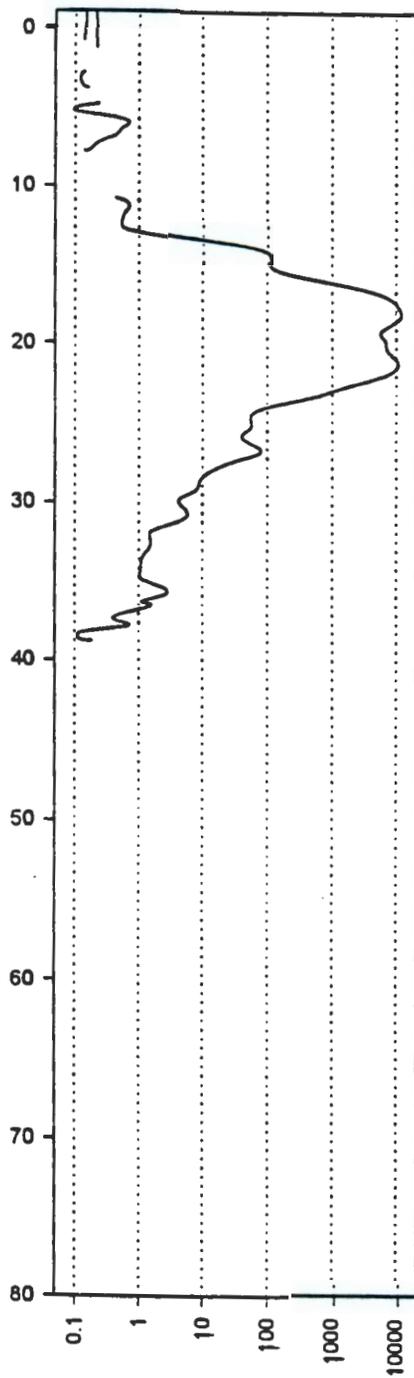


Geophysics - B2537

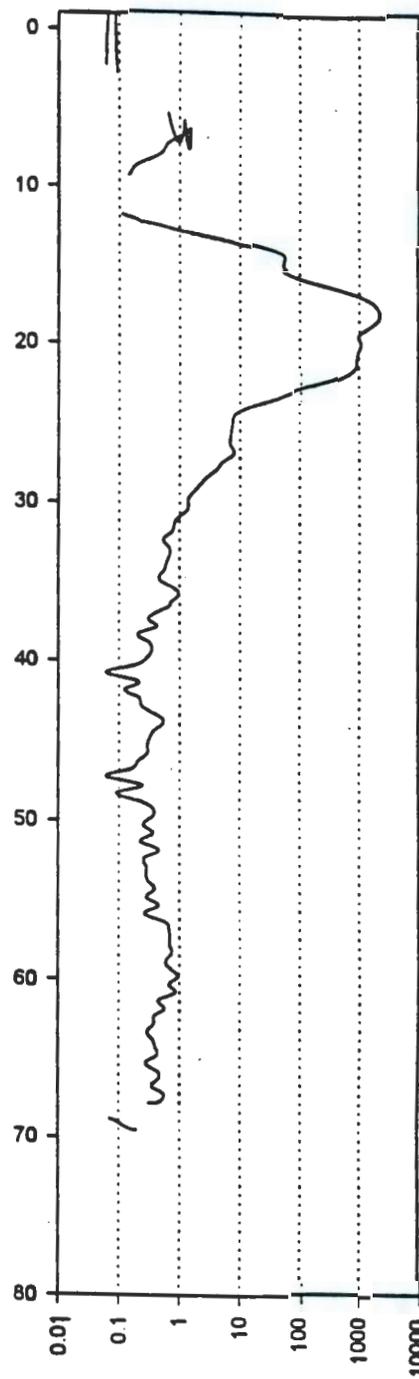
**Gross Gamma
(CPS (normalized))**



**Cesium-137
(pCi/g)**

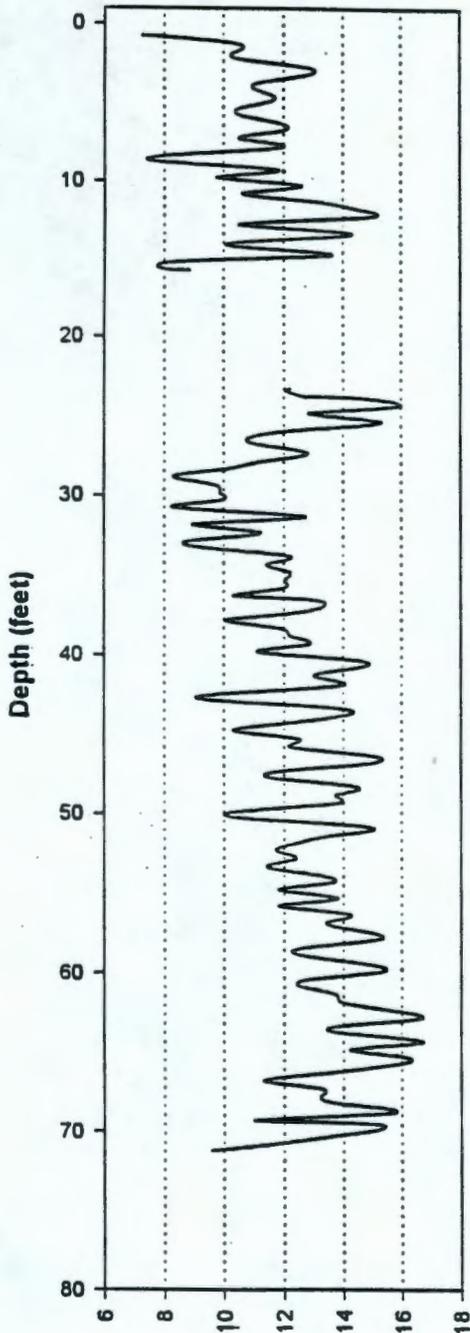


**Cobalt-60
(pCi/g)**

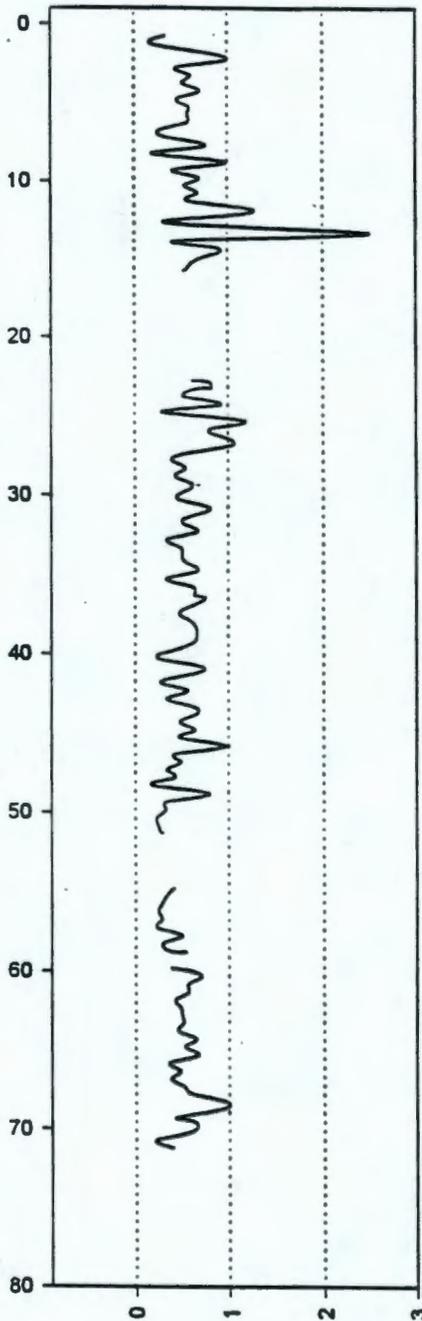


Geophysics - B2537

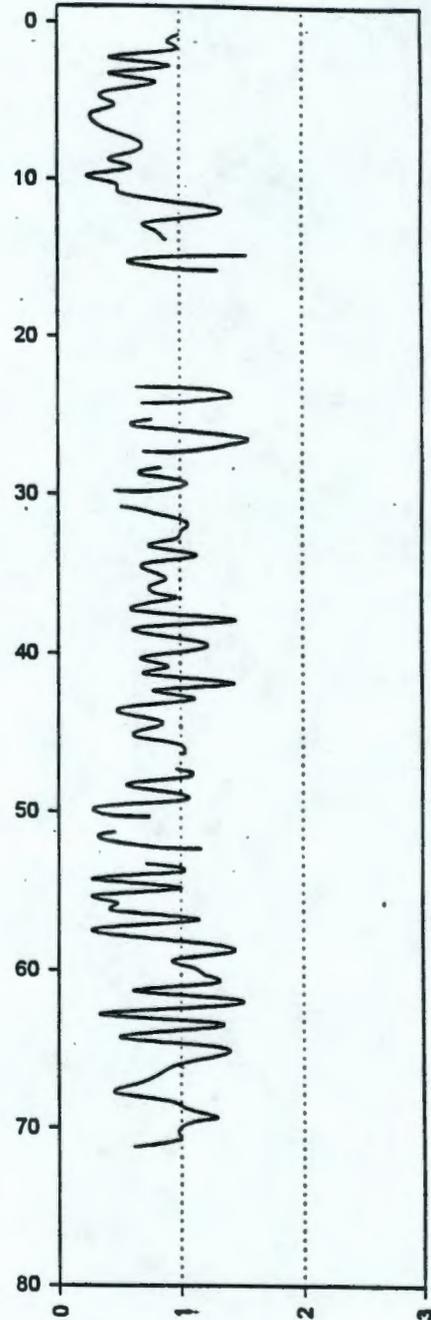
Potassium-40
(pCi/g)



Uranium
(pCi/g)

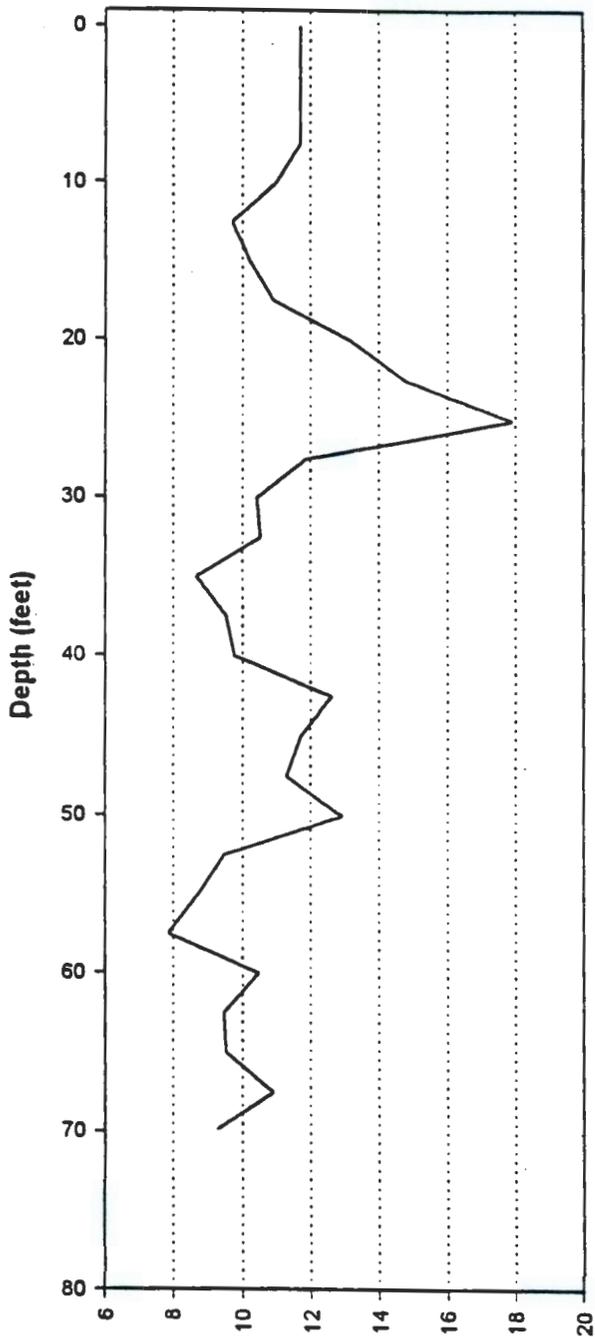


Thorium
(pCi/g)

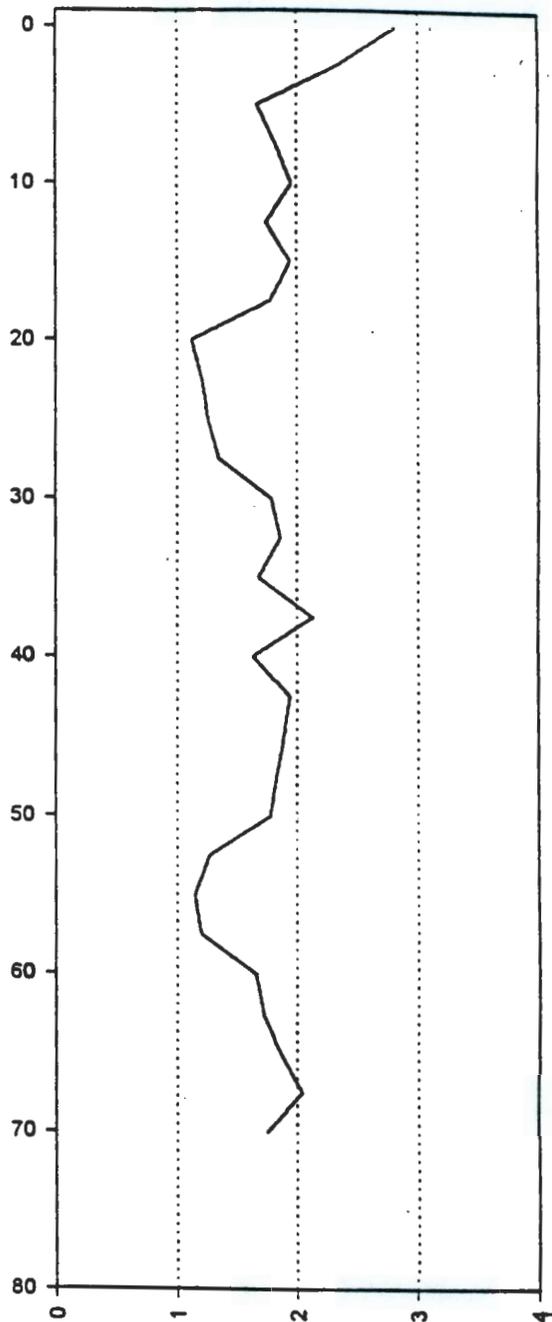


Geophysics - B2537

**Neutron Moisture
(vol. %)**

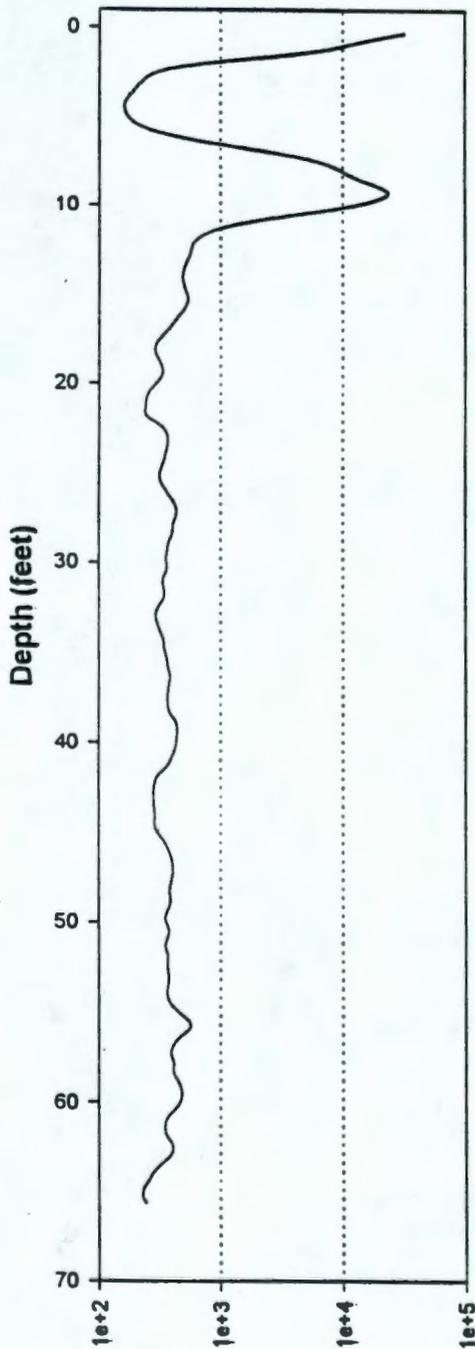


**Bulk Density
(g/cc)**

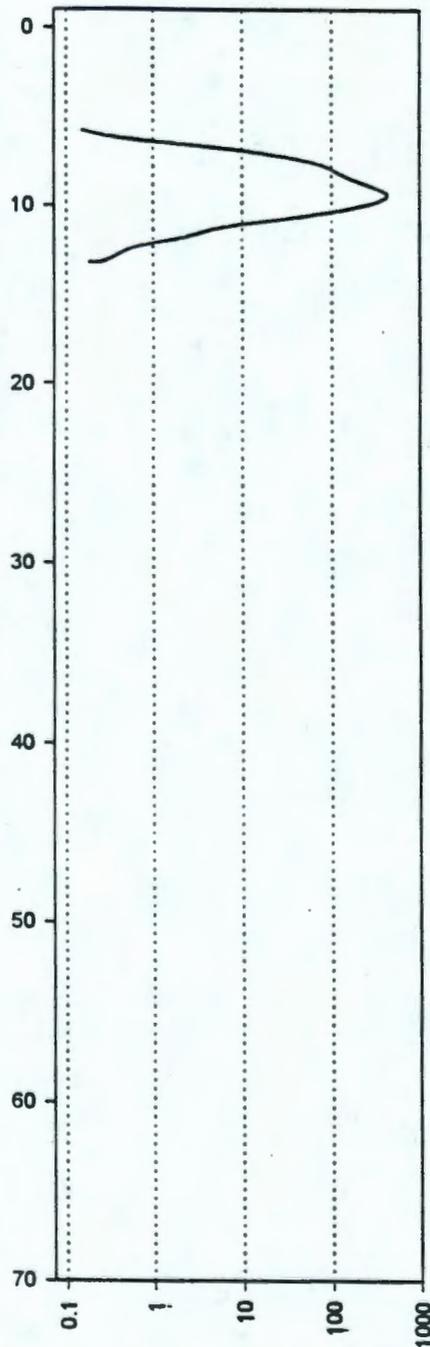


Geophysics for B2539

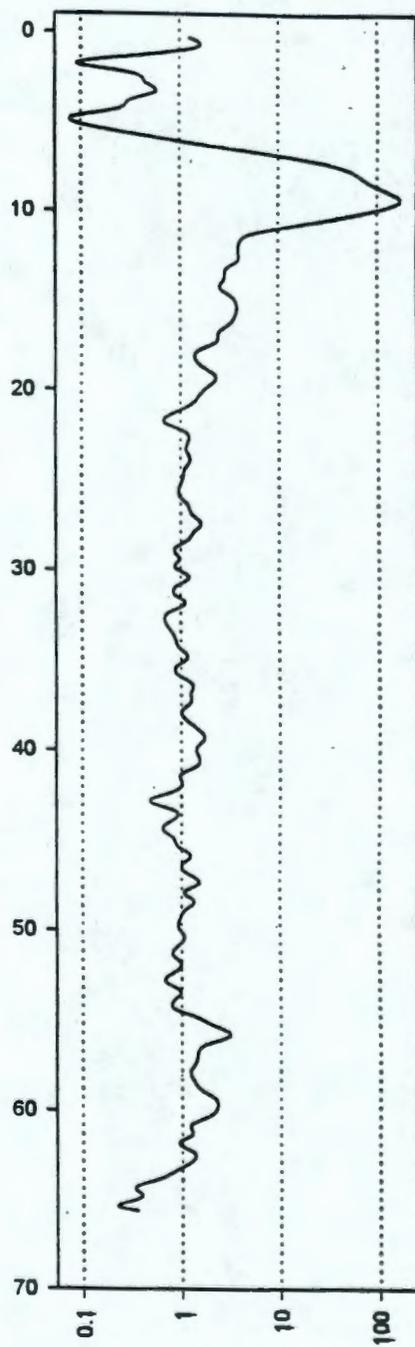
**Gross Gamma
(CPS (normalized))**



**Cesium-137
(pCi/g)**



**Cobalt-60
(pCi/g)**

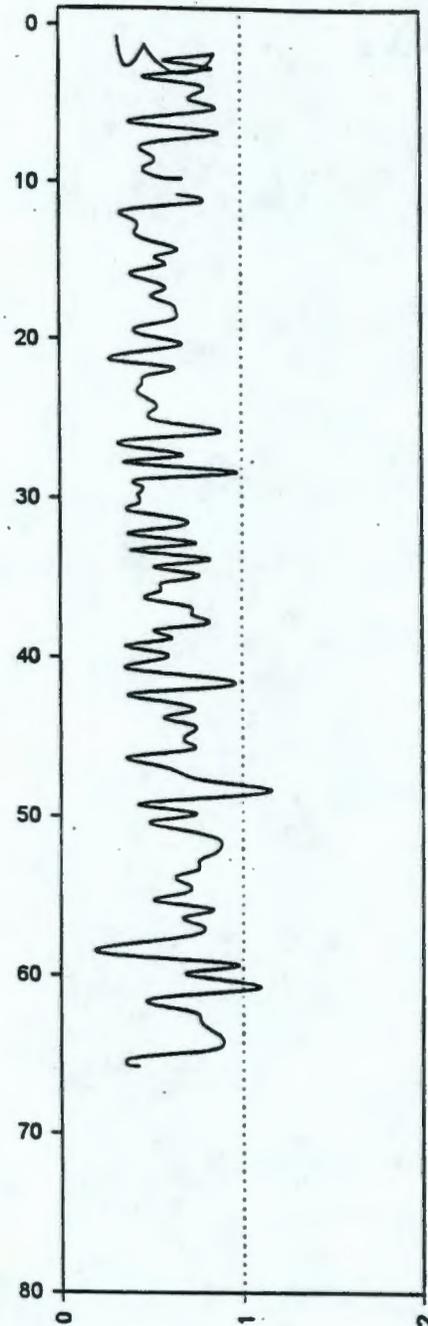
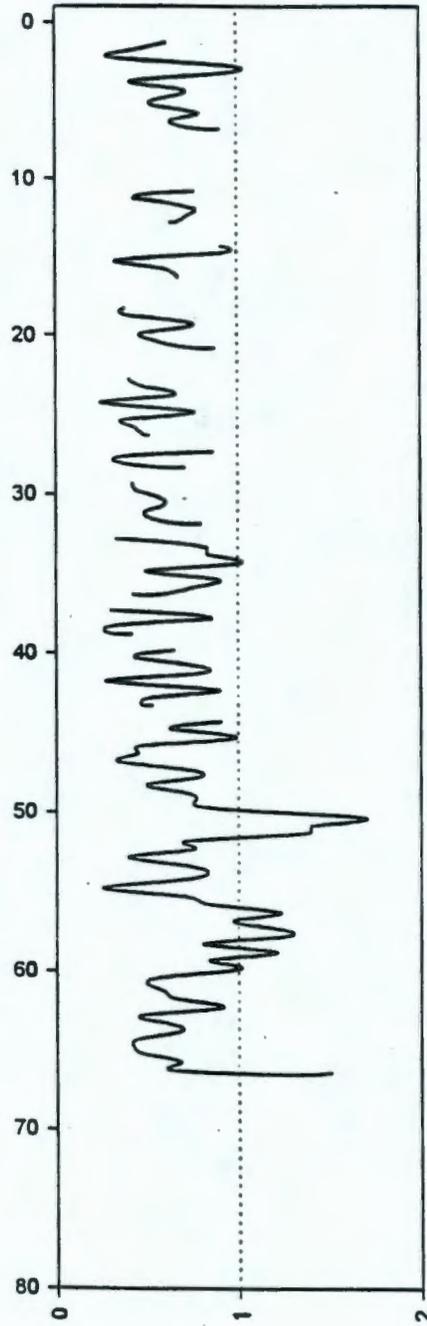
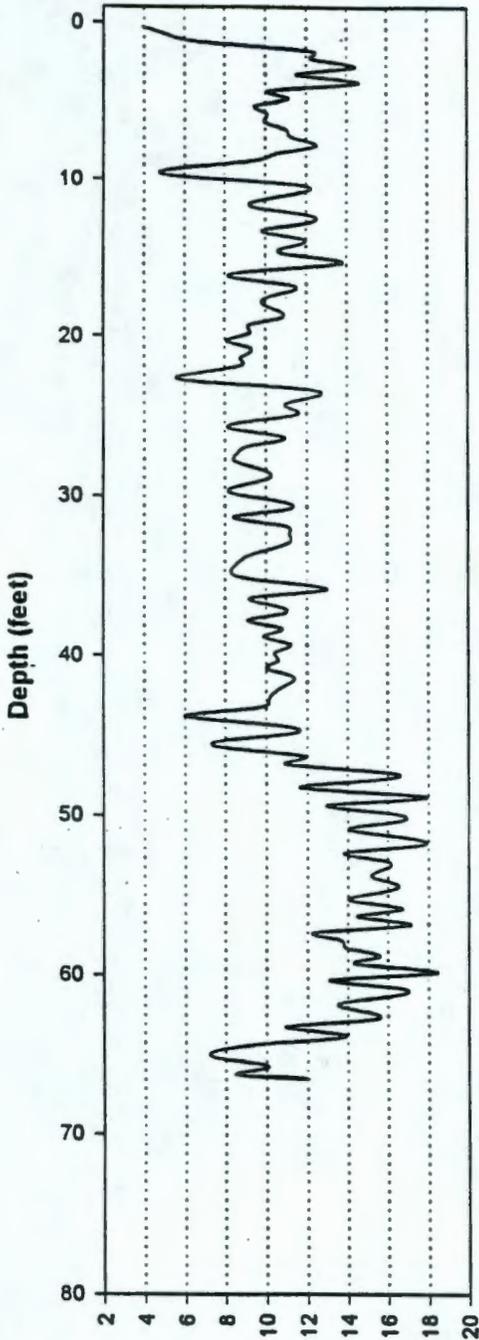


Geophysics for B2539

**Potassium-40
(pCi/g)**

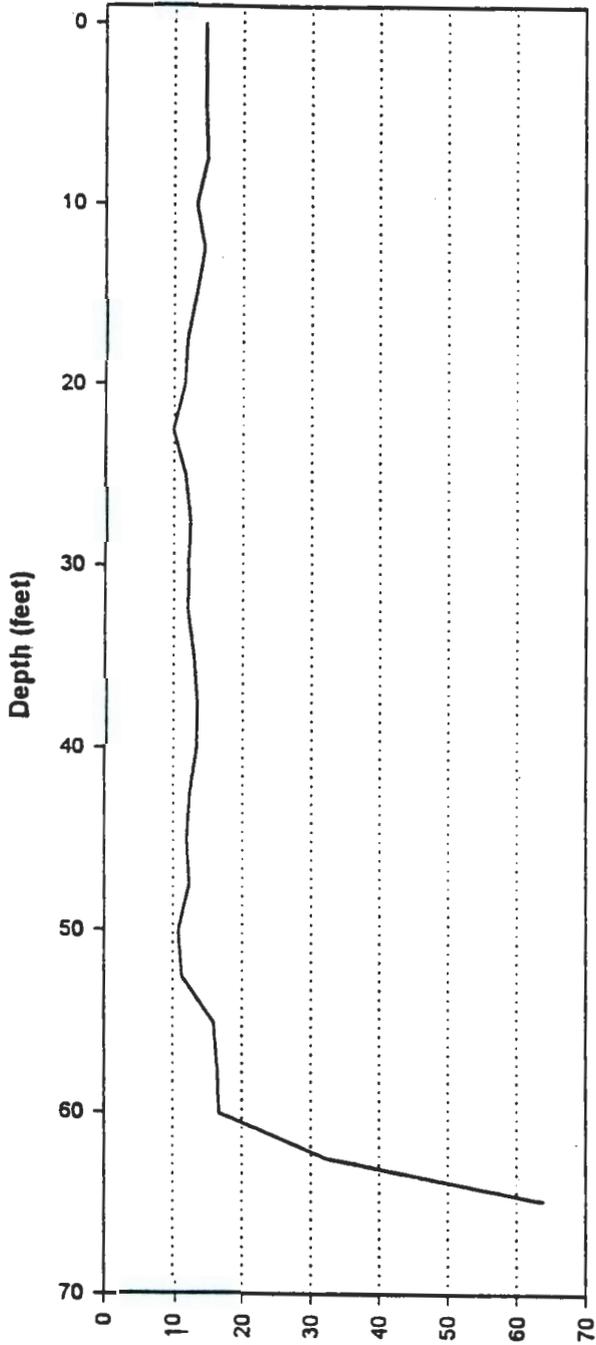
**Uranium
(pCi/g)**

**Thorium
(pCi/g)**

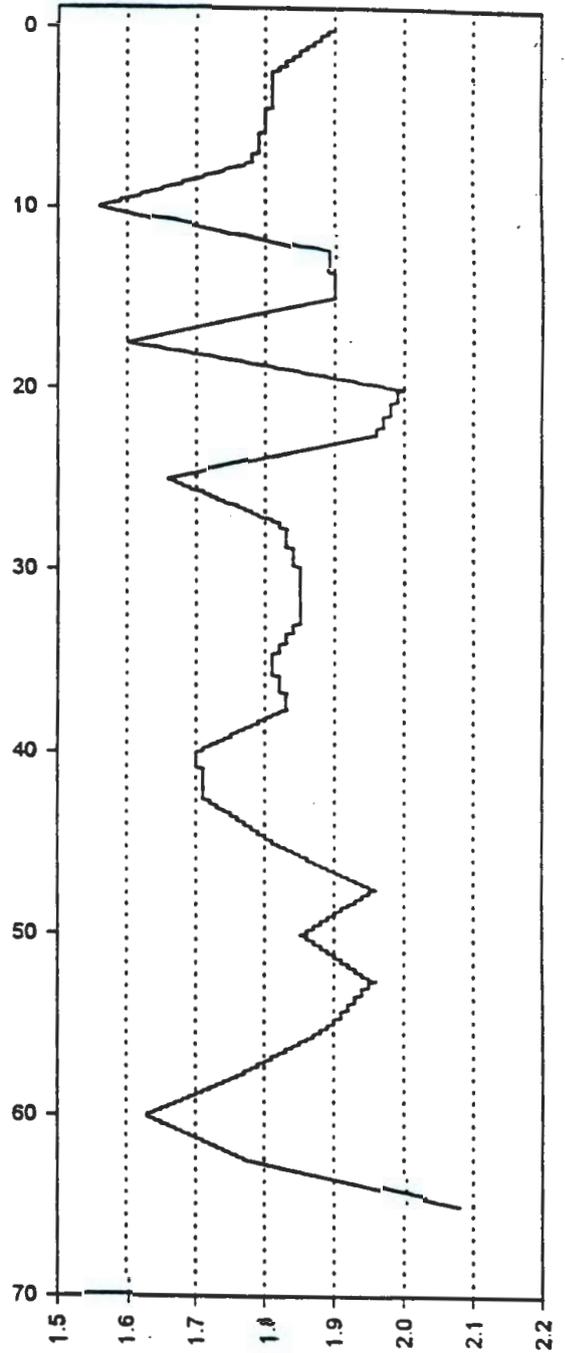


Geophysics for B2539

**Neutron moisture
(vol %)**

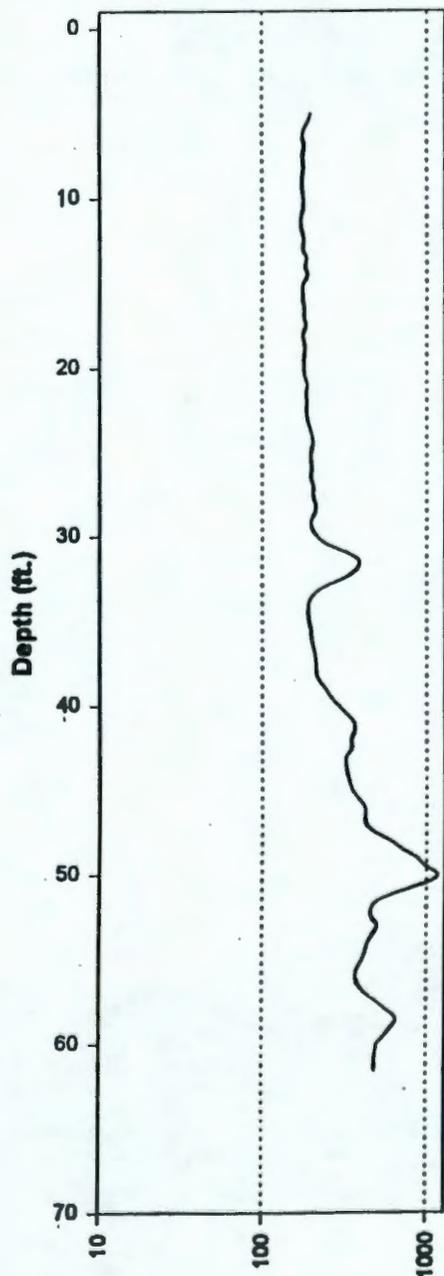


**Bulk Density
(g/cc)**

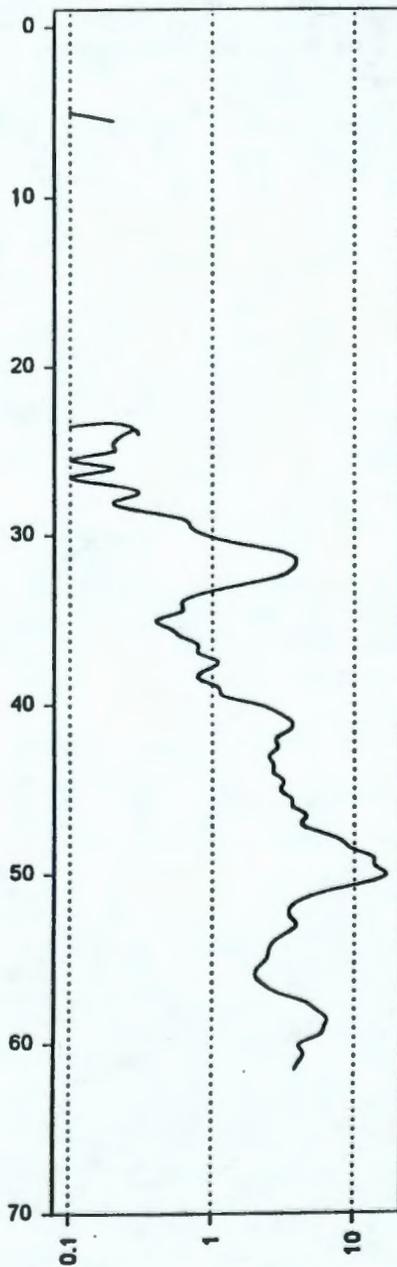


Geophysics for 199-N-35

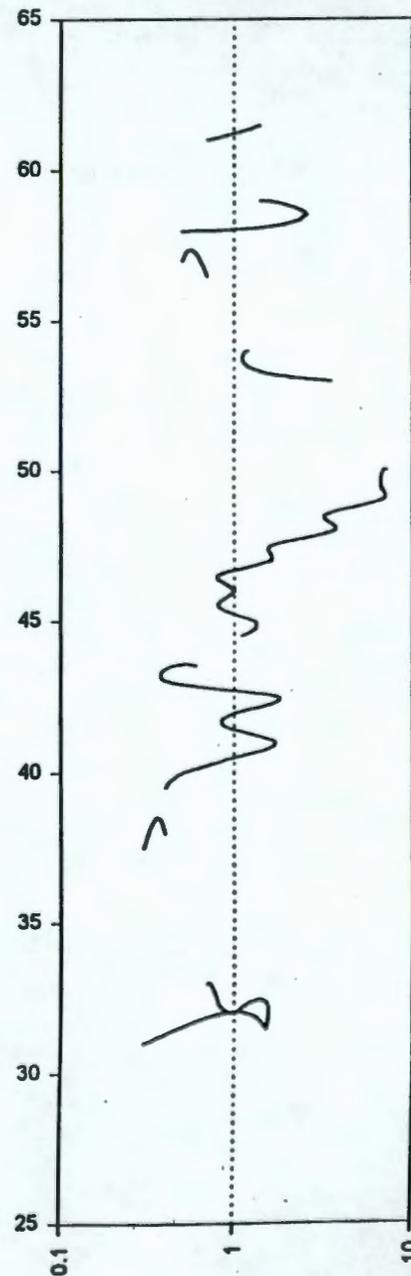
Gross Gamma pCi/g



Cobalt-60 pCi/g



Antimony-125 pCi/g

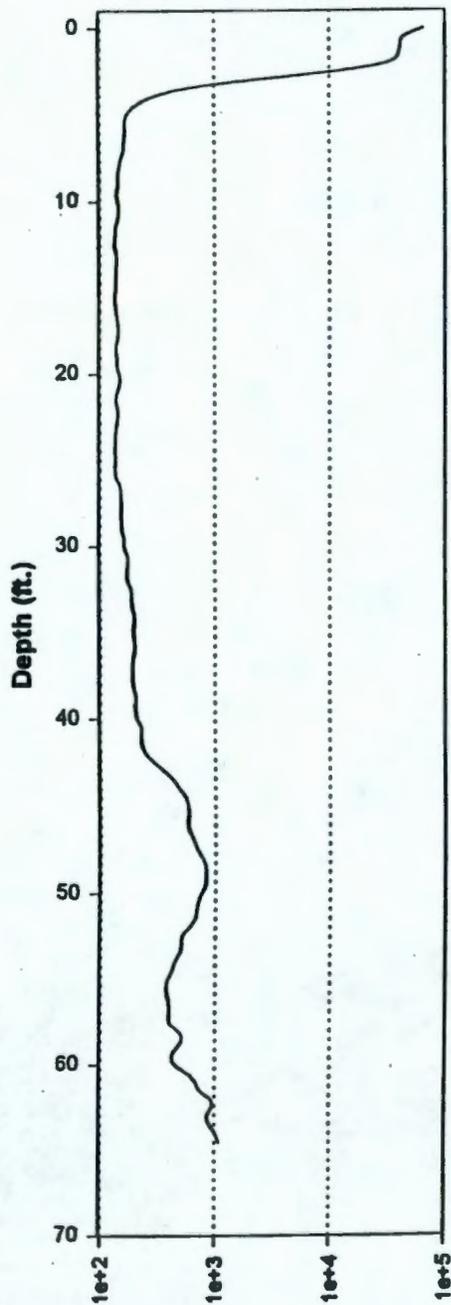


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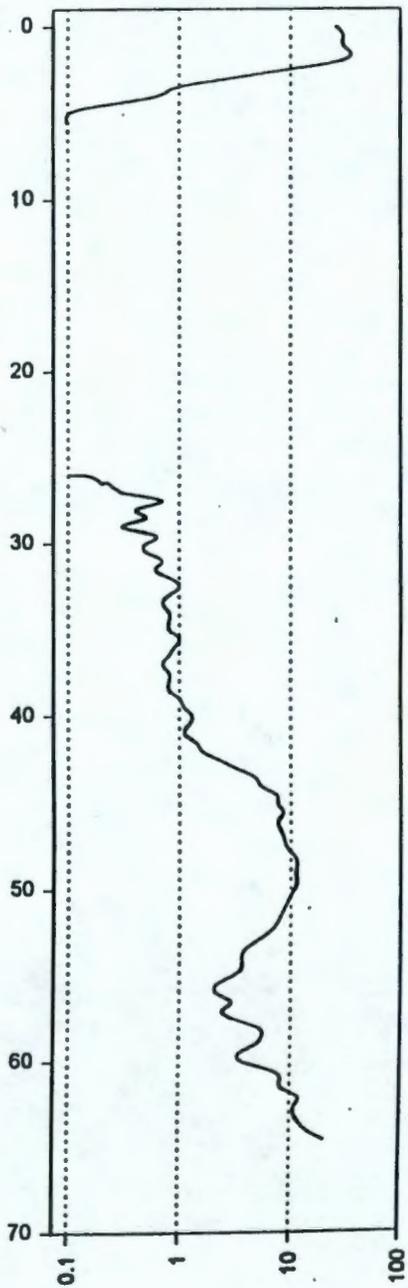
9613492.7064

Geophysics for 199-N-45

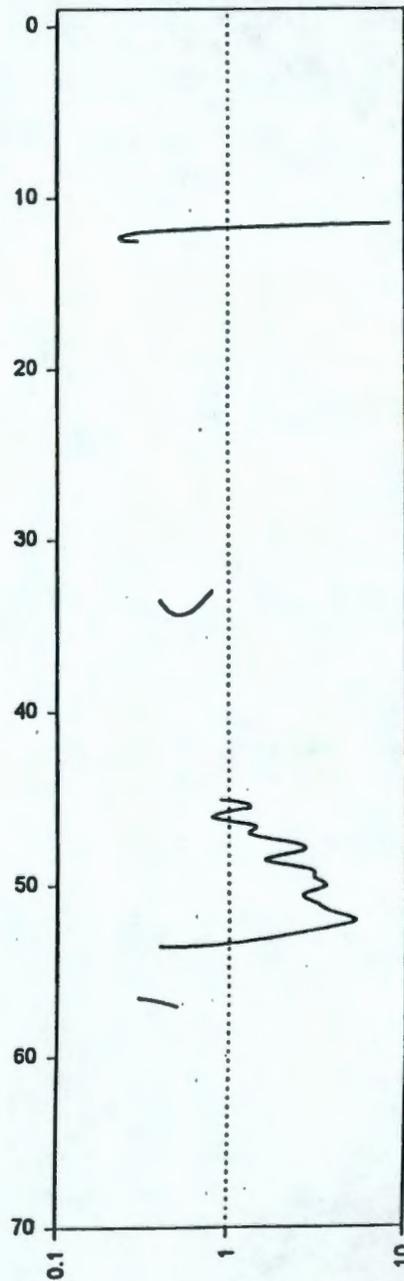
Gross Gamma pCi/g



Cobalt-60 pCi/g



Antimony-125 pCi/g

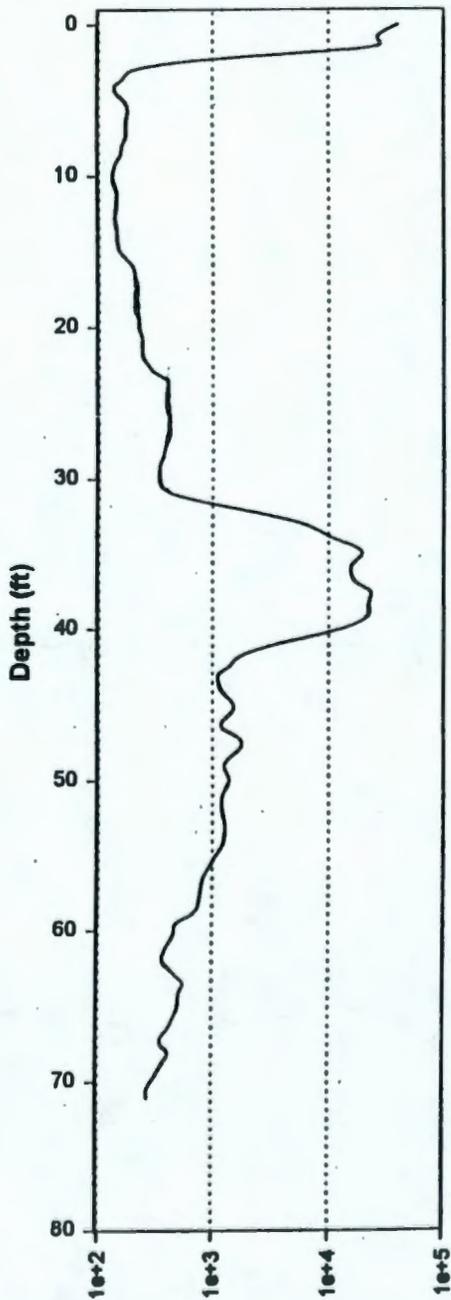


9613492.7065

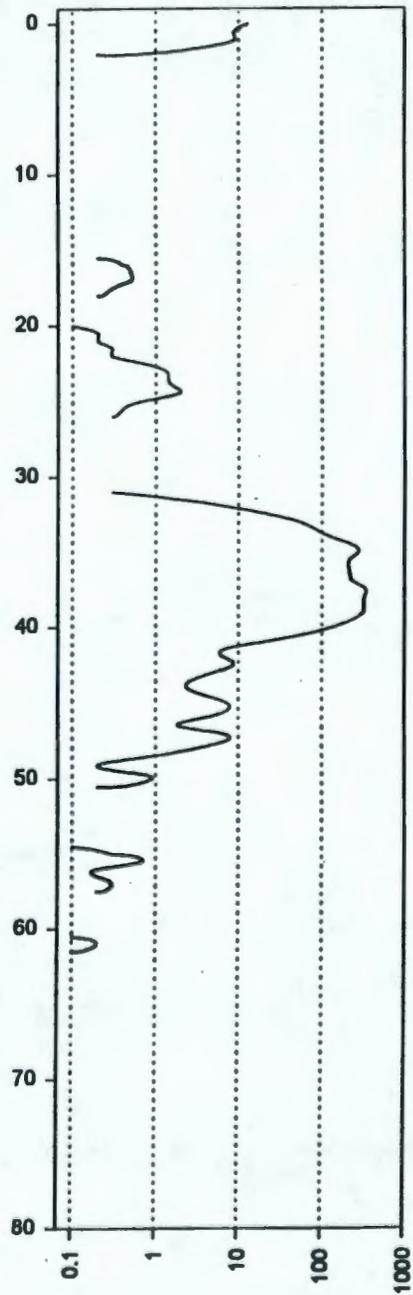
027237

Geophysics for 199-N-67

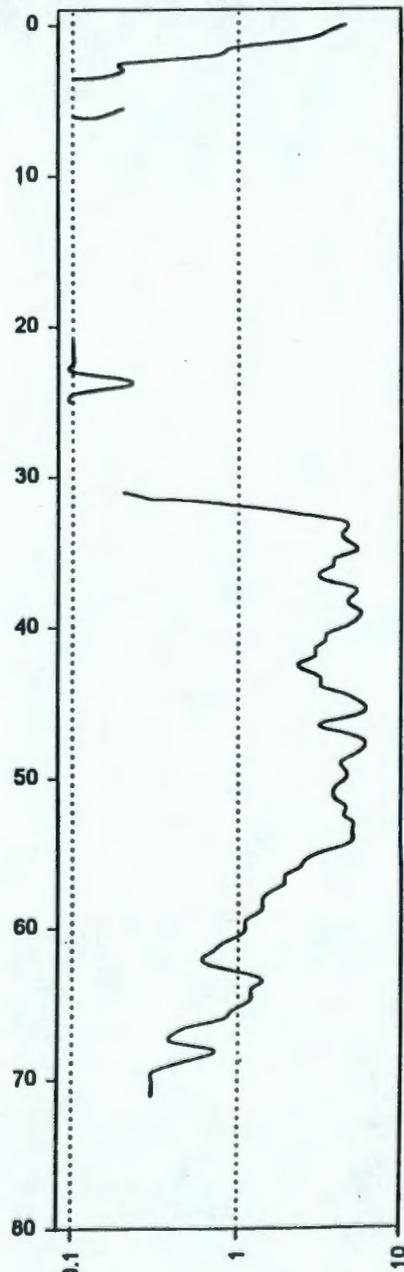
Gross Gamma (pCi/g)



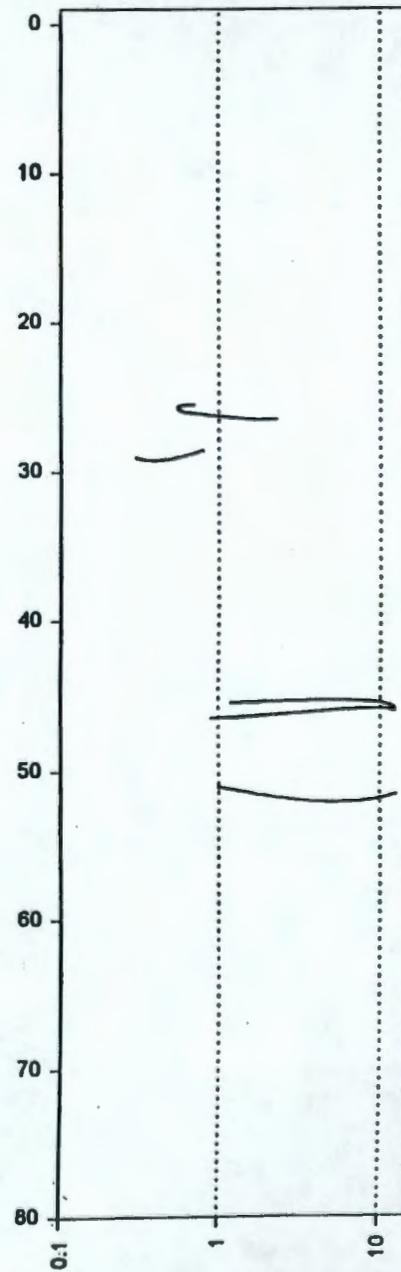
Cesium-137 pCi/g



Cobalt-60 pCi/g



Antimony-125 pCi/g

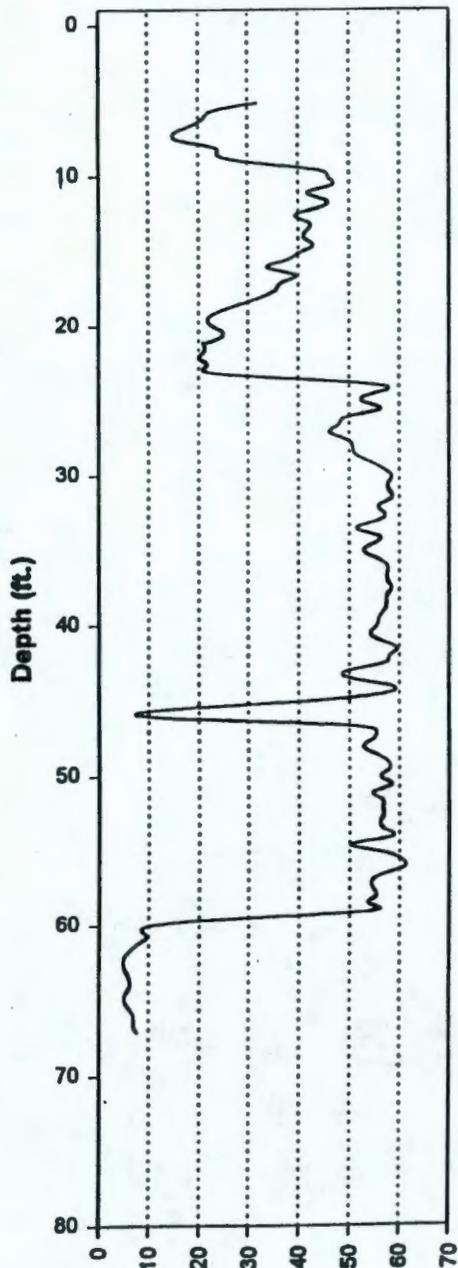


9613492.7066

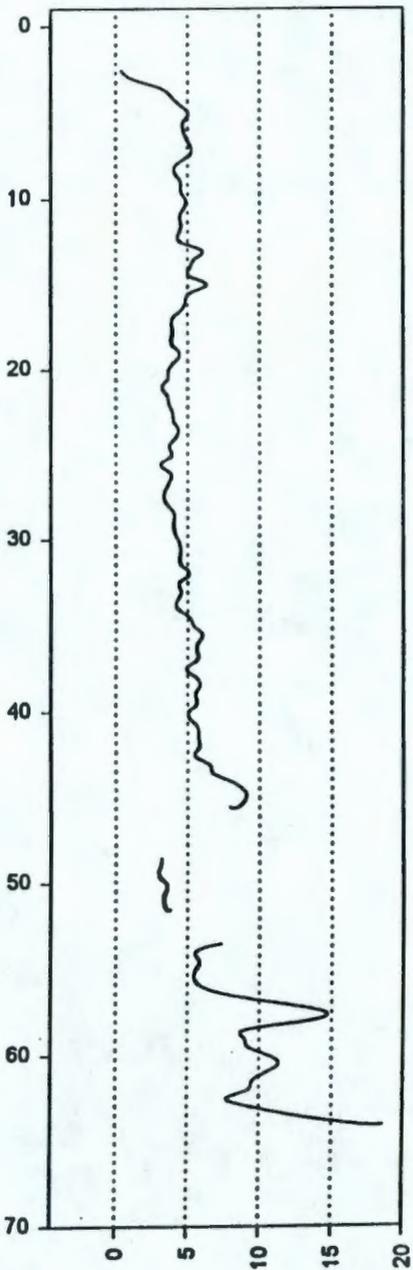
027237

Neutron Moisture (% volume fraction) for Wells 199-N-67, 199-N-45, 199-N-35
Groundwater

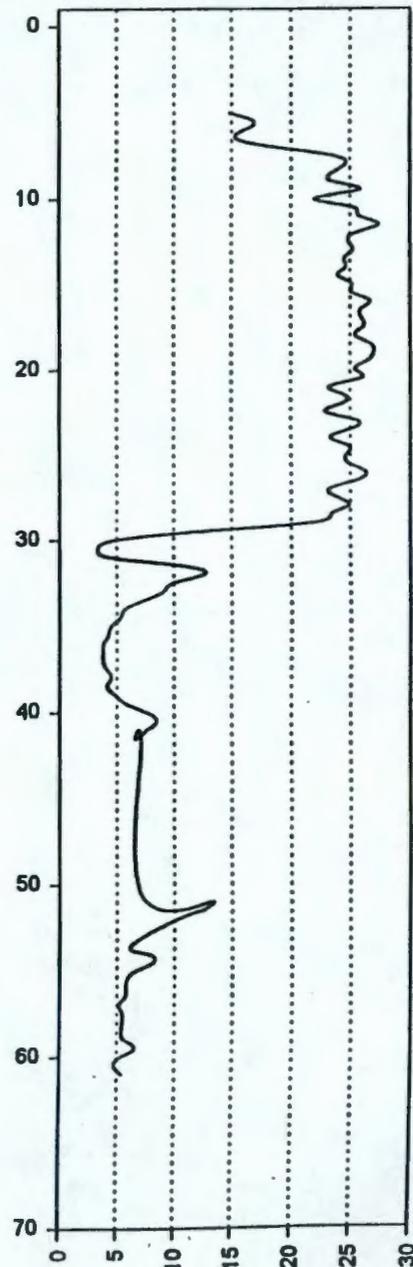
199-N-67
July 20, 1995



199-N-45
July 18, 1995



199-N-35
July 21, 1995

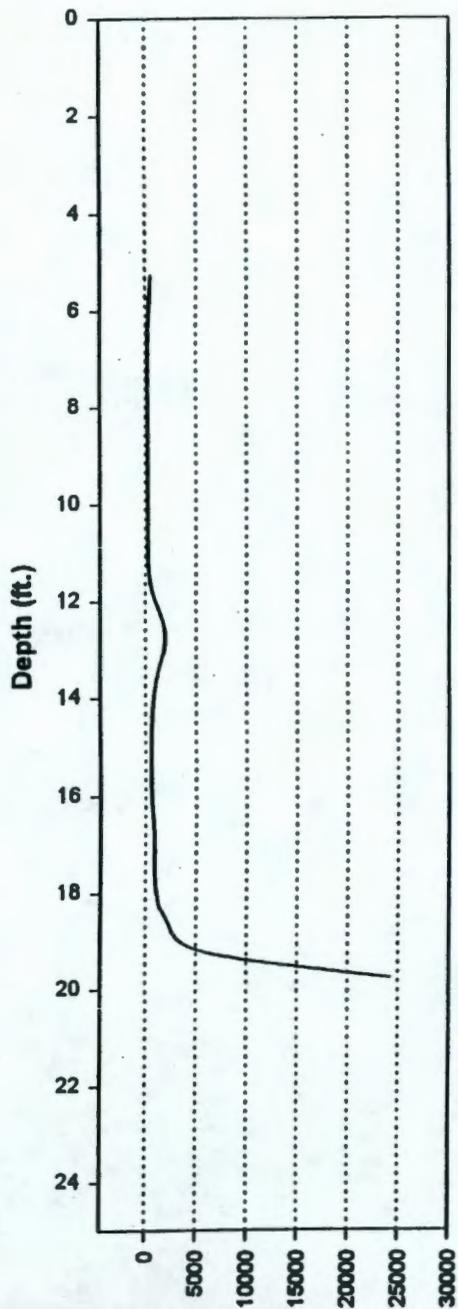


9613492.7067

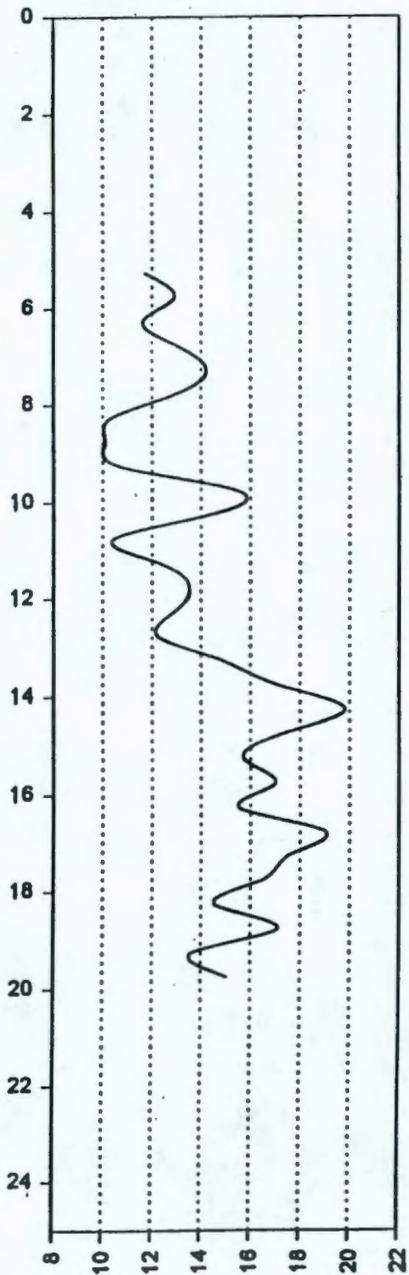
027237

Geophysics for PNL - RES1

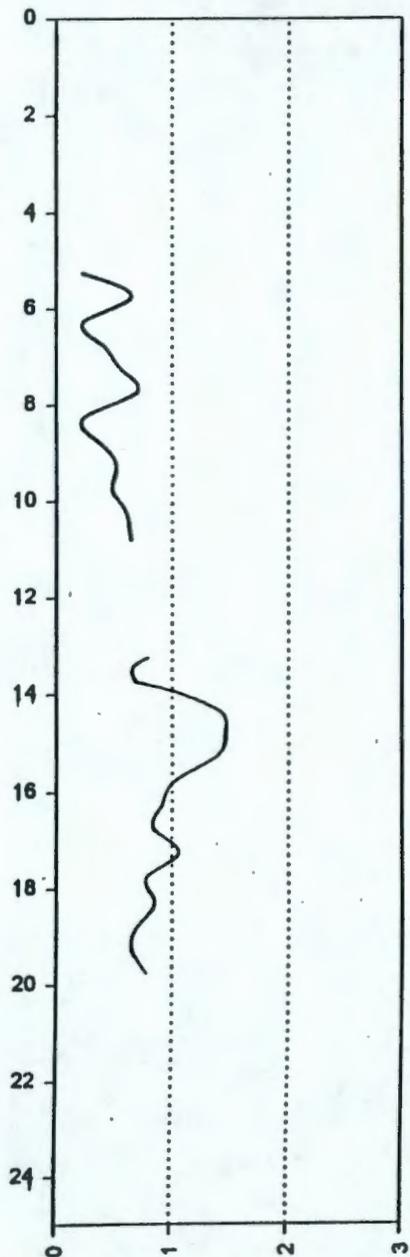
Gross Gamma pCi/g



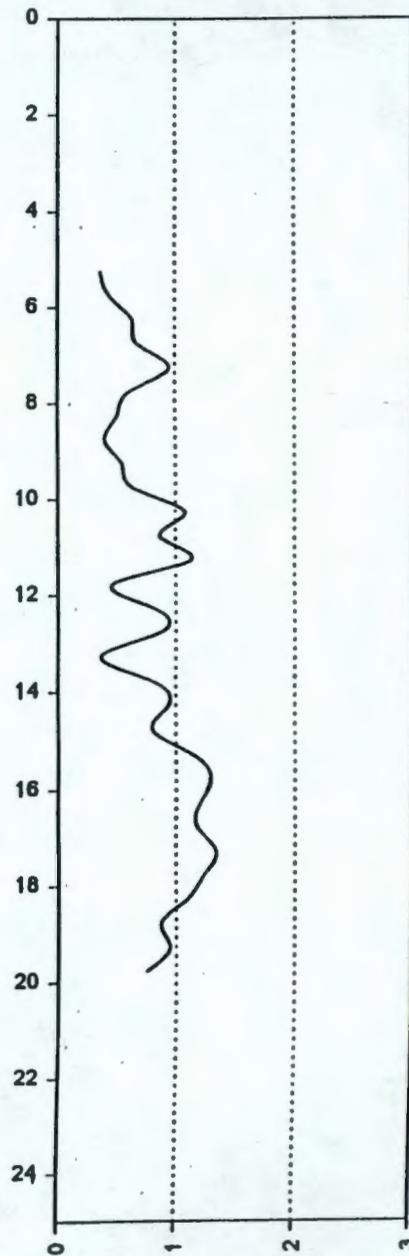
Potassium pCi/g



Uranium pCi/g



Thorium pCi/g



9613492.7068

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9613492.7069

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ATTACHMENT E

PARTIAL PHYSICAL PROPERTIES DATA FOR B2537

Physical Properties Data from Split Spoon Liners Collected from Borehole B2537.

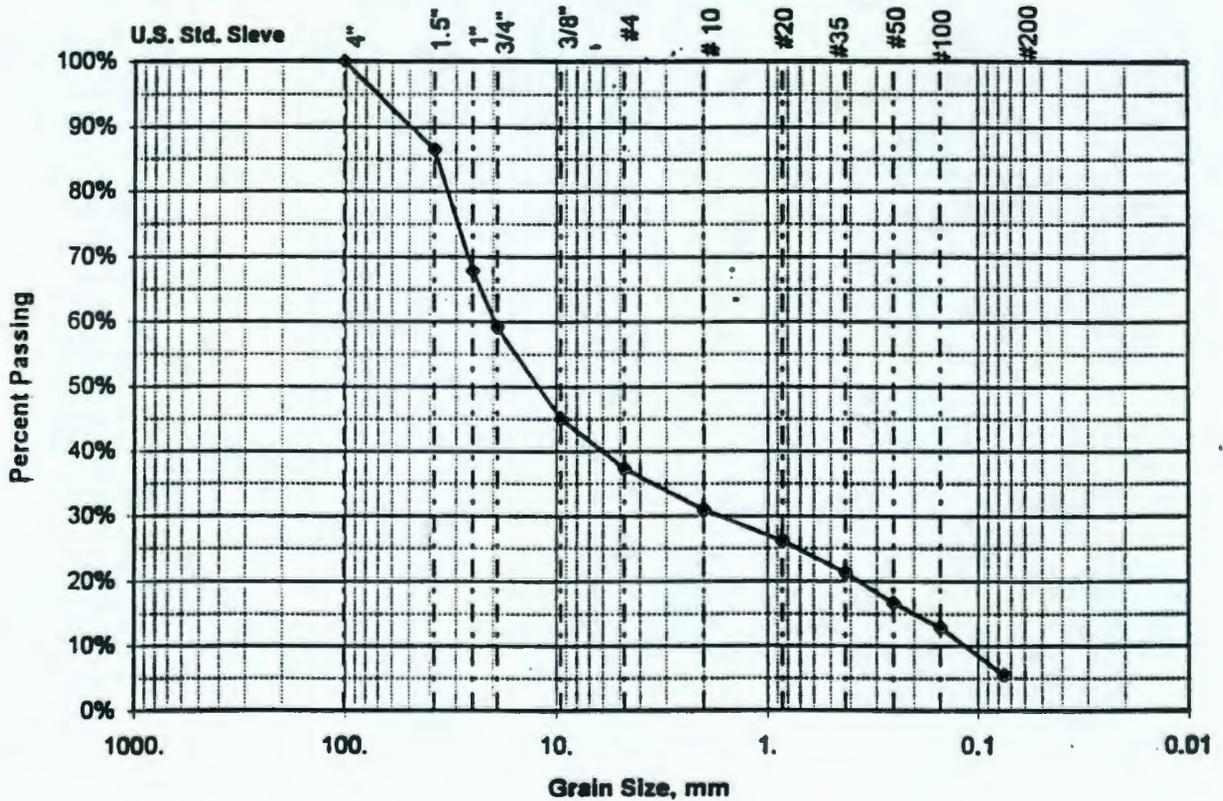
Sample No.	Sample Depth (ft)	Bulk Density (g/cc)	Porosity	Saturated Hydraulic Conductivity (average)(cm/s)
BOGL72	14.5-16.5	2.08	0.24	3.2×10^{-4}
BOGL74	23.0-25.0	1.76	0.35	3.0×10^{-5}
BOGL80	42.0-44.0	2.00	0.26	8.2×10^{-4}
BOGL85	62.0-63.8	1.96	0.28	7.4×10^{-4}

GEOTECHNICAL ENGINEERING LABORATORY
GEL-07
SIEVE ANALYSIS

WELL #	1301N/1325-N	DEPTH	14.5-16.5ft	LAB#	BOGL72	WELL #	82537
TESTED BY	PRH	CONTACT	D. Weeks	PHONE	372-9326	DATE	01/09/96

SAMPLE WT (g)	SIEVE SIZE IN.	CUMULATIVE WEIGHT	% WEIGHT RETAINED	% PASSING	Grain Size (mm)	COMMENTS
2487.0	4"	0.0	0.0	100.0	101.6	
	1.5"	337.7	13.6	86.4	38.1	
	1"	802.4	32.3	67.7	25.0	
	3/4"	1016.5	40.9	59.1	19.0	
	3/8"	1358.1	55.0	45.0	9.5	
	#4	1561.1	62.8	37.2	4.75	
WT. -#10 SAMP.(g) 225.3	# 10	1718.5	69.1	30.9	2.00	
	#20	35.4	15.7	26.0	0.850	split
	#35	71.2	31.6	21.1	0.425	
	#50	104.2	46.2	16.6	0.250	
	#100	131.5	58.4	12.9	0.150	
	#200	185.7	82.4	5.4	0.075	

Sieve Analysis Data for Sample BOGL72



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

Checked By: _____

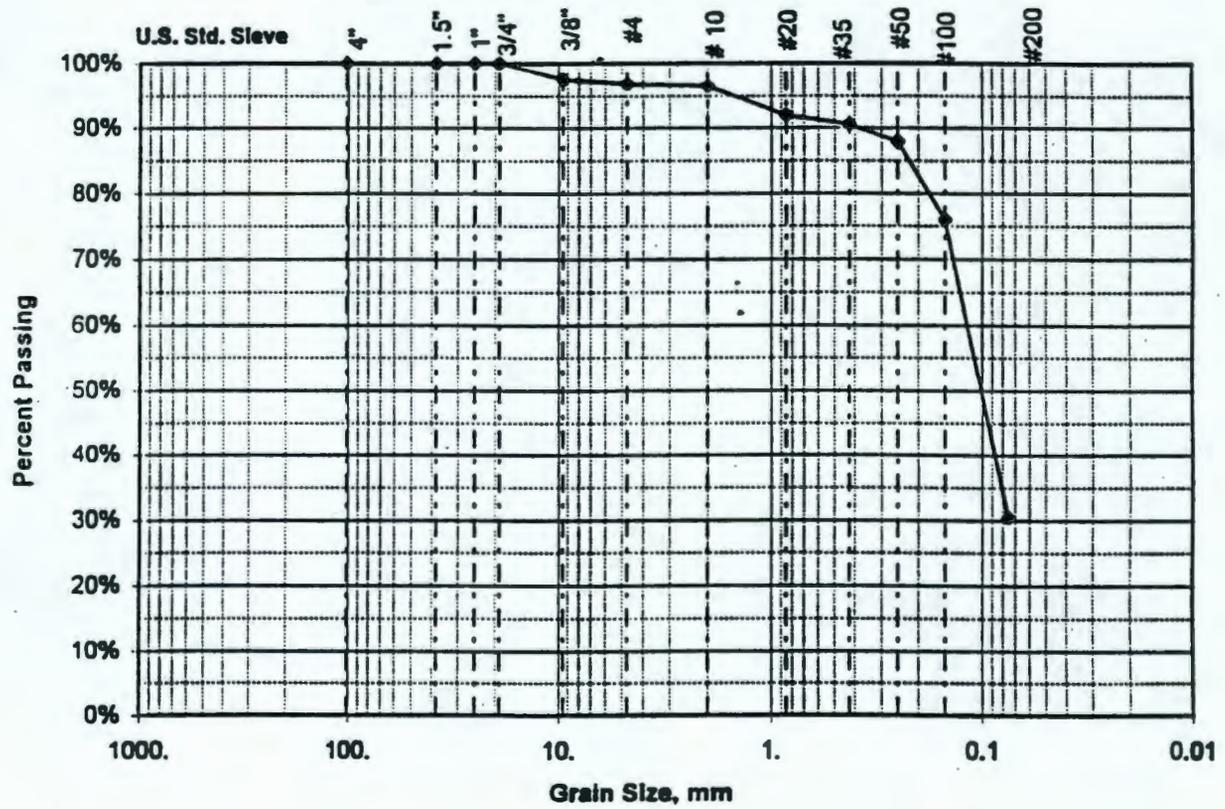
Date: _____

GEOTECHNICAL ENGINEERING LABORATORY
GEL-07
SIEVE ANALYSIS

WELL # 1301N/1325-N	DEPTH 23.0-25.0	LAB# BOGL74	WELL # B2537
TESTED BY PRH	CONTACT D. Weeks	PHONE 372-9326	DATE 01/09/96

SAMPLE WT (g)	SIEVE SIZE IN.	CUMULATIVE WEIGHT	% WEIGHT RETAINED	% PASSING	Grain Size (mm)	COMMENTS
192.7	4"	0.0	0.0	100.0	101.6	
	1.5"	0.0	0.0	100.0	38.1	
	1"	0.0	0.0	100.0	25.0	
	3/4"	0.0	0.0	100.0	19.0	
	3/8"	4.8	2.5	97.5	9.5	
	#4	6.2	3.2	96.8	4.75	
WT. #10 SAMP.(g)	#10	6.8	3.5	96.5	2.00	
	#20	9.3	4.8	91.8	0.850	split
192.7	#35	12.0	6.2	90.5	0.425	
	#50	17.2	8.9	87.9	0.250	
	#100	41.0	21.3	75.9	0.150	
	#200	132.0	68.5	30.4	0.075	

Sieve Analysis Data for Sample BOGL74



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

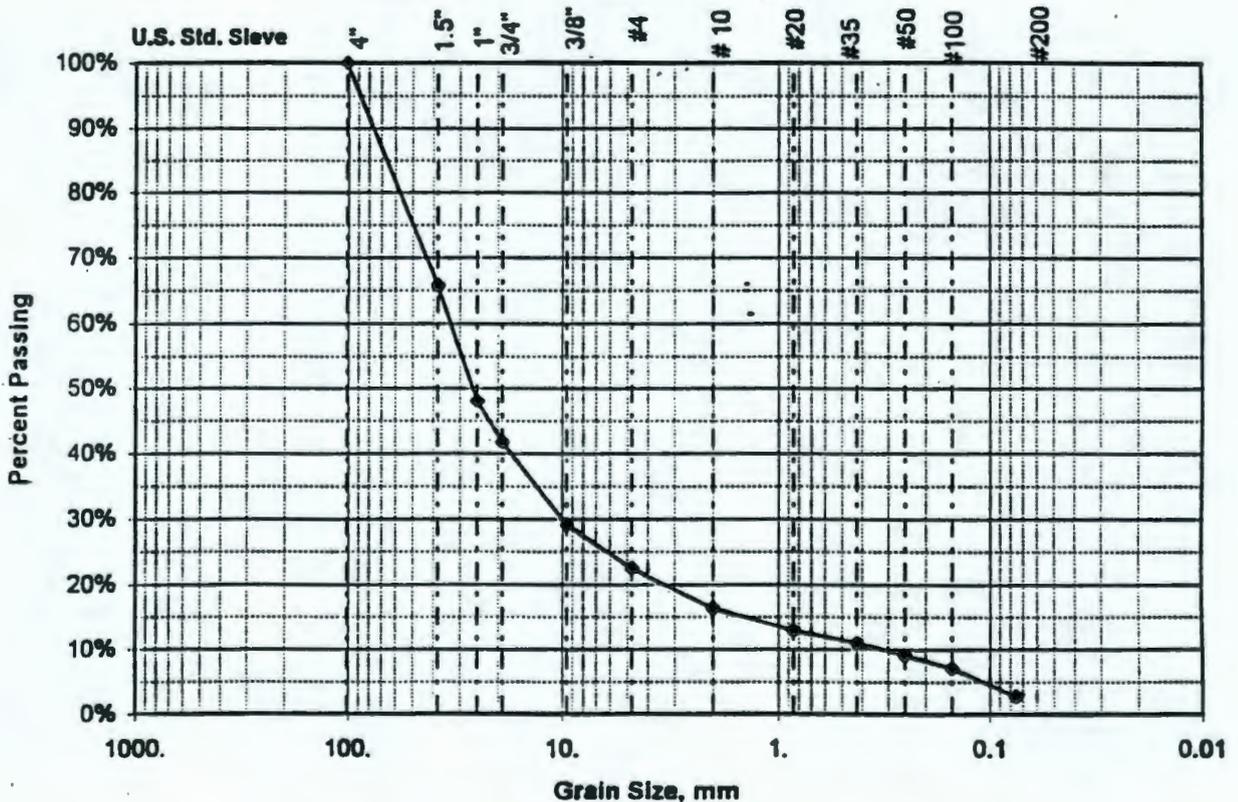
Checked By: _____ Date: _____

GEOTECHNICAL ENGINEERING LABORATORY
GEL-07
SIEVE ANALYSIS

WELL # 1301N/1325-N	DEPTH 18.0 ft	LAB# BOGL76	HEIS # B2537
TESTED BY PRH	CONTACT D. Weeks	PHONE 372-9326	DATE 12/19/95

SAMPLE WT (g)	SIEVE SIZE IN.	CUMULATIVE WEIGHT	% WEIGHT RETAINED	% PASSING	Grain Size (mm)	COMMENTS
3211.3	4"	0.0	0.0	100.0	101.6	
	1.5"	1100.2	34.3	65.7	38.1	
	1"	1670.0	52.0	48.0	25.0	
	3/4"	1872.8	58.3	41.7	19.0	
	3/8"	2276.3	70.9	29.1	9.5	
	#4	2494.5	77.7	22.3	4.75	
WT. #10 SAMP.(g) 169.7	# 10	46.0	27.1	16.3	2.00	split
	#20	71.9	42.4	12.9	0.850	
	#35	86.5	51.0	10.9	0.425	
	#50	101.4	59.8	9.0	0.250	
	#100	116.2	68.5	7.0	0.150	
	#200	133.8	78.8	4.7	0.075	

Sieve Analysis Data for Sample BOGL76



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

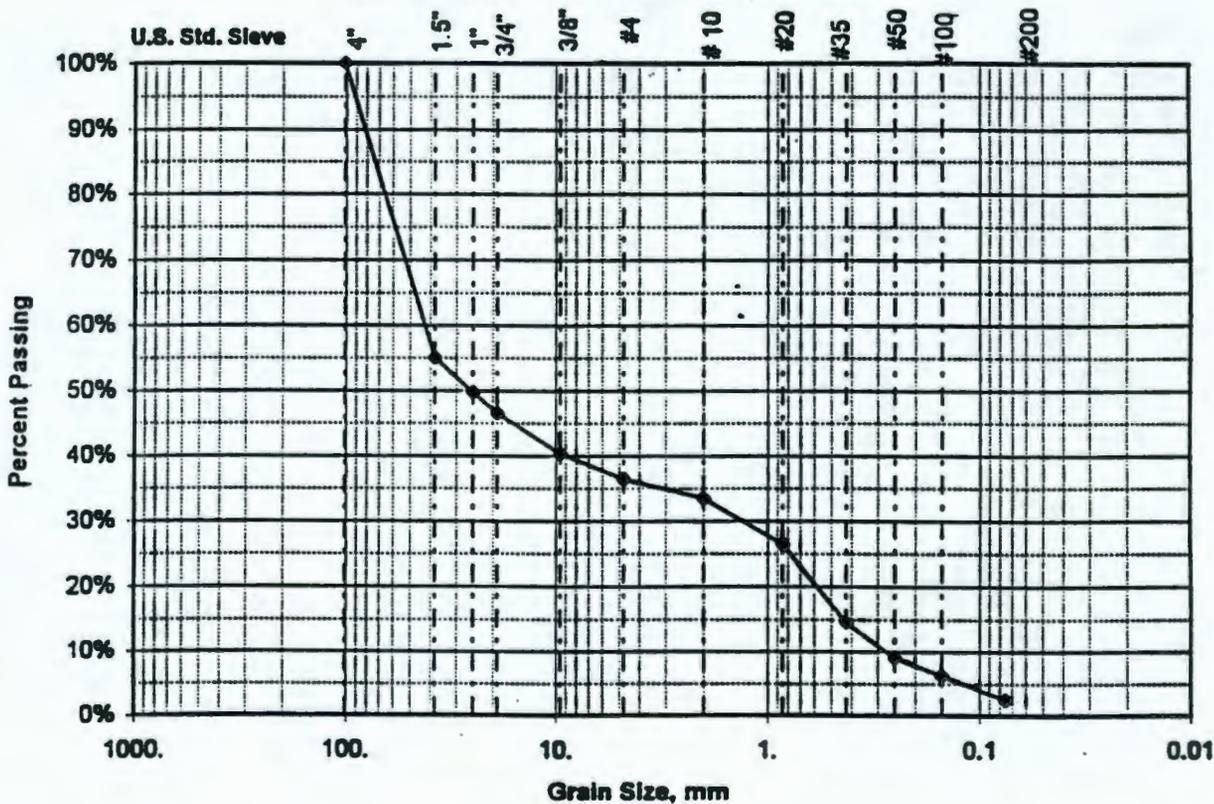
Checked By: *John Relyea* Date: *1-5-96*

GEOTECHNICAL ENGINEERING LABORATORY
GEL-07
SIEVE ANALYSIS

WELL #	1301N/1325-N	DEPTH	28.0 ft	LAB#	BOGL77	HEIS #	B2537
TESTED BY	PRH	CONTACT	D. Weeks	PHONE	372-9326	DATE	12/19/95

SAMPLE WT (g)	SIEVE SIZE IN.	CUMULATIVE WEIGHT	% WEIGHT RETAINED	% PASSING	Grain Size (mm)	COMMENTS
2520.7	4"	0.0	0.0	100.0	101.6	
	1.5"	1135.0	45.0	55.0	38.1	
	1"	1269.2	50.4	49.6	25.0	
	3/4"	1347.9	53.5	46.5	19.0	
	3/8"	1505.4	59.7	40.3	9.5	
	#4	1603.6	63.6	36.4	4.75	
WT.-#10 SAMP.(g) 235.3	#10	19.0	8.1	33.4	2.00	split
	#20	64.3	27.3	26.4	0.850	
	#35	141.7	60.2	14.5	0.425	
	#50	176.9	75.2	9.0	0.250	
	#100	195.3	83.0	6.2	0.150	
	#200	213.7	90.8	3.3	0.075	

Sieve Analysis Data for Sample BOGL77



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

Checked By: J. P. Reagen Date: 1-5-96

9613492.7076

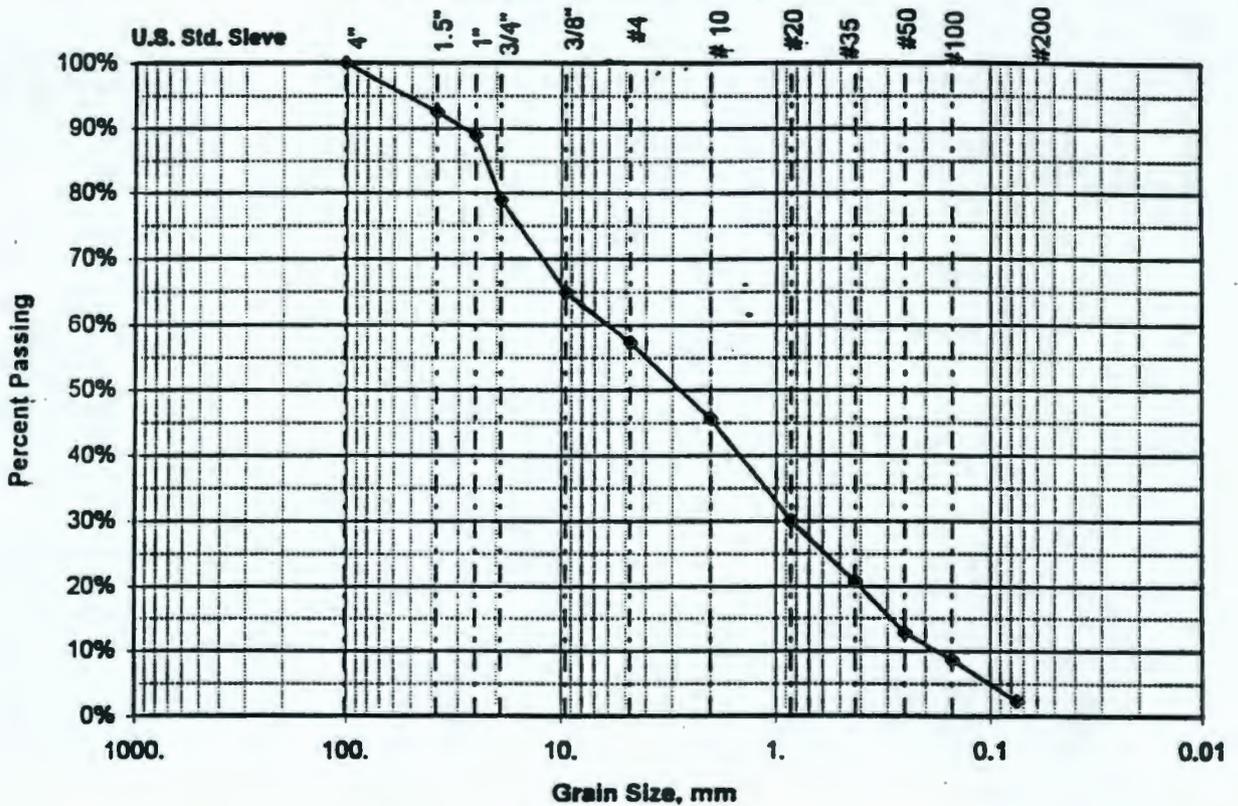
027237

GEOTECHNICAL ENGINEERING LABORATORY
GEL-07
SIEVE ANALYSIS

WELL #	1301N/1325-N	DEPTH	32.7 ft	LAB#	BOGL78	HEIS #	B2537
TESTED BY	PRH	CONTACT	D. Weeks	PHONE	372-9326	DATE	12/19/95

SAMPLE WT (g)	SIEVE SIZE IN.	CUMULATIVE WEIGHT	% WEIGHT RETAINED	% PASSING	Grain Size (mm)	COMMENTS
3231.3	4"	0.0	0.0	100.0	101.6	
	1.5"	242.2	7.5	92.5	38.1	
	1"	360.6	11.2	88.8	25.0	
	3/4"	681.3	21.1	78.9	19.0	
	3/8"	1134.6	35.1	64.9	9.5	
	#4	1380.7	42.7	57.3	4.75	
WT. #10 SAMP.(g) 259.0	#10	52.4	20.2	45.7	2.00	split
	#20	123.5	47.7	30.0	0.850	
	#35	165.4	63.9	20.7	0.425	
	#50	201.3	77.7	12.8	0.250	
	#100	220.2	85.0	8.6	0.150	
	#200	239.2	92.4	4.4	0.075	

Sieve Analysis Data for Sample BOGL78



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

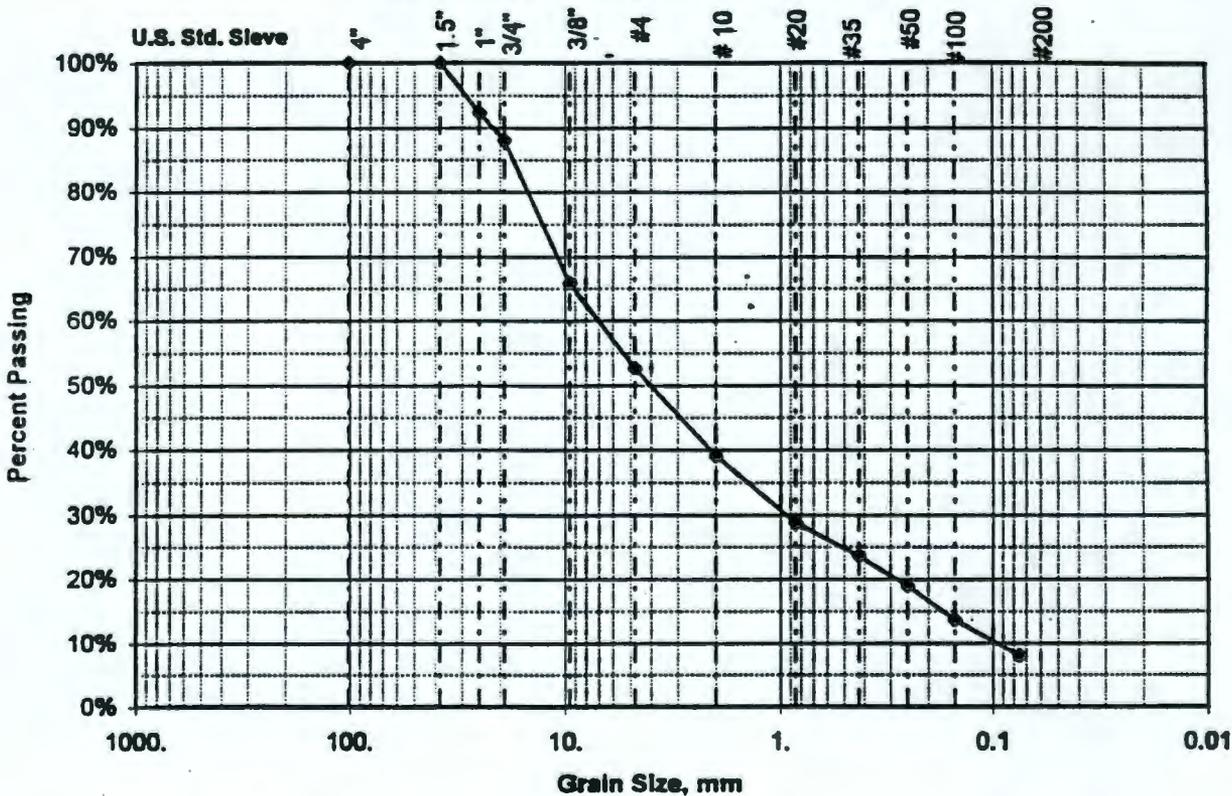
Checked By: *J.F. Relyea* Date: *1-5-96*

GEOTECHNICAL ENGINEERING LABORATORY
GEL-07
SIEVE ANALYSIS

WELL # 1301N/1325-N	DEPTH 42.0-44.0	LAB# BOGL80	WELL # 82537
TESTED BY PRH	CONTACT D. Weeks	PHONE 372-9326	DATE 01/09/96

SAMPLE WT (g)	SIEVE SIZE IN.	CUMULATIVE WEIGHT	% WEIGHT RETAINED	% PASSING	Grain Size (mm)	COMMENTS
2383.7	4"	0.0	0.0	100.0	101.6	
	1.5"	0.0	0.0	100.0	38.1	
	1"	183.6	7.7	92.3	25.0	
	3/4"	285.3	12.0	88.0	19.0	
	3/8"	814.9	34.2	65.8	9.5	
	#4	1130.5	47.4	52.6	4.75	
WT. #10 SAMP. (g) 257.2	#10	1451.2	60.9	39.1	2.00	
	#20	68.4	26.6	28.7	0.850	split
	#35	102.6	39.9	23.5	0.425	
	#50	132.7	51.6	18.9	0.250	
	#100	168.0	65.3	13.6	0.150	
	#200	204.7	79.6	8.0	0.075	

Sieve Analysis Data for Sample BOGL80



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

Checked By: _____

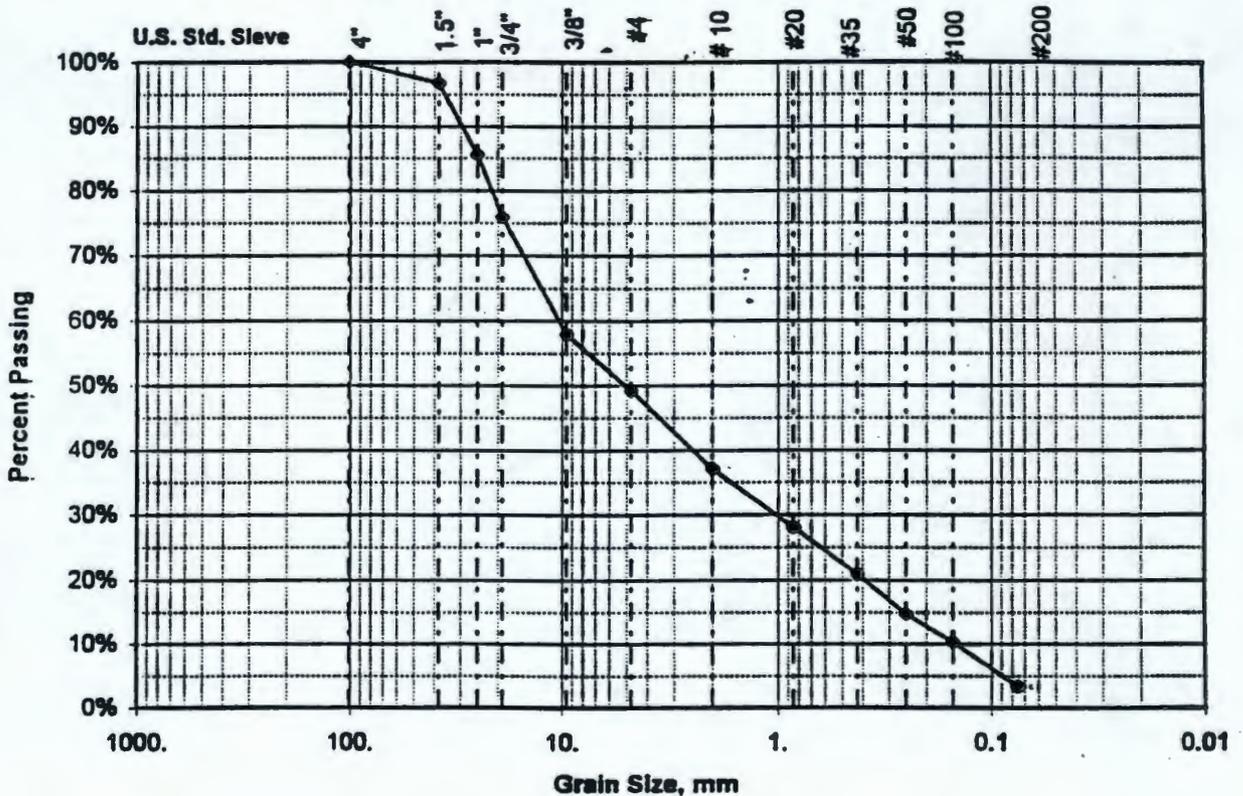
Date: _____

GEOTECHNICAL ENGINEERING LABORATORY
GEL-07
SIEVE ANALYSIS

WELL #	1301N/1325-N	DEPTH	47.0 ft	LAB#	BOGL82	HEIS #	B2537
TESTED BY	PRH	CONTACT	D. Weeks	PHONE	372-9326	DATE	12/19/95

SAMPLE WT (g)	SIEVE SIZE IN.	CUMULATIVE WEIGHT	% WEIGHT RETAINED	% PASSING	Grain Size (mm)	COMMENTS
2528.4	4"	0.0	0.0	100.0	101.6	
	1.5"	84.3	3.3	96.7	38.1	
	1"	364.5	14.4	85.6	25.0	
	3/4"	610.0	24.1	75.9	19.0	
	3/8"	1064.3	42.1	57.9	9.5	
	#4	1285.7	50.9	49.1	4.75	
WT. #10 SAMP. (g) 276.5	#10	67.9	24.6	37.1	2.00	split
	#20	118.7	42.9	28.0	0.850	
	#35	158.8	57.4	20.9	0.425	
	#50	193.9	70.1	14.7	0.250	
	#100	218.9	79.2	10.2	0.150	
	#200	243.9	88.2	5.8	0.075	

Sieve Analysis Data for Sample BOGL82



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

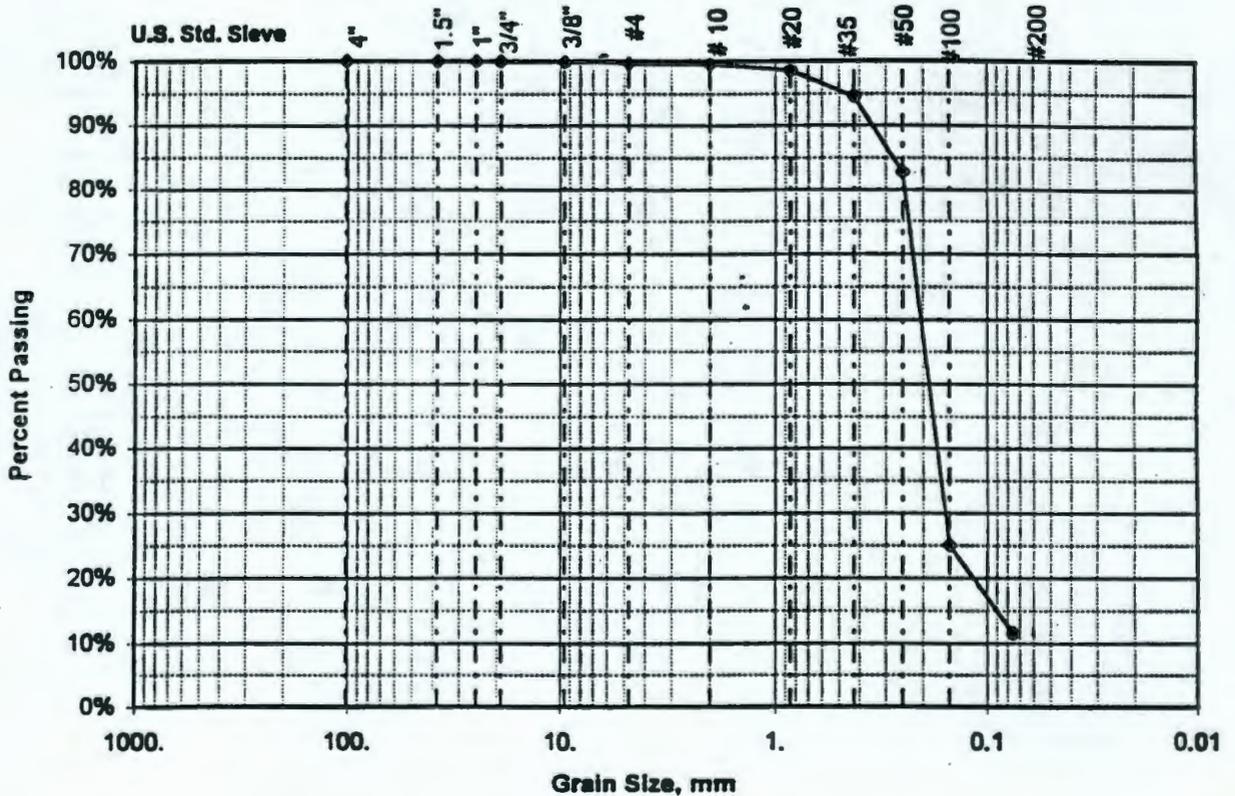
Checked By: *J. H. [Signature]* Date: 1-5-96

GEOTECHNICAL ENGINEERING LABORATORY
GEL-07
SIEVE ANALYSIS

WELL #	1301N/1325-N	DEPTH	52.0 ft	LAB#	BOGL83	HEIS #	B2537
TESTED BY	PRH	CONTACT	D. Weeks	PHONE	372-9326	DATE	12/19/95

SAMPLE WT (g)	SIEVE SIZE IN.	CUMULATIVE WEIGHT	% WEIGHT RETAINED	% PASSING	Grain Size (mm)	COMMENTS
1911.0	4"	0.0	0.0	100.0	101.6	
	1.5"	0.0	0.0	100.0	38.1	
	1"	0.0	0.0	100.0	25.0	
	3/4"	0.0	0.0	100.0	19.0	
	3/8"	1.9	0.1	99.9	9.5	
	#4	7.5	0.4	99.6	4.75	
WT. #10 SAMP. (g) 242.3	#10	0.3	0.1	99.5	2.00	split
	#20	2.8	1.2	98.5	0.850	
	#35	12.5	5.2	94.5	0.425	
	#50	41.2	17.0	82.7	0.250	
	#100	181.3	74.8	25.1	0.150	
	#200	214.0	88.3	11.6	0.075	

Sieve Analysis Data for Sample BOGL83



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

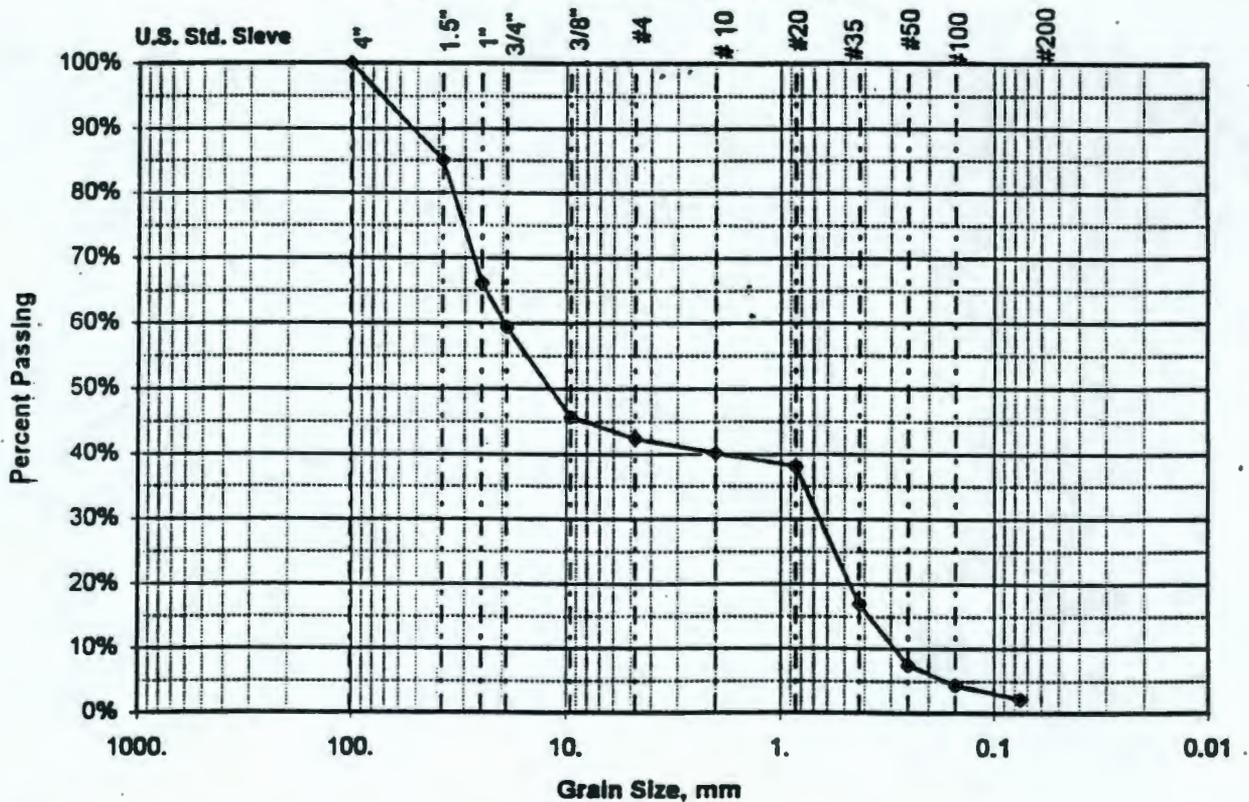
Checked By: J. P. Belyea Date: 1-5-96

GEOTECHNICAL ENGINEERING LABORATORY
GEL-07
SIEVE ANALYSIS

WELL #	1301N/1325-N	DEPTH	59.5 ft	LAB#	BOGL84	HEIS #	B2537
TESTED BY	PRH	CONTACT	D. Weeks	PHONE	372-9326	DATE	12/19/95

SAMPLE WT (g)	SIEVE SIZE IN.	CUMULATIVE WEIGHT	% WEIGHT RETAINED	% PASSING	Grain Size (mm)	COMMENTS
2656.0	4"	0.0	0.0	100.0	101.6	
	1.5"	397.3	15.0	85.0	38.1	
	1"	900.9	33.9	66.1	25.0	
	3/4"	1080.3	40.7	59.3	19.0	
	3/8"	1445.1	54.4	45.6	9.5	
	#4	1534.0	57.8	42.2	4.75	
WT. #10 SAMP. (g) 198.6	# 10	10.5	5.3	40.0	2.00	split
	#20	20.1	10.1	38.0	0.850	
	#35	119.3	60.1	16.9	0.425	
	#50	163.6	82.4	7.4	0.250	
	#100	178.4	89.8	4.3	0.150	
	#200	187.6	94.4	2.3	0.075	

Sieve Analysis Data for Sample BOGL84



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

Checked By: J. J. Reilly Date: 1-5-96

9613492.7081

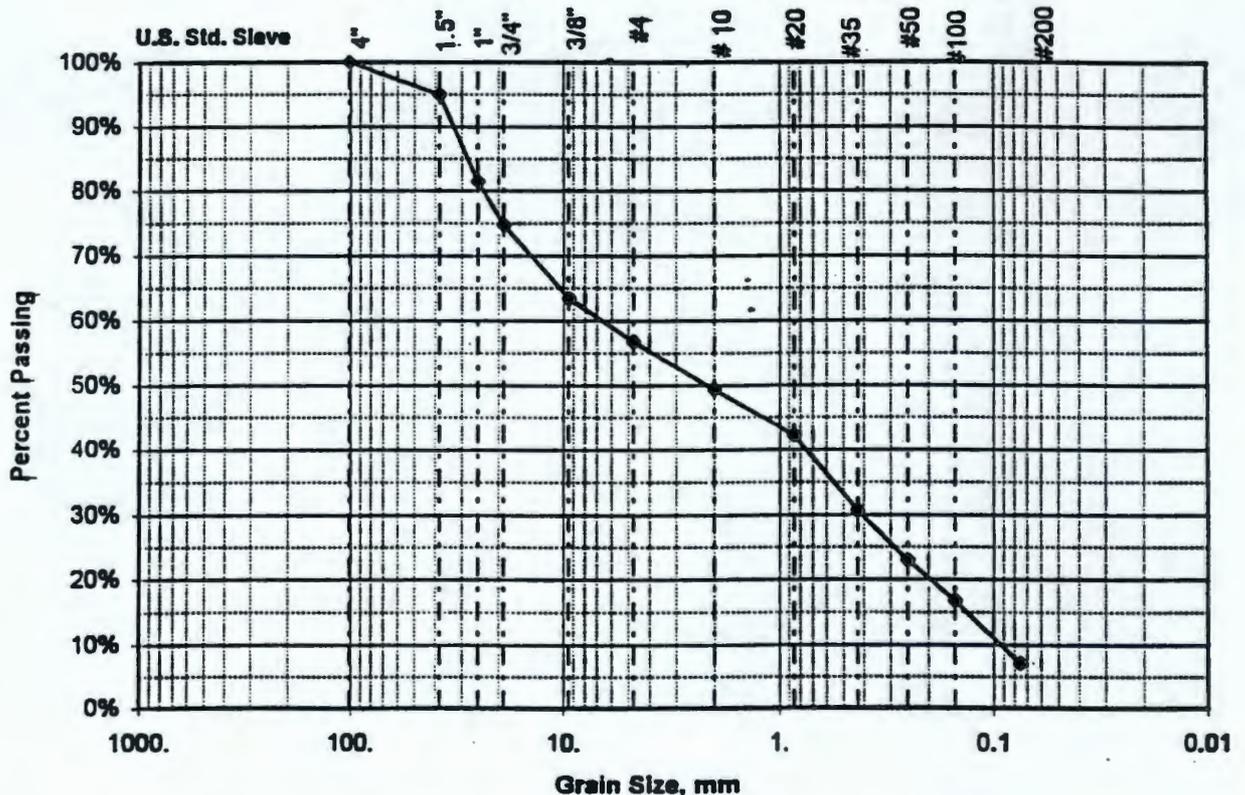
027237

GEOTECHNICAL ENGINEERING LABORATORY
GEL-07
SIEVE ANALYSIS

WELL # 1301N/1325-N	DEPTH 60.0-63.8	LAB# BOGL85	WELL # B2537
TESTED BY PRH	CONTACT D. Weeks	PHONE 372-9326	DATE 01/09/96

SAMPLE WT (g)	SIEVE SIZE IN.	CUMULATIVE WEIGHT	% WEIGHT RETAINED	% PASSING	Grain Size (mm)	COMMENTS
2259.8	4"	0.0	0.0	100.0	101.6	
	1.5"	115.7	5.1	94.9	38.1	
	1"	420.2	18.6	81.4	25.0	
	3/4"	571.4	25.3	74.7	19.0	
	3/8"	826.1	36.6	63.4	9.5	
	#4	978.1	43.3	56.7	4.75	
WT. #10 SAMP. (g) 250.5	#10	1147.8	50.8	49.2	2.00	
	#20	35.9	14.3	42.2	0.850	split
	#35	94.8	37.8	30.6	0.425	
	#50	133.7	53.4	22.9	0.250	
	#100	165.4	66.0	16.7	0.150	
	#200	214.9	85.8	7.0	0.075	

Sieve Analysis Data for Sample BOGL85



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

Checked By: _____

Date: _____

