GJ-HAN-90
Tank C-108

Vadose Zone Characterization Project at the Hanford Tank Farms

Tank Summary Data Report for Tank C-108

October 1997

U.S. Department of Energy

GRAND JUNCTION OFFICE

Work Performed Under DOE Contract No. DE-AC13-96GJ87335 for the U.S. Department of Energy
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CONTROL NO.: 3100-T98-0171

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Project Manager
Department of Energy S7-54
Richland Operations Office
825 Jadwin Ave.
Richland, WA 99352
ATTN: David Shafer

Subject: Contract No. DE-AC13-96GJ87335—Submittal of Tank Summary Data Report for Tank C-108 (GJ-HAN-90)

Dear Mr. Shafer:

Enclosed is one (1) copy of the subject Tank Summary Data Report (TSDR). This report is being submitted for your information/records and should be considered final. By cover of this letter a copy is being provided to DOE-GJO for their records.

Should technical questions or comments arise, please do not hesitate to contact John Brodeur or myself at (509) 946-3635.

Sincerely,

James F. Bertsch
Project Manager

JFB/shn
Enclosure
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October 1997

Prepared for
U.S. Department of Energy
Albuquerque Operations Office
Grand Junction Office
Grand Junction, Colorado

Prepared by
MACTEC-ERS
Grand Junction Office
Grand Junction, Colorado

Work performed under DOE Contract No. DE–AC13–96GJ87335 for the U.S. Department of Energy.

Contents

Contents (continued)

Figures

Vadose Zone Characterization Project at the Hanford Tank Farms

Tank Summary Data Report for Tank C-108

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Executive Summary

The U.S. Department of Energy (DOE) Richland Operations Office tasked the DOE Grand Junction Office (GJO) with performing a baseline characterization of the gamma-ray-emitting radionuclides that are distributed in the vadose zone sediments surrounding the single-shell tanks (SSTs) at the Hanford Site. This project helps to identify possible sources of any subsurface contamination encountered during the logging and to determine the implications of the contamination for Tank Farm operations. The acquired data establish a contamination baseline that can be used for future data comparisons, tank-leak verifications, and for developing contaminant flow-and-transport models.

Information regarding vadose zone contamination was acquired by logging the monitoring boreholes positioned around the SSTs using a spectral gamma logging system (SGLS). This system employs a high-purity germanium detector and is designed to acquire laboratory-quality assays of the gamma-emitting radionuclides in the sediments. This report documents the spectral gamma-ray logging results obtained from the monitoring boreholes that surround tank C-108.

Tank C-108 is categorized as sound with interim stabilization and intrusion prevention completed. The tank is currently listed as containing noncomplexed waste that consists of 66,000 gallons (gal) of sludge, with no interstitial liquid remaining (Hanlon 1997).

Cesium-137 (^{137}Cs) and cobalt-60 (^{60}Co) were the major gamma-emitting contaminants detected in the vadose zone sediments surrounding this tank. The majority of the ^{137}Cs contamination is confined to the near-surface and shallow subsurface regions of the backfill material surrounding tank C-108. The majority of the ^{60}Co contamination consists of an extensive contaminant plume distributed within the native sediments below the tank farm excavation near the northeast side of the tank. Isolated occurrences of uranium-235 (^{235}U) were detected at the ground surface in two boreholes. A thin zone of europium-154 (^{154}Eu) was detected at the approximate depth of a cascade line in one borehole, and a single occurrence of europium-152 (^{152}Eu) was detected in a dual-cased borehole.

On the basis of shape factor analysis results, the ^{137}Cs contamination is, in most cases, interpreted to be uniformly distributed in the backfill material around the boreholes associated with tank C-108. This contamination most likely resulted from surface spills and/or airborne contamination releases related to routine tank farm operations. It appears that the contamination has been driven downward in the backfill material as deep as 30 feet (ft) by precipitation infiltration.

A distinct zone of subsurface ^{137}Cs and ^{154}Eu contamination was detected in a borehole located near the C-108-to-C-109 cascade line. However, shape factor analysis of the data indicates the contamination detected by the SGLS probably consists of residual waste contained within the cascade piping and that little or no leakage has occurred.

Subsurface ^{60}Co and ^{137}Cs contamination detected between 45 and 95 ft in boreholes clustered near the northeast side of tank C-108 probably represents the remnant of a plume that originated

from a single contaminant source, such as a leak from tank C-108 or C-111. The historical gross-gamma data indicate that other short-lived radionuclides, such as ruthenium-106 (^{106}Ru) or antimony-125 (^{125}Sb), may have initially coexisted with the ^{60}Co contamination around two of these boreholes but have since decayed to levels below the detection limit of the SGLS.

The data obtained using the SGLS and the geologic and historical information available from other sources do not identify any active leaks from tank C-108. However, the data indicate that surface spills have occurred and that contaminant plumes originating from subsurface leaks from other tanks exist in the vicinity of this tank. These contaminant plumes may be related to activities associated with tank C-108 or other nearby tanks.

Continued monitoring of the boreholes surrounding this tank is recommended to identify changes in the distribution of the contaminant plumes identified within the vadose zone. Because the lithology appears to play an important role in the radionuclide distribution beneath this tank, especially for ^{60}Co, further lithologic characterization is recommended by logging a few of the boreholes using a long counting time or a high efficiency system. The SGLS can be utilized for these purposes to properly define the individual natural radionuclide concentrations, and, thus, better characterize site-specific geology.

1.0 Introduction

1.1 Background

The U.S. Department of Energy (DOE) Richland Operations Office tasked the DOE Grand Junction Office (GJO) with characterizing and establishing a baseline of man-made radionuclide concentrations in the vadose zone surrounding the single-shell tanks (SSTs) at the Hanford Site. These tasks are being accomplished using spectral gamma-ray borehole geophysical logging measurements made in the boreholes surrounding the tanks. The primary objective of this project is to provide data on the tanks for use by DOE organizations. These data may also be used to develop an SST Closure Plan in compliance with the Resource Conservation and Recovery Act and to prepare an Environmental Impact Statement for the Tank Waste Remediation Systems program.

1.2 Scope of Project

The scope of this project is to locate and identify the gamma-ray-emitting radionuclides and determine their concentrations in the vadose zone sediment by logging the monitoring boreholes around the SSTs with a Spectral Gamma Logging System (SGLS). Additional details regarding the scope and general approach to this characterization program are included in the project management plan (DOE 1997c) and baseline monitoring plan (DOE 1995b). This project may help to identify possible sources of any subsurface contamination encountered during the logging and to determine the implications of the contamination for Tank Farm operations. The acquired data will establish a contamination baseline that can be used for future data comparisons, for tank-leak verifications, and to help develop contaminant flow-and-transport models.

1.3 Purpose of Tank Summary Data Report

A Tank Summary Data Report (TSDR) will be prepared for each SST to document the results of the spectral gamma-ray logging in the boreholes around the tank. Each TSDR provides a brief review and a summary of existing information about a specific tank and an assessment of the implications of the spectral gamma-ray log information, including recommendations on future data needs or immediate corrective action, where appropriate. Appendix A of each TSDR presents logs of radionuclide concentrations versus depth for all boreholes around that specific tank. A comprehensive Tank Farm Report will be prepared for each tank farm after completion of characterization logging of all boreholes in the subject farm.

2.0 Spectral Gamma-Ray Log Measurements

2.1 Data Acquisition and Processing

The concentrations of individual gamma-ray-emitting radionuclides in the sediments surrounding a borehole can be calculated from the activities in the gamma-ray energy spectra measured in the borehole using calibrated instrumentation. Spectral gamma-ray logging is the process of collecting gamma-ray spectra at sequential depths in a borehole. Figure 1 shows a gamma-ray spectrum with peaks at energies, from 0 to 2,700 kilo-electron-volts (keV), that are characteristic of specific radionuclides. The spectrum includes peaks from naturally occurring radionuclides ^{40}K, ^{238}U, and ^{232}Th (KUT) and from man-made contaminants (e.g., ^{137}Cs and ^{60}Co). Gamma-ray source concentrations are cited in terms of picocuries per gram (pCi/g), even though this unit technically describes decay rate per unit mass of sample rather than concentration. The use of decay rate per unit mass is widespread in environmental work, where health and safety issues relate to the radioactivity, not the chemical concentration.

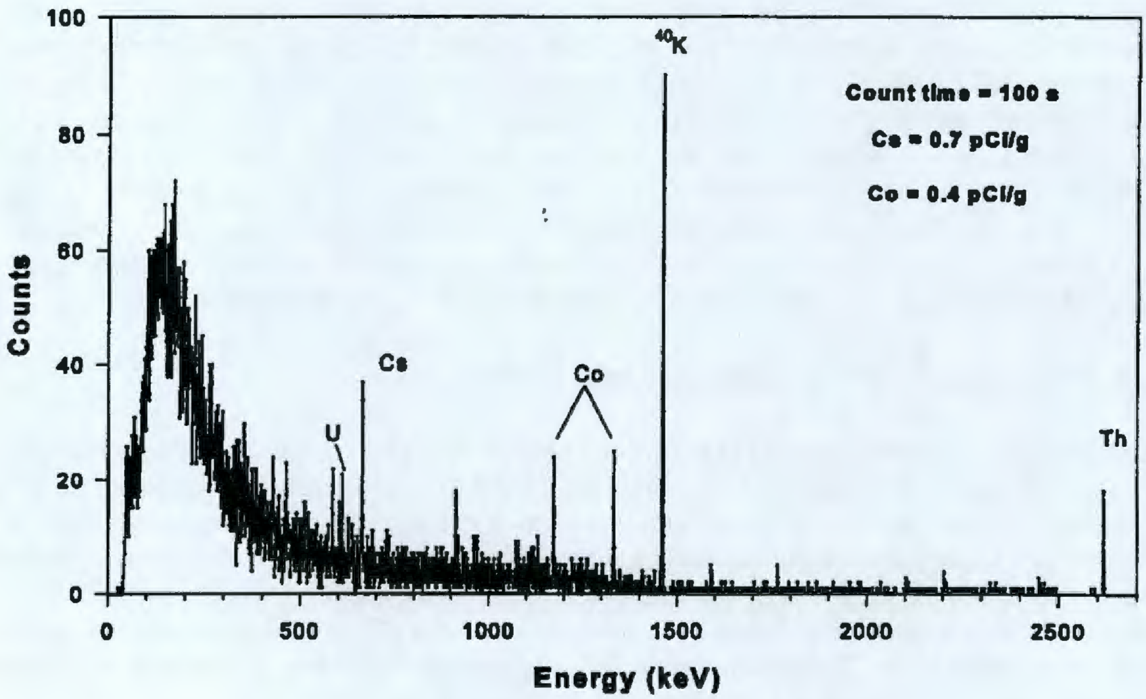

Figure 1. Gamma-Ray Spectrum

Data are acquired in boreholes near the tanks according to methods described in the logging procedures (DOE 1997b). Typical counting times at each measurement position are about 100 seconds (s), with a spectrum being collected every 0.5 foot (ft) along the length of the borehole.

Long data acquisition times can reduce the uncertainties in the calculated concentrations presented on the logs. However, economic and time constraints limit the amount of time available for data collection. The statistical uncertainty for gamma rays emitted from low-activity radionuclides such as ^{238}U and ^{232}Th can be high for this counting time, and the logs for these radionuclides will show high levels of statistical uncertainty, as evidenced on the logs by scatter in the plotted data and wide confidence intervals.

The minimum detection level (MDL) of a radionuclide represents the lowest concentration at which the positive identification of a gamma-ray peak for that radionuclide is statistically defensible. The spectrum analysis program calculates the MDL for a particular peak on the basis of a statistical analysis of the spectral background level in the vicinity of the peak. The same equations that translate peak intensities into decay rates per unit-sample mass also translate the MDLs from counts per second (cps) to picocuries per gram. A description of the MDL calculation is included in the data analysis manual (DOE 1997a).

The gamma-ray spectra measured in a borehole are processed using a variety of software programs to obtain the concentrations of individual gamma-ray-emitting radionuclides. All the algorithms used in the concentration calculations and their application is discussed in the data analysis manual (DOE 1997a). These calculated data, which are usually presented as vertical profiles, are used to make an interpretation of vadose zone contamination associated with each borehole. When data from all the boreholes associated with a specific tank have been processed and interpreted, a correlation interpretation is made of the vadose zone contamination surrounding each tank.

The initial SGLS calibration report (DOE 1995a) contains the results obtained from operating the logging tools in calibration models. The calibration report presents the mathematical functions used to convert the measured peak area count rates to radioelement concentration in picocuries per gram. The SGLS is routinely recalibrated (DOE 1997d) to ensure the accuracy of the calculated radionuclide concentrations. The calculated radionuclide concentrations derived with these conversion factors may be as much as 14 percent higher than the actual in situ concentrations because the concentrations of the calibration models are expressed in terms of gamma-ray activity per unit-sample mass of *dry* bulk material. However, the measurements made in the calibration models were in a water-saturated environment. The conversion factors in the calibration report (DOE 1995a) are strictly applicable only when the logged formation has the same water content as the calibration-model test zones. The vadose zone contains pore-space water in various percentages of saturation from near 0 percent to near 100 percent, and the boreholes are logged dry. Corrections for pore-space water cannot presently be applied to the vadose zone measurements because the in situ water content is not being measured.

The calibration data from which conversion factors were derived were recorded with a logging tool in a borehole drilled through a uniform homogeneous isotropic gamma-ray-source material. If the gamma-ray sources in the borehole being logged are not uniformly distributed in the sediments, the conversion factor produces apparent concentrations. The concentrations calculated for the top and bottom of a borehole are also apparent concentrations, because the source-to-detector geometries at these locations differ from the source-to-detector geometries during calibration.

When gamma-ray spectra are measured in cased boreholes, a casing correction must be applied to the peak count rates to compensate for gamma-ray attenuation by the casing. This correction function is described in the calibration report (DOE 1995a), and the data analysis manual (DOE 1997a) describes the application of the correction function in the data processing.

2.2 Shape Factor Analysis

Insights into the distribution of the radionuclides identified by the SGLS can be provided by using an analytical method known as shape factor analysis (Wilson 1997). Shape factor analysis takes advantage of 1) the SGLSs ability to record the specific energies of detected gamma rays, and 2) the Compton downscattering caused by the interaction of gamma rays with matter between the gamma-ray source and the detector.

Compton scattering results in higher energy photons being converted to lower energy photons; hence, Compton scattering within and outside of the detector accounts for the low-energy continuum in a pulse height spectrum. Many factors exterior to the detector influence the low-energy portion of the spectrum of gamma rays incident on the detector and thereby affect the low-energy continuum in the pulse height spectrum. Wilson (1997) has shown that variations in gamma-ray source distribution relative to a borehole produce measurable changes in the shapes of the pulse height spectra recorded by logging the boreholes. The spectral shape changes are quantified by ratios of counts from various portions of the pulse height spectrum, and these ratios are used to assess the distribution of the source.

Shape factor analysis can also be used to identify the presence of brehmsstrahlung radiation from the beta-emitting radionuclide ^{90}Sr. Beta particles, emitted from the radioactive decay of ^{90}Sr, interact with the electromagnetic fields within the substances they traverse. The deflection and resulting deceleration of the beta particles produce x-rays, known as brehmsstrahlung radiation, which are detected in the lower energy portion of the gamma-ray spectrum. In instances of high total gamma-ray activity, a preponderance of lower energy gamma radiation may be due to the presence of beta emitters such as ^{90}Sr.

Additional information on shape factor analysis theory is provided in Wilson (1997).

2.2.1 Specific Shape Factors

As stated previously, the ratios of gamma-ray counts from various portions of a spectrum are indicators of gamma-ray source distribution. Three ratios are used in shape factor analysis. These ratios, known as shape factors, are designated CsSF1, CoSF1, and SF2.

- CsSF1 is the ratio of the total number of counts in the continuum window (60 to 650 keV) to the counts in the ^{137}Cs peak. This shape factor is useful for evaluating the distribution of the radionuclide ^{137}Cs.

- CoSF1 is the ratio of the total number of counts in the continuum window (60 to 650 keV) to the sum of the counts in the two ^{60}Co peaks (1173 and 1332 keV). This shape factor is useful for evaluating the distribution of the radionuclide ^{60}Co.

- SF2 is the ratio of the total number of counts in the lower energy portion of the continuum window (60 to 350 keV) to the counts in the higher energy portion of the continuum window (350 to 650 keV). This parameter is somewhat sensitive to the radionuclide distribution, but is most applicable to the identification of the beta emitter ^{90}Sr and in distinguishing remote ^{137}Cs or ^{60}Co from ^{90}Sr.

At low concentrations, high uncertainties in the ^{137}Cs and ^{60}Co peak count rates and in the net continuum count rates cause large errors in the calculated values of CsSF1 and CoSF1, respectively. A minimum count rate of 1 cps must be present for the calculated CsSF1 to be meaningful, and a minimum count rate of 2 cps must be present for CoSF1 (Wilson 1997).

The values of CsSF1, CoSF1, and SF2 also become less reliable as the radionuclide concentrations and count rates become very high and the dead time increases. Inaccuracies in the measurement of the spectral regions occur when system dead time increases to above about 20 percent. The effect on shape factors is relatively small for dead times up to 40 percent. For measurements made at dead times below 20 percent, distortion of the spectrum is negligible (Wilson 1997).

2.2.2 Interpretation of Shape Factors

Values of CsSF1, CoSF1, and SF2 that can be expected for radionuclides in various distributions were established from investigations by Wilson (1997). These distributions are: 1) contamination confined to the borehole region, such as when contaminants occur on the borehole casing, 2) contamination uniformly distributed throughout the formation around the borehole, and 3) contamination in the formation but at discrete locations remote from the detector. The expected CsSF1, CoSF1, and SF2 values for various distributions of ^{137}Cs are summarized below.

^{137}Cs or ^{60}Co Source Distribution	Spectral Shape Factor	
	CsSF1 or CoSF1	SF2
Stuck on inside of 6-inch (in.) casing	4.5 - 5.5	2.8
Stuck on outside of 6-in. casing	6.8 - 7.4	2.8
Uniformly distributed in formation	13 - 15	3.5
Discrete source 10 centimeter (cm) radial distance	~ 19	~ 3.8
Discrete source 30 cm radial distance	~ 37	~ 4.2
Discrete source more than 50 cm radially distant	80 - 100	4.4 - 5.0

When CsSF1, CoSF1, and SF2 values exceed those listed, the presence of ^{90}Sr is suggested. However, photons from intense gamma-ray sources remote from the borehole can also produce spectra with high CsSF1 and CoSF1 values, indicating that elevated values of these two shape factors alone are not sufficient for a ^{90}Sr identification. The presence of ^{90}Sr can usually be inferred with confidence when SF2 significantly exceeds the extreme value (about 4.5) for a distant source. The interpretation may be aided by an SF2-SF1 cross plot. If ^{90}Sr is absent, then as the distance between the borehole and the inner edge of a (cylindrically symmetric) ^{137}Cs source increases, the points on the SF2-SF1 cross plot define a "trend line." ^{90}Sr is indicated if the SF2 values are so high that the points on the cross plot lie well above the trend line. However, a ^{90}Sr concentration of about 1,000 pCi/g is necessary to produce a noticeable increase in count rates (DOE 1997a).

2.2.3 Uncertainties of Shape Factor Analysis

The counts resulting from ^{137}Cs and ^{60}Co in the continuum windows are corrected for background by subtracting the counts contributed by the naturally occurring radionuclides ^{40}K, ^{238}U, and ^{232}Th from the continuum windows. Counting statistics for the gamma rays associated with ^{238}U and ^{232}Th are poor for the 100-s counting time typically used by the SGLS in borehole logging; accordingly, there may be a considerable relative statistical uncertainty in the peak intensity that is used to calculate any background correction. To minimize the effects of statistical counting uncertainties in the calculated background corrections, the corrections are calculated at each depth point, then filtered with a Gaussian smoothing function. The correction at a particular depth point is the average over a 5-ft interval that extends 2.5 ft above and 2.5 ft below the point. The other source of experimental uncertainty is systematic uncertainty in the stripping factors. Errors in these constants have been minimized with an heuristic approach, but, in general, the stripping constant errors are the ultimate limitation on the accuracy of the background corrections.

The use of shape factor analysis is currently limited to evaluating the distributions of ^{137}Cs and ^{60}Co and to identifying the presence of ^{90}Sr. At this stage of the method's development, other gamma-ray-emitting radionuclides (i.e., ^{125}Sb, ^{154}Eu, and ^{152}Eu) interfere with shape factor analysis. The number of other radionuclides present in a borehole is a quality indicator. Non-zero values of this indicator may mark intervals of a borehole that are unsuitable for the application of shape factor analysis.

2.3 Log Data and Plots

The results of the processing and analysis of the log data presented in Appendix A, "Spectral Gamma-Ray Logs for Boreholes in the Vicinity of Tank C-108," are grouped into a set of data for each borehole. Each set includes a Log Data Report and log plots showing radionuclide concentration versus depth.

Log plots are presented that show the spatial distribution of the detected man-made radionuclides. Plots of the natural gamma-ray-emitting radionuclides, at the same vertical scale as the man-made contamination plots, allows for interpretation of geologic information and the correlation of these data with the man-made contamination. Rerun sections in selected boreholes are used to check the logging system for data acquisition repeatability.

The log plots show the concentrations of the individual radionuclides or the total gamma count rate in counts per second in each borehole. Where appropriate, log plots show the statistical uncertainties in the calculated concentrations at the 95-percent confidence level (±2 standard deviations).

A combination plot for each borehole shows the individual natural and man-made radionuclide concentrations, the total gamma log, and the Tank Farms gross gamma log. The total gamma log is a plot of the total number of gamma rays detected during each spectrum measurement. The combination plot provides information on the relative contributions of individual radionuclides to the total gamma-ray count. The total gamma log also provides a means for comparing the spectral data with the historical Tank Farms gross gamma log data.

Separate plots showing the results of shape factor analysis of some of the SGLS data are included with each set of borehole plots. The values of CsSF1, CoSF1 (as applicable), SF2, the radionuclide abundance expressed as counts per second, and applicable quality indicators are shown on graphs on these plots. The general expected values for the CsSF1, CoSF1 (as applicable), and SF2 parameters for radionuclides distributed uniformly in the formation or on the outside of the casing are shown on the plots as vertical lines.

The Tank Farms gross gamma log data were collected with a nonspectral logging system previously used by DOE contractors for leak-detection monitoring at the Hanford Tank Farms. This system does not identify specific radionuclides, but its logs provide an important historical record for the individual boreholes and offer a basis for temporal comparison. The gross gamma logs shown on the plots in Appendix A are the latest data available.

Rerun sections in selected boreholes are used to check the logging system for data acquisition repeatability and are provided as separate plots. Radionuclide concentrations shown on these plots are calculated independently from the separate gamma-ray spectra provided by the original and repeated logging runs.

The Log Data Report provides borehole construction information, casing information, logging system identification, and data acquisition parameters used for each log run. A log run is a set of spatially sequential spectra that are recorded in the borehole with the same data acquisition parameters. A single borehole may have several log runs, often occurring on different days because of the length of time required to log the deeper boreholes. The Log Data Report also contains analysis information, including analysis notes and log plot notes.

3.0 Review of Tank History

3.1 C Tank Farm

3.1.1 Construction History

The C Tank Farm is located in the east portion of the 200 East Area, north of 7th Avenue and west of Canton Avenue. This farm was constructed during 1943 and 1944 to store high-level radioactive waste generated by chemical processing of irradiated uranium fuel from C Plant. The tank farm consists of four Type I and twelve Type II single-shell storage tanks. Vadose zone boreholes are located around the tanks for purposes of leak detection. Figure 2 shows the relative positions of the storage tanks and the vadose zone monitoring boreholes around them.

All 16 tanks in the C Tank Farm were constructed to the first-generation tank design and were designed for non-boiling waste with a temperature of less than 220 °F. The twelve Type II tanks are 75 ft in diameter and have capacities of 530,000 gallon (gal) each. The four Type I tanks are 20 ft in diameter and have capacities of 55,000 gal each. Other than diameter, the Types I and II tanks are of the same basic design (Brevick et al. 1994a and 1994b).

The Type II tanks are domed and steel-lined, with a maximum operating depth (cascade overflow level) of approximately 17 ft above the center of the dished tank base; the tank base is 1 ft lower at its center than at its edges. The storage portion of each tank is lined with a 0.25-in.-thick carbon-steel liner. The steel liners on the tank sides extend to 19 ft above the dished bottoms of the tank bases. The interiors of the concrete dome tops are not steel lined, but were treated with a magnesium zincfluosilicate wash. The tanks are entirely below the ground surface and are covered with approximately 7.25 ft of backfill material (Brevick et al. 1994a and 1994b).

The twelve type II tanks are connected in four three-tank cascade series. These cascade series consist of tanks C-101, -102, and -103, C-104, -105, and -106, C-107, -108, and -109, and C-110, -111, and -112. The tanks in the cascade series are arranged with each successive tank sited at an elevation 1 ft lower than the previous tank, creating a gradient allowing fluids to flow from one tank to another as they were filled. The four Type I tanks are connected with tie lines. The tie lines allow the tanks to overflow to other tanks in the series and equalize tank volumes (Brevick et al. 1994a and 1994b).

For primary internal leak detection, tanks C-103, -106, and -107 are each equipped with an ENRAF level detector and tank C-110 is equipped with a manual tape. Tanks C-101, -102, -104, -105, -108, -109, -111, -112, -201, -202, -203, and -204 are not equipped with primary leak-detection sources (Hanlon 1997).

3.1.2 Geologic and Hydrologic Setting

Excavation for the construction of the C Tank Farm occurred in glaciofluvial sediments of the Hanford formation. These sediments consist primarily of cobbles, pebbles, and coarse to

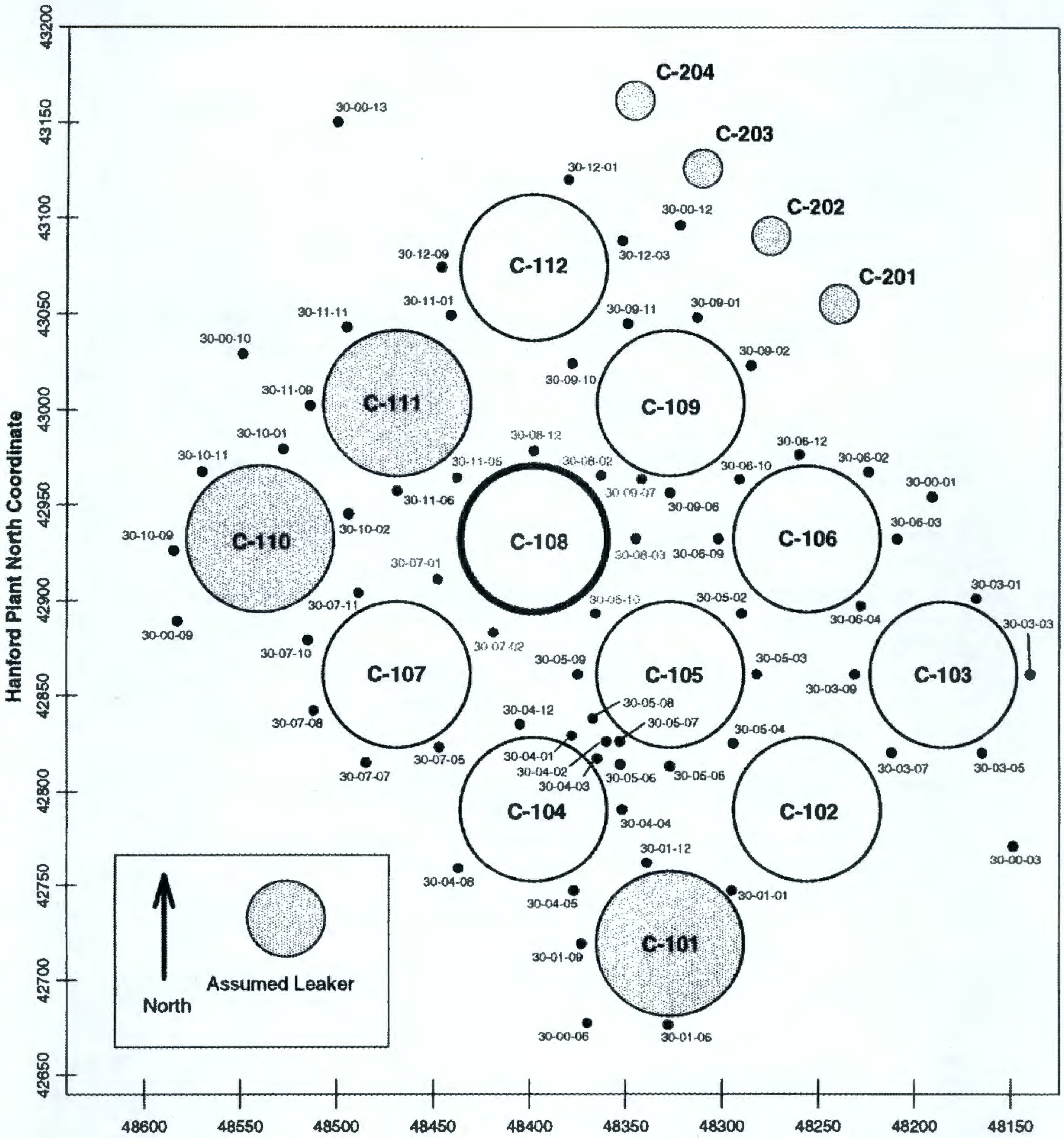

Figure 2. Plan View of Tanks and Boreholes in the C Tank Farm

medium sands with some silts. The excavated sediments were used as backfill around the completed tanks (Price and Fecht 1976).

Beneath the backfill material are the undisturbed sediments of the Hanford formation. The Hanford formation sediments consist of pebble to boulder gravel, fine- to coarse-grained sand, and silt. Three distinct facies were recognized by Lindsey (1992): gravel-dominated, sand-dominated, and silt-dominated (ordered from top to bottom of the formation). Baker et al. (1991) named these facies the coarse-grained deposits (generally referred to as the Pasco Gravels), the plane-laminated sand facies, and the rhythmite facies (commonly referred to as the Touchet Beds), respectively. The Hanford formation sediments extend to a depth of about 225 ft in the vicinity of the C Tank Farm (Lindsey 1993).

The distribution and similarities in lithologic succession of the facies types described above indicate the Hanford formation can be divided into three stratigraphic sequences across the 200 East Area. These sequences are designated: 1) upper gravel, 2) sandy, and 3) lower gravel. The sequences are composed mostly of the gravel-dominated and sand-dominated facies. The silt-dominated facies are relatively rare except in the southern part of the 200 East Area. Because of the variability of Hanford deposits, contacts between the sequences can be difficult to identify (DOE 1993).

In the vicinity of the C Tank Farm, the upper gravel sequence is dominated by deposits typical of the gravel-dominated facies of the Hanford formation. Lesser occurrences of the sand-dominated facies are encountered locally (DOE 1993). The upper gravel sequence consists of well-stratified gravels with lenticular sand and silt interbeds and extends to a depth of approximately 61 to 73 ft (23 to 35 ft below the base of the tank farm excavation). Strata within this interval generally dip to the east-southeast and thin to the south (Lindsey 1993). However, strata near the transition from the gravel-dominated to the sand-dominated facies locally dip to the north and east (Price and Fecht 1976).

The sandy sequence generally consists of deposits typical of the sand-dominated facies of the Hanford formation (DOE 1993). The sandy sequence is characterized by well-stratified coarse- to medium-grained sand with minor pebble and lenticular silt interbeds less than 1 ft thick. Localized silty intervals greater than 1 ft thick may be present and could potentially host perched water horizons that would probably not be laterally extensive because of pinchouts and clastic dikes. The sandy sequence extends to a depth of approximately 198 ft (Lindsey 1993).

The lower gravel sequence of the Hanford formation is dominated by deposits typical of the gravel-dominated facies. Local intercalated intervals of the sand-dominated facies are also found (DOE 1993). This unit is composed of interbedded sands and gravels with few silt interbeds. Perched water is considered unlikely in this unit. The lower gravel sequence is about 27 ft thick and extends to a depth of approximately 225 ft (Lindsey 1993).

The Ringold Formation directly underlies the Hanford formation in the vicinity of the C Tank Farm. The Ringold Formation is approximately 70 ft thick and extends to a depth of 295 ft. A thin, discontinuous silt-rich layer that dips to the south and pinches out to the north and west is present in the southern portion of the tank farm. Perched water may occur at the top of this unit. A variably cemented pebble to cobble gravel with a sand matrix occurs stratigraphically below the silt-rich layer. This gravel may contain mud interbeds that could cause perched water to form if the mud is cemented or well enough developed (Lindsey 1993).

In the vicinity of the C Tank Farm, the uppermost aquifer occurs within the Ringold Lower Mud Unit at a depth of approximately 245 ft (Lindsey 1993; PNNL 1997). This uppermost aquifer is generally referred to as the unconfined aquifer, but includes locally confined to semi-confined areas DOE 1993).

The Ringold Formation is underlain by the Columbia River Basalt Group, which includes approximately 50 basalt flows. Sandwiched between the various basalt flows are sedimentary interbeds, collectively called the Ellensberg Formation. The Ellensberg Formation consists of mud, sand, and gravel deposited between volcanic eruptions. These sediments and porous flow tops and bottoms form confined aquifers that extend across the Pasco Basin (PNNL 1997).

At the Hanford Site, recharge of the unconfined aquifer by precipitation is highly variable depending on climate, vegetation, and soil texture. Recharge from precipitation is highest in coarse-textured soils with little or no vegetation (PNNL 1997). Fayer and Walters (1995) estimate that recharge to the unconfined aquifer in the area of the C Tank Farm is approximately 2 to 4 in. per year.

For more detailed information about the geology and hydrogeology below the C Tank Farm, the reader is referred to the following documents: Price and Fecht (1976), Caggiano and Goodwin (1991), Lindsey (1993), Lindsey (1995), and PNNL (1997).

3.1.3 Tank Contents

The C Tank Farm received a variety of waste types beginning in 1945. Initially, tanks C-101, -102, -103, -104, -105, and -106 received metal waste, and tanks C-107, -108, -109, -110, -111, and -112 received byproduct cake solution and waste solution from the first decontamination waste cycle (referred to collectively as first-cycle waste). Tanks C-201, -202, -203, and -204 were used to settle waste to allow the supernatant liquid to be sent to a crib (Brevick et al. 1994b). Over their operating life, the C Tank Farm tanks also received B-Plant decontamination waste, U Plant waste, cladding wastes, PUREX Plant fission product waste, waste water, and other waste types (Agnew 1997). A large amount of strontium from the PUREX Plant fission product waste remains in tank C-106 and has caused a high heat load in the tank (Brevick et al. 1994b).

The tanks in the C Tank Farm currently contain an estimated 1,976,000 gal of mixed wastes (Hanlon 1997) consisting primarily of various cladding wastes, tributyl phosphate and uranium recovery wastes, and sludge produced by in-tank scavenging (Agnew 1997). Detailed descriptions of the waste streams are presented in Anderson (1990) and Agnew (1995 and 1997). On the basis of information presented in Agnew (1997), some of the principal radionuclides in the tank wastes include ^{90}Sr, ^{137}Cs, ^{144}Ce, ^{151}Sm, ^{239}Pu, ^{240}Pu, ^{241}Pu, ^{63}Ni, ^{137m}Ba, ^{155}Eu, and ^{154}Eu.

The wastes currently contained in the C Tank Farm tanks are in the form of sludge, supernatant liquid, and interstitial liquid. Sludge is composed of a solid precipitate (hydrous metal oxides) that results from the neutralization of acid waste. The wastes were neutralized before being transferred to the tanks. Sludge forms the "solids" component of the tank waste. Liquids are present as supernatant and interstitial liquids. Supernatant liquid floats on the surface of the solid waste and interstitial liquid fills the interstitial voids within the solid waste. Interstitial liquid may be drainable if it is not held in the interstitial voids by capillary forces.

3.1.4 Tank Farm Status

All the tanks in the C Tank Farm were removed from service during the late 1970s and early 1980s (Brevick et al. 1994a). Nine tanks in the C Tank Farm are categorized as sound (C-102, -103, -104, -105, -106, -107, -108, -109, and -112), and seven are categorized as assumed leakers (C-101, -110, -111, -201, -202, -203, and -204) (Hanlon 1997). The tanks in the C Tank Farm that have been designated as "assumed leakers" are identified on Figure 2.

All the tanks in the C Tank Farm, except tanks C-103 and C-106, have been interim stabilized, and all the tanks, except tanks C-103, -105, and -106, have intrusion prevention completed. Tanks C-103, -105, and -106 have been partial interim isolated (Hanlon 1997).

Currently, tanks C-102 and C-103 are on the Organics Watch List and tank C-106 is on the High-Heat Load Watch List (Hanlon 1997). SSTs are added to a watch list because the waste in the tanks may be in a potentially unsafe condition and the handling of the waste material requires corrective action or special monitoring to reduce or eliminate the hazard. Resolution of the safety issues has been codified under Public Law 101-510 (generally known as the Wyden Amendment).

3.2 Tank C-108

Tank C-108 was constructed during 1943 and 1944 and was placed into service in September 1947 (Welty 1988). The tank received first-cycle waste from tank C-107 (Anderson 1990) and was full by March 1948. The tank waste began cascading to tank C-109 in March 1948; the entire C-107-to-C-109 cascade series was full by September 1948. During the second quarter of 1952, the first-cycle waste was pumped to tank B-106 (B Tank Farm). The tank received U-Plant waste intermittently from the fourth quarter of 1952 until the fourth quarter of 1960. The overflow line from tank C-108 to tank C-109 became plugged in December 1952 (Anderson 1990). The tank also received some first-cycle waste, evaporator bottoms, in-tank ferrocyanide waste, and waste water in 1957 (Anderson 1990; Agnew 1996). The U-Plant waste was pumped into ditches in the third quarter of 1956 and to a trench in the first quarter of 1958 (Anderson 1990). Tank C-108 received numerous waste types between 1961 and 1976, including coating waste, PUREX cladding waste, strontium recovery waste, semi-works waste, organic wash waste, and ion-exchange waste (Anderson 1990; Agnew 1996). Presently, the tank waste is classified as noncomplexed (Brevick et al. 1994b).

Dukelow (1974) reports that borehole 30-08-02, located halfway between tanks C-108 and C-109, had a steady increase in radiation levels at a depth of 48 ft between October 1974 and January 1975. However, there was no liquid-level decrease in tank C-108 or C-109 before or during this period. The radiation increase was assumed to be the result of lateral migration of existing contamination.

Jensen (1976) reports that a surface-level decrease of 0.5 in. occurred in tank C-108 in July 1976. The decrease was evaluated as a slow surface response to salt-well pumping, which began in early 1976. The pumping activity, performed through August 1976, was reported to have removed essentially all the liquid contents of the tank. The surface-level decrease was considered to be a settling of the solid waste in the tank as the liquid was removed.

Tank C-108 was declared inactive in late 1977. Intrusion prevention was completed by December 1982. A level adjustment was made in February 1984 to compensate for settling. Because the interstitial liquid had been removed, no further stabilization action was required; the tank was declared administratively stabilized in March 1984 (Brevick et al. 1994b).

The surface level of the waste in tank C-108 is monitored with a manual tape. The liquid waste volume is determined by the manual tape surface-level gauge, and the solid waste volume is determined by a sludge-level measurement device. There is no criterion for a surface-level decrease. The surface level of the tank waste, measured from 1991 to 1994, indicates fluctuating data with readings ranging between 18.25 and 20 in. (Brevick et al. 1994a). The tank is not equipped with liquid observation instrumentation (Hanlon 1997). The monitoring boreholes surrounding tank C-108 are the primary means of leak detection (Welty 1988).

Tank C-108 is categorized as sound with interim stabilization and intrusion prevention completed. The tank is currently listed as containing noncomplexed waste that consists of 66,000 gal of sludge, with no interstitial liquid remaining (Hanlon 1997).

4.0 Boreholes in the Vicinity of Tank C-108

Eight vadose zone monitoring boreholes surround tank C-108. These boreholes are 30-08-02, 30-09-07, 30-08-03, 30-05-10, 30-07-02, 30-07-01, 30-11-05, and 30-08-12. Boreholes 30-08-02, 30-08-03, and 30-08-12 are associated with tank C-108. Boreholes 30-07-01 and 30-07-02 are associated with tank C-107. Boreholes 30-05-10, 30-09-07, and 30-11-05 are associated with tanks C-105, -109, and -111, respectively. The locations of these boreholes are shown in red on Figure 2.

All the boreholes, except borehole 30-08-03, are lined with 6-in.-inside-diameter steel casing. Borehole 30-08-03 is lined with 8-in.-inside-diameter steel casing; a section of 12-in.-inside-diameter steel casing surrounds the upper portion of the 8-in. casing.

The algorithms used for the calculation of the radionuclide concentrations from the SGLS data incorporate a correction for the attenuation of the gamma-ray intensity by the borehole casing walls. The surface exposures of most the borehole casings are flush with small-diameter concrete pads, making accurate measurements of the borehole casing wall thicknesses difficult. Therefore, the casing wall thicknesses for the seven 6-in. boreholes and the single 8-in. borehole are assumed to be 0.280 in. and 0.322 in., respectively, on the basis of the published thickness for schedule-40, carbon-steel casing. The algorithm used for the calculation of radionuclide concentrations in borehole 30-08-03 does not include an attenuation correction factor for the region of the borehole containing the 12-in. casing. As a result, calculated radionuclide concentration values are reduced by approximately 45 to 50 percent along the dual-cased interval of the borehole.

The boreholes surrounding tank C-108 are completed above the water table and contain no water. The SGLS data were collected in the move/stop/acquire logging mode with a 100-s acquisition time at 0.5-ft depth intervals.

In 1993, Westinghouse Hanford Company (WHC) performed spectral gamma logging of 14 boreholes surrounding tanks C-105 and C-106 using the Radionuclide Logging System (RLS). This system is the intrinsic germanium logging system that was the predecessor to the SGLS. Borehole 30-05-10 was one of the 14 boreholes included in the RLS logging operation; it is also one of the boreholes located near tank C-108 that was logged by the SGLS. The 1993 RLS data are quantitative spectral gamma-ray log data and are of sufficient high quality to allow comparison to the 1997 SGLS data. Individual plots that compare the measured concentrations of man-made radionuclides for borehole 30-05-10 from 1993 and 1997 are included in Appendix A. A more detailed discussion about the characteristics of the RLS detector is included in the Tank Summary Data Reports for tanks C-105 (DOE 1997e) and C-106 (DOE 1997f).

Shape factor analysis was applied to spectral gamma data obtained from all the boreholes surrounding tank C-108. Data from specific boreholes that yielded generally conclusive and supportive shape factor results are illustrated on individual plots included in Appendix A.

The following sections present results of the spectral gamma-ray log data collected from the boreholes surrounding tank C-108. Appendix A contains the plots of the SGLS log data, a plot of the RLS log data from borehole 30-05-10, and plots showing shape factor results for boreholes 30-08-02, 30-09-07, 30-07-02, 30-07-01, and 30-08-12. The most recent historical gross gamma data are included on the combination plots in Appendix A. The SGLS and RLS data, shape factor analysis results, historical gross gamma logs from 1975 to 1996, and results from other investigations were used in the preparation of this report.

4.1 Borehole 30-08-02

Borehole 30-08-02 is located approximately 7 ft from the northeast side of tank C-108 and was given the Hanford Site designation 299-E27-94. This borehole was drilled in September 1974 to a depth of 100 ft using 6-in. casing. A drilling log was not available for this borehole; however, information presented in Chamness and Merz (1993) indicates that the borehole was not grouted or perforated. The top of the casing, which is the zero depth reference for the SGLS, is assumed to be flush with the ground surface. The total logging depth achieved by the SGLS was 99.0 ft.

The man-made radionuclides ^{137}Cs, ^{60}Co, and ^{154}Eu were detected in this borehole. The ^{137}Cs contamination was detected continuously from the ground surface to 24.5 ft, including two highly contaminated zones. A near-surface zone of high ^{137}Cs contamination (30 to 600 pCi/g) extends to a depth of 3 ft. Low levels of ^{137}Cs contamination occur between 3.5 and 18.5 ft with concentrations generally less than 1 pCi/g. A discrete subsurface zone of very high ^{137}Cs contamination (150 to 1,100 pCi/g) was detected from 20 to 22 ft. An isolated zone of weak ^{137}Cs contamination (less than 0.5 pCi/g) was detected from 47 to 49 ft.

A zone of moderate to high ^{60}Co contamination was detected from 46.5 to 79.5 ft. The highest ^{60}Co concentrations (about 7 to 10 pCi/g) were detected within the middle portion of this zone between 58 and 62.5 ft. The ^{60}Co contamination delineates an extensive contaminant plume located at considerable depth below the shallow subsurface ^{137}Cs contamination.

An isolated occurrence of ^{154}Eu was detected at a depth of 2.5 ft. A thin, nearly continuous zone of ^{154}Eu contamination, with concentrations ranging from 1 to 24 pCi/g, was detected from 19.5 to 22.5 ft.

The ^{40}K concentration values increase at 37.5 ft and generally remain elevated to a depth of 72.5 ft. The ^{40}K concentrations become increasingly variable between 55 and 74.5 ft. The ^{40}K concentration values increase again at 74.5 ft and remain elevated to the bottom of the logged interval. Although a drilling log was not available to support or contradict the KUT data, the increase in the ^{40}K concentrations at 37.5 ft probably represents a change in lithology from backfill material to the undisturbed gravel-dominated facies of the Hanford formation. The variable ^{40}K concentrations between 55 and 74.5 ft may represent sand or silt interbeds within the gravel-dominated facies. The increase in the ^{40}K concentration values at 74.5 ft may represent the contact between the gravel- and sand-dominated facies of the Hanford formation.

It was not possible to identify any of the 609-keV peaks used to derive the ^{238}U concentrations from 18 to 23.5 ft. In addition, it was not possible to identify any of the 1460- and 2614-keV peaks used to derive the ^{40}K and ^{232}Th concentrations between 20 and 22 ft. The KUT data were absent between 20 and 22 ft because this interval was logged by the SGLS in real time because the dead time exceeded 50 percent. Outside this region, the 609-keV peaks were not identified because high gamma-ray activity associated with the nearby ^{137}Cs peak (661 keV) created an elevated Compton continuum extending to the 609-keV region, causing the MDL to exceed the measured ^{238}U concentration. Furthermore, it was not possible to identify most of the 609-keV peaks in the lower region of the borehole between 57.5 and 65 ft. In this case, the high gamma-ray activity associated with the nearby ^{60}Co peaks (1173 and 1333 keV) created an elevated Compton continuum extending to the 609-keV region, causing the MDL to exceed the measured ^{238}U concentration.

The SGLS total gamma-ray plot reflects the distribution of the ^{137}Cs, ^{60}Co, and ^{154}Eu contamination around this borehole and some variations of the naturally occurring radionuclides in the contaminant-free depth intervals. The sharp increases in the count rate correspond closely with the zones of highly concentrated ^{137}Cs contamination and the isolated zone of ^{154}Eu contamination shown on the SGLS man-made plot. The zone of elevated total count rates between 45 and 80 ft corresponds closely with the ^{60}Co contamination detected by the SGLS. The relative increase in the total count rate at about 37 ft corresponds with the increase in the ^{40}K concentrations at this depth. The slight increase in the count rate near the bottom of the logged interval corresponds to the increases in the ^{40}K and ^{232}Th concentrations at this depth.

The historical gross gamma log data from 1980 to 1989 were reviewed. The most recent historical gross gamma data are presented on the combination plot. The gross gamma activity reflects the near-surface and shallow subsurface ^{137}Cs contamination shown on the SGLS plot. However, the gross gamma data do not reflect the distribution of the distinct subsurface ^{60}Co plume detected by the SGLS. A zone of elevated gross gamma activity occurs between 74 and 80 ft that does not correspond with any radionuclides illustrated by the SGLS plot. It is possible that the anomalous activity may have represented other short-lived radionuclides, such as ^{106}Ru or ^{125}Sb, that have decayed to less than detectable levels since 1989.

Summaries of the historical gross gamma log data from 1974 to 1987 presented in Welty (1988) identify the peak gamma-ray activity levels below a depth of 20 ft. Significant activity peaks were identified at depths of 21 and 48 ft on the earliest recorded log (October 1974).

The upper activity peak correlates to the depth of the ^{137}Cs and ^{154}Eu contamination detected on the SGLS plot. The activity peak shifted in depth as much as 5 ft, which is probably attributable to the depth-control problems related to the gross gamma system. In general, the anomalous activity at 21 ft gradually decreased in intensity from 1974 to 1980, possibly indicating the radioactive decay of the ^{154}Eu. The activity peak was no longer reported after 1980.

The lower activity peak was identified at 48 ft in November 1974. The activity peak increased in intensity until July 1975, then progressively decreased in intensity and slowly migrated to a depth of 75 ft by 1986.

Representative historical gross gamma-ray logs acquired between 1980 and 1989 are presented on a log plot included in Appendix A. The log-plot sequence illustrates the near-surface ^{137}Cs contamination detected on the SGLS plot and shows that this contamination probably originated sometime between January 1982 and June 1984. The log-plot sequence shows that the near-surface ^{137}Cs contamination did not migrate nor decrease in intensity during the reporting period.

The subsurface ^{137}Cs and ^{154}Eu contamination shown on the SGLS plot from 20 to 22 ft is also evident on the log-plot sequence. This contamination appears to have migrated downward as far as 4 ft through the vadose zone since 1980; however, the apparent movement may be attributable to the depth-control problems associated with the gross gamma system discussed previously.

In 1980, a large count-rate anomaly is evident on the log-plot sequence within the region of ^{60}Co contamination shown on the SGLS plot. Similar to the data reported in Welty (1988), the activity peak decreased in intensity and slowly migrated downward to a depth of 76 ft by 1986.

No further migration occurred from 1986 to 1989, but the intensity of the activity peak continued to decrease to about one-ninth of the count rate measured in 1980. Based on decay-rate calculations from the gross gamma log data, the decrease in the gross gamma activity between 1984 and 1988 indicates that both ^{106}Ru and ^{125}Sb may have been present within the contaminant plume during that time.

Plots of the spectrum shape factors as described in DOE (1997a) are included in Appendix A. The ^{137}Cs shape factor analysis results indicate that the ^{137}Cs contamination detected between 1 and 4 ft occurs as a thin zone within the formation. The CsSF1 values indicate that the ^{137}Cs contamination detected between 13 and 17 ft is distributed uniformly in the formation but becomes increasingly remote to the borehole below 17 ft. The CsSF1 and SF2 values between 17 and 23 ft are indicative of a line-source remote from the borehole. The ^{60}Co shape factor results indicate that the ^{60}Co contamination detected between 50 and 80 ft is distributed uniformly in the formation. The CoSF1 values along this interval are very close to the range expected for a uniform contaminant distribution.

The near-surface zone of ^{137}Cs contamination may have resulted from a large surface spill that migrated down into the backfill surrounding the borehole. On the basis of historical gross gamma log data, it appears that the spill occurred sometime between January 1982 and June 1984.

The distinct zone of ^{137}Cs and ^{154}Eu contamination detected between 19 and 23.5 ft may be the result of a leak from the C-108-to-C-109 cascade line; however, no documentation was available to indicate such a leak occurred. The discrete nature of the contaminant distribution suggests that this borehole is located near the C-108-to-C-109 cascade line. As discussed in Section 3.2, the cascade line became plugged in 1952. Consequently, the ^{137}Cs and ^{154}Eu contamination detected may consist of residual waste contained within the cascade piping. The shape factor analysis data indicate that this contamination is remote to the borehole, supporting the theory that it may be isolated to the region along the inside of the cascade line.

The zone of slightly increased ^{137}Cs between 13 and 17 ft suggest that contamination from the C-108-to-C-109 cascade line may have migrated upward into this region of the vadose zone, possibly during the time period that the cascade line was plugged. The shape factor analysis results indicate that most of this contamination is uniformly distributed in the formation around the borehole.

The zone of ^{137}Cs contamination detected from 47 to 49 ft may have originated from a surface spill or subsurface leak that migrated along the outside of the tank to the base of the tank footing, where it then preferentially migrated both downward and laterally within one of the basal gravel units below the tank farm excavation.

The significant zone of ^{60}Co contamination that underlies the base of the tank farm excavation probably originated from a leak from one of the tanks in the vicinity, including tank C-108. The shape factor analysis indicates that the contamination is distributed uniformly within the formation and is not confined to the vicinity of the casing. It is postulated that the ^{60}Co

contamination was originally identified in Welty (1988) at a depth of 48 ft in 1974. Historical gross gamma logs indicate that the contaminant plume migrated to a depth of 60 ft by 1980. The gross gamma log-plot sequence indicates that other short-lived radionuclides, such as ^{106}Ru and ^{125}Sb, may have initially coexisted with the ^{60}Co contamination and slowly migrated to deeper portions of the vadose zone between 1980 and 1986, but have since decayed to levels below the detection limit of the SGLS.

4.2 Borehole 30-09-07

Borehole 30-09-07 is located approximately 23 ft from the northeast side of tank C-108. It was given the Hanford Site designation 299-E27-135. This borehole was drilled in March 1982 to a depth of 125 ft using 6-in. casing. A drilling log was not available for this borehole; however, information presented in Chamness and Merz (1993) indicates that the borehole was grouted but not perforated. The depth of the grouted interval was not specified. The top of the casing, which is the zero depth reference for the SGLS, is approximately 2.5 ft above the ground surface. The total logging depth achieved by the SGLS was 124.5 ft.

The man-made radionuclides ^{137}Cs and ^{60}Co were detected in this borehole. The ^{137}Cs contamination was detected continuously from the ground surface to 9.5 ft and nearly continuously from 16.5 to 35.5 ft. An isolated zone of ^{137}Cs contamination was detected from 11.5 to 12.5 ft. A near-surface zone containing low to moderate ^{137}Cs concentrations (2 to 13 pCi/g) extends to a depth of 6 ft. The ^{137}Cs concentrations generally decrease to less than 1 pCi/g below this zone. The highest ^{137}Cs concentration (139 pCi/g) was detected at the ground surface. However, as described in Section 2.1, this is not an accurate concentration value because the source-to-detector geometry at the top of the borehole casing differs from source-to-detector geometry used in the calibration.

A continuous zone of ^{60}Co contamination was detected from 79 to 83.5 ft. The highest ^{60}Co concentration within this zone was about 1.7 pCi/g at a depth of 80 ft. A few low concentrations of ^{60}Co (0.1 to 0.2 pCi/g) were detected between 85 and 92.5 ft. The ^{60}Co distribution delineates a small contaminant plume located at considerable depth below the near-surface ^{137}Cs contamination.

The steady decrease in the ^{40}K concentration values from 26.5 to 40 ft is uncharacteristic compared to ^{40}K concentration profiles from other nearby boreholes. Information presented in Chamness and Merz (1993) indicates that the borehole was grouted but does not specify the grouted interval. Grout is sometimes added to stabilize sloughing portions of a borehole. After the grout hardens, the borehole is advanced through the grout plug. It is possible that the relatively lower ^{40}K concentrations between 26.5 and 40 ft indicate the presence of residual grout along this interval of the borehole.

The ^{40}K concentration values increase significantly from 40 to 41.5 ft and remain elevated to a depth of 73.5 ft. The ^{40}K concentration values increase again at 74 ft and remain elevated to a depth of about 118 ft. Although a drilling log was not available to support or contradict the KUT data, the increase in the background ^{40}K concentrations at 40 ft probably represents a change in lithology from backfill material to the undisturbed gravel-dominated facies of the Hanford formation. However, this increase could also mark the lower edge of the residual grout suspected to remain in this borehole. The increase in the ^{40}K concentration values at 74 ft may represent the contact between the gravel- and sand-dominated facies of the Hanford formation.

It was not possible to identify most of the 609-keV peaks used to derive the ^{238}U concentrations between the ground surface and 3.5 ft. This occurred because high gamma-ray activity associated with the nearby ^{137}Cs peak (661 keV) created an elevated Compton continuum extending to the 609-keV region, causing the MDL to exceed the measured ^{238}U concentration.

The SGLS total gamma-ray plot reflects the distribution of ^{137}Cs contamination in the upper region of the vadose zone, the ^{60}Co contamination in the lower region, and the naturally occurring radionuclides in the contaminant-free depth intervals. The count rate increases sharply at about 40 ft, corresponding to the increase in the ^{40}K concentration values at this depth. The count rate gradually decreases from 115 ft to the bottom of the logged interval, corresponding with decreases in the ^{40}K and ^{238}U concentrations along this depth interval.

The historical gross gamma log data from 1982 to 1994 were reviewed. The most recent historical gross gamma data are presented on the combination plot. The plot illustrates the near-surface ^{137}Cs contamination shown on the SGLS plot. A review of the historical data indicates that this contamination probably originated sometime between May 1982 and June 1984, and it does not appear to have migrated nor decreased in intensity during the reporting period. A slightly anomalous count rate occurs at a depth of 81 ft that may represent the ^{60}Co contamination detected by the SGLS within this region. This activity was evident at significantly higher count rates and at a slightly shallower depth on the earliest recorded historical gross gamma log (April 1982), indicating that some type of man-made contamination was present in this region of the vadose zone at that time.

Summaries of the historical gross gamma log data from 1982 to 1986 are presented in Welty (1988). An activity peak was identified at a depth of 76 ft in early 1982. The peak progressively decreased in intensity and slowly migrated downward to a depth of 81 ft by 1986. The rate at which the gross gamma counts diminished between 1982 and 1986 suggests that other short-lived radionuclides, such as ^{106}Ru or ^{125}Sb, may have augmented the ^{60}Co contamination detected by the SGLS at this depth, but have since decayed away. It was not possible to calculate reliable decay rates from the gross gamma log data because of the high counting uncertainty of the data.

Plots of the spectrum shape factors are included in Appendix A. Because the borehole casing rises approximately 0.5 ft above a 2-ft-high berm, the shape factor data collected from the upper 2.5 ft of the logged interval will not be considered in determining the distribution of contamination around this portion of the borehole casing. Below this interval, the ^{137}Cs shape factor results suggest that the ^{137}Cs contamination detected within the upper 3.5 ft of the backfill material (between 2.5 and 6 ft below the top of the casing) is distributed uniformly in the formation. Although the CsSF1 values within this zone are in excess of 20, the associated SF2 values are very close to those expected for a uniform distribution.

Valid ^{60}Co shape factor results could only be calculated for a small region at about 80 ft. These data indicate that the ^{60}Co contamination is in the formation rather than on the casing but is not uniformly distributed.

The near-surface zone of ^{137}Cs contamination probably resulted from a surface spill that has migrated down into the backfill surrounding the borehole. On the basis of historical gross gamma log data, it appears that the spill occurred sometime between May 1982 and June 1984. The shape factor analysis results suggest that this contamination is distributed uniformly in the formation around the borehole.

The isolated zone of ^{137}Cs contamination detected between 11.5 and 12.5 ft may represent surface contamination that has migrated along the surface of the tank dome into this region of the vadose zone. Most of the ^{137}Cs contamination detected below 15 ft was probably carried down during the drilling of this borehole or later migrated down the outside of the borehole casing.

The zone of ^{60}Co contamination detected between 79 and 92.5 ft probably represents the remnant of a plume that resulted from a remote subsurface source, such as a tank leak. The contamination appears to be related to the extensive ^{60}Co plume detected in borehole 30-08-02.

4.3 Borehole 30-08-03

Borehole 30-08-03 is located approximately 12 ft from the east side of tank C-108. It was given the Hanford Site designation 299-E27-51. This borehole was drilled in December 1944 to a depth of 150 ft. The borehole was started with a 50-ft length of permanent 12-in. surface casing and was completed to a nominal depth of 150 ft using 8-in. casing. The 8-in. casing was perforated from 48 to 148 ft and, according to the drilling log, the bottom of the 8-in. casing was sealed with half a sack of cement. The drilling log does not indicate if the annulus between the 8-in. and 12-in. casings was grouted. The thicknesses of the 8-in. and 12-in. casings are presumed to be 0.322 in. and 0.406 in., respectively. The top of the 8-in. casing, which is the zero depth reference for the SGLS, is approximately flush with the ground surface. The total logging depth achieved by the SGLS was 50.0 ft.

The current total depth of the borehole was measured at 50.5 ft below the top of the casing using a weighted tape, although this borehole was drilled to a total depth of 150 ft in 1944. The earliest historical gross gamma log (January 1975) recorded a depth of 58 ft. Since that time, the depths of the gross gamma log runs have become progressively shallower, decreasing to 50 ft by 1994. This decrease in depth indicates that the casing perforations have allowed loose sand to infiltrate into and slowly fill the borehole, or sand and silt has entered the hole from the ground surface.

The man-made radionuclides ^{137}Cs, ^{60}Co, ^{235}U, and ^{152}Eu were detected in this borehole. The ^{137}Cs contamination was measured continuously from the ground surface to the bottom of the logged interval (50 ft). A very shallow, near-surface zone of low ^{137}Cs contamination extends to a depth of 1.5 ft. Below this zone, the ^{137}Cs concentrations gradually diminish with depth to less than 0.5 pCi/g, then increase to about 4 pCi/g at the bottom of the logged interval. The highest concentration of ^{137}Cs (92 pCi/g) was detected at the ground surface. However, as described in Section 2.1, this is not an accurate concentration value because the source-to-detector geometry at the top of the borehole casing differs from source-to-detector geometry used in the calibration.

The presence of ^{60}Co and ^{235}U was detected at the ground surface with apparent concentrations of 0.09 pCi/g and 9.52 pCi/g, respectively. However, these are probably not accurate concentration values for reasons discussed previously. The gamma rays probably originated from an above-ground source, such as nearby contaminated equipment or contamination that is localized to the ground surface.

A single occurrence of ^{152}Eu was detected at a depth of 40.5 ft with a concentration of 0.28 pCi/g.

The ^{137}Cs concentrations measured between the ground surface and the bottom of the logged interval are reduced by the attenuation of the 661-keV gamma-ray energies along the double-cased interval of this borehole. Compared to ^{40}K concentration values obtained from nearby double-cased boreholes in the C Tank Farm, the radioassays for the ^{40}K concentration values may be reduced as much as 40 percent along this interval. As a result, the profile of the ^{137}Cs concentration values detected by the SGLS is not representative of the actual contaminant concentrations. In addition, potentially low ^{60}Co and ^{152}Eu concentrations within the backfill material may not have been detected by the SGLS because the ^{60}Co and ^{152}Eu radioassays may have been reduced below the detection limit along the double-cased interval.

As discussed previously, relatively lower ^{40}K concentration values were detected along the length of the logged interval, corresponding with the double-cased interval of the borehole. The presence of the 12-in. outer casing along this interval has attenuated the 1460-keV gamma ray, resulting in ^{40}K concentration values that are approximately 45 to 50 percent of the ^{40}K concentration values obtained from adjacent single-cased properly corrected boreholes in the C Tank Farm. Similarly, the 609-keV and 2614-keV gamma rays are attenuated by the double-cased interval, resulting in reduced ^{238}U and ^{232}Th concentration values. Furthermore, many of the 609-keV gamma-ray energies in this region were not detected by the SGLS because the ^{238}U radioassays were reduced below the detection limit by casing attenuation.

Despite the attenuation effects from the double-cased interval, the ^{40}K concentration values show an increase at a depth of 37 ft and remain elevated to the bottom of the logged interval. Although the drilling log was not detailed enough to either support or contradict the KUT data, the increase in the ^{40}K concentrations at 37 ft probably represents a change in lithology from backfill material to the undisturbed gravel-dominated facies of the Hanford formation.

The SGLS total gamma-ray plot reflects the presence of the man-made radionuclides in the near-surface portion of the borehole and at the bottom of the logged interval. The increase in the SGLS total count rate between 49 and 50 ft corresponds with the significant increase in the ^{137}Cs concentration values detected by the SGLS and may indicate the top of the perforations in the 8-in. borehole casing or the bottom of the 12-in. surface casing.

The historical gross gamma log data from 1975 to 1994 were reviewed. The most recent historical gross gamma data are presented on the combination plot. The plot does not illustrate the near-surface peak that is shown on the SGLS plots because no data were collected at the 1-ft and 2-ft intervals. Furthermore, this peak is not clearly evident on many of the historical gross gamma logs that were reviewed.

The attenuation of the 661-keV gamma-ray energies along the double-cased interval reduced most of the ^{137}Cs contaminant count rates to levels below the lower limits at which shape factors can be produced. As a result, the ^{137}Cs shape factor analysis results were generally inconclusive and were not used to determine the distribution of the ^{60}Cs contamination around this borehole.

The near-surface zone of ^{137}Cs contamination probably resulted from surface spills that migrated down into the backfill surrounding the borehole. Some of the ^{137}Cs concentrations detected below this contamination may have migrated down the outside of the borehole casing. However, the attenuation of the 661-keV gamma-ray energies along the double-cased interval make it difficult to ascertain if the deeper ^{137}Cs contamination resulted from a nearby subsurface source. Furthermore, the vertical extent of the contamination cannot be determined because of the limited depth logged by the SGLS.

4.4 Borehole 30-05-10

Borehole 30-05-10 is located approximately 9 ft from the southeast side of tank C-108 and was given the Hanford Site designation 299-E27-68. This borehole was drilled in November 1972 to a depth of 135 ft using 6-in. casing. The drilling report does not indicate if the borehole casing was perforated or grouted. The top of the casing, which is the zero depth reference for the SGLS, is approximately flush with the ground surface. However, the current total depth of the borehole was measured at 135.8 ft below the top of the casing using a weighted tape, indicating that the borehole casing was probably extended to accommodate fill material that was added to the surface of the tank farm after the borehole was completed. The total logging depth achieved by the SGLS was 135.5 ft.

The man-made radionuclides ^{137}Cs, ^{60}Co, and ^{235}U were detected in this borehole. A zone of low ^{137}Cs contamination, with concentrations decreasing with depth (3 to 0.2 pCi/g), extends from the ground surface to a depth of 16 ft. Small regions of very low ^{137}Cs contamination (less than 0.6 pCi/g) occur from 26 to 30 ft and 114.5 to 116.5 ft. A small zone of increasing ^{137}Cs contamination (0.25 to 2.5 pCi/g) occurs at the bottom of the logged interval (134.5 to 135.5 ft). Minor isolated occurrences of ^{137}Cs contamination are scattered throughout the rest of the borehole. The highest concentration of ^{137}Cs (142 pCi/g) was detected at the ground surface. However, as described in Section 2.1, this is not an accurate concentration value because the source-to-detector geometry at the top of the borehole casing differs from source-to-detector geometry used in the calibration.

Several small zones of ^{60}Co contamination were detected between 13 and 53.5 ft with concentrations less than 0.25 pCi/g.

A single occurrence of ^{235}U was detected at the ground surface with an apparent concentration of 6.7 pCi/g. However, for reasons discussed previously, this is probably not an accurate concentration value. The detected gamma rays probably originated from an above-ground source, such as nearby contaminated equipment or contamination that is localized to the ground surface.

The increase in the ^{40}K concentration values at 39.5 ft may represent a change in lithology from backfill material to the undisturbed gravel-dominated facies of the Hanford formation, even though no change in lithology is reported in the drilling log at this depth. The ^{40}K concentrations gradually decrease from 40 to 62 ft, then gradually increase from 62 to 90 ft. The drilling log reports a change from very coarse sand to coarse sand and silt at a depth of 65 ft. The lithologic information reported in the drilling log generally supports the interpretation that the increase in the ^{40}K concentrations at about 62 ft may represent the contact between the gravel- and sand-dominated facies of the Hanford formation.

A sharp increase in the ^{238}U concentrations was detected at 90 ft that corresponds to the beginning and end of individual log runs. This concentration decrease is most likely the result of radon venting up the borehole between log runs. The variability in the ^{238}U background is not related to changes in the efficiency of the logging system, but more likely to the weather conditions during a particular run. The 609-keV spectral peak used to calculate the ^{238}U concentration is actually emitted by ^{214}Bi, and the calculated ^{238}U concentration is only accurate if the ^{214}Bi and ^{238}U are in secular equilibrium. Because radon gas is an intermediate member of the ^{238}U decay chain, the equilibrium condition will be disturbed by changes in the weather conditions in the vicinity of the borehole. Wind, or the absence of it, affects the rate of radon venting from the borehole. The variations in the calculated ^{238}U background do not affect the determination of man-made gamma-ray-emitting nuclides from the SGLS data set.

The SGLS total gamma-ray plot reflects the ^{137}Cs contamination in the upper 15 ft of the borehole, but does not reflect the low concentrations of ^{137}Cs and ^{60}Co in the lower portion of the borehole. The total count rate accurately reflects the variations in the ^{40}K concentrations below a depth of about 35 ft.

A data plot included in Appendix A compares spectral gamma data collected with the RLS in 1993 to spectral gamma data collected with the SGLS in 1997. The plot shows generally good repeatability of the data in the upper region of the vadose zone where the concentrations of ^{137}Cs are continuous and exceed about 0.5 pCi/g. The data do not compare as well below about 30 ft, where ^{137}Cs concentrations are sporadic and less than 0.5 pCi/g. The RLS and SGLS data show three zones of ^{60}Co contamination in the upper region of the logged interval. Between 1993 and 1997, the ^{60}Co concentrations have decreased within each zone, illustrating the apparent radioactive decay of the ^{60}Co.

The historical gross gamma log data from 1975 to 1996 were reviewed. The most recent historical gross gamma data are presented on the combination plot. Apparently, no data were collected at the 1-ft and 2-ft intervals of the gross gamma-ray log, so the plot does not reflect the near-surface contamination detected by the SGLS. However, the earliest recorded historical gross gamma log (January 1975) shows anomalous activity in the upper 2 ft of the borehole, which was probably caused by the near-surface ^{137}Cs contamination. The early historical logs show a slight anomaly at a depth of about 13 ft, corresponding to the weak zone of ^{60}Co contamination identified on the SGLS plot.

Summaries of the historical gross gamma log data from 1973 to 1987 are presented in Welty (1988). An activity peak was identified at a depth of 20 ft in early 1974. The activity peak moved to a depth of 23 ft and gradually decreased to less than reportable levels (50 cps) by 1978. The historical activity may represent the decay of ^{60}Co and correspond with the weak zone of ^{60}Co contamination shown on the SGLS plot.

Both the ^{137}Cs and ^{60}Co shape factor analysis results were generally inconclusive because the concentrations of ^{137}Cs and ^{60}Co were too low to produce valid results. Therefore, the shape factor data were not used to determine the distribution of the man-made contamination detected around this borehole.

The ^{137}Cs concentration data shown on the SGLS plot indicate a zone of shallow subsurface contamination, probably resulting from surface spills that have migrated down into the backfill surrounding the borehole. The zone of slightly elevated ^{137}Cs contamination at about 8.5 ft may represent surface contamination that has migrated along the surface of the tank dome into this region of the vadose zone.

Most of the ^{137}Cs contamination detected below 20 ft was probably carried down during the drilling of this borehole or later migrated down the outside of the borehole casing. The zone of increasing ^{137}Cs contamination at the bottom of the logged interval is probably from particulate matter that has either fallen down the inside of the borehole or accumulated around the outside of the borehole casing.

The zones of ^{60}Co contamination detected from 13 to 14.5 ft and 23 to 26 ft may have resulted from a nearby pipeline leak. The isolated region of minor ^{60}Co contamination located from 47 to 53.5 ft may represent the remnant of a plume detected in other nearby boreholes and may be related to the cascade-line leak that occurred between tanks C-104 and C-105.

4.5 Borehole 30-07-02

Borehole 30-07-02 is located approximately 13 ft from the southwest side of tank C-108. It was given the Hanford Site designation 299-E27-88. This borehole was drilled in September 1974 to a depth of 100 ft using 6-in. casing. A drilling log was not available for this borehole; however, information presented in Chamness and Merz (1993) indicates that the borehole was not grouted or perforated. The top of the casing, which is the zero depth reference for the SGLS, is approximately flush with the ground surface. The total logging depth achieved by the SGLS was 99.0 ft.

The man-made radionuclide ^{137}Cs was detected in this borehole. A zone of low ^{137}Cs contamination extends from the ground surface to a depth of 32 ft with variable concentrations generally ranging from 1 to 4 pCi/g. A few low concentrations of ^{137}Cs (less than 0.2 pCi/g) were detected from 42.5 to 43 ft and at the bottom of the logged interval (99 ft). The highest concentration of ^{137}Cs (41 pCi/g) was detected at the ground surface. However, as described in Section 2.1, this is not an accurate concentration value because the source-to-detector geometry at the top of the borehole casing differs from source-to-detector geometry used in the calibration.

The ^{40}K concentration values increase at 40 ft and remain elevated to a depth of 59 ft. The ^{40}K concentration values increase again at 59 ft and remain elevated to the bottom of the logged interval. Although a drilling log was not available to support or contradict the KUT data, the increase in the ^{40}K concentrations at 40 ft probably represents a change in lithology from backfill material to the undisturbed gravel-dominated facies of the Hanford formation. The increase in the ^{40}K concentration values at 59 ft may represent the contact between the gravel- and sand-dominated facies of the Hanford formation.

The SGLS total gamma-ray plot reflects the distribution of the ^{137}Cs contamination around the upper portion of this borehole and the variations in the ^{40}K concentrations in the contaminant-free depth intervals. The increases in the total count rate below 39 and 59 ft correspond with increases in the ^{40}K concentration values at these depths.

Historical gross gamma logs from January 1975 through June 1994 were reviewed. The most recent historical gross gamma data are presented on the combination plot. No zones of anomalous gamma-ray activity were identified on any of the historical logs.

Summaries of the historical gross gamma log data from 1974 to 1987 included in Welty (1988) do not identify any zones of anomalous gamma-ray activity.

Plots of the spectrum shape factors are included in Appendix A. The ^{137}Cs shape factor results suggest that the ^{137}Cs contamination detected between the ground surface and 30 ft is distributed uniformly in the formation. The CsSF1 values along this interval are close to the range expected for a uniform distribution.

The ^{137}Cs contamination from the ground surface to 32.5 ft is probably the result of one or more surface spills that migrated into the backfill material around this borehole. The zone of slightly elevated ^{137}Cs contamination at about 9 ft may represent surface contamination that has migrated along the surface of the tank dome into this region of the vadose zone. The shape factor analysis results support this interpretation, indicating that most of this contamination is uniformly distributed around the borehole. The ^{137}Cs contamination at 42.5 and 43 ft was probably carried down during drilling operations. The ^{137}Cs contamination at the bottom of the borehole may be from particulate matter that fell down into the borehole.

4.6 Borehole 30-07-01

Borehole 30-07-01 is located approximately 13 ft from the southwest side of tank C-108 and was given the Hanford Site designation 299-E27-87. This borehole was drilled in September 1974 to a depth of 100 ft using 6-in. casing. The drilling log for this borehole was not available;

however, information presented in Chamness and Merz (1993) indicates that the borehole was not perforated or grouted. The top of the casing, which is the zero depth reference for the SGLS, is approximately flush with the ground surface. Total logging depth achieved by the SGLS was 100.0 ft.

The man-made radionuclide ^{137}Cs was detected in this borehole. The presence of ^{137}Cs was measured nearly continuously from the ground surface to 74 ft, delineating a broad zone of generally low ^{137}Cs concentrations with zones of relatively higher ^{137}Cs concentrations at depths of about 1.5, 3, 31.5, and 49 ft. A few occurrences of ^{137}Cs were detected at low concentrations (less than 0.5 pCi/g) from 75.5 to 87.5 ft. The highest concentration of ^{137}Cs (18.7 pCi/g) was detected at the ground surface; however, this is not an accurate concentration measurement because the source-to-detector geometry at the top of the borehole differs from the source-to-detector geometry used during calibration.

The ^{40}K concentration values increase slightly at 40 ft, become variable to a depth of 56 ft, then decrease significantly between 56 and 59 ft. The ^{40}K concentration values increase again at 59 ft and remain elevated to the bottom of the logged interval. Although a drilling log was not available to support or contradict the KUT data, the increase in the ^{40}K concentrations at 40 ft probably represents a change in lithology from backfill material to the undisturbed gravel-dominated facies of the Hanford formation. The variable ^{40}K concentrations between 40 and 56 ft may represent sand or silt interbeds within the gravel-dominated facies. The decreased ^{40}K concentration values between 56 and 59 ft may indicate the presence of a coarse-grained unit, such as a gravel lense, containing a somewhat higher concentration of mafic rocks derived from nearby basalts. The increase in the ^{40}K concentration values at 59 ft may represent the contact between the gravel- and sand-dominated facies of the Hanford formation.

The SGLS total gamma-ray plot reflects the distribution of the ^{137}Cs contamination where the concentrations exceed 1 pCi/g and the variations in the ^{40}K concentrations in the contaminant-free depth intervals. The decrease in the total count rate between 57 and 59 ft corresponds with the decrease in the ^{40}K concentration values along this depth interval.

Historical gross gamma logs from January 1975 through June 1994 were reviewed. The most recent historical gross gamma data are presented on the combination plot. No zones of anomalous gamma-ray activity were identified on any of the historical logs.

Summaries of the historical gross gamma log data from 1974 to 1987 included in Welty (1988) do not identify any zones of anomalous gamma-ray activity.

Plots of the spectrum shape factors are included in Appendix A. The ^{137}Cs shape factor results suggest that the distribution of the ^{137}Cs contamination detected between the ground surface and 50 ft varied from uniform in the formation to localized to the borehole casing.

The shape factors indicate that the deeper ^{137}Cs contamination detected between 50 and 58 ft primarily occurs in the formation at discrete locations remote from the borehole. The CsSF1 values along this interval are within the range expected for a remote distribution. In addition, the SF2 values generally support a remote contaminant distribution within this region of the vadose zone.

The ^{137}Cs contamination from the ground surface to 25 ft is probably the result of one or more surface spills that migrated into the backfill material around the borehole, while the ^{137}Cs contamination detected between 25 and 35 ft was probably carried down during the drilling of this borehole. The shape factor results support this interpretation.

The ^{137}Cs contamination detected from 39 to 60 ft is probably the result of a subsurface leak. The shape factor analysis results indicate that much of this contamination is distributed either uniformly or remotely in the formation and is not confined to the vicinity of the borehole casing. It is possible that the ^{137}Cs contamination from the leak source traveled down the outside of tank C-108, spread horizontally along the base of the tank, and then preferentially migrated both downward and laterally through the native sediments below the tank farm excavation.

Most of the ^{137}Cs contamination below about 60 ft was probably carried down during the drilling of this borehole or later migrated down the outside of the borehole casing.

4.7 Borehole 30-11-05

Borehole 30-11-05 is located approximately 10 ft from the northwest side of tank C-108. It was given the Hanford Site designation 299-E27-105. This borehole was drilled in April 1975 to a depth of 100 ft using 6-in. casing. A drilling log was not available for this borehole; however, information presented in Chamness and Merz (1993) does not indicate that the borehole was grouted or perforated. The top of the casing, which is the zero depth reference for the SGLS, is approximately flush with the ground surface. The total logging depth achieved by the SGLS was 99.5 ft.

The man-made radionuclide ^{137}Cs was detected in this borehole. The ^{137}Cs contamination was measured nearly continuously at low concentrations from the ground surface to a depth of 4.5 ft. Isolated occurrences of ^{137}Cs contamination at concentrations slightly above the MDL were detected from 11 to 12 ft and 47.5 to 54.5 ft. The highest concentration of ^{137}Cs (19.8 pCi/g) was detected at the ground surface; however, this is not an accurate concentration measurement because the source-to-detector geometry at the top of the borehole differs from the source-to-detector geometry used during calibration.

The ^{40}K concentration values increase slightly at about 39 ft and become variable from 40 to 46 ft and 60 to 65 ft. The ^{40}K concentration values increase again at about 65 ft and remain elevated to the bottom of the logged interval. Although a drilling log was not available to support or contradict the KUT data, the increase in the ^{40}K concentrations at 39 ft probably represents a change in lithology from backfill material to the undisturbed gravel-dominated facies of the Hanford formation. The two zones of variable ^{40}K concentrations may represent sand or silt interbeds within the gravel-dominated facies. The increase in the ^{40}K concentration values at 65 ft may represent the contact between the gravel- and sand-dominated facies of the Hanford formation.

A sharp decrease in the ^{238}U concentration was detected at 53 ft that corresponds to the beginning and end of individual log runs. This concentration decrease is most likely the result of radon venting up the borehole between log runs. The variability in the ^{238}U background is not related to changes in the efficiency of the logging system, but more likely to the weather conditions during a particular run. The 609-keV spectral peak used to calculate the ^{238}U concentration is actually emitted by ^{214}Bi, and the calculated ^{238}U concentration is only accurate if the ^{214}Bi and ^{238}U are in secular equilibrium. Because radon gas is an intermediate member of the ^{238}U decay chain, the equilibrium condition will be disturbed by changes in the weather conditions in the vicinity of the borehole. Wind, or the absence of it, affects the rate of radon venting from the borehole. The variations in the calculated ^{238}U background do not affect the determination of man-made gamma-ray-emitting nuclides from the SGLS data set.

The SGLS total gamma-ray plot reflects the near-surface ^{137}Cs contamination and the variations in the ^{40}K concentrations below a depth of about 35 ft. The total count rate increases at 37 and 60.5 ft, corresponding with increases in the ^{40}K concentration values at these depths.

Historical gross gamma-ray logs from January 1975 through July 1994 were reviewed. The most recent historical gross gamma data are presented on the combination plot. No zones of anomalous gamma-ray activity were identified on any of the historical logs.

Summaries of the historical gross gamma log data from 1974 to 1987 included in Welty (1988) do not identify any zones of anomalous gamma-ray activity.

The majority of the ^{137}Cs contaminant count rates detected throughout the logged interval of this borehole were below the lower limits required to produce CsSF1 results. As a result, shape factor analysis results were not used to determine the distribution of the ^{137}Cs contamination.

The near-surface contamination is probably the result of a surface spill that migrated into the backfill material around the borehole. The ^{137}Cs contamination detected below this zone was probably carried down during drilling of this borehole or later migrated down the outside of the borehole casing.

4.8 Borehole 30-08-12

Borehole 30-08-12 is located approximately 5 ft from the north side of tank C-108. It was given the Hanford Site designation 299-E27-95. This borehole was drilled in September 1974 to a depth of 100 ft using 6-in. casing. A drilling log was not available for this borehole; however, information presented in Chamness and Merz (1993) does not indicate that the borehole was grouted or perforated. The top of the casing, which is the zero depth reference for the SGLS, is approximately flush with the ground surface. The total logging depth achieved by the SGLS was 98.5 ft.

The man-made radionuclide ^{137}Cs was detected in this borehole. A broad zone of continuous ^{137}Cs contamination was detected at low concentrations from the ground surface to a depth of 37.5 ft. Within this zone, a region of slightly elevated ^{137}Cs contamination (1 to 4 pCi/g) occurs from 6 to 30 ft. A deeper zone of continuous ^{137}Cs contamination was also detected at low concentrations from 47 to 72.5 ft. The maximum concentration of ^{137}Cs (3.8 pCi/g) was detected at a depth of 60 ft. Although a higher concentration of ^{137}Cs (28.2 pCi/g) was detected at the ground surface, this is not an accurate concentration measurement because the source-to-detector geometry at the top of the borehole differs from the source-to-detector geometry used during calibration.

The ^{40}K concentration values increase at 38 ft and become variable between 40 and 55 ft. The ^{40}K concentration values increase again at 70 ft and remain elevated to the bottom of the logged interval. Although a drilling log was not available to support or contradict the KUT data, the increase in the ^{40}K concentrations at 38 ft probably represents a change in lithology from backfill material to the undisturbed gravel-dominated facies of the Hanford formation. The variable ^{40}K concentrations between 40 and 55 ft may represent sand or silt interbeds within the gravel-dominated facies. The increase in the ^{40}K concentration values at 70 ft may represent the contact between the gravel- and sand-dominated facies of the Hanford formation.

The SGLS total gamma-ray plot reflects the distribution of the ^{137}Cs contamination around the upper and middle portions of this borehole and the variations in the ^{40}K concentrations in the contaminant-free depth intervals. The total count-rate increases at 37 and 71 ft correspond with increases in the ^{40}K concentration values at these depths.

The historical gross gamma log data from 1975 to 1994 were reviewed. The most recent historical gross gamma data are presented on the combination plot. No zones of anomalous gamma-ray activity were identified on any of the historical logs.

Summaries of the historical gross gamma log data from 1974 to 1987 included in Welty (1988) do not identify any zones of anomalous gamma-ray activity.

Plots of the spectrum shape factors are included in Appendix A. The shape factors suggest that the ^{137}Cs contamination detected between 9 and 32 ft is mainly localized to the borehole casing. However, the shape factors indicate that the deeper ^{137}Cs contamination is distributed uniformly in the formation. The CsSF1 values between 57.5 and 60.5 ft are very close to the range expected for a uniform distribution. The higher CsSF1 values above and below this depth region are typical of a thin contaminated layer located within the formation.

The near-surface zone of ^{137}Cs contamination (0 to 5 ft) probably resulted from surface spills that have migrated down into the backfill surrounding the borehole. The zone of increased ^{137}Cs contamination at about 8 ft may represent surface contamination that has migrated along the surface of the tank dome into this region of the vadose zone. The shape factor analysis results indicate that most of the contamination detected below these zones (9 to 32 ft) is mainly localized to the borehole casing. This suggests that the near-surface contamination adhered to the borehole casing and was carried downward as the borehole was advanced, or the contamination later migrated down along the outside of the borehole casing.

The zone of ^{137}Cs contamination that occurs from 47.5 to 72.5 ft is probably the remnant of a plume that originated from a subsurface source, such as a leak from tank C-108 or C-111. The shape factor analysis results indicate that this contamination is uniformly distributed in the formation and is not confined to the vicinity of the borehole casing.

The ^{137}Cs contamination detected below 75 ft was probably carried down during the drilling of this borehole or later migrated down the outside of the borehole casing. The ^{137}Cs contamination detected at the bottom of the logged interval is probably particulate matter that has fallen down the inside of the borehole.

5.0 Discussion of Results

A correlation plot of the man-made radionuclide concentration profiles for the eight boreholes surrounding tank C-108 is presented in Figure 3. The man-made radionuclides ^{137}Cs, ^{60}Co, ^{152}Eu, ^{154}Eu, and ^{235}U were detected by the SGLS.

The SGLS detected moderate to high concentrations of ^{137}Cs at the ground surface in all the boreholes. Isolated occurrences of ^{235}U were detected at the ground surface in boreholes 30-08-03 and 30-05-10. A single occurrence of ^{60}Co was also detected at the ground surface in borehole 30-08-03. The source of this contamination is probably direct gamma radiation from nearby contaminated equipment or contamination that is localized to the ground surface. As described in Section 2.1, the concentration values calculated at the ground surface are not considered accurate because the source-to-detector geometry at the top of the borehole casing differs from the source-to-detector geometry used in the calibration. As a result, the ^{137}Cs, ^{235}U, and ^{60}Co concentration values detected at the ground surface using the SGLS are probably higher than the actual concentration levels of these radionuclides.

The SGLS detected near-surface and shallow subsurface ^{137}Cs contamination around all the boreholes. This contamination could have resulted from surface spills, airborne contamination releases, or a combination of these. The contamination may have migrated, in some undetermined manner, down around the outside of the boreholes. It is also possible, and more likely, that the contamination has been driven downward into the backfill material by precipitation infiltration. The latter interpretation is supported by the shape factor analysis results, which indicate that the ^{137}Cs is distributed in the formation as deep as 30 ft around many of the boreholes. If the contamination detected around the upper portions of the boreholes had been confined to the borehole casings or along the outside of the tank wall, then the total contamination in the vadose zone would be minor. However, the contamination has apparently migrated downward into the backfill material, so the volume of contaminated material is large and is a significant portion of the overall contamination in the vadose zone around this tank.

The near-surface zone of high ^{137}Cs contamination detected around borehole 30-08-02 probably resulted from a surface spill. Historical gross gamma log data indicate that the spill occurred sometime between January 1982 and June 1984. It appears that the majority of the

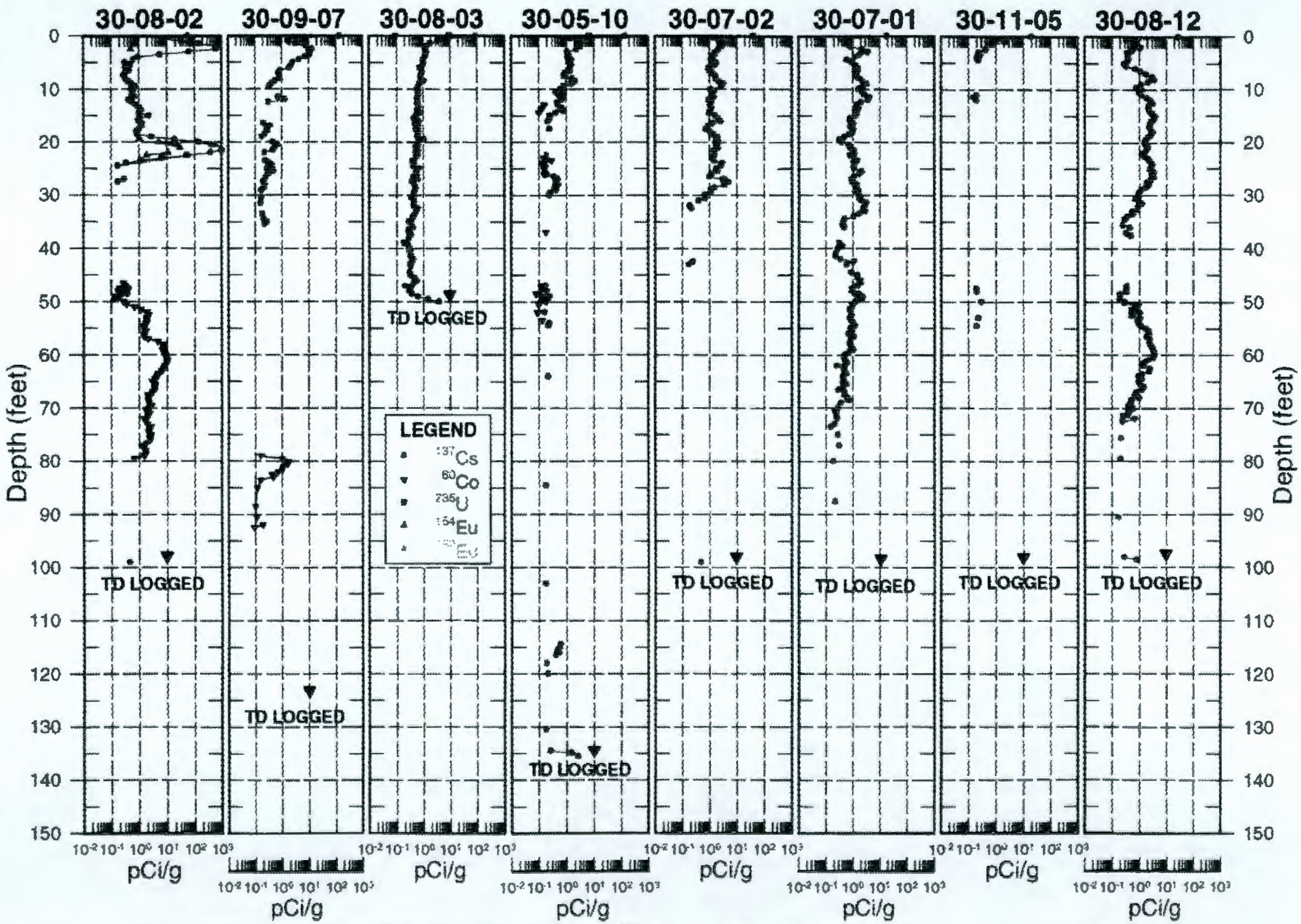

Figure 3. Correlation Plot of ^{137}Cs, ^{60}Co, ^{152}Eu, ^{154}Eu, and ^{235}U Concentrations in Boreholes Surrounding Tank C-108

^{137}Cs contamination was deposited in the upper 5 ft of the backfill material surrounding the borehole. Similar contaminated zones, albeit at lower concentrations, were detected in boreholes 30-09-07 and 30-09-10. The data indicate that although the surface spill was concentrated in the area near borehole 30-08-02, it probably spread over an area of about 100 ft in length between tanks C-108 and C-109. The shape factor analysis results support this interpretation by indicating that the near-surface ^{137}Cs contamination is uniformly distributed in the formation.

Small zones of relatively higher ^{137}Cs contamination were detected between 8 and 17 ft in boreholes 30-09-07, 30-05-10, 30-07-02, 30-07-01, and 30-08-12. These concentration increases may represent surface contamination that remobilized and migrated laterally along the surface of the tank dome into these regions of the backfill material.

The distinct zone of ^{137}Cs and ^{154}Eu contamination detected around borehole 30-08-02 from 19 to 23.5 ft may be the result of a leak from the C-108-to-C-109 cascade line; however, no documentation was available to indicate such a leak occurred. The discrete nature of this contaminated zone suggests that this borehole is located near the C-108-to-C-109 cascade line. As discussed in Section 3.2, the cascade line became plugged in 1952. Consequently, the ^{137}Cs and ^{154}Eu contamination detected may consist of residual waste contained within the cascade piping. The shape factor analysis data indicate that this contamination occurs as a thin linear source that is remote to the borehole, supporting the theory that it may be isolated to the region along the inside of the cascade line.

The zones of ^{60}Co contamination detected in boreholes 30-08-02 and 30-09-07 that underlie the base of the tank farm excavation could have originated from a leak from any of the tanks in the vicinity, including tank C-108. The shape factor analysis results for these boreholes indicate that the ^{60}Co contamination is distributed in the formation and not confined to the vicinity of the casing, suggesting that the ^{60}Co contamination has migrated a considerable distance both downward and laterally through the vadose zone and may be related to the same contaminant source. The rate of decrease of the gamma-ray intensity indicated by the historical gross gamma logs suggests that other short-lived radionuclides, such as ^{106}Ru or ^{125}Sb, may have initially coexisted with the ^{60}Co contamination around both of these boreholes but have since decayed to levels below the detection limit of the SGLS.

In borehole 30-05-10, the zones of ^{60}Co contamination detected from 13 to 14.5 ft and 23 to 26 ft may have resulted from a nearby pipeline leak. The isolated region of minor ^{60}Co contamination detected from 47 to 53.5 ft may represent the remnant of a plume related to the cascade-line leak described in Welty (1988) that occurred between tanks C-104 and C-105.

The zone of elevated ^{137}Cs contamination detected from 39 to 69 ft in borehole 30-07-01 may have originated from a subsurface leak. The shape factor analysis data indicate that much of this contamination is distributed either uniformly or remotely in the formation and is not confined to the vicinity of the borehole casing. It is possible that the ^{137}Cs contamination traveled from the leak source down along the outside of tank C-108, spread horizontally along the base of the tank, and then preferentially migrated both downward and laterally through the native sediments below the tank farm excavation into this region of the borehole.

The broad zone of ^{137}Cs contamination that occurs from 47.5 to 72.5 ft in borehole 30-08-12 is probably the remnant of a plume that originated from a subsurface source, such as a leak from tank C-108 or C-111. The shape factor analysis results indicate that this contamination is uniformly distributed in the formation and is not confined to the vicinity of the borehole casing. The depth of the ^{137}Cs contamination correlates with the ^{60}Co contamination detected in nearby boreholes 30-08-02 and 30-09-07 and may be related to the same contaminant source.

The comparison of the 1993 RLS and 1997 SGLS data collected from borehole 30-05-10 shows generally good repeatability of the ^{137}Cs distribution in the upper region of the borehole. The shapes of the RLS and SGLS ^{137}Cs profiles were very similar, suggesting that the ^{137}Cs contamination in this borehole is not actively mobile and has remained fixed in the vadose zone since 1993. The RLS and SGLS data illustrate the three zones of ^{60}Co contamination that occur in the upper region of the logged interval. Between 1993 and 1997, the ^{60}Co concentrations have decreased within each zone, indicating the apparent radioactive decay of the ^{60}Co.

6.0 Conclusions

The characterization of the gamma-ray-emitting contamination in the vadose zone surrounding tank C-108 was completed using the SGLS. The data obtained using the SGLS and the geologic and historical information available from other sources do not identify any active leaks from tank C-108. However, the data indicate that surface spills have occurred and that contaminant plumes originating from subsurface leaks from other tanks exist in the vicinity of this tank. These contaminant plumes may be related to activities associated with tank C-108 or other nearby tanks.

7.0 Recommendations

Tank C-108 is currently listed as containing approximately 66,000 gal of sludge, with no interstitial liquid remaining (Hanlon 1997). Continued monitoring of the boreholes surrounding this tank is recommended to identify changes in the distribution of the contaminant plumes identified within the vadose zone. Because the lithology appears to play an important role in the radionuclide distribution beneath this tank, especially for ^{60}Co, further lithologic characterization is recommended by logging a few of the boreholes using a long counting time or a high efficiency system. This system can properly define the individual natural radionuclide concentrations, and, thus, better characterize site-specific geology.

The intervals in which anomalous historical gross gamma-ray activity occurred in boreholes 30-08-02 and 30-09-07 should be relogged using a long counting time. This work might identify the remnants of other short-lived man-made radionuclides that may occur.

Borehole 30-08-03 should be plugged and abandoned because the logging data obtained from this double-cased borehole are attenuated and not representative of the actual man-made and natural radionuclide concentrations.

8.0 References

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Appendix A
Spectral Gamma-Ray Logs for Boreholes in the Vicinity of Tank C-108

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Spectral Gamma-Ray Borehole Log Data Report

Log Event A

Borehole 30-08-02

Borehole Information

Farm :	C	**Tank :**	C-108	**Site Number :**	299-E27-94
N-Coord :	42,965	**W-Coord :**	48,363	**TOC Elevation :**	647.00
Water Level, ft :	None	**Date Drilled :**	9/30/74		

Casing Record

Type :	Steel-welded	Thickness, in. :	0.280	ID, in. :	6
Top Depth, ft. :	0	Bottom Depth, ft. :	100		

Borehole Notes:

This borehole was drilled in September 1974 and completed to a depth of 100 ft with 6-in. casing. The casing thickness is presumed to be 0.280 in., on the basis of the published thickness for schedule-40, 6-in. steel tubing. No information was available that indicated the borehole casing was perforated or grouted; therefore, it is assumed that the borehole was not perforated or grouted. The top of the casing, which is the zero reference for the SGLS, is flush with the ground surface.

Equipment Information

Logging System :	1B	**Detector Type :**	HPGe	**Detector Efficiency :**	35.0 %
Calibration Date :	2/97	**Calibration Reference :**	GJO-HAN-14	**Logging Procedure :**	P-GJPO-1783

Log Run Information

Log Run Number :	1	**Log Run Date :**	3/18/97	**Logging Engineer:**	Gary Lekvold		
Start Depth, ft.:	0.0	**Counting Time, sec.:**	100	**L/R :**	L	**Shield :**	N
Finish Depth, ft. :	21.0	**MSA Interval, ft. :**	0.5	**Log Speed, ft/min.:**	n/a		

Log Run Number :	2	**Log Run Date :**	3/19/97	**Logging Engineer:**	Gary Lekvold		
Start Depth, ft.:	20.0	**Counting Time, sec.:**	100	**L/R :**	R	**Shield :**	N
Finish Depth, ft. :	24.5	**MSA Interval, ft. :**	0.5	**Log Speed, ft/min.:**	n/a		

Log Run Number :	3	**Log Run Date :**	3/19/97	**Logging Engineer:**	Gary Lekvold		
Start Depth, ft.:	22.5	**Counting Time, sec.:**	100	**L/R :**	L	**Shield :**	N
Finish Depth, ft. :	93.5	**MSA Interval, ft. :**	0.5	**Log Speed, ft/min.:**	n/a		

Log Event A

Borehole 30-08-02

Log Run Number :	4	Log Run Date :	3/20/97	Logging Engineer:	Alan Pearson		
Start Depth, ft.:	99.0	Counting Time, sec.:	100	L/R :	L	Shield :	N
Finish Depth, ft. :	92.5	MSA Interval, ft. :	0.5	Log Speed, ft/min.:	n/a		

Analysis Information

Analyst :	E. Larsen		
Data Processing Reference :	MAC-VZCP 1.7.9, Rev. 1	Analysis Date :	9/5/97

Analysis Notes :

This borehole was logged by the SGLS in four log runs. Excessive dead time (greater than 50 percent) was encountered during log run one at a depth of 21 ft. As a result, log run two was logged in real time from 20 to 24.5 ft. Log runs three and four were logged in live time from 22.5 to 99 ft, after the dead time dropped below 50 percent.

The pre- and post-survey field verification spectra met the acceptance criteria established for the peak shape and detector efficiency, confirming that the SGLS was operating within specifications. The energy calibration and peak-shape calibration from these spectra were used to establish the channel-to-energy parameters used in processing the spectra acquired during the logging operation.

Casing correction factors for a 0.280-in.-thick steel casing were applied during analysis.

The man-made radionuclides Cs-137, Co-60, and Eu-154 were detected around this borehole. Cs-137 contamination was detected continuously from the ground surface to 24.5 ft. Cs-137 contamination was also detected from 27 to 27.5 ft, 47 to 49 ft, and at the bottom of the logged interval (99 ft). The Co-60 contamination was detected continuously from 46.5 to 79.5 ft. The Eu-154 contamination was detected at 2.5 ft and nearly continuously from 19.5 to 22.5 ft.

An analysis of the shape factors associated with applicable segments of the spectra was performed. The shape factors provide insights into the distribution of the Cs-137 and Co-60 contamination and into the nature of zones of elevated total count gamma-ray activity not attributable to gamma-emitting radionuclides.

The K-40 concentration values increase at 37.5 ft and generally remain elevated to a depth of 72.5 ft. The K-40 concentrations become increasingly variable between 55 and 74.5 ft. The K-40 concentrations increase again at 74.5 ft and remain elevated to the bottom of the logged interval. The Th-232 concentrations gradually increase near 85 ft to the bottom of the logged interval.

Most of the K-40 and Th-232 concentration data are absent between 20 and 22 ft. The U-238 concentration data are absent between 18 and 23.5 ft and mostly absent between 57.5 and 65 ft.

Additional information and interpretations of log data are included in the main body of the Tank Summary Data Reports for tanks C-108 and C-109.

Borehole 30-08-02

Log Plot Notes:

Separate log plots show the man-made and the naturally occurring radionuclides. The natural radionuclides can be used for lithology interpretations. The headings of the plots identify the specific gamma rays used to calculate the concentrations.

Uncertainty bars on the plots show the statistical uncertainties for the measurements as 95-percent confidence intervals. Open circles on the plots give the MDL. The MDL of a radionuclide represents the lowest concentration at which positive identification of a gamma-ray peak is statistically defensible.

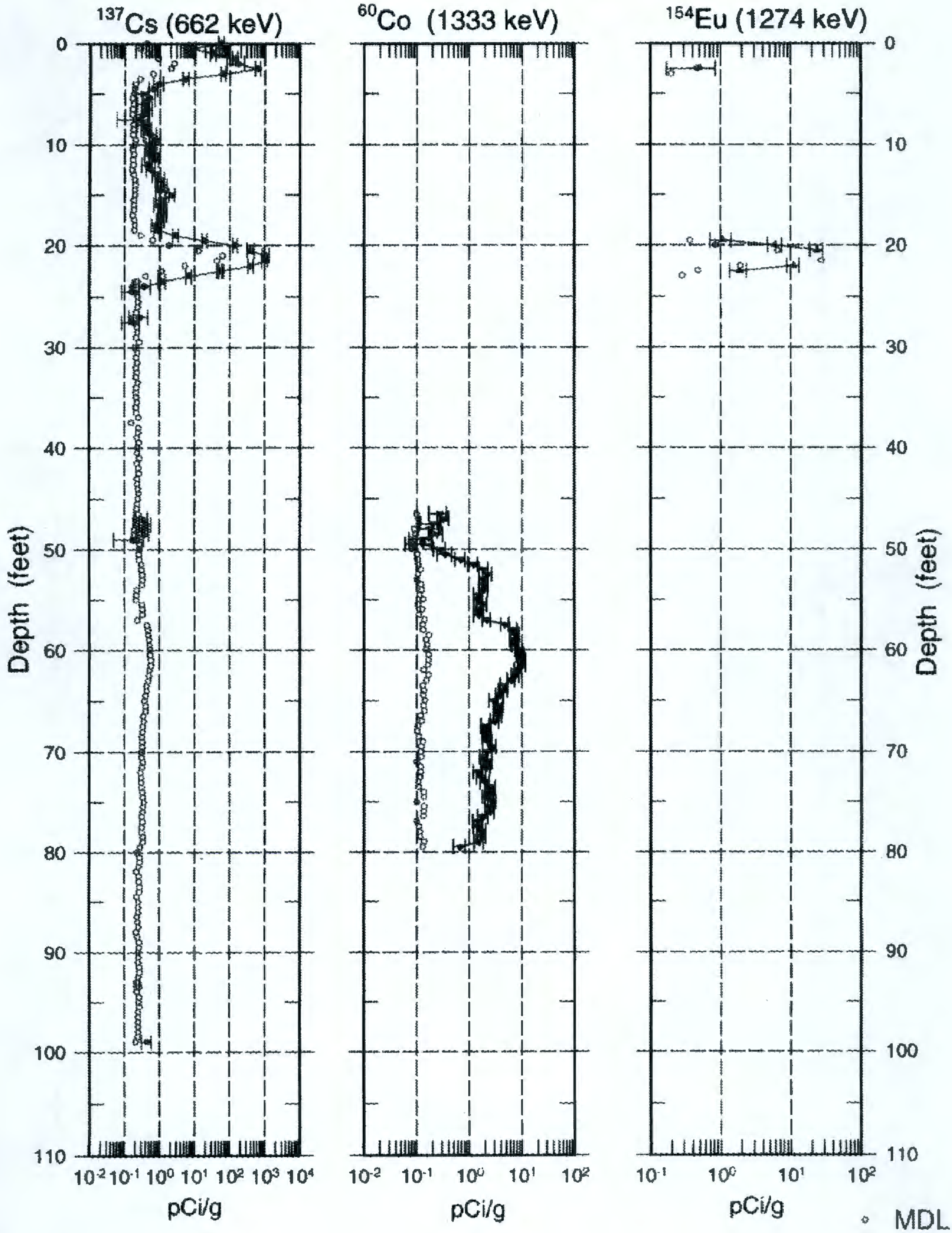
A combination plot includes the man-made and natural radionuclides, the total gamma derived from the spectral data, and the Tank Farms gross gamma log. The gross gamma plot displays the latest available digital data. No attempt has been made to adjust the depths of the gross gamma logs to coincide with the SGLS data.

A plot of representative historical gross gamma-ray logs from 1980 to 1989 is included. The headings of the plots identify the date on which the data in the plots were gathered.

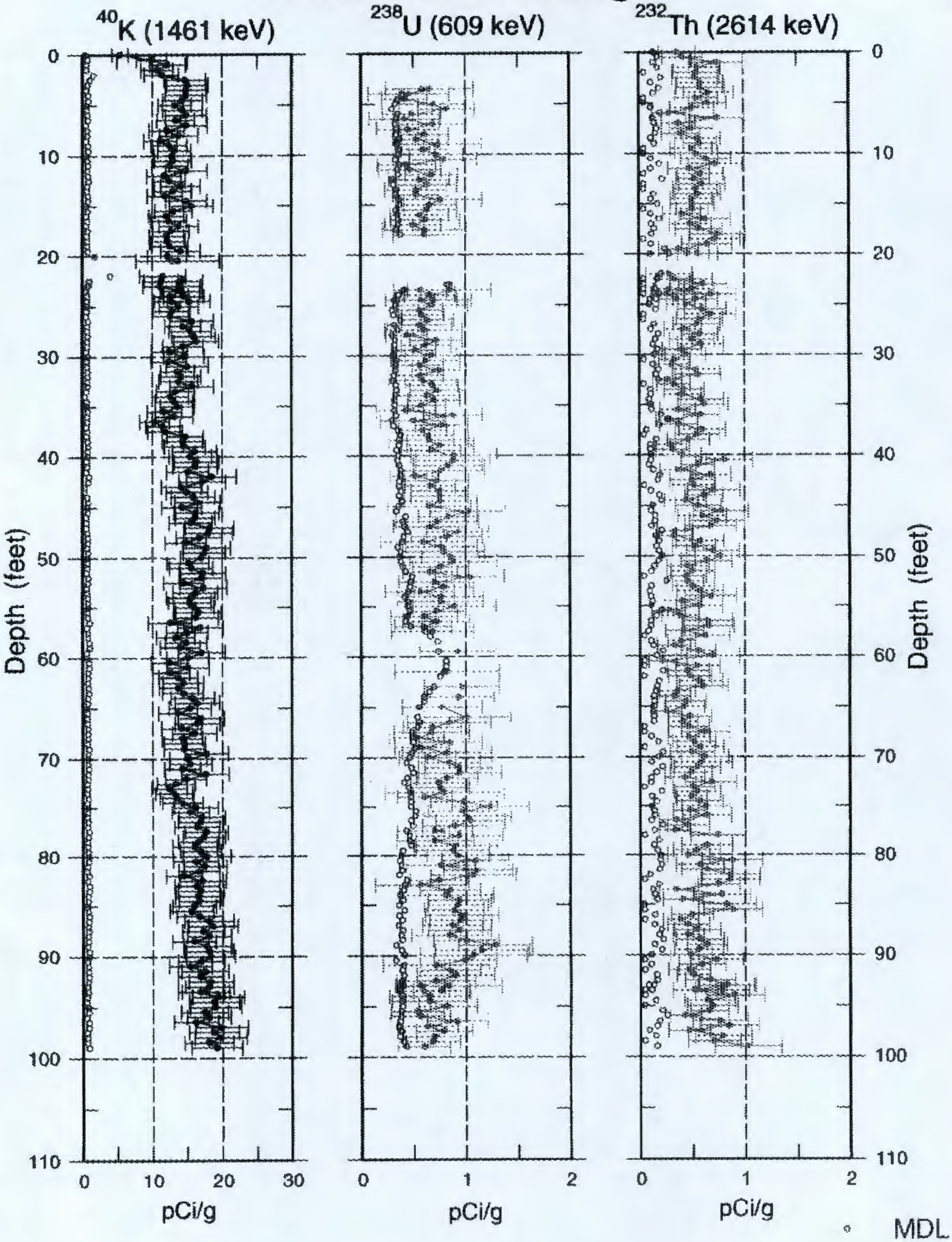
Plots of the spectrum shape factors are also included. The plots are used as an interpretive tool to help determine the radial distribution of man-made contaminants around the borehole.

30-08-02

Man-Made Radionuclide Concentrations



30-08-02
Natural Gamma Logs



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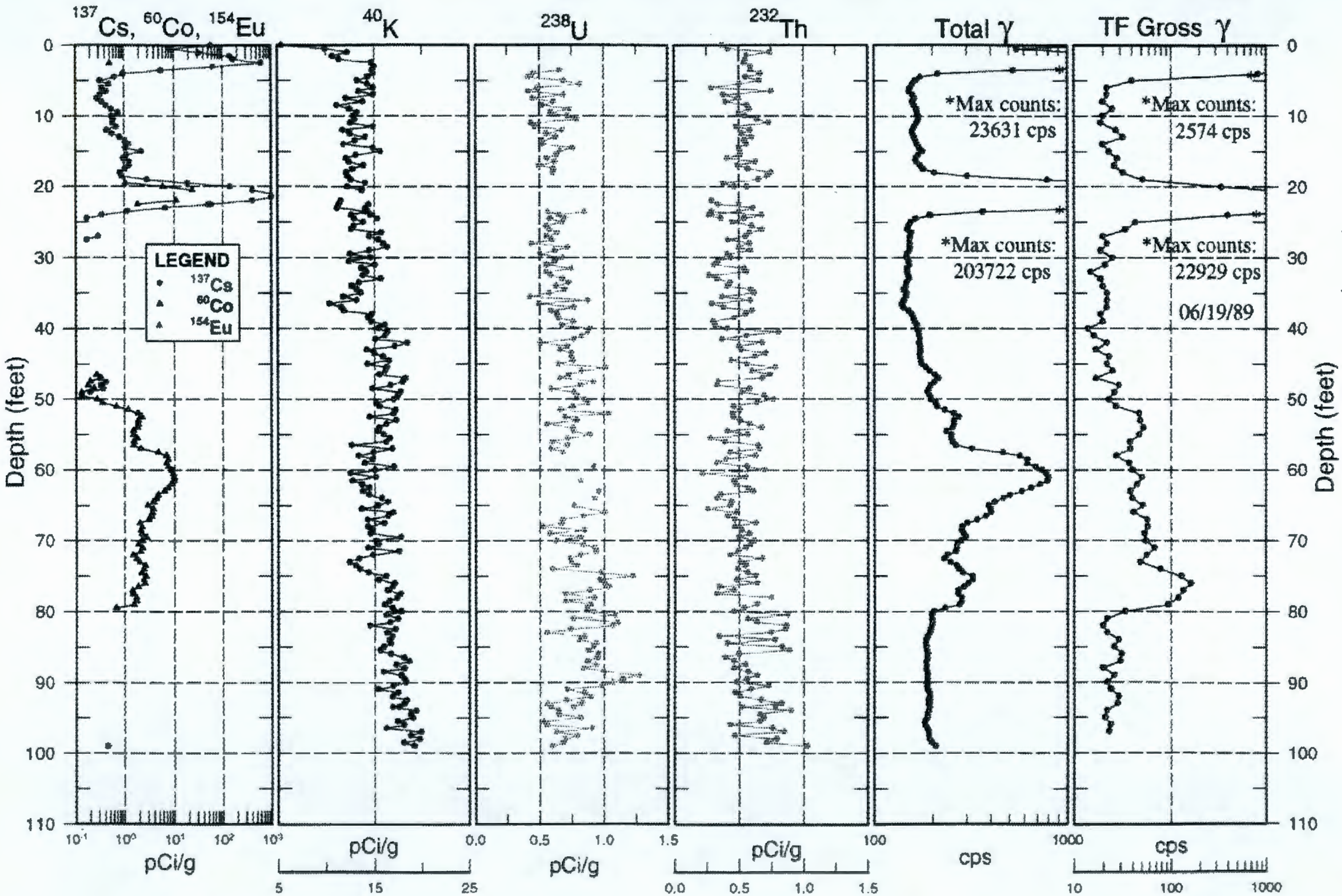
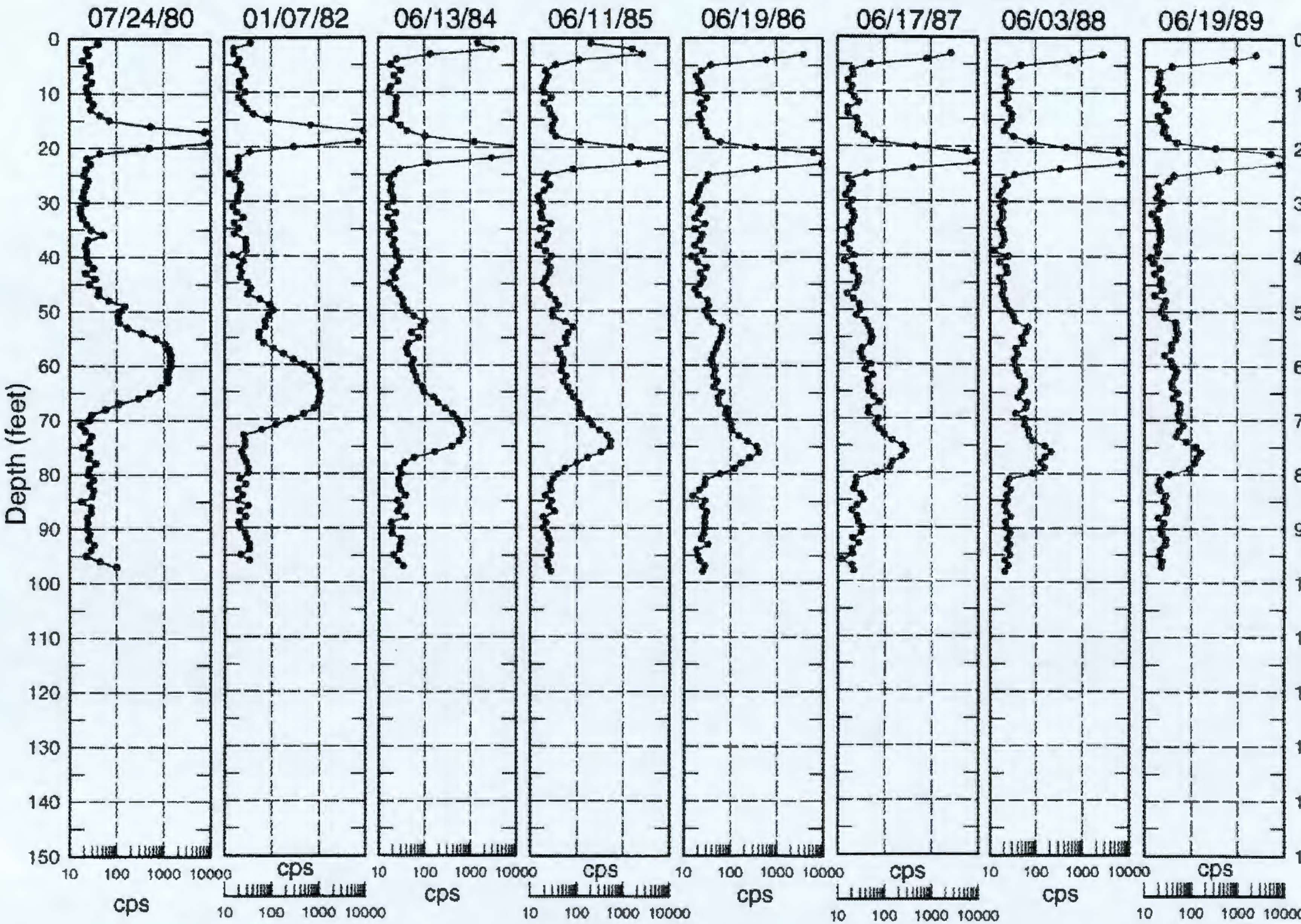


Historical Gross Gamma Logs for Borehole 30-08-02



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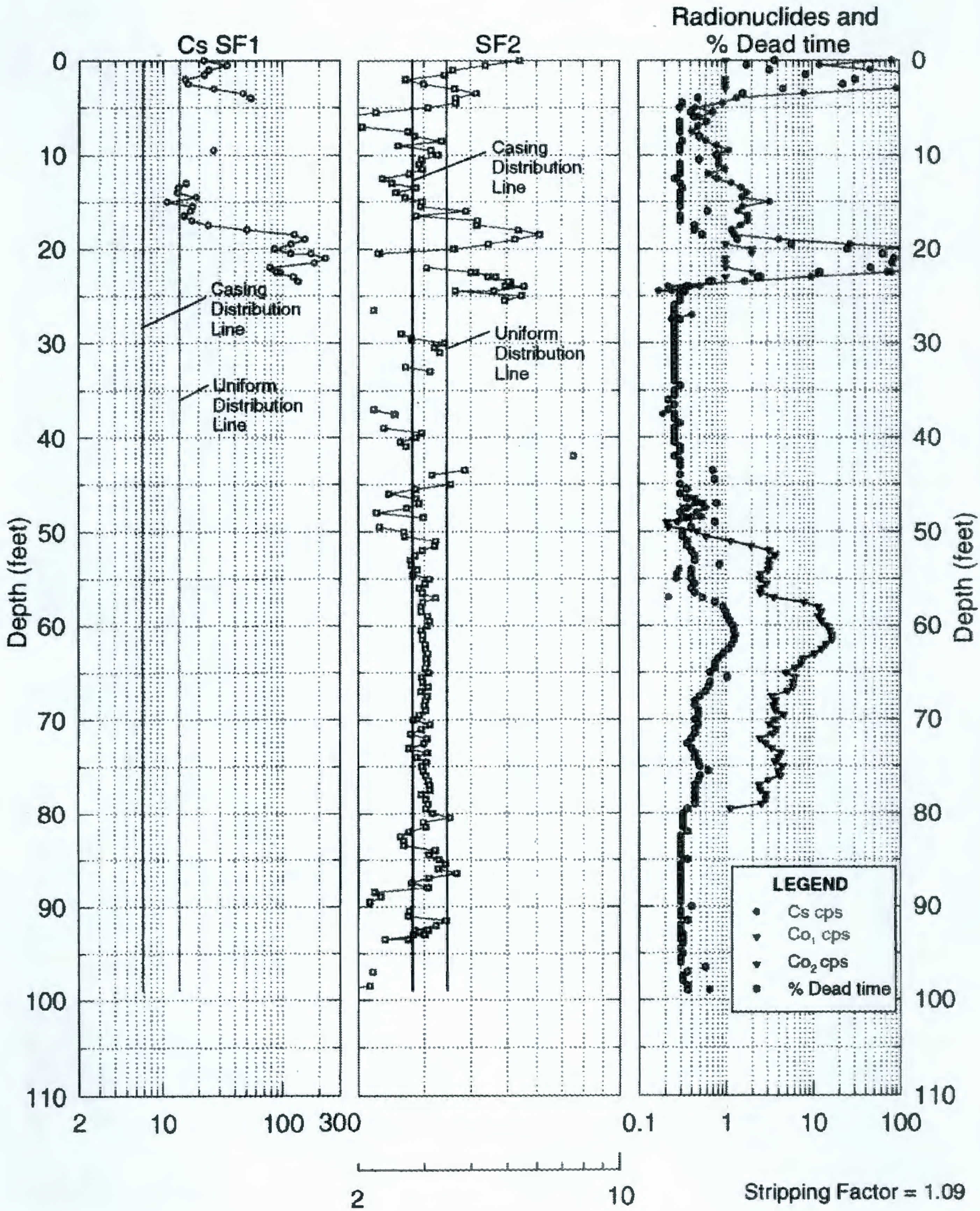

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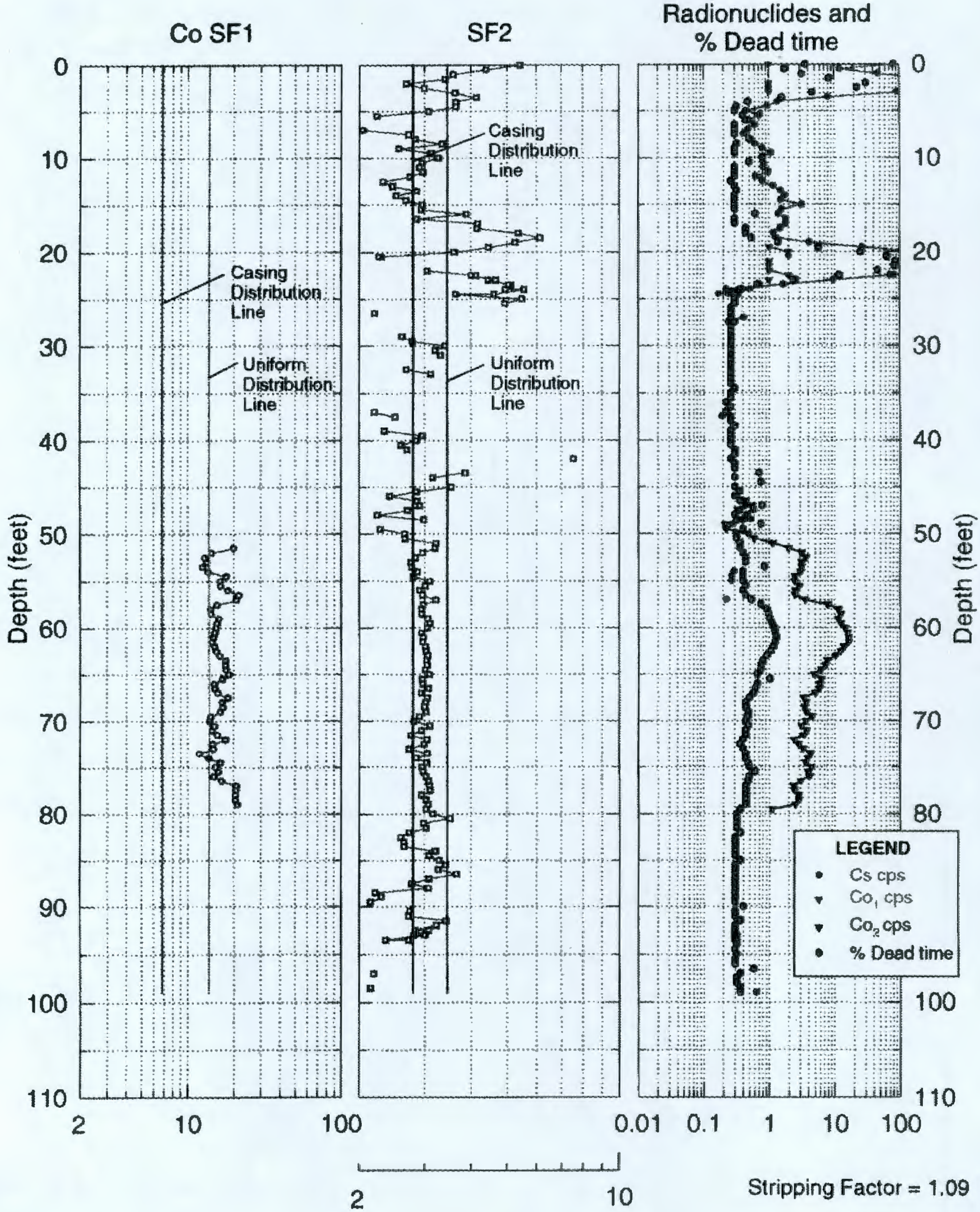
30-08-02 ^{60}Co Shape Factor Analysis Plot



Stripping Factor = 1.09

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Spectral Gamma-Ray Borehole Log Data Report

Log Event A

Borehole 30-09-07

Borehole Information

Farm :	C	Tank :	C-109	Site Number :	299-E27-135
N-Coord :	42,965	W-Coord :	48,342	TOC Elevation :	649 est.
Water Level, ft :	122.10	Date Drilled :	3/31/82		

Casing Record

Type :	Steel-welded	Thickness :	0.280	ID, in. :	6
Top Depth, ft. :	1	Bottom Depth, ft. :	125		

Borehole Notes:
This borehole was drilled in March 1982 and completed to a depth of 125 ft with 6-in. casing. The casing thickness is presumed to be 0.280 in., on the basis of the published thickness for schedule-40, 6-in. steel tubing. A drilling log was not available for this borehole; however, information presented in Chamness and Merz (1993) indicates that the borehole was grouted but not perforated. The depth of the grouted interval was not specified. The top of the casing, which is the zero reference for the SGLS, is approximately 2.5 ft above the ground surface. Because elevation data was not available for this borehole, the top of the casing was estimated to be approximately 649 ft.

Equipment Information

Logging System :	1B	Detector Type :	HPGe	Detector Efficiency :	35.0 %
Calibration Date :	2/97	Calibration Reference :	GJO-HAN-14	Logging Procedure :	P-GJPO-1783

Log Run Information

Log Run Number :	1	Log Run Date :	3/20/97	Logging Engineer:	Alan Pearson		
Start Depth, ft.:	0.0	Counting Time, sec.:	100	L/R :	L	Shield :	N
Finish Depth, ft. :	14.0	MSA Interval, ft. :	0.5	Log Speed, ft/min.:	n/a		

Log Run Number :	2	Log Run Date :	3/21/97	Logging Engineer:	Alan Pearson		
Start Depth, ft.:	124.5	Counting Time, sec.:	100	L/R :	L	Shield :	N
Finish Depth, ft. :	42.0	MSA Interval, ft. :	0.5	Log Speed, ft/min.:	n/a		

Log Run Number :	3	Log Run Date :	3/24/97	Logging Engineer:	Alan Pearson		
Start Depth, ft.:	43.0	Counting Time, sec.:	100	L/R :	L	Shield :	N
Finish Depth, ft. :	13.0	MSA Interval, ft. :	0.5	Log Speed, ft/min.:	n/a		

Analysis Information

Analyst : E. Larsen

Data Processing Reference : MAC-VZCP 1.7.9, Rev. 1 Analysis Date : 9/5/97

Analysis Notes :

This borehole was logged by the SGLS in three log runs. The pre-survey field verification spectra for all logging runs met the acceptance criteria established for peak shape and system efficiency but the post-survey field verification spectra for logging run two failed to meet the acceptance criteria. The energy and peak-shape calibration from the pre-survey field verification spectra were used to establish the channel-to-energy parameters used in processing the spectra acquired during the logging runs.

Casing correction factors for a 0.280-in.-thick steel casing were applied during analysis.

The man-made radionuclides Cs-137 and Co-60 were detected in this borehole. The Cs-137 contamination was detected continuously from the ground surface to 9.5 ft and nearly continuously from 16.5 to 35.5 ft. An isolated zone of Cs-137 contamination was detected from 11.5 to 12.5 ft. The Co-60 contamination was detected continuously from 79 to 83.5 ft and intermittently between 85 and 92.5 ft.

An analysis of the shape factors associated with applicable segments of the spectra was performed. The shape factors provide insights into the distribution of the Cs-137 and Co-60 contamination and into the nature of zones of elevated total count gamma-ray activity not attributable to gamma-emitting radionuclides.

The K-40 concentration values steadily decrease from 26.5 to 40 ft, increase significantly from 40 to 41.5 ft, and remain elevated to a depth of 73.5 ft. The K-40 concentrations increase again at about 74 ft, remain elevated to a depth of about 118 ft, then gradually decrease to the bottom of the logged interval.

Most of the U-238 concentration data are absent from the ground surface to 3.5 ft. The U-238 concentrations decrease from 120 ft to the bottom of the logged interval.

Additional information and interpretations of log data are included in the main body of the Tank Summary Data Reports for tanks C-108 and C-109.

Log Plot Notes:

Separate log plots show the man-made and the naturally occurring radionuclides. The natural radionuclides can be used for lithology interpretations. The headings of the plots identify the specific gamma rays used to calculate the concentrations.

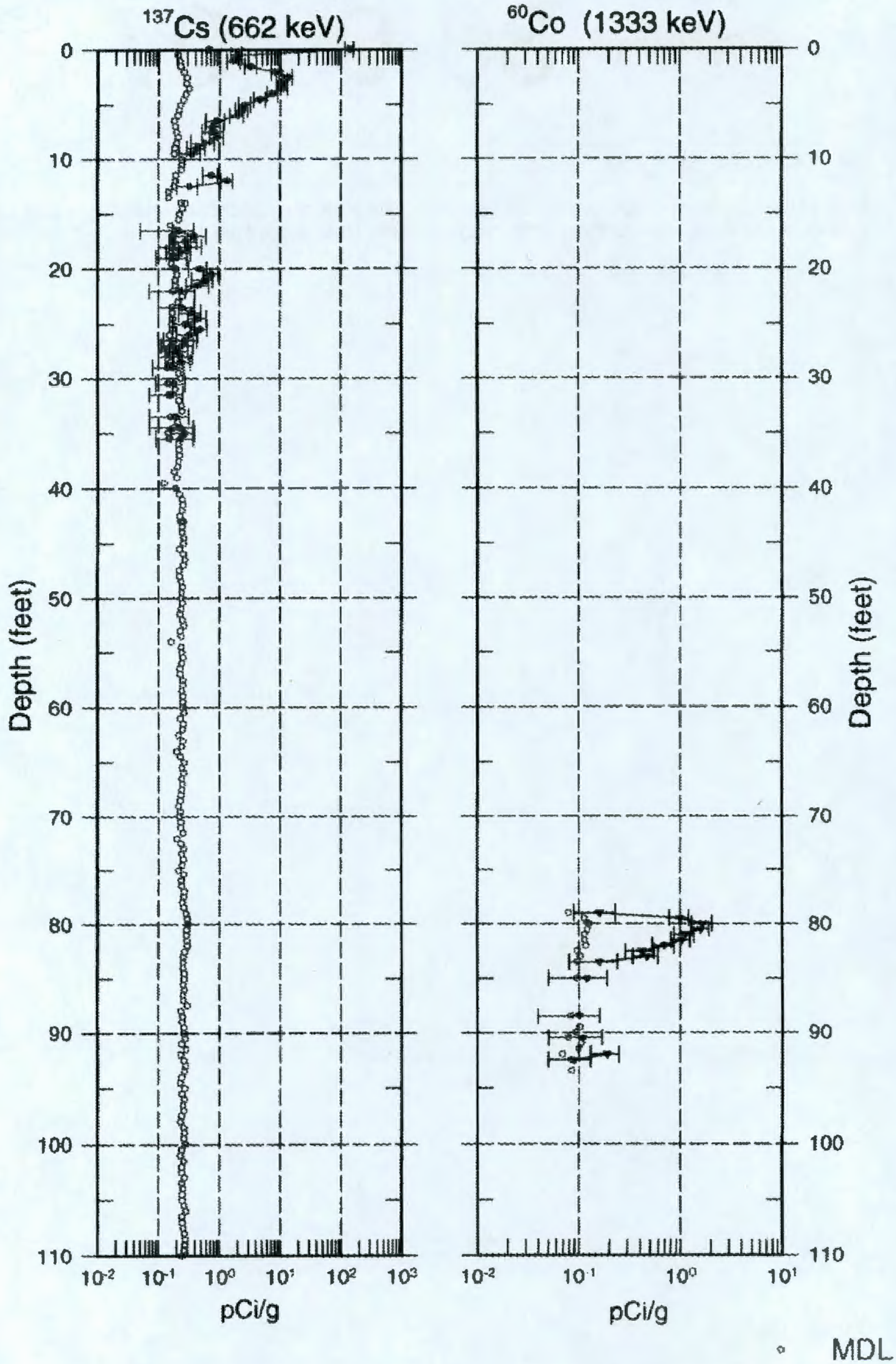
Uncertainty bars on the plots show the statistical uncertainties for the measurements as 95-percent confidence intervals. Open circles on the plots give the MDL. The MDL of a radionuclide represents the lowest concentration at which positive identification of a gamma-ray peak is statistically defensible.

A combination plot includes the man-made and natural radionuclides, the total gamma derived from the spectral data, and the Tank Farms gross gamma log. The gross gamma plot displays the latest available digital data. No attempt has been made to adjust the depths of the gross gamma logs to coincide with the SGLS data.

Plots of the spectrum shape factors are included. The plots are used as an interpretive tool to help determine the radial distribution of man-made contaminants around the borehole.

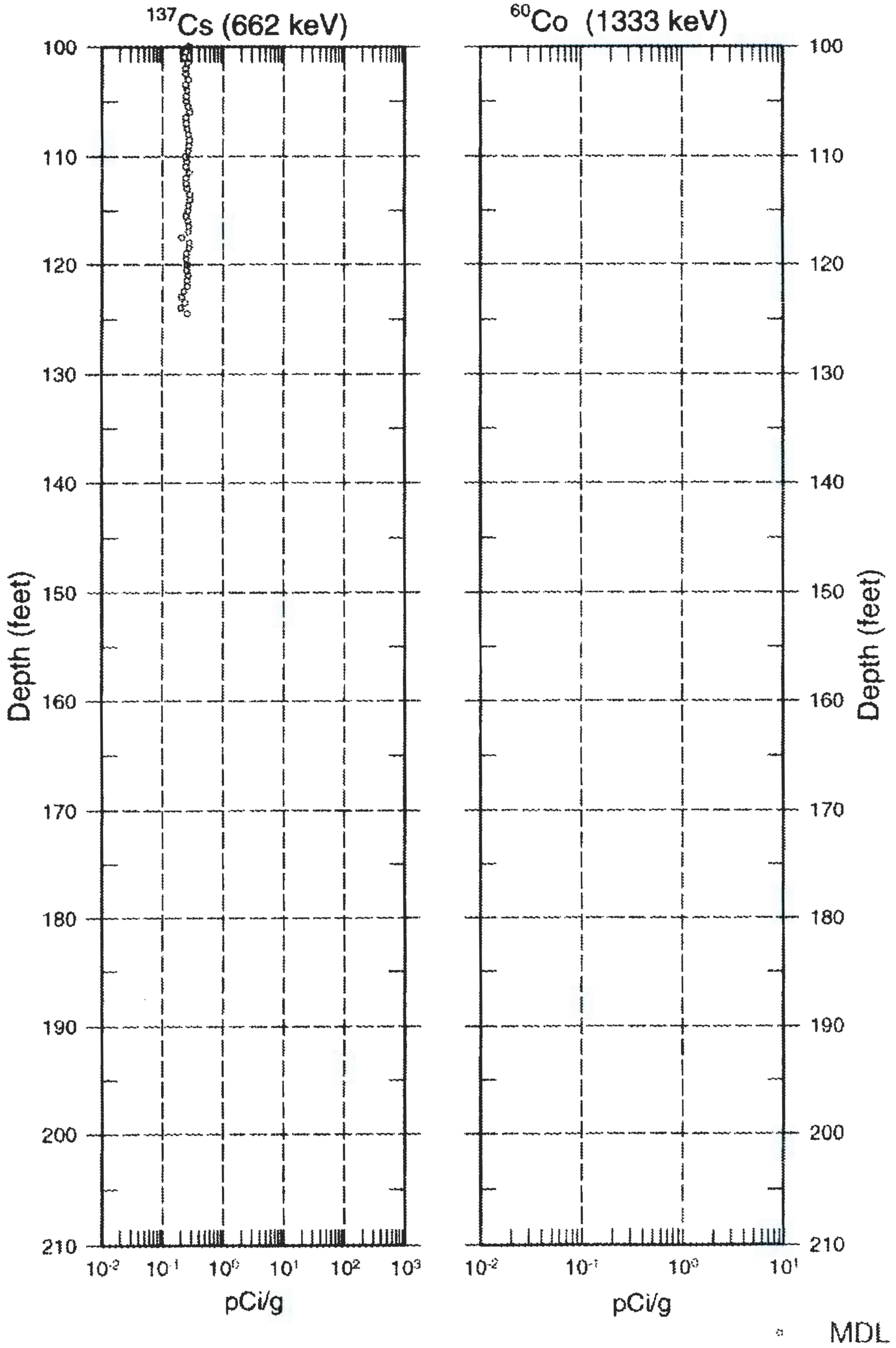
30-09-07

Man-Made Radionuclide Concentrations

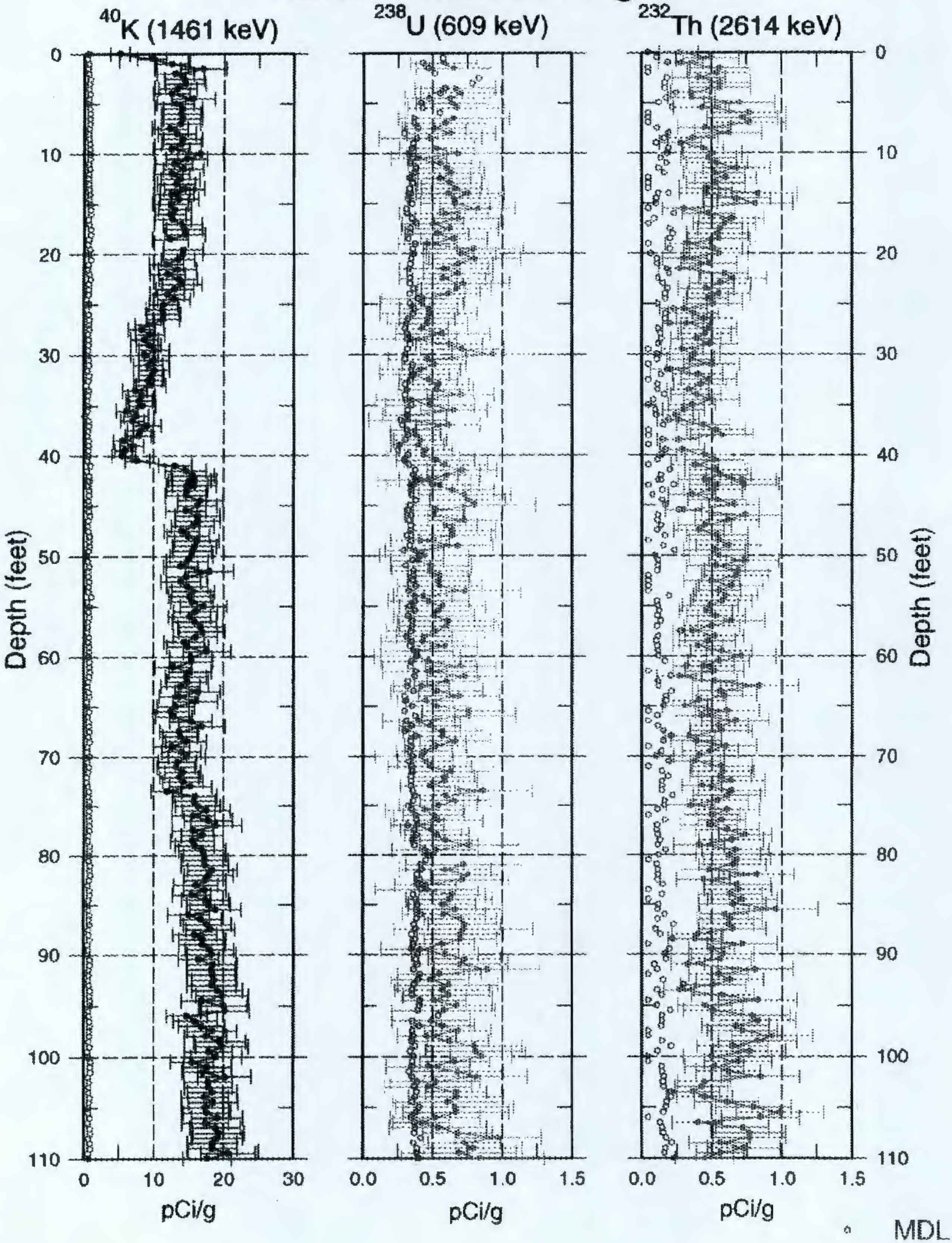


30-09-07

Man-Made Radionuclide Concentrations

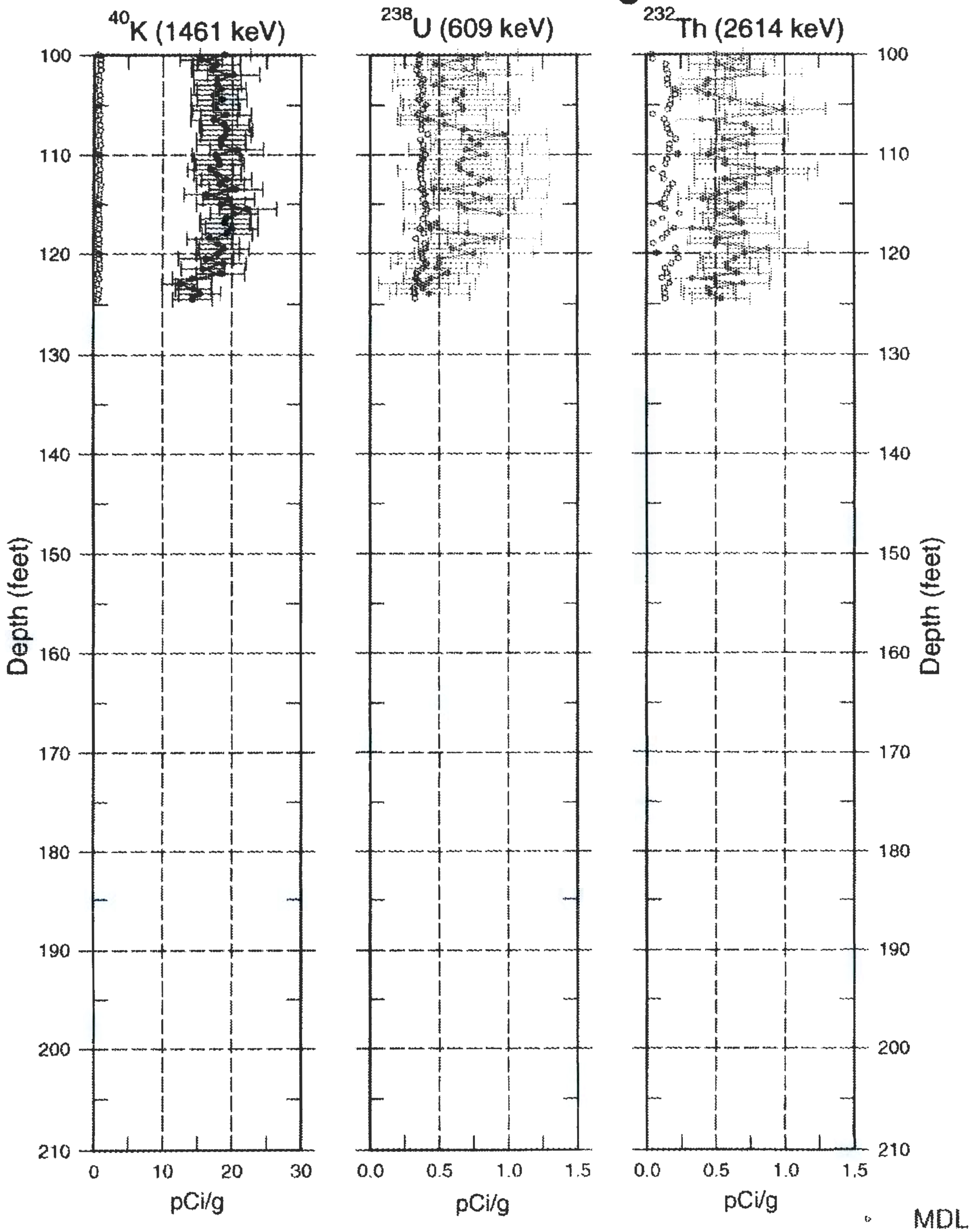


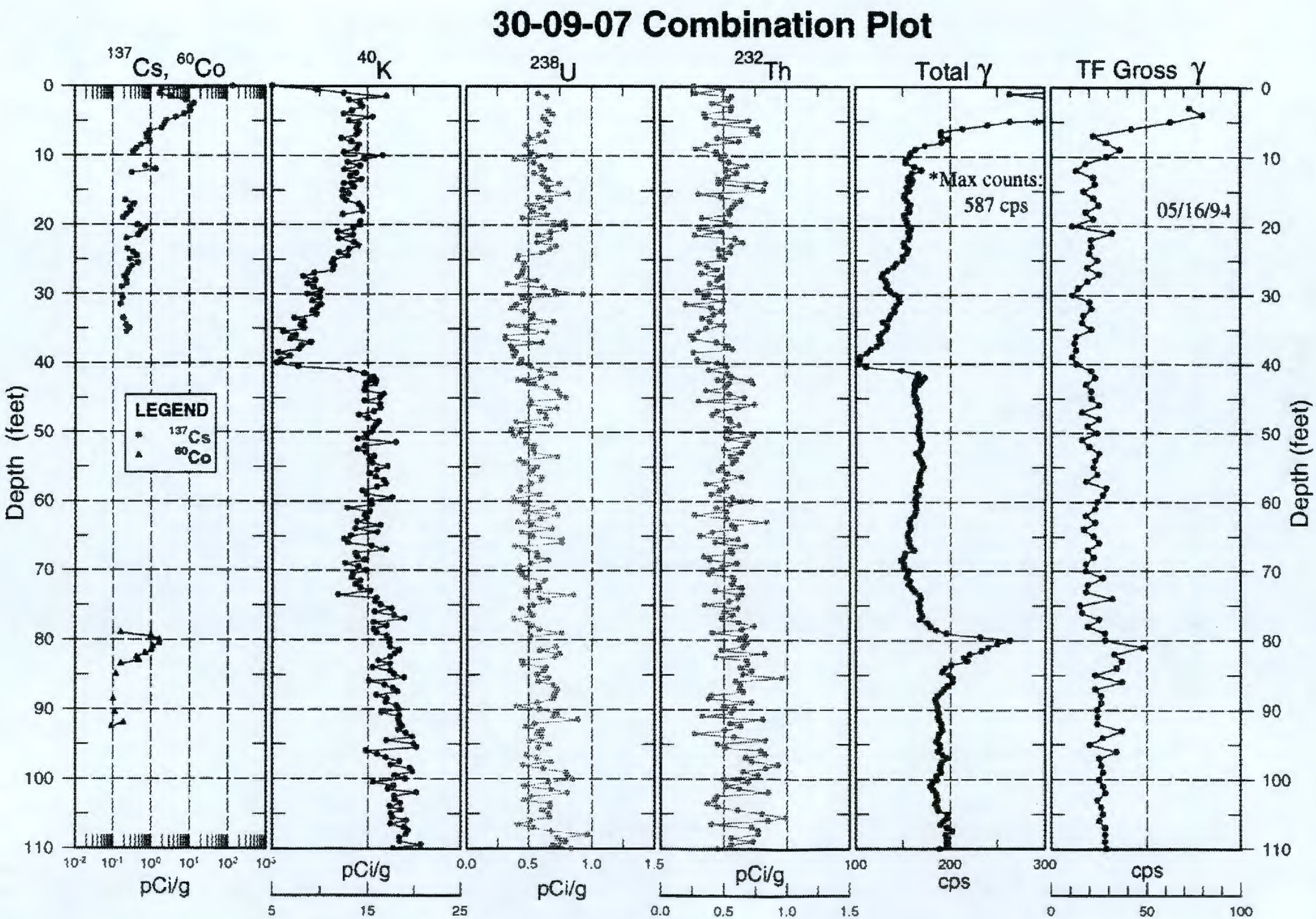
30-09-07
Natural Gamma Logs

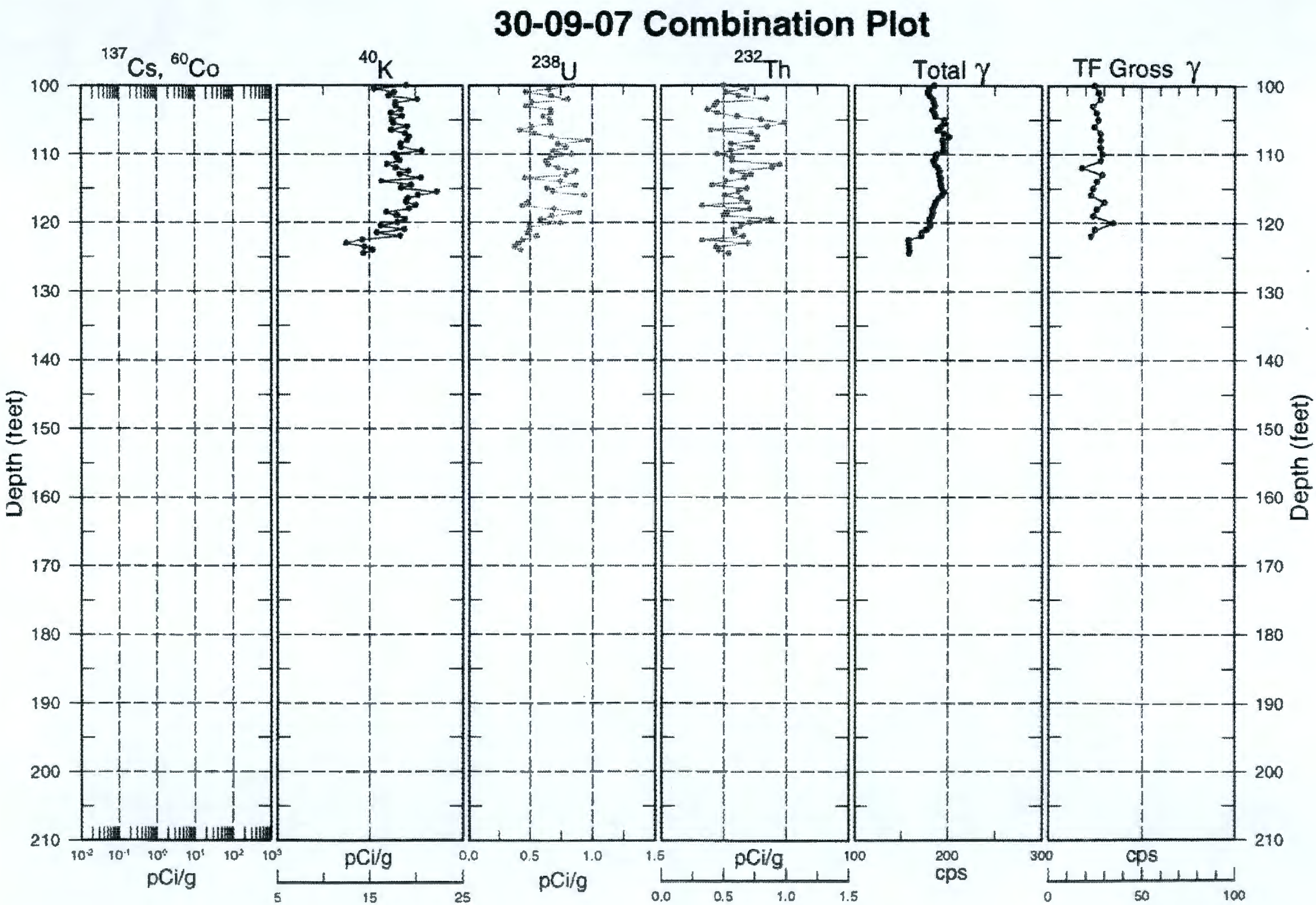


30-09-07

Natural Gamma Logs

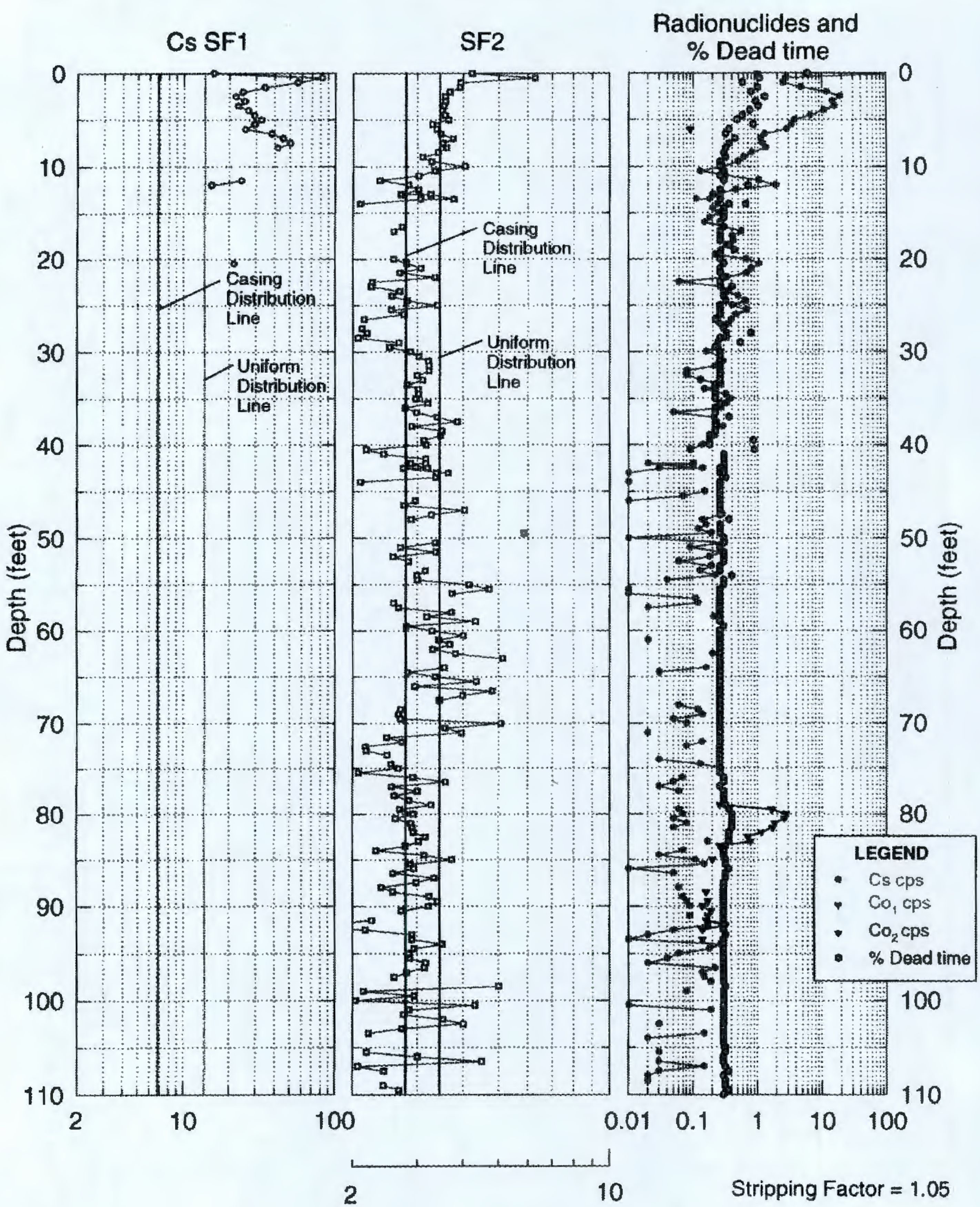



30-09-07 Combination Plot
137Cs, 60Co
40K
238U
232Th
Total γ
TF Gross γ
Depth (feet)
LEGEND
137Cs
60Co
*Max counts:
587 cps
05/16/94
pCi/g
cps

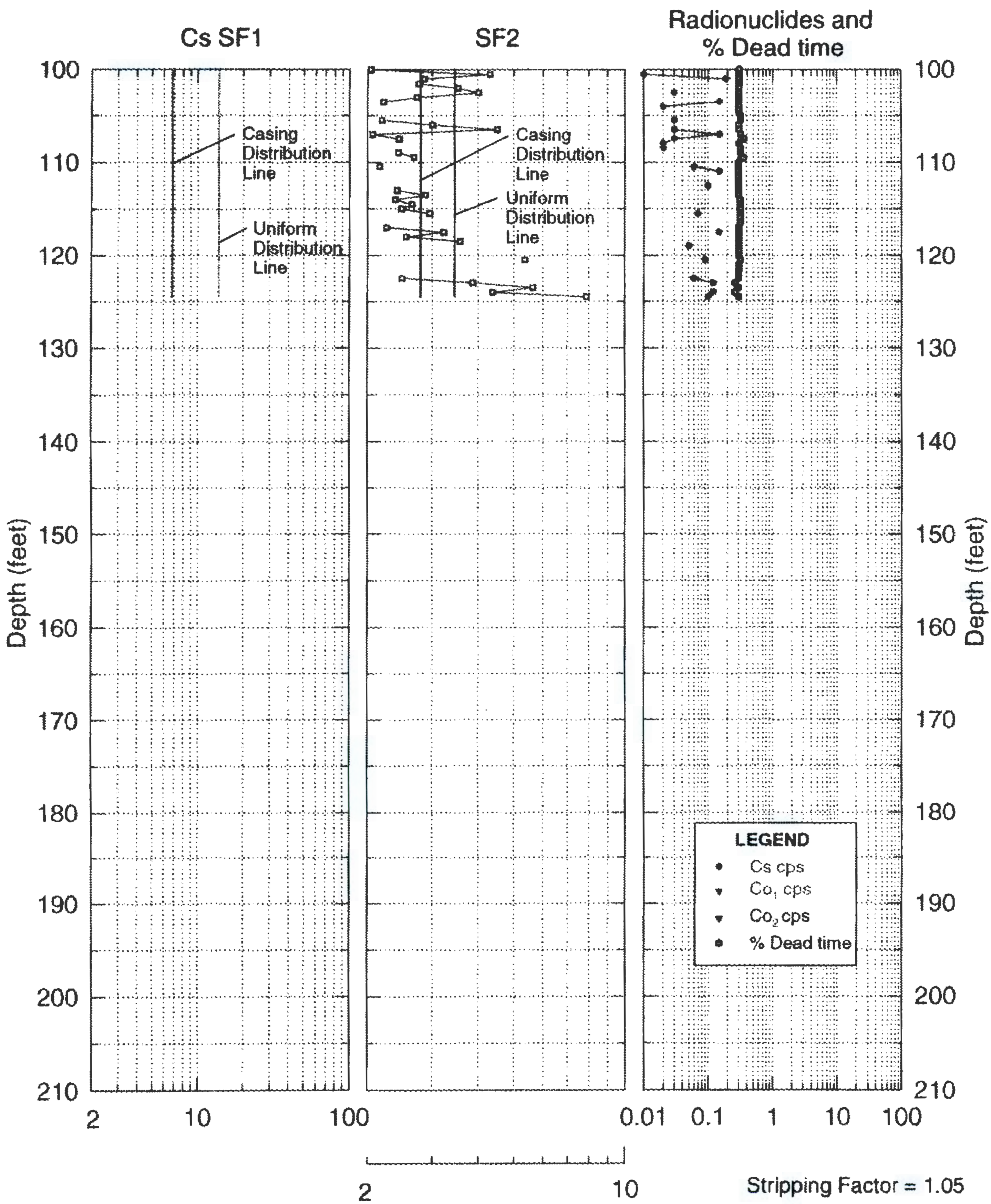


30-09-07 Combination Plot
137Cs, 60Co
40K
238U
232Th
Total γ
TF Gross γ
Depth (feet)
pCi/g
cps

30-09-07 ^{137}Cs Shape Factor Analysis Plot

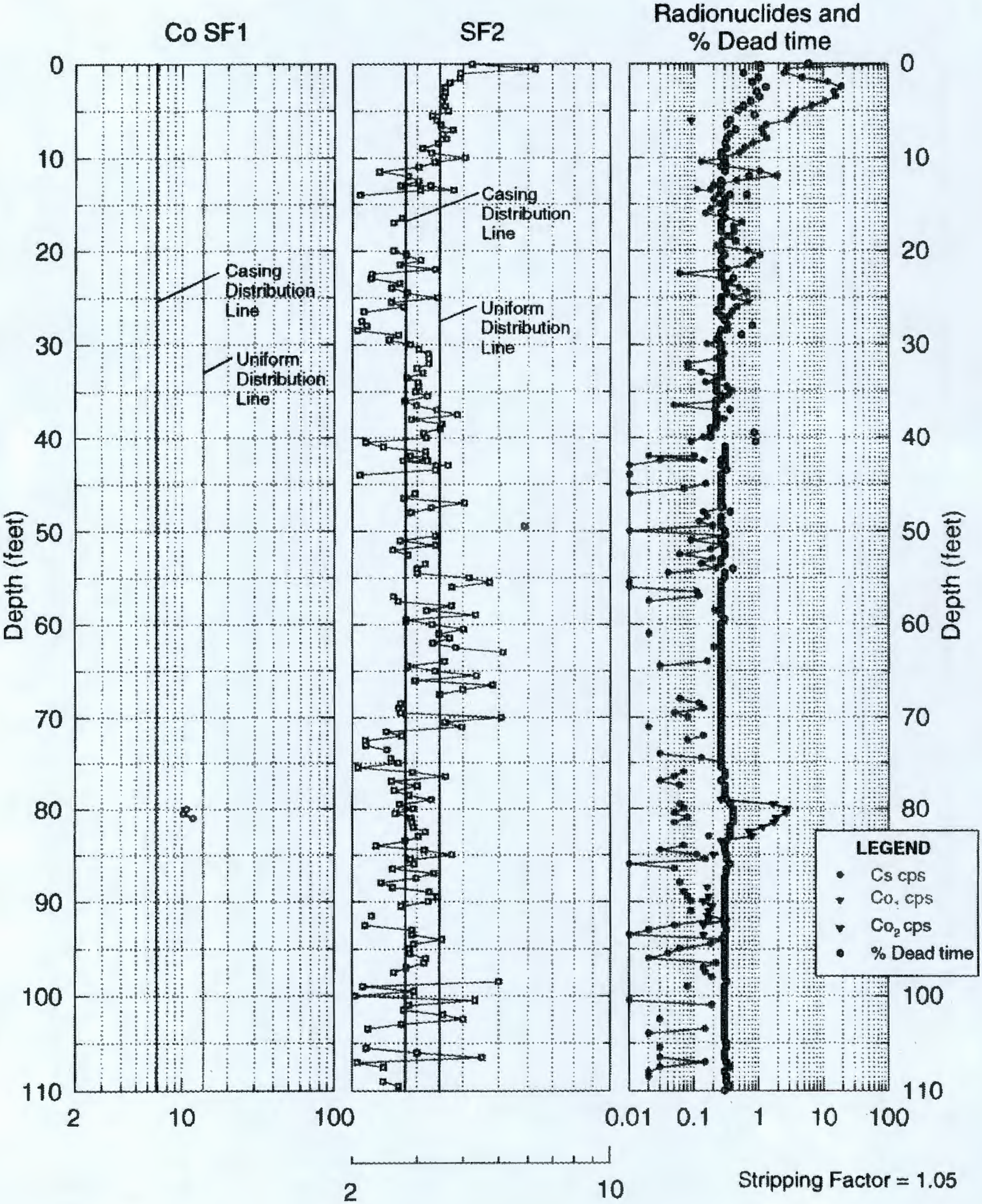


30-09-07 ^{137}Cs Shape Factor Analysis Plot



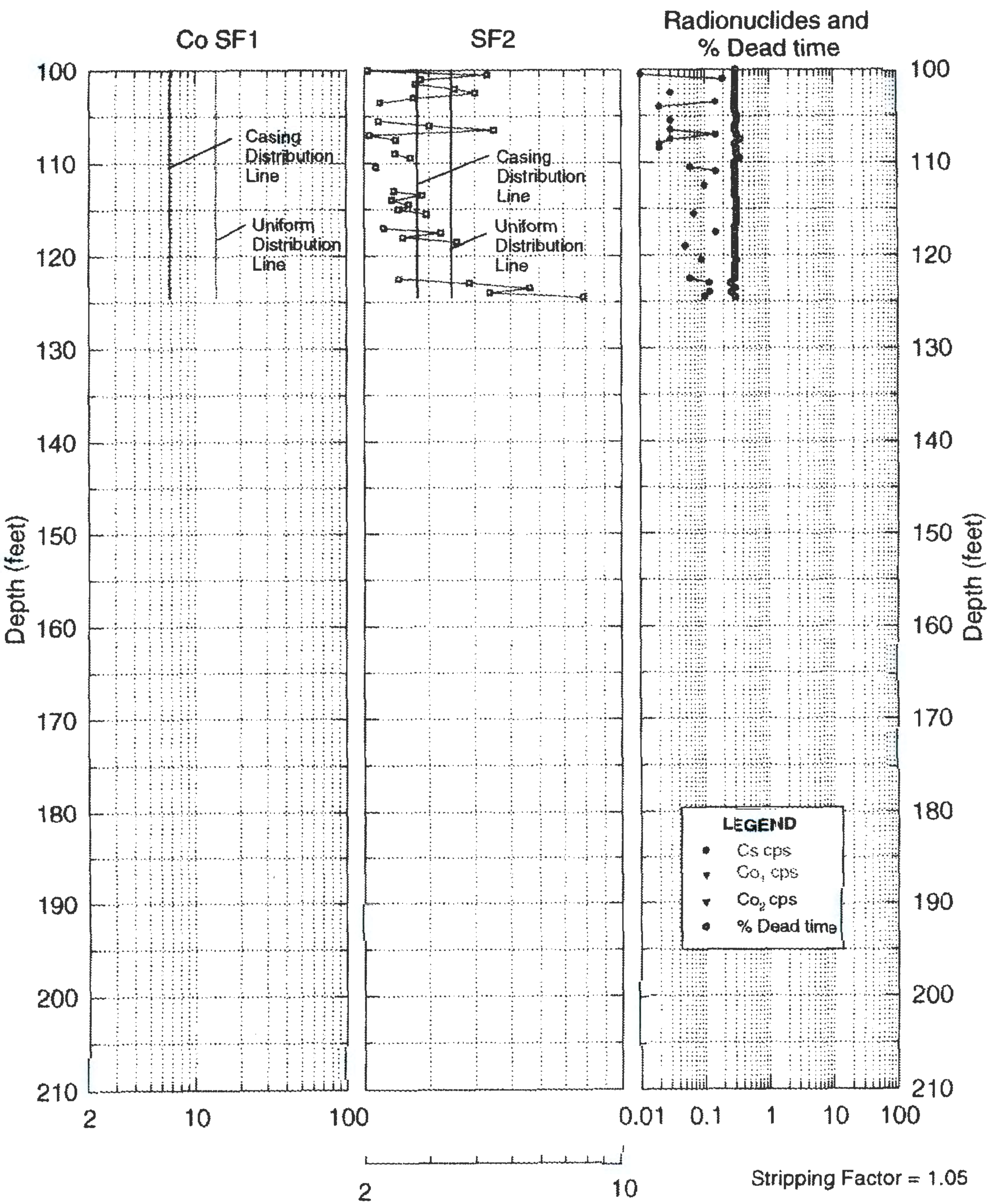
Stripping Factor = 1.05

30-09-07 ^{60}Co Shape Factor Analysis Plot



Stripping Factor = 1.05

30-09-07 ^{60}Co Shape Factor Analysis Plot



Spectral Gamma-Ray Borehole
Log Data Report

Log Event A

Borehole 30-08-03

Borehole Information

Farm :	C	Tank :	C-108	Site Number :	299-E27-51
N-Coord :	42,932	W-Coord :	48,345	TOC Elevation :	646.96
Water Level, ft :	None	Date Drilled :	12/31/44		

Casing Record

Type :	Steel-welded	Thickness :	0.322	ID, in. :	8
Top Depth, ft. :	0	Bottom Depth, ft. :	150		
Type :	Steel-welded	Thickness :	0.406	ID, in. :	12
Top Depth, ft. :	0	Bottom Depth, ft. :	50		

Cement Bottom, ft. : 150 Cement Top, ft. : 148

Borehole Notes:

This borehole was drilled in December 1944 to a depth of 150 ft. The borehole was started with a 50-ft length of permanent 12-in. surface casing and was completed to a nominal depth of 150 ft using 8-in. casing. According to the drilling log, the 8-in. casing was perforated from 48 to 148 ft and the bottom of the 8-in. casing was sealed with half a sack of cement. The drilling log does not indicate if the annulus between the 8-in. and 12-in. casings was grouted. The thickness of the 8-in. casing is presumed to be 0.322 in.; the thickness of the 12-in. casing is presumed to be 0.406 in. The top of the casing, which is the zero reference for the SGLS, is approximately flush with the ground surface.

The current total depth of the borehole was measured at 50.5 ft below the top of the casing using a weighted tape; however, this borehole was drilled to a total depth of 150 ft in 1944. The total depths of historical gross-gamma log runs have become progressively shallower over time, suggesting that the casing perforations have allowed loose sand to infiltrate into and slowly fill the borehole, or sand and silt have entered the borehole from the ground surface.

Equipment Information

Logging System :	1B	Detector Type :	HPGe	Detector Efficiency :	35.0 %
Calibration Date :	2/97	Calibration Reference :	GJO-HAN-14	Logging Procedure :	P-GJPO-1783

Log Run Information

Log Run Number :	1	Log Run Date :	3/20/97	Logging Engineer:	Alan Pearson		
Start Depth, ft.:	50.0	Counting Time, sec.:	100	L/R :	L	Shield :	N
Finish Depth, ft. :	0.0	MSA Interval, ft. :	0.5	Log Speed, ft/min.:	n/a		

Log Event A

Borehole 30-08-03

Analysis Information

Analyst : E. Larsen

Data Processing Reference : MAC-VZCP 1.7.9, Rev. 1 Analysis Date : 9/5/97

Analysis Notes :

This borehole was logged by the SGLS in one log run. The pre- and post-survey field verification spectra met the acceptance criteria established for the peak shape and detector efficiency, confirming that the SGLS was operating within specifications. The energy calibration and peak-shape calibration from these spectra were used to establish the channel-to-energy parameters used in processing the spectra acquired during the logging operation.

Casing correction factors for a 0.322-in.-thick steel casing were applied during analysis. The combined casing thickness along the double-cased interval of the borehole is greater than 0.322 in. Consequently, the calculated concentrations within this region are underestimated.

The man-made radionuclides Cs-137, Co-60, Eu-154, and U-235 were detected in this borehole. The Cs-137 contamination was measured continuously from the ground surface to the bottom of the logged interval (50 ft). The Co-60 and U-235 contamination was detected only at the ground surface. A single occurrence of Eu-154 was detected at 40.5 ft.

The 609-, 1460-, and 2614-keV gamma-ray energies have been attenuated along the double-cased interval of the borehole, resulting in reduced U-238, K-40, and Th-232 concentration values, respectively. As a result, approximately 60 percent of the 609-keV gamma-ray peaks in this region were not detected by the SGLS because the U-238 activities were reduced below the detection limit by casing attenuation.

Additional information and interpretations of log data are included in the main body of the Tank Summary Data Report for tank C-108.

Log Plot Notes:

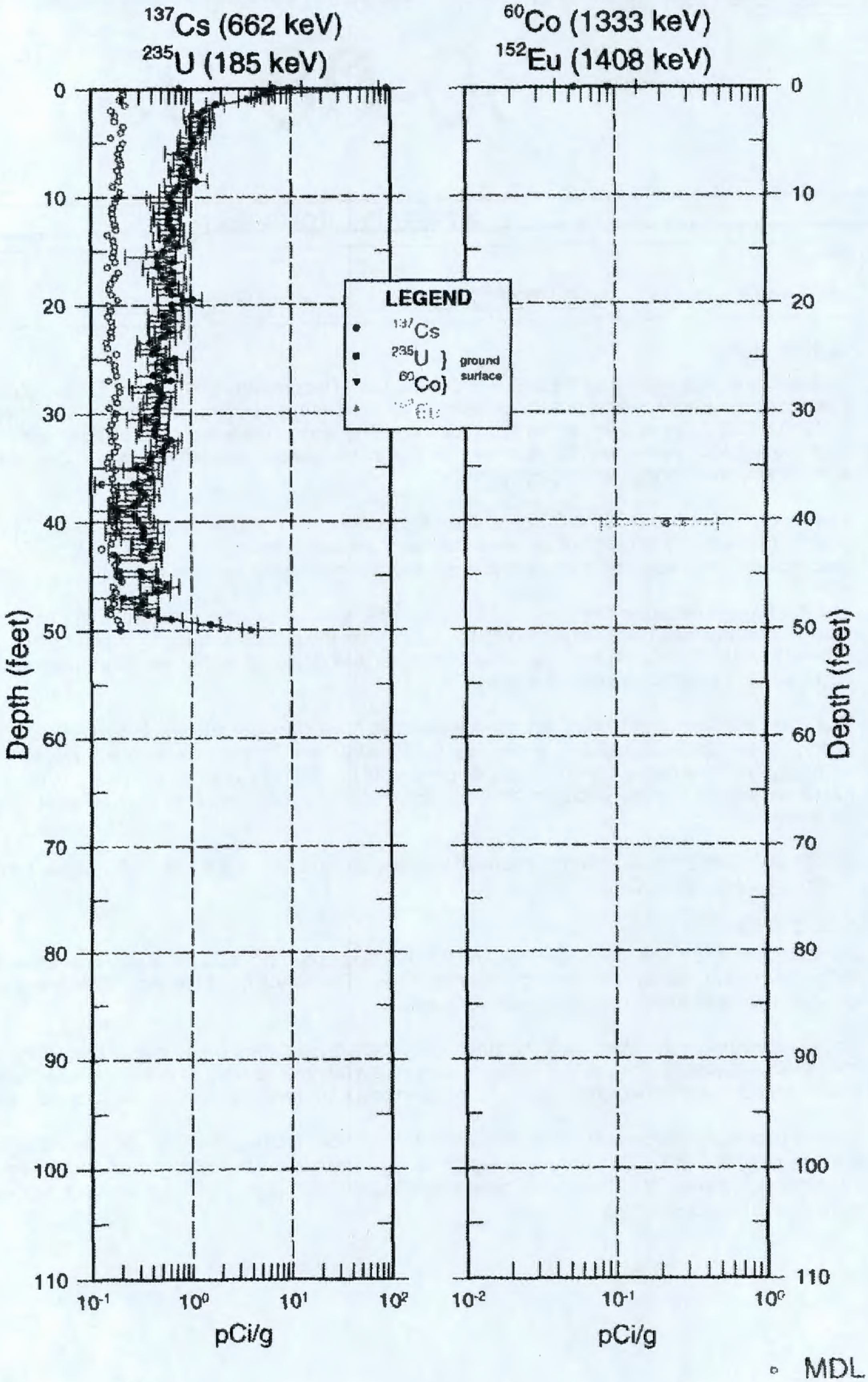
Separate log plots show the man-made and the naturally occurring radionuclides. The natural radionuclides can be used for lithology interpretations. The headings of the plots identify the specific gamma rays used to calculate the concentrations.

Uncertainty bars on the plots show the statistical uncertainties for the measurements as 95-percent confidence intervals. Open circles on the plots give the MDL. The MDL of a radionuclide represents the lowest concentration at which positive identification of a gamma-ray peak is statistically defensible.

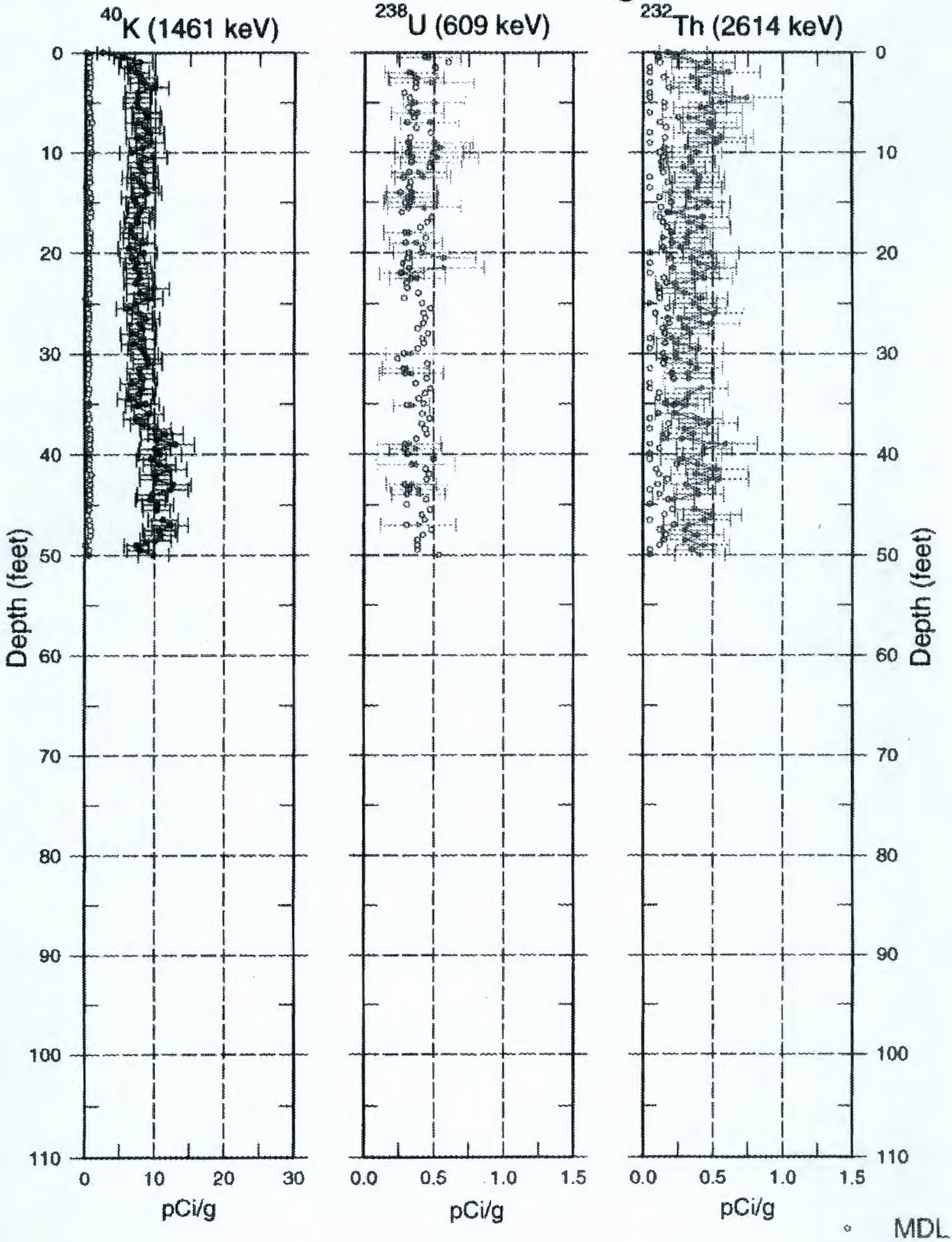
A combination plot includes the man-made and natural radionuclides, the total gamma derived from the spectral data, and the Tank Farms gross gamma log. The gross gamma plot displays the latest available digital data. No attempt has been made to adjust the depths of the gross gamma logs to coincide with the SGLS data.

30-08-03

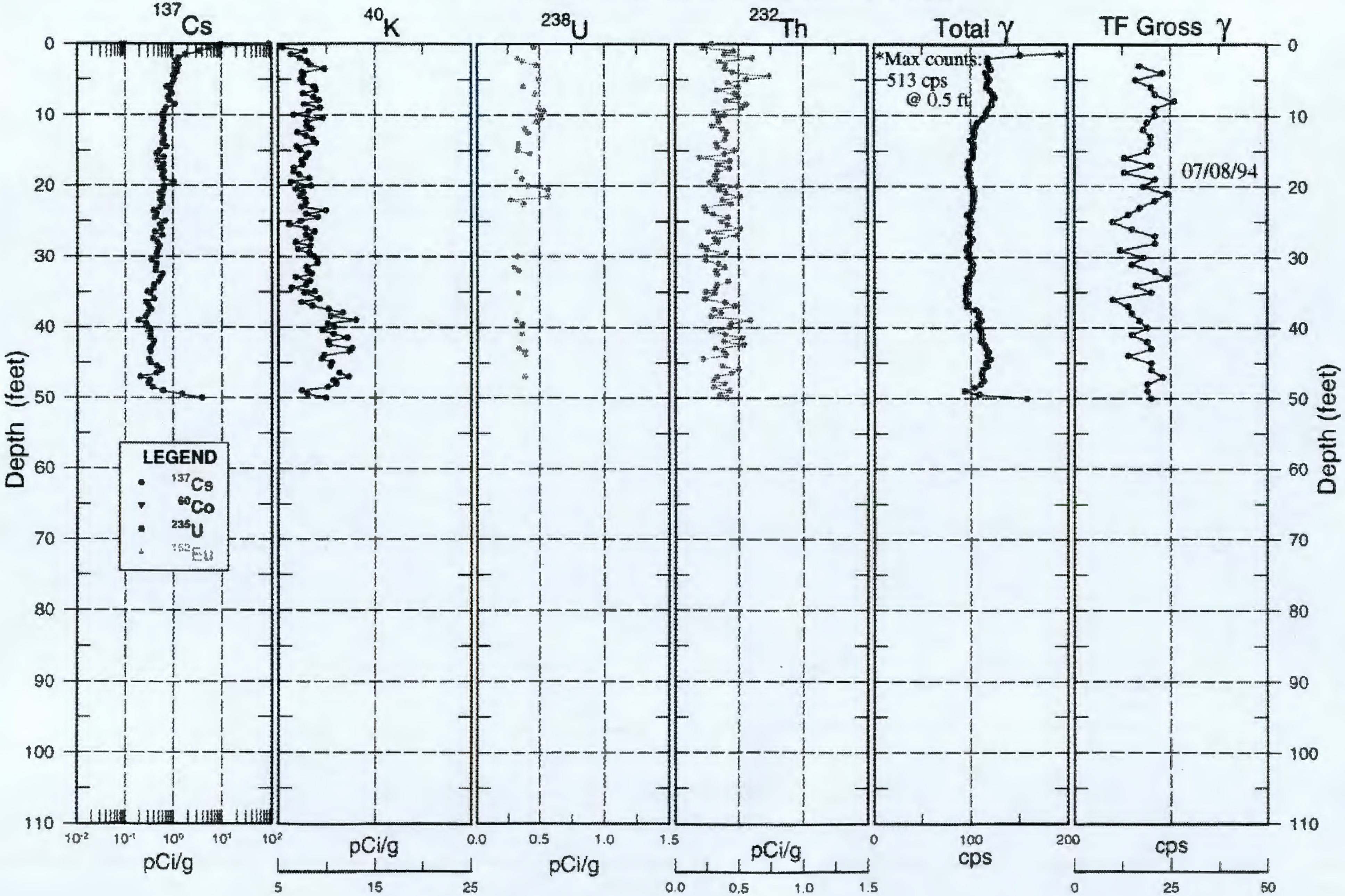
Man-Made Radionuclide Concentrations



30-08-03
Natural Gamma Logs



30-08-03 Combination Plot



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Spectral Gamma-Ray Borehole
Log Data Report

Log Event A

Borehole 30-05-10

Borehole Information

Farm :	C	Tank :	C-105	Site Number :	299-E27-68
N-Coord :	42,893	W-Coord :	48,366	TOC Elevation :	646.23
Water Level, ft :	None	Date Drilled :	11/30/72		

Casing Record

Type :	Steel-welded	Thickness :	0.280	ID, in. :	6
Top Depth, ft. :	0	Bottom Depth, ft. :	135		

Borehole Notes:
This borehole was drilled in November 1972 to a depth of 135 ft using 6-in. casing. The drilling report does not indicate if the borehole casing was perforated or grouted. The casing thickness is presumed to be 0.280 in., on the basis of the published thickness for schedule-40, 6-in. steel tubing. The top of the casing, which is the zero reference for the SGLS, is approximately flush with the ground surface. The current total depth of the borehole was measured at 135.8 ft below the top of the casing using a weighted tape, indicating that the borehole casing was probably extended to accommodate fill material that was added to the surface of the tank farm after the borehole was completed.

Equipment Information

Logging System :	2	Detector Type :	HPGe	Detector Efficiency :	35.0 %
Calibration Date :	10/96	Calibration Reference :	GJO-HAN-13	Logging Procedure :	P-GJPO-1783

Log Run Information

Log Run Number :	1	Log Run Date :	1/15/97	Logging Engineer:	Bob Spatz		
Start Depth, ft.:	0.0	Counting Time, sec.:	100	L/R :	L	Shield :	N
Finish Depth, ft. :	11.0	MSA Interval, ft. :	0.5	Log Speed, ft/min.:	n/a		

Log Run Number :	2	Log Run Date :	1/16/97	Logging Engineer:	Bob Spatz		
Start Depth, ft.:	10.0	Counting Time, sec.:	100	L/R :	L	Shield :	N
Finish Depth, ft. :	91.0	MSA Interval, ft. :	0.5	Log Speed, ft/min.:	n/a		

Log Run Number :	3	Log Run Date :	1/17/97	Logging Engineer:	Bob Spatz		
Start Depth, ft.:	135.5	Counting Time, sec.:	100	L/R :	L	Shield :	N
Finish Depth, ft. :	90.0	MSA Interval, ft. :	0.5	Log Speed, ft/min.:	n/a		

Borehole **30-05-10**

Analysis Information

Analyst : E. Larsen

Data Processing Reference : P-GJPO-1787 Analysis Date : 7/2/97

Analysis Notes :

This borehole was logged by the SGLS in three log runs. The pre- and post-survey field verification spectra met the acceptance criteria established for the peak shape and detector efficiency, confirming that the SGLS was operating within specifications. The energy calibration and peak-shape calibration from these spectra were used to establish the channel-to-energy parameters used in processing the spectra acquired during the logging operation.

Casing correction factors for a 0.280-in.-thick steel casing were applied during analysis.

The man-made radionuclides Cs-137, Co-60, and U-235 were detected in this borehole. Continuous Cs-137 contamination was detected from the ground surface to 16 ft, 26 to 30 ft, 114.5 to 116.5 ft, and at the bottom of the logged interval (134.5 to 135.5 ft). Isolated minor occurrences of Cs-137 contamination are scattered throughout the rest of the borehole. Several small zones of Co-60 contamination were detected between 13 and 53.5 ft. A single occurrence of U-235 was detected at the ground surface.

The K-40 concentration values increase at 39.5 ft, gradually decrease from 40 to 62 ft, then gradually increase from 62 to 90 ft. A sharp increase in the U-238 concentrations was detected at 90 ft.

Additional information and interpretations of log data are included in the main body of the Tank Summary Data Reports for tanks C-105 and C-108.

Log Plot Notes:

Separate log plots show the man-made and the naturally occurring radionuclides. The natural radionuclides can be used for lithology interpretations. The headings of the plots identify the specific gamma rays used to calculate the concentrations.

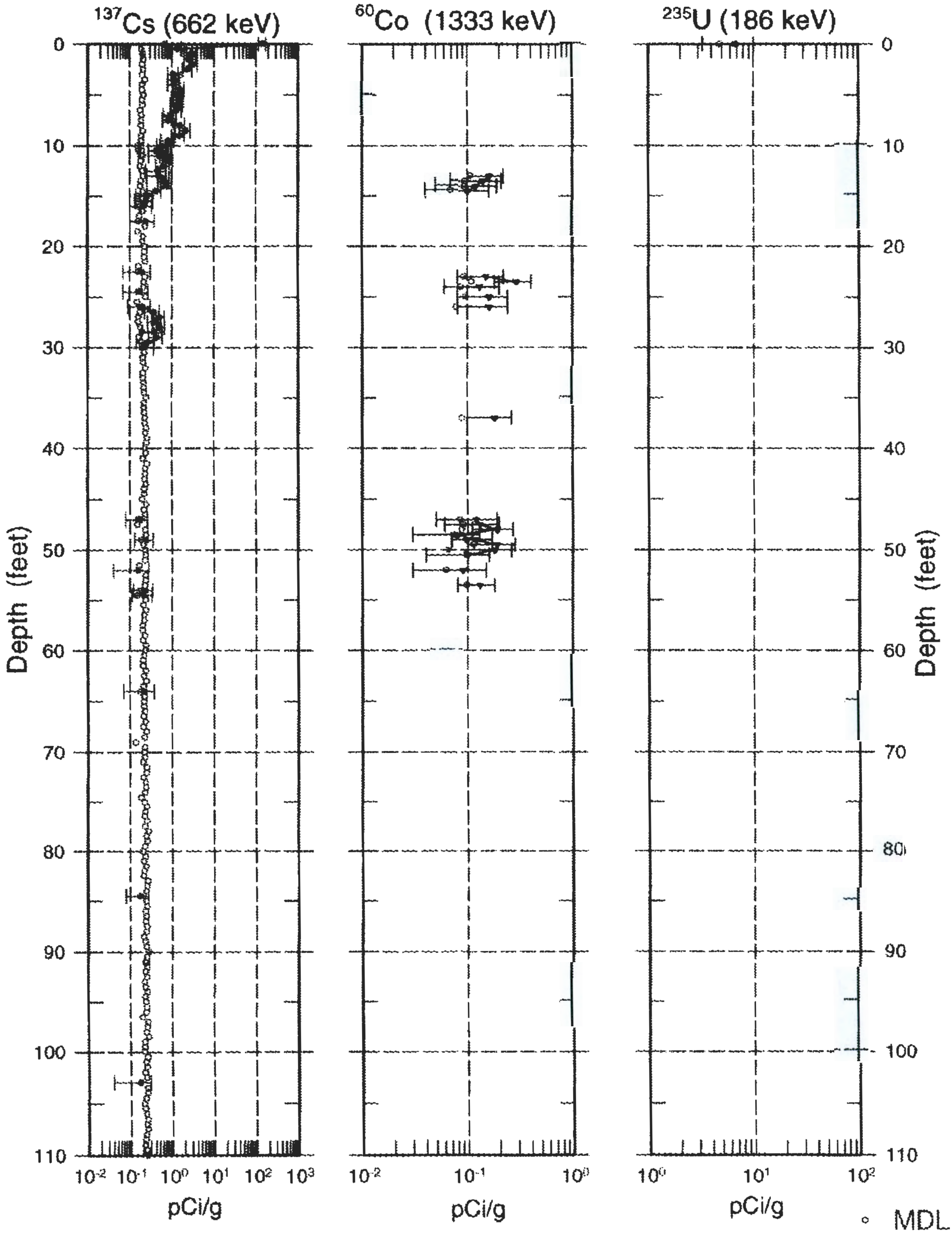
Uncertainty bars on the plots show the statistical uncertainties for the measurements as 95-percent confidence intervals. Open circles on the plots give the MDL. The MDL of a radionuclide represents the lowest concentration at which positive identification of a gamma-ray peak is statistically defensible.

A combination plot includes the man-made and natural radionuclides, the total gamma derived from the spectral data, and the Tank Farms gross gamma log. The gross gamma plot displays the latest available digital data. No attempt has been made to adjust the depths of the gross gamma logs to coincide with the SGLS data.

An additional log plot compares spectral gamma data collected with the Radionuclide Logging System (RLS) in 1993 with spectral gamma data collected with the SGLS in 1997. Uncertainty bars and MDLs are not included on these plots.

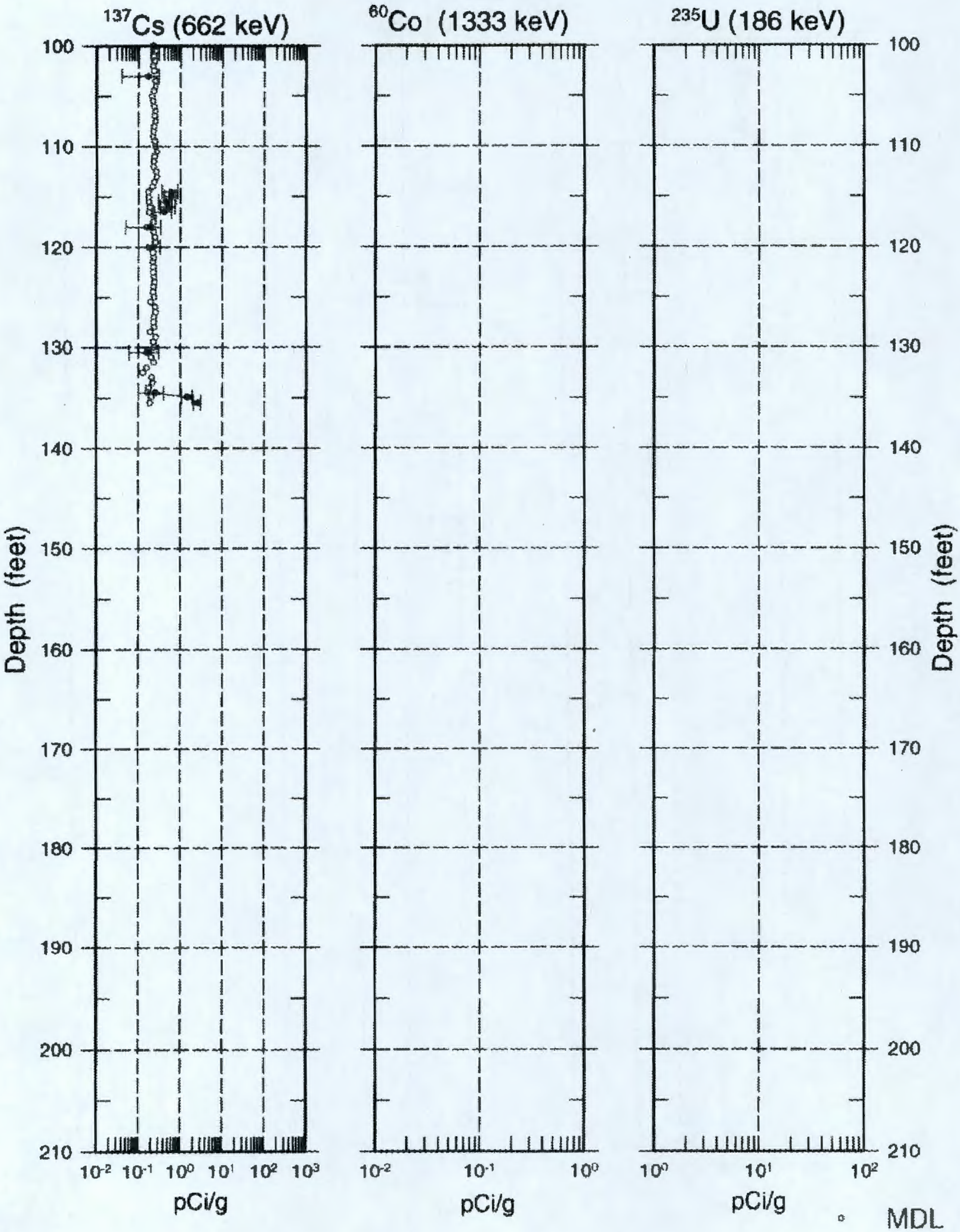
30-05-10

Man-Made Radionuclide Concentrations

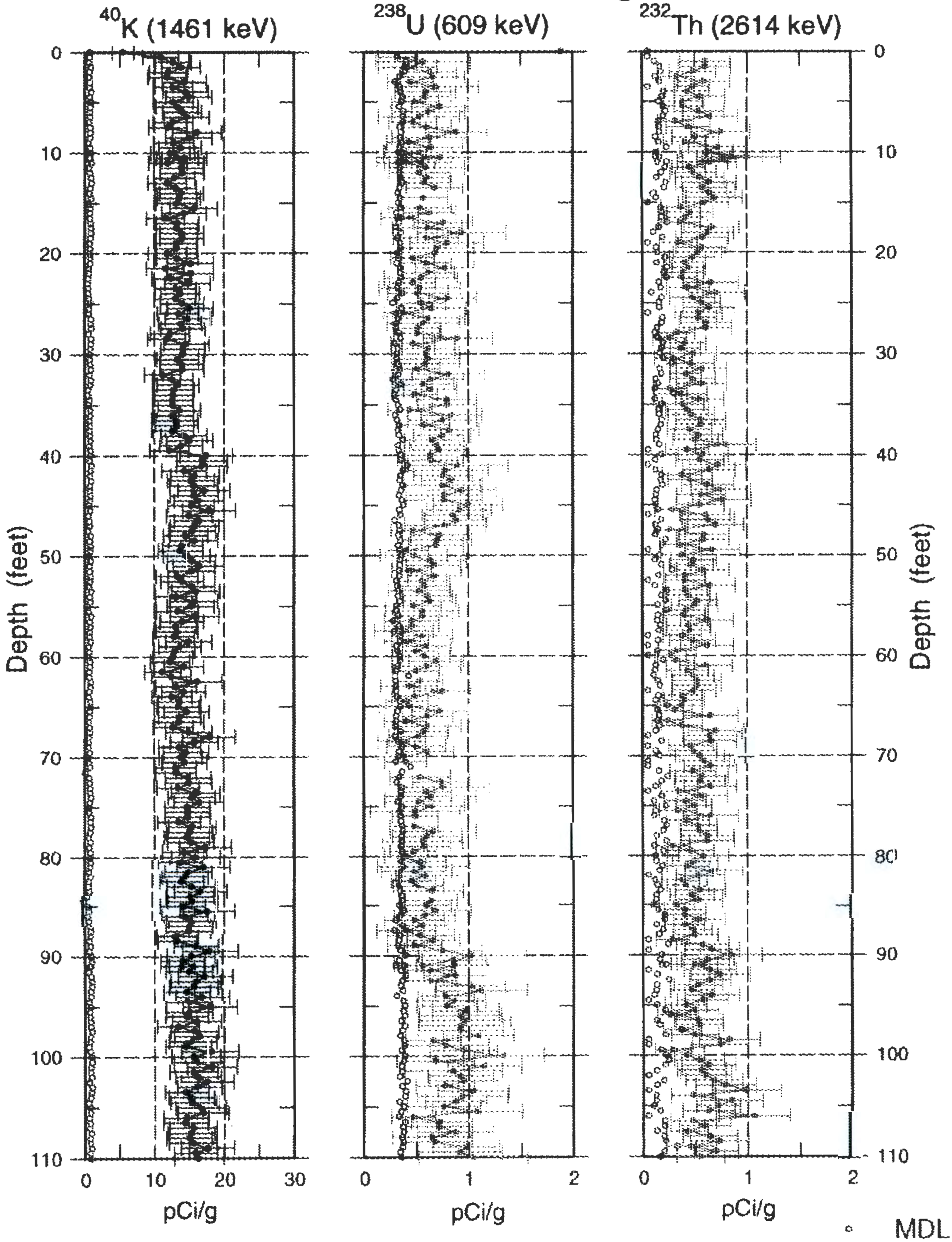


30-05-10

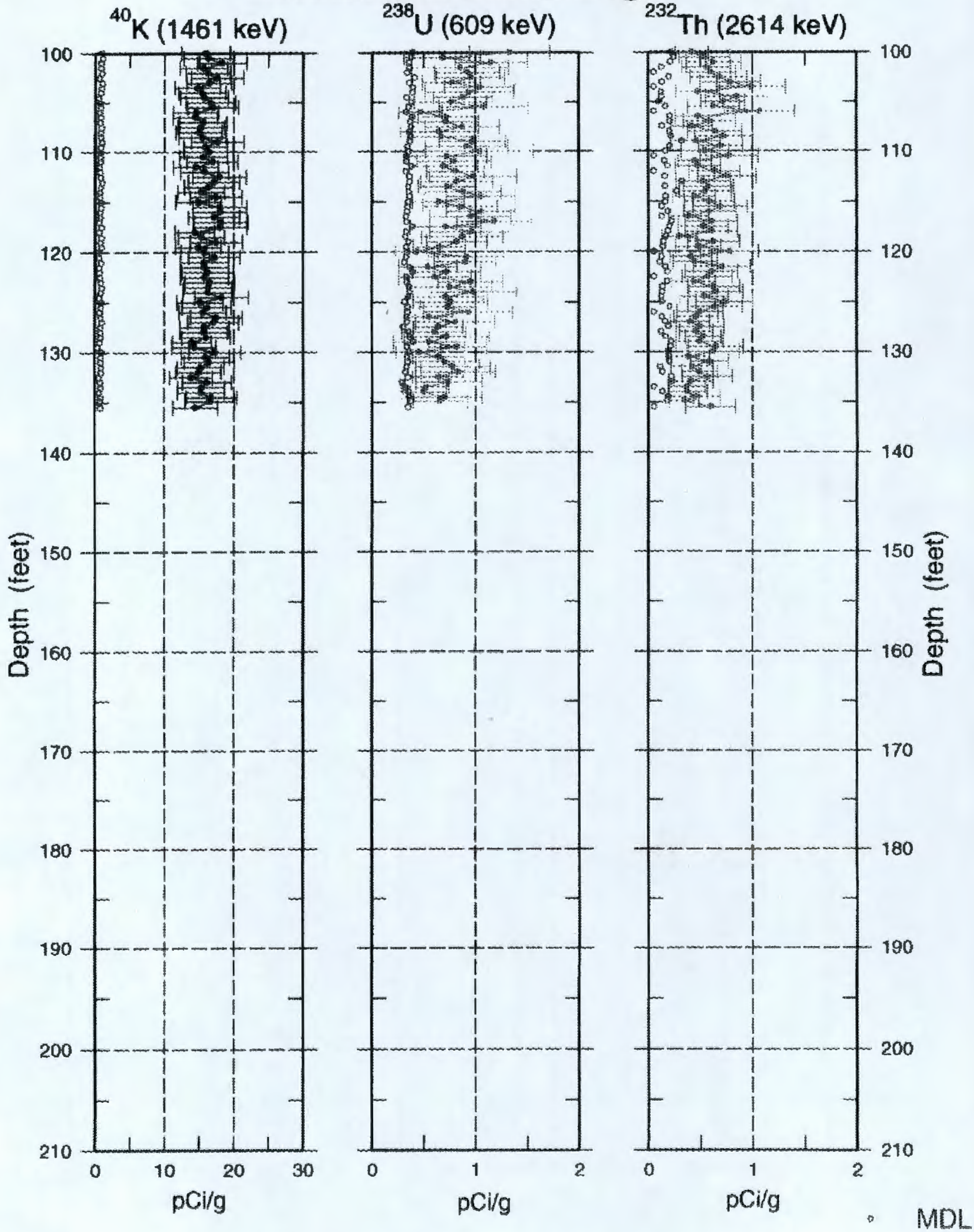
Man-Made Radionuclide Concentrations

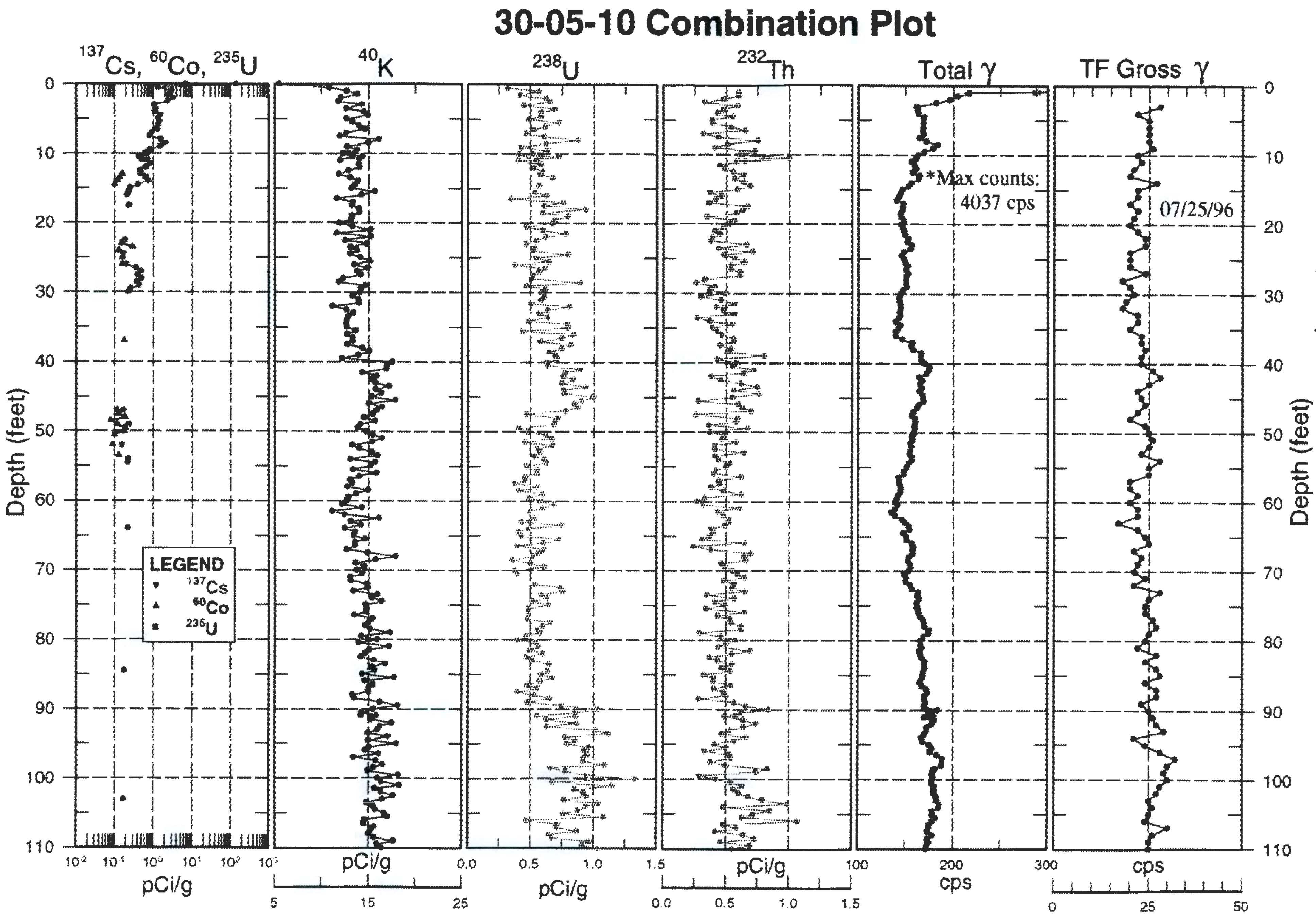


30-05-10
Natural Gamma Logs



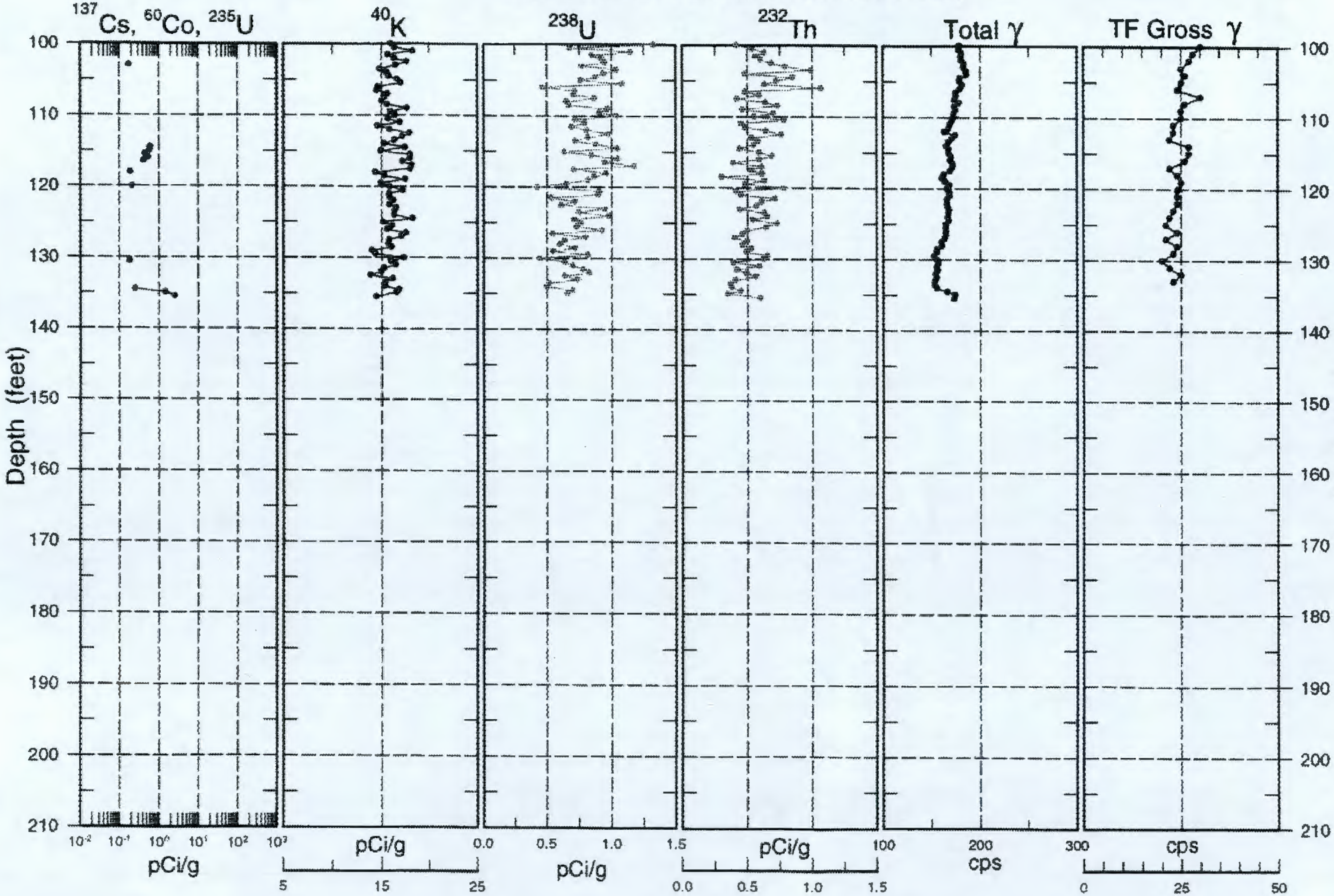
30-05-10
Natural Gamma Logs





30-05-10 Combination Plot
137Cs, 60Co, 235U
40K
238U
232Th
Total γ
TF Gross γ
Depth (feet)
pCi/g
cps
*Max counts: 4037 cps
07/25/96
LEGEND
137Cs
60Co
235U

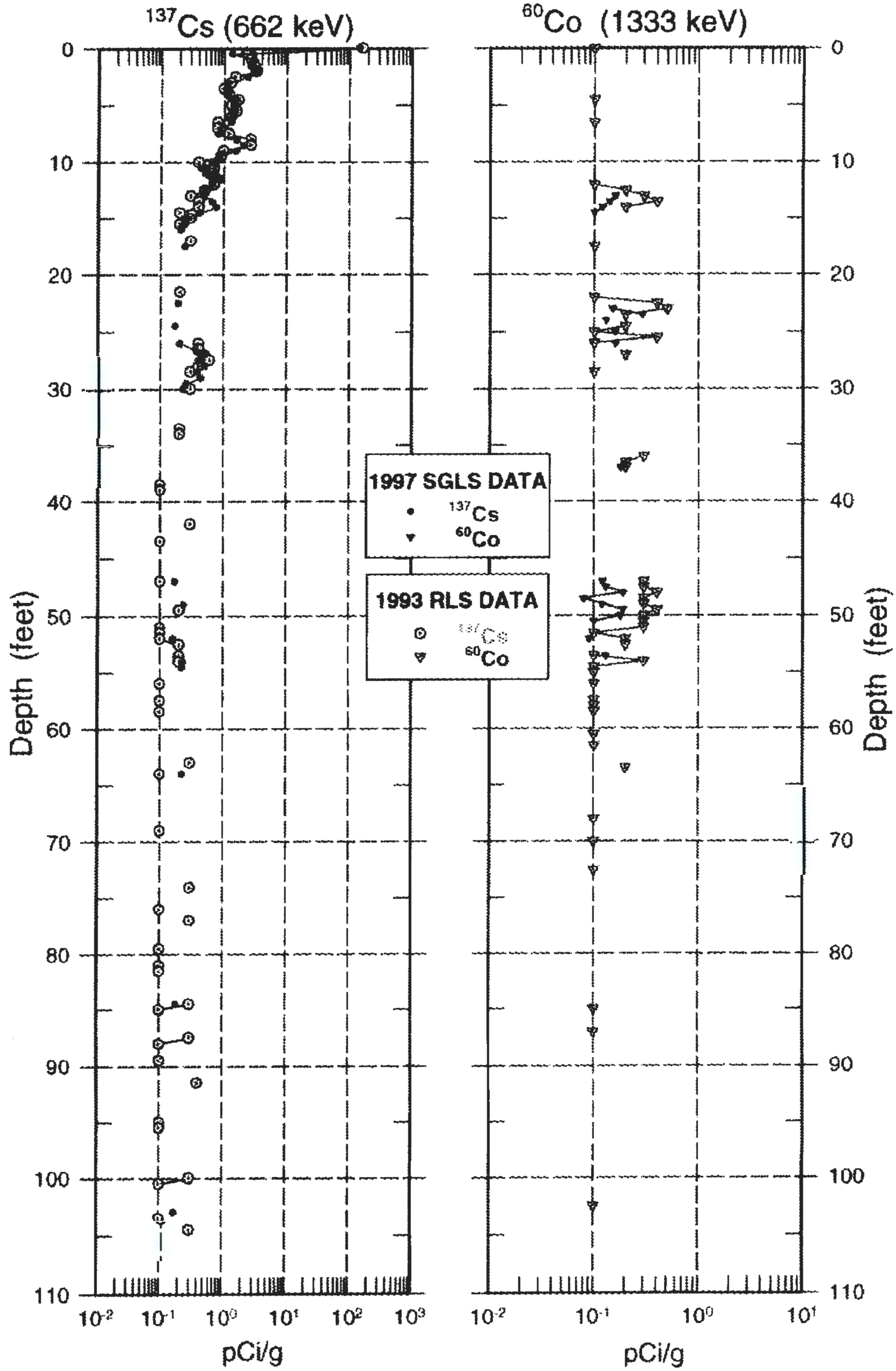
30-05-10 Combination Plot



30-05-10

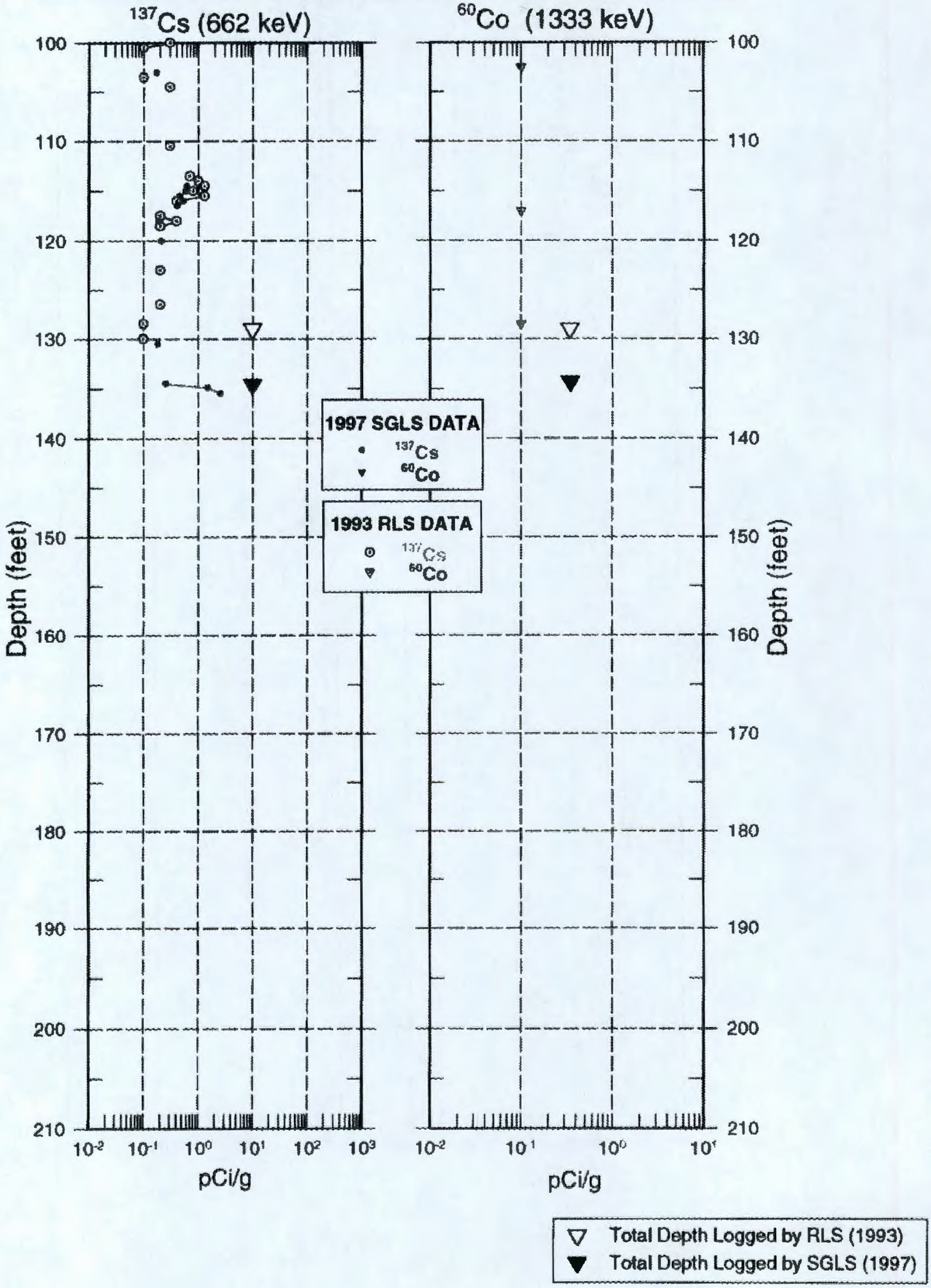
Man-Made Radionuclide Concentrations

1993/1997 Spectral Gamma Data Comparison



30-05-10

Man-Made Radionuclide Concentrations
1993/1997 Spectral Gamma Data Comparison



Spectral Gamma-Ray Borehole
Log Data Report

Log Event A

Borehole 30-07-02

Borehole Information

Farm :	C	Tank :	C-107	Site Number :	299-E27-88
N-Coord :	42,883	W-Coord :	48,419	TOC Elevation :	646.00
Water Level, ft :	None	Date Drilled :	9/30/74		

Casing Record

Type :	Steel-welded	Thickness :	0.280	ID, in. :	6
Top Depth, ft. :	0	Bottom Depth, ft. :	100		

Borehole Notes:
Borehole 30-07-02 was drilled in September 1974 to a depth of 100 ft with 6-in. casing. The casing thickness is presumed to be 0.280 in., on the basis of the published thickness for schedule-40, 6-in. steel tubing. No information concerning grouting or perforations was available; therefore, it is assumed that the borehole was not grouted or perforated. The top of the casing, which is the zero reference for the SGLS, is even with the ground surface.

Equipment Information

Logging System :	1B	Detector Type :	HPGe	Detector Efficiency :	35.0 %
Calibration Date :	2/97	Calibration Reference :	GJO-HAN-14	Logging Procedure :	P-GJPO-1783

Log Run Information

Log Run Number :	1	Log Run Date :	3/12/97	Logging Engineer:	Alan Pearson		
Start Depth, ft.:	0.0	Counting Time, sec.:	100	L/R :	L	Shield :	N
Finish Depth, ft. :	28.0	MSA Interval, ft. :	0.5	Log Speed, ft/min.:	n/a		

Log Run Number :	2	Log Run Date :	3/13/97	Logging Engineer:	Alan Pearson		
Start Depth, ft.:	27.0	Counting Time, sec.:	100	L/R :	L	Shield :	N
Finish Depth, ft. :	99.0	MSA Interval, ft. :	0.5	Log Speed, ft/min.:	n/a		

Log Event A

Borehole 30-07-02

Analysis Information

Analyst : D.L. Parker

Data Processing Reference : MAC-VZCP 1.7.9, Rev. 1 Analysis Date : 8/20/97

Analysis Notes :

This borehole was logged by the SGLS in two log runs. The pre- and post-survey field verification spectra met the acceptance criteria established for the peak shape and detector efficiency, confirming that the SGLS was operating within specifications. The energy calibration and peak-shape calibration from these spectra were used to establish the peak resolution and the channel-to-energy parameters used in processing the spectra acquired during the logging operation. There was some gain drift and it was necessary to adjust the established channel-to-energy parameters during processing of log data to maintain proper peak identification.

Casing correction factors for a 0.280-in.-thick steel casing were applied during analysis.

The only man-made radionuclide detected in this borehole was Cs-137. The presence of Cs-137 was measured almost continuously from the ground surface to 32 ft, at 42.5 and 43 ft, and at the bottom of the logged interval (99 ft).

An analysis of the shape factors associated with applicable segments of the spectra was performed. The shape factors provide insights into the distribution of the Cs-137 contamination and into the nature of zones of elevated total count gamma-ray activity not attributable to gamma-emitting radionuclides.

The U-238 and Th-232 concentration data are absent along several short intervals throughout the length of the borehole. The K-40 concentrations increase at 40 ft and remain elevated to 59 ft. Th-232 concentrations are highly variable over the depth of the borehole.

Additional information and interpretations of log data are included in the main body of the Tank Summary Data Reports for tanks C-107 and C-108.

Log Plot Notes:

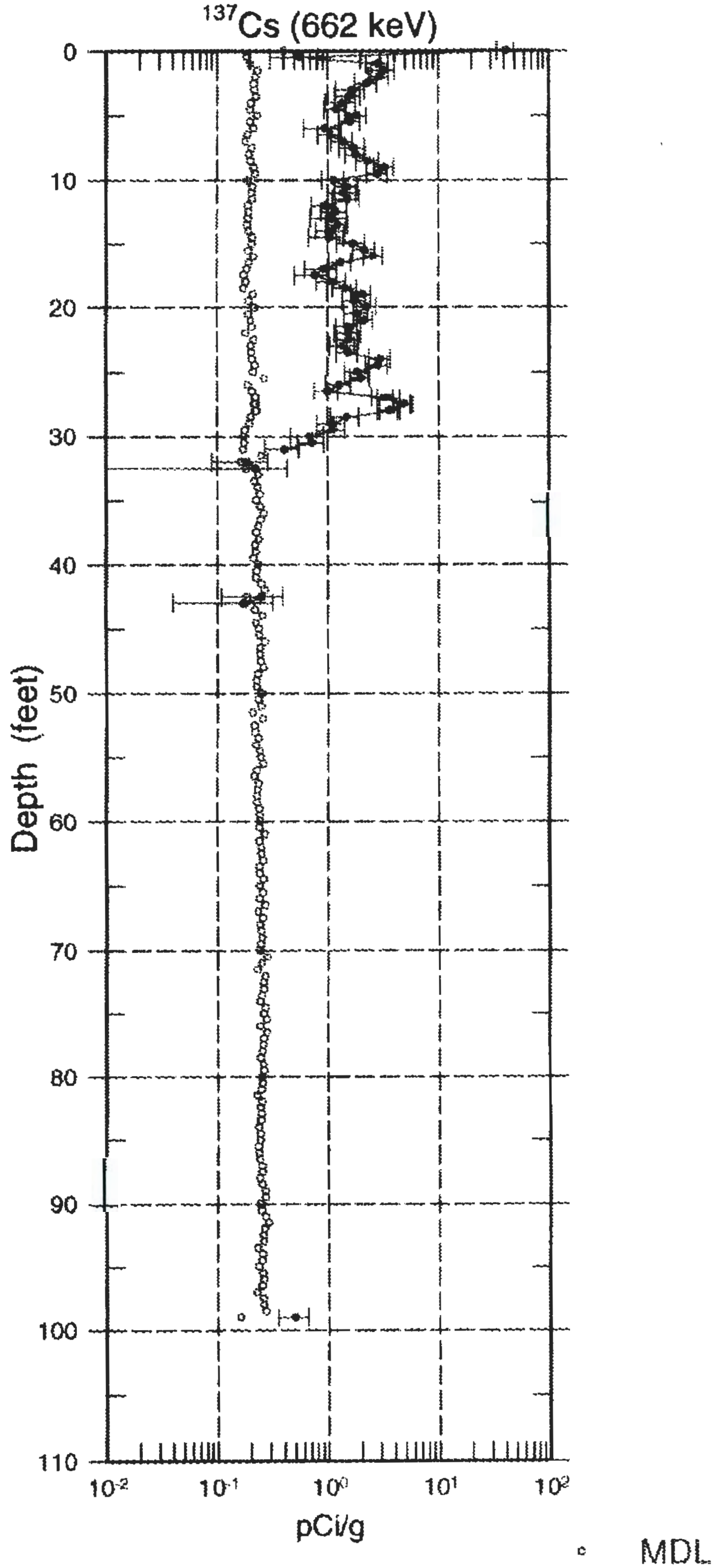
Separate log plots show the man-made and the naturally occurring radionuclides. The natural radionuclides can be used for lithology interpretations. The headings of the plots identify the specific gamma rays used to calculate the concentrations.

Uncertainty bars on the plots show the statistical uncertainties for the measurements as 95-percent confidence intervals. Open circles on the plots give the MDL. The MDL of a radionuclide represents the lowest concentration at which positive identification of a gamma-ray peak is statistically defensible.

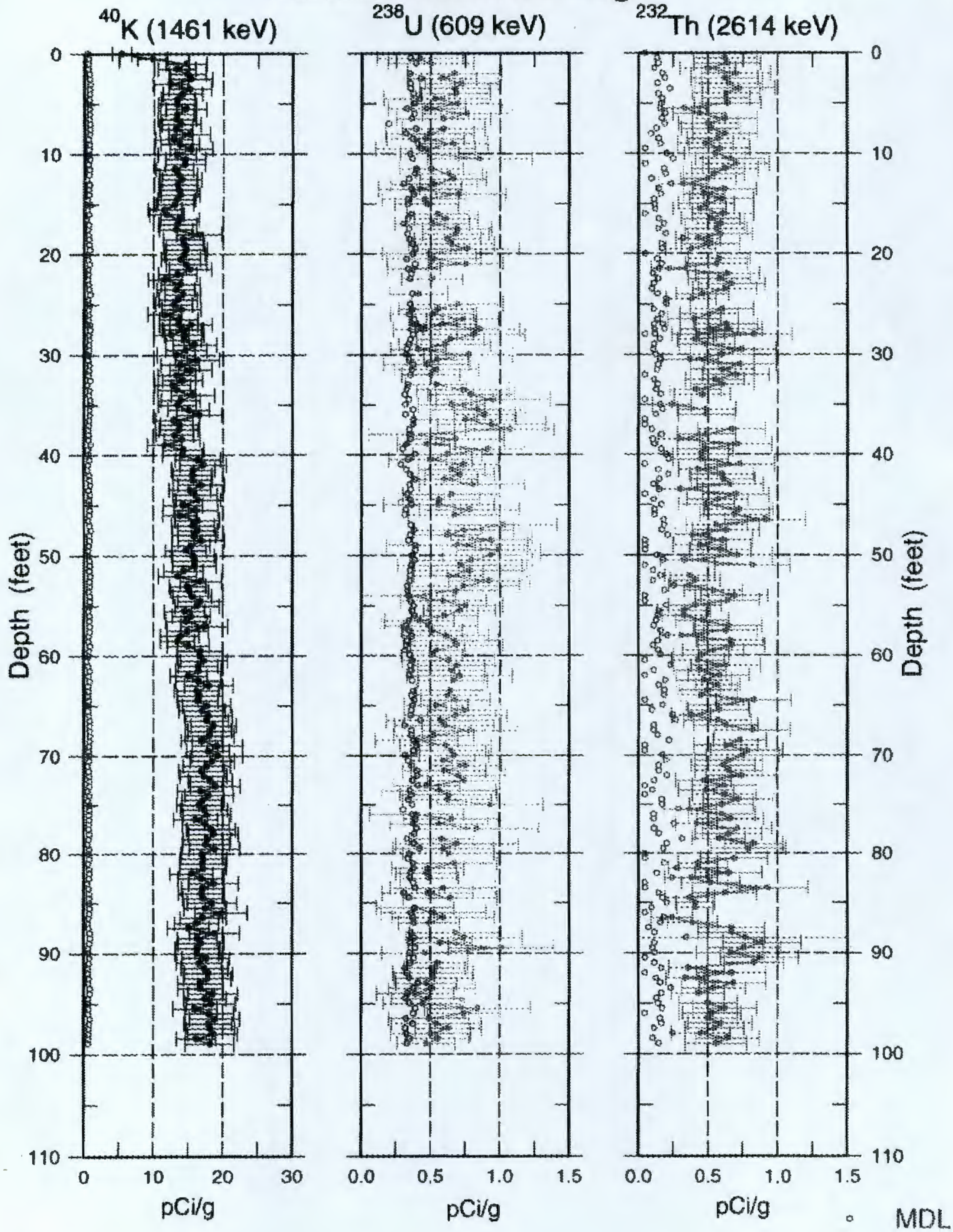
A combination plot includes the man-made and natural radionuclides, the total gamma derived from the spectral data, and the Tank Farms gross gamma log. The gross gamma plot displays the latest available digital data. No attempt has been made to adjust the depths of the gross gamma logs to coincide with the SGLS data.

A plot showing the results of the shape factor analysis is included with the set of plots for this borehole.

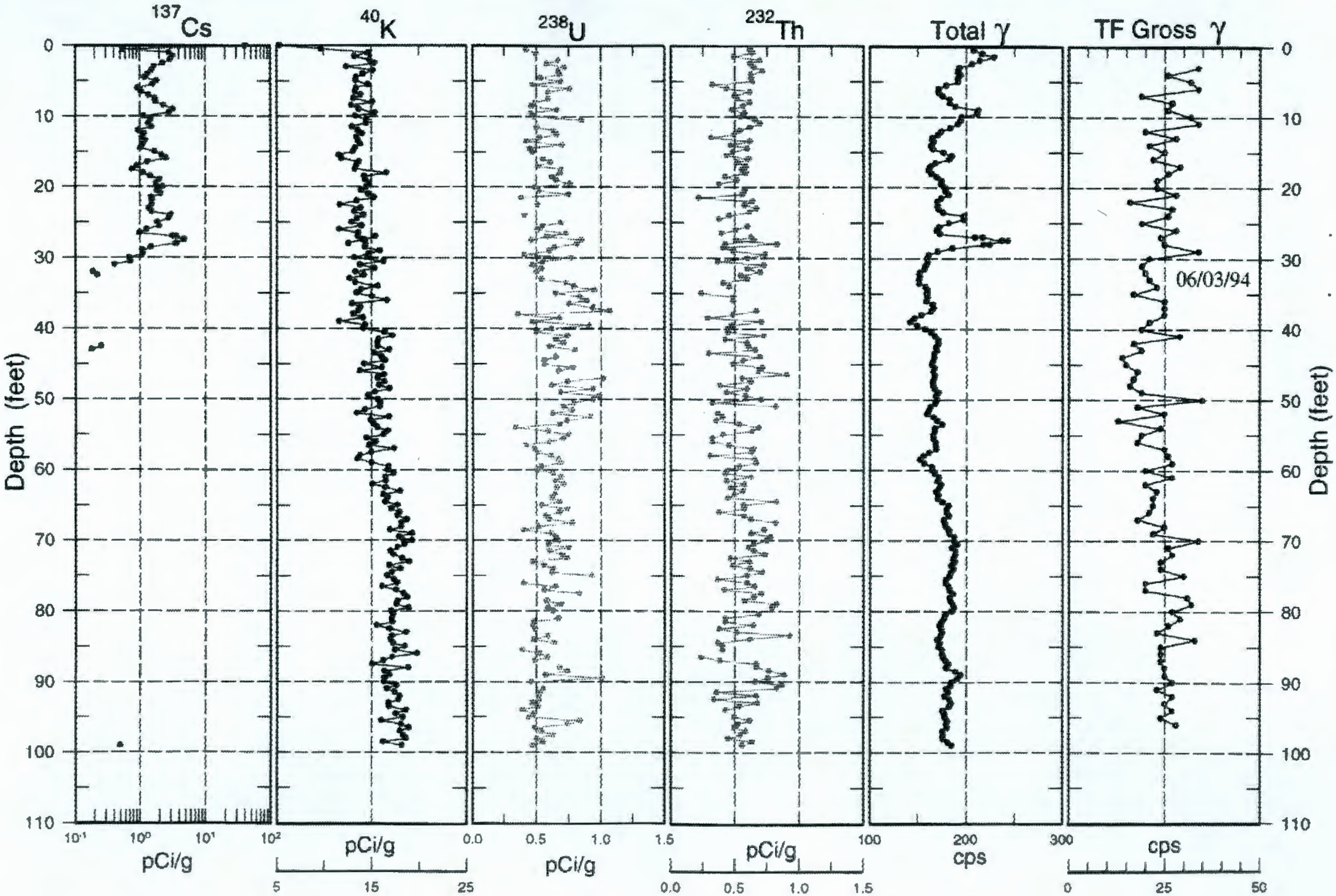
30-07-02
Man-Made Radionuclide Concentrations



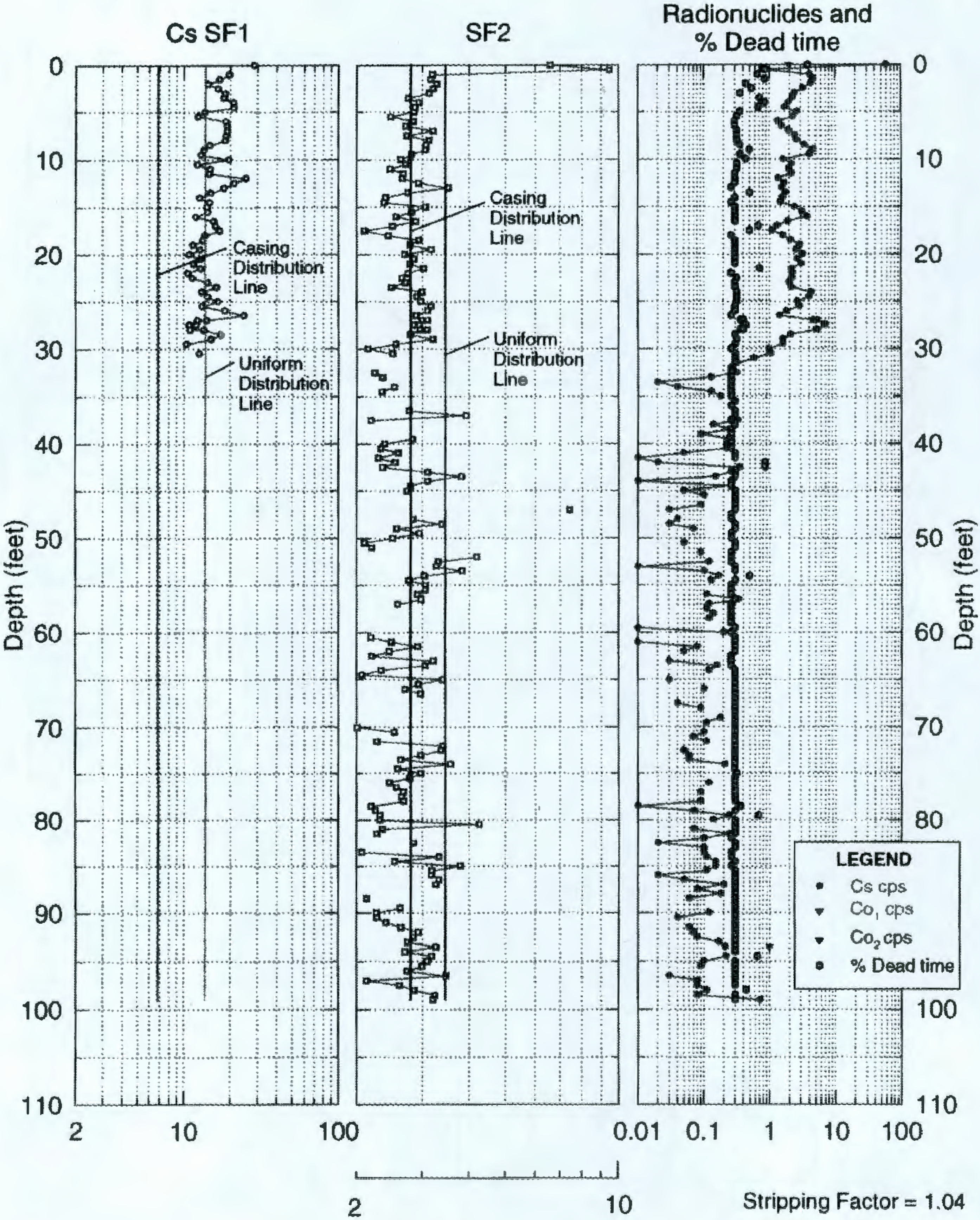
30-07-02
Natural Gamma Logs



30-07-02 Combination Plot



30-07-02 ^{137}Cs Shape Factor Analysis Plot



Stripping Factor = 1.04

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Spectral Gamma-Ray Borehole
Log Data Report

Log Event A

Borehole 30-07-01

Borehole Information

Farm : C
Tank : C-107
Site Number : 299-E27-87
N-Coord : 42,911
W-Coord : 48,448
TOC Elevation : 646.00
Water Level, ft : None
Date Drilled : 9/30/74

Casing Record

Type : Steel-welded
Thickness : 0.280
ID, in. : 6
Top Depth, ft. : 0
Bottom Depth, ft. : 100

Borehole Notes:
Borehole 30-07-01 was drilled in September 1974 to a depth of 100 ft with 6-in. casing. The casing thickness is assumed to be 0.280 in., on the basis of the published thickness for schedule-40, 6-in. steel tubing. No information concerning grouting or perforations was available; therefore, it is assumed that the borehole was not grouted or perforated. The top of the casing, which is the zero reference for the SGLS, is even with the ground surface.

Equipment Information

Logging System : 2
Detector Type : HPGe
Detector Efficiency : 35.0 %
Calibration Date : 10/96
Calibration Reference : GJO-HAN-13
Logging Procedure : P-GJPO-1783

Log Run Information

Log Run Number : 1
Log Run Date : 3/7/97
Logging Engineer: Bob Spatz
Start Depth, ft.: 100.0
Counting Time, sec.: 100
L/R : L
Shield : N
Finish Depth, ft. : 48.5
MSA Interval, ft. : 0.5
Log Speed, ft/min.: n/a

Log Run Number : 2
Log Run Date : 3/10/97
Logging Engineer: Bob Spatz
Start Depth, ft.: 49.5
Counting Time, sec.: 100
L/R : L
Shield : N
Finish Depth, ft. : 0.0
MSA Interval, ft. : 0.5
Log Speed, ft/min.: n/a

Log Event A

Borehole 30-07-01

Analysis Information

Analyst : D.L. Parker

Data Processing Reference : MAC-VZCP 1.7.9, Rev. 1 Analysis Date : 8/20/97

Analysis Notes :

This borehole was logged by the SGLS in two log runs. The pre- and post-survey field verification spectra met the acceptance criteria established for the peak shape and detector efficiency, confirming that the SGLS was operating within specifications. The energy calibration and peak-shape calibration from these spectra were used to establish the peak resolution and channel-to-energy parameters used in processing the spectra acquired during the logging operation. There was some gain drift and it was necessary to adjust the established channel-to-energy parameters during processing of log data to maintain proper peak identification.

Casing correction factors for a 0.280-in.-thick steel casing were applied during analysis.

The only man-made radionuclide detected in this borehole was Cs-137. The presence of Cs-137 was measured almost continuously from the ground surface to 74 ft and intermittently from 75.5 to 87.5 ft.

An analysis of the shape factors associated with applicable segments of the spectra was performed. The shape factors provide insights into the distribution of the Cs-137 contamination and into the nature of zones of elevated total count gamma-ray activity not attributable to gamma-emitting radionuclides.

The U-238 and Th-232 concentration data are absent along several short intervals throughout the length of the borehole. The K-40 and U-238 concentrations decrease at about 40 ft. Th-232 concentrations are highly variable below about 39 ft. K-40 concentrations decrease from about 56 to 59 ft. K-40 concentrations increase again at 59 ft and remain elevated to the bottom of the logged interval.

Additional information and interpretations of log data are provided in the main body of the Tank Summary Data Reports for tank C-107 and C-108.

Log Plot Notes:

Separate log plots show the man-made and the naturally occurring radionuclides. The natural radionuclides can be used for lithology interpretations. The headings of the plots identify the specific gamma rays used to calculate the concentrations.

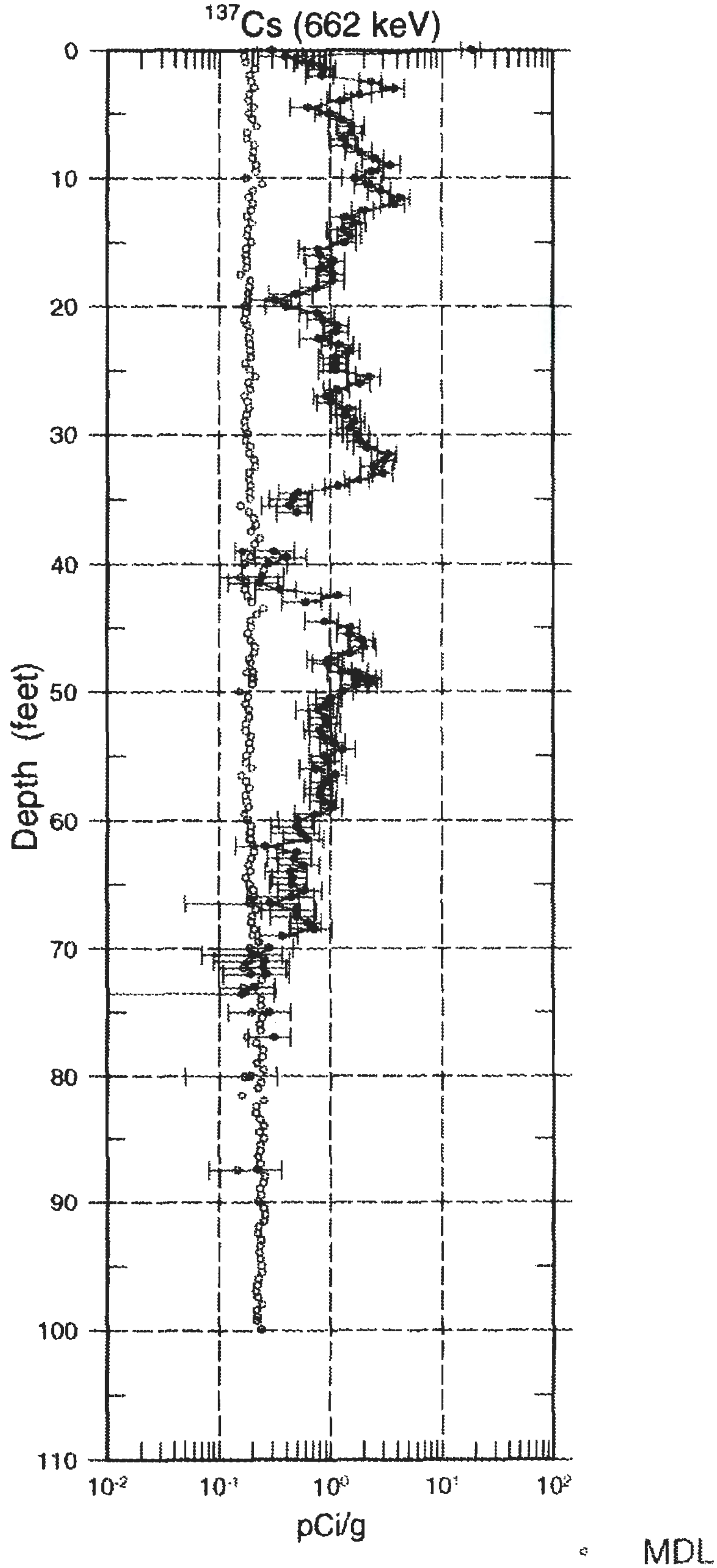
Uncertainty bars on the plots show the statistical uncertainties for the measurements as 95-percent confidence intervals. Open circles on the plots give the MDL. The MDL of a radionuclide represents the lowest concentration at which positive identification of a gamma-ray peak is statistically defensible.

A combination plot includes the man-made and natural radionuclides, the total gamma derived from the spectral data, and the Tank Farms gross gamma log. The gross gamma plot displays the latest available digital data. No attempt has been made to adjust the depths of the gross gamma logs to coincide with the SGLS data.

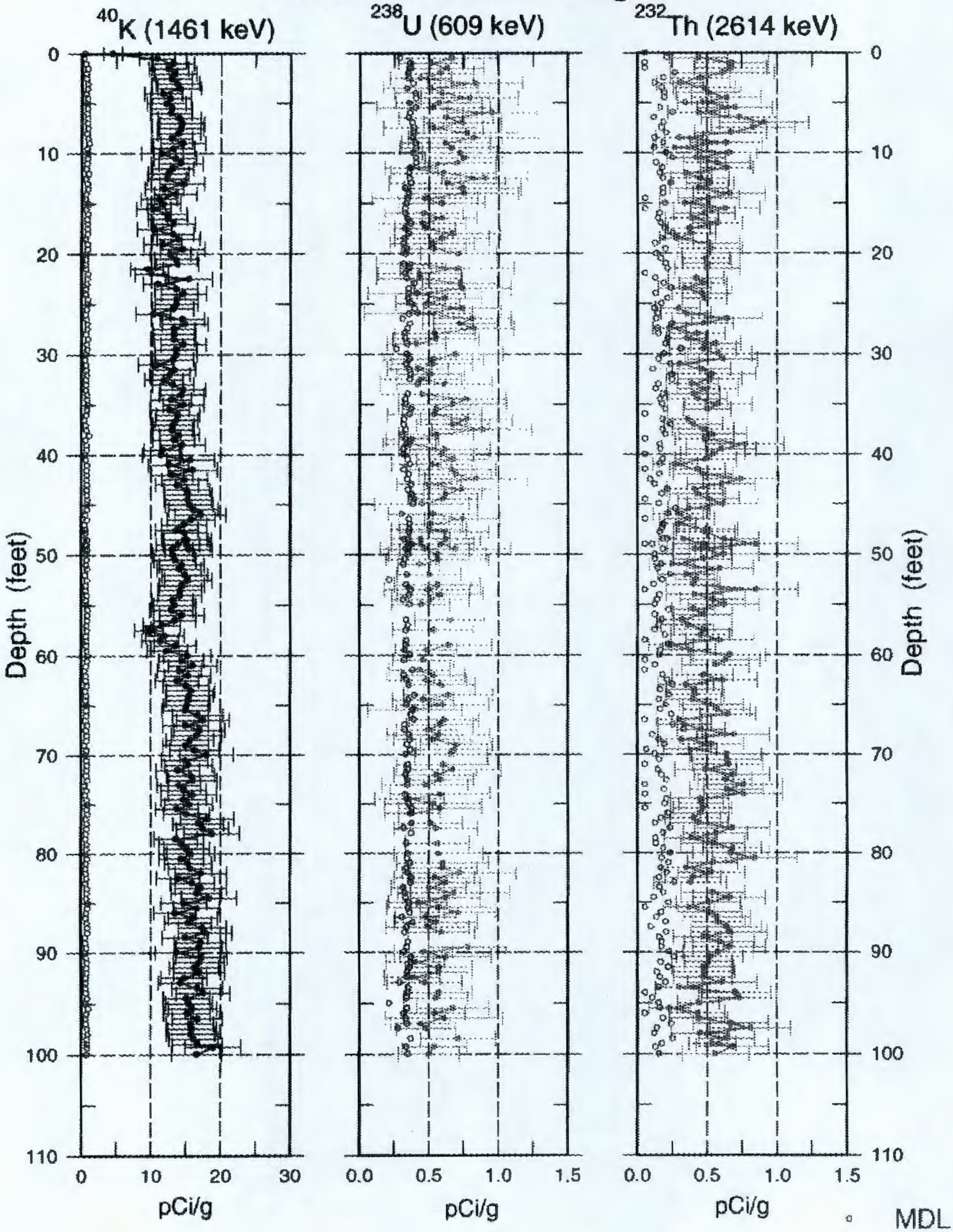
A plot showing the results of the shape factor analysis is included with the set of plots for this borehole.

30-07-01

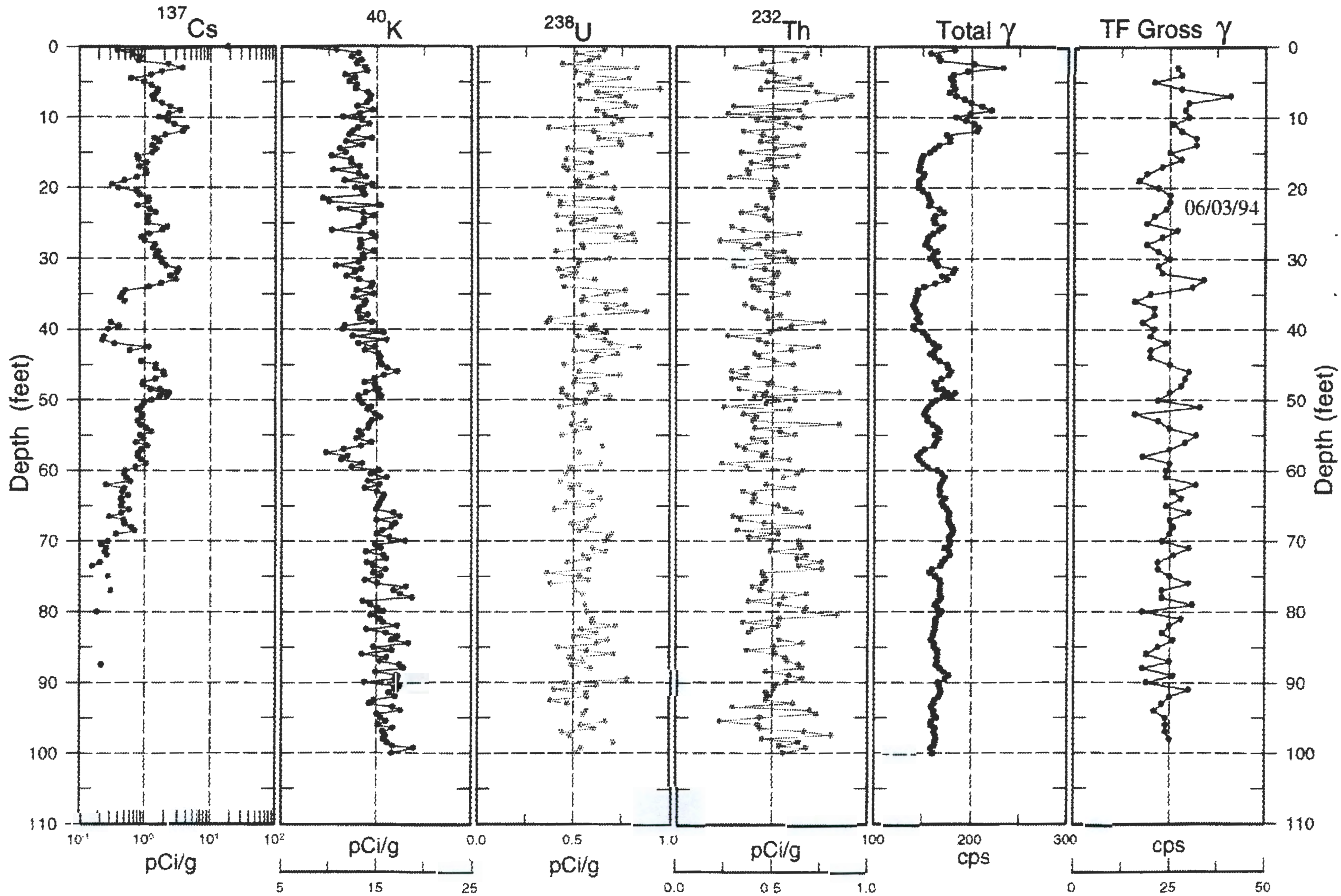
Man-Made Radionuclide Concentrations



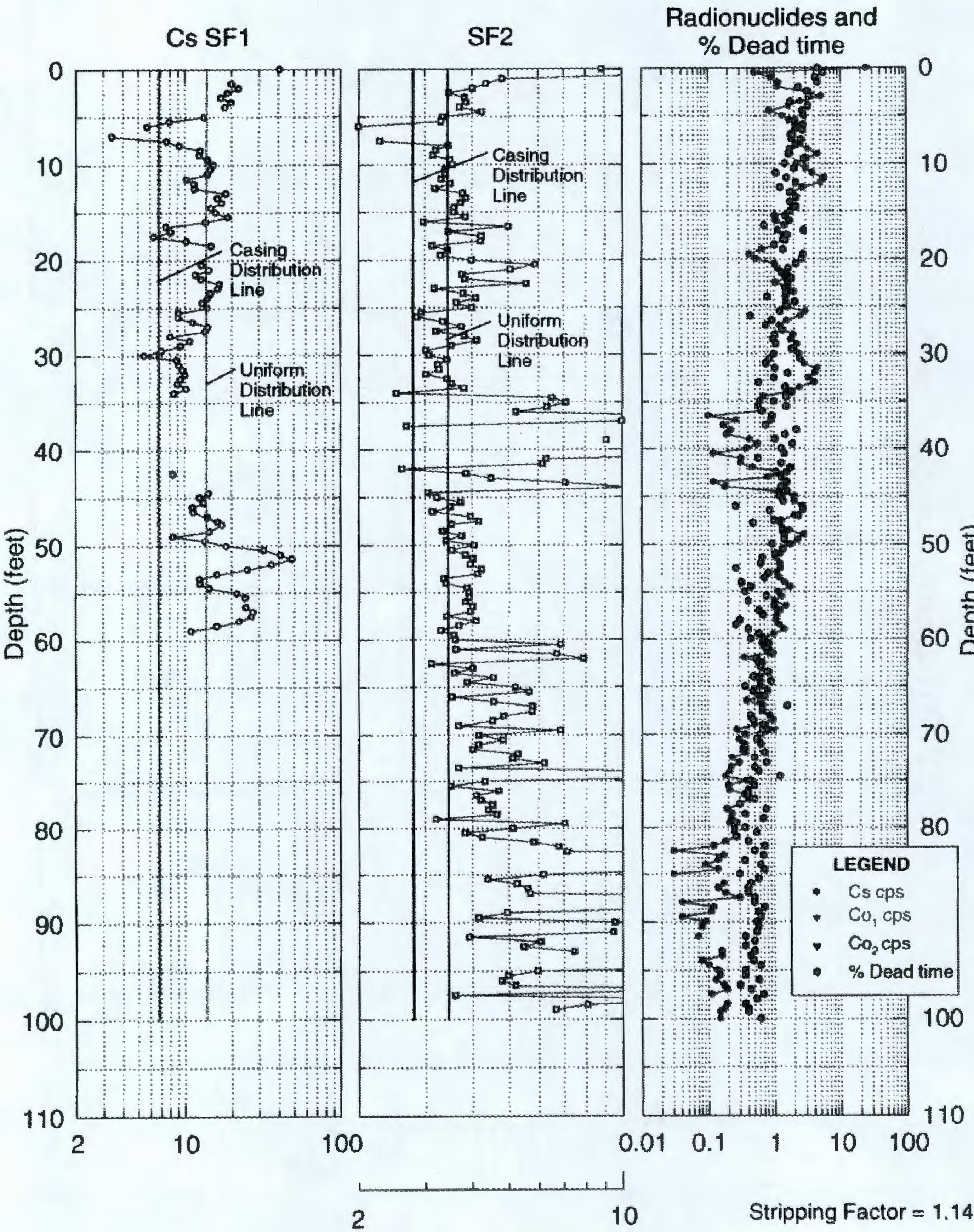
30-07-01
Natural Gamma Logs



30-07-01 Combination Plot



30-07-01 ^{137}Cs Shape Factor Analysis Plot



Stripping Factor = 1.14

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Spectral Gamma-Ray Borehole
Log Data Report

Log Event A

Borehole 30-11-05

Borehole Information

Farm :	C	Tank :	C-111	Site Number :	299-E27-105
N-Coord :	42,964	W-Coord :	48,438	TOC Elevation :	646.00
Water Level, ft :	None	Date Drilled :	4/30/75		

Casing Record

Type :	Steel-welded	Thickness :	0.280	ID, in. :	6
Top Depth, ft. :	0	Bottom Depth, ft. :	100		

Borehole Notes:
This borehole was drilled in April 1975 and completed to a depth of 100 ft with 6-in. casing. The casing thickness is presumed to be 0.280 in., on the basis of the published thickness for schedule-40, 6-in. steel tubing. No information was available that indicated the borehole casing was perforated or grouted; therefore, it is assumed that the borehole was not perforated or grouted. The top of the casing, which is the zero reference for the SGLS, is flush with the ground surface.

Equipment Information

Logging System :	1B	Detector Type :	HPGe	Detector Efficiency :	35.0 %
Calibration Date :	2/97	Calibration Reference :	GJO-HAN-14	Logging Procedure :	P-GJPO-1783

Log Run Information

Log Run Number :	1	Log Run Date :	3/4/97	Logging Engineer:	Alan Pearson		
Start Depth, ft.:	99.5	Counting Time, sec.:	100	L/R :	L	Shield :	N
Finish Depth, ft. :	53.0	MSA Interval, ft. :	0.5	Log Speed, ft/min.:	n/a		

Log Run Number :	2	Log Run Date :	3/5/97	Logging Engineer:	Alan Pearson		
Start Depth, ft.:	0.0	Counting Time, sec.:	100	L/R :	L	Shield :	N
Finish Depth, ft. :	13.0	MSA Interval, ft. :	0.5	Log Speed, ft/min.:	n/a		

Log Run Number :	3	Log Run Date :	3/5/97	Logging Engineer:	Alan Pearson		
Start Depth, ft.:	12.0	Counting Time, sec.:	100	L/R :	L	Shield :	N
Finish Depth, ft. :	54.0	MSA Interval, ft. :	0.5	Log Speed, ft/min.:	n/a		

Log Event A

Borehole 30-11-05

Analysis Information

Analyst : E. Larsen

Data Processing Reference : MAC-VZCP 1.7.9, Rev. 1 Analysis Date : 9/5/97

Analysis Notes :

This borehole was logged by the SGLS in three log runs. The pre- and post-survey field verification spectra met the acceptance criteria established for the peak shape and detector efficiency, confirming that the SGLS was operating within specifications. The energy calibration and peak-shape calibration from these spectra were used to establish the peak resolution and channel-to-energy parameters used in processing the spectra acquired during the logging operation. There were no fine gain adjustments made during these log runs.

Casing correction factors for a 0.280-in.-thick steel casing were applied during analysis.

The man-made radionuclide Cs-137 was detected in this borehole. The Cs-137 contamination was detected nearly continuously from the ground surface to 4.5 ft. An isolated zone of Cs-137 contamination was detected from 11 to 12 ft, and a few concentrations of Cs-137 were detected between 47.5 and 54.5 ft.

The K-40 concentrations increase slightly at about 39 ft and become variable from 40 to 46 ft and 60 to 65 ft. The K-40 concentrations increase at about 65 ft and remain elevated to the bottom of the logged interval (99.5 ft). There is a noticeable decrease in the U-238 background between 53 ft and the bottom of the logged interval.

Additional information and interpretations of log data are included in the main body of the Tank Summary Data Reports for tanks C-108 and C-111.

Log Plot Notes:

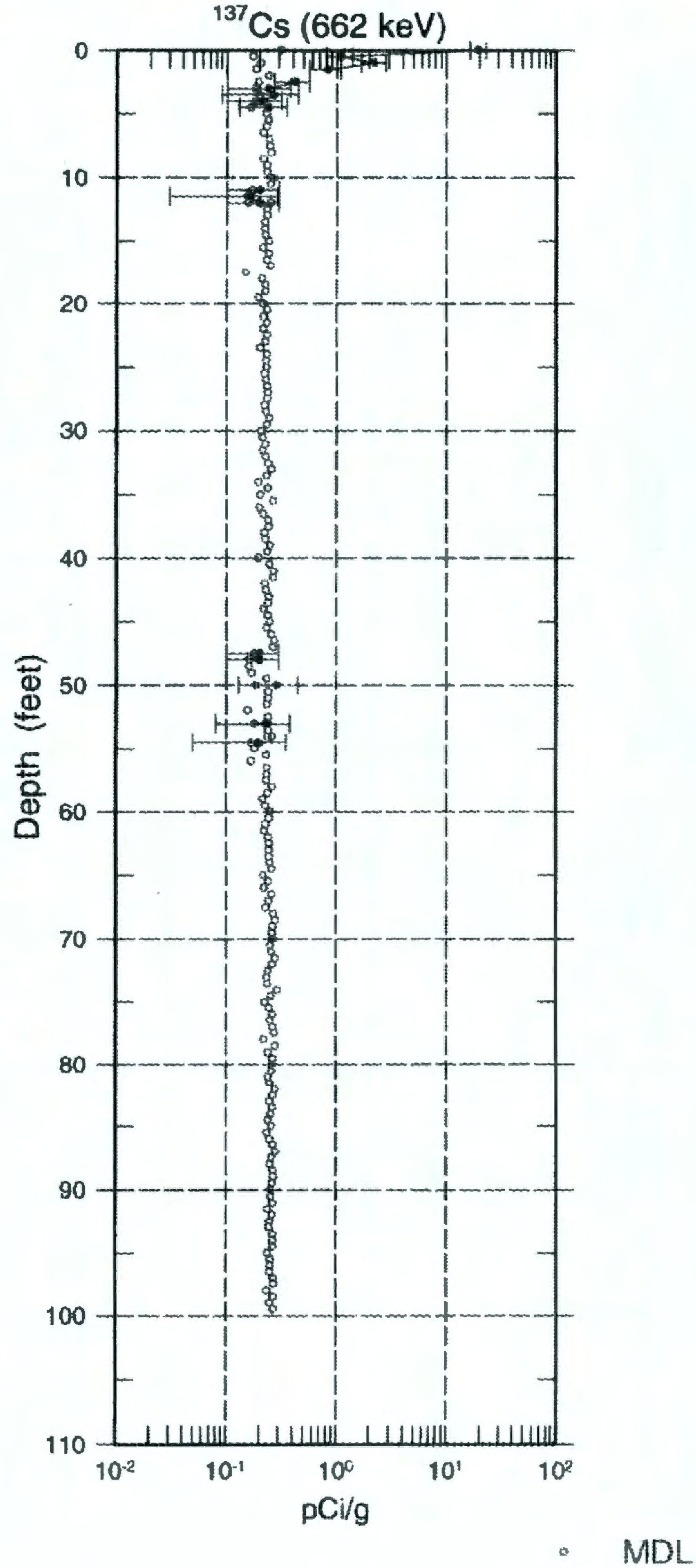
Separate log plots show the man-made and the naturally occurring radionuclides. The natural radionuclides can be used for lithology interpretations. The headings of the plots identify the specific gamma rays used to calculate the concentrations.

Uncertainty bars on the plots show the statistical uncertainties for the measurements as 95-percent confidence intervals. Open circles on the plots give the MDL. The MDL of a radionuclide represents the lowest concentration at which positive identification of a gamma-ray peak is statistically defensible.

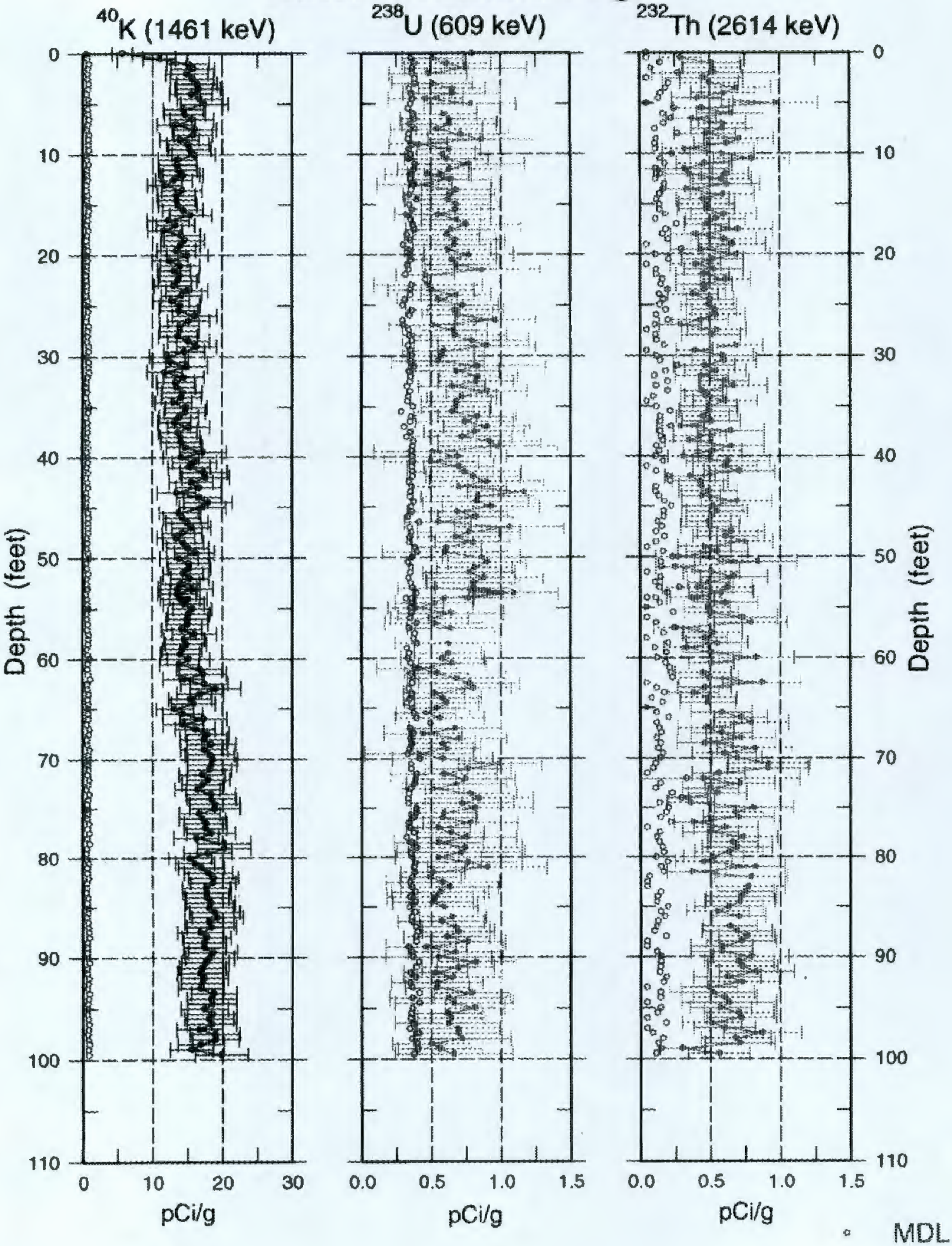
A combination plot includes the man-made and natural radionuclides, the total gamma derived from the spectral data, and the Tank Farms gross gamma log. The gross gamma plot displays the latest available digital data. No attempt has been made to adjust the depths of the gross gamma logs to coincide with the SGLS data.

30-11-05

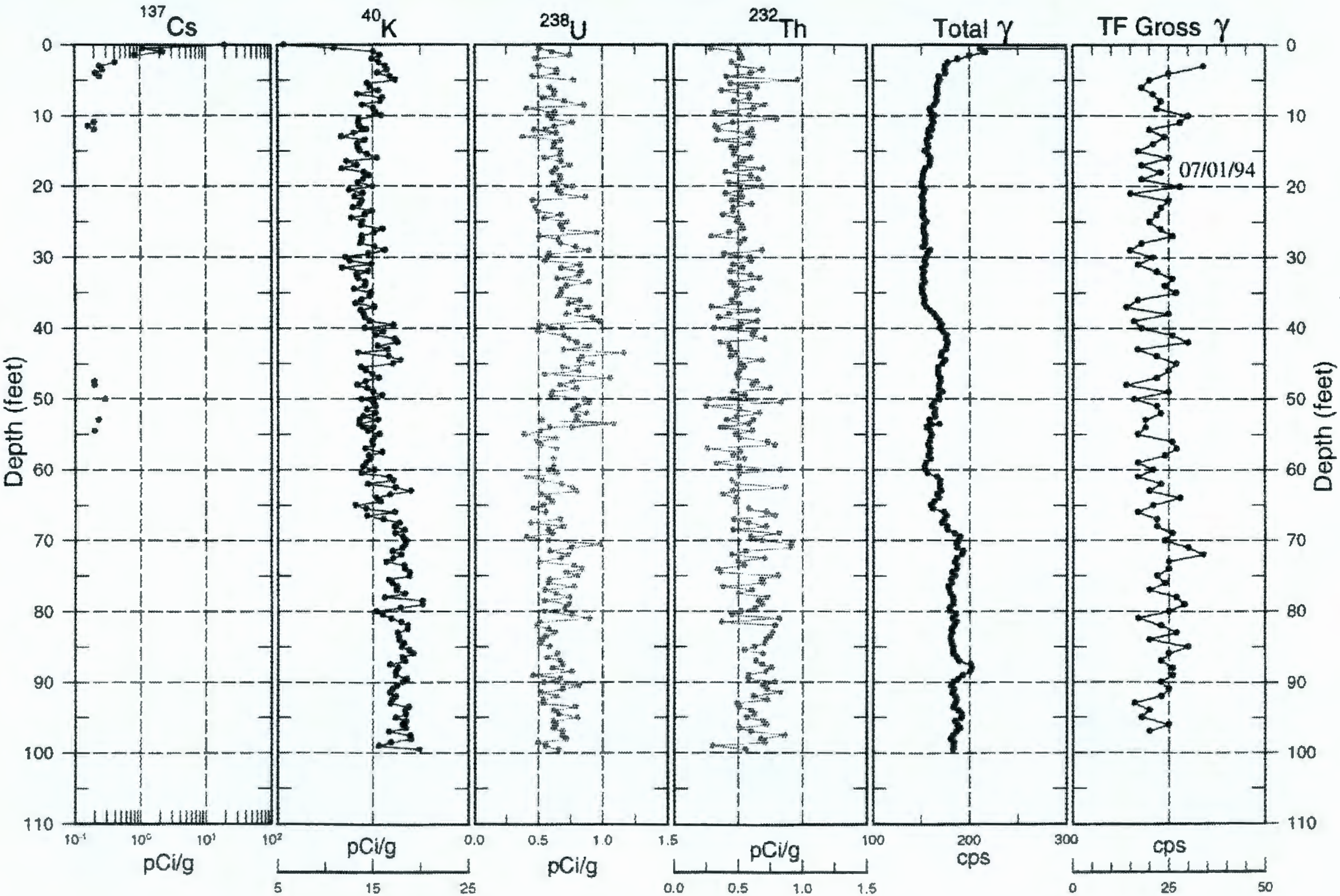
Man-Made Radionuclide Concentrations



30-11-05
Natural Gamma Logs



30-11-05 Combination Plot



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Spectral Gamma-Ray Borehole
Log Data Report

Log Event A

Borehole 30-08-12

Borehole Information

Farm :	C	Tank :	C-108	Site Number :	299-E27-95
N-Coord :	42,978	W-Coord :	48,398	TOC Elevation :	647.00
Water Level, ft :	None	Date Drilled :	9/30/74		

Casing Record

Type :	Steel-welded	Thickness, in. :	0.280	ID, in. :	6
Top Depth, ft. :	0	Bottom Depth, ft. :	100		

Borehole Notes:

This borehole was drilled in September 1974 and completed to a depth of 100 ft with 6-in. casing. The casing thickness is presumed to be 0.280 in., on the basis of the published thickness for schedule-40, 6-in. steel tubing. No information was available that indicated the borehole casing was perforated or grouted; therefore, it is assumed that the borehole was not perforated or grouted. The top of the casing, which is the zero reference for the SGLS, is flush with the ground surface.

Equipment Information

Logging System :	1B	Detector Type :	HPGe	Detector Efficiency :	35.0 %
Calibration Date :	2/97	Calibration Reference :	GJO-HAN-14	Logging Procedure :	P-GJPO-1783

Log Run Information

Log Run Number :	1	Log Run Date :	3/14/97	Logging Engineer:	Alan Pearson		
Start Depth, ft.:	0.0	Counting Time, sec.:	100	L/R :	L	Shield :	N
Finish Depth, ft. :	41.0	MSA Interval, ft. :	0.5	Log Speed, ft/min.:	n/a		

Log Run Number :	2	Log Run Date :	3/14/97	Logging Engineer:	Alan Pearson		
Start Depth, ft.:	98.5	Counting Time, sec.:	100	L/R :	L	Shield :	N
Finish Depth, ft. :	70.0	MSA Interval, ft. :	0.5	Log Speed, ft/min.:	n/a		

Log Run Number :	3	Log Run Date :	3/17/97	Logging Engineer:	Alan Pearson		
Start Depth, ft.:	71.0	Counting Time, sec.:	100	L/R :	L	Shield :	N
Finish Depth, ft. :	50.0	MSA Interval, ft. :	0.5	Log Speed, ft/min.:	n/a		

Log Event A

Borehole 30-08-12

Log Run Number :	4	**Log Run Date :**	3/18/97	**Logging Engineer:**	Bob Spatz
Start Depth, ft.:	51.0	**Counting Time, sec.:**	100	**L/R :** L	**Shield :** N
Finish Depth, ft. :	40.0	**MSA Interval, ft. :**	0.5	**Log Speed, ft/min.:**	n/a

Analysis Information

Analyst :	E. Larsen		
Data Processing Reference :	MAC-VZCP 1.7.9, Rev. 1	Analysis Date :	9/5/97

Analysis Notes :

This borehole was logged by the SGLS in four log runs. The pre- and post-survey field verification spectra met the acceptance criteria established for the peak shape and detector efficiency, confirming that the SGLS was operating within specifications. The energy calibration and peak-shape calibration from these spectra were used to establish the channel-to-energy parameters used in processing the spectra acquired during the logging operation.

Casing correction factors for a 0.280-in.-thick steel casing were applied during analysis.

The man-made radionuclide Cs-137 was detected in this borehole. The Cs-137 contamination was detected continuously from the ground surface to 37.5 ft and 47 to 72.5 ft. A few isolated concentrations of Cs-137 were detected between 75.5 ft and the bottom of the logged interval.

The K-40 concentration values increase at 38 ft and become variable between 40 and 55 ft. The K-40 concentrations increase again at 70 ft and remain elevated to the bottom of the logged interval.

An analysis of the shape factors associated with applicable segments of the spectra was performed. The shape factors provide insights into the distribution of the Cs-137 contamination and into the nature of zones of elevated total count gamma-ray activity not attributable to gamma-emitting radionuclides.

Additional information and interpretations of log data are included in the main body of the Tank Summary Data Report for tank C-108.

Log Plot Notes:

Separate log plots show the man-made and the naturally occurring radionuclides. The natural radionuclides can be used for lithology interpretations. The headings of the plots identify the specific gamma rays used to calculate the concentrations.

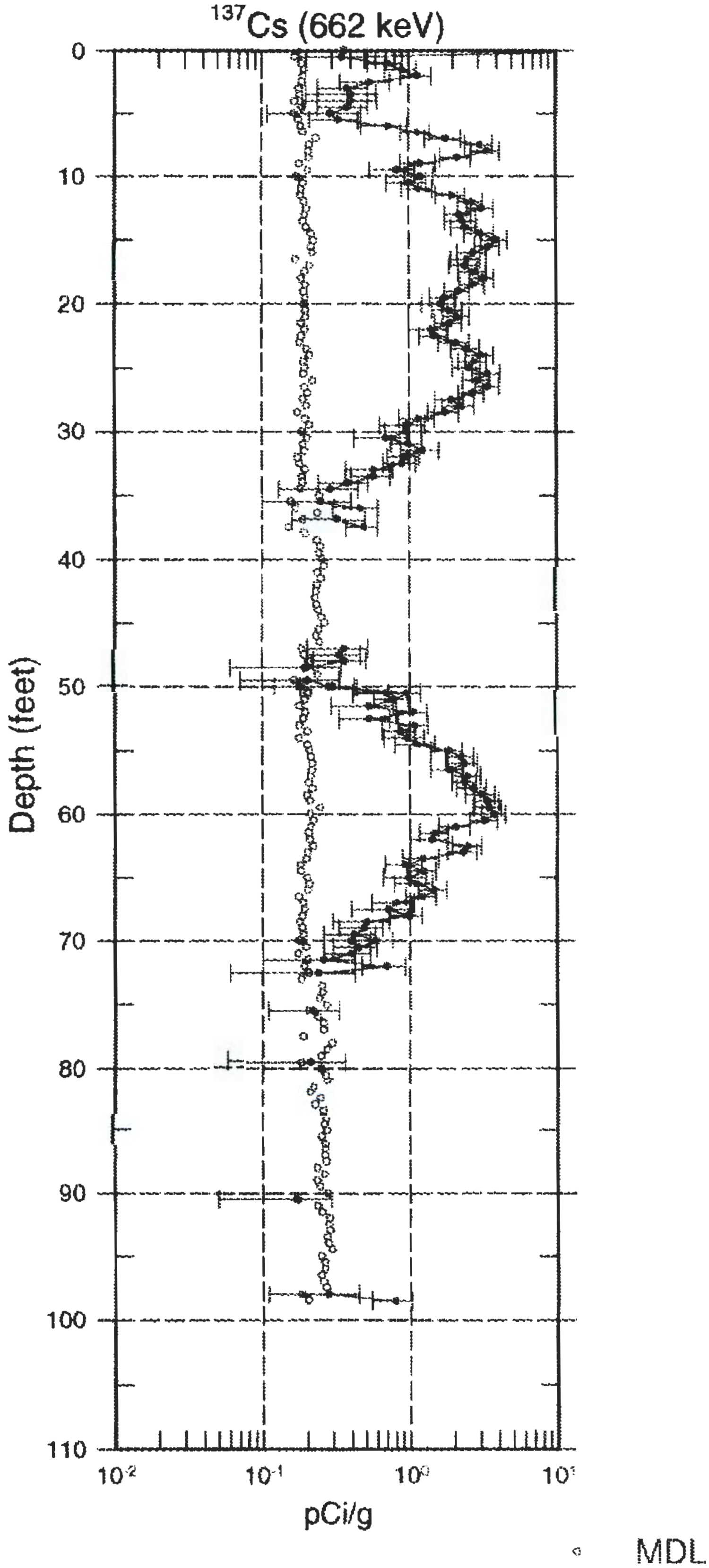
Uncertainty bars on the plots show the statistical uncertainties for the measurements as 95-percent confidence intervals. Open circles on the plots give the MDL. The MDL of a radionuclide represents the lowest concentration at which positive identification of a gamma-ray peak is statistically defensible.

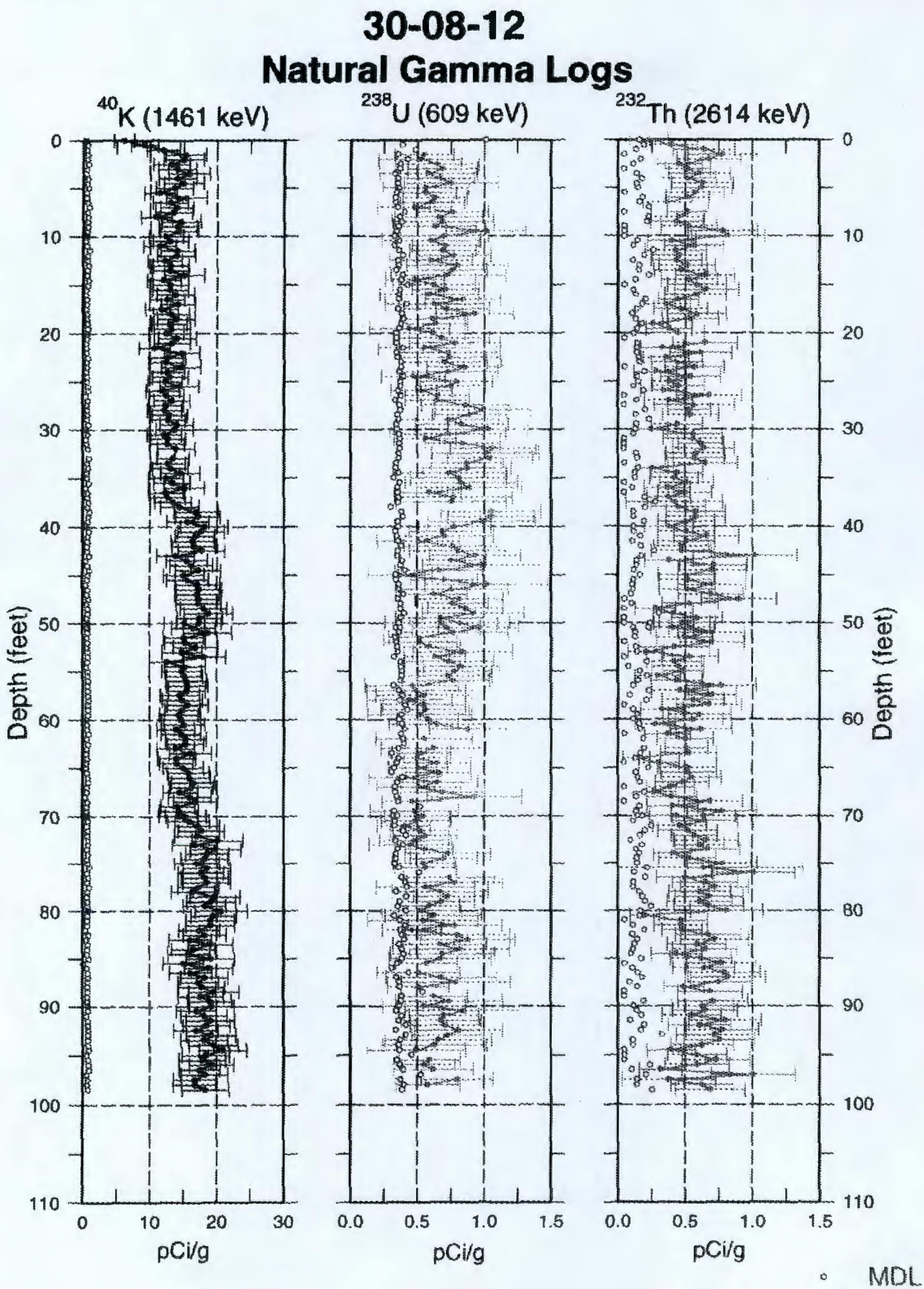
A combination plot includes the man-made and natural radionuclides, the total gamma derived from the spectral data, and the Tank Farms gross gamma log. The gross gamma plot displays the latest available digital data. No attempt has been made to adjust the depths of the gross gamma logs to coincide with the SGLS data.

Plots of the spectrum shape factors are included. The plots are used as an interpretive tool to help determine the radial distribution of man-made contaminants around the borehole.

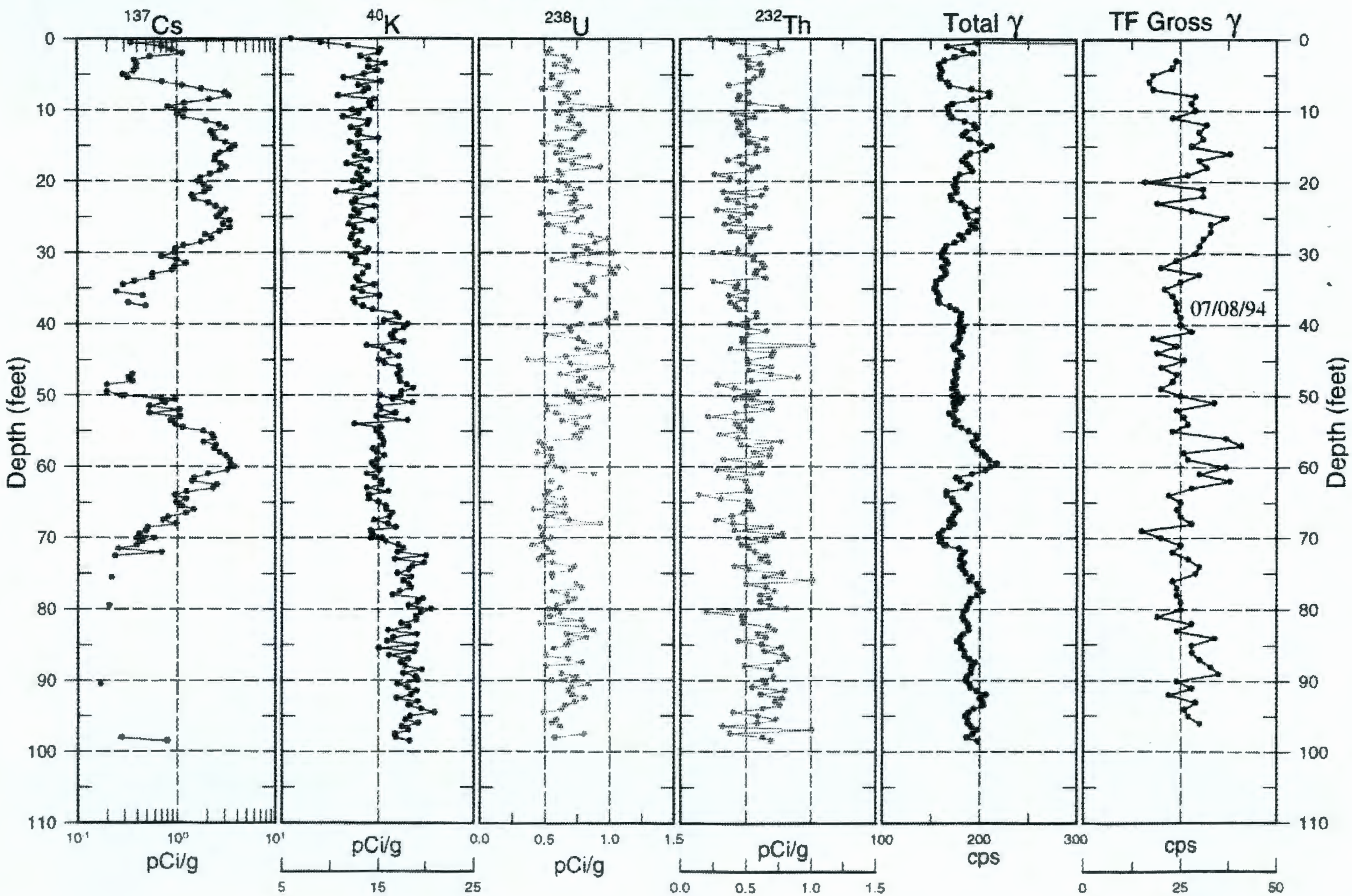
30-08-12

Man-Made Radionuclide Concentrations




30-08-12
Natural Gamma Logs
40K (1461 keV)
238U (609 keV)
232Th (2614 keV)
Depth (feet)
0
10
20
30
40
50
60
70
80
90
100
110
0
10
20
30
pCi/g
0.0
0.5
1.0
1.5
pCi/g
0.0
0.5
1.0
1.5
pCi/g
Depth (feet)
MDL

30-08-12 Combination Plot



30-08-12 ^{137}Cs Shape Factor Analysis Plot