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Hanford Tank Farms Vadose Zone

Addendum to the T Tank Farm Report

July 2000

Prepared for
U.S. Department of Energy
Richland Operations Office
Richland, Washington

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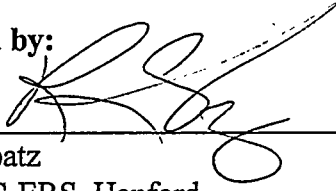
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Hanford Tank Farms Vadose Zone

Addendum to the T Tank Farm Report

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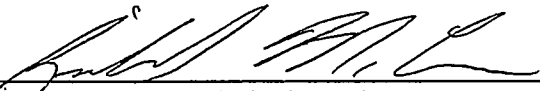


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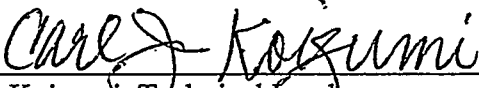
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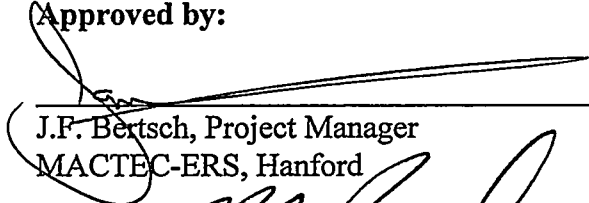


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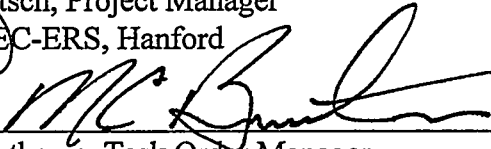
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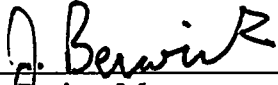
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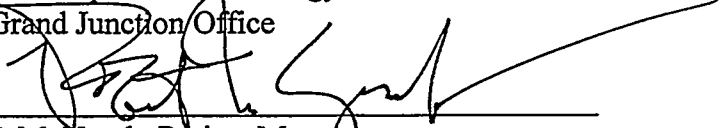
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Executive Summary

In 1994, the U.S. Department of Energy (DOE) Richland Operations Office (DOE-RL) requested the DOE Grand Junction Office (GJO), Grand Junction, Colorado, to perform a baseline characterization of gamma-emitting radionuclides in the vadose zone beneath and around the single-shell tanks (SSTs) at the Hanford Site. The T Tank Farm Report, which was prepared as part of this characterization project, was issued in September 1999 as document number GJO-99-101-TAR, GJO-HAN-27. That document reported the results of the spectral gamma logging characterizations at the T Tank Farm that were originally reported in Tank Summary Data Reports for each individual tank. The T Tank Farm Report provided background information, a history of the farm, geology and hydrology reviews, and a description and review of adjacent waste sites. Data derived from logging existing boreholes in the T Tank Farm were used to develop a three-dimensional model of the distribution of the contamination in the vadose zone.

Since the original T Tank Farm Report was issued, additional data have been collected and additional insights into the nature and distribution of contamination have been gained. The purpose of this addendum is to present these additional data and to provide revised visualizations of the subsurface contaminant distribution in the T Tank Farm.

A high rate logging system was developed and deployed in the T Tank Farm to measure cesium-137 (^{137}Cs) concentration levels in high gamma flux zones where the spectral gamma logging system was unable to collect usable data because of high dead times and detector saturation. This new system has enabled measurement of ^{137}Cs concentrations up to about 100 million picocuries per gram.

Other data collected since the T Tank Farm Report was issued include repeat logging measurements in boreholes collected between 1 and 4 years after the initial baseline data. In two boreholes these measurements have indicated possible concentration increases that are attributed to migration of contaminants through the vadose zone. Data analyses of historical gross gamma logging by Randall et al. (2000) indicate seven unstable intervals of gross gamma data collected from six boreholes between 1975 and 1994. Repeat logging data suggest that contaminant migration may be continuing within the T Tank Farm. However, the repeat logging was limited in scope and the gross gamma logging program was discontinued in 1994; no comprehensive vadose zone monitoring program currently exists.

On the basis of the evaluation of all new information and the work previously published in the T Tank Farm Report, contaminated intervals judged to be localized to the borehole or otherwise non-representative of subsurface contamination were removed from the data set used to create the three-dimensional visualizations of subsurface contamination for the T Tank Farm. As a result, the plumes depicted in the visualizations are more realistic and have been used to provide a rough estimate of contaminant inventories.

This addendum completes the baseline characterization of the T Tank Farm. The purpose of this characterization was to identify the nature and extent of contamination associated with gamma-emitting radionuclides in the T Tank Farm using existing boreholes. The T Tank Farm Report supplemented by this addendum serves as a baseline against which future measurements can be compared to identify changes in the vadose zone, track contaminant movement, and identify or verify future tank leaks. The visualizations represent a "snapshot" of the nature and extent of contamination associated with gamma-emitting radionuclides present in the vadose zone at the time of baseline logging. Baseline logging for the T Tank Farm was performed in mid- to late 1998.

1.0 Introduction

The T Tank Farm is located in the northern portion of the 200 West Area of the Hanford Site and consists of twelve 530,000-gallon (gal) and four 55,000-gal single-shell tanks (SSTs) (Figure 1). These tanks were constructed between 1943 and 1944 to store high-level radioactive waste generated during chemical processing of irradiated uranium reactor fuel. This waste was generated primarily at the T Plant, which is located about 2,000 feet (ft) east of the T Tank Farm. Seven of the twelve 530,000-gal tanks are designated as "assumed leakers." A total volume of 134,500 gal of liquid waste is estimated to have leaked from these tanks into the vadose zone sediments. The remaining five 530,000-gal tanks and the four 55,000-gal tanks are currently classified as sound (Hanlon 2000). Gross gamma logging in the leak detection boreholes was discontinued in 1994 and leak detection monitoring has since been based on internal tank measurements. No monitoring boreholes are located near the smaller 55,000-gal tanks.

In 1994, the U.S. Department of Energy (DOE) Richland Operations Office (DOE-RL) requested the DOE Grand Junction Office (GJO), Grand Junction, Colorado, to perform a baseline characterization of gamma-emitting radionuclides in the vadose zone at all Hanford SST farms using high resolution spectral gamma-ray logging methods in existing boreholes surrounding the tanks. DOE-GJO developed the Spectral Gamma Logging System (SGLS), which consists of a downhole sonde and surface support system (cable, winch, and electronic systems mounted in a custom-built truck). The downhole sonde contains a detector made from an n-type high purity germanium (HPGe) crystal with an approximate system efficiency of 35 percent. Using the SGLS, the baseline characterization of the T Tank Farm was completed in two logging episodes. Boreholes around tanks T-107 and T-110 were logged in 1995, and boreholes around the remaining tanks were logged in 1998. The results of the geophysical logging and radionuclide concentration log plots for individual boreholes were compiled and presented in 12 individual Tank Summary Data Reports (DOE 1995a, 1995b, 1998a, 1998b, 1998c, 1999b, 1999c, 1999d, 1999e, 1999f, 1999g, and 1999h).

The T Tank Farm Report was the eleventh tank farm report to be completed by the Hanford Tanks Farms Vadose Zone Project, and it was issued as document number GJO-99-101-TAR, GJO-HAN-27. Since that report was completed, additional spectral gamma-ray logging was performed and a high rate logging system (HRLS) was developed and deployed to collect data from borehole intervals where the SGLS detector was unable to collect data as a result of high gamma activity. Modifications to the T Tank Farm Report and contaminant visualizations are warranted to address the additional data. This document will discuss those modifications and serves as an addendum to the original report.

1.1 Background

A compilation of all borehole data collected for the baseline characterization was presented in the T Tank Farm Report issued in September 1999. Included within that report were

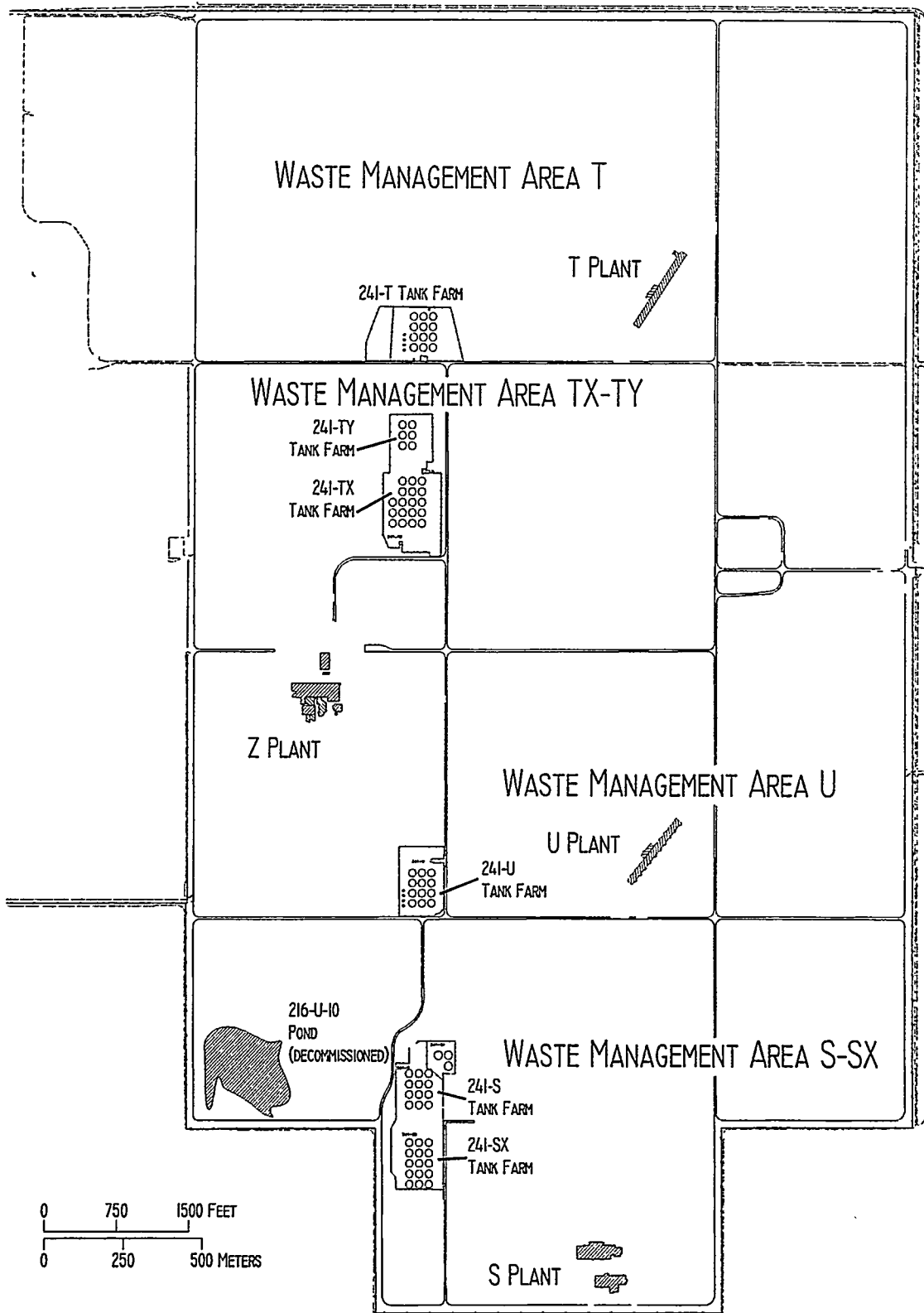


Figure 1. Map of the 200 West Area Showing the Location of the T Tank Farm

three-dimensional visualizations of contaminant distribution in the vadose zone around the T Tank Farm.

Since 1999, additional spectral data have been collected from repeat logging of selected borehole intervals and a High Rate Logging System (HRLS) has been developed to investigate intervals of high gamma flux where the SGLS was unable to collect usable spectral data.

1.2 Purpose and Scope

The purpose of this addendum is to present additional data that are relevant to the T Tank Farm and to provide revised visualizations of subsurface contamination that are based on re-evaluation of the interpreted data sets, as well as incorporation of HRLS data. Tank farm conditions, operational history, current status, and geologic conditions are discussed in the original T Tank Farm Report and relevant Tank Summary Data Reports, and will not be repeated in this addendum. The reader is referred to those documents for more detailed information.

Results of HRLS logging and SGLS repeat logging are presented on plots and summarized in tables included in appendices to this report. Because all but two boreholes in the T Tank Farm were modified in the late 1970s, shape factor analysis generally cannot be applied to borehole spectra collected from the T Tank Farm. In an apparent attempt to block contaminant migration within and along borehole casings, the original 6-inch (in.)-diameter casings were perforated near the bottom and in the upper 20 ft of the boreholes, and the 4-in.-diameter casings were grouted inside the 6-in. casings. The effects of the additional casing and variable thickness of annular grout cannot be accounted for in the shape factor analysis; therefore, shape factor results would be ambiguous or misleading.

In general, the HRLS data have been incorporated into the interpreted data set used to create the visualizations, and SGLS repeat logging data have not been included. The purpose of the baseline characterization project is to provide a "snapshot" of the nature and extent of gamma-emitting contamination. The primary justification for excluding SGLS repeat data is that only a small fraction of the total logging footage was re-logged. To routinely insert repeat logging data would thus distort the original baseline. Contaminant plumes shown in the visualizations are based on the original baseline data, as modified by analysis results and professional judgement of the analyst, with HRLS results included in intervals where the SGLS data were unusable.

Areas of potential contaminant movement are identified on the basis of comparison of repeat logging data and original baseline data, as well as on analysis of gross gamma data collected between 1975 and 1994. However, it is difficult to draw firm conclusions regarding recent contaminant movement because routine borehole monitoring was discontinued in 1994.

2.0 Summary of Additional Data

Additional data presented in this addendum include HRLS and SGLS repeat results. Also referenced in this addendum is work performed by Randall et al. (2000), which summarizes the historical gross gamma logging data for the T Tank Farm and identifies areas of possible contaminant movement within the vadose zone. In addition, SGLS results from four boreholes in the immediate vicinity of T Tank Farm are included in Appendix E. These boreholes were logged as part of the baseline logging effort; however, they appear to have intersected subsurface contamination not directly associated with the tanks in the T Tank Farm.

2.1 High Rate Logging System (HRLS)

During SGLS logging operations in the T Tank Farm, many subsurface intervals exhibited fields of very high gamma-ray flux, such that the SGLS detectors became saturated, yielding no usable spectral data.

DOE-GJO developed a special downhole sonde that is capable of recording gamma-ray spectra while operating in intense gamma-ray fields. The detector is a 6-millimeter (mm) by 8-mm, n-type HPGe crystal with a very low relative efficiency, and it can be operated with either of the SGLSs. This system, which is referred to as the HRLS, is configured to provide useful results for radionuclide concentrations ranging from several thousand to about 100 million picocuries per gram (pCi/g). Information regarding this system is provided in a base calibration report (DOE 1999a).

The HRLS operates normally in gamma-ray fluxes intense enough to "saturate" the SGLSs. Saturation refers to the circumstance in which the detector records spectra in which the peaks (full energy peaks) are tiny or even absent. This situation is an extreme manifestation of "pileup," which contributes to degradation of spectra (Knoll 1989). "Pulse pileup" occurs when the photon flux at the detector is so great that the probability is high that two or more photons will deposit their energies in the detector within a time interval that is short compared to the time resolution of the system. The electrical charge liberated by the several photons is then processed as if just one photon were involved. Pulse pileup events give output pulses with variable amplitudes because the amplitude of each output pulse depends on the total energy of the several captured photons that contribute to the pulse. The pulses with variable amplitudes add counts to the spectral background continuum, and the photons that participate in pileup are lost, in the sense that they contribute to the spectral background instead of a peak. Consequently, as pileup events increase in frequency, the spectral peaks become more and more obscure. Because peak counts are lost, the peak intensities are no longer proportional to the source concentrations.

Like the SGLSs, the HRLS is essentially nonparalyzable. "Nonparalyzable" and "paralyzable" describe system behavior during "dead periods" of data acquisition (Knoll 1989). In nonparalyzable systems, the deposition of photon energy in the detector is followed by a brief time interval, or dead period, of fixed duration, during which the output electrical pulse is being

processed. The system is unresponsive to any additional photons that enter the detector during the dead period. If the gamma-ray flux is intense, a significant number of photons enter the detector during dead periods, and are uncounted. Thus, the count rate rises as the gamma flux increases, but the count rate does not rise as rapidly as the flux. The count rate is non-linear in relation to flux, but linearity is imposed by applying the dead time correction to the recorded count rates (DOE 1995c).

In a paralyzable system, of which certain of the old Hanford Geiger-Mueller-based monitoring systems are examples, the deposition of photon energy in the detector is followed by a dead period, but the duration of this period is lengthened if additional photons enter the detector during the dead period. Thus, on average, the dead periods grow longer as the gamma flux increases. A consequence is that as the gamma flux on the detector increases, the output count rate rises, but the count rate eventually reaches a maximum and then decreases if the gamma flux continues to climb. Data from paralyzable systems may be ambiguous in high gamma-ray fluxes and may significantly underestimate contaminant concentrations.

Two tungsten shields that can be used individually or in combination are available to extend the range of the HRLS detector. One is a 0.31-in.-thick tungsten pipe sleeve, designated as the external shield, that fits over the sonde housing. The other is a 0.7-in.-thick tungsten "cup," designated as the internal shield, that fits over the high rate detector, filling the excess space inside the sonde normally occupied by the SGLS detector. By using the shields individually or in combination, the measurement range of the high rate detector can be extended from several thousand picocuries per gram without shielding to about 100 million pCi/g using maximum shielding.

The efficiency of the HRLS detector decreases rapidly with increasing gamma-ray energy, which is a consequence of the small size of the HPGe crystal. As a result, the HRLS is significantly more sensitive to cesium-137 (^{137}Cs) relative to other radionuclides such as cobalt-60 (^{60}Co) or europium-152/154 ($^{152/154}\text{Eu}$).

The HRLS presented a particularly difficult calibration challenge. Construction of test zones with uniformly distributed gamma-emitting radionuclides at high activity levels is not practical, for reasons of personnel exposure, cost, long-term surveillance requirements, and disposal. Hence, the calibration had to be carried out using existing calibration models. As a result, the relative degree of uncertainty for measurements made with the HRLS tool is significantly higher than the uncertainty in the SGLS data. The calibration is described in detail in the HRLS calibration report (DOE 1999a).

For the SGLS, dead time, casing, and water corrections are computed by the analytical software and the output values are concentrations in picocuries per gram. However, it was not practical to collect data for determination of casing and water correction factors for the HRLS. Only a dead time correction is applied to HRLS data by the analysis software. Depending on the borehole configuration and whether or not shields were used, it may be necessary to apply correction factors to the data after processing is completed.

Calibration measurements for the HRLS were made with a 0.28-in. steel sleeve in place over the sonde to simulate the effects of 6-in.-diameter schedule-40 casing, which is the most common borehole casing used in Hanford tank farm boreholes. HRLS data accurately reflect contaminant concentrations in unsaturated intervals with 6-in. schedule-40 casing. When other casing configurations are present, a correction factor must be applied. These correction factors were determined by calculating the attenuation for the assumed casing thickness relative to attenuation associated with a 0.28-in. thickness of steel. No water correction factor is available for HRLS spectral data.

When shields are used, an additional correction factor must be applied. Factors were determined for all three shield configurations (internal shield, external shield, and both shields) from field measurements of ^{137}Cs activity at 662 kilo-electron volts (keV). Shield correction factors for other energies can be determined by extrapolation of relative attenuation calculations.

Most boreholes in the T Tank Farm were modified in the late 1970s or early 1980s by installing a second casing. Typically a 4-in.-diameter casing was set inside the existing 6-in.-diameter casing with grout added to the annular space. In most double-cased boreholes, both casings extend to the same depth. In some instances, boreholes contain 6-, 8-, and 10-in.-diameter casings set inside each other and extending to different depths. Grout was usually added to seal the bottom of each casing depending on depth and configuration.

HRLS data correction factors for ^{137}Cs (662 keV) and ^{154}Eu (1275 keV) are provided in the following table:

Nuclide	6-in. Casing	4- & 6-in. Casing	6-, 8-, & 10-in. Casing	Internal Shield	External Shield	Both Shields
^{137}Cs (662 keV)	1.000	1.41	2.71	27.42	3.758	96.40
^{154}Eu (1275 keV)	1.000	1.29	2.07	6.68	2.02	12.6

2.2 Repeat Logging

Repeat logging using the SGLS is useful to evaluate possible contaminant movement over time by comparing concentration data. Analysis of historical gross gamma-ray logging by Randall et al. (2000) has also proved useful for determining potential movement, particularly in zones of high gamma flux. A sufficient amount of time has not passed since the implementation of the HRLS to collect repeat data that would provide meaningful comparisons.

2.2.1 Spectral Gamma Logging System (SGLS)

Repeat logging was performed on selected borehole intervals in the T Tank Farm using the SGLS. These boreholes were selected for repeat logging to check for possible contaminant movement, to confirm the presence of contaminants, and to detect additional contaminants

around boreholes. The repeat logging typically was performed over limited depth intervals of interest. To provide for proper comparison of spectral log data between the original baseline and the repeat logging, baseline data were corrected for decay and compared to the repeat logging results. To maintain consistency of the baseline data, repeat logging results were generally not included in the interpreted data set used in the development of the T Tank Farm contaminant visualizations.

2.2.2 Historical Gross Gamma Logging

An independent analysis of historical gross gamma-ray log data collected in the T Tank Farm between 1975 and 1994 was conducted by Randall et al. (2000). All historical log surveys for individual drywells (boreholes) were evaluated for each interval with elevated gross gamma count rates. Although data quality for individual records is poorly defined, comparison of a number of measurements over time allows observations to be made regarding the stability of a contaminant interval. Figure 2 shows the locations of the six boreholes where analysis indicated that intervals of historical gross gamma-ray log data were unstable. Conclusions from this analysis are discussed in this addendum to identify areas in the vadose zone where contaminant movement may have occurred and to support conclusions drawn from comparisons of the repeat logs with the original baseline data.

3.0 Discussion of Results

3.1 High Rate Logging

Logging was conducted using the HRLS in eight boreholes in the T Tank Farm where SGLS baseline results indicated zones of detector saturation or high system dead times resulting from fields of high gamma flux. Figure 2 shows the positions of these boreholes. The SGLS provides reliable results from background levels up to several thousand picocuries per gram when the external tungsten shield is used. However, zones of more intense radiation were encountered around a number of boreholes in which system dead times became excessive or the SGLS became saturated. The HRLS was used to collect spectral gamma data in intervals of high gamma flux. In general, the HRLS responds primarily to ^{137}Cs , because the sensitivity of the detector decreases rapidly with increasing gamma energy. The net effect is that detector sensitivity to ^{60}Co or $^{154/152}\text{Eu}$ is significantly less than for ^{137}Cs . In addition, pulse pileup effects at high count rates contribute to an elevated background, and peaks become less distinct. ^{60}Co and ^{154}Eu are frequently observed above and below zones of high gamma intensity, but are not detected by the HRLS. The presence of these nuclides in the high intensity zone is inferred, but can not be quantified. ^{137}Cs concentration values calculated from the HRLS data are shown on log plots for each borehole presented in Appendix A. A table in Appendix A summarizes borehole information where HRLS logging was conducted in the T Tank Farm. Included in the table are the depth intervals logged with the system, correction factors for the different shield

43300

43400

43500

43600

43700

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43900

44000

44100

44200

44300

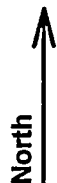
44400

44500

44600

44700

- T-204
- T-203
- T-202
- T-201



LEGEND

- Assumed Leaker
- Baseline Data
- SGLS Repeat Data
- HRLS Data
- SGLS, possible movement
- Historical Data, possible movement

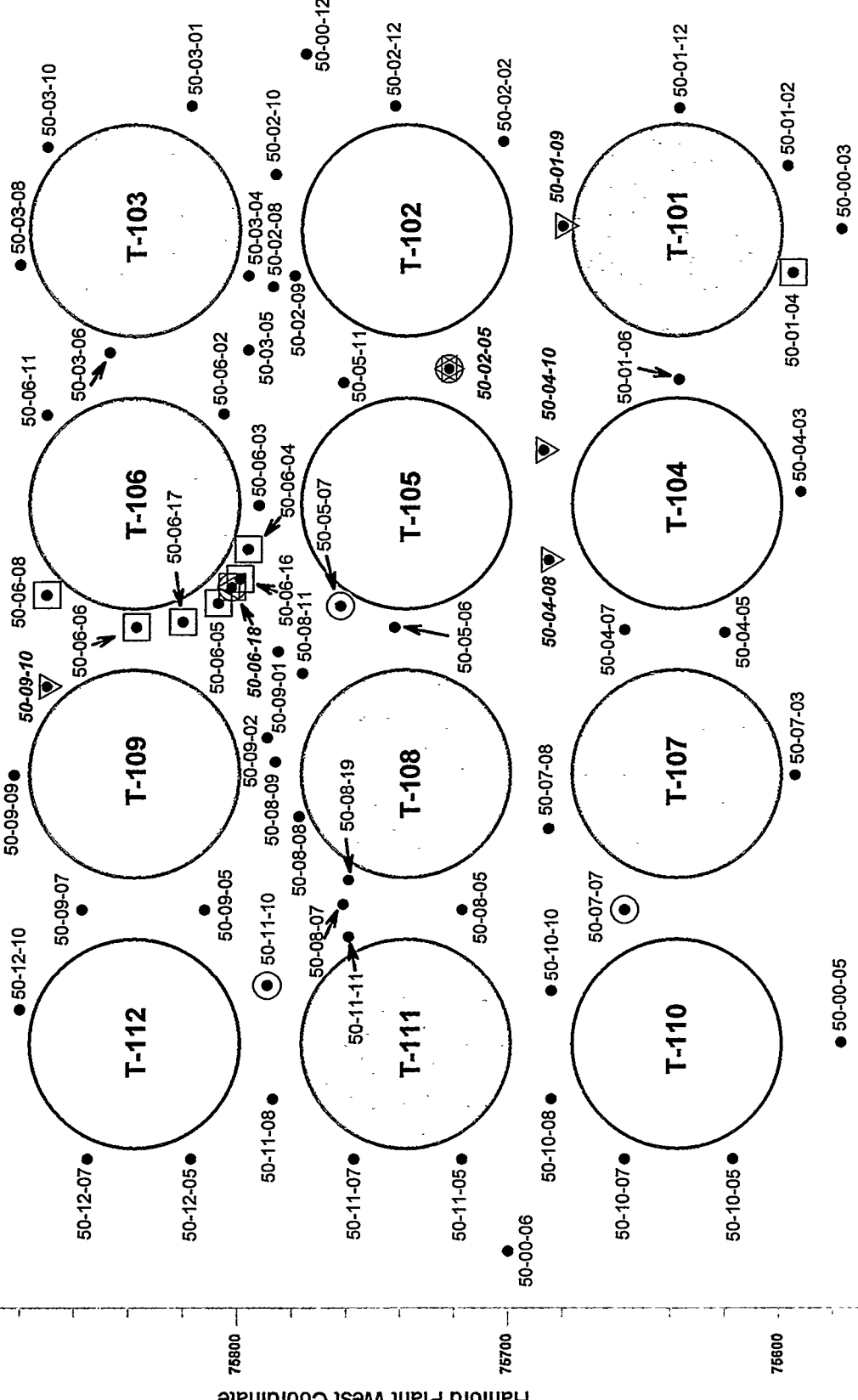
75900

75800

75700

75600

75500



Hanford Plant West Coordinate

75800

75700

75600

75500

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43200

43100

43000

42900

42800

Figure 2. Map of Possible Contaminant Movement for the T Tank Farm

configurations, and comments, as well as a general assessment of relative stability by Randall et al. (2000).

Borehole logging events are designated sequentially as A, B, C, etc. This designation describes separate episodes of data collection from a borehole. Thus, Event A is the initial logging event and referred to as the baseline, while Events B or C are subsequent events that could refer to either repeat or HRLS logging.

The depth intervals entered in the tables are those of log runs. A log run refers to a single sequential set of log data collected during an event. Multiple log runs may occur, for example, when using different shield configurations or when logging is terminated at the end of a day. Depth overlaps (1 ft) typically occur between two log runs.

3.2 Repeat Logging

SGLS repeat logging in the T Tank Farm was performed for selected depth intervals in five boreholes. Repeat logging data were collected approximately 1 year after the SGLS baseline data in four boreholes around tanks T-102, -105, -106, and -111 and approximately 4 years after the SGLS baseline data were collected in one borehole around tank T-107.

A table included in Appendix B summarizes SGLS repeat logging performed in the T Tank Farm and indicates the zones of investigation in each borehole, the reason for repeat logging, and an evaluation of the results. Appendix B also includes comparison log plots between baseline and repeat logging events. To provide a meaningful comparison, baseline contaminant concentrations were adjusted for decay to match the repeat logging date and plotted. Figure 2 shows the positions of these boreholes and denotes if possible contaminant movement has occurred.

On the basis of the comparison of baseline and repeat logging, data collected from two boreholes, 50-02-05 and 50-06-18, appear to indicate potential contaminant movement. However, all calculated concentration values were within the uncertainty of their respective measurements; consequently, no definitive conclusion can be drawn. These boreholes would be candidates for additional logging if a monitoring program were developed.

4.0 Three-Dimensional Visualizations

An objective of this addendum is to create revised three-dimensional visualizations of the major contamination plumes within the vadose zone in the vicinity of the T Tank Farm and to present views derived from those visualizations. ^{137}Cs , ^{60}Co , and ^{154}Eu were the predominant contaminants detected in the T Tank Farm and only these radionuclides are depicted in the visualizations. The software package from C Tech Development Corporation called "Environmental Visualization System" (EVS) was used to create the visualizations in both the

original T Tank Farm Report and in this addendum. However, some improvements to the data input and calculation parameters have been implemented since the original report and will be described in the following sections.

4.1 Interpreted Data Set

The first step in the visualization process is to create an interpreted data set that represents the input to the kriging process. Construction of the interpreted data set begins by creating a single text file that contains all the spectral gamma-ray data collected from both the SGLS baseline and HRLS logging activities. This data set includes the horizontal coordinates and depth of each data point and the calculated concentration value at that point for each contaminant of interest. The data set is then manually edited to remove borehole intervals that are judged to be localized to the borehole and thus not representative of the subsurface contaminant distribution. All of the editing and interpretation of the SGLS baseline data were previously reported in the T Tank Farm Report.

Tables included in Appendix C list all of the boreholes (grouped by tank) in the T Tank Farm that were included in the interpreted data set. The tables summarize the cumulative borehole contamination information gained by the SGLS and HRLS logging activities and give revised interpretations regarding the disposition of the data relative to the three-dimensional visualizations. Appendix C also includes log plots of each borehole showing the SGLS and HRLS interpreted data used to create the visualizations in this addendum.

Concentration values in the interpreted data set for T Tank Farm have not been corrected for decay. In the addendum to the SX Tank Farm Report (DOE 2000), data were corrected for decay to January 1, 2000. However, as work progressed in other tank farms, it was found that decay corrections would lead to significant loss of data, particularly for ^{60}Co , which has a half life of about 5 years. In several cases, correction for decay to January 1, 2000 would lead to situations where the maximum ^{60}Co value for a specific plume would fall below the minimum detectable level for the SGLS. Either the values would have to be portrayed below the minimum detection level (MDL), or the plume would be lost. Therefore, the decision was made to report data in terms of the time at which the baseline logging was performed. For the T Tank Farm, the time span for the SGLS baseline logging was accomplished in two episodes starting in mid-1995 around tanks T-107 and T-110, and finishing in early to mid-1998 around the remaining ten tanks. HRLS data were collected just over 1 year later in late 1999 (HRLS data were not collected from boreholes surrounding tanks T-107 or T-110). No adjustment for decay was made because the change in ^{137}Cs concentrations associated with decay over 1 year is about 2.3 percent, which is within the range of error in the HRLS data.

4.2 Development of Three-Dimensional Visualizations

The original visualizations utilized an "adaptive gridding" option that produces a model that contains estimated values everywhere inside a user-specified rectangular domain. In this

addendum a "convex hull boundary" option is selected. This option produces an irregular boundary that is defined by the distribution of measured data points, effectively restricting the extrapolation of parameters to that volume enclosed by the data points.

The total data domain of the calculations included all vadose zone boreholes within the T Tank Farm. The domain of the T Tank Farm was extended in the north-south and east-west directions to include the maximum and minimum borehole coordinate values. Borehole depths were converted to elevations, and the vertical parameter of the domain was set to include the highest and lowest sample points.

The data set derived from the SGLS data consists of measurement data at 0.5-ft intervals in vertical boreholes with a lateral separation generally on the order of tens of feet, resulting in a much greater data density in the vertical direction compared to the horizontal direction. To minimize processing time, search routines in the kriging algorithm utilize a limited number of data points closest to the calculation point, creating a situation in which a contaminated interval in a borehole tends to have an undue effect on nearby points. Because adjacent points in a single borehole are closer than points from another borehole, the data search routine is truncated after collecting all data points from a single hole. To offset this effect, data points in individual boreholes were averaged over 5-ft intervals, significantly reducing the size of the input data set and the processing time. More importantly, it "forced" the search algorithm to bring in data from multiple boreholes at most calculation points, resulting in a more realistic extrapolation of concentration values into the region between boreholes. To maintain fidelity to the original data, sphere plots and other representations of measurement data are based on the interpreted data set, which contains actual values at 0.5-ft vertical increments.

4.2.1 Geostatistical Model

The EVS software determines geostatistical structure by calculating three-dimensional variograms that are plots of the variance of the data as a function of the distance between data points. The variogram is described by two parameters, the range and sill. The range is the distance beyond which the data points are no longer correlated (i.e., they are independent of one another), and the sill is the variance of all the data.

For the T Tank Farm, the data did not show any significant decrease in variance as the data point-spacing decreased, implying that spatial correlation is poor and that more closely spaced data points are required to assess spatial variability. As a result, the geostatistical model takes on the form of the simple global variance value.

4.2.2 Three-Dimensional Plume Calculation and Visualizations

Kriging was used to estimate the contaminant concentration values at points on a three-dimensional grid. Once this concentration grid was developed, visualizations of the estimated contaminant concentrations could be produced in the form of a solid surface model. The

visualization can be moved, rotated, and viewed from any angle or direction; color printouts can also be produced.

Kriging is a spatial estimation technique that uses a weighted moving average technique in which the weighting factors are chosen to minimize the estimated variance. The influence of each sample point is determined by proximity, and weighting factors are based on the geostatistical structure. The kriging process calculates the average radionuclide concentrations of a volume of sediment by using the information from nearby sample points.

The kriging software applies a horizontal-to-vertical anisotropy ratio that allows the user to influence the "fabric" of the data set. The anisotropy ratio applies a biased weighting to data points in horizontal and vertical directions from a given data node. The program default is 10, which means that data points a given distance in the horizontal direction from a node will have an influence 10 times greater than data points at the same distance in a vertical direction.

Analyses were performed at several anisotropy values and the value that yielded results that appeared to best represent the measured distributions of each radionuclide was determined through trial and error. For the T Tank Farm, different anisotropy values were used for each contaminant. The primary criteria controlling selection of an appropriate anisotropy value was the appearance of the resulting plume while honoring the spectral gamma-ray data. Higher anisotropy values tend to produce more lateral exaggeration, which may result in a "stringy" appearance. Lower anisotropy values tend to increase the influence of contaminant values in the vertical direction, resulting in a more "bulbous" appearance. In general, using smaller anisotropy values tends to remove "ghost" contamination plumes. Anisotropy values used to create the visualizations presented in this addendum were 4 for ^{137}Cs , 7 for ^{60}Co , and 2 for ^{154}Eu .

For the three major contaminants of interest (^{137}Cs , ^{60}Co , and ^{154}Eu), the MDL for the SGLS was generally on the order of 0.1 pCi/g. In the preprocessing module, a value of 0.01 pCi/g was substituted for non-detects in the data file, allowing the presence of non-detects in the data set to have an impact on computation of nodal values during the kriging process, because data analysis is based on the logarithm of contaminant values. During post-processing, values less than 0.1 pCi/g were ignored.

During the kriging process, grids are constructed to encompass all data points in three-dimensional space. The horizontal extent of the grid is governed by the positions of the boreholes. The model does not extrapolate beyond the extent of either the range value or the kriging limit. As a result, both the grid and the associated visualizations can extend only to the maximum depth of the boreholes and the extent of the range.

In the visualization process, solid surfaces are created by connecting the three-dimensional points in space that have equal concentrations. The outermost solid surface of the plume is defined by a user-selected contamination threshold value or isopleth. As the isopleth is increased, progressively higher radionuclide concentration surfaces can be visualized. To view an inner surface, a cut section is inserted through the solid surface plume. Where a low concentration

volume surrounds a zone of higher concentration, a cut surface is helpful in visualizing the variation in concentration.

Tanks were portrayed by creating solid three-dimensional surfaces at the location of the tank centers. In regions occupied by tanks, the model does not insert a contamination barrier so that contamination in a borehole can theoretically have some influence on concentrations on the opposite side of the tank. In a geostatistical estimation calculation, however, the closest boreholes will have the greatest influence and the model will be close to the actual distribution, except for areas where there are few or no boreholes.

4.3 Potential Uncertainties and Inaccuracies

The visualizations presented in this report are based on estimated ^{137}Cs , ^{60}Co , and ^{154}Eu values as determined by geostatistical estimation (kriging) procedures applied to an interpreted data set that has been averaged over 5-ft depth intervals. In addition to the uncertainties associated with geostatistical estimation applied to an interpreted and averaged data set, there are other sources of uncertainty that must be considered, including uncertainties in the assay calculation process and counting error. The uncertainty in assay calculation is discussed in the base calibration report (DOE 1995c) and subsequent re-calibration reports and is estimated by combining errors associated with the calibration efficiency determination, counting statistics of the calibration measurements, and uncertainties in the model concentration values. The counting error is associated with the random nature of the radioactive decay process.

Potential model inaccuracies may also result from zones of high ^{137}Cs concentrations (and resultant detector saturation). Where SGLS detector saturation occurred in the original baseline, no concentration values could be calculated, or they were highly suspect. Therefore, a value of 9,900 pCi/g was placed in the database for kriging operations. In this addendum, ^{137}Cs concentration values computed from HRLS data were substituted in intervals where the SGLS was saturated. A concentration value was not assumed or substituted in the data base for kriging operations for saturated intervals where ^{60}Co and ^{154}Eu contaminants were inferred by SGLS data but not detected by the HRLS.

The calibration of the logging system assumes contamination uniformly distributed in a homogeneous medium that is effectively infinite in extent relative to the detector in both horizontal and vertical directions. This assumption is valid for most situations except at the very top and the bottom of the boreholes or where the concentration changes rapidly with depth or distance from the borehole. The data acquisition interval used to log the T Tank Farm boreholes (0.5 ft) provides adequate spatial resolution to characterize the situations where the contamination is not homogeneous in the vertical dimension. Two exceptions apply for those boreholes located around tanks T-107 and T-110. These boreholes were logged in 1995 at the beginning of the Hanford Tank Farms Vadose Zone project, and the data acquisition parameters were somewhat different than other boreholes in the T Tank Farm. These boreholes were logged with the SGLS operating in continuous logging mode with a 200-second (s) counting time while

moving at 0.3 foot per minute (ft/min). This method of operation corresponds to a data acquisition interval of about 1 ft, which also provides for adequate spatial resolution of contaminants.

Most inaccuracies or errors in the visualizations are insignificant compared to the inaccuracy caused by the introduction of contamination along the borehole and the generation of so-called false plumes. However, the potential for the generation of a false plume from contaminated boreholes is considered during the interpretation process. Specific borehole intervals suspected to be primarily borehole contamination have been removed from the interpreted data set as discussed previously.

A major potential source of error in the visualizations for the T Tank Farm is the lack of any data from under the tanks. Significant levels of contamination could exist under some tanks, in particular under tank T-106; however, no data are available from this volume. If such data were to be included, it is likely that the plumes portrayed in the visualizations would extend further into the volume underneath the tanks. Lack of data also affects the ^{60}Co and ^{154}Eu concentration values in the high gamma flux intervals.

The visualizations are intended to provide the reader with an understanding of how gamma-emitting contaminants that have leaked from the tanks may be distributed in the vadose zone sediments. A valuable attribute of the visualizations is that they can be utilized to define areas of concern in which to focus future characterization and monitoring efforts.

The contamination plumes presented in the visualizations were evaluated by comparing the visualizations with the spectral gamma-ray log data from the individual monitoring boreholes surrounding the tanks. The interpretation of each plume or group of plumes is discussed in Section 4.4.

4.4 Discussion of Visualizations

The following section presents a discussion of the visualizations created with the interpreted data set as discussed in the previous section. The visualizations are provided in Appendix D in the order in which they are discussed.

Appendix Figures D-1 through D-9 illustrate the man-made radionuclides (^{137}Cs , ^{60}Co , ^{154}Eu , ^{152}Eu , ^{238}U , ^{235}U , ^{126}Sn , ^{94}Nb , and ^{125}Sb) that were derived from the interpreted data set for all boreholes logged in the T Tank Farm. These figures portray the data values at 0.5-ft intervals as spheres that are colored and sized to show the relative radionuclide concentration. The concentrations are presented with logarithmic color scales that range from 0.1 to as high as 100 million pCi/g. The borehole numbers are indicated to facilitate correlation of the three-dimensional representation of the data in the remaining figures and the interpreted data set plots presented in Appendix C.

Figures D-10 through D-16 show horizontal planar slices at various depths in the T Tank Farm. These slices illustrate the distribution of the major contaminants (^{137}Cs , ^{60}Co , and ^{154}Eu) that occur at concentrations greater than 0.5 pCi/g. The depths of these slices were selected to indicate a balance of the highest concentration and maximum extent of plumes that existed between the selected depth intervals.

The horizontal slice from the 6-ft depth represents the best representation of the lateral and average concentration of contamination that exists between the ground surface and the interval lying just above the surface of the tank domes. In general, the visualization slice at the 6-ft depth shows there is a mostly continuous plume of ^{137}Cs contamination bisecting the T Tank Farm orientated in a east-west direction.

There is also good correlation with ^{137}Cs contamination between depths of 6 and 10 ft. The 10-ft depth represents an interval just below the top of the dome. This visualization is slightly inaccurate in that the contaminant plume appears to be located along the side of the tanks and not along the top of the dome. To place the tanks in the visualizations, cylinders with flat tops and bottoms were modeled. If the tank's dome could be modeled as a curved surface then the visualizations would show the contaminant plumes covering a portion of the dome extending to the 10-ft contour around the top of the dome.

The slice at the 20-ft depth shows two separate contaminant plumes continuing from the 10-ft depth between tanks T-104 and T-107, and along the southeast side of tank T-106. Also at this depth, three new contaminant plumes become apparent: ^{137}Cs southeast and west of tank T-101 and ^{154}Eu along the southeast side of tank T-103. These leaks probably originated from piping or other fixtures at or near the maximum working level of the tanks. Previous investigations have suggested that the spare fill lines located along the southeast side of tanks T-101 and T-103 are probably the source of the leaks that occurred after these tanks were overfilled (DOE 1999b, 1999d). The cascade overflow line is probably the source of the contaminant plume located on the west side of tank T-101 (DOE 1999b). The visualizations indicate that the plumes associated with the spare fill line leaks continue to a depth of at least 71 ft.

At the 24-ft slice, ^{60}Co also occurs within the contaminant plume detected along the southeast side of tank T-103. In addition, this is approximately the depth of the highest ^{137}Cs concentration associated with the contaminant plume on the southeast side of tank T-101. The ^{137}Cs plume shown between tanks T-104 and T-107 represents the deepest ^{137}Cs contamination from a surface source.

The slice at the 39-ft depth, which is approximately the base of the tank farm excavation, shows a large contaminant plume containing multiple radionuclides around most of tank T-106. Tank T-106 suffered a steel liner failure and leaked an estimated 115,000 gal of waste to the soil column over a 3-month period in 1973 (DOE 1999g). The visualization shows that at this depth tank T-106's contaminant plume has spread mostly in a southward direction and probably continues under the north half of tank T-109. In addition, at approximately this depth, the

highest ^{137}Cs concentration value (66,426,000 pCi/g) for the entire T Tank Farm was measured in a borehole along the southeast quadrant of tank T-106.

This slice also shows that the plume originating from tank T-103 is growing larger toward the southeast with ^{60}Co contamination becoming more widespread. Tank T-109 is classified as an assumed leaker based on a historical in-tank liquid-level decrease. Evidence of this leak may be appearing at the 39-ft depth along the northwest quadrant of the tank as indicated by the ^{60}Co and ^{154}Eu contamination. However, this plume is probably commingled with the plume originating from tank T-106 (DOE 1998b).

Along the west side of tank T-101, ^{60}Co has replaced ^{137}Cs in the contaminant plume that appears to be continuous from the 20-ft depth. On the southeast side of tank T-101 the ^{137}Cs contaminant plume is also continuous at fairly high concentrations. A new ^{137}Cs plume is shown at this depth between tanks T-102 and T-105. This contaminant occurs within a 10-ft interval at the base of the tanks, which implies that tank T-102 or T-105 has leaked and that there may be a much larger body of ^{137}Cs contamination nearby (DOE 1999c).

The slice at the 51-ft depth shows that the ^{60}Co plumes from tanks T-103 and T-106 have combined in a north-south direction and are spreading westward from T-106. ^{60}Co and ^{154}Eu contaminant plumes originating from tanks T-103 and T-106 have also spread under the eastern half of tank T-105. A ^{60}Co and ^{154}Eu plume between tanks T-101 and T-104 appears to be emerging from the large ^{137}Cs plume on the southeast side of tank T-101. In addition, the plume between tanks T-102 and -105 is dominated by ^{60}Co at this depth. The ^{60}Co plume located between tanks T-101 and T-102 is not present on the 51-ft slice because the concentration values fell below the 0.5-pCi/g isopleth; however, ^{60}Co contamination is clearly shown on the interpretation log plot.

The final slice at the 71-ft depth indicates that all of the plumes have combined and appear to be at their greatest lateral extent. This depth horizon is in the lower portion of the Hanford formation about 10 ft above the contact with the early Palouse soil. An extensive ^{60}Co plume, oriented in a southwest to northeast direction, extends from tank T-106 toward tanks T-101 and T-104, completely under tank T-105, and under most of tanks T-108 and T-109. The ^{60}Co plume between tanks T-108 and T-109 is probably from a leak associated with tank T-106 (DOE 1998a). Multiple sources are probably responsible for this extensive ^{60}Co contamination. In addition, an extensive ^{154}Eu plume is present from tanks T-103 and T-106 and high concentrations of ^{137}Cs are present around tanks T-101 and T-106. The calculated distribution of this contaminant is largely influenced by three deep boreholes that have high ^{137}Cs concentrations at the bottom of their logged intervals. However, the vertical extent of the plume is poorly defined because no boreholes in the vicinity extend through the bottom of these contaminant plumes.

Figures D-17 through D-26 are three-dimensional visualizations that illustrate the major contamination plumes within the vadose zone at the T Tank Farm. The figures show the plumes created with the EVS software superimposed over the SGLS and HRLS data from the interpreted

data sets. In these ten figures, the plumes of interest are presented with a degree of transparency to view the data that define the plumes.

Figure D-17 shows the distribution of the ^{137}Cs contamination viewed from below and looking toward the northwest. Figure D-18 shows the distribution of the ^{137}Cs contamination viewed from above and looking toward the southeast. Figures D-19 and D-20 show the distribution of the ^{60}Co and ^{154}Eu contamination, respectively, viewed from below the tank farm and looking toward the northwest. These figures portray the distribution of the three major contaminants in the vadose zone immediately below the tank farm. Note that Figures D-17, D-19, and D-20 represent views from a common vantage point.

Figures D-21 through D-23 show a view from below and looking toward the northeast through a portion of the ^{137}Cs , ^{60}Co , and ^{154}Eu plumes cut by an east-west-trending vertical plane that lies at the southern edge of tanks T-101, T-102, and T-103. Figure D-21 exposes the interior of the ^{137}Cs plume showing the highest concentration values around tank T-101. This view also shows that the borehole identifying the ^{137}Cs plume is contaminated to the bottom of the logged interval, implying that the vertical extent of the plume has not been determined. Figures D-22 and D-23 show the ^{60}Co and ^{137}Cs plumes and the ^{154}Eu and ^{137}Cs plumes, respectively, originating from tank T-103. All three visualizations show the depth to the top of the contaminant plumes originating from tanks T-101 and T-103.

Figure D-24 shows a view from below and looking toward the northwest through a portion of the ^{137}Cs plume cut by a north-south-trending vertical plane that lies at the eastern edge of tanks T-103, T-106, and T-109. This cut exposes the interior of the ^{137}Cs plume showing the highest concentration values. This view also shows that two boreholes have ^{137}Cs contamination extending to the bottom of their logged intervals, indicating the plume may extend to deeper depths. The bottom of the surface contamination is clearly shown as being separated from the top of the contaminant plume emerging from tank T-106.

Figures D-25 and D-26 show a view from above and looking toward the northwest through a portion of the ^{60}Co and ^{137}Cs plumes and the ^{154}Eu and ^{137}Cs plumes, respectively, cut by a north-south-trending vertical plane that lies at the eastern edge of tanks T-103, T-106, and T-109. These views show the extent of contaminant plumes surrounding these tanks and that many boreholes have ^{60}Co and ^{154}Eu contamination extending to the bottom of their logged intervals, indicating that the depth of the plumes has not been determined.

4.5 Contaminated Volume and Total Activity Estimate

With completion of the revised visualizations, it was possible to calculate a rough estimate of the volume of contaminated soil and total activity inventory as a function of contaminant threshold level within the plumes shown in the T Tank Farm visualizations. Volume estimates are prepared by numerically integrating the volume within the specified isosurface. Contaminant inventories (in Curies) are calculated by numerically integrating the total mass within the

isosurface. The total mass for each volumetric element is determined by multiplying the specific activity (concentration) in picocuries per gram by the mass per unit volume (density) for each element. A density of 1.8 grams per cubic centimeter (g/cm^3) was assumed in the volume calculation.

These estimates are based on the kriged values extrapolated from the interpreted data set, where concentration values have been averaged over 5-ft intervals. They represent the volumes of the contaminated formation and total radioactivity for ^{137}Cs , ^{60}Co , and ^{154}Eu . The total activity values were not decayed to a specific date but span over approximately a 4-year period starting and ending when the first SGLS and last HRLS data were collected, respectively. These estimates are based entirely on the data from the baseline spectral gamma characterization program (SGLS data), with HRLS data included in zones of detector saturation. The data sets used for the volume and total activity inventory estimates did not include any historical gross gamma or soil sample data.

High rate intervals indicate only ^{137}Cs concentration values; however, it is considered likely that ^{60}Co and $^{152/154}\text{Eu}$ also existed in these zones. However, in high rate intervals where concentration values for these radionuclides were not known, the interpreted data sets, visualizations, and contaminant inventories do not reflect their possible existence. In addition, ^{152}Eu , $^{235/238}\text{U}$, ^{126}Sn , ^{94}Nb , and ^{125}Sb were not considered for the inventory estimates. The total contribution of these radionuclides is estimated to be minor. A further limitation of this inventory is that no data are available from directly under the tanks where presumably the highest concentrations of radionuclides would exist. Therefore, the following volume and activity estimates for ^{137}Cs , ^{60}Co , and ^{154}Eu represent a lower bound.

The following tables list the contaminated soil volumes and total activities that occur at or above each threshold level for ^{137}Cs , ^{60}Co , and ^{154}Eu .

Contaminant Threshold (pCi/g)	^{137}Cs	Total Activity (Curies)
	Contaminated Volume (Cubic Meters)	
0.5	44,040	1,024
5	21,180	1,023
50	11,260	1,022
500	6,346	1,016
5,000	3,064	991
50,000	1,184	889
5×10^5	263	592
1×10^6	150	458
2×10^6	73.8	296

Contaminant Threshold (pCi/g)	⁶⁰ Co	Total Activity (Curies)
	Contaminated Volume (Cubic Meters)	
0.5	34,150	0.59
1.0	25,970	0.58
5	12,710	0.51
10	8,615	0.45
50	1,312	0.15
100	174	0.032

Contaminant Threshold (pCi/g)	¹⁵⁴ Eu	Total Activity (Curies)
	Contaminated Volume (Cubic Meters)	
0.5	23,610	0.83
1.0	17,920	0.82
5	8,757	0.76
10	6,238	0.72
50	2,283	0.53
100	1,152	0.39
200	460	0.24
300	255	0.16
400	149	0.11

5.0 Conclusions

The purpose of this addendum is to provide an update to the original T Tank Farm Report that was issued in 1999. The essential interpretations and conclusions in the original report are unchanged. However, since the original report was issued, knowledge has been gained that provides a more complete framework by which the contaminant distribution can be viewed. In addition, enhancements to the data collection have been made since the T Tank Farm Report was issued. Some of the more important improvements in the understanding of the log data have resulted from the following:

- Significant levels of ¹³⁷Cs, ⁶⁰Co, and ¹⁵⁴Eu exist within the formation at depths of at least 123 ft. The vertical extent of contaminant plumes is not fully defined, because a number of boreholes are contaminated to total depth.

- Analysis of historical gross gamma logging data from 1975 to 1994 provides a qualitative identification of contaminant movement. In addition, repeat logging using the SGLS has allowed for quantitative determination of concentration increases between 1998 and 1999. However, there has been no comprehensive effort to monitor changes in vadose zone contamination since 1994.
- The HRLS has allowed determination of maximum concentration values in borehole intervals where the SGLS was saturated. ¹³⁷Cs concentrations as high as 66,400,000 pCi/g were detected, providing an improved basis to estimate the volume of contaminated soil and contaminant inventory in the vadose zone. It also provides a baseline against which future measurement can be made to detect contaminant movement in high gamma flux zones.

Integration of the HRLS data and re-calculation of the spatial distribution based on the revised interpreted data set has resulted in an improved visualization of subsurface contaminant distribution in the T Tank Farm. Conclusions stated in the original T Tank Farm Report remain appropriate and will not be reiterated. However, one finding of major significance is that evaluation of repeat logging data and independent assessment of historical gross gamma data appear to both indicate that contaminant movement through the vadose zone has occurred in the past and appears to be continuing. Figure 2 shows boreholes where contamination increases have occurred in the past and appear to be continuing. This information is based on SGLS repeat logging results, HRLS results, and work performed by Randall et al. (2000).

6.0 Recommendations

Recommendations included in the original T Tank Farm Report remain valid. The baseline data reported in the T Tank Farm Report and this addendum have provided an indication of the nature and extent of contamination associated with gamma-emitting radionuclides. Evaluation of historical data and SGLS repeat logging of selected boreholes appears to indicate that contaminant migration is continuing. However, the gross gamma logging program was terminated in 1994, and limited new data are available to assess continuing migration from 1994 to the present. Therefore, it is imperative that a routine vadose zone monitoring program be reinstated within the T Tank Farm as soon as possible. It is not necessary to monitor all boreholes; the T Tank Farm baseline data clearly indicate where monitoring data are required. In addition to routine gamma monitoring, consideration should be given to implementation of a moisture logging program to detect and monitor changes in vadose zone moisture conditions. This is particularly important because infiltration of precipitation and surface runoff and/or water from pipeline leaks may be remobilizing contamination from past tank leaks.

Additional boreholes should be drilled and samples collected to further investigate contaminant plumes identified by the baseline study. This is particularly important for the area immediately

to the southeast of tank T-102, where the spare fill lines may have leaked and where ^{60}Co contamination appears to be continuing to move.

The contaminated volume and total activity inventory are based entirely on the SGLS baseline data set, supplemented by HRLS data. There is a significant body of additional information that should be evaluated to provide a more accurate representation of subsurface plumes and a better assessment of contaminated volume and total activity. Specifically, this includes the gross gamma data and soil sample data. These data should be evaluated and converted to equivalent ^{137}Cs concentrations and incorporated into the interpreted data set used to construct the visualizations.

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Appendix A
Summary of High Rate Logging Results
for the T Tank Farm

Table A-1. Summary of High Rate Logging Results for the T Tank Farm

Borehole	Depth for Each Log Run (ft)	Shield/Correction Factor ^a	Comment
50-01-04	90-122.5	NS/1.00 DC ^b	The highest apparent ¹³⁷ Cs concentration value was 19,371,000 pCi/g detected at the 24.5-ft depth. At 121 ft, standing water was measured. Calculated ¹³⁷ Cs concentration values below 121.0 ft were not corrected for water and are under compensated. ¹³⁷ Cs concentration values derived from baseline and HRLS data show good repeatability between 75 and 120 ft. ¹³⁷ Cs contamination was detected at the bottom of the logged interval, indicating that the bottom of the contamination plume has not been determined. H/D ^c indicate the interval between 15 and 70 ft was stable and from 75 to 90 ft was undetermined. ¹³⁷ Cs was indirectly inferred as the major contaminant in both intervals by fitting a ¹³⁷ Cs decay curve to the historical total gamma-ray data.
	65-91		
	33-66		
	17-34		
	21-30	IS/27.42	
50-06-04	39-70	NS/1.00	The highest ¹³⁷ Cs concentration value was 674,000 pCi/g detected at the 36.5-ft depth. The interval between 34 and 41 ft probably contains ⁶⁰ Co and ^{152/154} Eu, but these contaminants were not detected by the HRLS. H/D indicate the interval between 29 and 42 ft was stable and identified ¹³⁷ Cs by fitting a decay curve to the historical gross gamma-ray data. From 42 to 66 ft and 66 to 90 ft, H/D show both intervals as undetermined and indicate ¹⁰⁶ Ru as the possible contaminant by fitting a decay curve to the data.
	34-40		
	25-35		
	34-40	ES/3.758	
50-06-05	47.5-118.5	NS/1.00 DC	The highest apparent ¹³⁷ Cs concentration value was 66,426,000 pCi/g detected at the 43.5-ft depth. The interval between 32 and 118.5 ft probably contains ⁶⁰ Co but was undetected by the HRLS. H/D indicate the intervals from 27 to 60 ft, 60 to 94 ft, and 94 to 120 ft are stable. ¹³⁷ Cs was identified as the probable contaminant by fitting the ¹³⁷ Cs decay curve to the historical total gamma-ray data.
	33-48.5		
	28-34		
	44.5-49	IS/27.42	
	32-45.5		

^a Shield configuration options: NS - No shield; ES - External shield; IS - Internal shield; BS -Both shields.

^b DC - Double Casing. ¹³⁷Cs concentrations were multiplied by 1.41 to correct for the presence of 4-in. and 6-in. casings. Data were collected using a 200-s counting time at 6-in. intervals.

^c H/D - Historical data from Randall et al. (2000).

Table A-1 (cont'). Summary of High Rate Logging Results for the T Tank Farm

Borehole	Depth for Each Log Run (ft)	Shield/Correction Factor ^a	Comment
50-06-06	32-76	NS/1.00 DC	The highest apparent ¹³⁷ Cs concentration value was 137,000 pCi/g detected at the 42-ft depth by the HRLS. The interval between 34 and 43 ft probably contains ⁶⁰ Co and ^{152/154} Eu, but these contaminants were not detected by the HRLS. H/D indicate that the intervals from 29 to 68 ft and 68 to 110 ft were unstable early and 110 to 120 ft was stable. ¹³⁷ Cs and ⁶⁰ Co were identified as the probable contaminants by fitting a decay curve to the historical total gamma-ray data. From 110 to 120 ft, H/D indirectly infer that ¹⁵⁴ Eu was present.
50-06-08	36.5-60	NS/1.00 DC	The highest apparent ¹³⁷ Cs concentration value was 190,000 pCi/g detected at the 35.5-ft depth by the HRLS. The interval between 34 and 41 ft probably contains ⁶⁰ Co and ^{152/154} Eu, but these contaminants were not detected by the HRLS. ¹³⁷ Cs concentration values derived from baseline and HRLS data show good repeatability between 55 and 60 ft. H/D indirectly infer ¹³⁷ Cs from 28 to 44 ft was stable, ¹³⁷ Cs, ⁶⁰ Co, and ¹⁰⁶ Ru from 44 to 89 ft was stable, and ¹³⁷ Cs and ¹⁰⁶ Ru from 89 to 120 ft was undetermined.
	32-37.5		
	34-39	IS/27.42	
50-06-16	32-50	NS/1.00	The highest apparent ¹³⁷ Cs concentration value was 8,000 pCi/g detected at the 40-ft depth by the HRLS. ¹³⁷ Cs concentrations were multiplied by 2.71 to correct for the presence of 6-in., 8-in., and 10-in. casings. The interval between 35 and 40.5 ft probably contains ⁶⁰ Co and ^{152/154} Eu, but these contaminants were not detected by the HRLS. H/D indirectly infer ¹³⁷ Cs from 10 to 20 ft, ¹³⁷ Cs, ⁶⁰ Co, and ¹⁰⁶ Ru from 30 to 63 ft, and ⁶⁰ Co, ¹⁵⁴ Eu, and ¹⁰⁶ Ru from 63 to 90 ft were all stable.
50-06-17	47.5-86.5	NS/1.00	The highest apparent ¹³⁷ Cs concentration value was 19,304,000 pCi/g detected at the 46-ft depth by the HRLS. ¹³⁷ Cs concentrations were multiplied by 1.699 to correct for the presence of 6-in. and 10-in. casings. The interval between 34 and 86.5 ft probably contains ¹⁵⁴ Eu, but this contaminant was not detected by the HRLS. H/D indicate ¹³⁷ Cs contamination from 28 to 52 ft and ¹³⁷ Cs and ¹⁰⁶ Ru from 52 to 90 ft, which are all stable.
	48.5-34		
	30-35		
	35-48	ES/3.758	

^a Shield configuration options: NS - No shield; ES - External shield; IS - Internal shield; BS -Both shields.

^b DC - Double Casing. ¹³⁷Cs concentrations were multiplied by 1.41 to correct for the presence of 4-in. and 6-in. casings. Data were collected using a 200-s counting time at 6-in. intervals.

^c H/D - Historical data from Randall et al. (2000).

Table A-1 (con't). Summary of High Rate Logging Results for the T Tank Farm

Borehole	Depth for Each Log Run (ft)	Shield/Correction Factor ^a	Comment
50-06-18	33-65	NS/1.00	The highest apparent ¹³⁷ Cs and ¹⁵⁴ Eu concentration values were 75,000 and 5,700 pCi/g detected at 42.5 and 43.5 ft, respectively, by the HRLS. ¹³⁷ Cs and ¹⁵⁴ Eu concentrations were multiplied by 2.71 and 2.071, respectively, to correct for the presence of 6-in., 8-in., and 10-in. casings. The interval between 35 and 45 ft probably contains ⁶⁰ Co and ¹⁵² Eu, but these contaminants were not detected by the HRLS. At 65 ft, ¹³⁷ Cs concentration values derived from baseline and HRLS data show good repeatability. H/D indicate gross gamma-ray data were not available for this borehole.

^a Shield configuration options: NS - No shield; ES - External shield; IS - Internal shield; BS -Both shields.

^b DC - Double Casing. ¹³⁷Cs concentrations were multiplied by 1.41 to correct for the presence of 4-in. and 6-in. casings. Data were collected using a 200-s counting time at 6-in. intervals.

^c H/D - Historical data from Randall et al. (2000).

Borehole 50-01-04

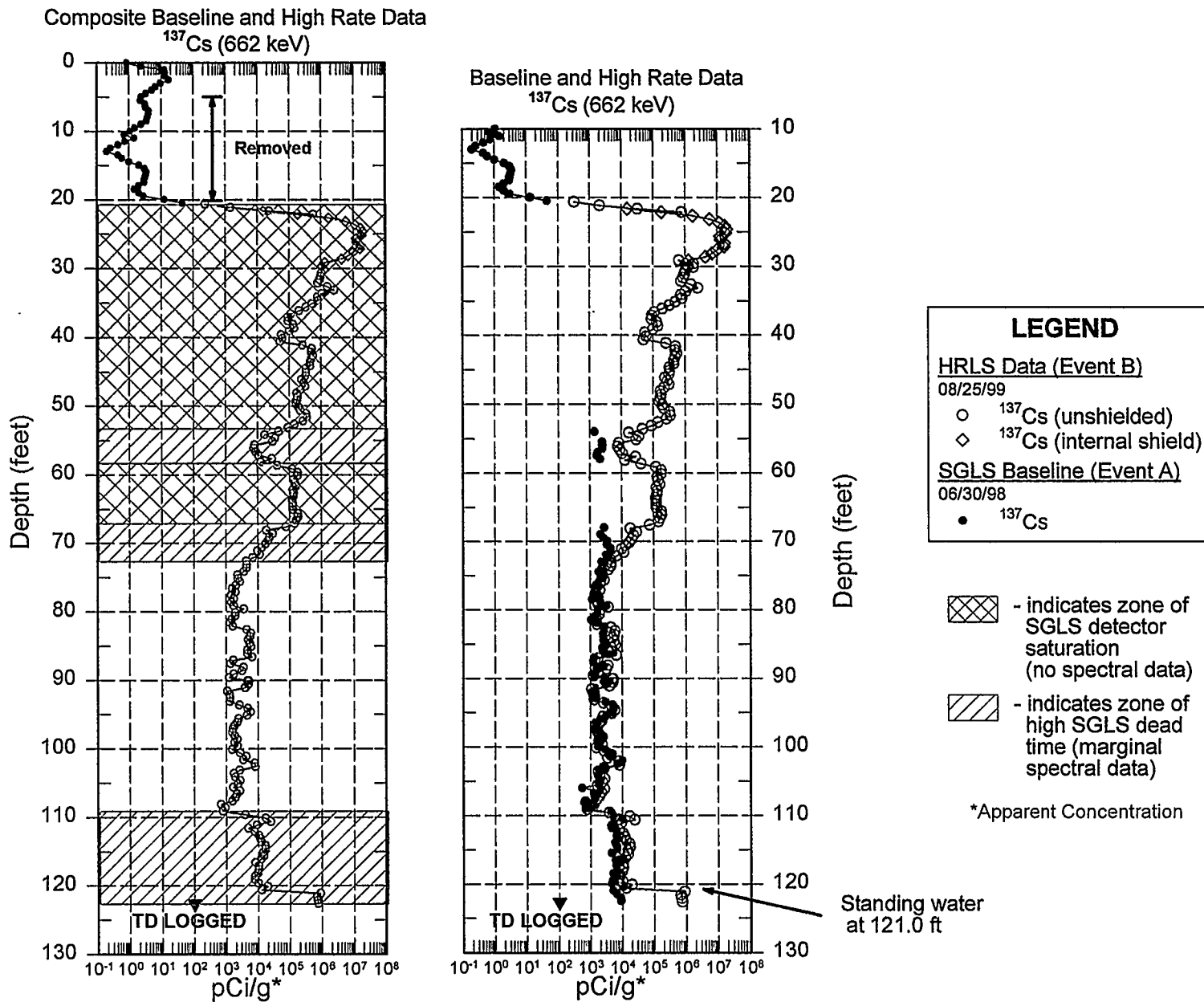
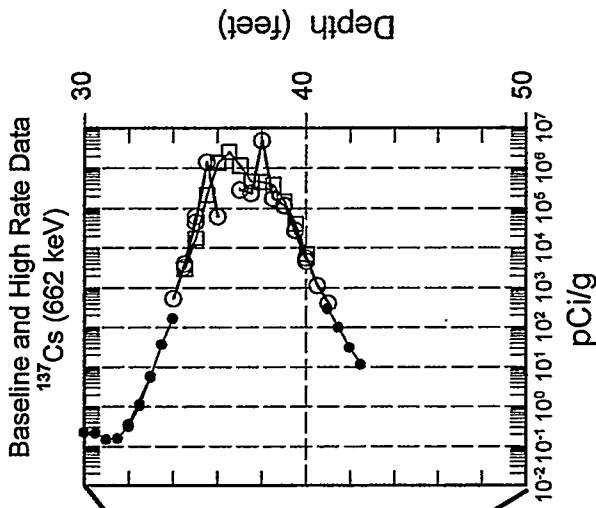
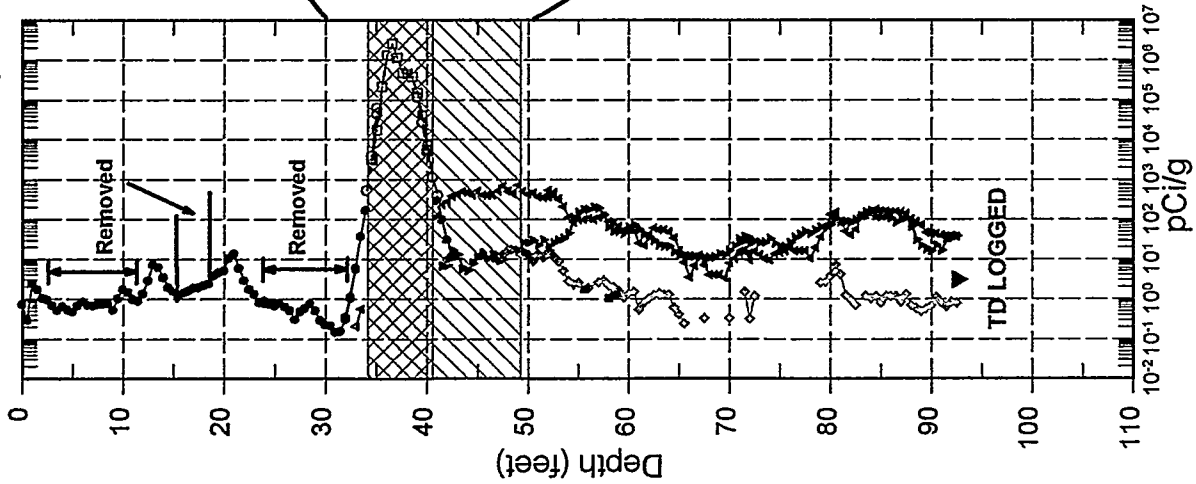


Figure A-1. Summary of High Rate Logging Results for the T Tank Farm

Borehole 50-06-04

Composite Baseline Data and High Rate Data



LEGEND	
HRLS Data (Event B)	
○	¹³⁷ Cs (unshielded)
□	¹³⁷ Cs (external shield)
SGLS Baseline (Event A)	
●	¹³⁷ Cs
▲	¹⁵⁴ Eu
▼	⁶⁰ Co
◇	¹⁵² Eu
▣	¹²⁶ Sn

- indicates zone of SGLS detector saturation (no spectral data)

- indicates zone of high SGLS dead time (marginal spectral data)

Figure A-2. Summary of High Rate Logging Results for the T Tank Farm

Borehole 50-06-05

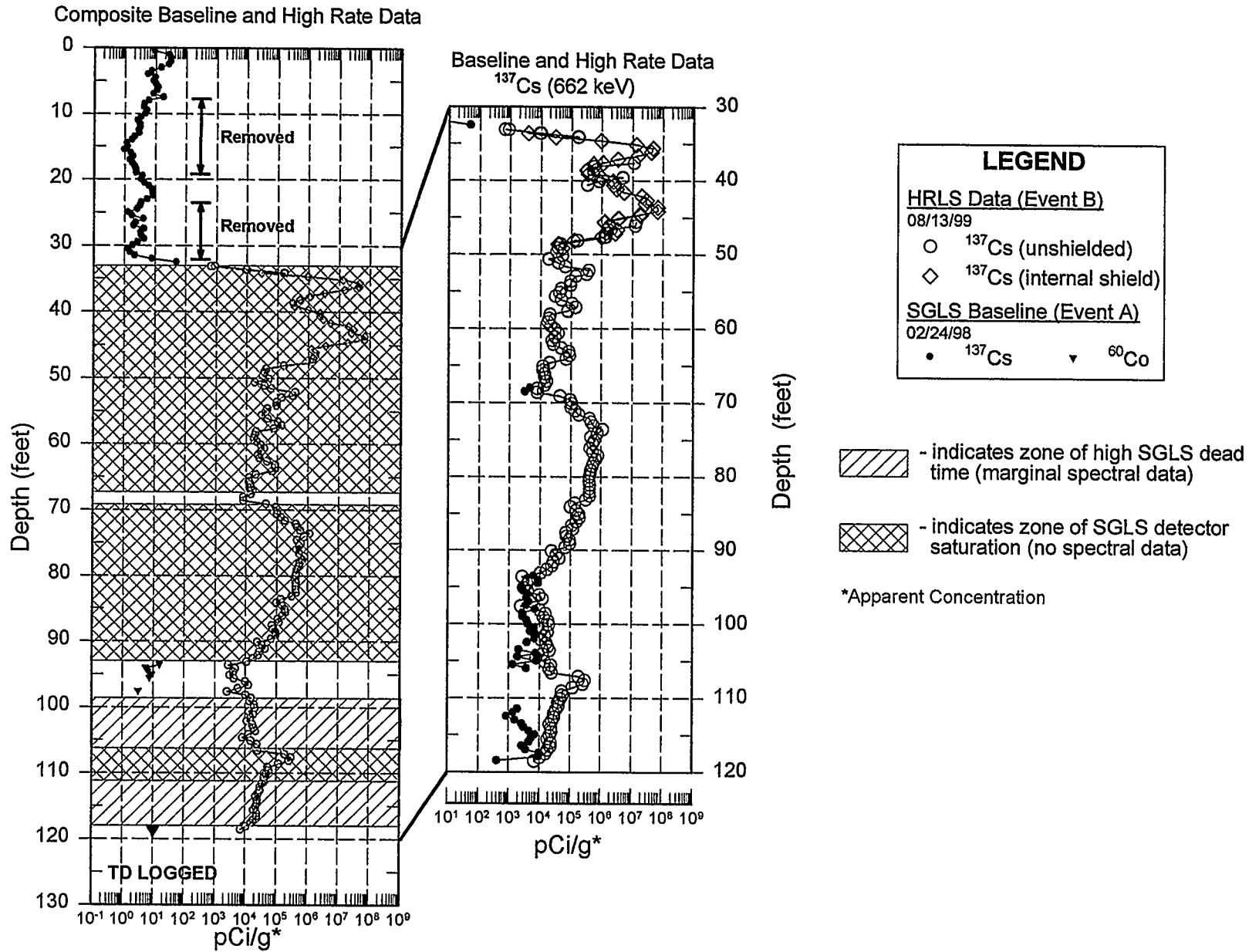
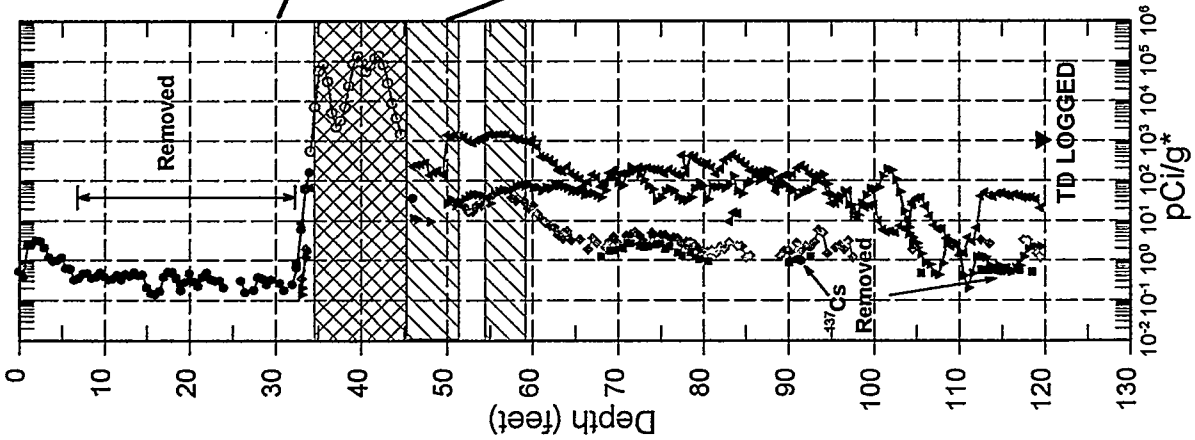




Figure A-3. Summary of High Rate Logging Results for the T Tank Farm

Borehole 50-06-06

Composite Baseline and High Rate Data



LEGEND	
<u>HRLS Data (Event B)</u> 08/24/99	○ ¹³⁷ Cs (unshielded)
<u>SGLS Baseline (Event A)</u> 02/13/98	● ¹³⁷ Cs
	◆ ¹⁵² Eu
	▼ ⁶⁰ Co
	◻ ¹²⁶ Sn
	▲ ¹⁵⁴ Eu
	▲ ¹²⁵ Sb

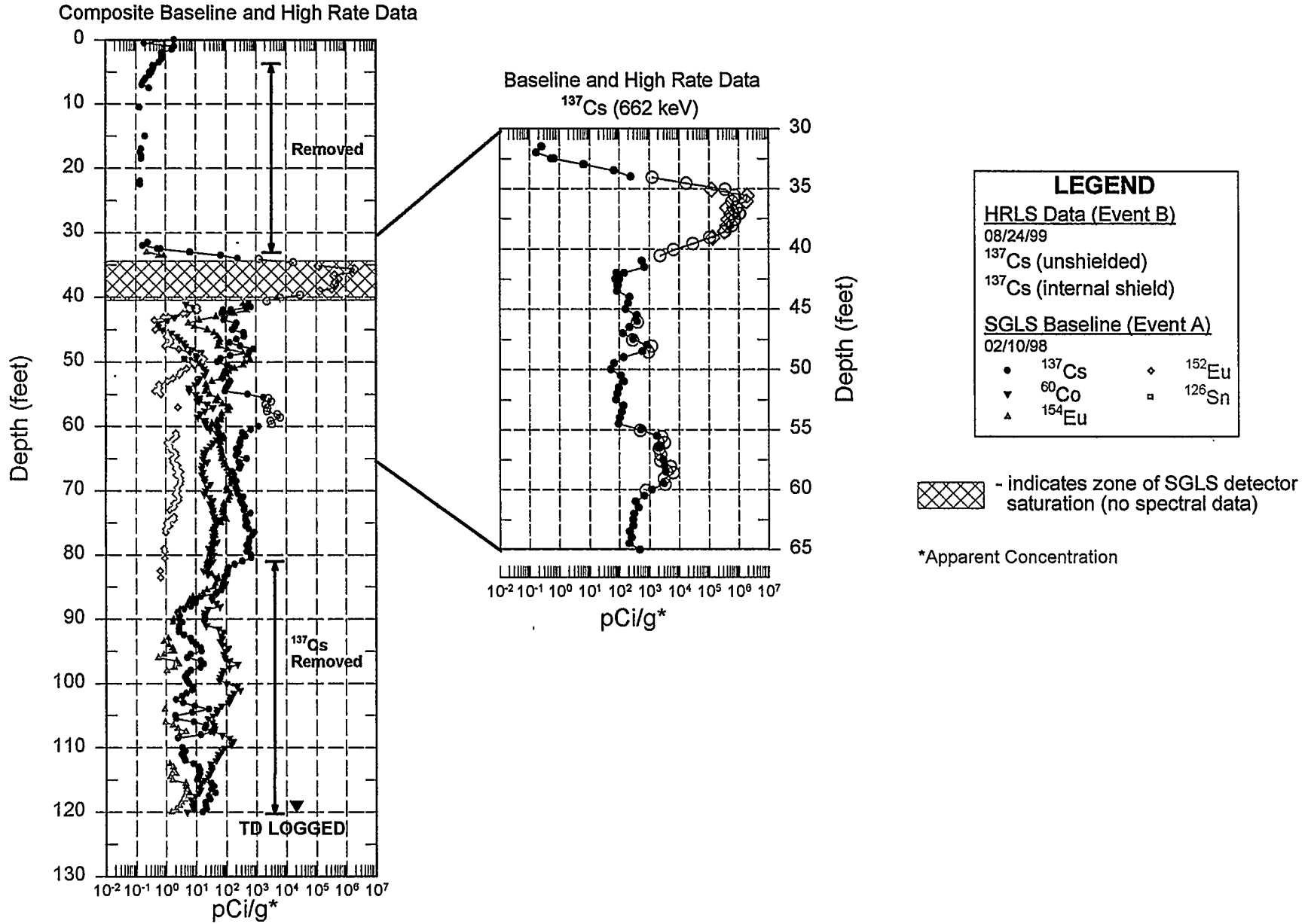
 - indicates zone of high SGLS dead time (marginal spectral data)
 - indicates zone of SGLS detector saturation (no spectral data)

*Apparent Concentration

Figure A-4. Summary of High Rate Logging Results for the T Tank Farm

Borehole 50-06-08

DOE/Grand Junction Office
July 2000

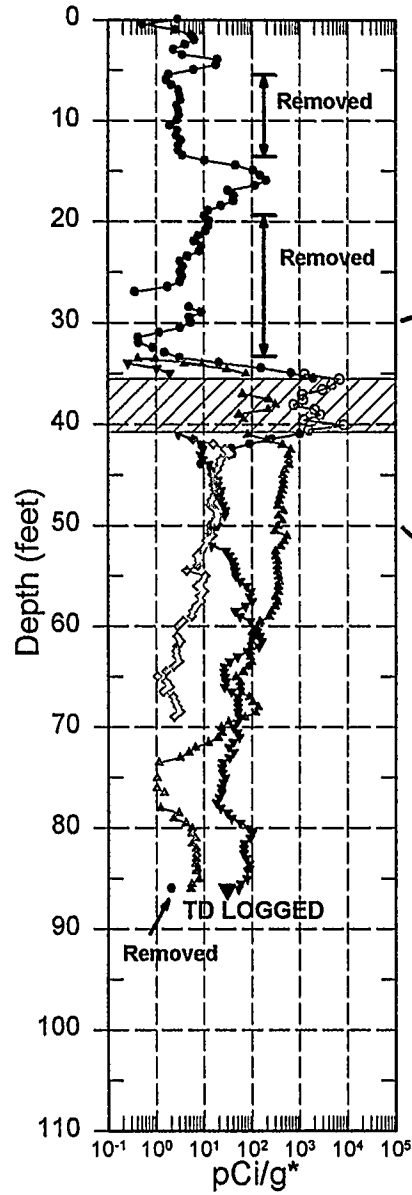


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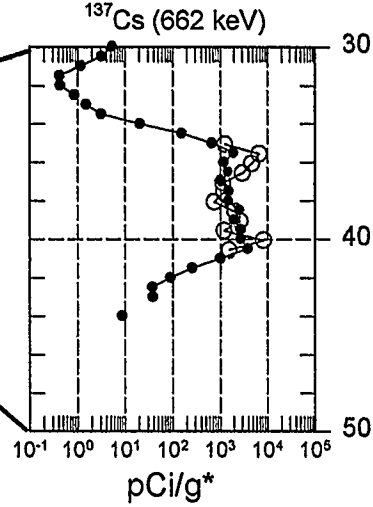
Figure A-5. Summary of High Rate Logging Results for the T Tank Farm

Borehole 50-06-16

Composite Baseline and High Rate Data



Baseline and High Rate Data



LEGEND

HRLS Data (Event B)
08/12/99

^{137}Cs (unshielded)

SGLS Baseline (Event A)
02/26/98

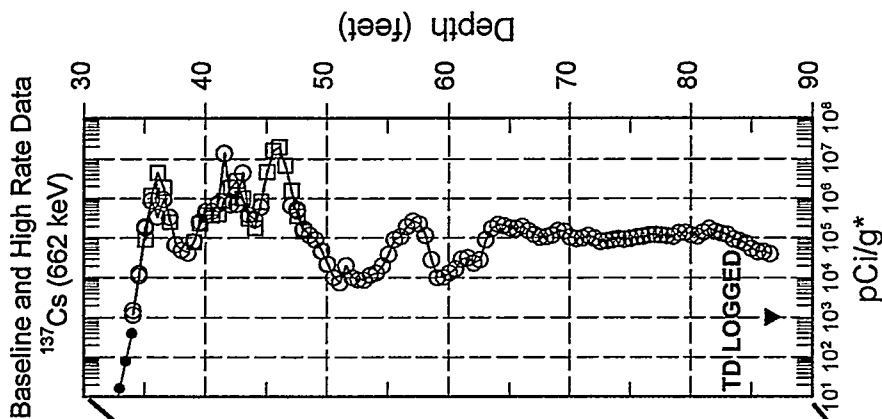
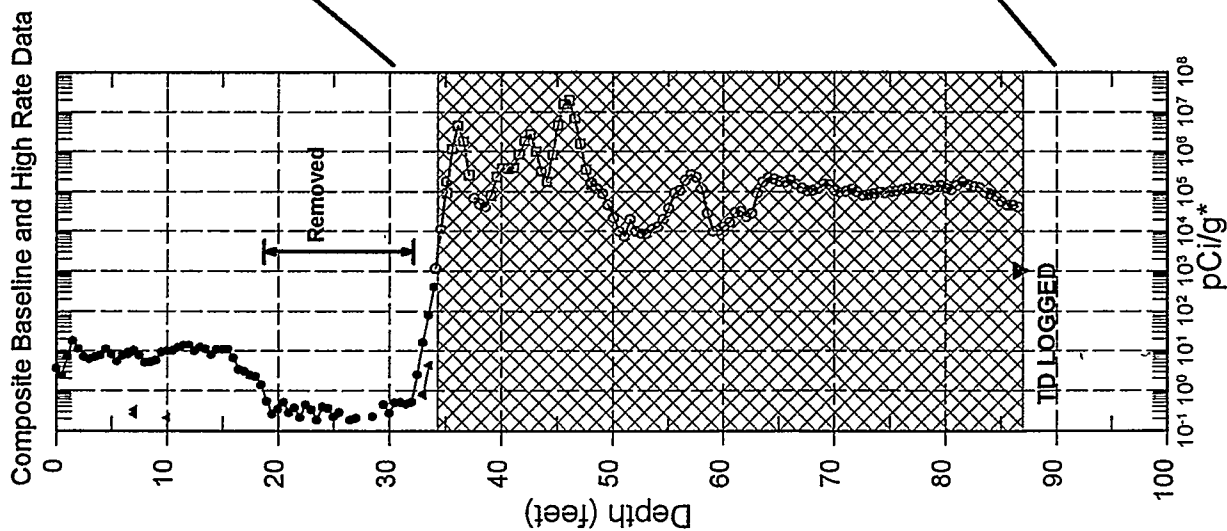
• ^{137}Cs	▲ ^{154}Eu
▼ ^{60}Co	◊ ^{152}Eu

- indicates zone of high SGLS dead time (marginal spectral data)

*Apparent Concentration

Figure A-6. Summary of High Rate Logging Results for the T Tank Farm

Borehole 50-06-17



LEGEND

HRLS Data (Event B)
08/23/99

- ¹³⁷Cs (unshielded)
- ¹³⁷Cs (external shield)

SGLS Baseline (Event A)
02/19/98

- ¹³⁷Cs
- ▲ ¹⁵⁴Eu

▨ - indicates zone of SGLS detector saturation (no spectral data)

*Apparent Concentration

Figure A-7. Summary of High Rate Logging Results for the T Tank Farm

Borehole 50-06-18

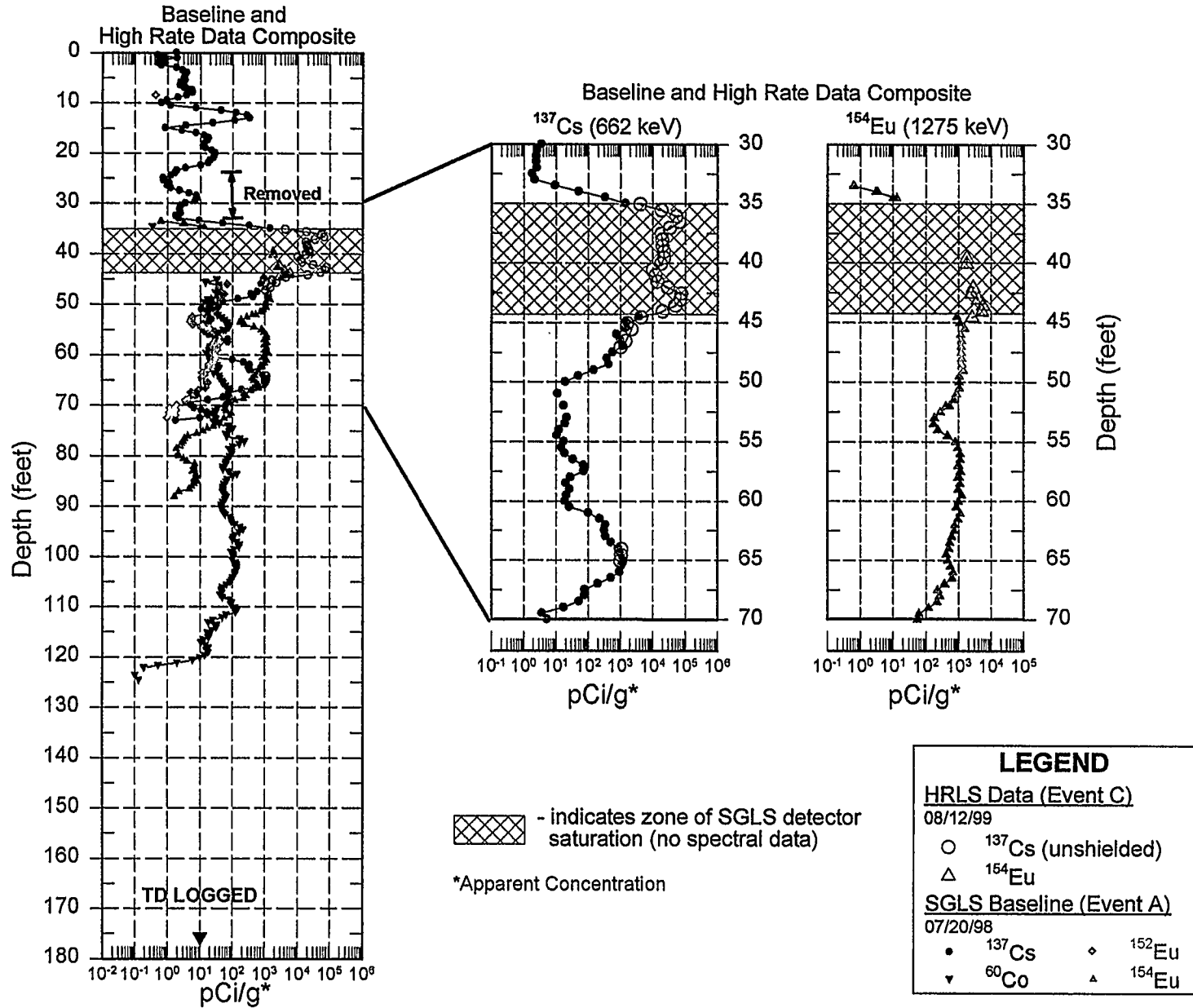


Figure A-8. Summary of High Rate Logging Results for the T Tank Farm

Appendix B
Summary of Repeat Logging Results
for the T Tank Farm

Table B-1. Summary of Repeat Logging Results for the T Tank Farm

Borehole	Depth (ft)	Logging Unit/ Counting Time		Reason for Repeat	Evaluation
		Baseline	Repeat		
50-02-05	45-75	G2B/ 200 s	G2B/ 200 s	CM ^a	<p>SGLS repeat data indicate that movement of ⁶⁰Co contamination may have occurred from 49 to 50.5 ft, 59.5 to 63 ft, and at 69.5 ft. ⁶⁰Co concentrations in those intervals are slightly higher than the calculated decay of baseline data; however, the differences are within the estimated uncertainty measurements. ¹³⁷Cs concentrations appear to be stable. H/D^c indicate ¹³⁷Cs concentrations from 30 to 45 ft are stable but ⁶⁰Co concentrations from 45 to 54 ft and 54 to 70 ft are unstable. This borehole is recommended for additional monitoring.</p>
50-05-07	68-87, 60-69	G1B/ 200 s	G2B/ 200 s	CM	<p>SGLS repeat data indicate that ⁶⁰Co concentrations from 64.5 to 84.5 ft are stable. Below the standing water level and extending to total logging depth, 84.4 to 87 ft, discrepancies are shown between the ⁶⁰Co concentration values derived from baseline and repeat data. These differences are the result of different water correction factors that were applied to the data sets during the analysis process. H/D indicate the interval from 4 to 18 ft is stable and from 58 to 90 ft ⁶⁰Co contamination was unstable early.</p>
	72-87				<p>SGLS relog data were used to check the performance of the logging system. Data show good repeatability and depth control.</p>

^a CM - Contaminant movement.

^b SD - Spatially define contaminants.

^c CP - Confirm presence of contamination.

^d IAC - Identify additional contaminants.

^e H/D - Historical data from Randall et al. (2000).

Table B-1 (con't.). Summary of Repeat Logging Results for the T Tank Farm

Borehole	Depth (ft)	Logging Unit/ Counting Time		Reason for Repeat	Evaluation
		Baseline	Repeat		
50-07-07	40-50	G1/ 0.3 ft per minute @ 1-ft intervals	G2B/ 200 s	SD ^b	SGLS repeat data indicate that ¹³⁷ Cs concentrations appear to be stable. Between 43.4 and 45 ft, a 0.5-ft depth error seems to separate the baseline and repeat data. This 0.5-ft separation is probably not a depth error but was caused by the method in which the baseline data were collected (continuous logging mode) over 1-ft intervals. SGLS repeat data confirmed the spacial distribution of the ¹³⁷ Cs contamination in the interval. ⁶⁰ Co contamination was not detected by the repeat data and may have decayed to levels below the minimum detection limit (MDL) of the SGLS detector. H/D indicate the interval from 36 to 48 ft was undetermined.
50-11-10	65-80	G2B/ 200 s	G2B/ 400 s	CP ^c	SGLS repeat data indicate that ⁶⁰ Co concentrations appear to be stable. The cause of the slightly lower ⁶⁰ Co concentrations in repeat data when compared to the calculated decay of the baseline data is unknown. However, the difference may be related to the longer system counting time, which reduced the MDL. H/D indicate no gamma-ray-emitting contamination was identified in this borehole.

^a CM - Contaminant movement.

^b SD - Spatially define contaminants.

^c CP - Confirm presence of contamination.

^d IAC - Identify additional contaminants.

^e H/D - Historical data from Randall et al. (2000).

Table B-1 (con't.). Summary of Repeat Logging Results for the T Tank Farm

Borehole	Depth (ft)	Logging Unit/ Counting Time		Reason for Repeat	Evaluation
		Baseline	Repeat		
50-06-18	45-130	G2B/ 200 s	G2B/ 1,000 s	IAC ^d	<p>The highest apparent ¹³⁷Cs concentration value of 75,000 pCi/g was detected at the 45.5-ft depth by the HRLS. Repeat logging of this interval used a very long system count time in an attempt to identify processed uranium-235/238, plutonium-239/240, neptunium-237, and americium-241 that were detected in soil samples from this depth. If present, the low energy gamma rays of these isotopes were probably attenuated by the borehole's triple casing and fell below the MDL of the SGLS and were not detected. Comparison of decayed baseline and repeat data indicates that ⁶⁰Co and ^{152/154}Eu concentrations appear to have increased slightly from 45 to 50.5 ft, 55 to 62 ft, and at 66 ft. However, the concentration differences are within the estimated uncertainty measurements. In addition, the calculation of the repeat data's concentration values from 45 to 51 ft may have been affected by high system dead-time encountered through that interval. At 130 ft, the bottom of the repeat interval, low concentrations of ⁶⁰Co contamination were detected. The occurrence of ⁶⁰Co contamination at this depth is approximately 6 ft below the depth where baseline data previously measured the contaminant (124.5 ft). However, the detection of the ⁶⁰Co in this interval may be related to the longer system counting time, which reduced the MDL. ¹³⁷Cs concentration values derived from baseline and repeat data show good repeatability between 45 and 72 ft. H/D denote total gamma-ray data were not available for this borehole. Additional monitoring is recommended.</p>

^a CM - Contaminant movement.

^b SD - Spatially define contaminants.

^c CP - Confirm presence of contamination.

^d IAC - Identify additional contaminants.

^e H/D - Historical data from Randall et al. (2000).

Borehole 50-02-05

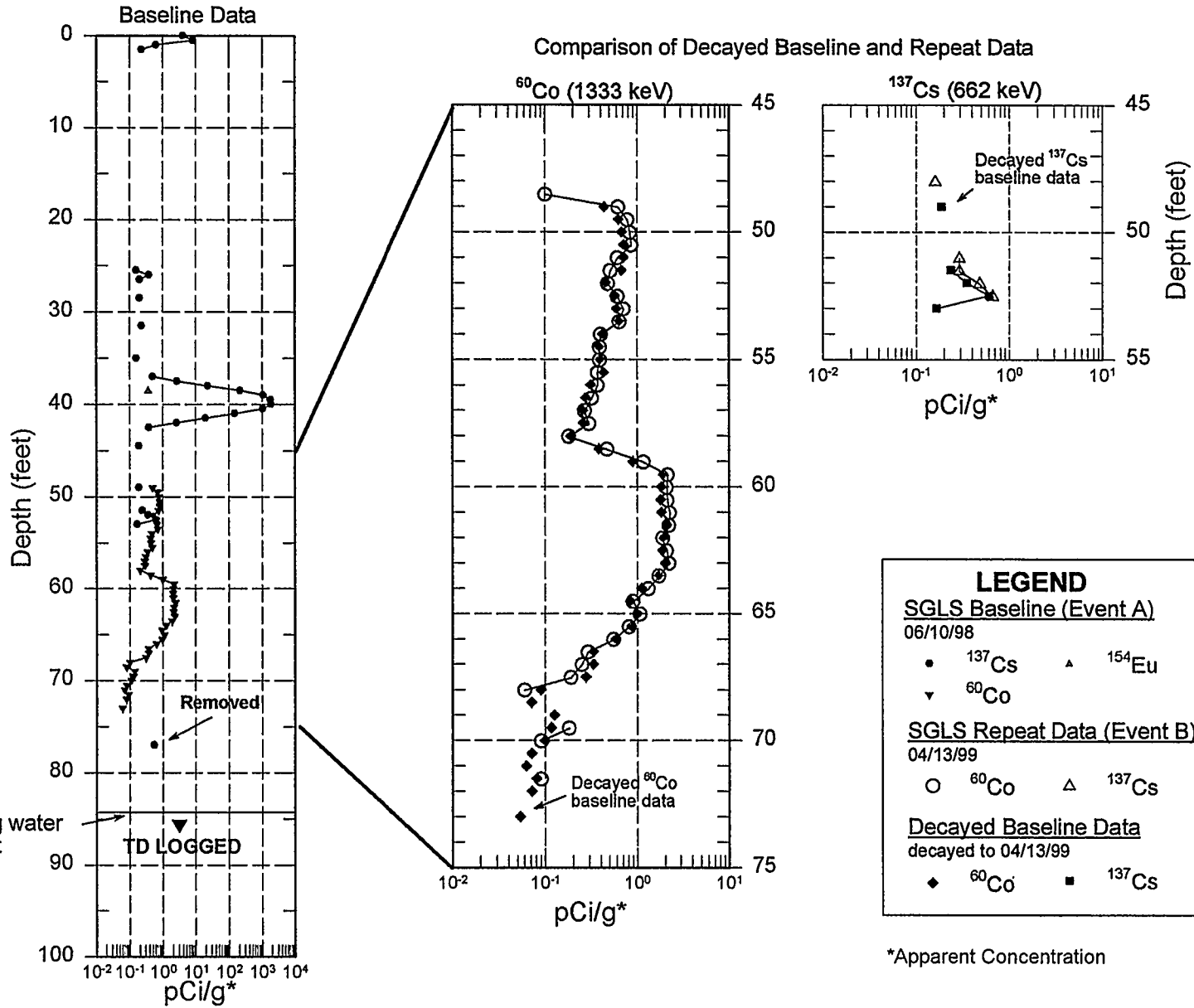


Figure B-1. Summary of Repeat Logging Results for the T Tank Farm

Borehole 50-05-07

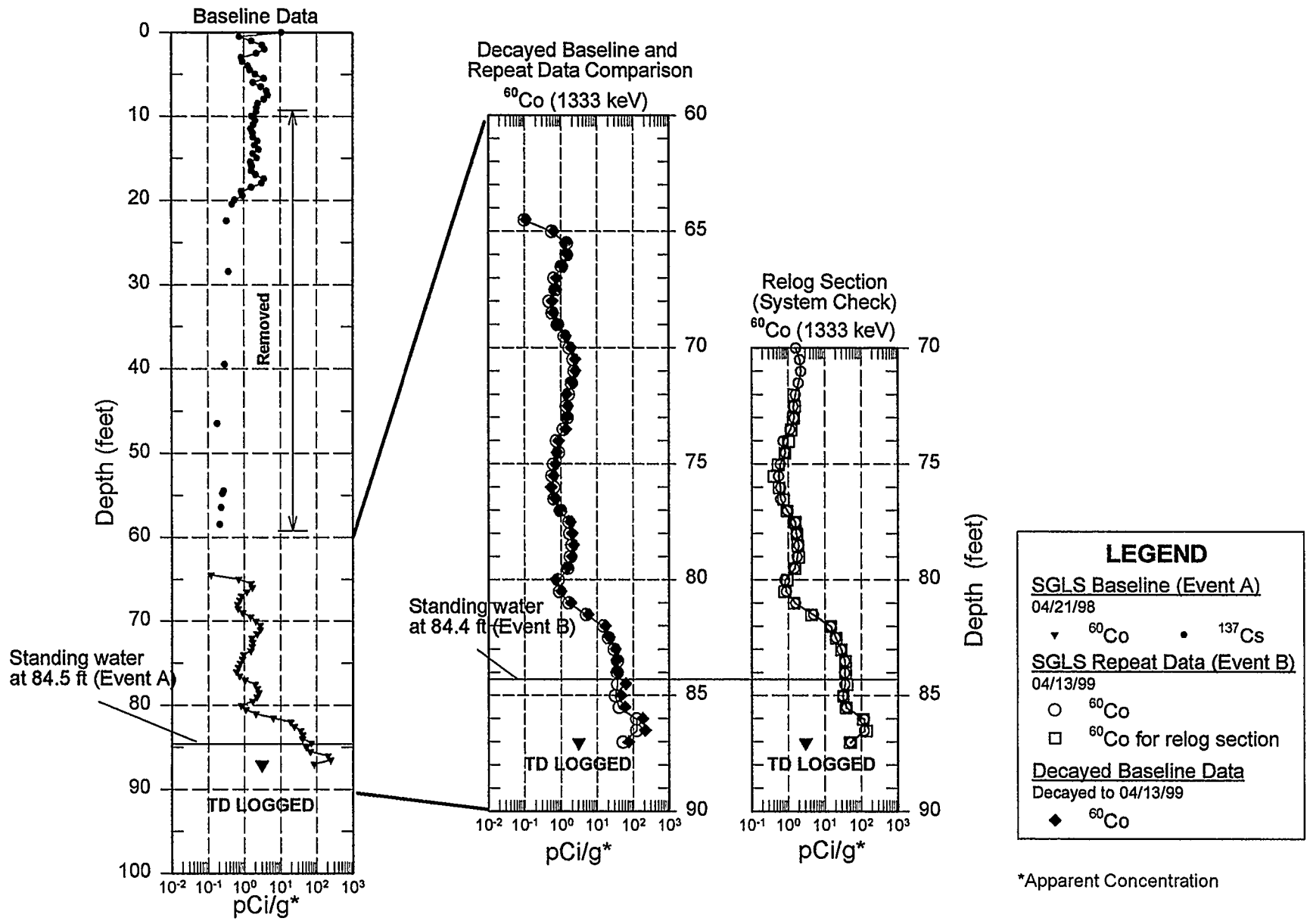


Figure B-2. Summary of Repeat Logging Results for the T Tank Farm

Borehole 50-07-07

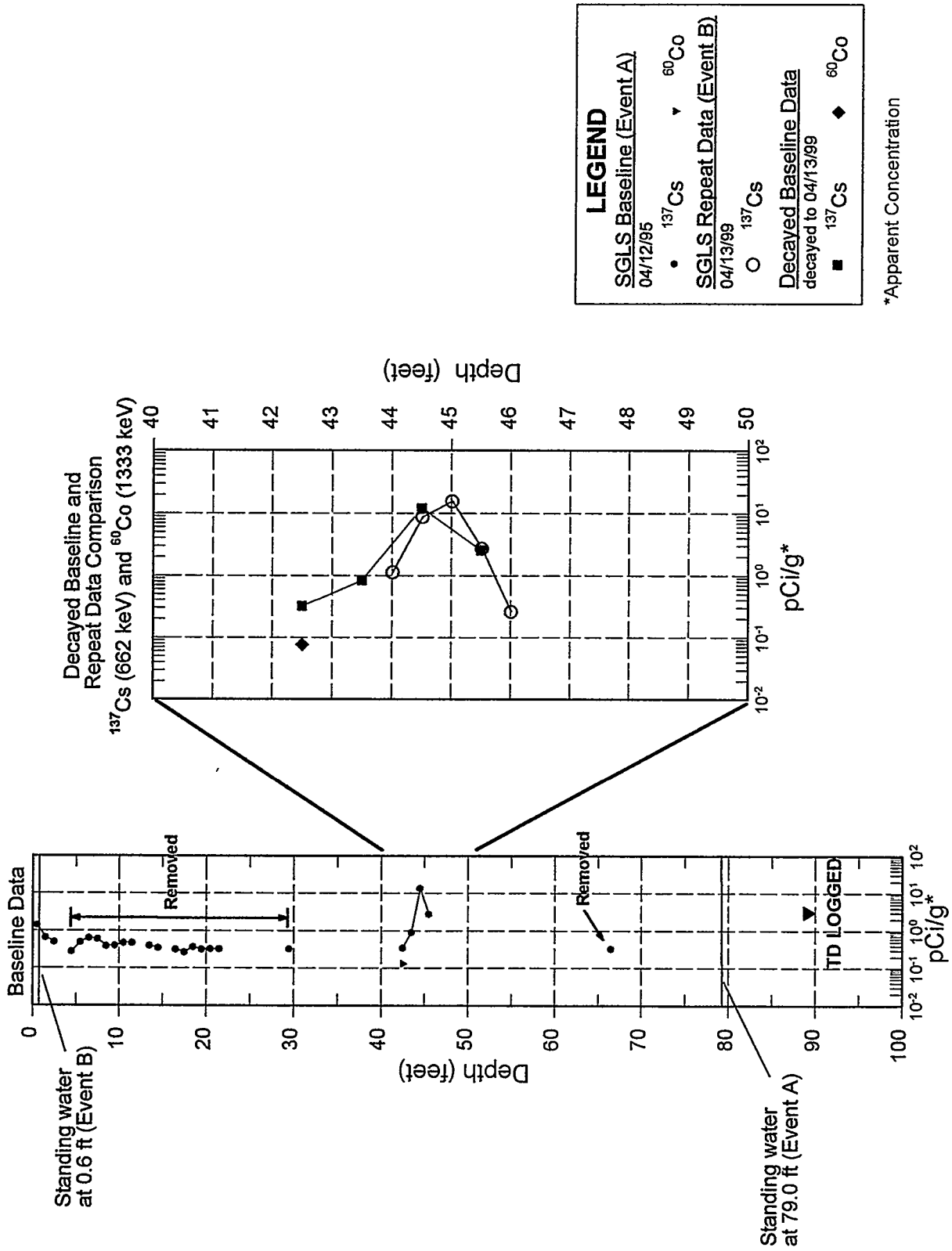
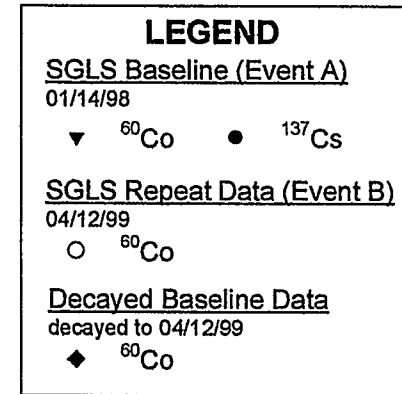
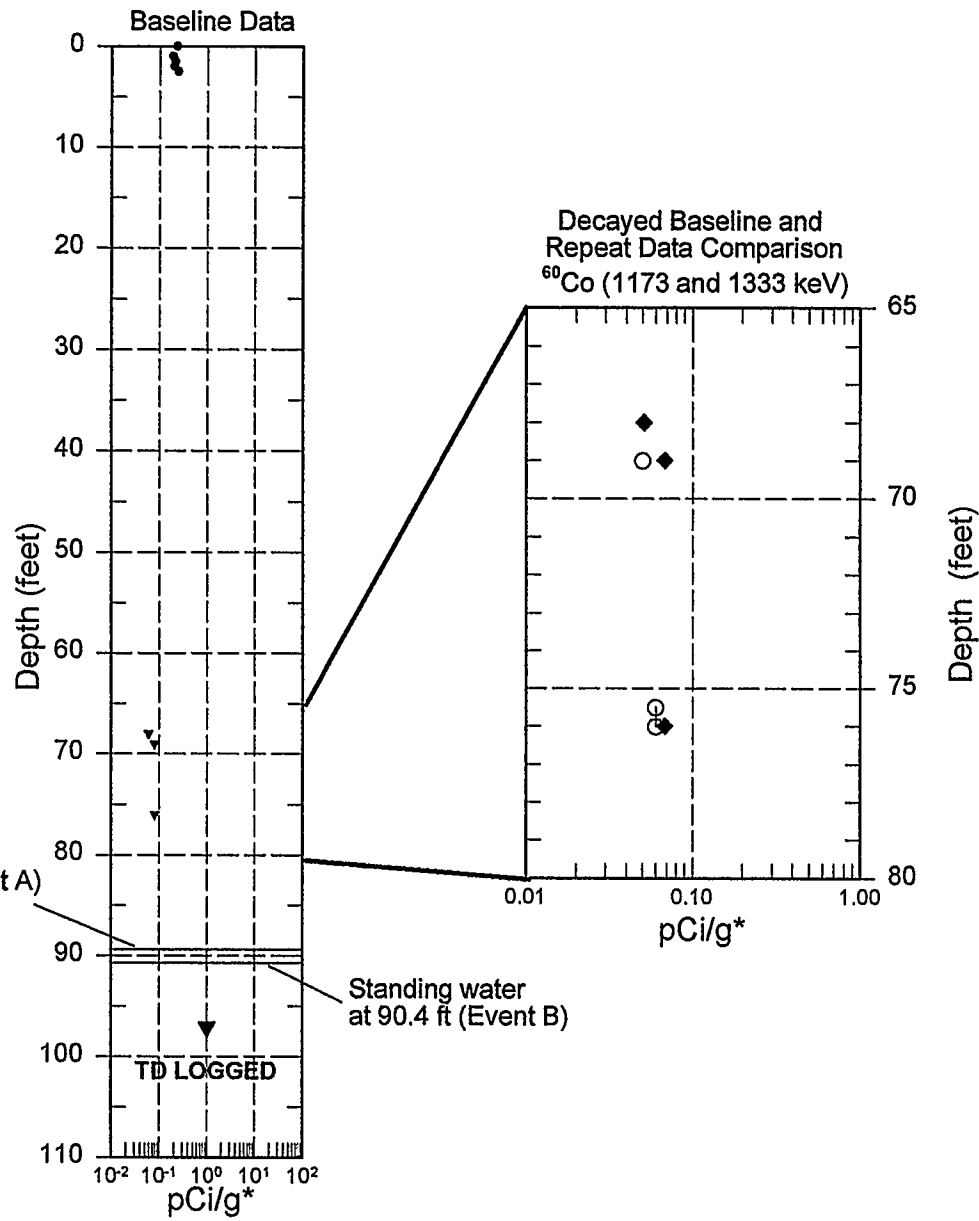


Figure B-3. Summary of Repeat Logging Results for the T Tank Farm

Borehole 50-11-10



*Apparent Concentration

Figure B-4. Summary of Repeat Logging Results for the T Tank Farm

Borehole 50-06-18

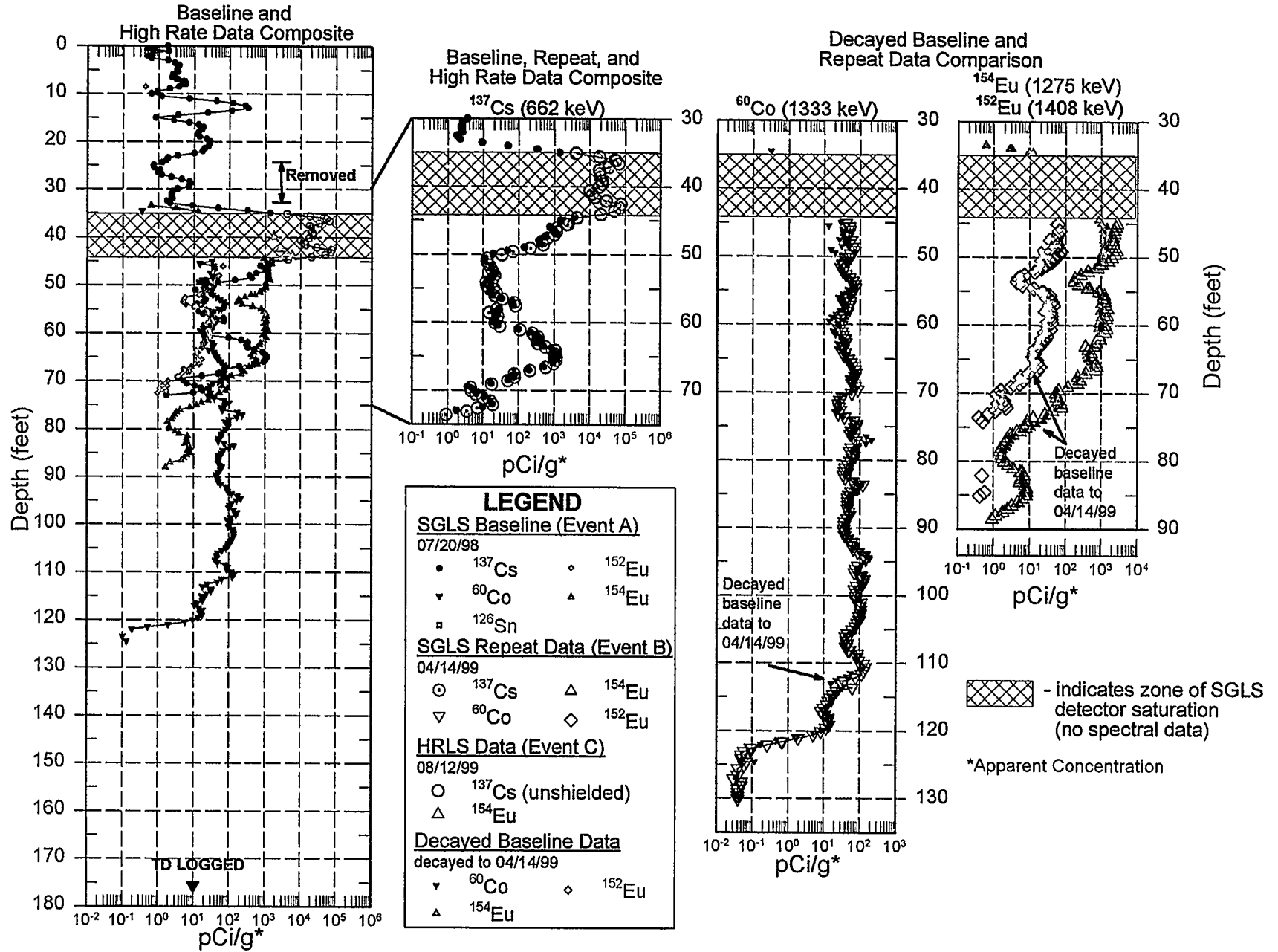


Figure B-5. Summary of Repeat Logging Results for the T Tank Farm

Appendix C
Summary of Interpreted Data Set
for the T Tank Farm

Table C-1. Summary of Interpreted Data Set for T-00 Boreholes

Borehole	Depth Interval (ft)	Source ^a	SFA ^e	Disposition/Comments
50-00-03	0-3	SS ^b	N/A ^f	¹³⁷ Cs included.
	38-99.5	BE ^c		Isolated ¹³⁷ Cs removed.
	128-139			Continuous ¹³⁷ Cs removed.
50-00-05	0-1.5	SS	N/A	¹³⁷ Cs included.
	15-137	BE		Isolated ¹³⁷ Cs removed.
	36.5-38.5	P ^d		⁶⁰ Co included.
50-00-06	0-2	SS	N/A	¹³⁷ Cs included.
	111-145	BE		Intermittent ¹³⁷ Cs removed.
50-00-08	0-0.5	SS	N/A	¹³⁷ Cs included.
	75	BE		Isolated ¹³⁷ Cs removed.
50-00-09	0	BE	N/A	Isolated ¹³⁷ Cs removed.
	47-95	P		Continuous ⁶⁰ Co, ¹⁵⁴ Eu, and ¹⁵² Eu contamination included.
	97-119.5			Mostly continuous ⁶⁰ Co and ¹⁵⁴ Eu contamination included.
50-00-10	0-17	BE	N/A	Continuous ¹³⁷ Cs removed.
	115.5-116			Isolated ¹³⁷ Cs removed.
50-00-12	0-140	BE	N/A	Intermittent ¹³⁷ Cs removed.

^a Source - Source of contamination in judgment of analyst

^b SS - Surface spill

^c BE - Borehole effects (e.g., dragdown, inside/outside casing contamination)

^d P - Probable contamination plume

^e SFA - Shape Factor Analysis

^f N/A - Not available, the borehole was finished with grout and multiple casings

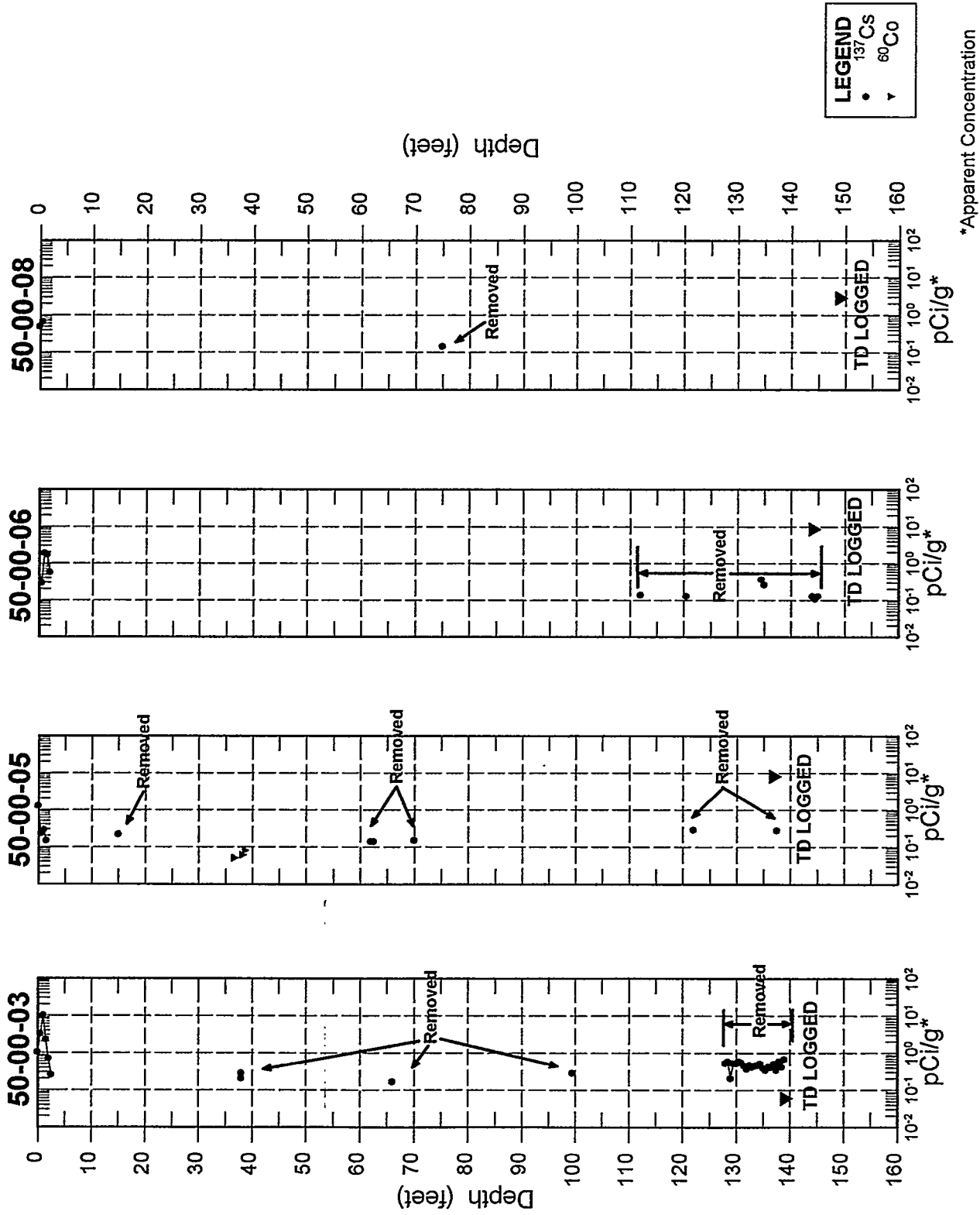


Figure C-1. Summary of Interpreted Data Set for T-00 Boreholes

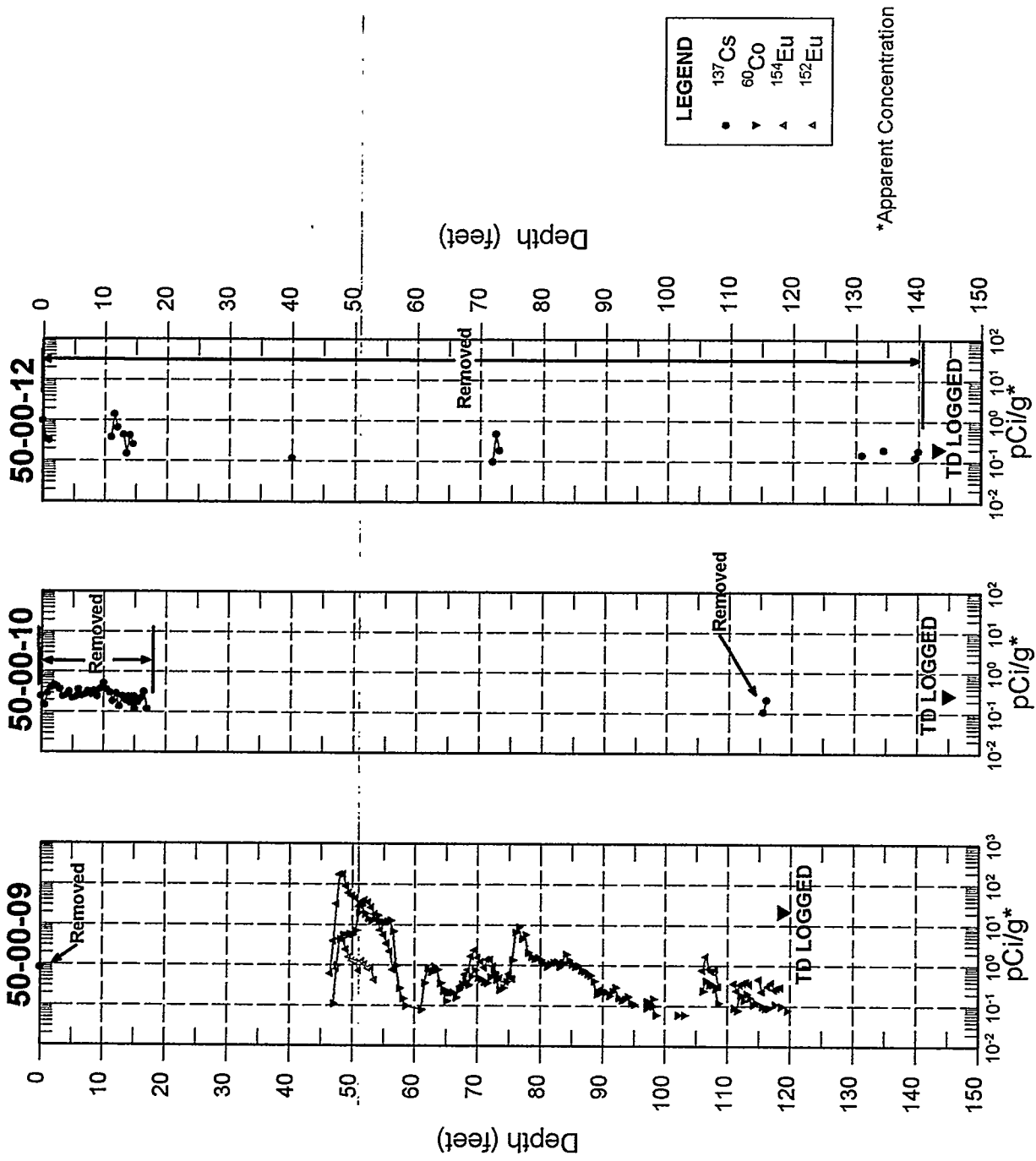


Figure C-1 (cont.). Summary of Interpreted Data Set for T-00 Boreholes

Table C-2. Summary of Interpreted Data Set for T-101 Boreholes

Borehole	Depth Interval (ft)	Source ^a	SFA ^e	Disposition/Comments
50-01-02	0-4	SS ^b	N/A ^f	Continuous ¹³⁷ Cs included.
	4.5-26	BE ^c		Intermittent ¹³⁷ Cs removed.
50-01-04	0-3.5	SS	N/A	¹³⁷ Cs included.
	4-19.5	BE		Continuous ¹³⁷ Cs removed.
	20-122.5	P ^d		HRLS data, continuous ¹³⁷ Cs included. ¹³⁷ Cs is present at the bottom of the logged interval, indicating that the bottom of the contamination plume has not been identified.
50-01-06	0-2.5	SS	N/A	¹³⁷ Cs included.
	3-36	BE		Mostly continuous ¹³⁷ Cs removed.
	49.5-87.5	P		Continuous ⁶⁰ Co, ¹⁵⁴ Eu, and isolated ¹⁵² Eu included. ⁶⁰ Co is present at the bottom of the logged interval, indicating that the bottom of the contamination plume has not been identified.
50-01-09	0-8.5	SS	N/A	¹³⁷ Cs included.
	12.5-17	BE		Continuous ¹³⁷ Cs removed.
	17.5-24	P		Continuous ¹³⁷ Cs and ¹⁵⁴ Eu included.
	24.5-34	BE		Intermittent ¹³⁷ Cs and ⁶⁰ Co removed.
	35-48.5	P		Continuous ⁶⁰ Co included.
	68.5-86			Mostly continuous ⁶⁰ Co included.
50-01-12	0-6	BE	N/A	Isolated ¹³⁷ Cs removed.
	35.5-38	P		Continuous ⁶⁰ Co and isolated ¹⁵⁴ Eu included.

^a Source of contamination in judgment of analyst

^b SS - Surface spill

^c BE - Borehole effects (e.g., dragdown, inside/outside casing contamination)

^d P - Probable contamination plume

^e SFA - Shape Factor Analysis

^f N/A - Not available, the borehole is finished with grout and multiple casings

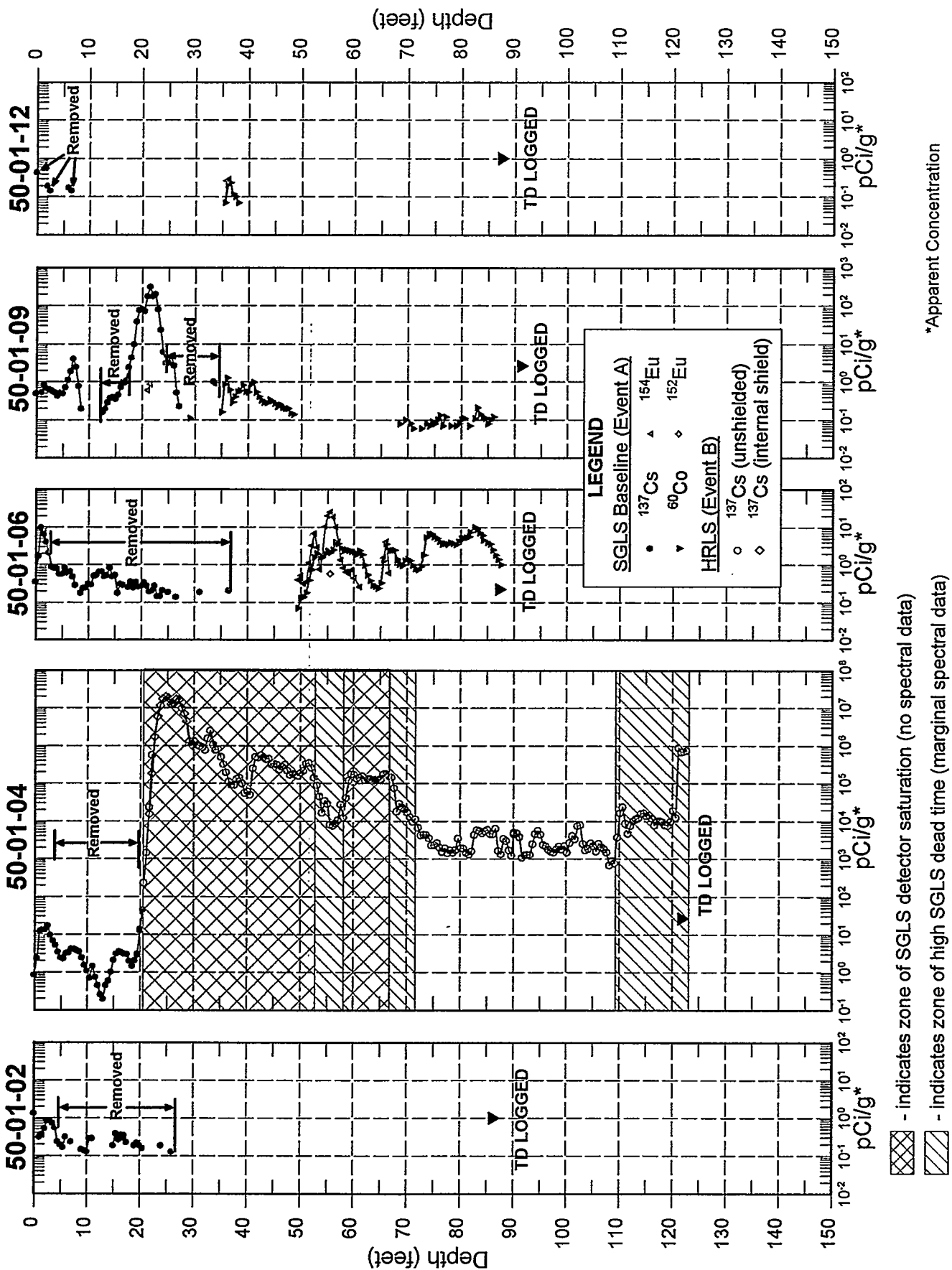


Figure C-2. Summary of Interpreted Data Set for T-101 Boreholes

Table C-3. Summary of Interpreted Data Set for T-102 Boreholes

Borehole	Depth Interval (ft)	Source ^a	SFA ^e	Disposition/Comments
50-02-02	0 and 85	BE ^c	N/A ^f	Isolated ¹³⁷ Cs removed.
50-02-05	0-1.5	SS ^b	N/A	¹³⁷ Cs included.
	25.5-35	P ^d		Intermittent ¹³⁷ Cs included.
	37-42.5			Continuous ¹³⁷ Cs and isolated ¹⁵⁴ Eu included.
	44.5-53			Intermittent ¹³⁷ Cs included.
	49-73			Continuous ⁶⁰ Co included.
	77	BE		Isolated ¹³⁷ Cs removed.
50-02-08	0-2	BE	N/A	¹³⁷ Cs removed.
	39.5-49	P		Continuous ⁶⁰ Co, ¹⁵⁴ Eu, ¹⁵² Eu, ⁹⁴ Nb, and isolated ²³⁸ U included.
	53-53.5, 67-70.5, and 83.5			Intermittent ⁶⁰ Co and ¹⁵⁴ Eu included.
50-02-09	0-5.5	SS	N/A	¹³⁷ Cs included.
	6-35.5	BE		Mostly continuous and intermittent ¹³⁷ Cs removed.
	39.5-45.5	P		Continuous ⁶⁰ Co and ¹⁵⁴ Eu included.
	50.5-51, 60-62, and 79.5-87.5	BE		Intermittent ¹³⁷ Cs removed.
50-02-10	0-26.5	BE	N/A	Intermittent ¹³⁷ Cs removed.
50-02-12	0-0.5	BE	N/A	Isolated ¹³⁷ Cs removed.

^a Source - Source of contamination in judgment of analyst

^b SS - Surface spill

^c BE - Borehole effects (e.g., dragdown, inside/outside casing contamination)

^d P - Probable contamination plume

^e SFA - Shape Factor Analysis

^f N/A - Not available, the borehole was finished with grout and multiple casings

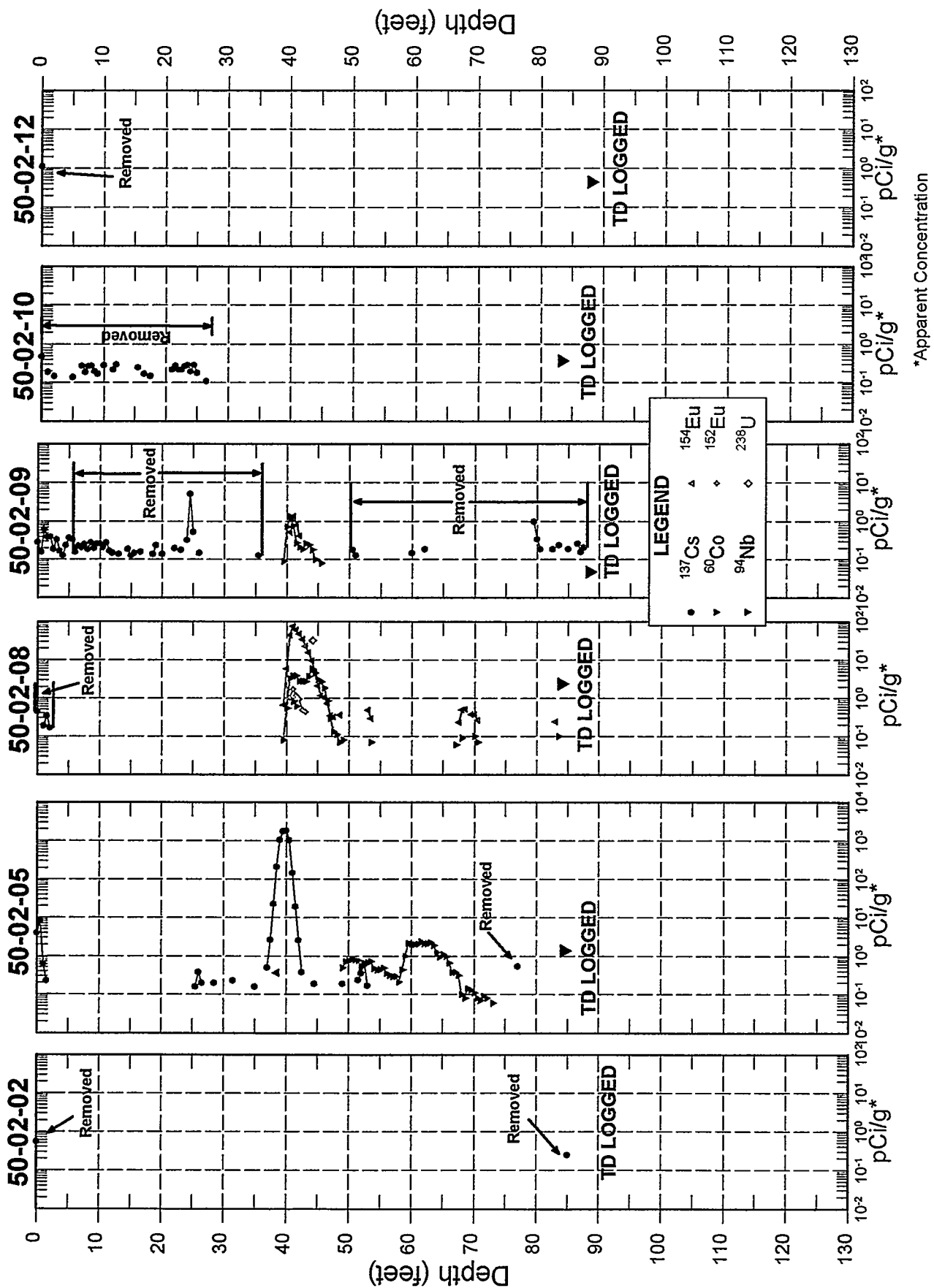


Figure C-3. Summary of Interpreted Data Set for T-102 Boreholes

Table C-4. Summary of Interpreted Data Set for T-103 Boreholes

Borehole	Depth Interval (ft)	Source ^a	SFA ^e	Disposition/Comments
50-03-01	0	BE ^c	N/A ^f	Isolated ¹³⁷ Cs removed.
50-03-04	1-4.5	SS ^b	N/A	Intermittent ¹³⁷ Cs included.
	5-7 and 17	BE		¹³⁷ Cs removed.
	20-49.5	P ^d		Continuous ¹³⁷ Cs, ⁶⁰ Co, ^{152/154} Eu, ⁹⁴ Nb, ¹²⁶ Sn, and isolated ²³⁸ U and ¹²⁵ Sb contamination included.
	53.5-91.5, and 96			Mostly continuous and intermittent ⁶⁰ Co and ¹⁵⁴ Eu included.
	102			Isolated ¹⁵² Eu included.
50-03-05	0-3	SS	N/A	¹³⁷ Cs included.
	3.5-6 and 29	BE		¹³⁷ Cs removed.
	41.5-63.5	P		Continuous ⁶⁰ Co, ¹⁵⁴ Eu, and intermittent ¹⁵² Eu included.
	68-71, 76.5-81			Intermittent ⁶⁰ Co and ¹⁵⁴ Eu included.
	84, 107.5, and 112.5			Isolated ⁶⁰ Co and ¹⁵⁴ Eu included.
50-03-06	0-0.5	SS	N/A	¹³⁷ Cs included.
	1-12.5 and 98	BE		¹³⁷ Cs removed.
	66-95	P		Continuous ⁶⁰ Co contamination included.
	66-81			Intermittent ¹⁵⁴ Eu included.
	109.5-110			Isolated ⁶⁰ Co included.
50-03-08	0-2	BE	N/A	¹³⁷ Cs removed.
50-03-10	0	BE	N/A	Isolated ¹³⁷ Cs removed.

^a Source of contamination in judgment of analyst

^b SS - Surface spill

^c BE - Borehole effects (e.g., dragdown, inside/outside casing contamination)

^d P - Probable contamination plume

^e SFA - Shape Factor Analysis

^f N/A - Not available, the borehole is finished with grout and multiple casings

Table C-5. Summary of Interpreted Data Set for T-104 Boreholes

Borehole	Depth Interval (ft)	Source ^a	SFA ^c	Disposition/Comments
50-04-03	0-9	SS ^b	N/A ^f	Continuous ¹³⁷ Cs included.
	9.5-22.5	BE ^c		¹³⁷ Cs removed.
	23-27	SS		Continuous ¹³⁷ Cs included.
	27.5-78.5	BE		Isolated and intermittent ¹³⁷ Cs removed.
50-04-05	0-20.5	SS	N/A	Continuous ¹³⁷ Cs included.
	21.5-84.5	BE		Isolated and intermittent ¹³⁷ Cs removed.
50-04-07	0-16	SS	N/A	Continuous ¹³⁷ Cs included.
	16.5-21.5	BE		¹³⁷ Cs removed.
	22-26	SS		¹³⁷ Cs included.
	27-92	BE		Isolated and intermittent ¹³⁷ Cs removed.
50-04-08	0-6.5	SS	N/A	Continuous ¹³⁷ Cs included.
	7-22.5 and 87	BE		Intermittent and isolated ¹³⁷ Cs removed.
	67.5-81	P ^d		Continuous ⁶⁰ Co included.
	92.5-95.5			Intermittent ⁶⁰ Co included.
50-04-10	0-2	SS	N/A	¹³⁷ Cs included.
	2.5-20.5, 57.5, and 78	BE		Intermittent and isolated ¹³⁷ Cs removed.
	67-87.5	P		Continuous ⁶⁰ Co included. ⁶⁰ Co contamination is present at the bottom of the logged interval, indicating that the bottom of the contamination plume has not been identified.

^a Source - Source of contamination in judgment of analyst

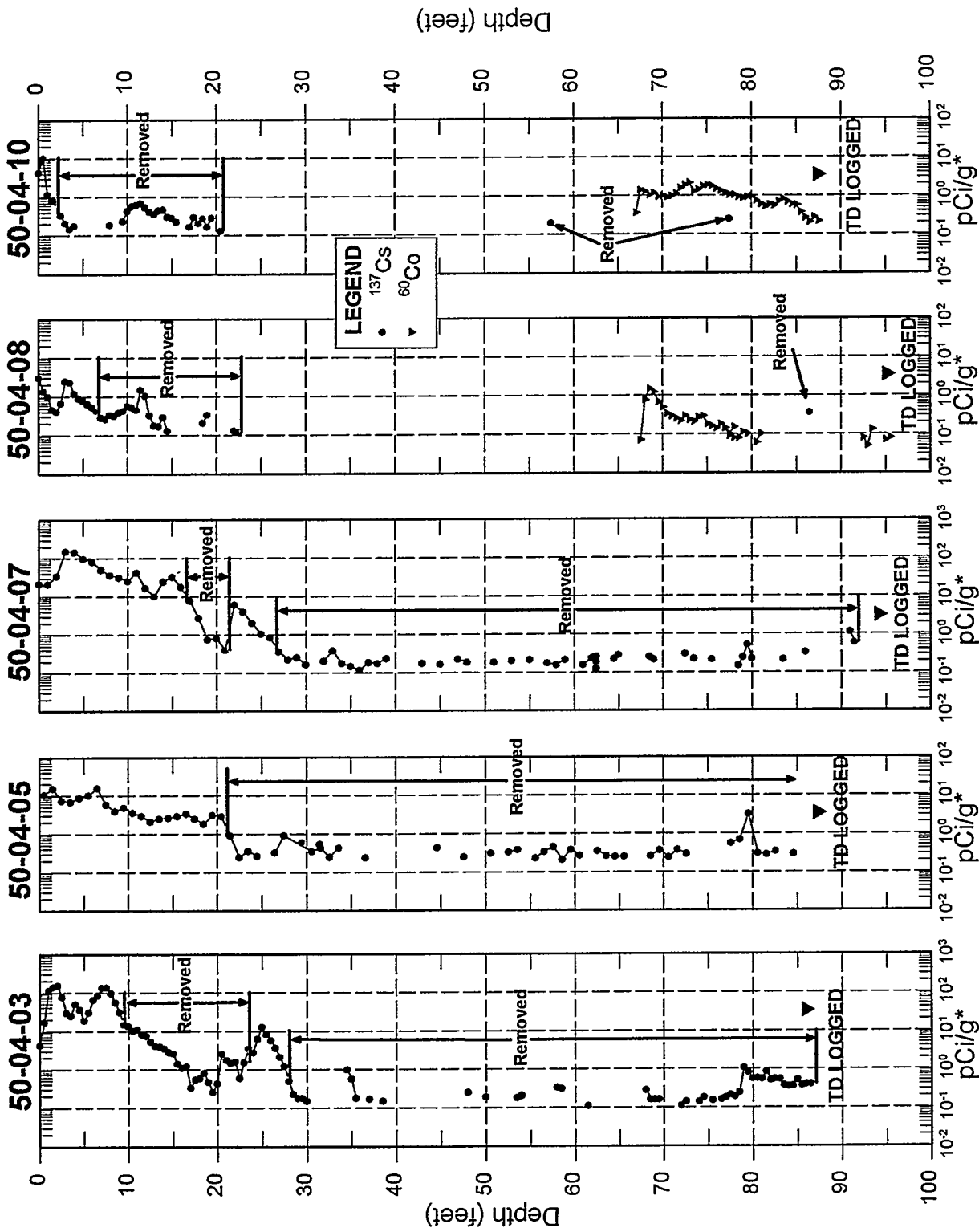
^b SS - Surface spill

^c BE - Borehole effects (e.g., dragdown, inside/outside casing contamination)

^d P - Probable contamination plume

^e SFA - Shape Factor Analysis

^f N/A - Not available, the borehole is finished with grout and multiple casings



*Apparent Concentration

Figure C-5. Summary of Interpreted Data Set for T-104 Boreholes

Table C-6. Summary of Interpreted Data Set for T-105 Boreholes

Borehole	Depth Interval (ft)	Source ^a	SFA ^e	Disposition/Comments
50-05-06	0-12.5	SS ^b	N/A ^f	Continuous ¹³⁷ Cs included.
	13-37.5 and 116	BE ^c		Intermittent and isolated ¹³⁷ Cs removed.
	66-76	P ^d		Continuous ⁶⁰ Co included.
	81 and 83.5			Isolated ⁶⁰ Co included.
50-05-07	0-9.5	SS	N/A	Continuous ¹³⁷ Cs included.
	10-58	BE		Continuous and isolated ¹³⁷ Cs removed.
	64.5-87	P		Continuous ⁶⁰ Co included. ⁶⁰ Co is present at the bottom of the logged interval, indicating that the bottom of the contamination plume has not been determined.
50-05-11	0-3.5	BE	N/A	¹³⁷ Cs removed.
	57.5-58 and 64	P		Isolated ⁶⁰ Co included.
	86.5-96 and 98.5-102.5			Continuous ⁶⁰ Co included.

^a Source - Source of contamination in judgment of analyst

^b SS - Surface spill

^c BE - Borehole effects (e.g., dragdown, inside/outside casing contamination)

^d P - Probable contamination plume

^e SFA - Shape Factor Analysis

^f N/A - Not available, the borehole is finished with grout and multiple casings

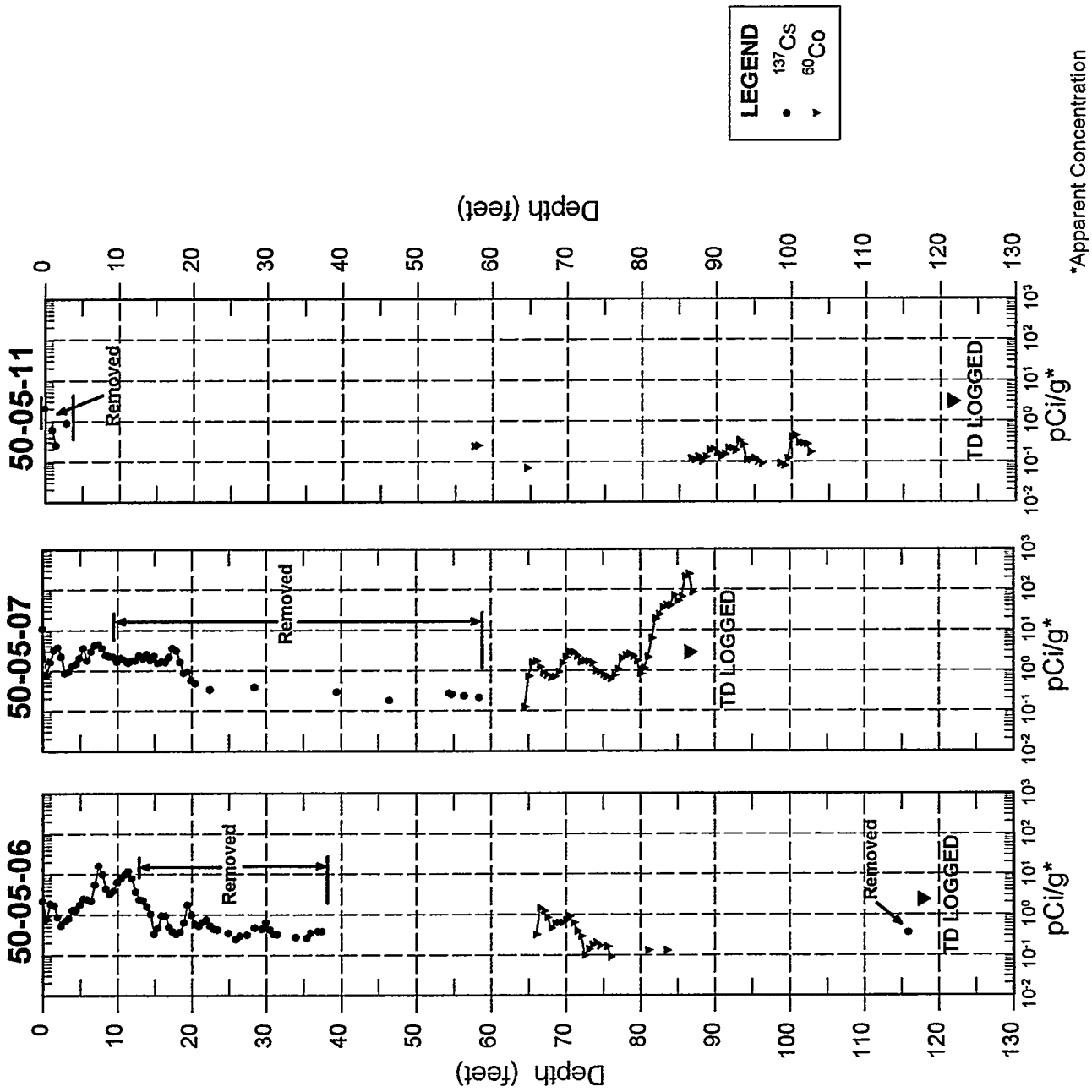


Figure C-6. Summary of Interpreted Data Set for T-105 Boreholes

Table C-7. Summary of Interpreted Data Set for T-106 Boreholes

Borehole	Depth Interval (ft)	Source ^a	SFA ^e	Disposition/Comments
50-06-02	0-5	SS ^b	N/A ^j	¹³⁷ Cs contamination included.
	5.5-29.5	BE ^c		¹³⁷ Cs removed.
	45-123	P ^d		⁶⁰ Co, ^{152/154} Eu, ²³⁸ U, and ²³⁵ U included. ⁶⁰ Co and ¹⁵⁴ Eu contamination are present at the bottom of the logged interval, indicating that the bottom of the contaminant plume has not been determined.
	118-123	BE		¹³⁷ Cs removed.
50-06-03	0-2.5	SS	N/A	¹³⁷ Cs included.
	3-16 and 27.5	BE		¹³⁷ Cs removed.
	19.5-21.5	P		¹³⁷ Cs and ¹⁵⁴ Eu included.
	33.5-119			¹³⁷ Cs, ⁶⁰ Co, ^{152/154} Eu, and ¹²⁶ Sn contamination included. ⁶⁰ Co and ¹⁵⁴ Eu contamination are present at the bottom of the logged interval.
50-06-04	0-1.5	SS	D ^f	¹³⁷ Cs contamination included.
	2-11.5, 15-18.5, and 23.5-32	BE	Local ^g	¹³⁷ Cs removed.
	12-14.5	SS	D	¹³⁷ Cs contamination included.
	19-23		R ^h	¹³⁷ Cs contamination included.
	32.5-40	P	Ina. ⁱ	HRLS data, ¹³⁷ Cs contamination included. ⁶⁰ Co and ^{152/154} Eu contamination are probably present in the interval but were not detected by the HRLS.
	40.5-92			¹³⁷ Cs, ⁶⁰ Co, ^{152/154} Eu, and ¹²⁶ Sn contamination included. ⁶⁰ Co and ^{152/154} Eu contamination are present at the bottom of the logged interval.

^a Source - Source of contamination in judgment of analyst

^b SS - Surface spill

^c BE - Borehole Effects (e.g., dragdown, inside/outside casing contamination)

^d P - Probable contamination plume

^e SFA - Shape Factor Analysis

^f D - Contamination distributed in formation

^g Local - SFA indicated contamination is confined to the vicinity of the borehole casing

^h R - Contamination is remote from borehole

ⁱ Ina. - Inapplicable to apply shape factor method to this radionuclide

^j N/A - Not available, the borehole is finished with grout and multiple casings

Table C-7 (con't.). Summary of Interpreted Data Set for T-106 Boreholes

Borehole	Depth Interval (ft)	Source ^a	SFA ^e	Disposition/Comments
50-06-16	0-5	SS	N/A	¹³⁷ Cs included.
	5.5-13.5, 19-32.5 and 86	BE		¹³⁷ Cs removed.
	14-18.5	SS		¹³⁷ Cs included.
	33-34.5	P		¹³⁷ Cs, ⁶⁰ Co, and ¹⁵⁴ Eu included.
	35-40.5			HRLS data, continuous ¹³⁷ Cs included. ⁶⁰ Co and ¹⁵² Eu contamination are probably present in the interval but were not detected by the HRLS.
	37-39.5			Continuous ¹⁵⁴ Eu included.
	41-86			Mostly continuous ¹³⁷ Cs, ⁶⁰ Co, and ^{152/154} Eu included. ⁶⁰ Co and ¹⁵⁴ Eu contamination are present at the bottom of the logged interval.
50-06-18	0-23	SS	N/A	¹³⁷ Cs and ¹⁵⁴ Eu included.
	23.5-33	BE		¹³⁷ Cs removed.
	33.5-35	P		¹³⁷ Cs, ⁶⁰ Co, and ¹⁵⁴ Eu included.
	35.5-44.5			HRLS data, continuous ¹³⁷ Cs, and intermittent ¹⁵⁴ Eu included. ⁶⁰ Co and ¹⁵² Eu contamination are probably present in the interval but were not detected by the HRLS.
	45-125			Continuous ¹³⁷ Cs, ⁶⁰ Co, ^{152/154} Eu, and isolated ¹²⁶ Sn included.
	64-65			HRLS data, continuous ¹³⁷ Cs included.

^a Source - Source of contamination in judgment of analyst

^b SS - Surface spill

^c BE - Borehole Effects (e.g., dragdown, inside/outside casing contamination)

^d P - Probable contamination plume

^e SFA - Shape Factor Analysis

^f D - Contamination distributed in formation

^g Local - SFA indicated contamination is confined to the vicinity of the borehole casing

^h R - Contamination is remote from borehole

ⁱ Ina. - Inapplicable to apply shape factor method to this radionuclide

^j N/A - Not available, the borehole is finished with grout and multiple casings

Table C-7 (con't.). Summary of Interpreted Data Set for T-106 Boreholes

Borehole	Depth Interval (ft)	Source ^a	SFA ^e	Disposition/Comments
50-06-17	0-18.5	SS	N/A	¹³⁷ Cs and ¹⁵⁴ Eu contamination included.
	19-32	BE		¹³⁷ Cs removed.
	32.5-35	P		¹³⁷ Cs and ¹⁵⁴ Eu contamination included.
	35.5-86			HRLS data, continuous ¹³⁷ Cs included. ¹⁵⁴ Eu and other contaminants are probably present in the interval but were not detected by the HRLS. ¹³⁷ Cs contamination is present at the bottom of the logged interval.
50-06-06	0-5	SS	N/A	¹³⁷ Cs included.
	5.5-32, 91, and 114.5	BE		Mostly continuous and isolated ¹³⁷ Cs removed.
	32.5-34.5	P		⁶⁰ Co and ^{152/154} Eu included.
	35-46			HRLS data, ¹³⁷ Cs included. ⁶⁰ Co and ^{152/154} Eu contamination are probably present in the interval but were not detected by the HRLS.
	46-120			¹³⁷ Cs, ⁶⁰ Co, ^{152/154} Eu, ¹²⁶ Sn, and ¹²⁵ Sb included. ⁶⁰ Co and ^{152/154} Eu contamination are present at the bottom of the logged interval, indicating that the bottom of the contamination plume has not been determined.

^a Source - Source of contamination in judgment of analyst

^b SS - Surface spill

^c BE - Borehole Effects (e.g., dragdown, inside/outside casing contamination)

^d P - Probable contamination plume

^e SFA - Shape Factor Analysis

^f D - Contamination distributed in formation

^g Local - SFA indicated contamination is confined to the vicinity of the borehole casing

^h R - Contamination is remote from borehole

ⁱ Ina. - Inapplicable to apply shape factor method to this radionuclide

^j N/A - Not available, the borehole is finished with grout and multiple casings

Table C-7 (con't.). Summary of Interpreted Data Set for T-106 Boreholes

Borehole	Depth Interval (ft)	Source ^a	SFA ^e	Disposition/Comments
50-06-08	0-3.5	SS	N/A	¹³⁷ Cs included.
	4-22.5 and 31.5-32	BE		¹³⁷ Cs removed.
	33.5-34.5	P		¹³⁷ Cs and ¹⁵⁴ Eu included.
	35-40.5			HRLS data, ¹³⁷ Cs included. ⁶⁰ Co and ^{152/154} Eu contamination are probably present in the interval but were not detected by the HRLS.
	41-81			¹³⁷ Cs, ⁶⁰ Co, and ^{152/154} Eu included.
	55-60			HRLS data, ¹³⁷ Cs included.
	81.5-120.5	BE		¹³⁷ Cs removed.
	81.5-120.5	P		⁶⁰ Co and ^{152/154} Eu included. ⁶⁰ Co and ¹⁵⁴ Eu contamination are present at the bottom of the logged interval.
50-06-05	0-8	SS	N/A	¹³⁷ Cs included.
	8.5-19 and 24.5-32.5	BE		¹³⁷ Cs removed.
	19.5-24	P		¹³⁷ Cs included.
	33-119	P		HRLS data, continuous ¹³⁷ Cs included. ⁶⁰ Co and other contaminants are probably present in the interval but were not detected by the HRLS. ¹³⁷ Cs contamination is present at the bottom of the logged interval.
	93.5-97			⁶⁰ Co included.
50-06-11	0-10.5	BE	N/A	Isolated ¹³⁷ Cs removed.
	36.5-41 and 76.5-82.5	P		Intermittent ⁶⁰ Co included. ⁶⁰ Co contamination is present at the bottom of the logged interval.

^a Source - Source of contamination in judgment of analyst

^b SS - Surface spill

^c BE - Borehole Effects (e.g., dragdown, inside/outside casing contamination)

^d P - Probable contamination plume

^e SFA - Shape Factor Analysis

^f D - Contamination distributed in formation

^g Local - SFA indicated contamination is confined to the vicinity of the borehole casing

^h R - Contamination is remote from borehole

ⁱ Ina. - Inapplicable to apply shape factor method to this radionuclide

^j N/A - Not available, the borehole is finished with grout and multiple casings

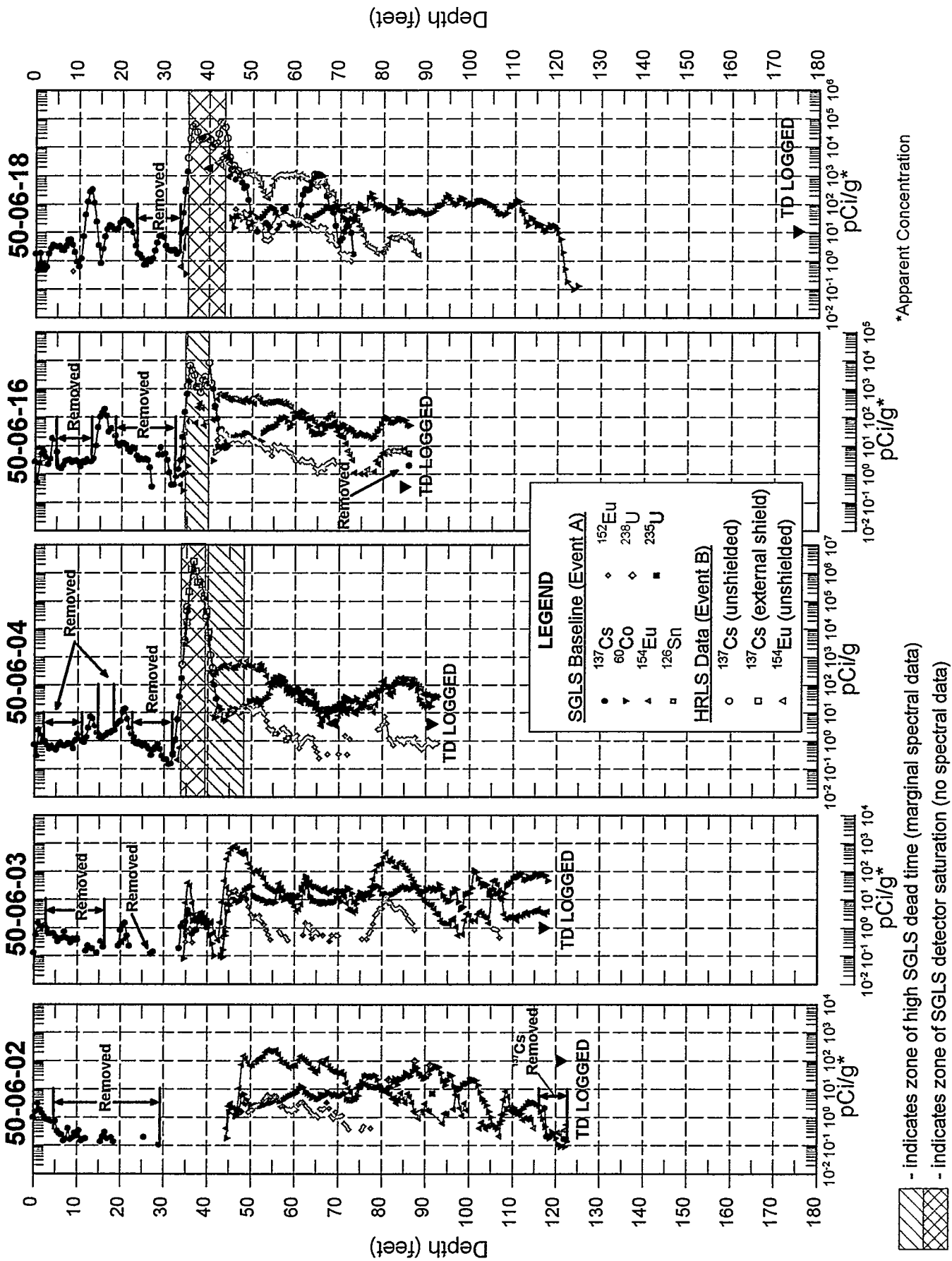


Figure C-7. Summary of Interpreted Data Set for T-106 Boreholes

Table C-8. Summary of Interpreted Data Set for T-107 Boreholes

Borehole	Depth Interval (ft)	Source ^a	SFA ^e	Disposition/Comments
50-07-03	0-1	SS ^b	N/A ^f	¹³⁷ Cs included.
	1.5-4.5	BE ^c		¹³⁷ Cs removed.
	5-15	SS		Continuous ¹³⁷ Cs included.
	15.5-81.5	BE		Isolated and intermittent ¹³⁷ Cs removed.
	42-45.5	P ^d		⁶⁰ Co included.
50-07-07	0.5-2.5	SS	N/A	¹³⁷ Cs included.
	4.5-29.5 and 67	BE		Isolated and intermittent ¹³⁷ Cs removed.
	42.5-45.5	P		Continuous ¹³⁷ Cs and isolated ⁶⁰ Co included.
50-07-08	0-7.5	SS	N/A	¹³⁷ Cs included.
	8.5-83.5	BE		Intermittent and isolated ¹³⁷ Cs removed.

^a Source - Source of contamination in judgment of analyst

^b SS - Surface spill

^c BE - Borehole effects (e.g., dragdown, inside/outside casing contamination)

^d P - Probable contamination plume

^e SFA - Shape Factor Analysis

^f N/A - Not available, the borehole is finished with grout and multiple casings

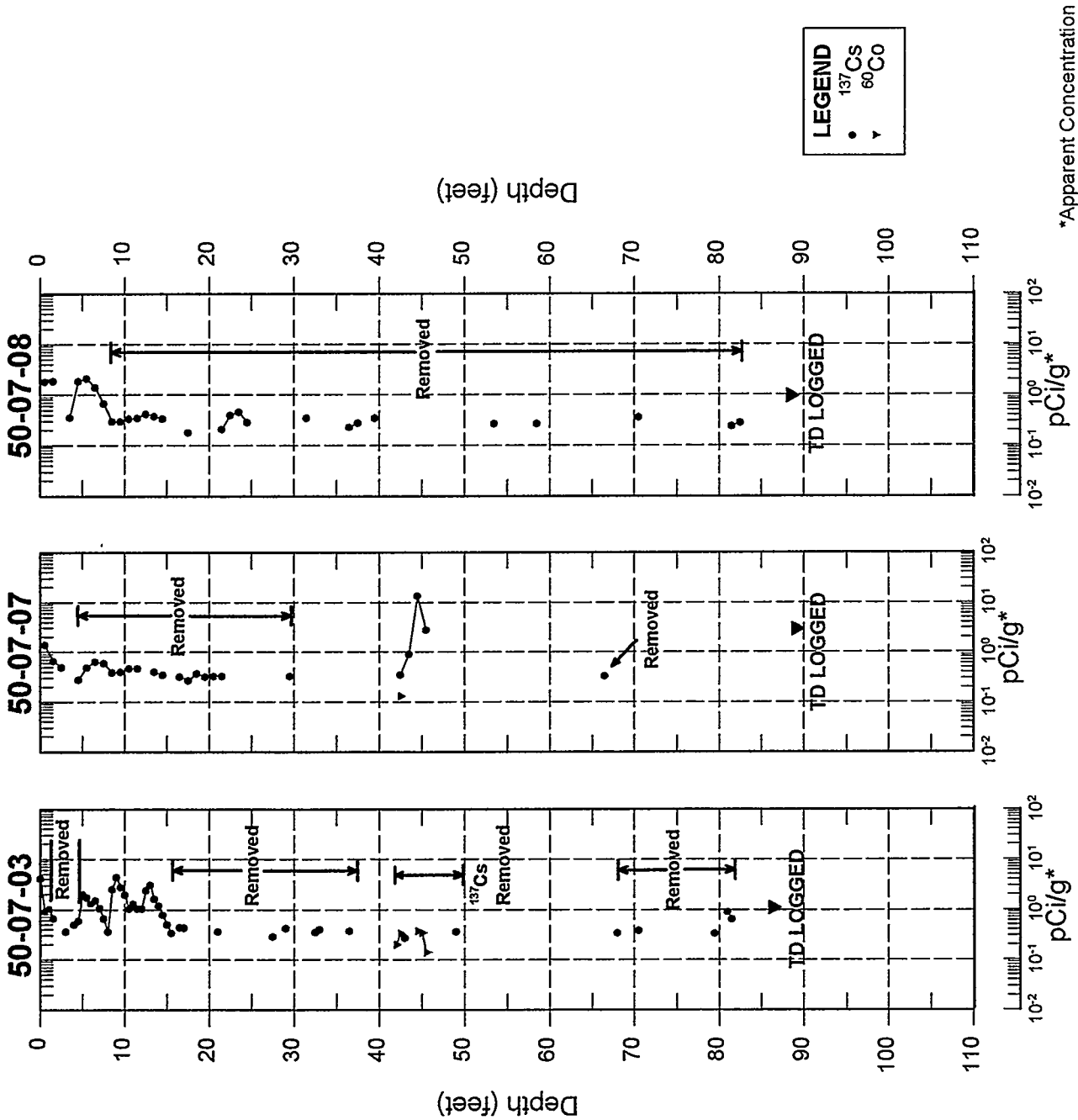


Figure C-8. Summary of Interpreted Data Set for T-107 Boreholes

Table C-9. Summary of Interpreted Data Set for T-108 Boreholes

Borehole	Depth Interval (ft)	Source ^a	SFA ^c	Disposition/Comments
50-08-05	0-2.5	SS ^b	N/A ^f	¹³⁷ Cs included.
	11-18 and 79	BE ^c		Isolated and intermittent ¹³⁷ Cs removed.
50-08-07	0-3	SS	N/A	¹³⁷ Cs included.
	69-95.5 and 103.5-110.5	P ^d		Continuous and intermittent ⁶⁰ Co included.
	101-119	BE		¹³⁷ Cs removed.
50-08-19	0-3	SS	N/A	¹³⁷ Cs included.
	8-11.5	BE		Isolated ¹³⁷ Cs removed.
	68-86	P		Continuous ⁶⁰ Co included. ⁶⁰ Co contamination is present at the bottom of the logged interval, indicating that the bottom of the contaminant plume has not been determined.
50-08-08	0-1	SS	N/A	¹³⁷ Cs included.
	3.5-7	BE		¹³⁷ Cs removed.
	67-88.5	P		Mostly continuous ⁶⁰ Co contamination included.
50-08-09	0-4.5	SS	N/A	¹³⁷ Cs included.
	7-9.5	BE		¹³⁷ Cs removed.
	64.5-87	P		Continuous ⁶⁰ Co included.
50-08-11	0-10.5	SS	N/A	Continuous ¹³⁷ Cs included.
	11-64	BE		¹³⁷ Cs removed.
	54.5-60	P		Intermittent ⁶⁰ Co included.
	63-88			Continuous ⁶⁰ Co, and ^{152/154} Eu included.
	85.5-97.5			Intermittent ¹³⁷ Cs included.
	89-112.5			Intermittent ⁶⁰ Co and ¹⁵⁴ Eu included.
	102-135.5	BE		¹³⁷ Cs removed.

^a Source - Source of contamination in judgment of analyst

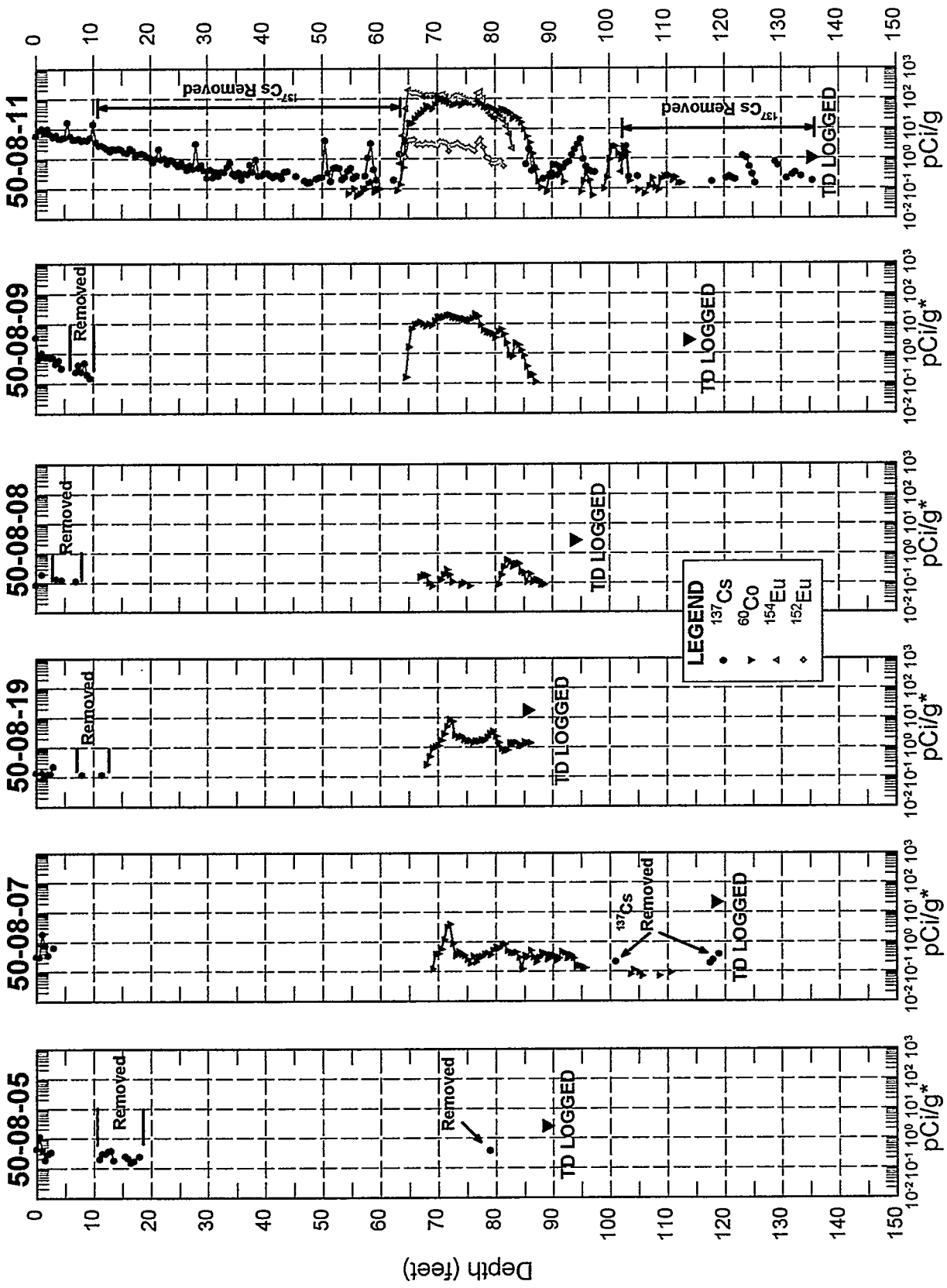
^b SS - Surface spill

^c BE - Borehole effects (e.g., dragdown, inside/outside casing contamination)

^d P - Probable contamination plume

^e SFA - Shape Factor Analysis

^f N/A - Not available, the borehole was finished with grout and multiple casings



*Apparent Concentration

Figure C-9. Summary of Interpreted Data Set for T-108 Boreholes

Table C-10. Summary of Interpreted Data Set for T-109 Boreholes

Borehole	Depth Interval (ft)	Source ^a	SFA ^e	Disposition/Comments
50-09-01	0-6	Pipeline	N/A ^f	¹³⁷ Cs and ¹⁵⁴ Eu included.
	6.5-19.5	BE ^c		¹³⁷ Cs removed.
	48.5-86	P ^d		Continuous ⁶⁰ Co, ¹⁵⁴ Eu, and mostly continuous ¹⁵² Eu contamination included. ⁶⁰ Co contamination is present at the bottom of the logged interval, indicating that the bottom of the contaminant plume has not been determined.
50-09-02	0-8	SS ^b	N/A	¹³⁷ Cs included.
	8.5-34	BE		¹³⁷ Cs removed.
	63.5-86	P		Continuous ⁶⁰ Co, ¹⁵⁴ Eu, and intermittent ¹⁵² Eu included. ⁶⁰ Co contamination is present at the bottom of the logged interval.
50-09-05	0	BE	N/A	¹³⁷ Cs removed.
	69-85.5	P		Intermittent ⁶⁰ Co included.
50-09-07	0-2	BE	N/A	Isolated ¹³⁷ Cs removed.
50-09-09	0-2.5	BE	N/A	Isolated ¹³⁷ Cs removed.
50-09-10	0-9.5	SS	N/A	¹³⁷ Cs included.
	10-23	BE		¹³⁷ Cs removed.
	38.5-42.5	P		Continuous ⁶⁰ Co and ^{152/154} Eu included.
	48-119.5			Continuous ⁶⁰ Co and ¹⁵⁴ Eu, and intermittent ¹⁵² Eu included. ⁶⁰ Co and ¹⁵⁴ Eu contamination are present at the bottom of the logged interval.
	82-119.5	BE		¹³⁷ Cs removed.

^a Source - Source of contamination in judgment of analyst

^b SS - Surface spill

^c BE - Borehole effects (e.g., dragdown, inside/outside casing contamination)

^d P - Probable contamination plume

^e SFA - Shape Factor Analysis

^f N/A - Not available, the borehole was finished with grout and multiple casings

Table C-11. Summary of Interpreted Data Set for T-110 Boreholes

Borehole	Depth Interval (ft)	Source ^a	SFA ^d	Disposition/Comments
50-10-05	0-4.5	BE ^c	N/A ^e	¹³⁷ Cs removed.
	5-16	SS ^b		Continuous ¹³⁷ Cs included.
	16.5-28.5	BE		¹³⁷ Cs removed.
50-10-07	0.5-1, 40.5, and 83	BE	N/A	Isolated ¹³⁷ Cs removed.
50-10-08	1-2	BE	N/A	Isolated ¹³⁷ Cs removed.
50-10-10	0-1.5	SS	N/A	¹³⁷ Cs included.
	2.5-74.5	BE		Intermittent and isolated ¹³⁷ Cs removed.

^a Source - Source of contamination in judgment of analyst

^b SS - Surface spill

^c BE - Borehole effects (e.g., dragdown, inside/outside casing contamination)

^d SFA - Shape Factor Analysis

^e N/A - Not available, the borehole was finished with grout and multiple casings

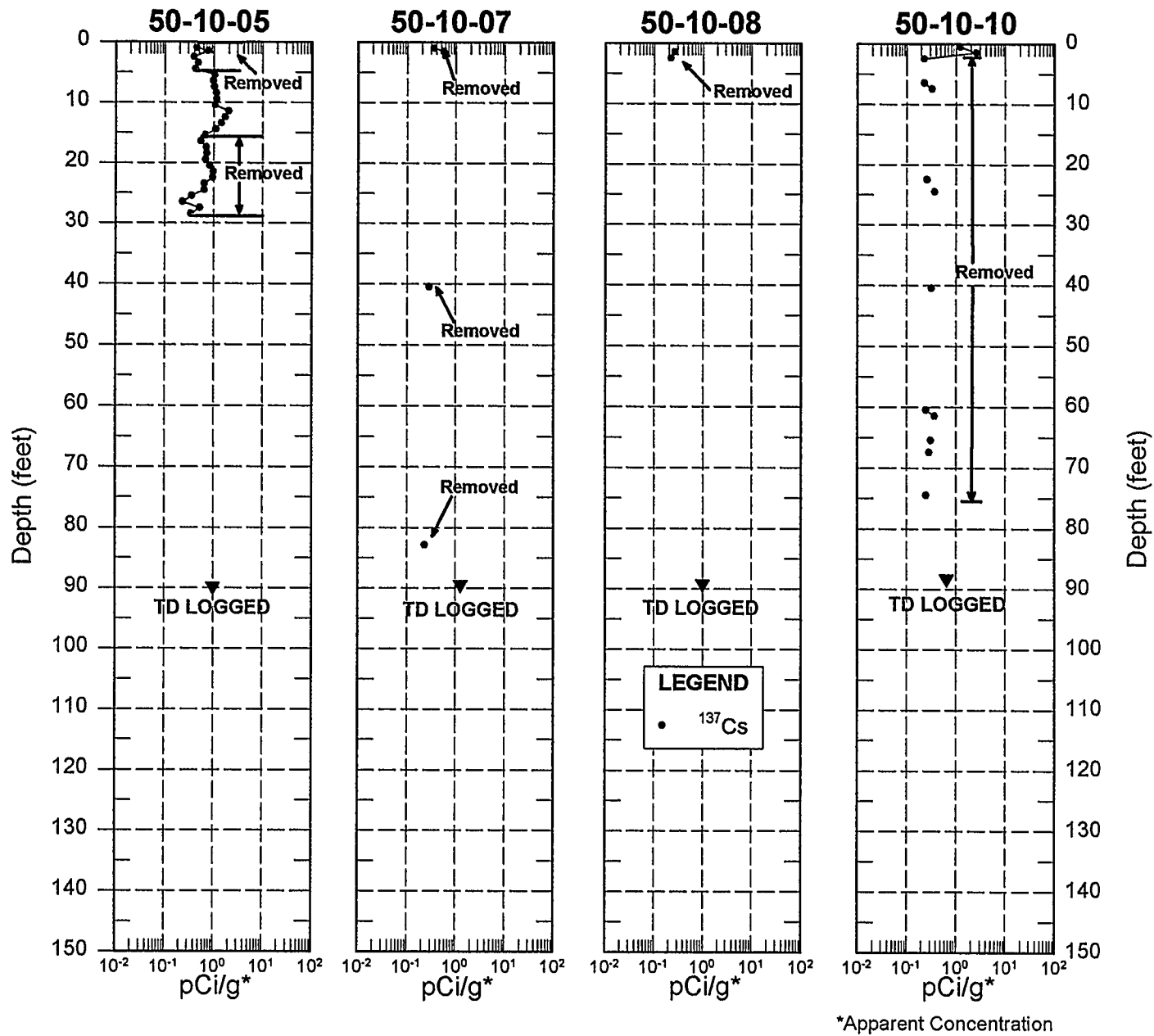


Figure C-11. Summary of Interpreted Data Set for T-110 Boreholes

Table C-12. Summary of Interpreted Data Set for T-111 Boreholes

Borehole	Depth Interval (ft)	Source ^a	SFA ^e	Disposition/Comments
50-11-05	0	BE ^c	N/A ^f	Isolated ¹³⁷ Cs removed.
50-11-07	0-6.5	SS ^b	N/A	¹³⁷ Cs included.
	84	BE		Isolated ¹³⁷ Cs removed.
50-11-08	0-0.5	SS	N/A	¹³⁷ Cs included.
	10.5-13.5	BE		Isolated ¹³⁷ Cs removed.
50-11-10	0-2.5	SS	N/A	¹³⁷ Cs included.
	68-69	P ^d		Intermittent ⁶⁰ Co included.
50-11-11	0-13.5	SS	N/A	Continuous ¹³⁷ Cs included.
	68.5-71.5	P	Inc. ^g	Continuous ⁶⁰ Co included.

^a Source - Source of contamination in judgment of analyst

^b SS - Surface spill

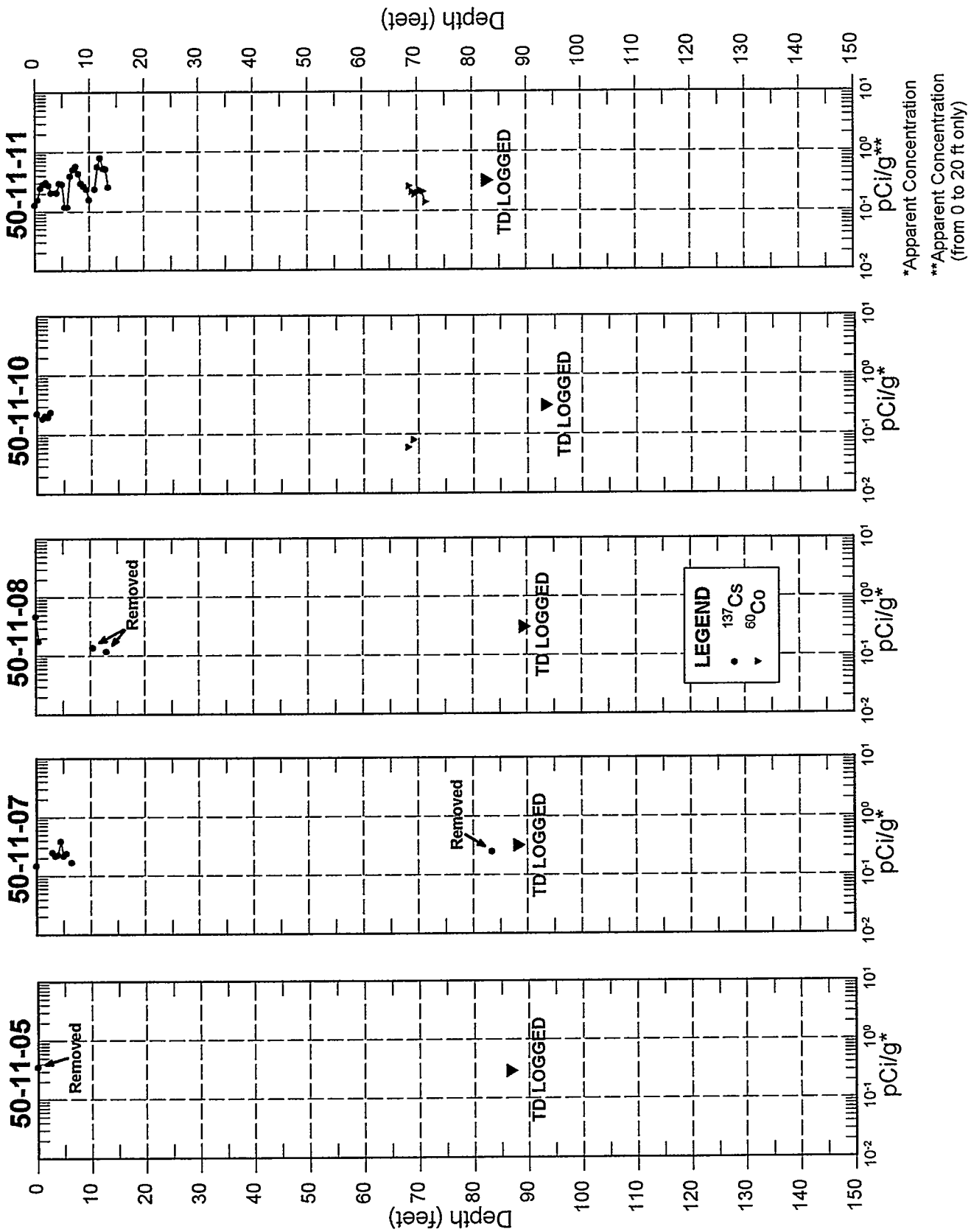
^c BE - Borehole effects (e.g., dragdown, inside/outside casing contamination)

^d P - Probable contamination plume

^e SFA - Shape Factor Analysis

^f N/A - Not available, the borehole was finished with grout and multiple casings

^g Inc. - Inconclusive, generally due to low or rapidly changing concentrations



*Apparent Concentration
 **Apparent Concentration
 (from 0 to 20 ft only)

Figure C-12. Summary of Interpreted Data Set for T-111 Boreholes

Table C-13. Summary of Interpreted Data Set for T-112 Boreholes

Borehole	Depth Interval (ft)	Source ^a	SFA ^d	Disposition/Comments
50-12-05	0-19.5	BE ^c	N/A ^e	Intermittent ¹³⁷ Cs removed.
50-12-07	0-6	SS ^b	N/A	Continuous ¹³⁷ Cs included.
	6.5-14	BE		¹³⁷ Cs removed.
	14.5-20	SS		Continuous ¹³⁷ Cs included.
	20.5-24.5	BE		¹³⁷ Cs removed.
50-12-10	0	BE	N/A	Isolated ¹³⁷ Cs removed.

^a Source - Source of contamination in judgment of analyst

^b SS - Surface spill

^c BE - Borehole effects (e.g., dragdown, inside/outside casing contamination)

^d SFA - Shape Factor Analysis

^e N/A - Not available, the borehole was finished with grout and multiple casings

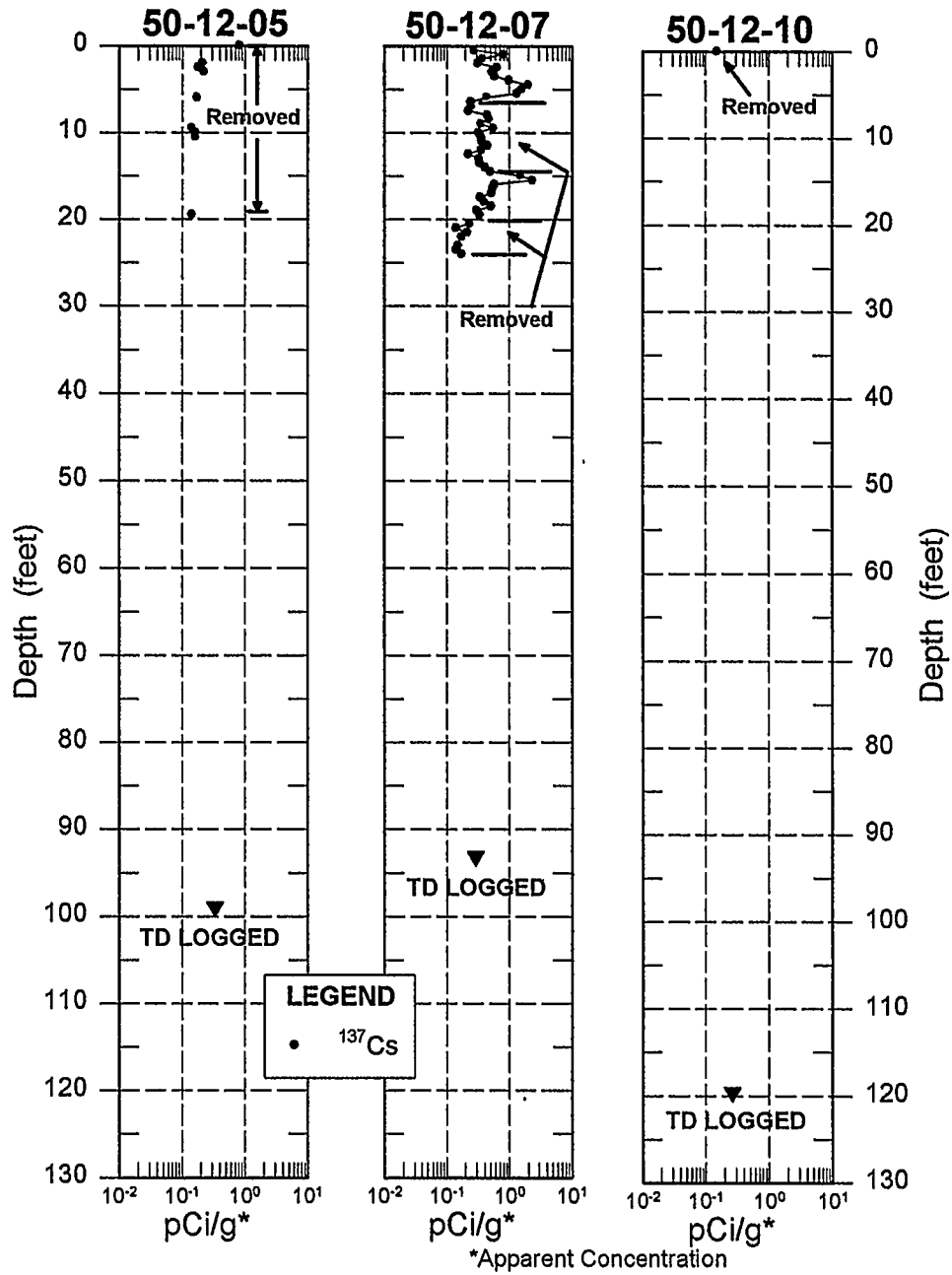


Figure C-13. Summary of Interpreted Data Set for T-112 Boreholes

Appendix D
T Tank Farm Visualizations

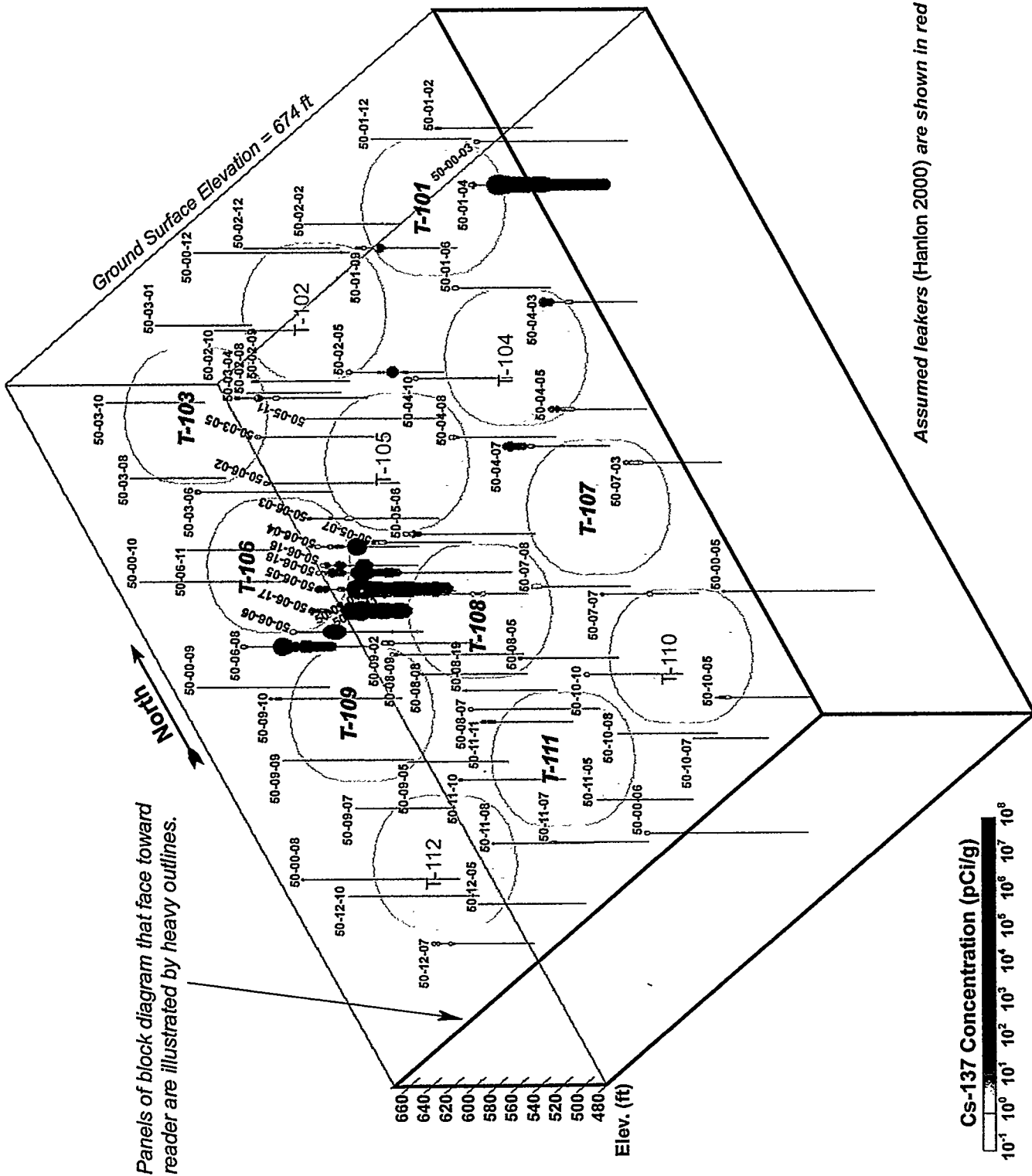


Figure D-1. T Tank Farm Visualization

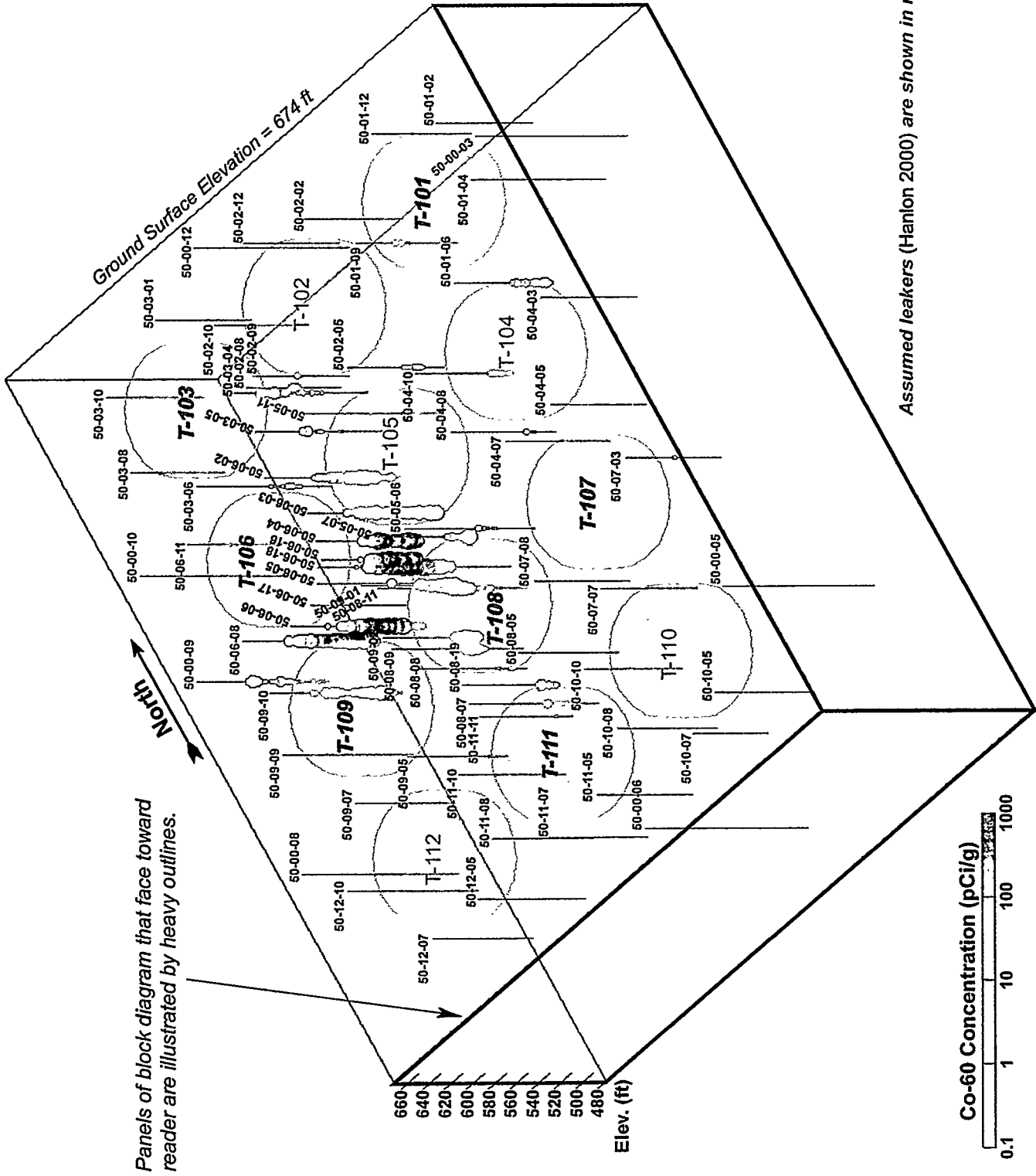


Figure D-2. T Tank Farm Visualization

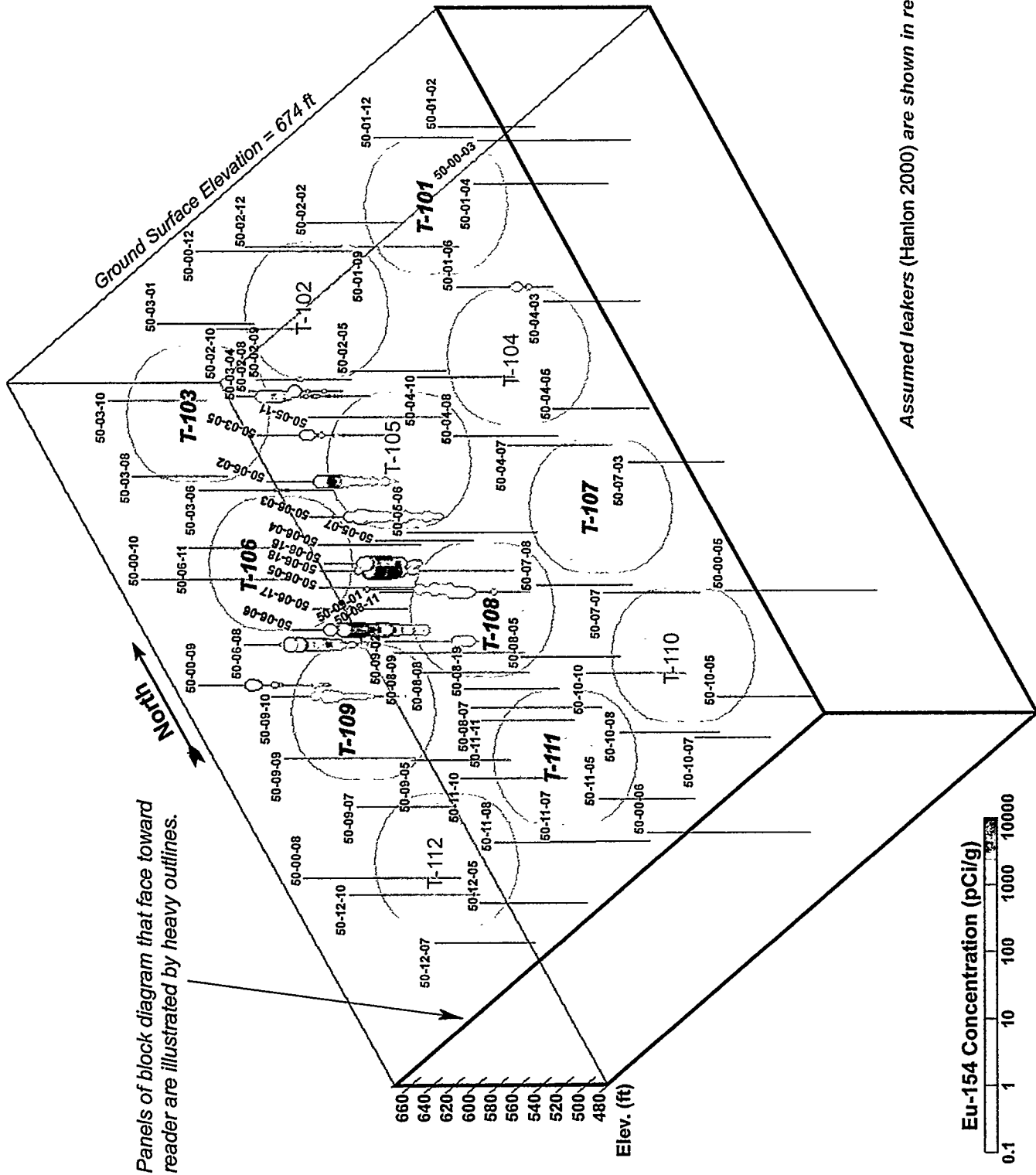


Figure D-3. T Tank Farm Visualization

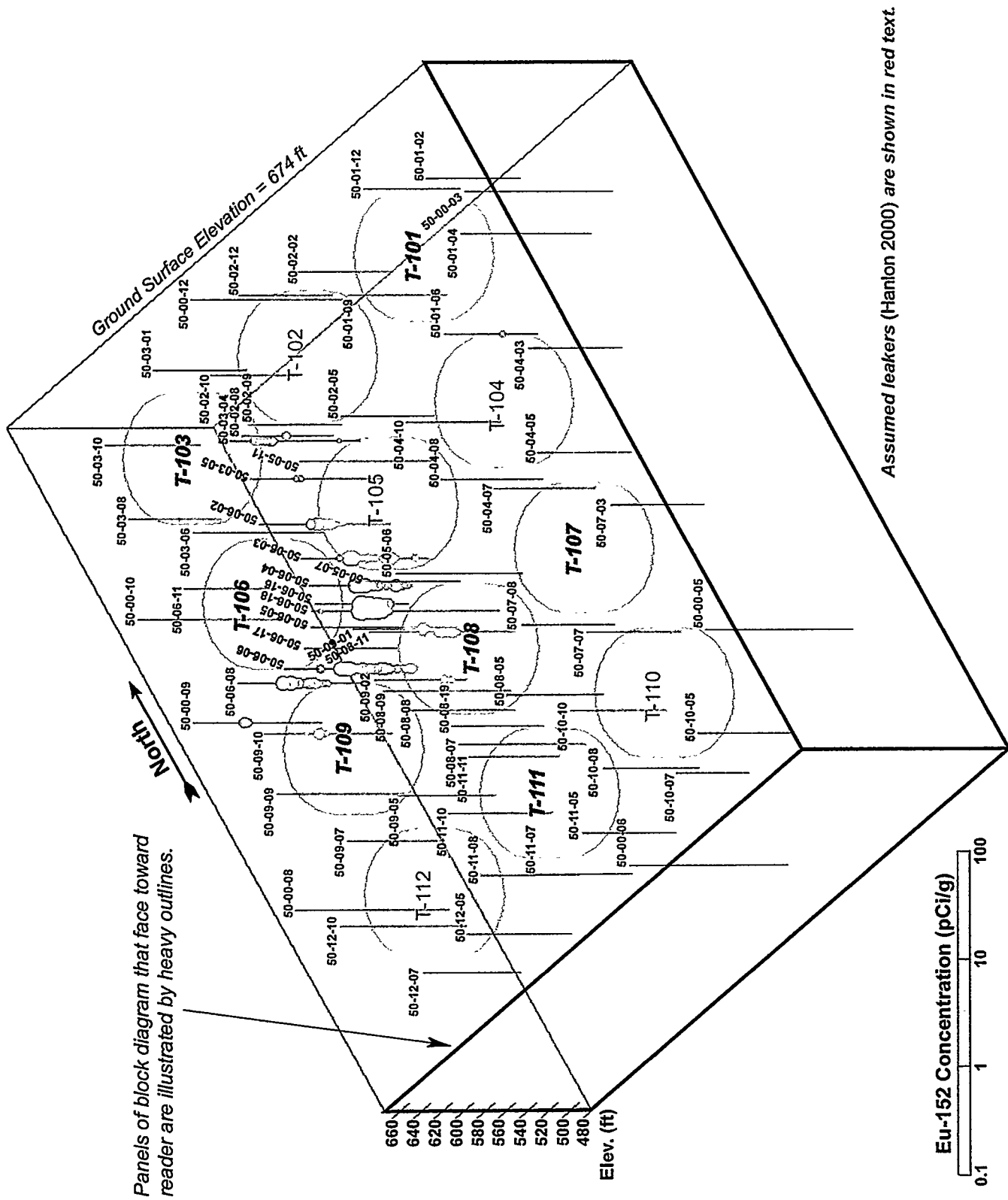


Figure D-4. T Tank Farm Visualization

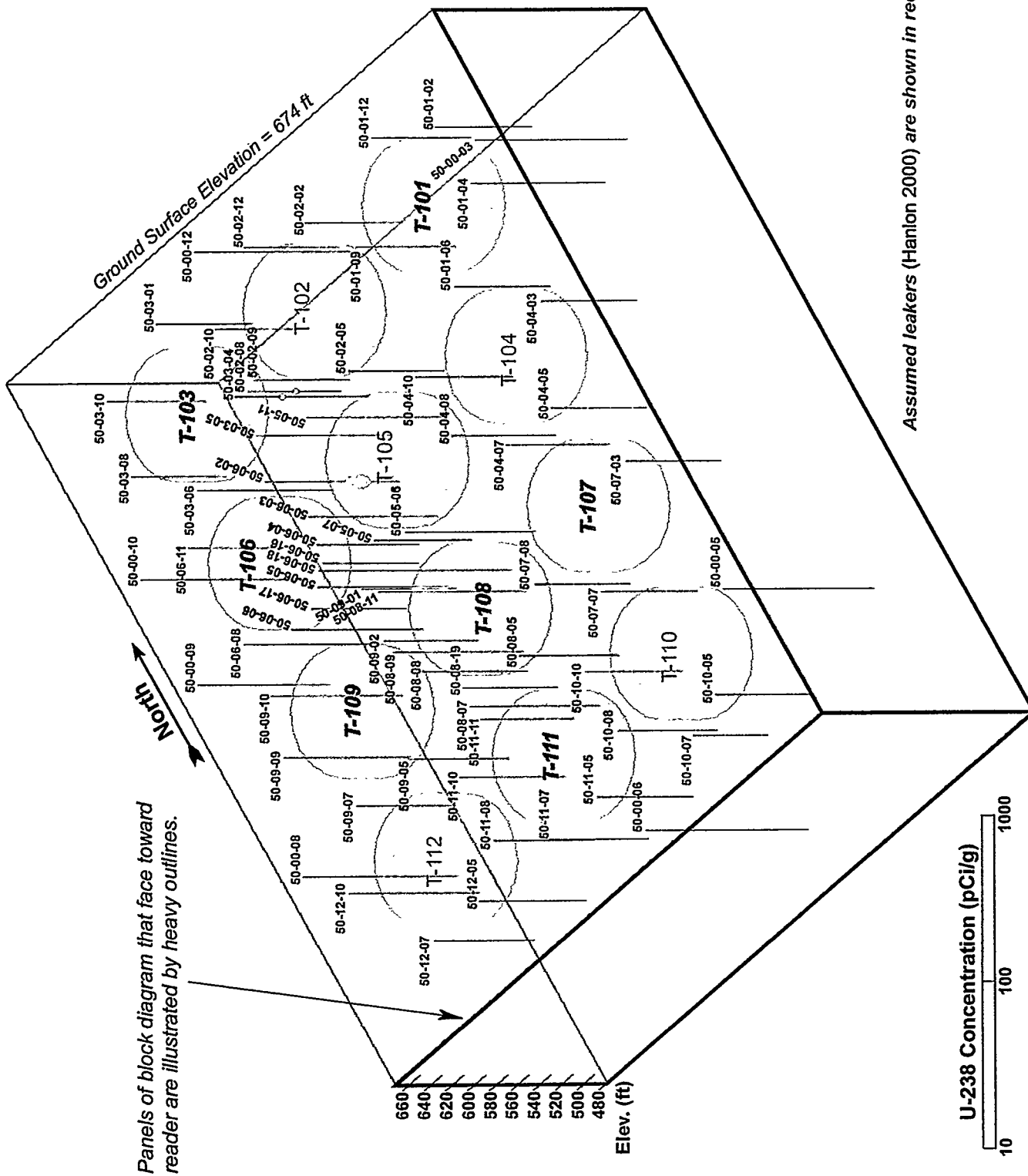


Figure D-5. T Tank Farm Visualization

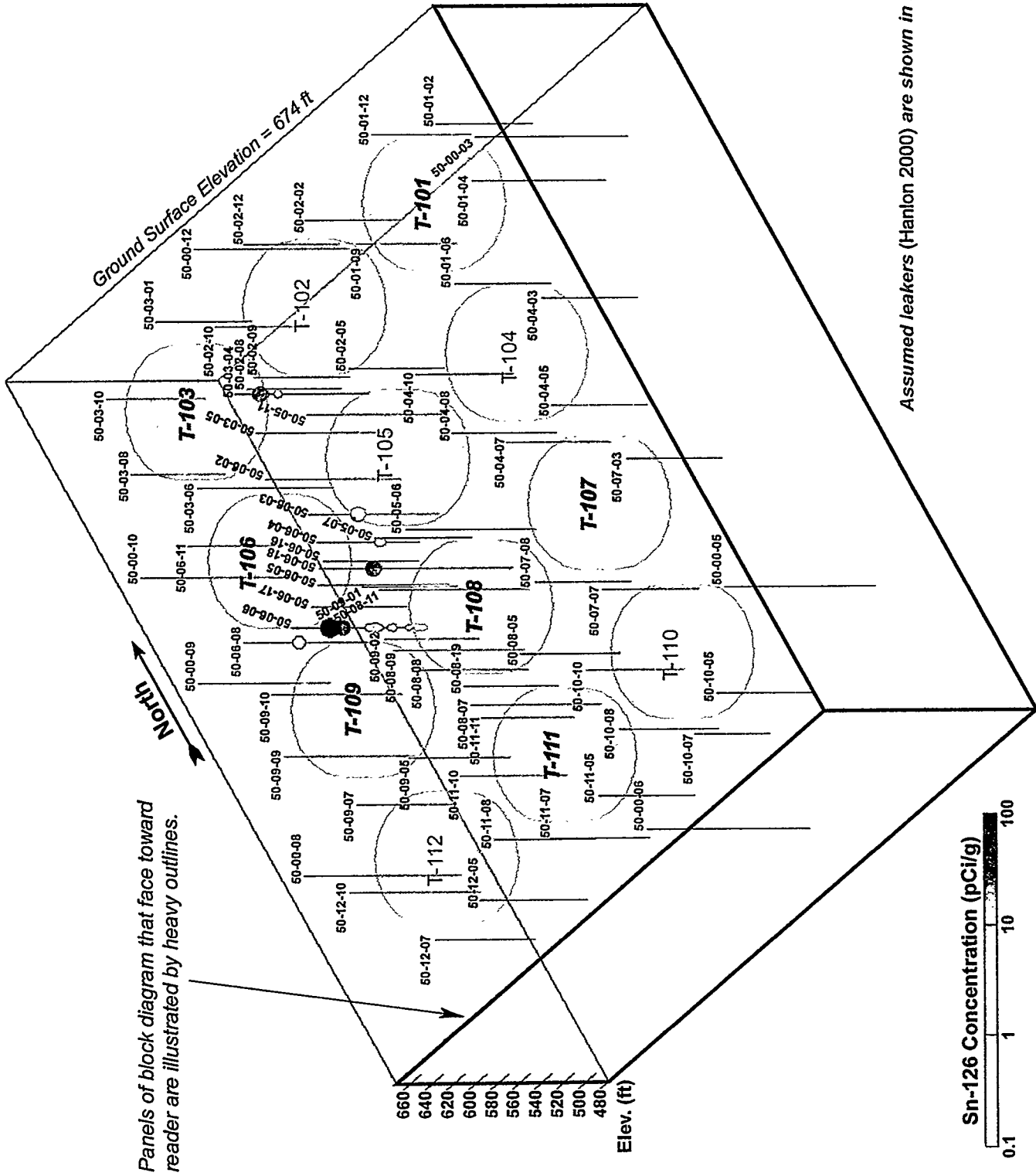


Figure D-7. T Tank Farm Visualization

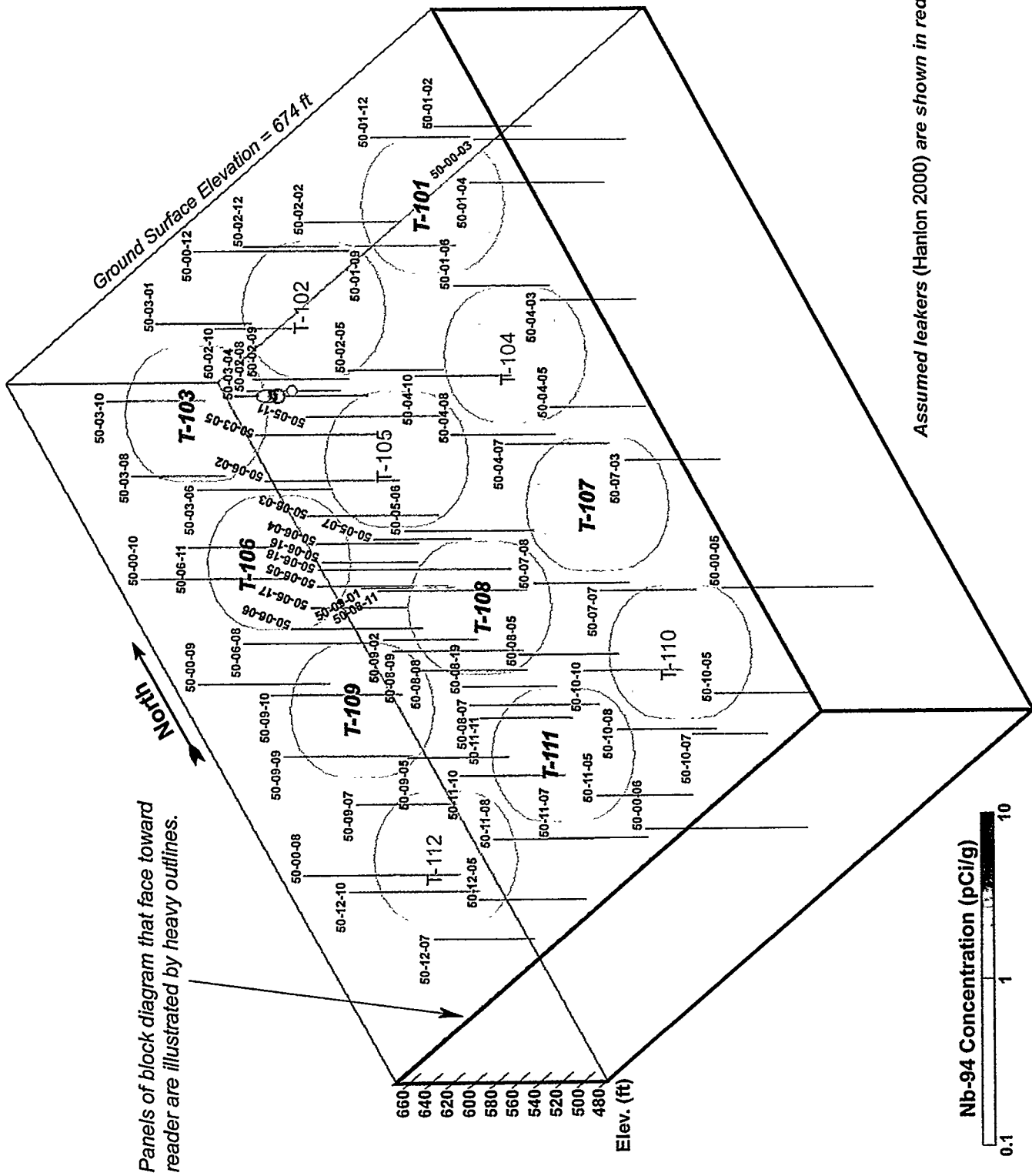


Figure D-8. T Tank Farm Visualization

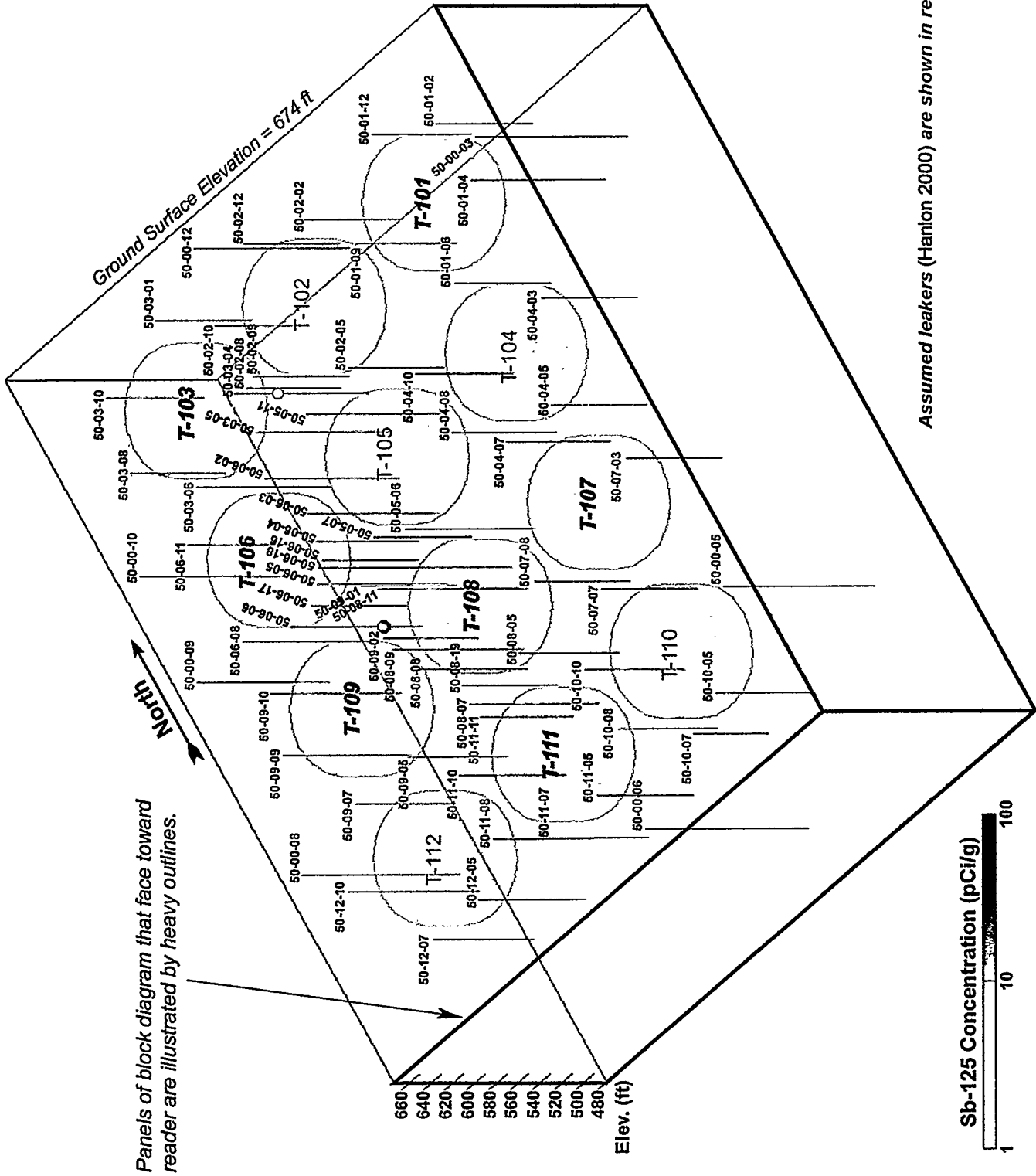
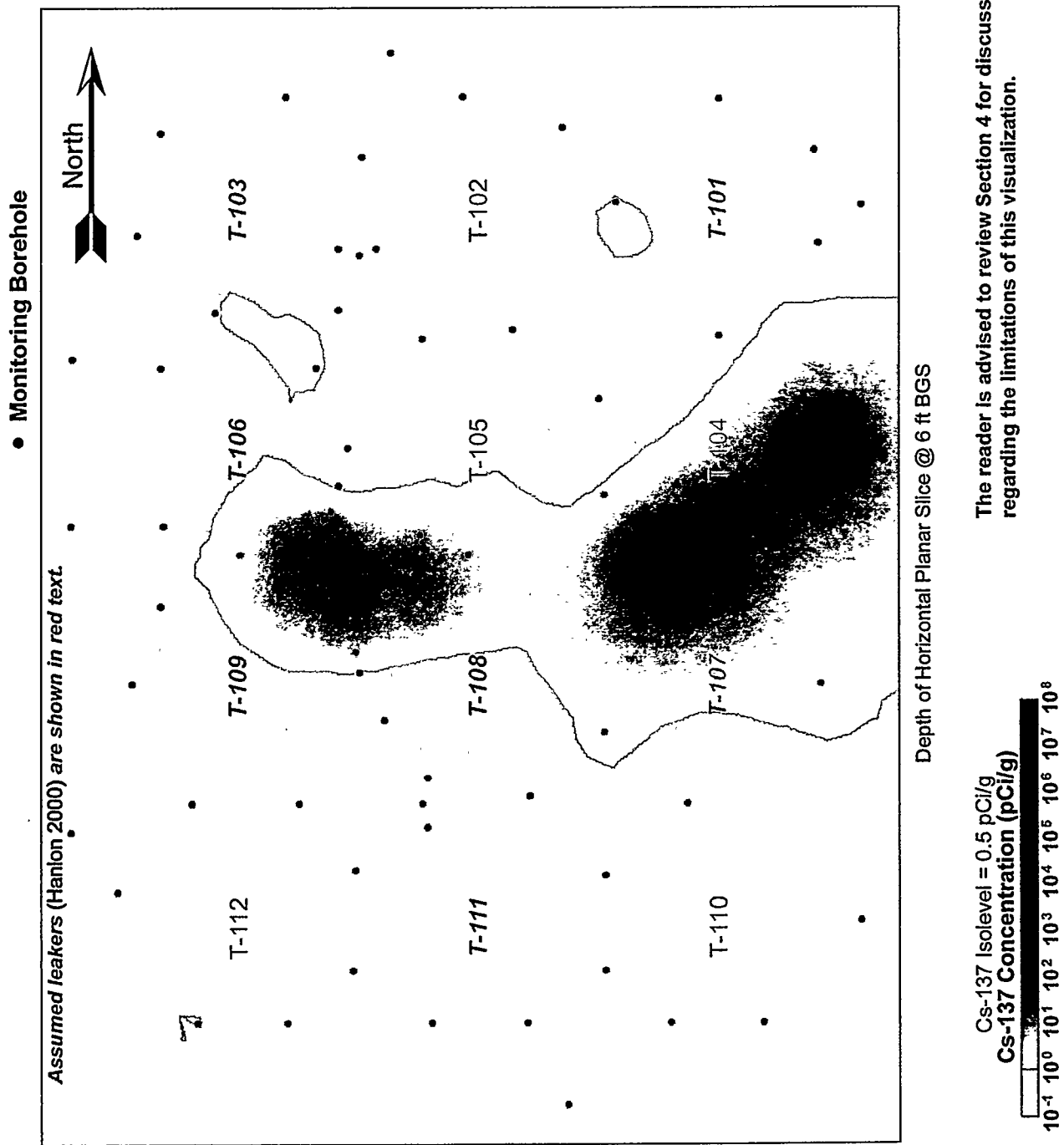


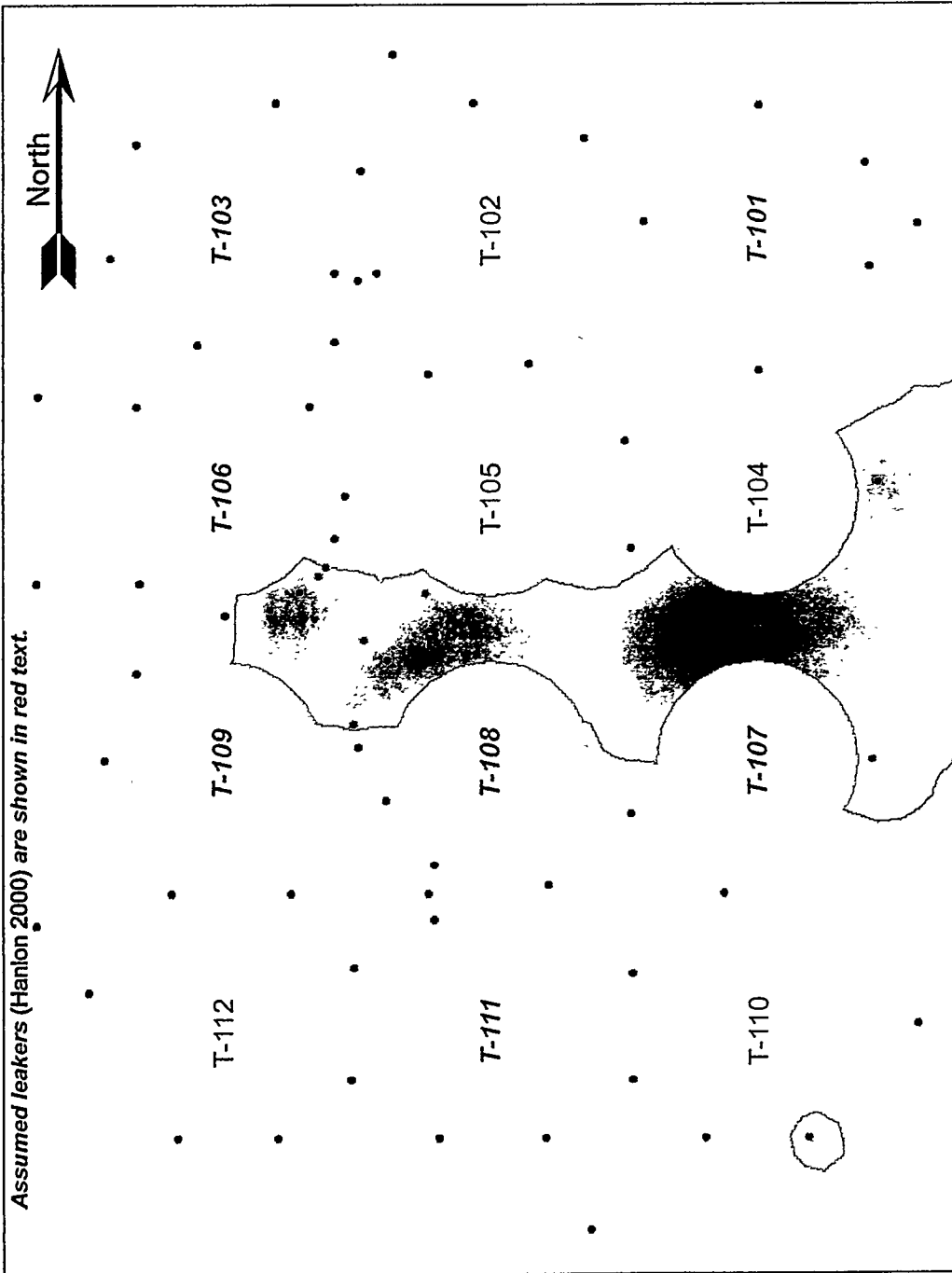
Figure D-9. T Tank Farm Visualization



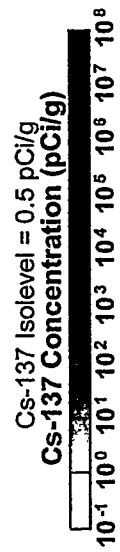
The reader is advised to review Section 4 for discussions regarding the limitations of this visualization.

Figure D-10. T Tank Farm Visualization

● Monitoring Borehole



Depth of Horizontal Planar Slice @ 10 ft BGS



The reader is advised to review Section 4 for discussions regarding the limitations of this visualization.

Figure D-11. T Tank Farm Visualization

The reader is advised to review Section 4 for discussions regarding the limitations of this visualization.

● Monitoring Borehole

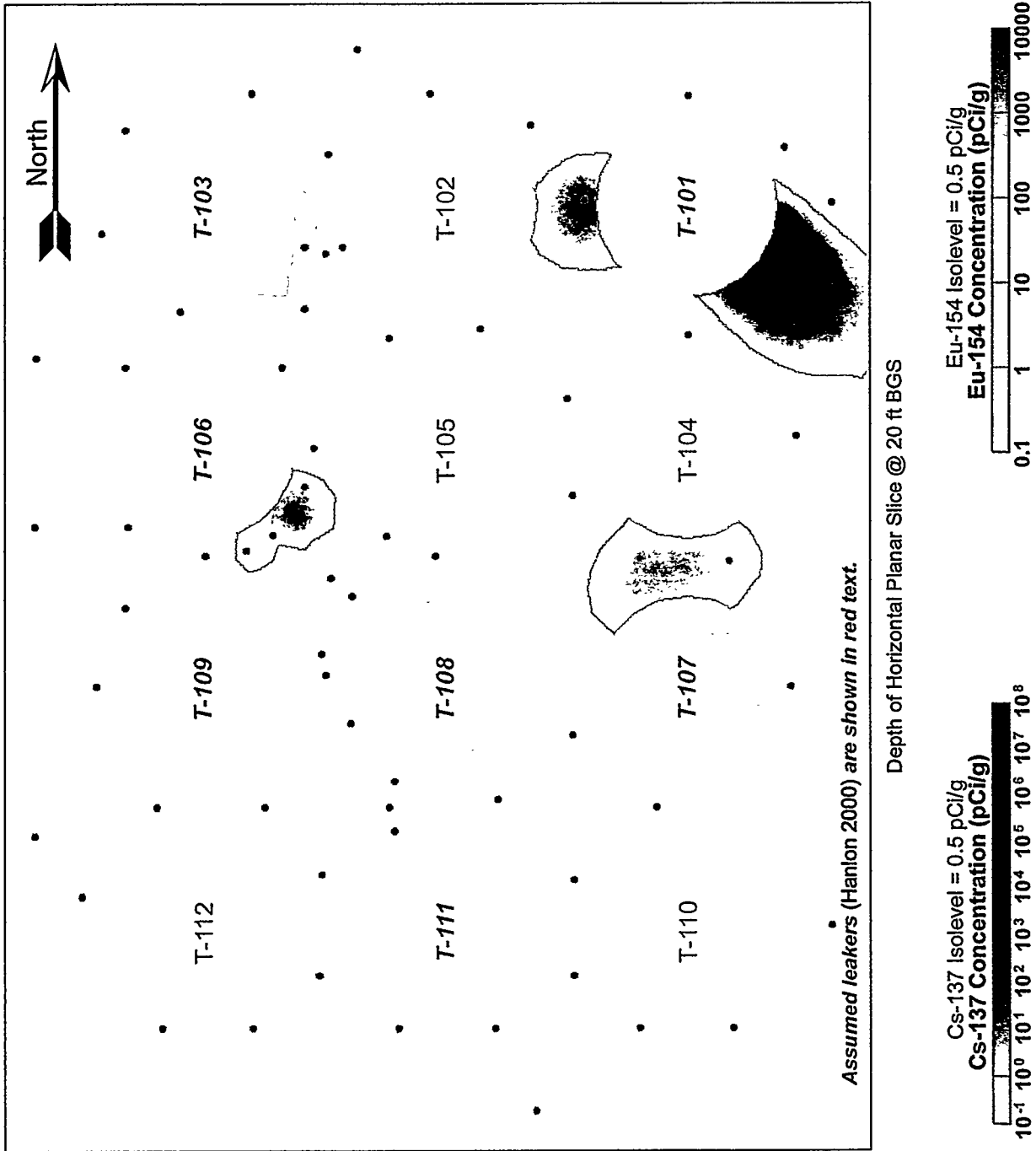


Figure D-12. T Tank Farm Visualization

The reader is advised to review Section 4 for discussions regarding the limitations of this visualization.

● Monitoring Borehole

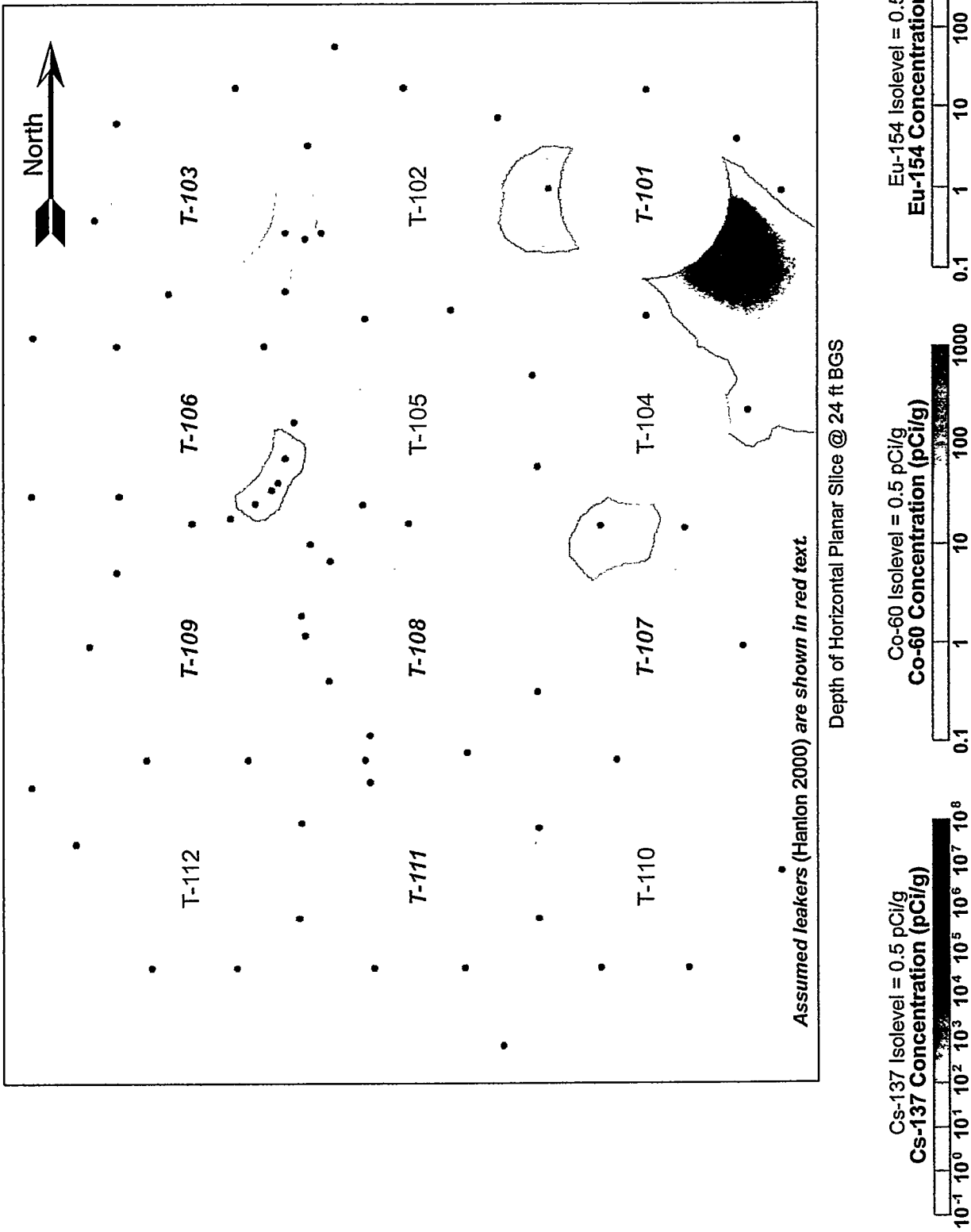


Figure D-13. T Tank Farm Visualization

The reader is advised to review Section 4 for discussions regarding the limitations of this visualization.

• Monitoring Borehole

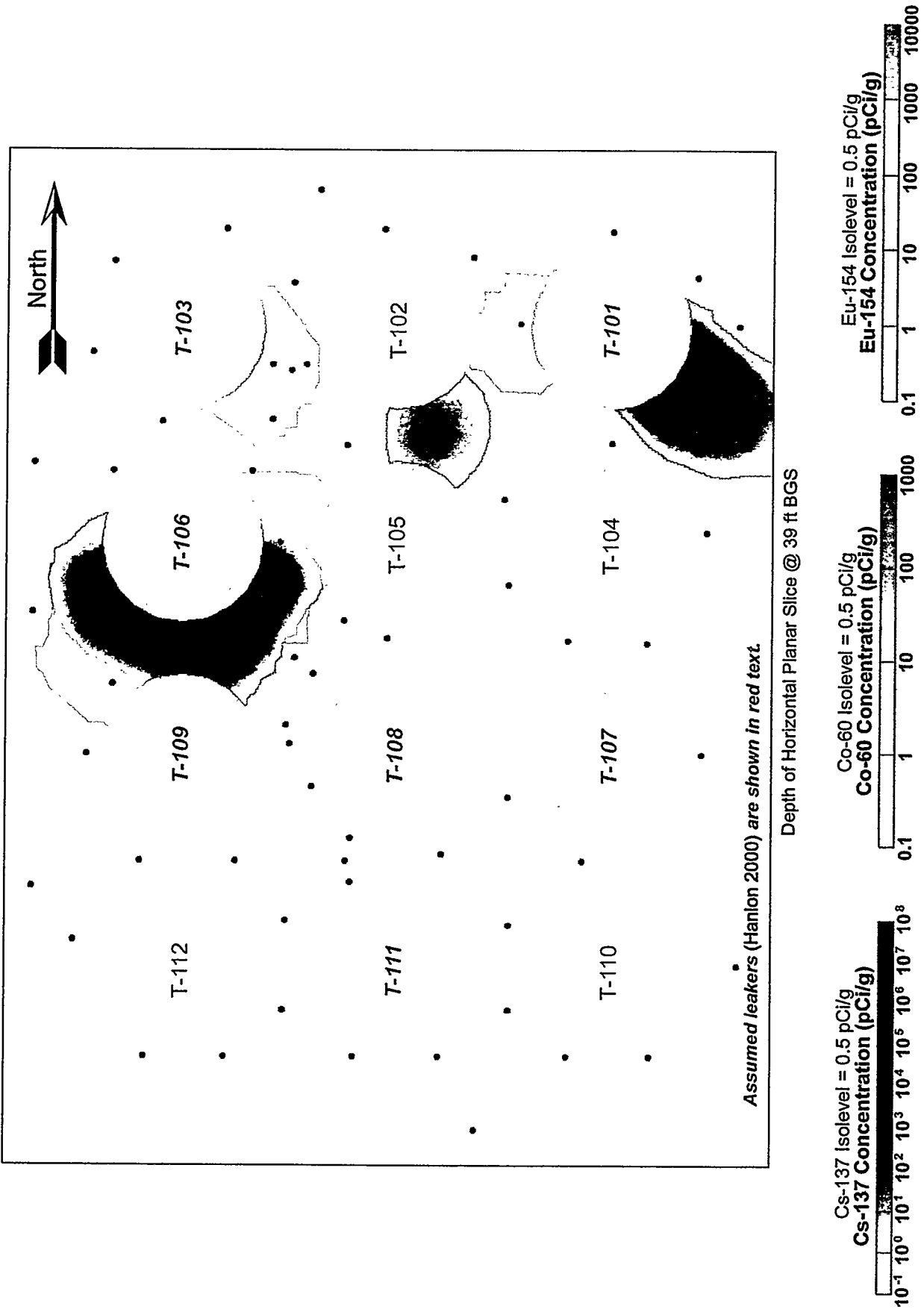


Figure D-14. T Tank Farm Visualization

The reader is advised to review Section 4 for discussions regarding the limitations of this visualization.

● Monitoring Borehole

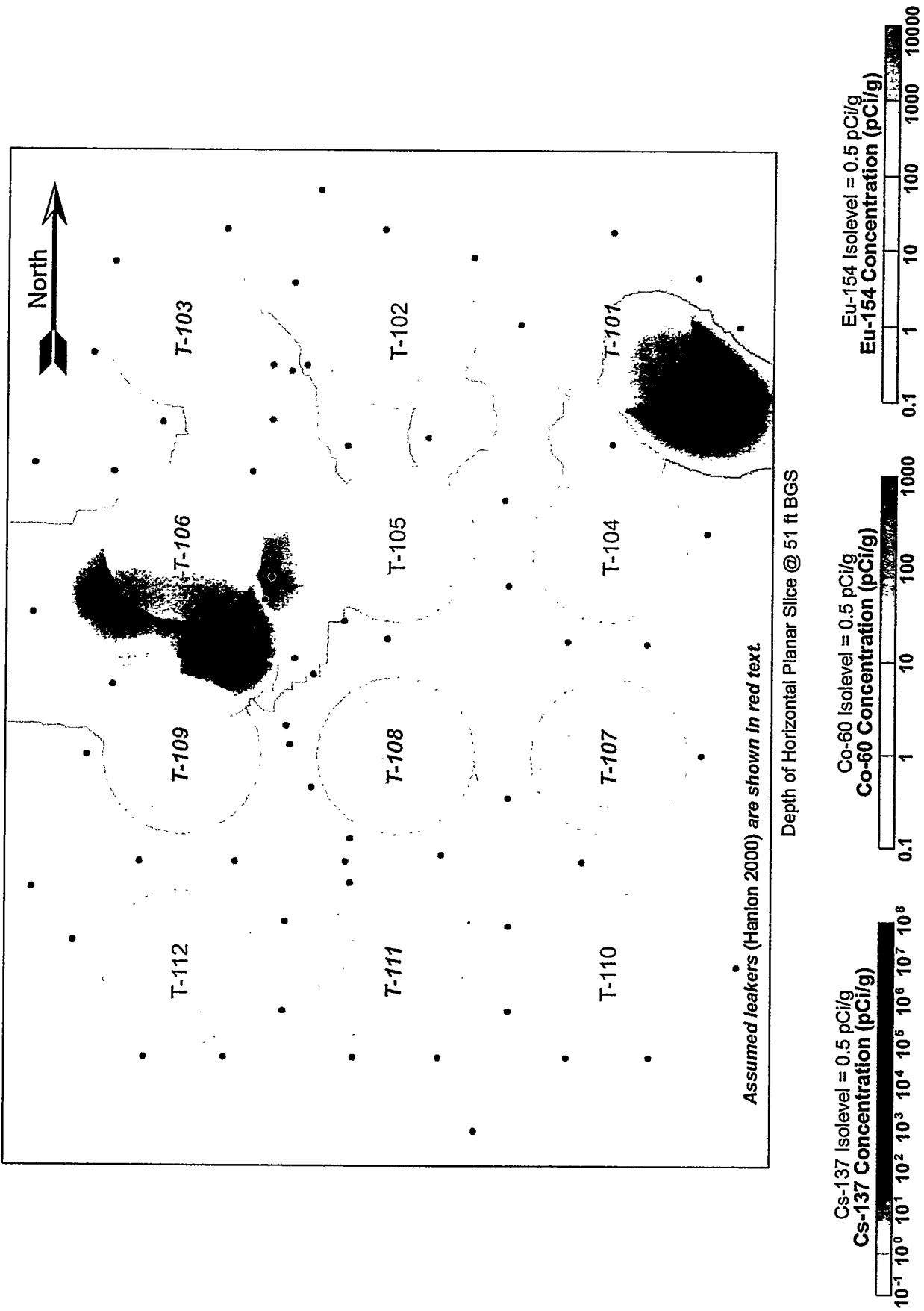
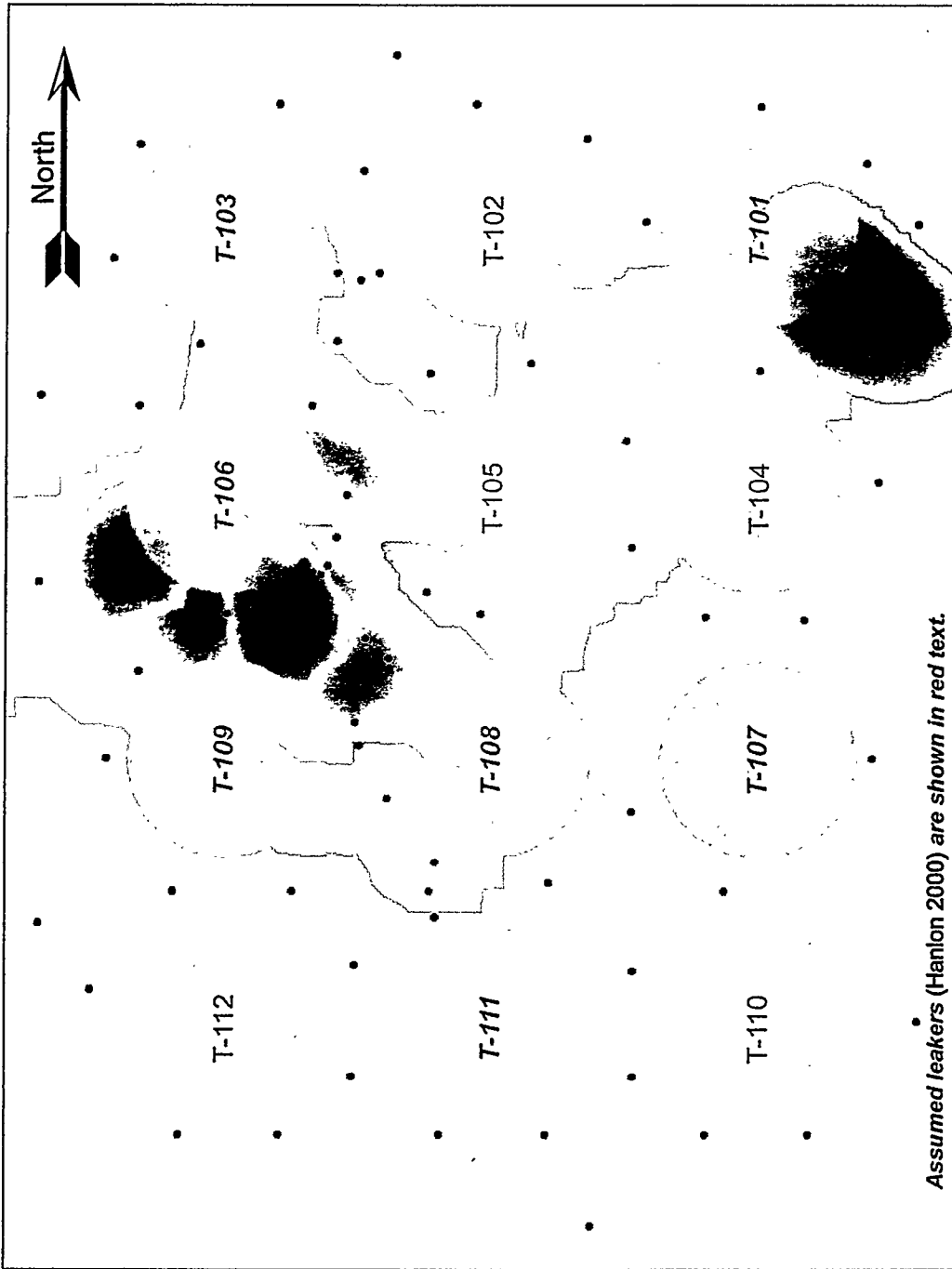


Figure D-15. T Tank Farm Visualization

The reader is advised to review Section 4 for discussions regarding the limitations of this visualization.

● Monitoring Borehole



Assumed leakers (Hanlon 2000) are shown in red text.

Depth of Horizontal Planar Slice @ 71 ft BGS

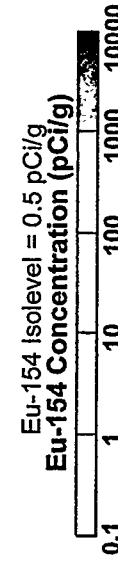
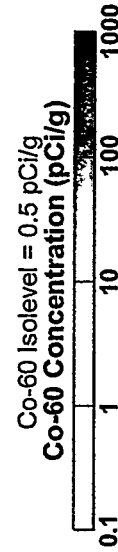
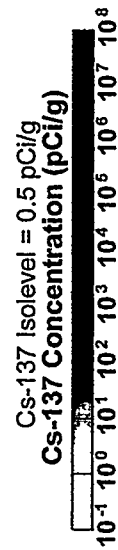
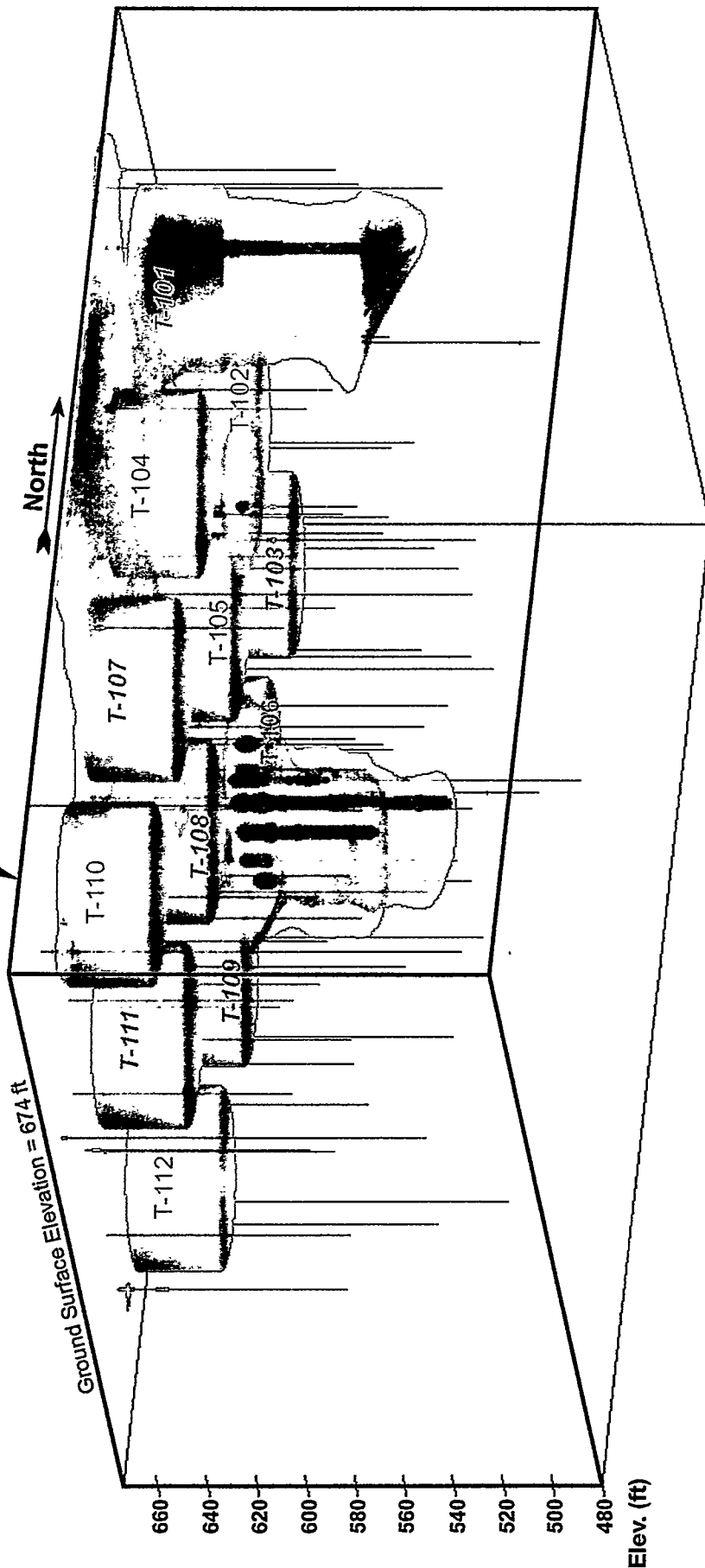


Figure D-16. T Tank Farm Visualization

Panels of block diagram that face toward reader are illustrated by heavy outlines.

Assumed leakers (Hanton 2000) are shown in red text.



The reader is advised to review Section 4 for discussions regarding the limitations of this visualization.

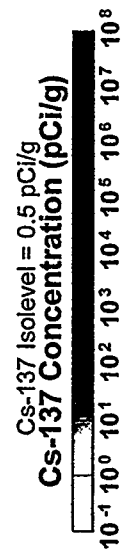
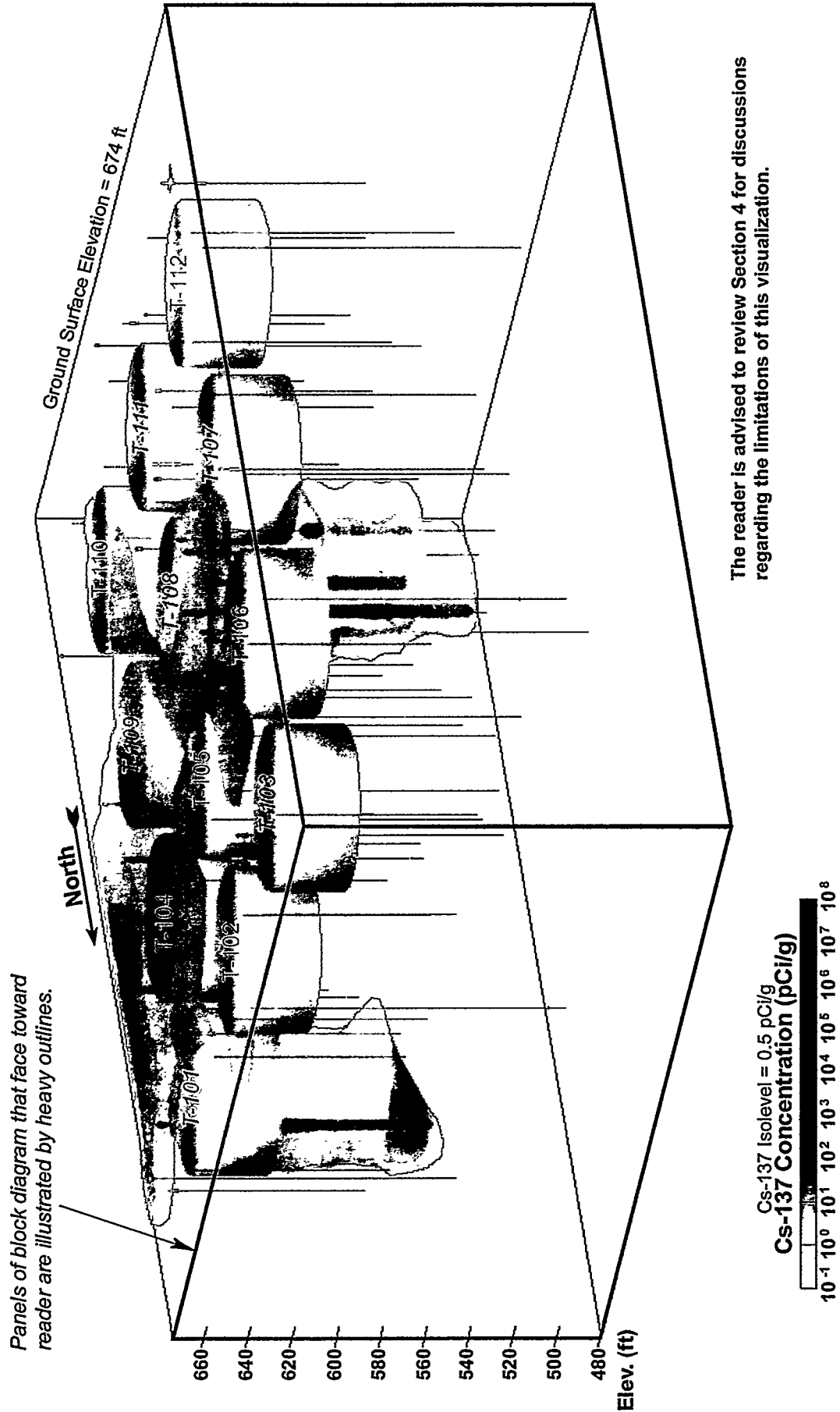


Figure D-17. T Tank Farm Visualization

Assumed leakers (Hanlon 2000) are shown in red text.

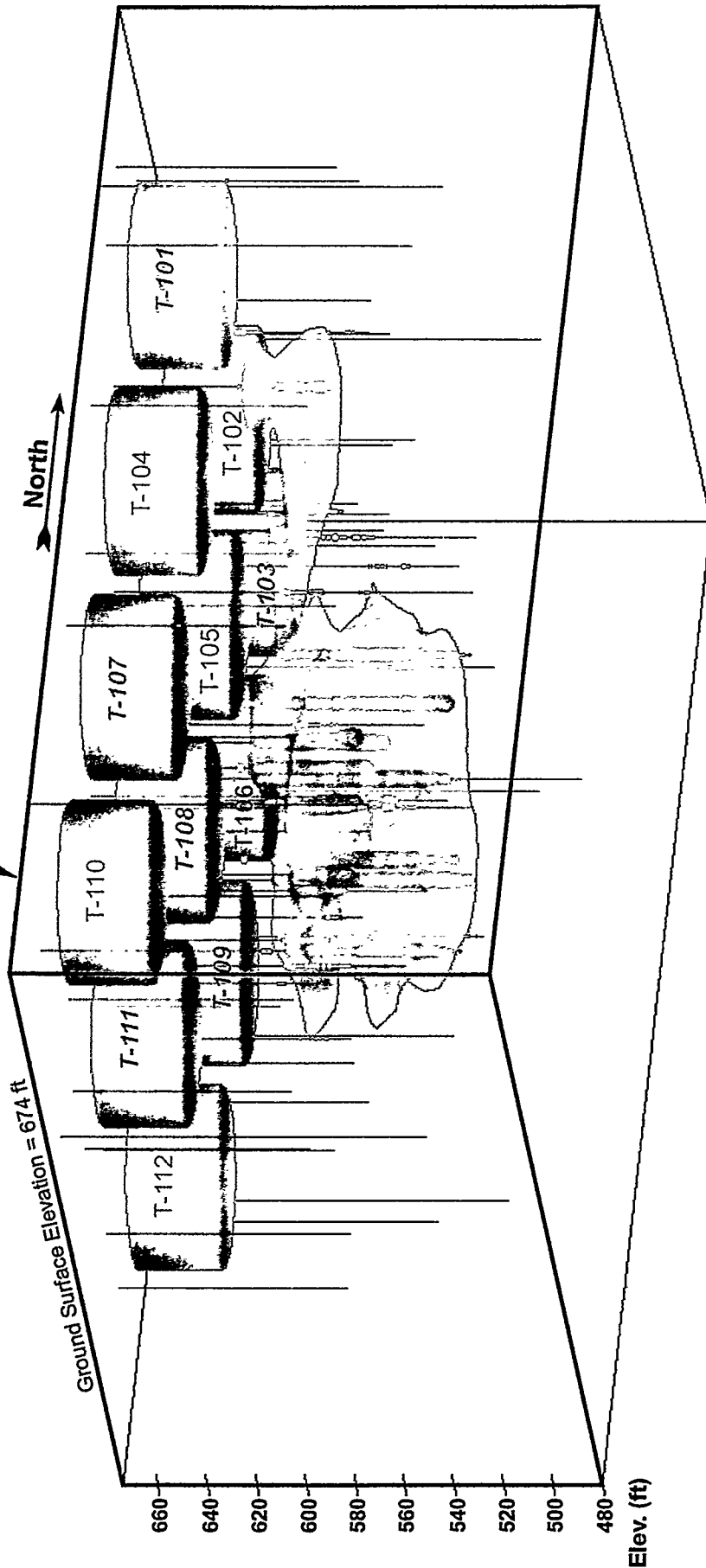


The reader is advised to review Section 4 for discussions regarding the limitations of this visualization.

Figure D-18. T Tank Farm Visualization

Panels of block diagram that face toward reader are illustrated by heavy outlines.

Assumed leakers (Hanlon 2000) are shown in red text.



The reader is advised to review Section 4 for discussions regarding the limitations of this visualization.

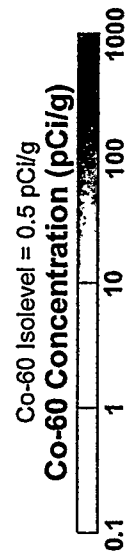


Figure D-19. T Tank Farm Visualization

Assumed leakers (Hanlon 2000) are shown in red text.

Panels of block diagram that face toward reader are illustrated by heavy outlines.

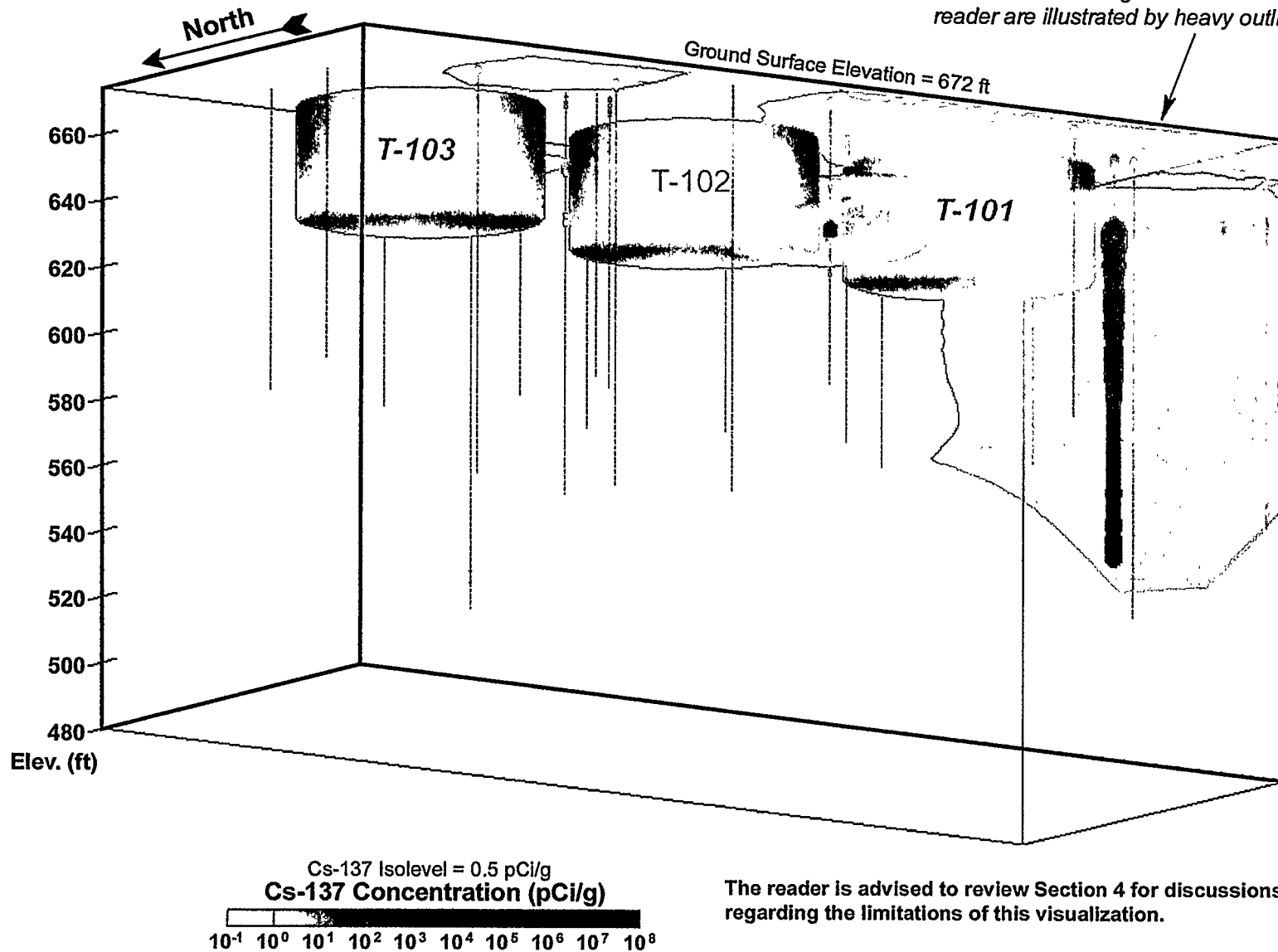


Figure D-21. T Tank Farm Visualization

The reader is advised to review Section 4 for discussions regarding the limitations of this visualization.

Assumed leakers (Hanlon 2000) are shown in red text.

Panels of block diagram that face toward reader are illustrated by heavy outlines.

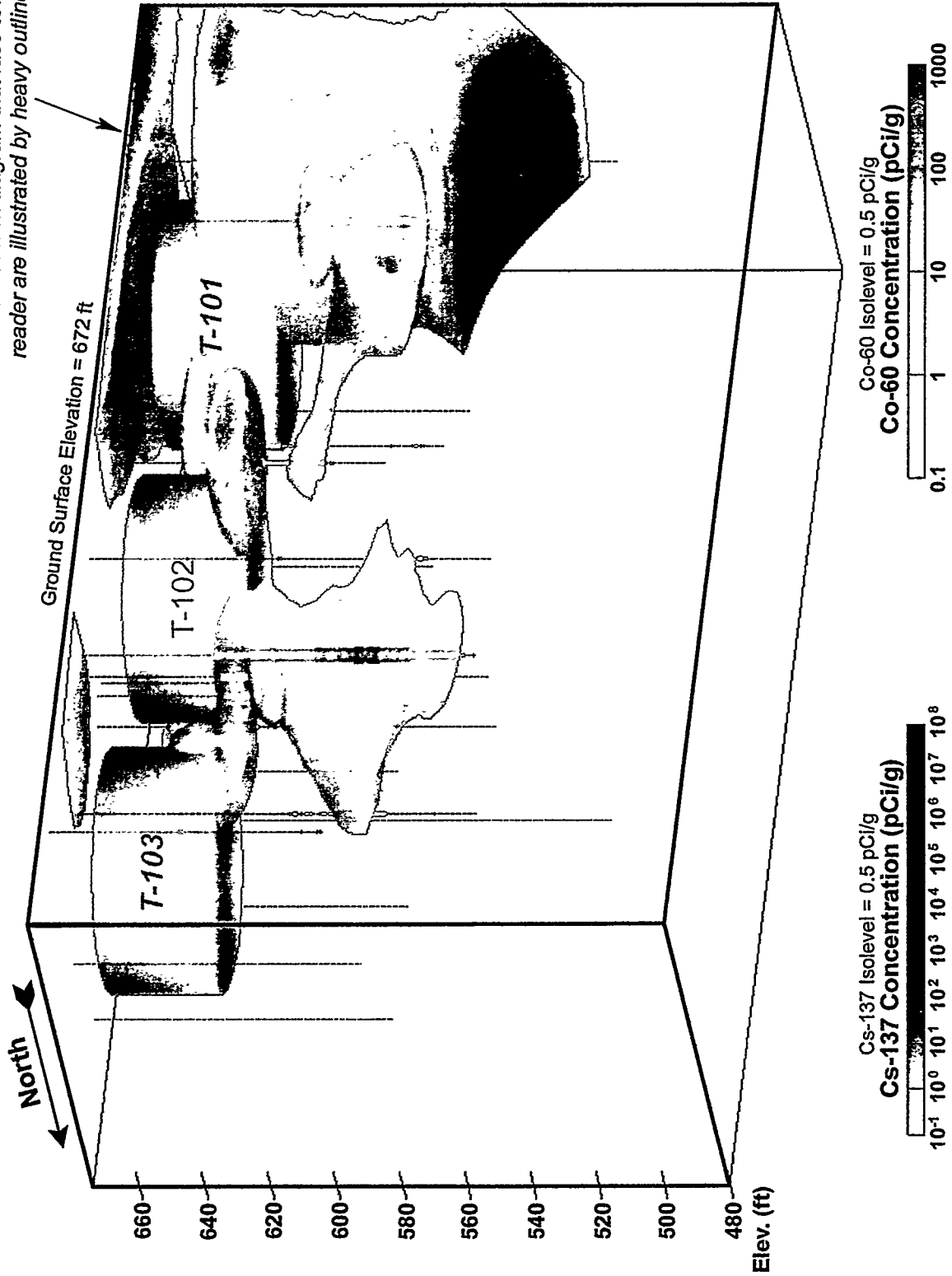


Figure D-22. T Tank Farm Visualization

The reader is advised to review Section 4 for discussions regarding the limitations of this visualization.

Assumed leakers (Hanlon 2000) are shown in red text.

Panels of block diagram that face toward reader are illustrated by heavy outlines.

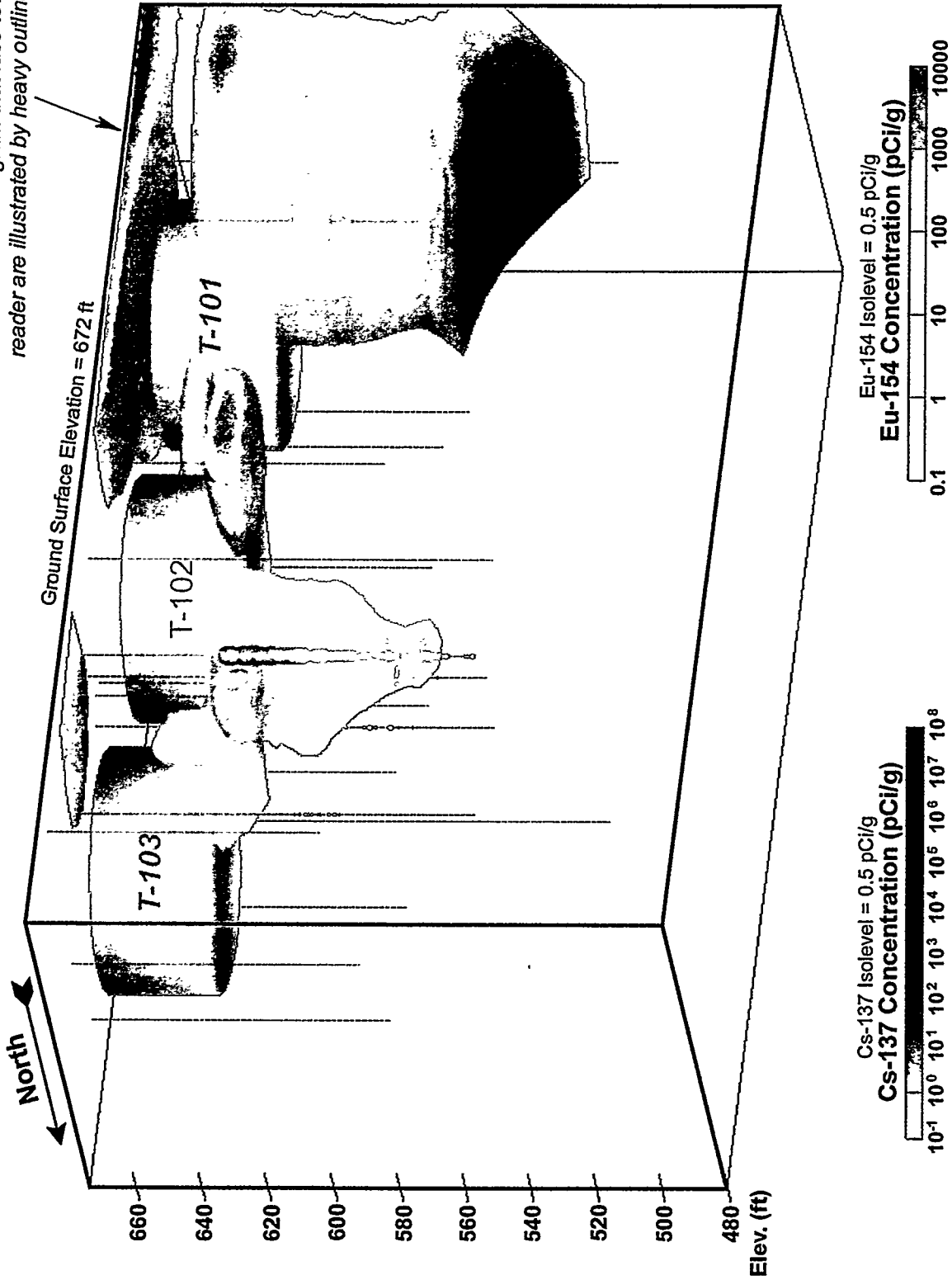
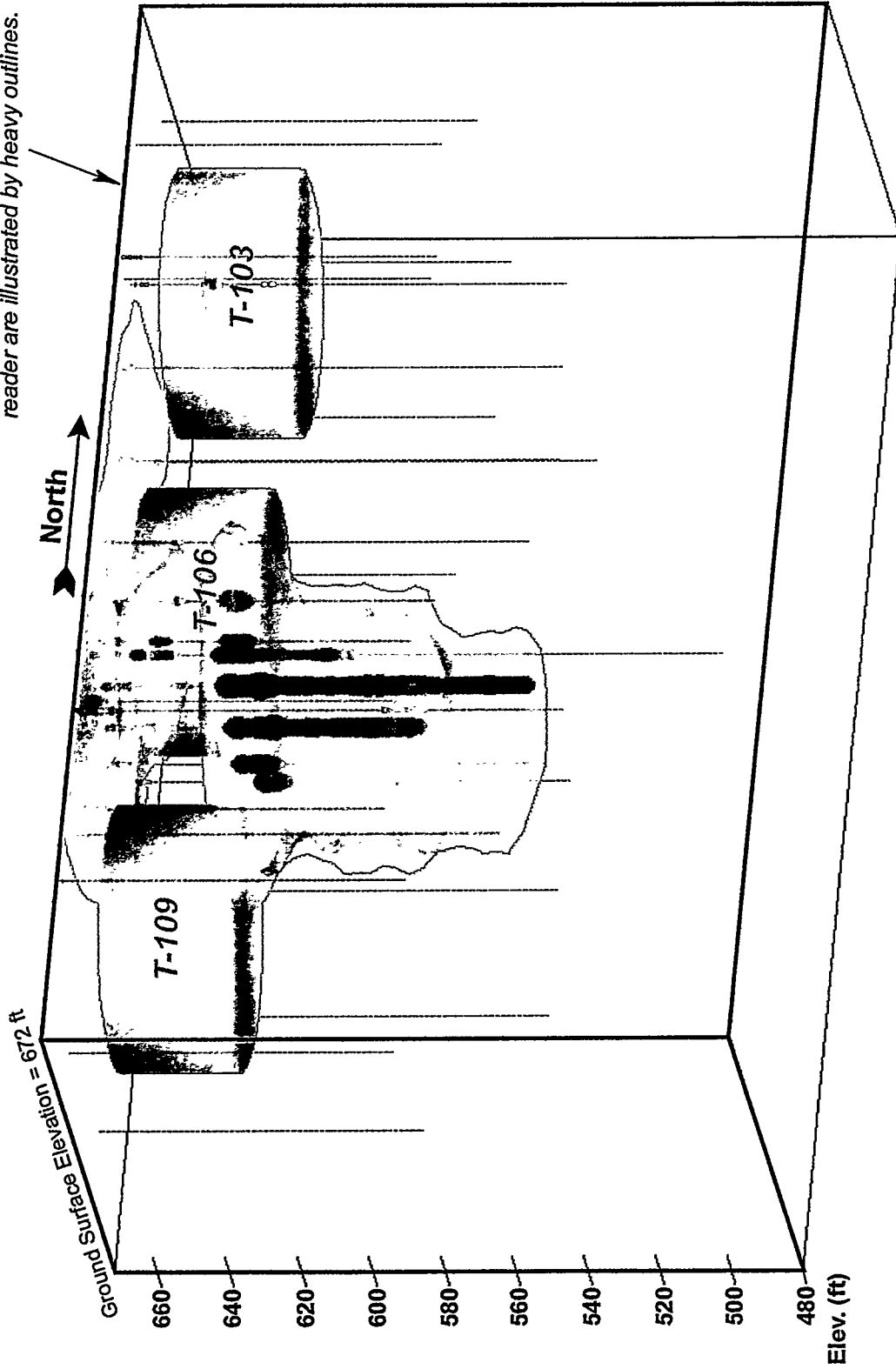


Figure D-23. T Tank Farm Visualization

Assumed leakers (Hanlon 2000) are shown in red text.

Panels of block diagram that face toward reader are illustrated by heavy outlines.



Cs-137 Isolevel = 0.5 pCi/g

Cs-137 Concentration (pCi/g)

10⁻¹ 10⁰ 10¹ 10² 10³ 10⁴ 10⁵ 10⁶ 10⁷ 10⁸

The reader is advised to review Section 4 for discussions regarding the limitations of this visualization.

Figure D-24. T Tank Farm Visualization

The reader is advised to review Section 4 for discussions regarding the limitations of this visualization.

Panels of block diagram that face toward reader are illustrated by heavy outlines.

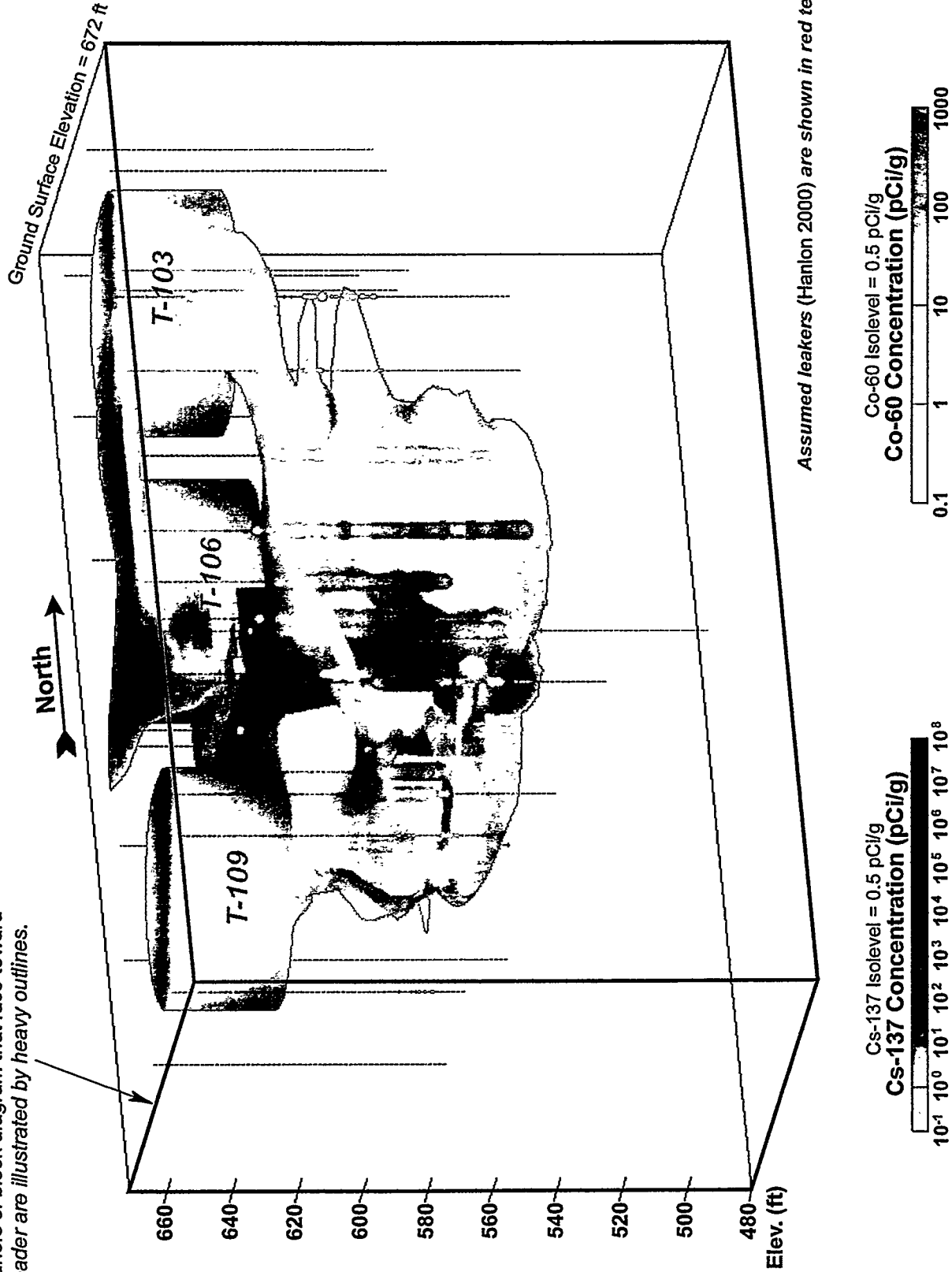
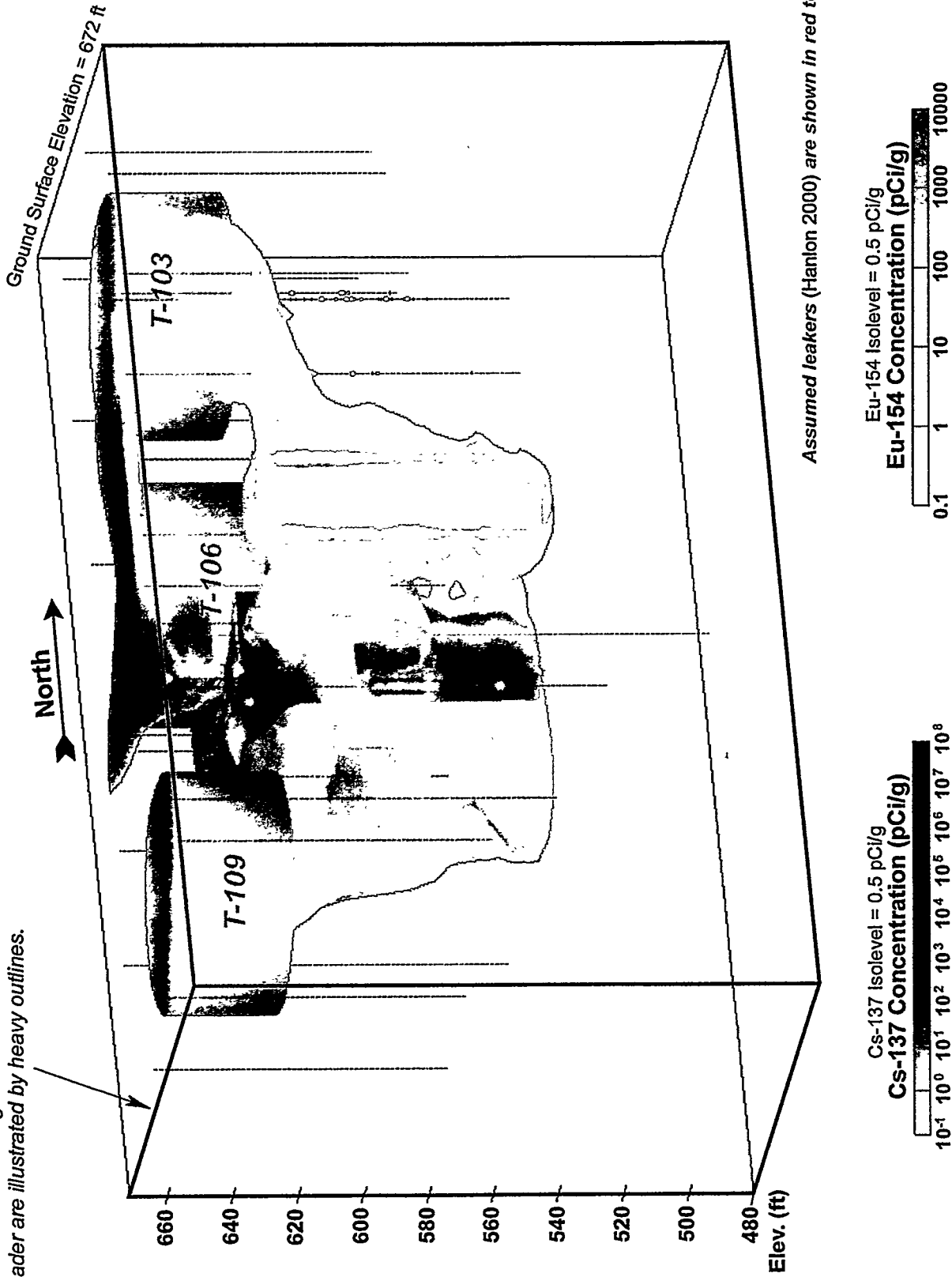


Figure D-25. T Tank Farm Visualization

The reader is advised to review Section 4 for discussions regarding the limitations of this visualization.

Panels of block diagram that face toward reader are illustrated by heavy outlines.



Assumed leakers (Hanlon 2000) are shown in red text.

Figure D-26. T Tank Farm Visualization

Appendix E
Summary of Additional Borehole Data in the
Vicinity of the T Tank Farm

Summary of Additional Borehole Data in the Vicinity of the T Tank Farm

R.G. McCain, MACTEC-ERS, February 2, 2000

Introduction

In the course of baseline vadose zone characterization activities for the T Tank Farm, several boreholes not associated with any specific tank and located around the periphery of the T Tank Farm were logged using the SGLS. These boreholes include 299-W10-3, 50-00-01 (299-W10-8), 50-00-02 (299-W11-23), and 50-00-05 (299-W11-53). It was later determined that the data obtained from these boreholes were not relevant to the investigation of contamination in the immediate vicinity of the tanks. Hence, these boreholes are not discussed in the individual Tank Summary Data Reports or the T Tank Farm Report. The purpose of this appendix is to present log data from these boreholes and to provide a discussion of the results.

Figure F-1 shows the location of each of the above boreholes relative to the T Tank Farm. Combination plots showing concentrations of man-made and naturally occurring radionuclides are also included. All figures are included at the end of this appendix. A brief discussion of results for each borehole is presented in the following sections.

Borehole 299-W10-3

Borehole 299-W10-3 is located approximately 45 ft southwest of tank T-203 near the northeast corner of the 216-T-7 crib and tile field and southeast of the 216-T-32-1 and 216-T-32-2 cribs (See Figure F-1). Information concerning the construction of this borehole is provided by a well construction and completion summary report and Chamness and Merz (1993). Borehole 299-W10-3 was drilled in September 1947 and completed to a depth of 75 ft using 8-in.-diameter casing. In 1951, the borehole was deepened to 239 ft using 8-in. casing, which was then perforated between 194 and 230 ft. In July 1967, a 6-in.-diameter screen with a lead packer was installed inside the 8-in.-diameter casing from 181 to 237 ft after the borehole had been cleaned out. A cement plug was added from 234 to 237 ft. The presence of grout is not reported in the completion summary report or Chamness and Merz (1993). Borehole 299-W10-3 was logged from July 27-31, 1998. The zero reference for the SGLS was the top of the 8-in. casing, which is approximately even with the ground surface. Ground water level was measured at 220.6 ft. The total logging depth reached by the SGLS was 229.0 ft.

A generalized casing correction factor was applied to the data collected between the ground surface and 180.5 ft, using a presumed thickness of 0.322 in. for 8-in.-diameter schedule-40 pipe. For the screened interval between 181 and 229 ft, a correction factor for a casing thickness of 0.602 in. was used, which represents the combined thickness of both the 6-in. and 8-in.-diameter

schedule-40 pipe. In addition, a generalized water correction was applied within the saturated interval from 220.6 ft to the bottom of the borehole.

A combination plot for borehole 299-W10-3 is included as Figure F-2. The man-made radionuclides ^{137}Cs , ^{60}Co , and ^{154}Eu were detected by the SGLS. ^{137}Cs contamination was detected intermittently from the ground surface to 36 ft at low concentrations ranging from 0.1 to about 0.3 pCi/g. Continuous ^{137}Cs contamination was detected from 38.5 to 149 ft at concentrations ranging from 0.2 pCi/g to a peak concentration of 874 pCi/g at 41.5 ft. ^{137}Cs contamination was detected intermittently between 150 and 196 ft at low concentrations ranging from 0.13 to 0.3 pCi/g. Mostly continuous ^{137}Cs contamination was detected between 204 and 222 ft at concentrations ranging from 0.17 to 0.95 pCi/g.

^{60}Co contamination was detected intermittently between 214 and 229 ft (bottom of the logged interval) at low concentrations ranging from 0.06 to 0.22 pCi/g. The maximum ^{60}Co concentration of 0.22 pCi/g was detected within the saturated interval at a depth of 228.5 ft.

^{154}Eu contamination was detected continuously between 45 and 52 ft at low concentrations ranging from 0.21 to 0.95 pCi/g. The maximum ^{154}Eu concentration of 0.95 pCi/g was detected at the 46.5-ft depth. A single occurrence of ^{154}Eu contamination was detected at 57 ft at a low concentration of 0.14 pCi/g.

The plot of the naturally occurring radionuclides shows that the potassium-40 (^{40}K) concentrations increase at 46 ft. This increase probably represents the contact between sand and underlying finer grained material within the Hanford formation. The driller's log notes a contact between "sand" and "sand and loam" at 41 ft. An increase in concentrations of thorium-232 (^{232}Th) and ^{40}K at approximately 82 ft may represent the contact between the Hanford formation and the early Palouse soil unit. Sharp decreases in the ^{40}K and ^{232}Th concentrations from 95 to 98 ft and 103 to 107 ft and a slight increase in the uranium-238 (^{238}U) in the lower zone are diagnostic of the two caliche layers within the underlying Plio-Pleistocene interval. The drilling log reports that the lithology between 95 and 115 ft was caliche, sand, and gravel. These caliche layers can be correlated among boreholes across the T Tank Farm.

Most of the ^{238}U concentrations shown on the plot of the naturally occurring radionuclides appear to be affected by the presence of radon gas in the borehole. Quantitation of natural ^{238}U is based on measurement of gamma rays from the daughter isotope bismuth-214 (^{214}Bi) at 609.32 keV or alternately at 1764.5 keV. Normally, ^{214}Bi (half life of 19.7 minutes) achieves secular equilibrium with ^{238}U after several million years, primarily because of the long half lives for intermediate daughters, particularly uranium-234 (^{234}U), thorium-230 (^{230}Th), and radium-226 (^{226}Ra) (247,000, 80,000 and 1,602 years, respectively). Radon-222 (^{222}Rn) is produced by the decay of ^{226}Ra . Because ^{222}Rn is a gas, it can migrate through the subsurface. ^{222}Rn has a half-life of 3.8 days, and the remaining daughters in the decay chain to ^{214}Bi have half lives on the order of minutes. When radon accumulates, ^{214}Bi will achieve secular equilibrium with ^{222}Rn within a few hours, resulting in a net increase in ^{214}Bi as radon progeny are deposited on the casing, and ^{238}U concentrations calculated from SGLS data will be higher. As the radon gas

dissipates, the "excess" ^{214}Bi associated with the radon will quickly decay away, and ^{238}U concentrations will appear to decrease. This phenomenon appears to have played a major role in the ^{238}U concentrations observed in borehole 299-W10-3.

When logging was performed, the borehole appeared to have been closed for a long time, allowing radon gas to accumulate inside the casing. For log runs 1 through 4, the borehole was logged from the ground surface to a depth of 213 ft. Because the sonde moves downward relatively slowly, radon concentrations apparently remained fairly undisturbed during logging. When the sonde was withdrawn after logging, the faster motion out of the borehole encouraged upward movement of air and loss of radon. The abrupt changes in ^{238}U at 36 to 37 ft, 94 to 95 ft, and 153 to 154 ft coincide with the transitions between logging runs on separate days, and most likely represent changes in radon concentration rather than variations in ^{238}U content. Relatively high ^{238}U concentrations from 181 to 214 ft are probably associated with the perforated interval from 194 to 230 ft that represents the zone of radon infiltration. Log run five (229 to 213 ft) probably represents natural ^{238}U concentrations not affected by the radon gas, because the sonde was run to the bottom of the borehole and logging was performed in an upward direction, encouraging greater air circulation prior to data collection.

Log run six represents a repeat run from 70 to 55 ft used as a data quality check. Good agreement is observed for ^{137}Cs , ^{40}K , and ^{232}Th concentrations between the original and repeat runs, but ^{238}U concentrations are significantly lower in the repeat section, most likely due to radon loss associated with circulation of the air column in the borehole.

The SGLS total gamma-ray plot reflects the ^{137}Cs contamination that was detected above 10 pCi/g between 38 and about 90 ft. Below 90 ft, the variations in ^{137}Cs are less evident in the total gamma-ray plot because of the relatively low concentration compared to the scale of the plot.

Shape factor analysis was performed to determine the distribution of contamination with respect to the borehole. The ^{137}Cs shape factor results suggest that the source of the ^{137}Cs contamination detected from 40 to 52 ft, 76 to 80 ft, and 115 to 120 ft is uniformly distributed in the formation. The ^{137}Cs contamination from 53 to 75 ft, 80 to 115 ft, and 128 to 140 ft appears to be somewhat localized to the borehole, suggesting that these zones are the result of dragdown, indicating that the contaminant plumes were encountered when the borehole was drilled. From 90 to 96 ft, the ^{137}Cs contamination is probably confined to the outer surface of the casing. The shape factors cannot be interpreted from 104 to 105 ft and 109 to 110 ft because the ^{137}Cs count rate rises and falls too quickly and is distorted by thin bed geometry. Shape factor analysis cannot be performed on the dual casing interval below 181 ft.

Historical gross gamma-ray logging was conducted in borehole 299-W10-3 in 1959, 1970, and 1976 and published by Fecht et al. (1977). From that data, Fecht et al. (1977) suggest that radionuclide contamination beneath the 216-T-7 crib moved downward in the sediment column 1.8 meter (m) (about 6 ft) between 1959 and 1976. The other boreholes used to monitor the 216-T-7 crib facility were not drilled deep enough to confirm or refute this observation. The data

from this borehole also indicate that waste possibly broke through to the ground water beneath this site (Fecht et al. 1977).

Borehole 299-W10-3 was used as a ground water monitoring well for the 216-T-7 crib and tile field. The 216-T-7 crib is located in the southwest quarter of the T Tank Farm, and the tile field is located to the west, just outside the T Tank Farm fence. Figure F-1 shows the location of these features relative to borehole 299-W10-3 and the T Tank Farm. The 216-T-7 crib is a wooden structure approximately 12 ft by 12 ft, and the associated tile field is approximately 310 by 84 ft. The liquid release point was approximately 20 ft below the ground surface. The crib and tile field operated between 1948 and 1955 and were deactivated after reaching design capacity. During the operational period, approximately 29,100,000 gal of second-cycle waste, 221-T building waste, and 224-T building waste was added to the soil column (DOE 1992). Radionuclides within the waste include ^{137}Cs , ruthenium-106 (^{106}Ru), strontium-90 (^{90}Sr), ^{60}Co , ^{238}U , and plutonium (DOE 1992).

The 216-T-32 cribs are located to the west of the T Tank Farm approximately 100 ft north of the 216-T-7 crib. Crib 216-T-32 consists of two wooden structures approximately 12 by 12 ft and 26 ft deep, located about 40 ft apart. The cribs were fed by a single pipeline from tank T-201. The crib facility operated between 1946 and 1952. During its operational period, approximately 7,660,000 gal of transuranic (TRU)-contaminated waste was added to the soil column (DOE 1992). Radionuclides within the waste include ^{137}Cs , ^{106}Ru , ^{90}Sr , ^{60}Co , ^{238}U , and plutonium (DOE 1992).

The ^{137}Cs contamination detected in the vadose zone around borehole 299-W10-3 can be attributed to waste disposal at the nearby 216-T-7 crib and tile field, and probably also from the 216-T-32 cribs. Historical gross gamma-ray anomalies in boreholes surrounding the 216-T-7 crib correlate with anomalies identified in borehole 299-W10-3. A review of SGLS data presented in the Tank Summary Data Reports for tanks T-109 (DOE 1998b) and T-112 (DOE 1998c) shows no correlation with the contamination detected in borehole 299-W10-3.

The occurrence of low ^{60}Co and ^{137}Cs concentrations below 214 ft suggests that there is contamination in the ground water. This observation concurs with Fecht et al. (1977), which suggested that breakthrough to the ground water probably occurred under the 216-T-7 crib and tile facility. The drilling log reports that the water level was measured at 214 ft after the borehole was deepened in 1951 and 208.8 ft in 1993; the water level is now (1998) measured at 220.6 ft. No ground water sample data were available to confirm or refute this interpretation.

Borehole 50-00-01

Borehole 50-00-01 is located approximately 60 ft north of the T Tank Farm (See Figure F-1). This borehole is located outside of the T Tank Farm's perimeter fence and about 120 ft north-northeast of tank T-101. The Hanford Site designation is 299-W10-08. Information concerning the construction of this borehole is provided in the drilling log, the well construction and completion report, a well maintenance planning report, and Chamness and Merz (1993).

Borehole 50-00-01 was drilled in June 1973 to a depth of 251 ft using 6-in.-diameter casing. The borehole was completed by installing a number 10 slotted screen from 205 to 251 ft inside the 6-in. casing and pulling back the 6-in. casing to 210 ft. Details regarding the exact size and composition of the slotted screen casing were not available for review. The drilling log and Chamness and Merz (1993) do not indicate that grout was used to finish the installation of the borehole.

Borehole 50-00-01 was logged from August 3-6, 1998. The zero reference for the SGLS was the ground surface (0 ft). The top of the 6-in. casing is located 2.8 ft above the ground surface. The ground water level was measured at a depth of 227.1 ft. The total logging depth reached by the SGLS was 246 ft. A correction factor for 0.280-in.-thick casing was applied to the data acquired from the ground surface to 210 ft. For the slotted screen interval between 205 and 246 ft, a casing correction factor equivalent to 5-in. casing was used. The use of this correction factor for the slotted screen interval will probably slightly overestimate the concentrations. A correction factor was also applied for the 18.9-ft water-filled interval at the bottom of the borehole.

A combination log plot for borehole 50-00-01 is included as Figure F-3. The man-made radionuclides ^{137}Cs and ^{60}Co were detected by the SGLS. ^{137}Cs contamination was detected continuously from the ground surface to 15.5 ft at concentrations ranging from 0.1 pCi/g to a peak concentration of 9.45 pCi/g at 0.5 ft. Two isolated occurrences of ^{137}Cs contamination were detected at 96.5 and 117 ft at low concentrations of 0.23 pCi/g. Mostly continuous ^{137}Cs contamination was detected from 122 to 127 ft at low concentrations ranging from 0.2 to 0.42 pCi/g.

A single occurrence of ^{60}Co contamination was detected at 209.5 ft by the SGLS at a low concentration of 0.12 pCi/g.

The plot of the naturally occurring radionuclides shows an increase in ^{40}K concentrations between 40.5 and 56 ft that may represent an increase in clay content. The ^{40}K , ^{238}U , and ^{232}Th concentrations increase between 83 and 91 ft, which represents the early Palouse soil interval. The drilling log reports that mostly clayey-sandy-silt is present between those depths. The decrease in the ^{40}K and ^{232}Th concentrations from 91 to 113 ft represents the Plio-Pleistocene interval. The increase in the ^{238}U concentrations between 105 and 108 ft represents the lower caliche zone within the Plio-Pleistocene interval and can be correlated with many other SGLS log profiles across the T Tank Farm. The drilling log reports that the lithology between 95 and 115 ft was mostly sandy caliche with a calcareous matrix. At 113 ft, the ^{40}K and ^{232}Th concentrations increase slightly and probably represent the top of the Ringold Formation. Sand and gravel are reported by the drilling log between 125 and 251 ft. ^{40}K concentrations increase slightly below 205 ft; this increase is probably caused by the general correction factor that overcompensated for the ^{40}K concentrations in the screened interval, rather than a change in lithology.

The SGLS total gamma-ray plot reflects the influence of the ^{137}Cs contamination measured from the ground surface to about 14 ft and the variations in the measured concentrations of the

naturally occurring radionuclides throughout the borehole. Variations in total gamma activity related to lithology are evident at 40 ft and from 83 to 91 ft. The bottom of the 6-in. casing at 210 ft is also indicated on the SGLS total count-rate profile. Between 214 and 227 ft (top of the groundwater), the gross gamma-ray profile is slightly elevated and is probably the result of less shielding through the slotted screen interval. Below 227 ft, the presence of ground water has added additional shielding, resulting in slightly decreased gross gamma-ray activity at the detector.

Shape factor analysis was performed for the interval of ^{137}Cs near the ground surface. Shape factor analysis results suggest that the ^{137}Cs contamination detected from 1 to 4 ft is somewhat localized to the borehole. Shape factors cannot be interpreted below 5 ft because the count rate for the ^{137}Cs contamination drops rapidly below 1 count per second (cps).

Shape factor analysis was not performed to evaluate the distribution of the ^{60}Co contamination at 209.5 ft because the ^{60}Co count rate was below the minimum limit (2 cps) required to produce interpretable shape factors.

Historical gross gamma-ray profiles for borehole 50-00-01 were not available for review. Historically, this borehole was used to monitor ground water level and may have never been logged. Ground water samples from this well show elevated levels of technetium-99 (^{99}Tc) and tritium (^3H). Borehole 50-00-01 is located between boreholes 299-W10-15 and 299-W11-27 (See Figure F-1). Increases in specific conductance in these wells led to a RCRA Phase I groundwater quality assessment of the T waste management area (Hodges 1998). Evaluation of water chemistry data from these wells indicates that at least some of the observed groundwater contamination in this area may originate from within the T Tank Farm (Hodges 1998).

The ^{137}Cs contamination detected in the vadose zone between the ground surface and 15 ft could be attributed to an undetermined surface spill, pipeline leak, or airborne contamination. The low concentrations of ^{137}Cs contamination detected in the vadose zone from 122 to 126 ft likely migrated from a remote source along the bed boundary at the top of the Ringold Formation.

Borehole 50-00-02

Borehole 50-00-02 is located approximately 215 ft northeast of tank T-101 and 125 ft west of the trench facilities 216-T-14 through 216-T-17. This borehole is also known by the Hanford Site designation 299-W11-23. Information concerning the construction of this borehole is provided in the drilling log, the well completion report, and Chamness and Merz (1993). Borehole 50-00-02 was drilled in July 1973 to a depth of 252 ft using 6-in.-diameter casing. Because problems were encountered while finishing the borehole, the borehole had to be completed at 242 ft. A knifing tool was used to perforate the casing from 200 to 212 ft and 227 to 240 ft. There is no mention of grout in the drilling log or Chamness and Merz (1993).

Borehole 50-00-02 was logged from September 22-23, 1998. The zero reference for the SGLS was the top of the ground surface. The top of the 6-in. casing is about 2.5 ft above the ground

surface. A water level indicator measured ground water at a depth of 238 ft. The total logging depth reached by the SGLS was 240.5 ft.

A correction factor for 0.280-in.-thick casing was used for data analysis, which is based on the published value for wall thickness of schedule-40 steel pipe. A general correction was also applied for the 5.3-ft water-filled interval at the bottom of the borehole.

A combination log plot for borehole 50-00-02 is included as Figure F-4. The man-made radionuclides ^{137}Cs and ^{60}Co were detected by the SGLS around this borehole. ^{137}Cs contamination was detected continuously from the ground surface (0 ft) to 34.5 ft at concentrations ranging from 0.2 pCi/g to a peak concentration of 97 pCi/g measured at 1.5 ft, and from 36.5 to 42.5 ft at concentrations ranging from 0.2 pCi/g to a peak concentration of 3.2 pCi/g at 39.5 ft. Intermittent ^{137}Cs contamination was detected between 46.5 and 48 ft at low concentrations ranging from 0.2 to 0.3 pCi/g. Mostly continuous ^{137}Cs contamination ranging from 0.2 to 5.2 pCi/g was detected between 60 and 140 ft.

A single occurrence of ^{60}Co contamination was detected at 232.5 ft at a low concentration of 0.09 pCi/g.

The plot of the naturally occurring radionuclides shows an increase in ^{40}K concentrations between 34.5 and 59 ft that probably represents finer grained sediments within the Hanford formation, although the drilling log does not have enough detail to confirm this observation. An increase in the ^{238}U and ^{232}Th concentrations between 89 and 99 ft probably represents the early Palouse soil interval. The drilling log reports mostly silt is found between those depths. The decrease in the ^{40}K and ^{232}Th concentrations from 99 to 120 ft probably represents the Plio-Pleistocene interval. The increase in the ^{238}U concentrations between 111 and 118 ft indicates the lower caliche bed within the Plio-Pleistocene interval and can be correlated across the T Tank Farm. The drilling log reports that the interval between 100 and 125 ft was mostly silt, fine sand, and caliche. At 122 ft, slight increases in ^{40}K , ^{238}U , and ^{232}Th concentrations indicate the top of the Ringold Formation. The drilling log reports hard-packed sand and gravel between 126 and 252 ft. Below 237 ft, the ground water has provided additional shielding that results in slightly decreased ^{40}K concentrations.

The SGLS total gamma-ray plot reflects the ^{137}Cs contamination above 3 pCi/g between the ground surface and about 90 ft. The total gamma plot below 90 ft correlates well with the ^{40}K log. The early Palouse soil between 90 and 98 ft and the top of the Ringold Formation at 122 ft are clearly reflected on the total gamma-ray profile. Below 237 ft, the presence of ground water has added additional shielding, resulting in slightly decreased gross gamma-ray activity.

Shape factors were calculated for the measured gamma-ray spectra. Shape factor results from this borehole reflect a complex distribution of ^{137}Cs contamination. The ^{137}Cs shape factor results suggest that the ^{137}Cs contamination detected from 1 to 6 ft, 60 to 62.5 ft, 76 to 81 ft, 90 to 99 ft, and 101 to 106 ft is uniformly distributed in the surrounding formation. The shape factor results from 6 to 29.5 ft, 37.5 to 42 ft, 62.5 to 75.5 ft, 83 to 88 ft, and 127.5 to 133 ft indicate that the

¹³⁷Cs contamination is somewhat localized to the borehole. From 30 to 32 ft and 88.5 to 89.5 ft, the ¹³⁷Cs contamination appears to be confined to the outer surface of the casing. The shape factors cannot be interpreted from 32.5 to 33.5 ft because the count rate for the ¹³⁷Cs drops rapidly below 1 cps. Shape factors cannot be interpreted from 99 to 100.5 ft, 106.5 to 108.5 ft, and 133.5 to 134.5 ft because the ¹³⁷Cs count rate is just above 1 cps and is affected by thin bed geometry.

The shape factor results suggest the borehole intersected pre-existing zones of ¹³⁷Cs contamination that were then subject to dragdown. The available documentation does not indicate whether or not contamination was encountered as the borehole was drilled.

Shape factor analysis was not used to determine the distribution of the ⁶⁰Co contamination at 232 ft because the ⁶⁰Co count rate was below the minimum limit (2 cps) required to produce shape factor results.

Borehole 50-00-02 is located approximately 125 west of a waste complex comprised of trenches 216-T-14, 216-T-15, 216-T-16, and 216-T-17 (See Figure F-1). Each trench is approximately 275 ft long by 10 ft wide by 10 ft deep. Each was operated for less than 1 year during 1954. In that operating time, trenches 216-T-14, 216-T-15, and 216-T-16 each received about 264,000 gal of waste and trench 216-T-17 received about 207,000 gal of waste. These trenches all received first-cycle supernatant waste from the 221-T facility via tanks T-104, -105, and -106. Trench 216-T-14 is closest to borehole 50-00-02. The trenches were all deactivated after they reached their design capacity (DOE 1992). The known inventory of radionuclides include ¹³⁷Cs, ¹⁰⁶Ru, ⁹⁰Sr, ²³⁸U, and plutonium (Fecht et al. 1977).

Historical gross gamma-ray logs were not available for review for borehole 50-00-02, but were available for nearby borehole 299-W11-69. These measurements were conducted in 1963 and 1976 and published by Fecht et al. (1977). Borehole 299-W11-69 is located approximately 40 ft west and equidistant between the ends of the 216-T-14 trench. Borehole 299-W11-69 is about 130 ft northeast of borehole 50-00-02. The 1963 log for borehole 299-W11-69 shows anomalous activity at about 29 ft. By 1976, the thickness of that zone had increased downward to about 42 ft with some additional activity being detected at about 16 ft. There is also anomalous activity shown at the ground surface on both logs between 0 and about 3 ft. The ¹³⁷Cs contamination detected in borehole 50-00-02 is much more extensive and only generally correlates with the historical log data from borehole 299-W11-69.

The ¹³⁷Cs contamination detected in the vadose zone around borehole 50-00-02 could be attributed to the nearby trench complex, but the evidence is inconclusive. A surface spill or an underground pipeline leak could also be a plausible source. This ¹³⁷Cs contamination does not appear to correlate with contaminant plumes associated with the T Tank Farm.

Borehole 50-00-05

Borehole 50-00-05 is nominally associated with tank T-110; however, this borehole was not logged until July 15-20, 1998, well after the Tank Summary Data Report for tank T-110 (DOE 1995b) was completed in April 1995. Although the Tank Summary Data Report for tank T-110 did not include these data, the original conclusions regarding the tank are not altered.

Borehole 50-00-05 is located approximately 22 ft east of tank T-110 and is also known by the Hanford Site designation 299-W11-53. Information concerning the construction of this borehole is provided in the drilling log and Chamness and Merz (1993). Available records show that this borehole was drilled in September 1944, concurrent with tank farm construction, and was completed to a depth of 150 ft. The drilling log reports that 12-in. and 10-in. casings were telescoped down during the borehole installation, but all of the casings were withdrawn when the final 6-in.-diameter casing was installed from the ground surface to 150 ft. The 6-in. casing was pre-perforated between 50 and 150 ft. Drilling records indicate that a cement (grout) plug was added at the bottom of the borehole.

At the time of logging, both a 6-in. and 4-in. casing were observed at the ground surface. No records are available regarding the 4-in. casing, which is presumed to have been installed when other boreholes in the T Tank Farm were modified in the late 1970s. There is no information as to the depth of the 4-in. casing; however, it is assumed to be present over the entire length of the logged interval. Grout is also assumed to be present because it was the standard practice in the T Tank Farm to grout the annular space between the inner and outer casings after a borehole was modified. A correction factor for 0.517-in. casing was used for data reduction. This correction factor is equivalent to the combined thickness for 4-in. and 6-in. casings, based on published values for schedule-40 pipe. No correction was applied for annular grout.

The zero reference for the SGLS was the top of the 4-in. casing, which is approximately even with the ground surface. The borehole is located on a gentle slope about 3 ft above the level of the ground surface within the tank farm. The total logging depth achieved by the SGLS was 137.5 ft. A water level indicator measured standing water at 136.3 ft, which is probably due to surface runoff that has accumulated inside the casing. A general water correction was applied to the water-filled interval in the bottom 1.2 ft of the borehole.

A combination log plot for 50-00-05 is included as Figure F-5. The man-made radionuclides ^{137}Cs and ^{60}Co were detected by the SGLS in this borehole. ^{137}Cs contamination was detected continuously from the ground surface to 1.5 ft at concentrations ranging from 0.15 to 1.3 pCi/g. Isolated occurrences of ^{137}Cs contamination were detected at 15, 62, 70, 122, and 137.5 ft at low concentrations ranging from 0.14 to 0.29 pCi/g. The maximum ^{137}Cs concentration in this borehole was 1.3 pCi/g measured at the ground surface.

^{60}Co contamination was detected between 36.5 and 38.5 ft at low concentrations ranging from 0.5 to 0.8 pCi/g. The maximum ^{60}Co concentration in this borehole was 0.8 pCi/g measured at 38.5 ft.

Shape factor analysis could not be used to evaluate the distribution of radionuclide contamination around this borehole because the borehole is double cased. This configuration results in a higher level of downscatter continuum, which precludes calculation of reliable shape factors.

The plot of the naturally occurring radionuclides shows an increase in ^{40}K , ^{238}U , and ^{232}Th concentrations at approximately 43 ft that may represent an increase in clay and silt content. Between 50 and 62 ft, an abrupt decrease in natural radionuclides and total gamma count rate occurs. This decrease appears to be associated with the penetration of grout into the formation. Evaluation of historical gross gamma data indicates that the decrease in gross gamma count rates occurred abruptly in 1978, which corresponds to the time frame in which borehole modifications were being made in the T Tank Farm. The original driller's log indicates that 50 ft is the top of the "preperforated" interval. Therefore, the observed change in concentrations in this depth interval is attributed to the presence of an unknown amount of grout rather than any lithologic change. The decrease in the ^{40}K and ^{232}Th concentrations between 96 and 111 ft probably represents the Plio-Pleistocene unit. The increase in the ^{238}U concentrations between 106 and 109 ft is associated with the lower caliche bed and can be correlated across the T Tank Farm. The top of the Ringold Formation is probably located at 112 ft, where the ^{40}K and ^{232}Th concentrations increase slightly. Unfortunately, sample descriptions in the drilling log are not sufficiently detailed to confirm the above interpretation.

The SGLS total gamma-ray plot reflects the influence of the ^{137}Cs contamination near the ground surface and the variations in the naturally occurring radionuclides throughout the borehole. The most recently acquired historical gross gamma log (October 18, 1993) is presented on the combination plot. This profile generally corresponds to the SGLS total count rate profile.

The historical gross gamma log data from 1975 to 1993 and the log data summaries from 1973 to 1987 presented in Welty (1988) were reviewed. Log data summaries presented in Welty (1988) report anomalous gross gamma activity at 28 ft from data collected in September 1973. The earliest historical gross gamma logs available in electronic format (1975) show two anomalous activity peaks between 33 and 47 ft. A time-sequence plot of selected historical gross gamma-ray data acquired between 1975 and 1993 is included as Figure F-6.

The low concentrations of ^{60}Co contamination detected by the SGLS between 36 and 38 ft correspond to the upper activity peak observed in historical gross gamma logs. Examination of historical data indicates that the contamination was detected prior to 1973. The early gross gamma logs show two distinct zones: one at about 33 to 39 ft and a second at about 40 to 47 ft. A plot of average historical count rates from these depth intervals is included as Figure F-7. Note the steep decay observed in the historical data from January 1975 through about mid-1978. This cannot be explained by backward extrapolation of a decay curve for ^{60}Co . These data strongly suggest that other more short-lived radionuclides, such as ^{106}Ru , were the dominant source of gamma activity during the late 1970s.

The source of the ^{60}Co contamination is unknown. Low levels of ^{60}Co were also detected at depths from 40 to 45 ft in borehole 50-07-03, which is located approximately 100 ft north-northwest of 50-00-05 (see Figure F-1). However, no equivalent ^{60}Co or ^{137}Cs were detected in borehole 50-10-05, which is located approximately 60 ft to the southwest. ^{137}Cs was detected from 42 to 46 ft in borehole 50-07-07, which is located approximately 94 ft west-northwest of 50-00-05. In both 50-07-03 and 50-07-07, the contamination occurs approximately at the base of the tank farm excavation. The contamination observed in borehole 50-00-05 is significantly higher.

The Tank Summary Data Report for Tank T-110 (DOE 1995b) concluded that tank T-110 was not leaking and that the ^{137}Cs contamination measured in borehole 50-07-07 probably originated from a leak associated with tank T-107. The Tank Summary Data Report for Tank T-107 (DOE 1995a) concluded that the contamination detected in boreholes 50-07-03 and 50-07-07 was inconclusive and could be from a surface or subsurface source. Tank T-107 was declared an assumed leaker in 1975 on the basis of increased gross gamma-ray activity at the base of the tank from these two boreholes. One plausible source for this contamination is a leak from the southeast quadrant of tank T-107. However, borehole 50-00-05 is located on the periphery of the tank farms and the observed contamination occurs at a higher elevation, suggesting it is unlikely that contamination originating from T-107 flowed along the base of the tank farm excavation to this borehole. Because borehole 50-00-05 is located 22 ft east of tank T-110 on the periphery of the tank farm, it is probably located above the side slope of the tank farm excavation and the contamination may be at approximately the contact between the tank farm excavation and undisturbed soil. A more credible source would thus be located to the east, or upslope along the excavation contact, suggesting the contamination may have resulted from a pipeline leak or a leak or spill from the 241-T-153 or 241-TR-153 diversion boxes. The ^{60}Co observed in boreholes 50-00-05 and 50-07-03 may be related to a common plume that originated at a leak or spill to the east and flowed westward along the excavation boundary. Additional boreholes along the eastern margin of the T Tank Farm would be required to investigate this possibility.

Summary and Conclusions

Of the four boreholes discussed in this appendix, at least three appear to have intersected subsurface contamination unrelated to leaks from the T Tank Farm. Given the complex nature of subsurface geologic conditions, the extent of the vadose zone, tank farms operational history, and the proximity of liquid waste disposal sites, it is highly likely that vadose zone contamination in the vicinity of the T Tank Farm has been affected by multiple plumes originating from a variety of sources, which include tank leaks, liquid waste disposal sites, pipeline leaks, and spills or leaks associated with routine tank farm operations.

As shown on Figure F-1, a number of boreholes exist in the vicinity of liquid waste sites that were not logged as part of the tank farms vadose zone characterization project. These boreholes should be logged and the data evaluated in the context of the existing baseline data for the T Tank Farm. Such an evaluation would help significantly in assessing the relative extent to which tank waste has impacted the groundwater in the vicinity of T Tank Farm.

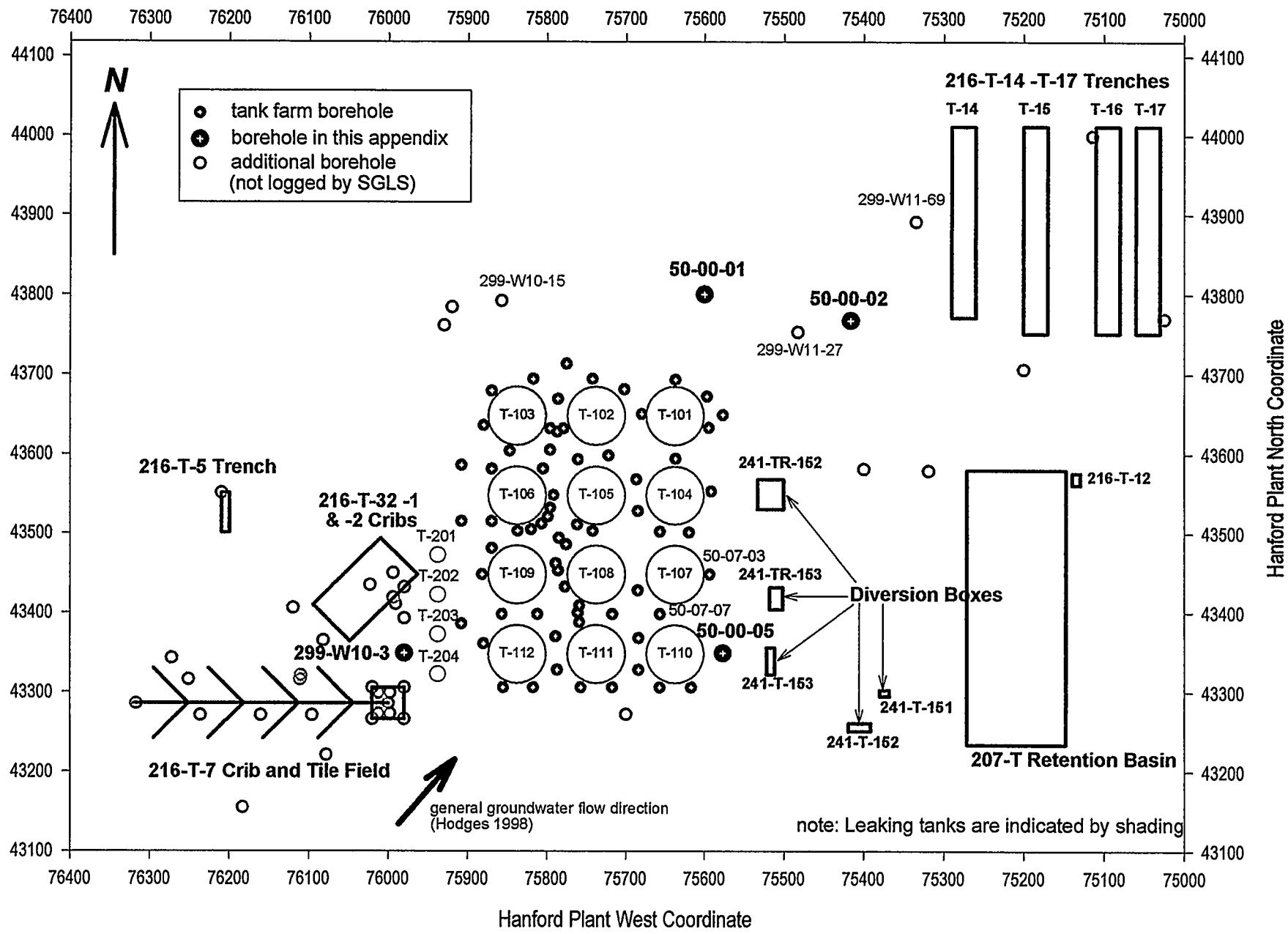


Figure E-1. T Tank Farm and Vicinity

299-W10-3 Combination Plot

Note: repeat log data indicated by + in a contrasting color

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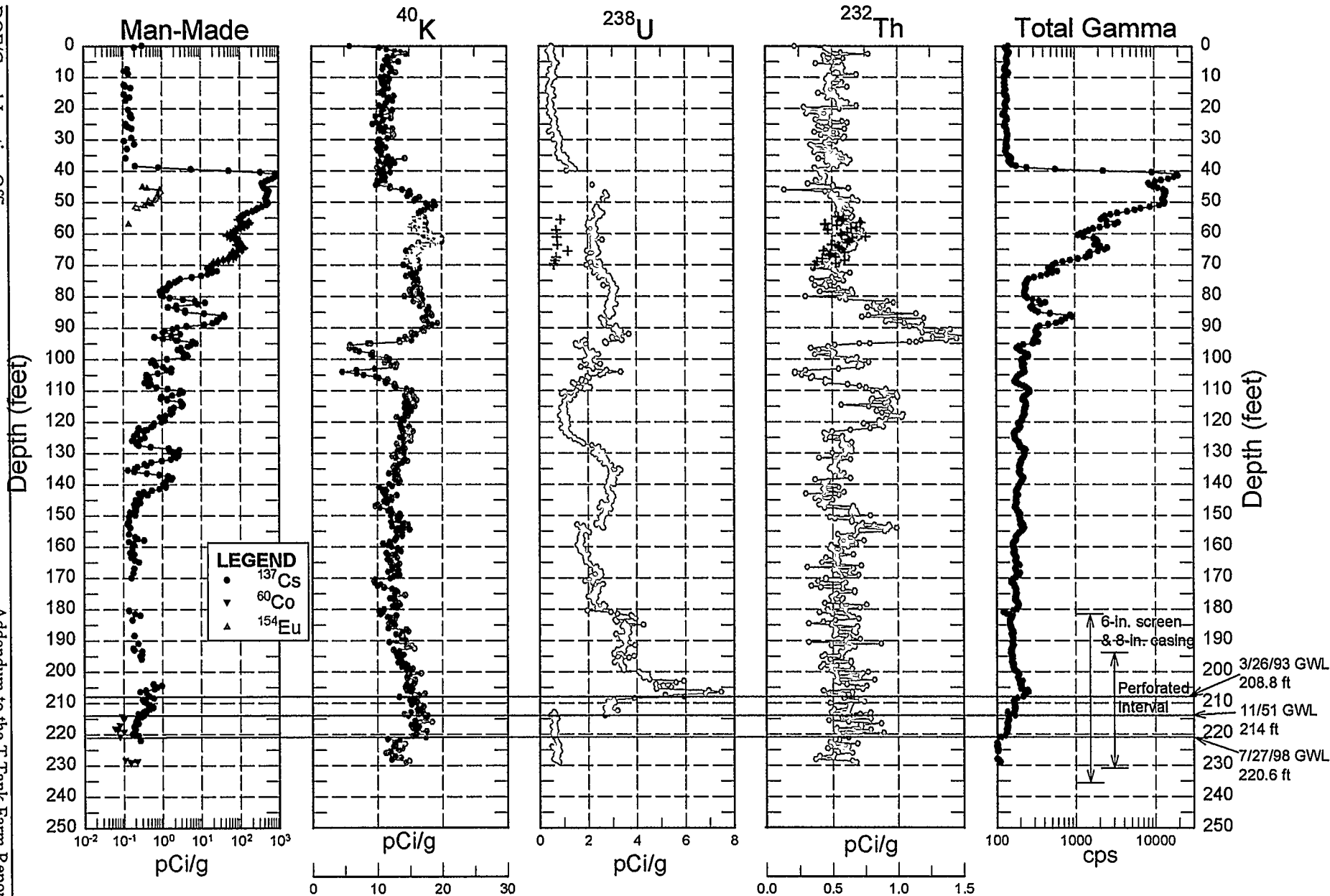


Figure E-2. Log Plot for 299-W10-3

50-00-01 Combination Plot

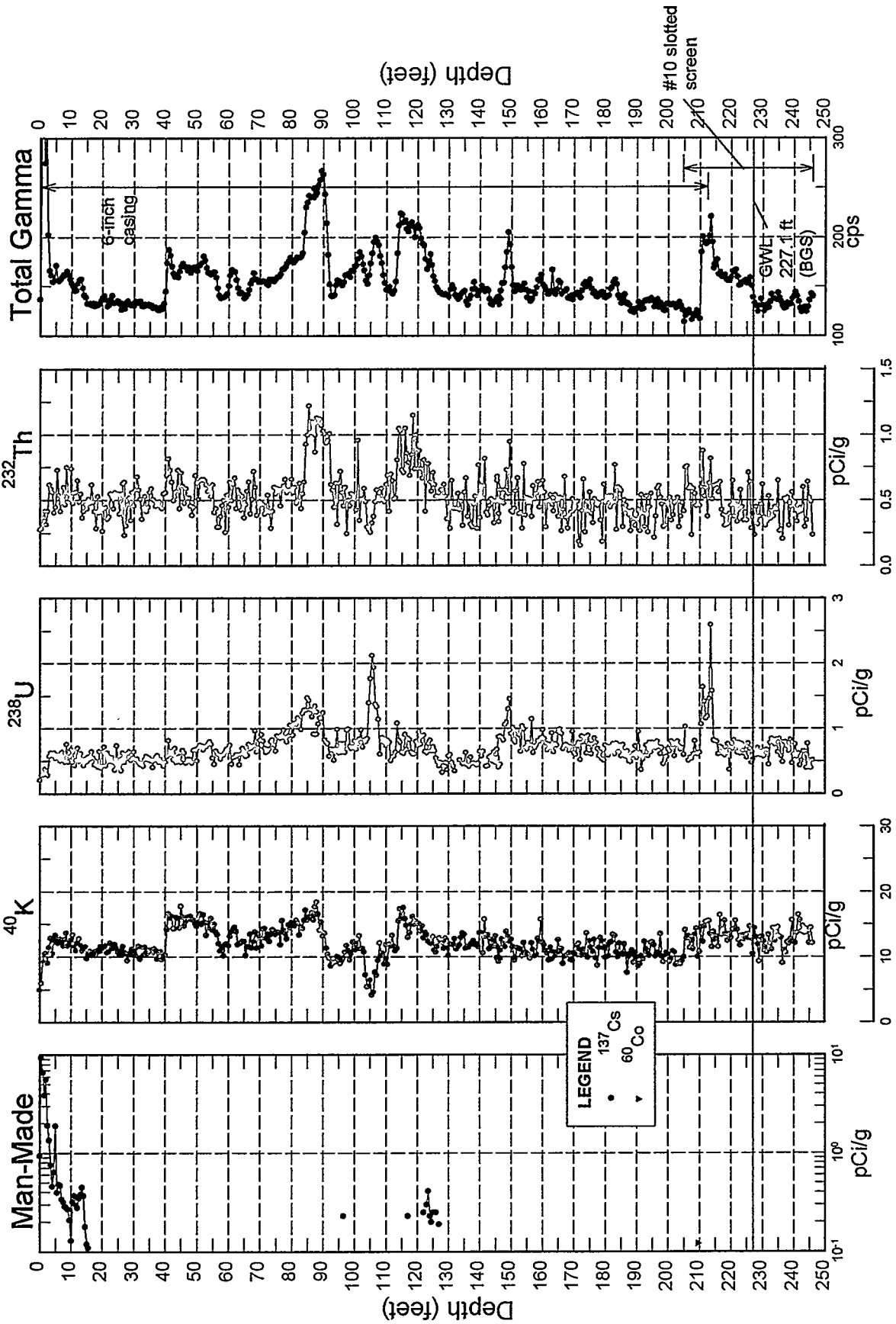


Figure E-3. Log Plot for 50-00-01 (299-W10-8)

50-00-02 Combination Plot

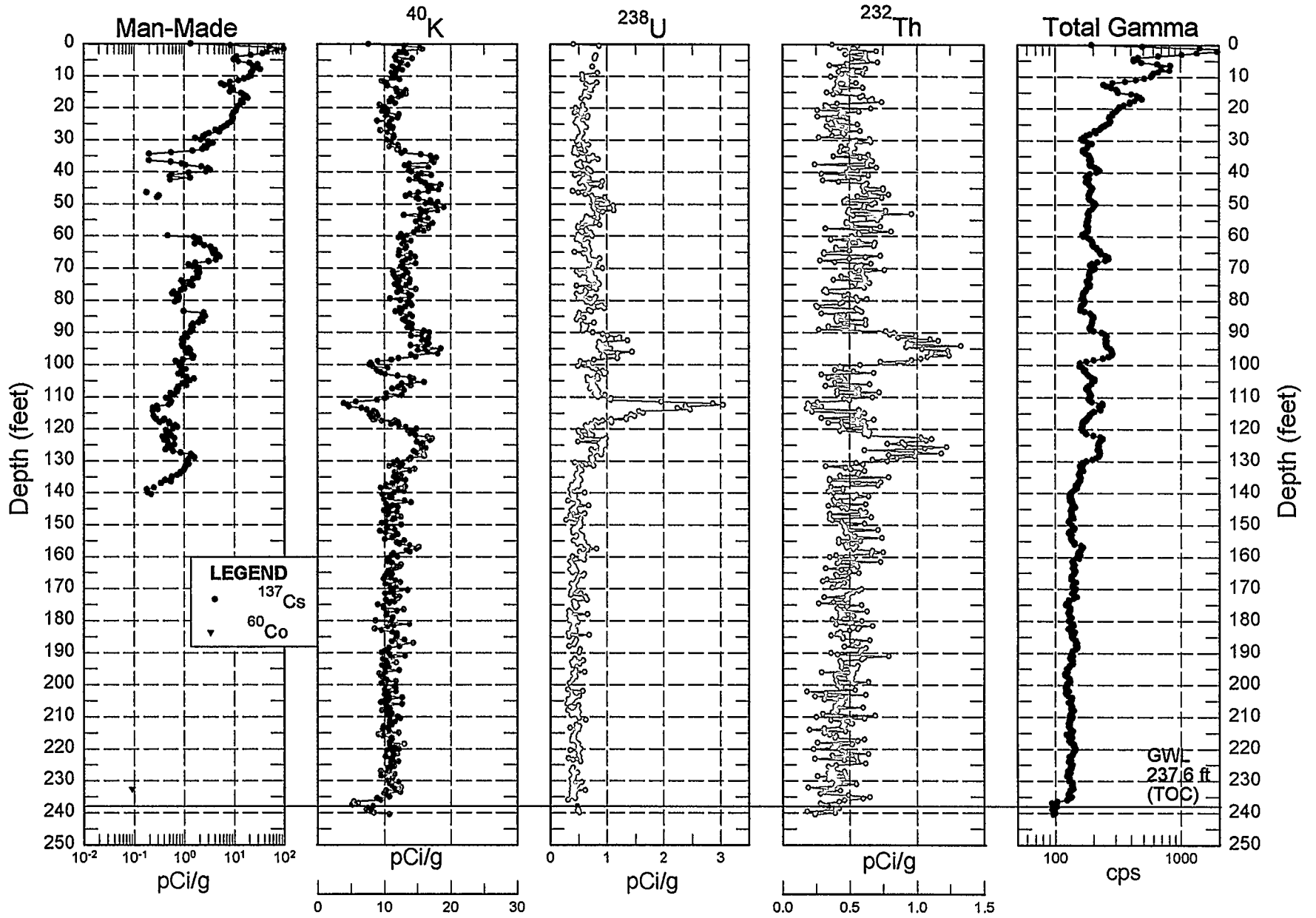


Figure E-4. Log Plot for 50-00-02 (299-W11-23)

50-00-05 Combination Plot

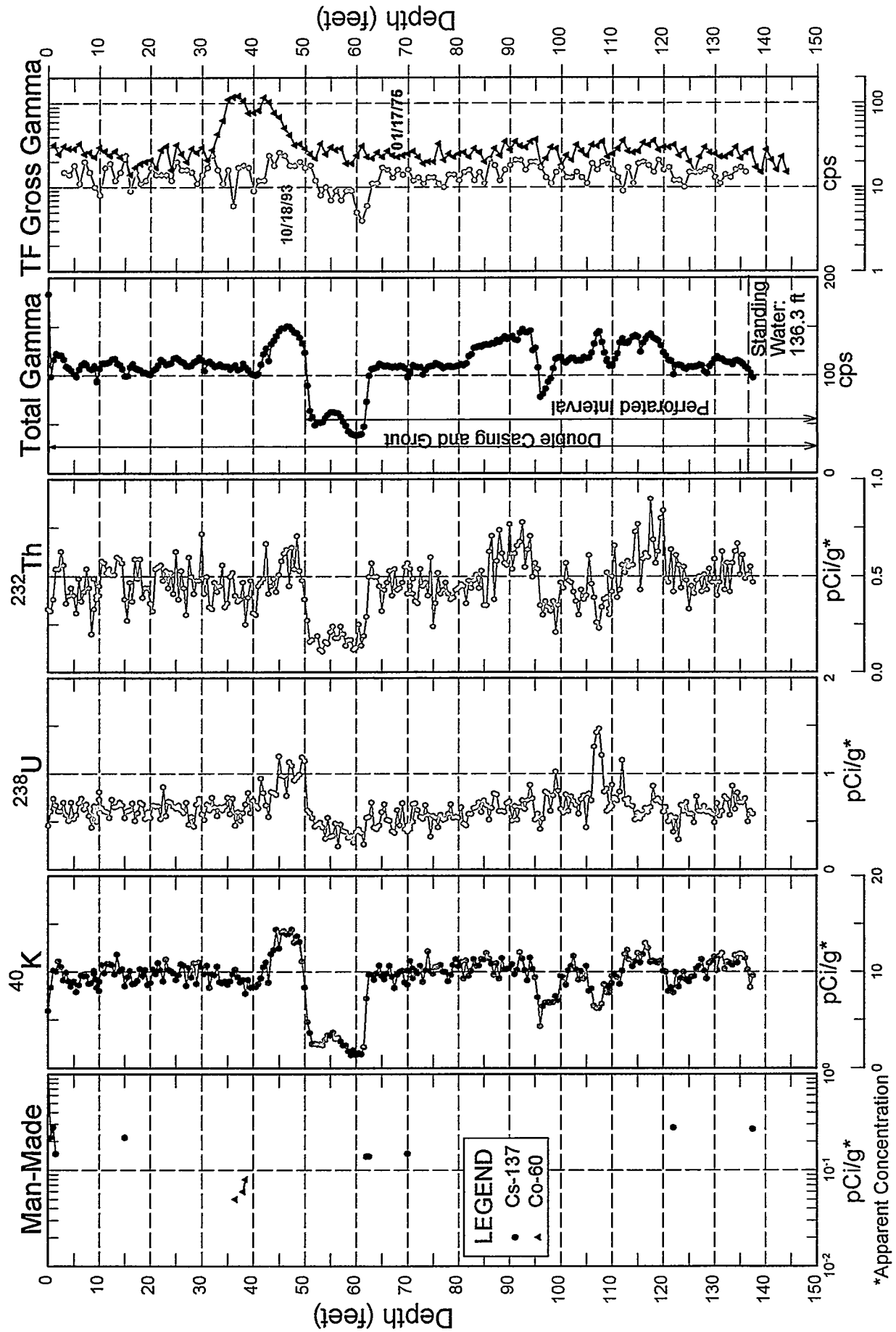


Figure E-5. Log Plot for 50-00-05 (299-W11-53)

Historical Gross Gamma Plot for Borehole 50-00-05

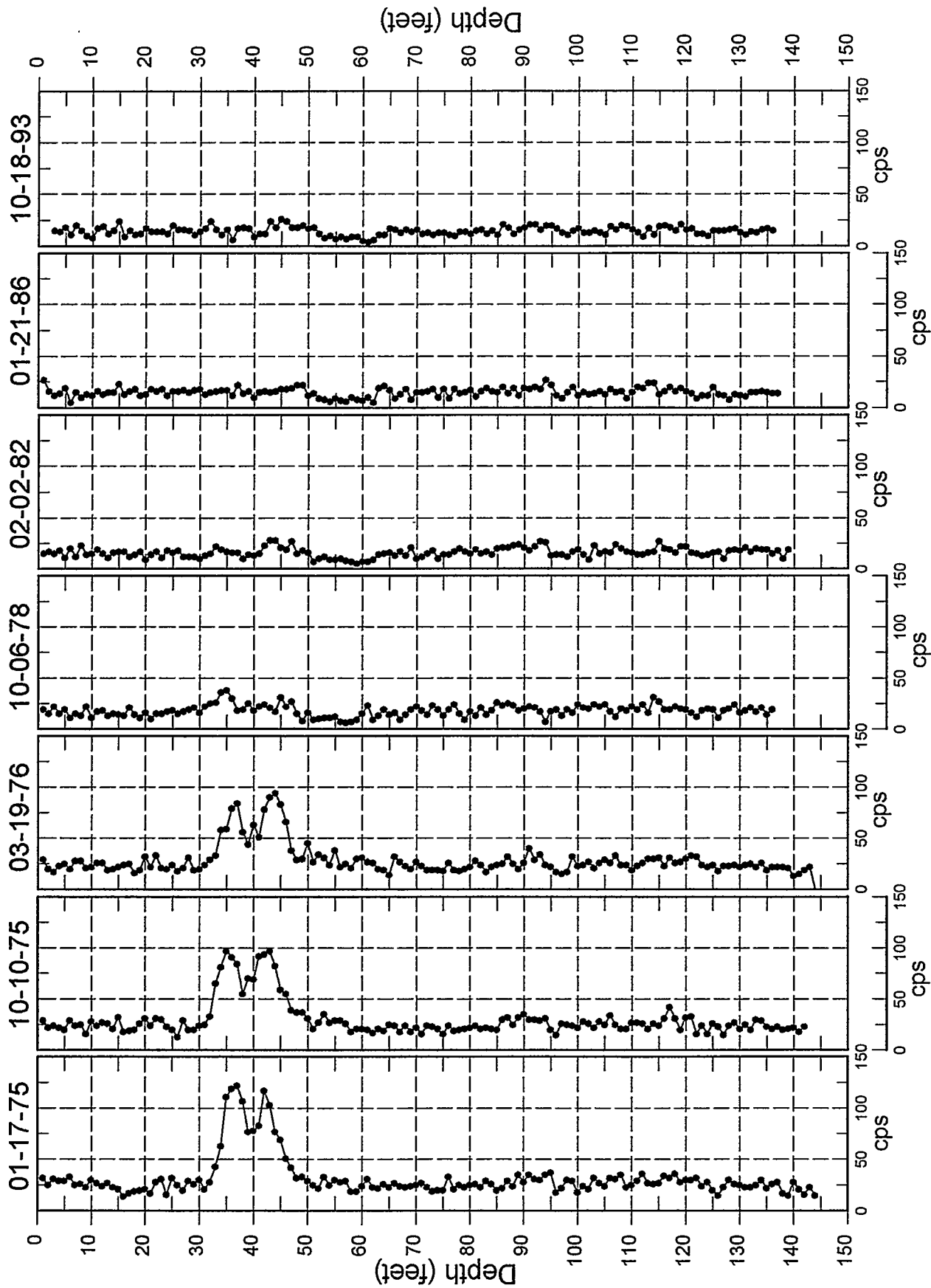


Figure E-6. Historical Gross Gamma Logs for 50-00-05 (299-W11-53)

50-00-05 Historical Gross Gamma Data

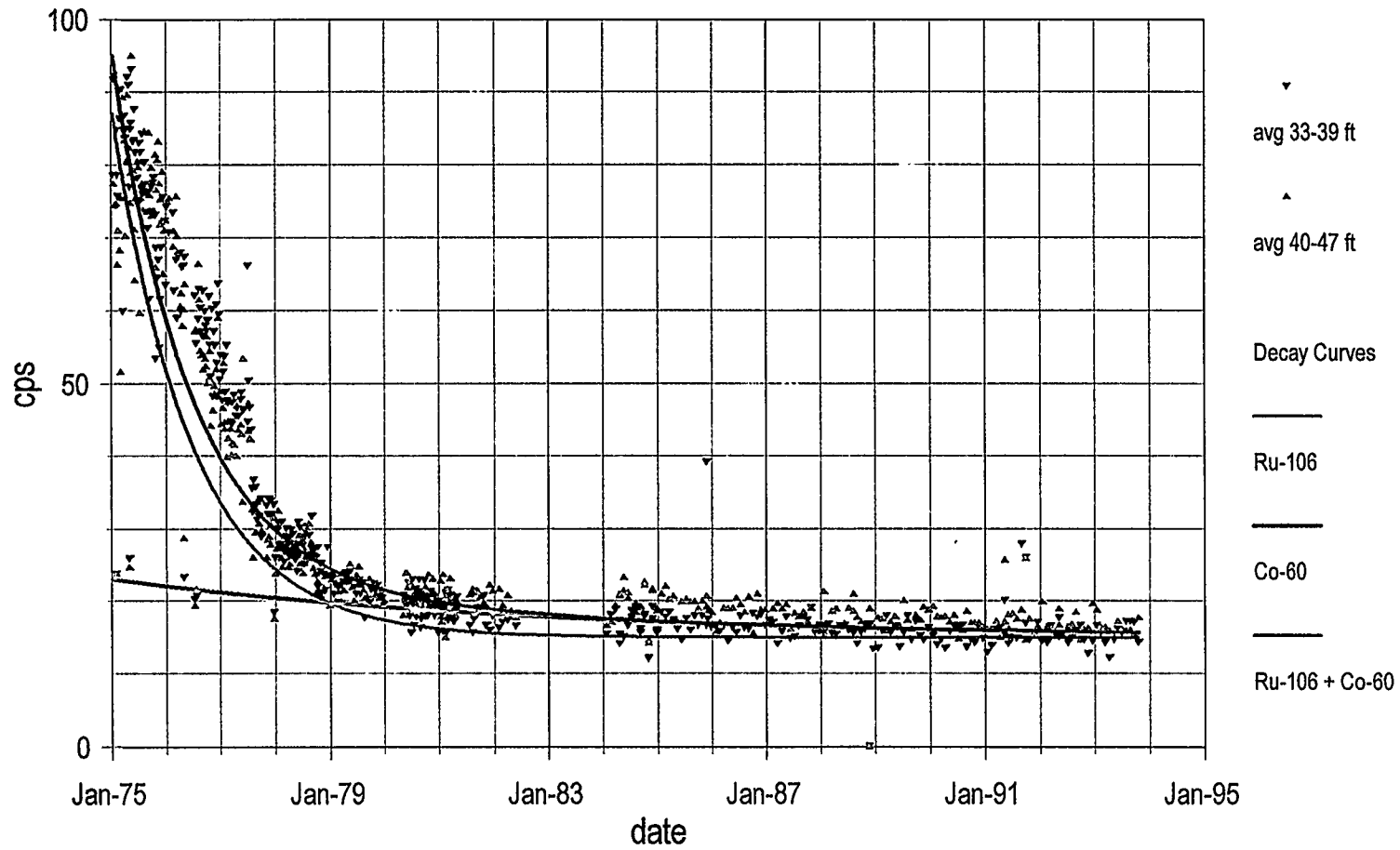


Figure E-7. Historical Time Series Data for 50-00-05 (299-W11-53)