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GJO-HAN-18

Hanford Tank Farms Vadose Zone

Addendum to the C Tank Farm Report

September 2000

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U.S. Department of Energy

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

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Hanford Tank Farms Vadose Zone

Addendum to the C Tank Farm Report

September 2000

Prepared for
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Office of River Protection
Richland, Washington

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Hanford Tank Farms Vadose Zone

Addendum to the C Tank Farm Report

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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 at all Hanford single-shell tank (SST) farms using high resolution spectral gamma-ray logging methods in existing boreholes surrounding the tanks. In 1998, Congress established the Office of River Protection (ORP) at Hanford, an autonomous organization that reports directly to DOE Headquarters. ORP is responsible for managing all aspects of the Tank Waste Remediation System (TWRS) project, including characterization of the vadose zone potentially impacted by the SSTs. The responsibility for the baseline characterization project, originally under the auspices of DOE-RL, was transferred to ORP in December 1998.

The C Tank Farm Report, which was prepared as part of this characterization project, was issued as document GJO-98-39-TAR, GJO-HAN-18 in July 1998. That document reported the results of the spectral gamma logging characterizations at the C Tank Farm that were originally reported in Tank Summary Data Reports for each individual tank. The C 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 were used to develop a three-dimensional model of the distribution of the contamination in the vadose zone in the immediate vicinity of the C Tank Farm.

Since the original C Tank Farm Report was issued, additional data have been collected, new analysis techniques developed, 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 C Tank Farm.

A high rate logging system was developed and deployed in the C 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. Three boreholes in the C Tank Farm were logged with the high rate logging system. ^{137}Cs was identified in two of these boreholes. The high gamma flux in the third borehole was attributed to a remote source such as a pipeline.

Other data collected since the C Farm Report was issued include repeat logging measurements acquired approximately 2 years after the initial baseline data were collected. Measurements from one of these boreholes have indicated radionuclide concentration increases that are attributed to migration of contaminants through the vadose zone at the present time. The maximum depth of cobalt-60 (^{60}Co) has increased in borehole 30-06-10 from 112.0 ft in 1993 to 116.5 ft in 1997 and then to 123.5 ft in 1999. Unfortunately, little data are available for a reliable assessment of recent movement because routine gross gamma logging was discontinued in 1994. However,

ORP is planning to initiate a spectral gamma monitoring program in fiscal year (FY) 2001 that will assess and track any potential and/or ongoing contaminant movement for selected drywells in the C Tank Farm.

The interpreted data set presented in the C Tank Farm Report was revised to incorporate the high rate data and to remove contaminants linked to borehole effects. The decision to remove additional contamination from boreholes was based on the results of the previous shape factor analysis, experience gained in this and other tank farms, and the judgment of the analysts. This new data set was used to create the three-dimensional visualizations of subsurface contamination presented in this addendum. As a result, the plumes depicted in the visualizations are more realistic and have been used to provide an estimate of contaminant inventories. The visualizations will also prove useful in directing future characterization work in the C Tank Farm.

This addendum completes the baseline characterization of the C Tank Farm. The purpose of the characterization was to identify the nature and extent of contamination associated with gamma-emitting radionuclides in the C Tank Farm using data collected from existing boreholes. This work serves as a baseline against which future measurements can be compared to identify changes in the vadose zone, to track gamma-emitting radionuclide contaminant movement, and to identify or verify future tank leaks.

1.0 Introduction

The C Tank Farm is located in the central portion of the 200 East Area of the Hanford Site (Figures 1 and 2). This tank farm consists of 12 first-generation 100-series single-shell tanks (SSTs) and four 200-series tanks. Each 100-series tank has a capacity of 530,000 gallons (gal), and each 200-series tank has a capacity of 55,000 gal; therefore, the C Tank Farm has a capacity to store a total of 6,580,000 gal of waste. These tanks currently store a total of 1,812,000 gal of high-level nuclear waste that was generated primarily from the chemical processing of irradiated uranium fuel. Tanks C-101, -110, -111, -201, -202, -203, and -204 are currently listed in Hanlon (2000) as "assumed leakers" and are estimated to have leaked a total of 29,250 gal of high-level radioactive liquid to the vadose zone.

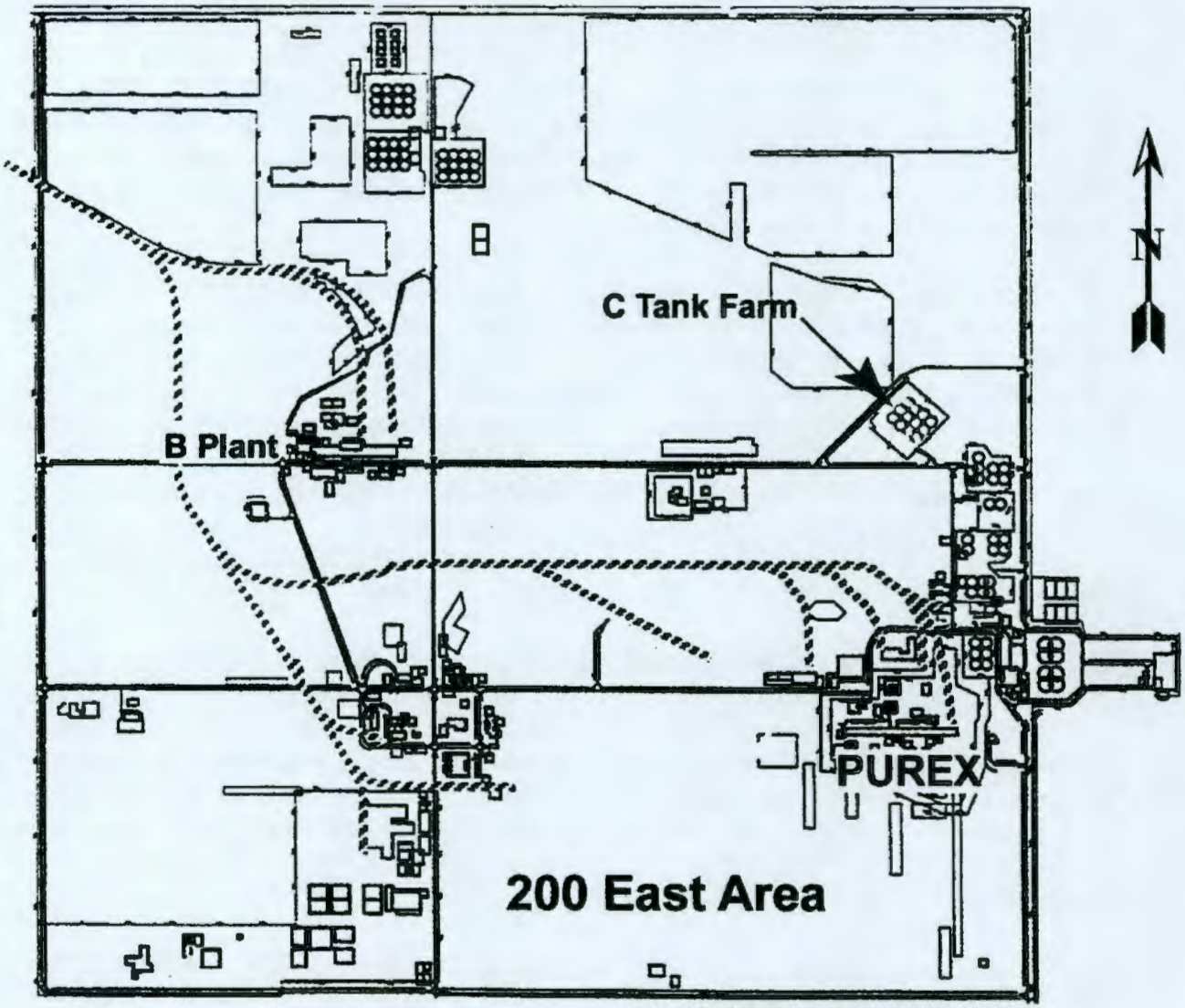
In 1994, the U.S. Department of Energy (DOE) Richland Operations Office (DOE-RL) requested the DOE Grand Junction Office (GJO), Grand Junction, Colorado, to perform a baseline characterization of gamma-emitting radionuclides in the vadose zone at all Hanford SST farms using high resolution spectral gamma-ray logging methods in existing boreholes surrounding the tanks (Figure 3). In 1998, Congress established the Office of River Protection (ORP) at Hanford, an autonomous organization that reports directly to DOE Headquarters. ORP is responsible for managing all aspects of the Tank Waste Remediation System (TWRS) project, including characterization of the vadose zone potentially impacted by the SSTs. The responsibility for the baseline characterization project, originally under the auspices of DOE-RL, was transferred to ORP in December 1998.

DOE-GJO deployed 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 an n-type high purity germanium (HPGe) semiconductor detector with approximately 35-percent efficiency. The baseline C Tank Farm geophysical logging was completed in 1997, and the results of the radionuclide concentration logs for individual boreholes were compiled and presented in 12 individual Tank Summary Data Reports (DOE 1997b, 1997c, 1997d, 1997e, 1997f, 1997g, 1997h, 1997i, 1997j, 1997k, 1998a, and 1998b).

The C Tank Farm Report was completed by the Hanford Tank Farms Vadose Zone Project in July 1998. Since it was completed, additional work has been performed, and modifications to the original report are warranted. This document will discuss those modifications and serves as an addendum to the original report. The original report was issued as document GJO-98-39-TAR, GJO-HAN-18.

1.1 Background

A compilation of all borehole data collected for the baseline characterization was presented in the original C Tank Farm Report. Included within that report were three-dimensional visualizations of contaminant distribution in the vadose zone around the C Tank Farm.



Modified from Narbutovskih (1998)

Figure 1. Map of the 200 East Area Showing the Location of the C Tank Farm

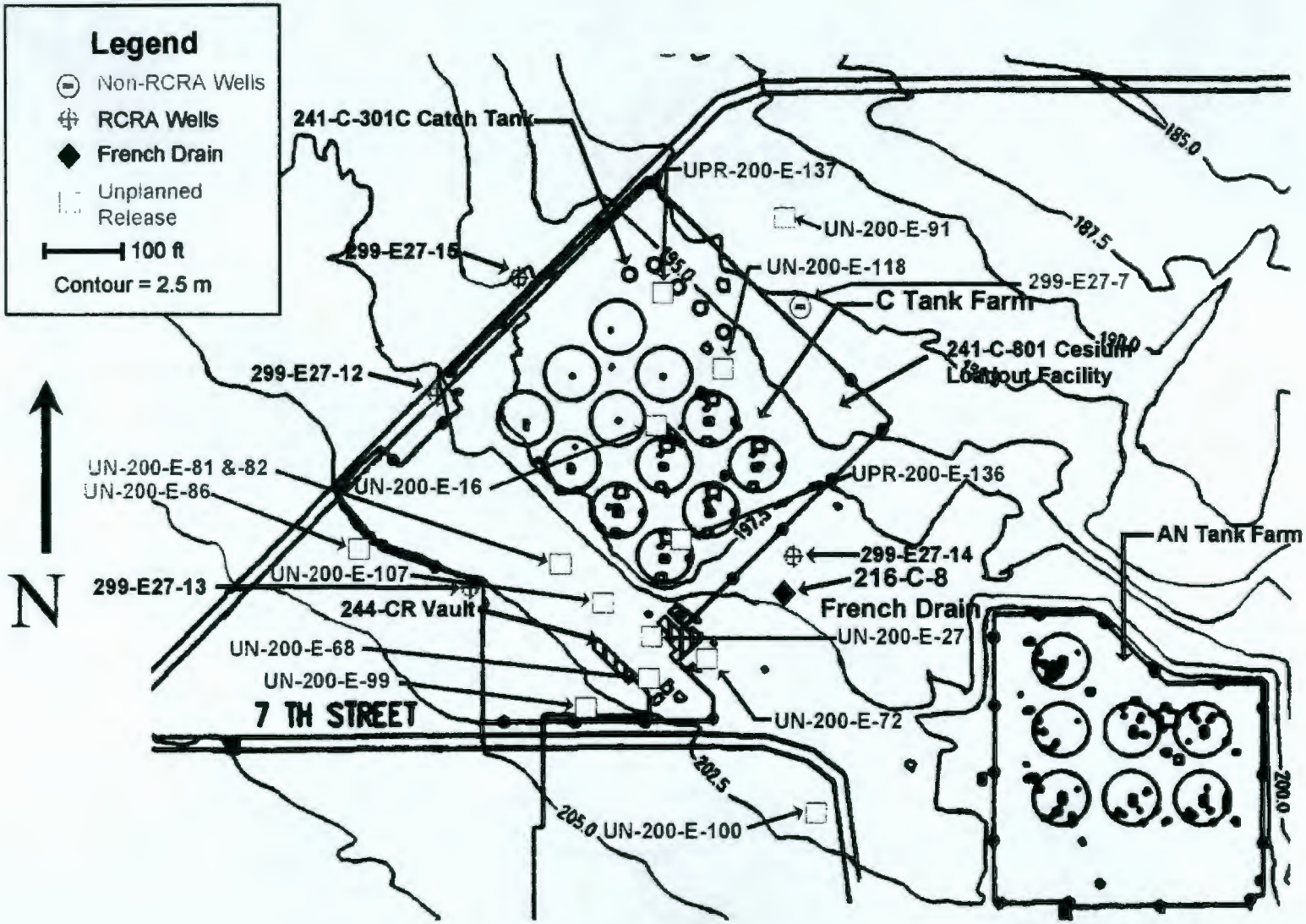


Figure 2. Map of Boreholes, Groundwater Wells, and Waste Sites Near the C Tank Farm

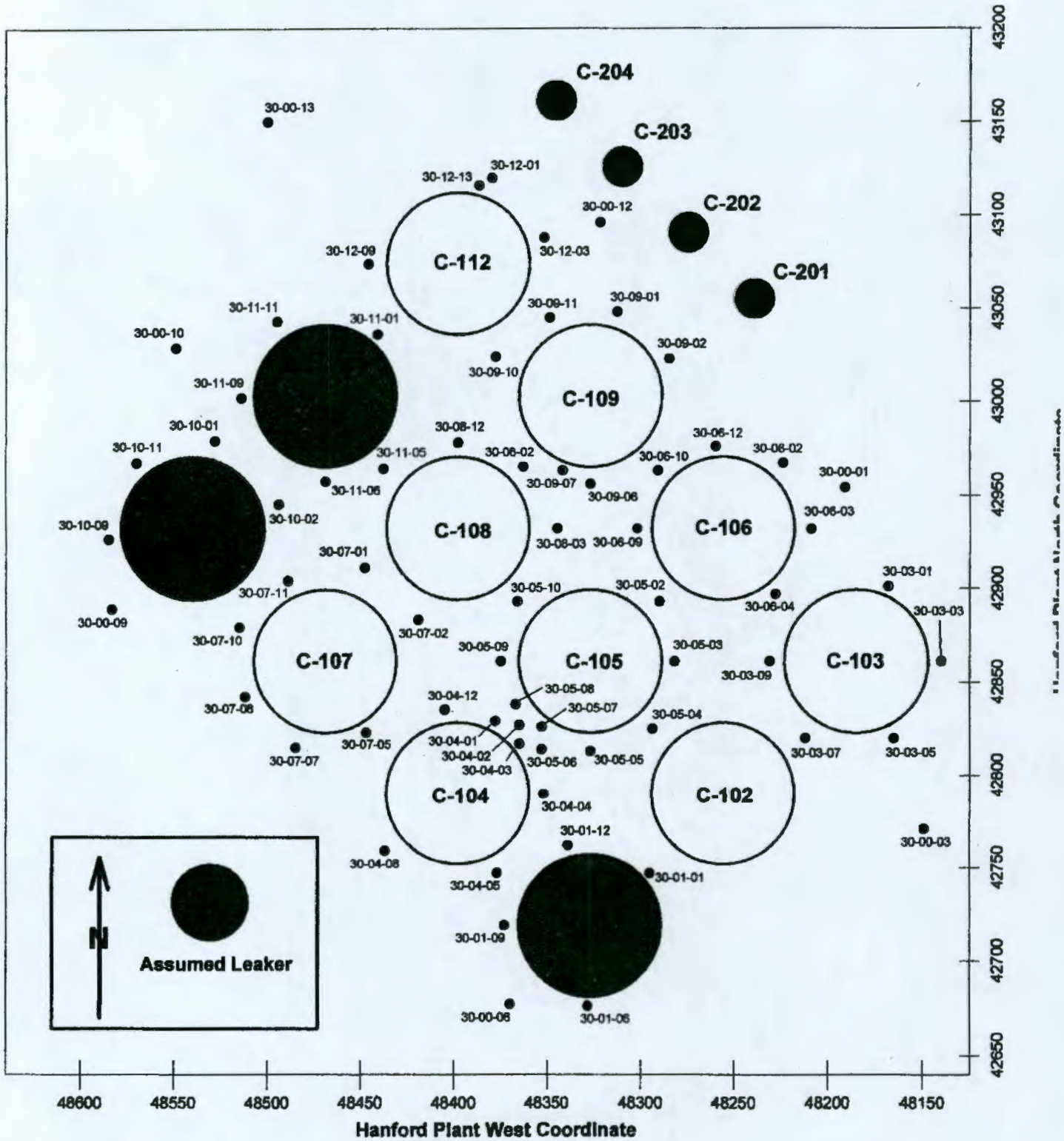


Figure 3. Map of the C Tank Farm Showing the Location of Monitoring Boreholes

Since the original C Tank Farm Report was issued in 1998, additional data have been obtained and enhancements have been made in the data evaluation process. Shape factor analysis had been applied to the original baseline spectral data prior to issuing the C Tank Farm Report. However, experience in the interpretation of these data led to a more liberal approach when removing data suspected of being attributed to borehole effects. Other data have been acquired by repeat logging of selected borehole intervals. Finally, a high rate logging tool has been deployed to investigate intervals of very 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 relevant to the C Tank Farm, and to provide revised visualizations of subsurface contamination that are based on re-evaluation of the original data, as well as incorporation of high rate log data. Tank farm conditions, operational history, current status, and geologic conditions are discussed in the original C Tank Farm Report and in relevant Tank Summary Data Reports (DOE 1997a, 1997b, 1997c, 1997d, 1997e, 1997f, 1997g, 1997h, 1997i, 1997k, 1998a, and 1998b), and will not be restated in this report. The reader is referred to those documents for detailed information.

Results of repeat and high rate logging are summarized in tables included in appendices to this report. Log plots for both the repeat and high rate data also included in the appendices.

In general, only the high rate data have been incorporated into the interpreted data set used to create the visualizations. Repeat logging data are generally not incorporated into the interpreted data set, unless the data clarify ambiguities in the original log data. The primary justification for excluding repeat data is that only a small fraction of the total logging footage was re-logged. To routinely insert these data would thus distort the original baseline. Discrepancies between repeat logging and the original logs are discussed in the text, and areas where potential contaminant movement is evident are identified, but the contaminant plumes shown in the visualizations are based on the original data, as modified by professional judgment, with HRLS results included in intervals where the SGLS was saturated.

Although areas of potential contaminant movement are identified on the basis of comparison of repeat logging data and original baseline data, 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 data from high rate logging and repeat logging. Improvements in data analysis and interpretation methods are applied to all borehole data where appropriate.

2.1 High Rate Logging

During SGLS logging operations in the C Tank Farm in 1997, it soon became apparent that a few subsurface intervals exhibited very high gamma-ray fluxes, such that the SGLS detectors became saturated, yielding no usable data.

On the basis of this experience and in response to recommendations from the Expert Panel, (a panel of experts appointed by DOE to provide independent oversight of vadose zone technical investigations [DOE 1997a]), DOE-GJO designed a sonde capable of recording gamma-ray spectra while operating in intense gamma-ray fluxes. The detector is a low-efficiency, 6-millimeter (mm) by 8-mm n-type HPGe detector. The sonde containing the detector is operated by either of the SGLSs. This system is referred to as the High Rate Logging System (HRLS). Information regarding this system and its calibrations are described in a base calibration report (DOE 1999).

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.

Two tungsten shields that can be used individually or in combination are available to extend the range of the high rate detector. One is a 0.31-inch (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 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 high rate tool is significantly higher than the uncertainty in the SGLS data. DOE (1999) describes the calibration in detail.

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 high rate 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. 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. The correction factor is 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.

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) collected from borehole 30-05-07 inside of C Tank Farm. Shield correction factors for other energy levels can be determined by extrapolation of relative attenuation calculations.

^{137}Cs was the only radionuclide detected with the HRLS in the C Tank Farm. All boreholes logged by the HRLS in the C Tank Farm appear to have had 6-in. schedule-40 casing. High rate data correction factors for ^{137}Cs (662 keV) are provided in the following table:

6-in. Casing	Internal Shield	External Shield	Both Shields
1.000	27.42	3.758	96.40

2.2 Repeat Logging

Repeat logging using the SGLS and HRLS is useful to evaluate possible contaminant movement over time by comparing concentration data. A sufficient amount of time has not passed since the implementation of the HRLS to collect repeat data that would provide meaningful comparisons. Repeat logging using the SGLS was only conducted in two boreholes. Unfortunately, little data are available for a reliable assessment of recent movement because routine gross gamma logging was discontinued in 1994. However, ORP is planning to initiate a spectral gamma monitoring program in fiscal year (FY) 2001 that will assess and track any potential and/or ongoing contaminant movement for selected drywells in the C Tank Farm.

2.2.1 Spectral Gamma Logging System (SGLS)

Repeat logging was performed for two borehole intervals in the C Tank Farm using the SGLS. One of these boreholes was selected for repeat logging primarily because of a zone that exhibited an elevated total gamma count rate in the absence of significant concentrations of radionuclides. The other borehole was selected for repeat logging to investigate the possibility of recent contaminant movement. The repeat logging typically was performed with longer counting times over limited depth intervals. Plots of repeat logging data are presented in Appendix B. To provide for proper comparison of log data between the original baseline and the repeat logging, concentrations were normalized for decay. No repeat logging data were included in the development of the C Tank Farm contaminant visualizations.

2.2.2 Historical Gross Gamma Logging

Routine gross gamma logs were routinely run in C Tank Farm boreholes prior to 1994, and historical gross gamma data are available in electronic format from 1975 to 1994. To date, only a limited evaluation of historical data has been performed. A comprehensive assessment of historical data has not yet been performed for this tank farm. Evaluation of historical data has been shown to be valuable in identifying borehole intervals where gamma anomalies have existed in the past. Increases or instability in gamma activity levels may be an indication of subsurface contaminant movement. However, analysis of historical data is beyond the scope of this project.

3.0 Discussion of Results

3.1 High Rate Logging

Logging was conducted using the HRLS in all borehole intervals where the original SGLS logs indicated high dead times or zones of detector saturation resulting from very high gamma fluxes. The SGLS provides reliable results from background levels up to several thousand picocuries per gram. However, zones of more intense radiation were encountered around a few boreholes in which dead times became excessive or the detector became saturated. The HRLS detected ^{137}Cs as the primary radionuclide in all but one of these intervals.

Table A-1 (Appendix A) summarizes high rate logging data for the C Tank Farm. Included in the table are the depth intervals of each log run. A log run refers to a single sequential set of log data collected during a borehole logging event. Multiple log runs may occur, for example, when using different shield configurations or when logging is terminated at the end of a day and resumed the next day. Depth overlaps (1 ft) typically occur between two log runs. The shield configuration and the corresponding correction factors for each log run are also listed on the table. The comments column of the table generally includes a brief description of the maximum

concentration detected and the date to which the HRLS data were corrected for decay. A list of the specific HRLS data points used to create the interpreted HRLS data set is also included in these comments. The interpreted HRLS data set is the high rate data that were added to the baseline SGLS data.

^{137}Cs concentration values calculated from the high rate data are presented on plots for each borehole (Figures A-1, A-2, and A-3, Appendix A). All HRLS ^{137}Cs concentration values have been corrected for decay to the date of the SGLS baseline. Each of these figures includes two graphs. The graph on the left plots the baseline SGLS data with the interpreted HRLS data to produce a composite baseline. Intervals of contamination that were removed from the interpreted data set are noted on this graph. Creation of the interpreted data set will be discussed in more detail in Section 4.1. The graph on the right plots all the baseline SGLS and HRLS data collected near the interval logged with the high rate tool. The scale has been expanded to allow the reader to compare the data.

Figure A-1 includes an additional graph on the far right. This graph displays ^{137}Cs concentrations calculated from corrected HRLS data that were collected using all shield configurations in borehole 30-05-07 from 59.0 to 48.0 ft. This interval provided adequate gamma flux to the detector using all four shield configurations (no shield, external shield, internal shield, and both shields) to calculate ^{137}Cs concentrations for each configuration. The uncorrected data (not shown) were used to calculate shield correction factors (Section 2.1) for the high rate tool.

The legend on each graph separates the data by borehole logging event. 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 SGLS baseline, while Events B or C are subsequent events that could refer to either repeat or HRLS logging.

3.2 Repeat Logging

Repeat logging was performed in two borehole intervals in the C Tank Farm. Data were collected approximately 2 years after the original baseline data were collected in 1997.

Table B-1 (Appendix B) lists all the repeat logging performed in the C Tank Farm using the SGLS and indicates the zones of investigation in each borehole, the reason for repeat logging, and an evaluation of the results. Figures B-1 and B-2 (Appendix B) include comparison log plots for the repeat logging events.

Log results for borehole 30-04-03, included in Figure B-1 (Appendix B) indicated little change in the contaminant profile. The gamma anomaly between 20 and 30 ft appears to be caused by the ^{137}Cs and cobalt-60 (^{60}Co) concentrations, which shape factor analysis suggests may be remote from the borehole. Remote contaminants tend to cause a disproportional increase in the total

count rate when compared to the increase of the contaminant concentration. This increase is due to the additional Compton scattering caused by the increased source to detector spacing.

Repeat log results for borehole 30-06-10 are shown in Figure B-2. The primary interval of interest in this borehole is the ^{60}Co plume detected below approximately 86 ft. Prior to the SGLS baseline logging, this borehole had been logged in 1993 by the Westinghouse Geophysics Group with the Radionuclide Logging System (RLS), which is comparable to the SGLS. On April 16, 1993, the maximum depth at which ^{60}Co was detected with the RLS was 112.0 ft. When SGLS baseline logging was conducted on January 29, 1997, ^{60}Co was detected at a maximum depth of 116.5 ft. By March 3, 1999, SGLS repeat logging detected ^{60}Co to a depth of 123.5 ft. From 86 ft to about 108 ft, ^{60}Co levels appear to be relatively constant, after correcting for decay. Below 108 ft, however, ^{60}Co levels are clearly increasing over time, strongly suggesting that either ^{60}Co is migrating downward in the vicinity of the borehole or that lateral migration is occurring. Although count rates were relatively low, and there is significant "noise" in the data, a cursory examination of historical gross gamma data indicates that an anomaly was evident in this interval as early as 1984. Gross gamma data were averaged over 5-ft intervals and plotted as a function of time. These plots are included in Appendix B. For the 85- to 90-ft interval, gross count levels appear to increase in early 1984. Successive 5-ft intervals clearly show the increase occurring at a later time, suggesting downward migration. The downward migration rate appears to be increasing. This interval appears to correlate with ^{60}Co detected at a higher elevation to the west between tanks C-108 and C-109, and at a similar depth in borehole 30-06-12.

3.3 Changes to the Interpreted Data Set

The original interpreted data set presented in the C Tank Farm Report was updated by adding the high rate data to zones of SGLS detector saturation. The results of shape factor analysis were used to identify and eliminate intervals from the data set used to create the original visualizations where contamination is attributable to borehole effects. Intervals that were removed from the original data set are indicated in black on the interpreted data set plots included in Appendix C. The shape factor results were re-assessed and additional intervals were determined to be the result of borehole effects. This tank farm appears to have experienced surface flooding events in the past that may have resulted in surface contamination being carried down the outside of the boreholes. These changes are indicated in red italics on the correlation plots included in Appendix C. In addition, a few occurrences of uranium-235 (^{235}U) that were originally reported in the C Tank Farm Report have been removed from the data set. Further analysis has concluded these peaks of ^{235}U were erroneously selected by the analysis software.

Table C-1 (Appendix C) includes the rationale for removing specific depth intervals from the interpreted data set used to create the three-dimensional visualizations. Plots of boreholes surrounding each tank are also included in Appendix C to provide a visual representation of the contaminated intervals.

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 C Tank Farm and to present views derived from those visualizations. ^{137}Cs, ^{60}Co, ^{154}Eu, and ^{152}Eu were all detected in the C Tank Farm. Visualizations were created for each of these radionuclides except ^{152}Eu, which occurs in association with ^{154}Eu. The development of the geostatistical models and the resulting visualizations are described in the C Tank Farm Report. The software package from C Tech Development Corporation called "Environmental Visualization System" (EVS) was used to create the visualizations in both the original C Tank Farm Report and in this addendum. Improvements to the data input and calculation parameters implemented since the original report 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. This data set consists of the original interpreted data set presented in the C Tank Farm Report with the HRLS data added and contamination intervals removed that are judged to be localized to the borehole and thus not representative of the subsurface contaminant distribution.

All baseline SGLS data collected during 1997 in the C Tank Farm have been updated in this addendum to reflect current analysis practices and procedures. In addition, insights gained during the Expert Panel discussions have aided in judging the nature of subsurface contaminant distribution as detected by the SGLS and HRLS.

The baseline concentration values presented in the interpreted data set have not been corrected for decay, and therefore represent their 1997 values. Correcting for decay to the present would have resulted in many occurrences of the shorter lived isotopes being portrayed at values below the current minimum detection level (MDL). High rate data collected in 1999 are adjusted for decay back to 1997.

Construction of the interpreted data set begins by creating a text file that contains all individual measurements from the SGLS and HRLS data. The data set includes the horizontal coordinates and depth of each data point and the concentration value at that point. The data set is edited to remove borehole intervals identified as non-representative, and to add HRLS data to zones of SGLS detector saturation.

4.2 Development of Three-Dimensional Visualizations

The total data domain of the calculations included all vadose zone boreholes within the C Tank Farm with the exception of boreholes 30-00-11, 30-00-13, 30-00-22, and 30-00-24, which monitor accessory facilities located away from the tanks. Figure 2 shows the locations of these

four boreholes, surrounding groundwater monitoring wells, and adjacent waste sites. The domain of the C 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 original visualizations utilized an adaptive gridding option that produces a model that contains estimated values everywhere inside a rectangular domain. A convex hull boundary option was selected to produce the visualizations shown in this addendum. This option produces an irregular boundary that is defined by the distribution of measured data points, and restricts the extrapolation of concentration values to that volume in the immediate vicinity of the data points.

The interpreted data set 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. This creates 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, and the data search routine is terminated after collecting the maximum number of data points, frequently all from a single borehole. 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 "forces" 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 C 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 at points on a three-dimensional grid. Once this concentration grid was developed, visualizations of the estimated concentration of each radionuclide 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.

The kriging process calculates the average radionuclide concentrations of a volume of sediment by using the information from nearby sample points. The influence of each sample point is determined by proximity, and weighting factors are based on the geostatistical structure.

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. An anisotropy value of 4 was selected for the ^{137}Cs, ^{60}Co, and ^{154}Eu plume calculations.

The MDLs for ^{137}Cs, ^{60}Co, and ^{154}Eu were generally between 0.1 and 1.0 pCi/g. In the preprocessing module, a value of 0.01 pCi/g was substituted for non-detects for each radionuclide 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. During post-processing, values less than 0.1 pCi/g for ^{137}Cs, ^{60}Co, and ^{154}Eu 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 isolevel. To view an inner surface, a cut section is inserted through the solid surface plume. As the isolevel is increased, progressively higher radionuclide concentration surfaces can be visualized. 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 have some influence on concentrations on the opposite side of the tank. In a geostatistical estimation calculation, 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 radionuclide 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. These include uncertainties in the assay calculation process as well as counting error. The uncertainty in assay calculation is discussed in the base calibration report (DOE 1995) and subsequent recalibration reports. It 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 8,000 pCi/g was placed in the database for kriging operations. In this addendum, concentration values computed from high rate log data were substituted in the previously saturated intervals. However, other radionuclides may not have been detected in zones of detector saturation, and may thus be under-represented in the interpreted data set and the visualizations, if they are not present in sufficient concentrations to be 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 C Tank Farm boreholes (0.5 ft) provides adequate spatial resolution to characterize the situations where the contamination is not homogeneous in the vertical dimension.

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.

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 radionuclide 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.

Figure D-1 illustrates the ^{137}Cs contamination derived from the interpreted data set for all boreholes logged in the C Tank Farm. This figure portrays 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 10^8 pCi/g. The borehole numbers are indicated to facilitate correlation of the three-dimensional representation of the data in the remaining figures with the plan plot and the correlation plots presented in Appendix C.

Figures D-2 and D-3 portray ^{60}Co and ^{154}Eu, respectively. The logarithmic color scales have also been changed to reflect the concentration range of each radionuclide.

Figures D-4 through D-16 show horizontal planar slices at various depths in the C Tank Farm. The slices illustrate the distribution of contaminants that occur at concentrations greater than the isolevels listed on each figure. The depths of these slices were selected to indicate a balance of concentration and areal extent of plumes.

The first slice at 2 ft (Figure D-4) shows the distribution of the near-surface contamination associated with surface spills. The next slice at 8 ft (Figure D-5), near the top of the tanks, shows fairly wide spread ^{137}Cs contamination around tanks C-101 through C-106 and near tanks C-107 and C-112. The subsequent slice at 18 ft (Figure D-6), near the depth of the cascade lines, shows the tops of the two major plumes in the C Tank Farm. Both of these plumes appear to be associated with cascade lines: one between tanks C-104 and C-105, the other between tanks C-108 and C-109. The cascade line leak between tanks C-108 and C-109 is inferred from the data presented in this addendum, as there are no historical references to a cascade line leak between these tanks. The next slice at 24 ft (Figure D-7) also shows these two plumes and a small ^{137}Cs plume on the west side of tank C-101, which is an assumed leaker. The ^{137}Cs near C-101 may be related to a leak from the spare inlet nozzles located on the west side of this tank.

The next slice at 38 ft (Figure D-8) is located near the bottom of the tanks. The plume between C-104 and C-105 continues to this depth. The ^{60}Co on the north side of tank C-112 is thought to originate from a surface spill that may have migrated down the side of the tank and spread near its base.

The remaining slices (Figures D-9 through D-16) primarily show contaminant plumes that are thought to be associated with the two cascade line leaks. The slice from 47 ft shows the two plumes extrapolated underneath the nearby tanks. The next slice at 56 ft shows similar distribution of contaminants; however, ^{60}Co is also observed northeast of tank C-109. This ^{60}Co may have migrated under tank C-109 from the cascade line leak. The slice at 68 ft shows the maximum vertical extent of ^{137}Cs and ^{154}Eu associated with the leak in the cascade line between tanks C-104 and C-105. The plumes originating between tanks C-108 and C-109 and east of tank C-105 are shown to spread laterally to the east in the next two slices at 78 and 89 ft. The slices from 104 and 114 ft suggest that the C-104 to C-105 cascade line leak plume may have migrated to the northeast corner of the farm near tank C-103. The C-108 to C-109 cascade line leak plume appears to have migrated between tanks C-109 and C-106 at these depths. The repeat logging has identified ongoing contaminant movement that intersects borehole 30-06-10 and appears to be moving downward. The final slice at 125 ft shows the deepest occurrence of ^{60}Co associated with the C-104 to C-105 cascade line leak that has migrated laterally to the north of tank C-103. It should be noted that these visualizations represent contaminant distributions as of 1997. Repeat logging of borehole 30-06-10 in 1999 indicated the ^{60}Co between tanks C-106 and C-109 has migrated down to 123.5 ft. If the visualizations included the repeat data, this extent of the ^{60}Co plume shown on the 125-ft slice would have been significantly greater.

Figures D-17 through D-19 are three-dimensional visualizations that illustrate contamination plumes for each major radionuclide within the vadose zone at the C Tank Farm. The figures show the plumes created with the EVS software superimposed over the SGLS and HRLS data from the interpreted data set. In these figures, the plumes are presented with a degree of transparency to view the data that define the plume. Figures D-17 and D-18 show the ^{137}Cs and ^{60}Co plumes, respectively. Both figures are viewed looking up at the tanks from the south. In Figure D-18, the progression of ^{60}Co plumes downward and to the east is clearly evident. Figure D-19 shows the ^{154}Eu plumes viewed from the south looking down on the tanks.

The final two visualizations, Figures D-20 and D-21, show the plumes associated with the two cascade line leaks in the vicinity of tanks C-104 through C-109. Figure D-20 exposes the interior of the plume associated with the C-104 to C-105 cascade line leak. It is viewed from the south of tanks C-104, -105, and -106 looking up at the tanks and is cut by two vertical planes. One vertical plane trends southwest-northeast and passes through tanks C-104, -105, and -106. The other plane trends north-south and passes just west of tank C-106. Figure D-21 exposes the interior of the plume associated with the C-108 to C-109 cascade line leak. It is viewed from the north of tanks C-107, -108, and -109 looking up at the tanks and is cut by a vertical plane passing through tanks C-107, -108, and -109. Together, the two figures allow the reader to visualize the structure and extent of these plumes.

4.5 Contaminated Volume and Total Activity Estimate

With completion of the revised visualizations, it became possible to calculate an estimate of the volume of contaminated soil and total activity inventory as a function of contaminant threshold level within the plumes shown in the C 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 activity for each volumetric element is determined by multiplying the specific activity (concentration) in picocuries per gram by the mass per volume (density) for each element. A density of 1.8 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 represents values at the time of the baseline logging in 1997. The activities have not been corrected for decay. These estimates are based entirely on the data from the baseline spectral gamma characterization program (SGLS), with HRLS data included in zones of detector saturation. The data sets used for the volume and total activity inventory estimates did not included any data from historical gross gamma logs, or any soil sample data.

The contribution from ^{60}Co and ^{154}Eu may be underestimated because these data are not always measured accurately by the HRLS in zones of high gamma flux. 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. In addition, substantial contamination may exist in the vadose zone at depths below the bottoms of many of the boreholes.

The table below lists the threshold levels, the contaminated soil volume, and total activity that occurs at or above each level for ^{137}Cs, ^{60}Co, and ^{154}Eu.

Contaminant	Contaminant Threshold (pCi/g)	Contaminated Volume (Cubic Meters)	Total Activity (Curies)
^{137}Cs	0.5	18,260	7.32
	5	6,118	7.22
	50	1,214	6.94
	500	459	6.34
	5,000	179	4.89
	10,000	113	3.95
	20,000	59.9	2.71
	25,000	46.9	2.29

Contaminant	Contaminant Threshold (pCi/g)	Contaminated Volume (Cubic Meters)	Total Activity (Curies)
^{60}Co	0.1	19,740	6.76×10^{-3}
	0.3	2,527	2.42×10^{-3}
	0.5	1,063	1.51×10^{-3}
	1	288	6.85×10^{-3}
	2	65.8	2.36×10^{-4}
^{154}Eu	0.1	1,966	5.10×10^{-4}
	0.3	141	8.71×10^{-5}
	0.4	83	6.19×10^{-5}

5.0 Conclusions

The purpose of this addendum is to provide an update to the original C Tank Farm Report that was issued in 1998. 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 and analysis process have been made since the C Tank Farm Report was issued. Some of the more important improvements in the understanding of the log data have resulted from the following:

- Although re-evaluation of shape factor results and other data provided justification for eliminating many borehole contamination intervals from the interpreted data set, most intervals of significant contamination remain.

- Contamination associated with gamma-emitting radionuclides does exist in the formation at significant depth (at least 125 ft).

- Repeat logging using the SGLS has allowed for identification and quantitative determination of concentration increases. Moreover, it is evident that contaminant migration within the C Tank Farm is ongoing.

- High rate geophysical logging has allowed determination of maximum concentrations in contamination plumes, providing an improved basis to estimate the volume of contaminated soil and contaminant inventory in the vadose zone. It also provides a method for future quantitative comparisons of contaminant movement in high gamma flux zones using repeat logging if a monitoring program is implemented.

Re-evaluation of existing data, integration of the high rate data, and re-calculation of the spatial distribution based on the revised interpreted data set have resulted in an improved visualization of subsurface contaminant distribution in the C Tank Farm. Conclusions stated in the original

C Tank Farm Report remain appropriate and will not be entirely reiterated. However, one finding of major significance is that evaluation of repeat logging data indicate that ^{60}Co movement through the vadose zone has occurred in the past and appears to be continuing. This conclusion is also supported by a limited review of historical gross gamma data. Unfortunately, little data are available for a reliable assessment of recent movement because routine gross gamma logging was discontinued in 1994. However, ORP is planning to initiate a spectral gamma monitoring program in fiscal year (FY) 2001 that will assess and track any potential and/or ongoing contaminant movement for selected drywells in the C Tank Farm.

There appears to be little contamination around tanks C-110 and C-111, both of which are assumed leakers. Leak volume estimates for these tanks are 2,000 and 5,500 gal, respectively (Hanlon 2000). The contaminants from these tanks may have migrated downward and did not reach the lateral extent necessary to be intersected by the surrounding monitoring boreholes. Historical logs from one borehole (30-10-09) near tank C-110 did show elevated count rate below the bottom of the tank. This activity decayed to background by 1978 and probably represents shorter lived isotopes that may have resulted from a tank leak prior to 1975. Historical logs near tank C-111 showed no evidence of a past leak from this tank.

Tank C-101 is also designated an assumed leaker, with an estimated leak volume of 20,000 gal (Hanlon 2000). However, there appears to be relatively little evidence of subsurface vadose contamination in the vicinity of this tank. The contamination associated with the tank C-101 leak appears to be held very near the tank itself and may not be well-represented in the baseline data collected from the monitoring boreholes.

The large plume originating between tanks C-104 and C-105 appears to be from the cascade line connecting these two tanks. It is possible that one or both of these tanks may have leaked, but the apparent depth and location of the suspected origin of the plume suggest that the most likely source is the cascade line. This plume appears to have migrated downward and eastward of tank C-103 to a depth of at least 125 ft. The maximum depth of this plume in the vicinity of its source is questionable because of the limited depth of boreholes in that area.

A second large plume near tanks C-108 and C-109 also appears to have originated between the two tanks near the location of a cascade line. However, no reference supporting this conclusion could be located. This plume also appears to have migrated to the east and to a depth of at least 125 ft. Repeat logging data from borehole 30-06-10 indicate that downward and possibly lateral movement within this plume was continuing as late as March 1999. The distributions of contaminants related to both of these large plumes appear to be controlled at least in part by stratigraphic features.

6.0 Recommendations

Recommendations included in the original C Tank Farm Report have not substantially changed. Areas where recommendations have been implemented have resulted in improvements in the

understanding of the nature and extent of vadose zone contamination in the C Tank Farm. Two areas have been particularly useful in providing the updates in this addendum. These include the introduction of high rate logging and repeat SGLS logging.

The baseline data reported in the C Tank Farm Report and in this addendum have provided an indication of the nature and extent of subsurface contamination associated with gamma-emitting radionuclides. The gross gamma logging program was terminated in 1994, and little new data are available to assess continuing migration. Limited repeat logging data from the SGLS clearly show continuing contaminant migration as late as March 1999. ORP is currently planning to initiate a spectral gamma monitoring program in FY 2001 that will assess and track any potential and/or ongoing contaminant movement for selected drywells in the C Tank Farm. The monitoring program will identify the extent of continuing contaminant migration, and will provide data that can be used to verify contaminant transport models. It is not necessary to monitor all boreholes; the C Tank Farm baseline data clearly indicate where monitoring data are required and provide guidance as to measurement frequency.

Moisture logging in boreholes in the C Tank Farm would provide valuable data regarding the presence of moisture in the vadose zone, which may be a controlling factor for contaminant migration.

Although gross gamma count rates are relatively low, a brief examination of historical gross gamma data from borehole 30-06-10 clearly shows initiation of contamination between 85 and 90 ft in early 1984, with increasing contamination in lower intervals occurring in subsequent years. This behavior is confirmed by RLS and SGLS data collected in 1993, 1997, and 1999. A thorough evaluation of historical gross gamma data for the C Tank Farm should be performed. In addition, borehole logs and other available geologic data should be studied to obtain a detailed understanding of stratigraphy. The two major plumes in the C Tank Farm exhibit both lateral and downward migration that appears to be currently active. Integration of historical gross gamma data and geologic conditions may provide important information on contaminant migration rates and the effects of stratigraphy and geologic conditions in contaminant migration.

7.0 References

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

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

Borehole Number	Log Run Depth Interval (ft)	Shield/ Correction Factor [a]	Comments
30-05-07	30.0 - 35.5	NS/1.00	^{137}Cs was identified from 67.0 to 33.5 ft. The highest concentration (10^7 pCi/g) occurs at 37.5 ft. All shield configurations were used from 59.0 to 48.0 ft to provide calibration data used to calculate shield correction factors. The HRLS ^{137}Cs data added to the baseline data: 34.0 - 35.5 ft HRLS ^{137}Cs (w/no shield); 36.0 - 41.0 ft HRLS ^{137}Cs (w/both shields); 41.5 - 67.0 ft HRLS ^{137}Cs (w/no shield).
	34.5 - 42.5	NS/1.00	
	35.0 - 67.0	BS/96.4	
	41.5 - 46.0	NS/1.00	
	45.0 - 67.0	NS/1.00	
	48.0 - 59.0	ES/3.758	
	48.0 - 59.0	IS/27.42	
30-07-11	0.0 - 5.0	NS/1.00	^{137}Cs was identified from 1.0 to 4.0 ft. The highest concentration (10^5 pCi/g) occurs at 2.5 ft. ^{154}Eu likely occurs in the high rate interval. The HRLS ^{137}Cs data added to the baseline data: 1.5 - 3.5 ft HRLS ^{137}Cs (w/no shield).
30-12-13	8.0 - 12.0	NS/1.00	No man-made radionuclides identified in the high rate spectra. Possible remote source such as a pipeline.

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

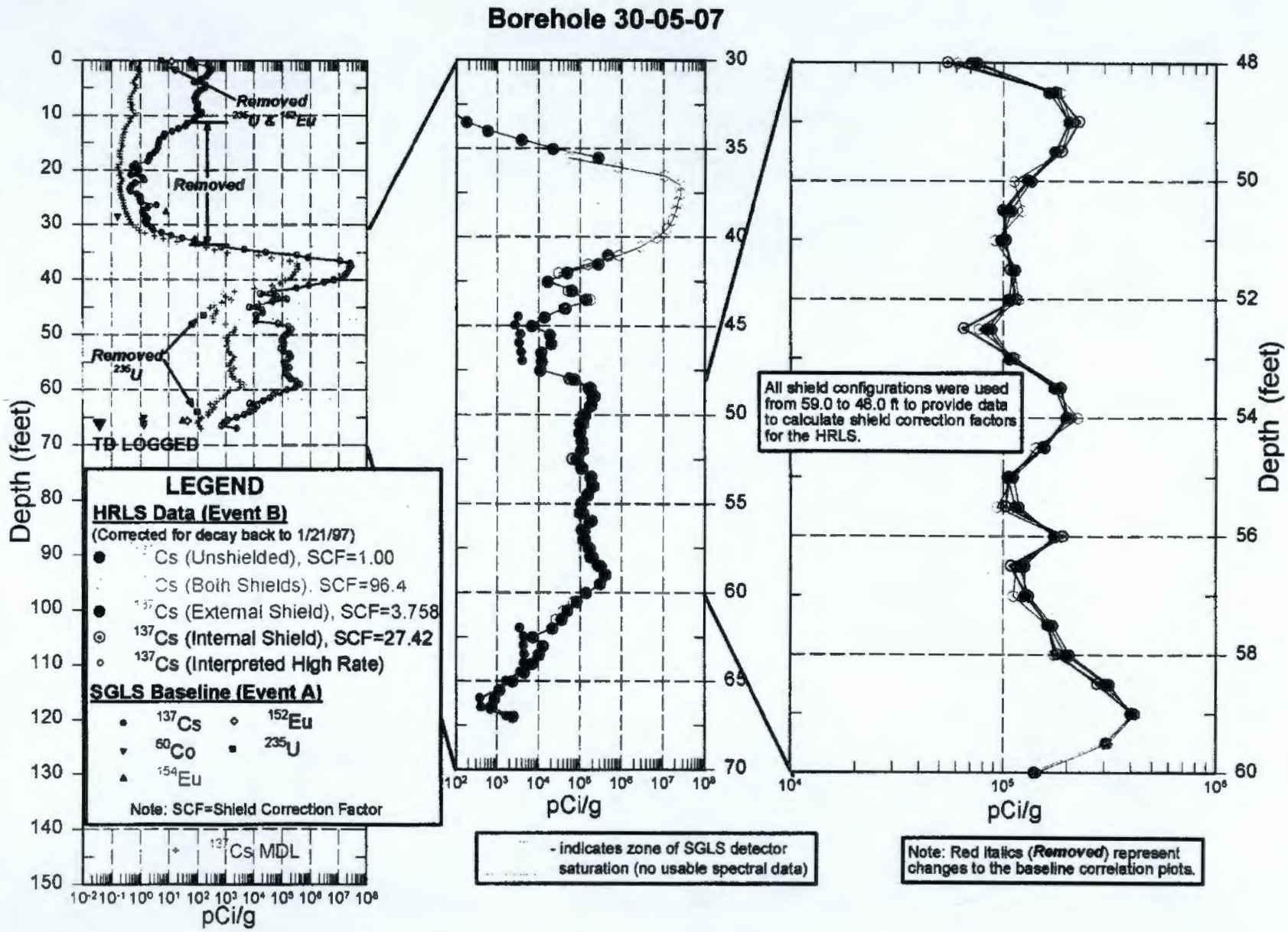

Figure A-1. Summary of High Rate Logging Results for the C Tank Farm

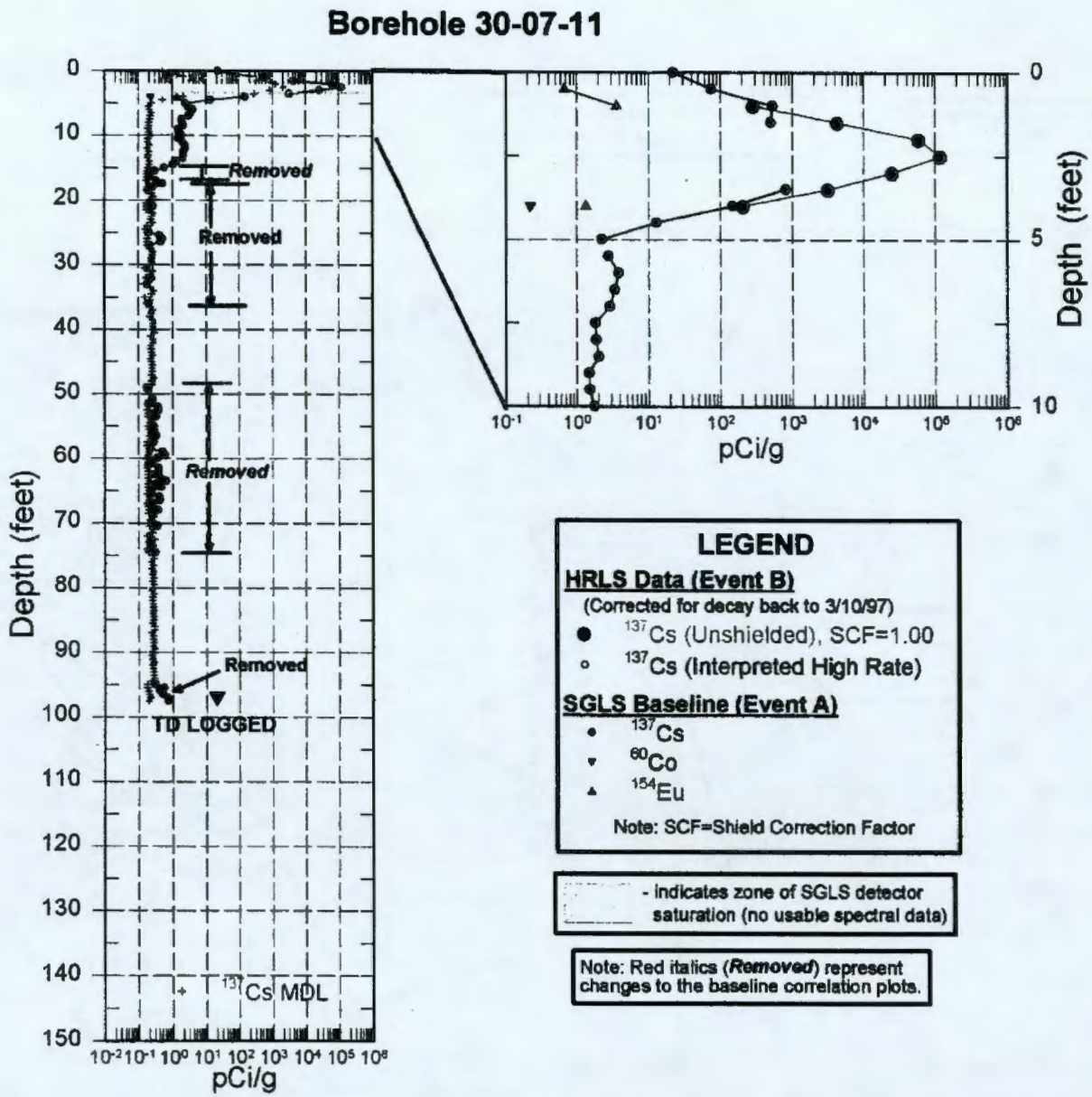

Figure A-2. Summary of High Rate Logging Results for the C Tank Farm

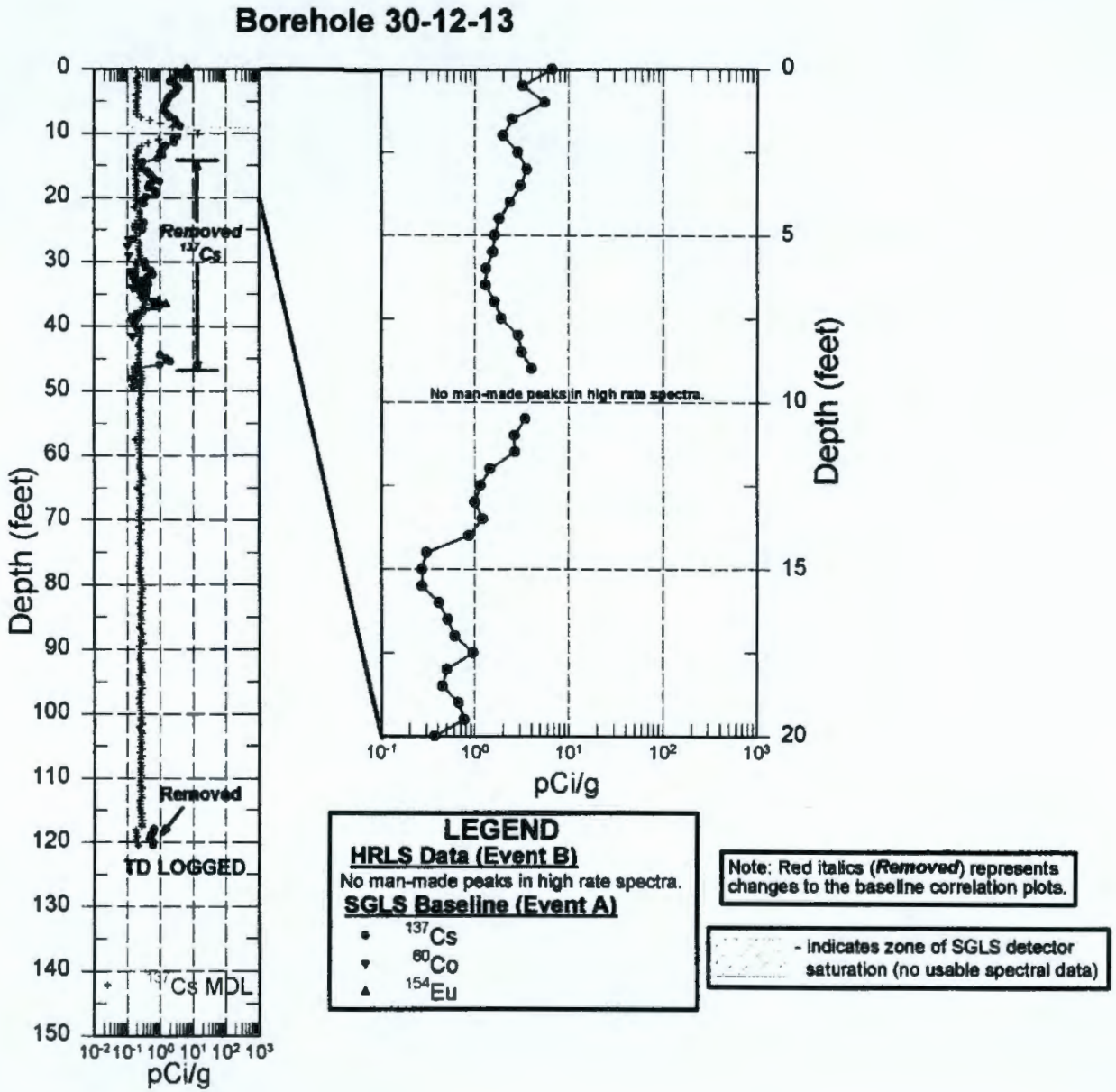

Figure A-3. Summary of High Rate Logging Results for the C Tank Farm

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

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

Borehole Number	Depth Interval (ft)	Reason for Repeat [a]	Logging Unit & (count time)		Evaluation
			Baseline	Repeat	
30-04-03	20.0-30.0	TGA	G1A (100 s)	G2B (200 s)	No change in contaminant concentration or distribution. Gamma anomaly appears to be due to remote ^{137}Cs and ^{60}Co.
30-06-10	75.0-129.0	CM	G2A (100 s)	G2B (100 s)	Increases in ^{60}Co concentration are evident in comparison of RLS data from 1993, SGLS baseline data (1997), and SGLS repeat data (1999).

[a] Reason for Repeat: CM - Suspected contaminant movement; TGA - Total gamma anomaly

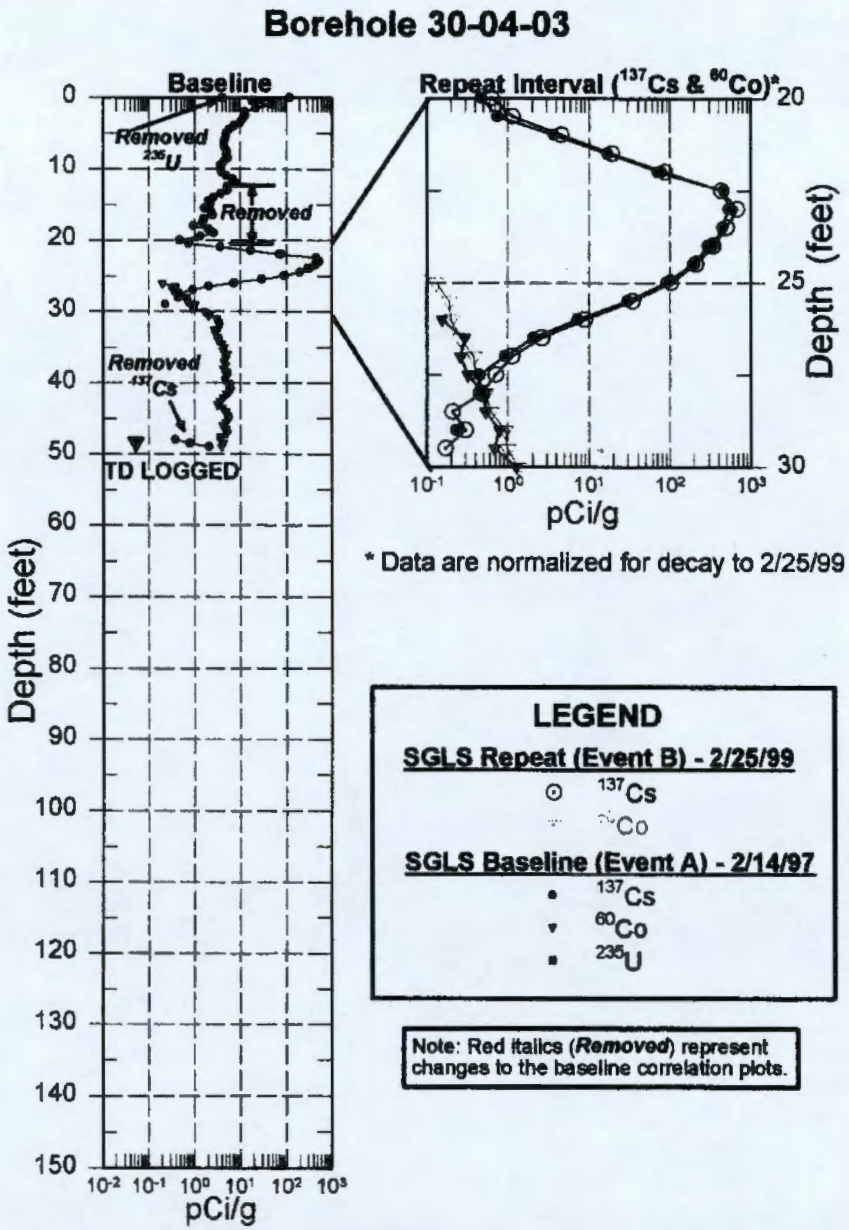

Figure B-1. Summary of Repeat Logging Results for the C Tank Farm

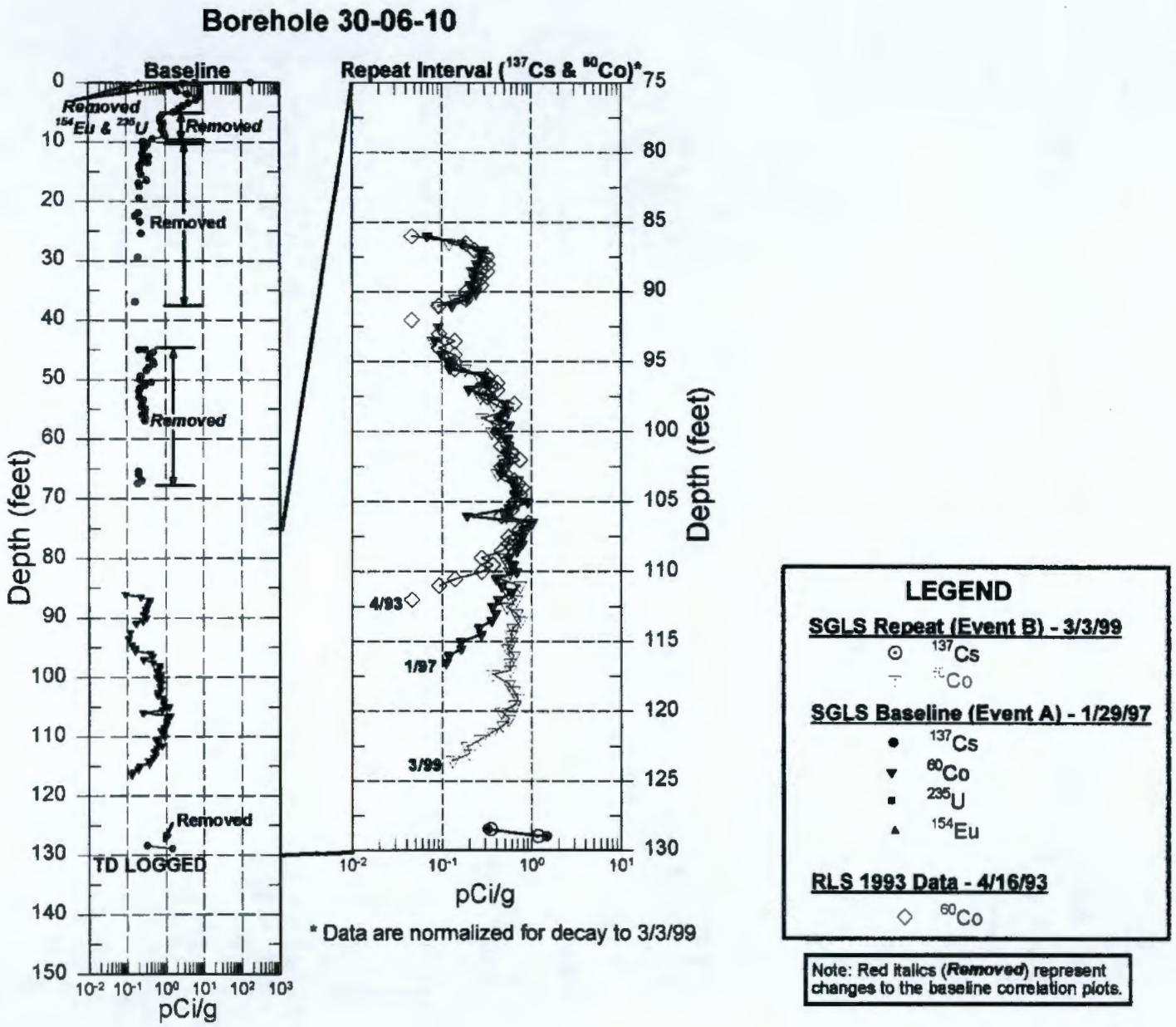

Figure B-2. Summary of Repeat Logging Results for the C Tank Farm

Borehole 30-06-10
Gross Gamma Data

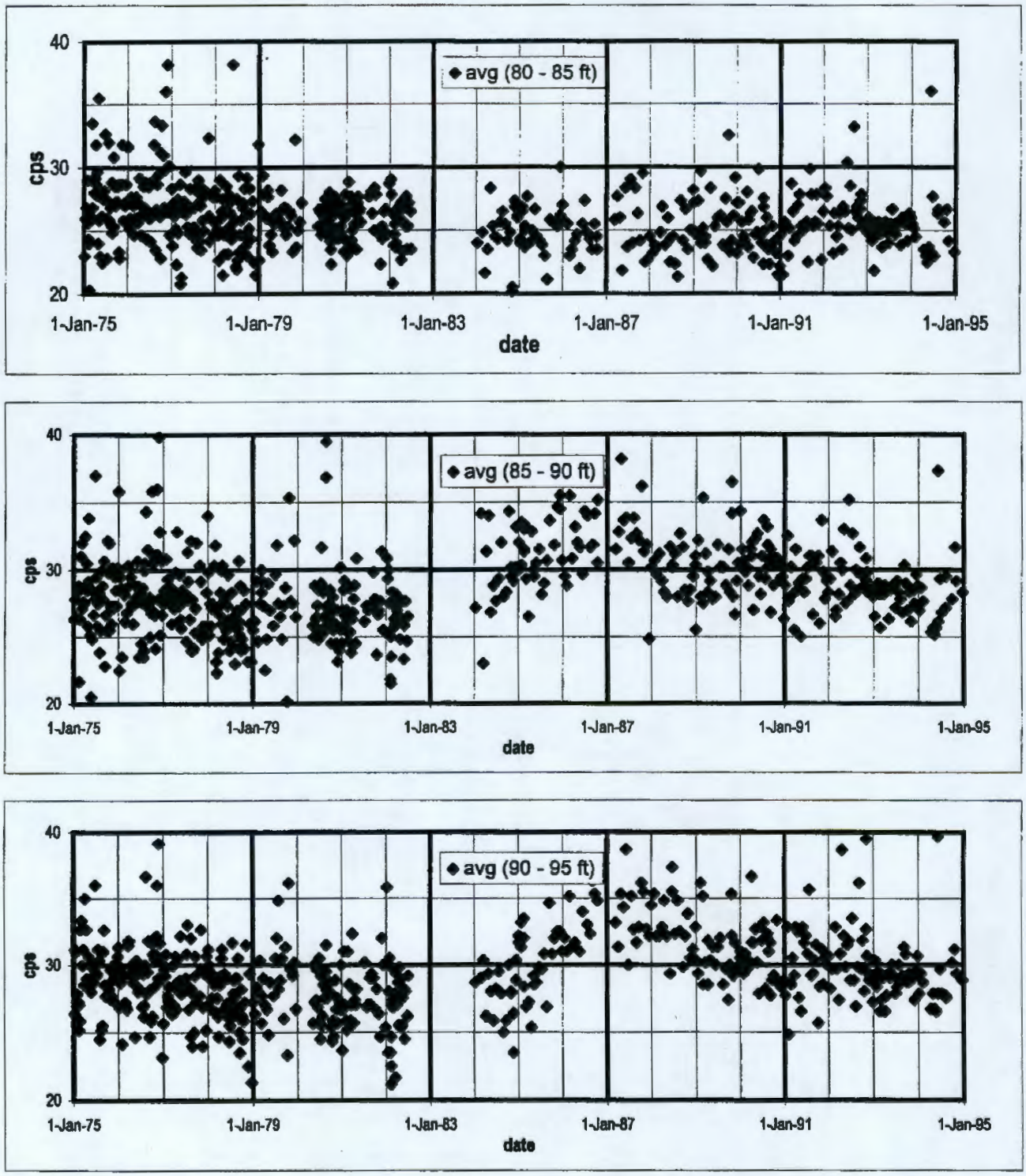

Figure B-3. Borehole 30-06-10 Gross Gamma Data

Borehole 30-06-10
Gross Gamma Data

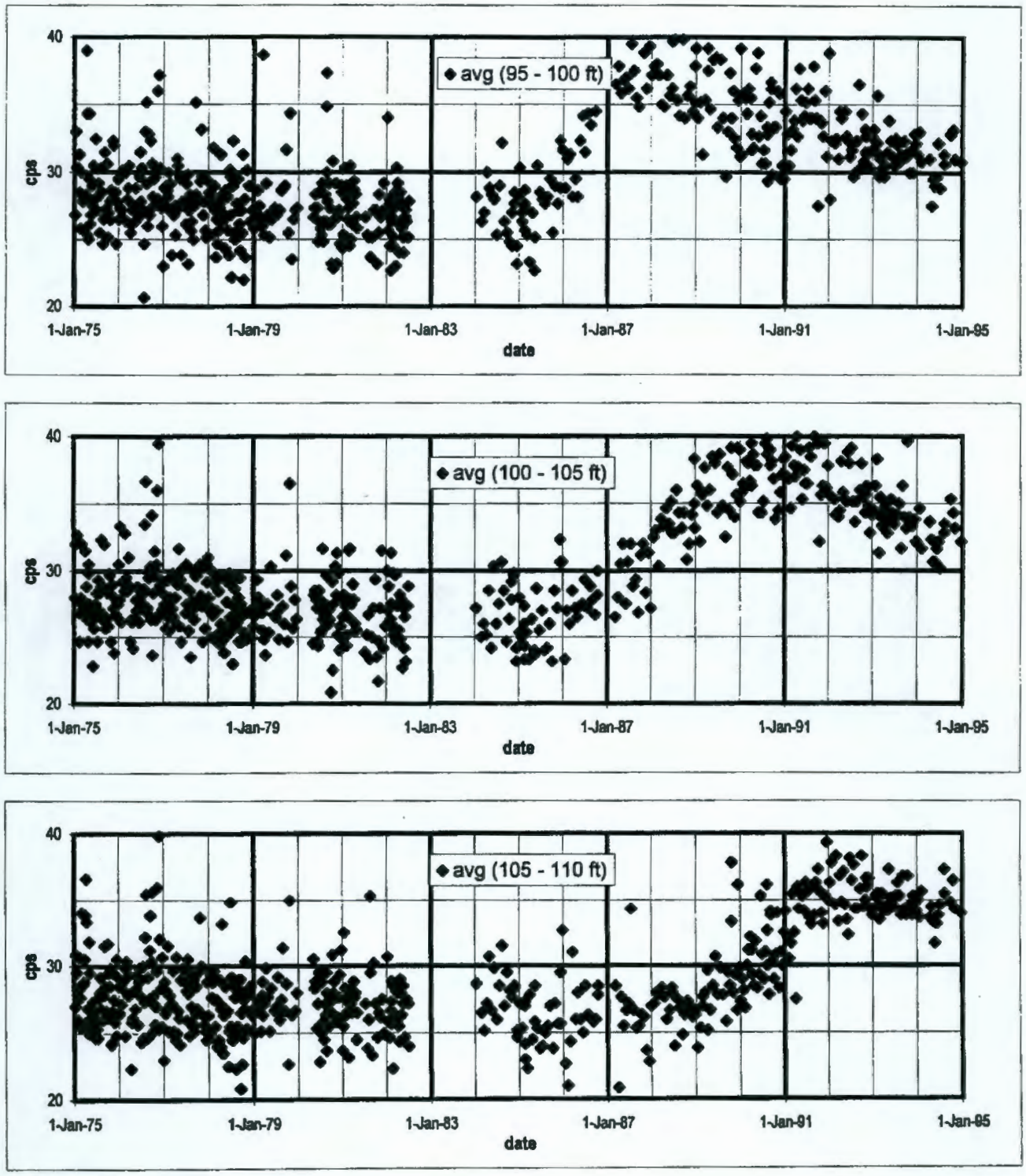

Figure B-4. Borehole 30-06-10 Gross Gamma Data

Borehole 30-06-10
Gross Gamma Data

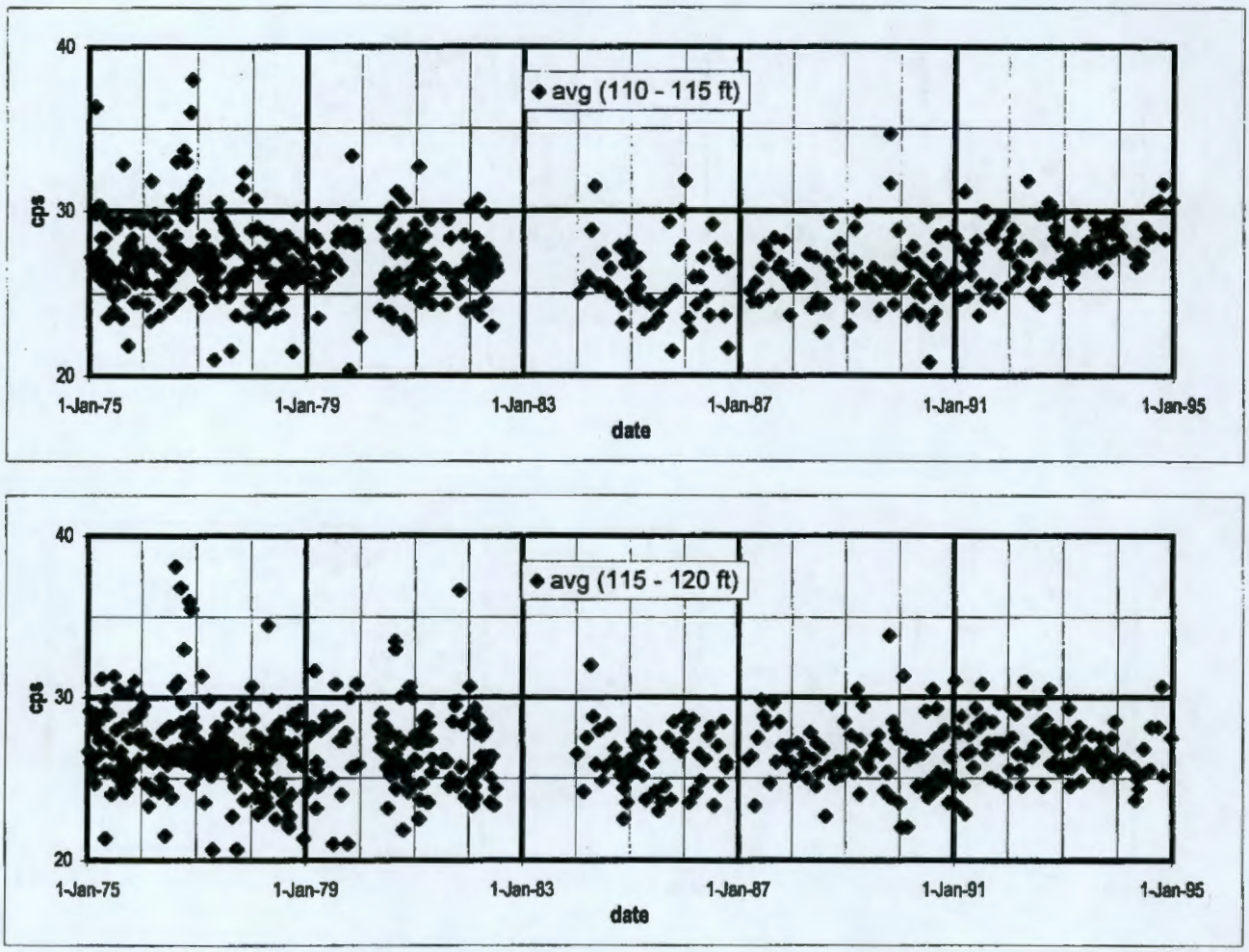

Figure B-5. Borehole 30-06-10 Gross Gamma Data

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

Table C-1. Summary of Interpreted Data Set for the C Tank Farm

Borehole Number	Depth Interval (ft)	Source[a]	SFA[e]	Disposition/Comments
30-01-01	0.0 - 1.5	SS[b]	R[i]	Included ^{137}Cs.
	2.0 - 43.0	BE[c] & P[d]	Inc.[g]	Removed ^{137}Cs; appears to be dragdown.* Included ^{60}Co; correlates w/other boreholes.
	43.5 - 97.0	None	Ina.[j]	No man-made contaminants detected.
	97.5 - 98.0	BE	Ina.	Removed ^{137}Cs; probably particulate contamination that fell in from the ground surface.
30-01-06	0.0 - 3.5	SS	D[f]	Included ^{137}Cs.
	4.0 - 30.5	BE	Ina.	Removed ^{137}Cs; appears to be dragdown.*
	31.0 - 34.5	None	Ina.	No man-made contaminants detected.
	35.0 - 38.5	P	D	Included ^{137}Cs and ^{60}Co; possible C-101 tank leak.
	39.0 - 55.0	None	Ina.	No man-made contaminants detected.
	55.5	BE	Ina.	Removed ^{137}Cs; appears to be dragdown.*
	56.0 - 97.0	None	Ina.	No man-made contaminants detected.
	97.5 - 98.5	BE	Ina.	Removed ^{137}Cs; probably particulate contamination that fell in from the ground surface.
30-00-06	0.0 - 2.5	SS	Ina.	Included ^{137}Cs.
	3.0 - 5.0	BE	Ina.	Removed ^{137}Cs; appears to be dragdown.
	5.5 - 56.5	None	Ina.	No man-made contaminants detected.
	57.0 - 111.0	BE	Ina.	Removed ^{137}Cs and ^{60}Co; perforated casing.
30-01-09	0.0 - 4.0	SS	D	Included ^{137}Cs.
	4.5 - 17.0	BE	Ina.	Removed ^{137}Cs; appears to be dragdown.*
	17.5 - 24.0	None	Ina.	No man-made contaminants detected.

[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 - Plume of contamination.
[e] SFA - Shape Factor Analysis
[f] D - Contamination distributed in formation.
[g] Inc. - Inconclusive, generally due to low or rapidly changing concentrations.
[h] Local - Contamination is confined to the vicinity of the borehole casing.
[i] R - Contamination is remote from the borehole.
[j] Ina. - Inapplicable to apply SFA in this instance.

* - indicates changes to original interpreted data set presented in C Tank Farm Report.

Table C-1 (con't.). Summary of Interpreted Data Set for the C Tank Farm

Borehole Number	Depth Interval (ft)	Source[a]	SFA[e]	Disposition/Comments
30-01-09 (con't.)	24.5 - 40.0	P	R	Included ^{137}Cs; ^{60}Co; ^{152}Eu and ^{154}Eu; possible C-101 tank leak.
	40.5 - 97.0	None	Ina.	No man-made contaminants detected.
	97.5	BE	Ina.	Removed ^{137}Cs; probably particulate contamination that fell in from the ground surface.
30-01-12	0.0 - 5.5	SS	D	Included ^{137}Cs.
	6.0 - 40.5	BE	Inc.	Removed ^{137}Cs; appears to be dragdown.*
	41.0 - 61.5	BE	Ina.	Removed ^{137}Cs; appears to be dragdown.
	62.0 - 99.0	None	Ina.	No man-made contaminants detected.
	99.5	BE	Ina.	Removed ^{137}Cs; probably particulate contamination that fell in from the ground surface.
30-03-01	0.0 - 2.5	SS	D	Included ^{137}Cs.
	3.0 - 79.0	BE	Local[h]	Removed ^{137}Cs; appears to be dragdown.*
	79.5 - 124.5	BE & P	Ina.	Removed ^{137}Cs; appears to be dragdown.* Included ^{60}Co; correlates w/other boreholes.
30-03-03	0.0 - 11.0	SS	Ina.	Included ^{137}Cs.
	11.5 - 41.0	BE	Ina.	Removed ^{137}Cs; appears to be dragdown; water filled.*
	41.5 - 84.5	None	Ina.	No man-made contaminants detected.
	85.0 - 97.5	P	Ina.	Included ^{60}Co; correlates w/other boreholes.
	98.0	BE	Ina.	Removed ^{137}Cs; probably particulate contamination that fell in from the ground surface.*
30-03-05	0.0 - 1.5	SS	D	Included ^{137}Cs.
	2.0 - 24.0	BE	Local	Removed ^{137}Cs; appears to be dragdown.*
	24.5 - 83.5	BE	Inc.	Removed ^{137}Cs; appears to be dragdown.*

[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 - Plume of contamination.
[e] SFA - Shape Factor Analysis
[f] D - Contamination distributed in formation.
[g] Inc. - Inconclusive, generally due to low or rapidly changing concentrations.
[h] Local - Contamination is confined to the vicinity of the borehole casing.
[i] R - Contamination is remote from the borehole.
[j] Ina. - Inapplicable to apply SFA in this instance.

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Table C-1 (con't.). Summary of Interpreted Data Set for the C Tank Farm

Borehole Number	Depth Interval (ft)	Source[a]	SFA[e]	Disposition/Comments
30-03-05 (con't.)	84.0 - 97.5	None	Ina.	No man-made contaminants detected.
	98.0 - 100.0	BE	Ina.	Removed ^{137}Cs; probably particulate contamination that fell in from the ground surface.
30-00-03	0.0 - 4.0	SS	Ina.	Included ^{137}Cs.
	4.5 - 6.5	BE	Ina.	Removed ^{137}Cs; appears to be dragdown.*
	7.0 - 16.5	BE	Ina.	Removed ^{137}Cs; appears to be dragdown.
	17.0 - 55.0	None	Ina.	No man-made contaminants detected.
	55.5 - 118.5	BE	Ina.	Removed ^{137}Cs; perforated casing.
30-03-07	0.0 - 10.5	SS	D	Included ^{137}Cs. Removed ^{60}Co; appears to be surface shine.*
	11.0 - 62.0	BE	Inc.	Removed ^{137}Cs; appears to be dragdown.*
	62.5 - 92.0	None	Ina.	No man-made contaminants detected.
	92.5 - 96.5	BE	Ina.	Removed ^{137}Cs; probably particulate contamination that fell in from the ground surface.
30-03-09	0.0 - 10.0	SS	D	Included ^{137}Cs. Removed ^{154}Eu and ^{152}Eu; appears to be surface shine.*
	10.5 - 25.0	BE	Inc.	Removed ^{137}Cs; appears to be dragdown.*
	25.5 - 29.5	BE	Inc.	Removed ^{137}Cs; appears to be dragdown.
	30.0 - 61.0	BE	Inc.	Removed ^{137}Cs; appears to be dragdown.*
	61.5 - 77.5	BE	Ina.	Removed ^{137}Cs; appears to be dragdown.*
	78.0 - 98.5	BE & P	Ina.	Removed ^{137}Cs; appears to be dragdown.* Included ^{60}Co; correlates w/other boreholes.
30-04-01	0.0 - 5.0	SS	D	Included ^{137}Cs.
	5.5 - 20.0	BE	Local	Removed ^{137}Cs; appears to be dragdown.*

[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 - Plume of contamination.
[e] SFA - *Shape Factor Analysis*
[f] D - Contamination distributed in formation.
[g] Inc. - Inconclusive, generally due to low or rapidly changing concentrations.
[h] Local - Contamination is confined to the vicinity of the borehole casing.
[i] R - Contamination is remote from the borehole.
[j] Ina. - Inapplicable to apply SFA in this instance.

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Table C-1 (con't.). Summary of Interpreted Data Set for the C Tank Farm

Borehole Number	Depth Interval (ft)	Source[a]	SFA[e]	Disposition/Comments
30-04-01 (con't.)	20.5 - 49.0	BE	Inc.	Removed ^{137}Cs; appears to be dragdown.*
30-04-02	0.0 - 8.0	SS	D	Included ^{137}Cs. Removed ^{235}U; analytical error.*
	8.5 - 37.5	BE	Inc.	Removed ^{137}Cs; appears to be dragdown.*
	38.0 - 68.0	BE & P	Ina.	Removed ^{137}Cs; appears to be dragdown.* Included ^{60}Co; correlates w/other boreholes.
	68.5 - 75.5	BE	Inc.	Removed ^{137}Cs; appears to be dragdown.*
	76.0 - 133.5	None	Ina.	No man-made contaminants detected.
	134.0 - 134.5	BE	Ina.	Removed ^{137}Cs; probably particulate contamination that fell in from the ground surface.
30-04-03	0.0 - 20.5	SS	D	Included ^{137}Cs. Removed ^{235}U; analytical error.*
	21.0 - 27.0	P	D & R	Included ^{137}Cs and ^{60}Co; cascade line leak.
	27.5 - 49.0	BE & P	Ina.	Removed ^{137}Cs; appears to be dragdown.* Included ^{60}Co; correlates w/other boreholes.
30-04-04	0.0 - 5.0	SS	R	Included ^{137}Cs.
	5.5 - 24.5	BE	Inc.	Removed ^{137}Cs; appears to be dragdown.*
	25.0 - 43.0	BE	Ina.	Removed ^{137}Cs; appears to be dragdown.
	43.5 - 58.0	BE	Inc.	Removed ^{137}Cs; appears to be dragdown.*
	58.5 - 98.5	BE	Ina.	Removed ^{137}Cs; appears to be dragdown.
30-04-05	0.0 - 13.5	SS	D	Included ^{137}Cs.
	14.0 - 58.0	BE	Inc.	Removed ^{137}Cs; appears to be dragdown.*
	58.5 - 69.0	None	Ina.	No man-made contaminants detected.

[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 - Plume of contamination.
[e] SFA - Shape Factor Analysis
[f] D - Contamination distributed in formation.
[g] Inc. - Inconclusive, generally due to low or rapidly changing concentrations.
[h] Local - Contamination is confined to the vicinity of the borehole casing.
[i] R - Contamination is remote from the borehole.
[j] Ina. - Inapplicable to apply SFA in this instance.

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Table C-1 (con't.). Summary of Interpreted Data Set for the C Tank Farm

Borehole Number	Depth Interval (ft)	Source[a]	SFA[e]	Disposition/Comments
30-04-05 (con't.)	69.5 - 98.5	BE	Ina.	Removed ^{137}Cs; appears to be dragdown.
30-04-08	0.0 - 1.5	SS	D	Included ^{137}Cs.
	2.0 - 25.5	BE	Local	Removed ^{137}Cs; appears to be dragdown.*
	26.0 - 70.5	BE	Inc.	Removed ^{137}Cs; appears to be dragdown.*
	71.0 - 143.0	None	Ina.	No man-made contaminants detected.
30-04-12	0.0 - 1.5	SS	Ina.	Included ^{137}Cs.
	2.0 - 62.0	BE	Inc.	Removed ^{137}Cs; appears to be dragdown.* Included ^{60}Co; correlates w/other boreholes.
	62.5 - 89.0	BE	Ina.	Removed ^{137}Cs; appears to be dragdown.
	89.5 - 134.5	None	Ina.	No man-made contaminants detected.
	135.0	BE	Ina.	Removed ^{137}Cs; probably particulate contamination that fell in from the ground surface.
30-05-02	0.0 - 3.0	SS	D	Included ^{137}Cs. Removed ^{154}Eu; appears to be surface shine.*
	3.5 - 27.0	BE	Inc.	Removed ^{137}Cs; appears to be dragdown.*
	27.5 - 127.5	BE	Ina.	Removed ^{137}Cs; appears to be dragdown.* Included ^{60}Co; correlates w/other boreholes.
30-05-03	0.0 - 6.0	SS	D	Included ^{137}Cs.
	6.5 - 36.5	BE	Inc.	Removed ^{137}Cs; appears to be dragdown.*
	37.0 - 98.5	BE	Ina.	Removed ^{137}Cs; appears to be dragdown.* Included ^{60}Co; correlates w/other boreholes.
30-05-04	0.0 - 2.5	SS	D	Included ^{137}Cs.

[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 - Plume of contamination.
[e] SFA - Shape Factor Analysis
[f] D - Contamination distributed in formation.
[g] Inc. - Inconclusive, generally due to low or rapidly changing concentrations.
[h] Local - Contamination is confined to the vicinity of the borehole casing.
[i] R - Contamination is remote from the borehole.
[j] Ina. - Inapplicable to apply SFA in this instance.

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Table C-1 (con't.). Summary of Interpreted Data Set for the C Tank Farm

Borehole Number	Depth Interval (ft)	Source[a]	SFA[e]	Disposition/Comments
30-05-04 (con't.)	3.0 - 118.0	BE	Ina.	Removed ^{137}Cs; appears to be dragdown.* Included ^{60}Co; correlates w/other boreholes.
30-05-05	0.0 - 5.0	SS	D & R	Included ^{137}Cs.
	5.5 - 84.5	BE	Inc.	Removed ^{137}Cs; appears to be dragdown.* Included ^{60}Co; correlates w/other boreholes.
	85.0 - 96.5	None	Ina.	No man-made contaminants detected.
	65.5 - 98.5	BE	Ina.	Removed ^{137}Cs; appears to be dragdown.* Included ^{60}Co; correlates w/other boreholes.
30-05-06	0.0 - 11.0	SS	D	Included ^{137}Cs. Removed ^{235}U; analytical error.*
	11.5 - 26.0	BE	Inc.	Removed ^{137}Cs; appears to be dragdown.*
	26.5 - 57.5	BE	Ina.	Removed ^{137}Cs; appears to be dragdown.*
30-05-07	0.0 - 11.0	SS	Inc	Included ^{137}Cs. Removed ^{235}U and ^{152}Eu; analytical error.*
	11.5 - 31.0	BE	Inc.	Removed all; appears to be dragdown.*
	31.5 - 33.5	P & BE	Inc.	Included ^{137}Cs; possible cascade line leak. Removed ^{154}Eu; intermittent occurrences.*
	34.0 - 35.5	P	Ina.	Used HRLS ^{137}Cs (w/no shield).* Included ^{137}Cs; possible cascade line leak.*
	36.0 - 41.0	P	Ina.	Used HRLS ^{137}Cs (w/both shields).* Included ^{137}Cs; possible cascade line leak.*
	41.5 - 67.0	P	Ina.	Used HRLS ^{137}Cs (w/no shield). Included ^{137}Cs; possible cascade line leak.* Included SGLS ^{60}Co; ^{152}Eu, and ^{154}Eu; possible cascade line leak. Removed ^{235}U; no ^{238}U; analytical error.*
30-05-08	0.0 - 9.5	SS	D	Included ^{137}Cs and ^{60}Co.

[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 - Plume of contamination.
[e] SFA - Shape Factor Analysis
[f] D - Contamination distributed in formation.
[g] Inc. - Inconclusive, generally due to low or rapidly changing concentrations.
[h] Local - Contamination is confined to the vicinity of the borehole casing.
[i] R - Contamination is remote from the borehole.
[j] Ina. - Inapplicable to apply SFA in this instance.

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Table C-1 (con't.). Summary of Interpreted Data Set for the C Tank Farm

Borehole Number	Depth Interval (ft)	Source[a]	SFA[e]	Disposition/Comments
30-05-08 (con't.)	10.0 - 13.5	BE	Inc.	Removed ^{137}Cs; appears to be dragdown.*
	14.0 - 22.0	P	Ina.	Included ^{137}Cs; ^{60}Co and ^{154}Eu; possible cascade line leak.
	22.5 - 27.5	BE	Ina.	Removed ^{137}Cs; appears to be dragdown.*
	28.0 - 49.0	BE & P	Inc.	Removed ^{137}Cs; appears to be dragdown.* Included ^{60}Co; possible cascade line leak.
30-05-09	0.0 - 2.5	SS	R	Included ^{137}Cs.
	3.0 - 65.5	BE	Inc.	Removed ^{137}Cs; appears to be dragdown.*
	66.0 - 86.5	BE	Ina.	Removed ^{137}Cs; appears to be dragdown.
	87.0 - 100.5	None	Ina.	No man-made contaminants detected.
	101.0	BE	Ina.	Removed ^{137}Cs; probably particulate contamination that fell in from the ground surface.
30-05-10	0.0 - 2.5	SS	Ina.	Included ^{137}Cs. Removed ^{235}U; analytical error.*
	3.0 - 54.5	BE & P	Ina.	Removed ^{137}Cs; appears to be dragdown.* Included ^{60}Co; possible cascade line leak.
	55.0 - 130.5	BE	Ina.	Removed ^{137}Cs; appears to be dragdown.
	131.0 - 134.0	None	Ina.	No man-made contaminants detected.
	134.5 - 135.5	BE	Ina.	Removed ^{137}Cs; probably particulate contamination that fell in from the ground surface.
30-06-02	0.0 - 1.0	SS	R	Included ^{137}Cs.
	1.5 - 14.5	BE	Inc.	Removed ^{137}Cs; appears to be dragdown.*
	15.0 - 38.0	BE	Ina.	Removed ^{137}Cs; appears to be dragdown.
	38.5 - 61.0	BE	Ina.	Removed ^{137}Cs; appears to be dragdown.*
	61.5 - 103.5	None	Ina.	No man-made contaminants detected.

[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 - Plume of contamination.
[e] SFA - Shape Factor Analysis
[f] D - Contamination distributed in formation.
[g] Inc. - Inconclusive, generally due to low or rapidly changing concentrations.
[h] Local - Contamination is confined to the vicinity of the borehole casing.
[i] R - Contamination is remote from the borehole.
[j] Ina. - Inapplicable to apply SFA in this instance.

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Table C-1 (con't.). Summary of Interpreted Data Set for the C Tank Farm

Borehole Number	Depth Interval (ft)	Source[a]	SFA[e]	Disposition/Comments
30-06-02 (con't.)	104.0	BE	Ina.	Removed ^{137}Cs; appears to be dragdown.
	104.5 - 114.5	None	Ina.	No man-made contaminants detected.
	115.0 - 122.5	BE	Ina.	Removed ^{137}Cs; probably particulate contamination that fell in from the ground surface.
30-00-01	0.0 - 1.5	SS	Ina.	Included ^{137}Cs.
	2.0 - 23.5	BE	Ina.	Removed ^{137}Cs; appears to be dragdown.*
	24.0 - 45.0	BE	Ina.	Removed ^{137}Cs; appears to be dragdown.
	45.5 - 67.5	BE	Ina.	Removed ^{137}Cs and ^{60}Co; casing appears to have become contaminated as a result of perforations.*
30-06-03	0.0 - 1.5	SS	Inc.	Included ^{137}Cs.
	2.0 - 76.5	BE	Inc.	Removed ^{137}Cs; appears to be dragdown.*
	77.0 - 98.0	None	Ina.	No man-made contaminants detected.
	98.5	BE	Ina.	Removed ^{137}Cs; probably particulate contamination that fell in from the ground surface.
30-06-04	0.0 - 8.0	SS	D	Included ^{137}Cs.
	8.5 - 53.0	BE	Inc.	Removed ^{137}Cs; appears to be dragdown.*
	53.5 - 93.0	BE & P	Ina.	Removed ^{137}Cs; appears to be dragdown.* Included ^{60}Co; correlates w/other boreholes.
	93.5 - 110.5	None	Ina.	No man-made contaminants detected.
	111.0 - 129.5	BE	Ina.	Removed ^{137}Cs; probably particulate contamination that fell in from the ground surface.
30-06-09	0.0 - 2.0	SS	D	Included ^{137}Cs. Removed ^{235}U; analytical error.*
	2.5 - 17.0	BE	Local	Removed ^{137}Cs; appears to be dragdown.*

[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 - Plume of contamination.
[e] SFA - Shape Factor Analysis
[f] D - Contamination distributed in formation.
[g] Inc. - Inconclusive, generally due to low or rapidly changing concentrations.
[h] Local - Contamination is confined to the vicinity of the borehole casing.
[i] R - Contamination is remote from the borehole.
[j] Ina. - Inapplicable to apply SFA in this instance.

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Table C-1 (con't.). Summary of Interpreted Data Set for the C Tank Farm

Borehole Number	Depth Interval (ft)	Source[a]	SFA[e]	Disposition/Comments
30-06-09 (con't.)	17.5 - 40.5	BE	Ina.	Removed ^{137}Cs; appears to be dragdown.* Included ^{60}Co; correlates w/other boreholes.
	41.0 - 45.5	BE	Inc.	Removed ^{137}Cs; appears to be dragdown.*
	46.0 - 74.0	BE	Ina.	Removed ^{137}Cs; appears to be dragdown.*
	74.5	P	Ina.	Included ^{60}Co; correlates w/other boreholes.
	75.0 - 90.5	None	Ina.	No man-made contaminants detected.
	91.0 - 98.5	BE	Ina.	Removed ^{137}Cs; probably particulate contamination that fell in from the ground surface.
30-06-10	0.0 - 5.0	SS	D	Included ^{137}Cs. Removed ^{235}U and ^{154}Eu; analytical error.*
	5.5 - 9.5	BE	Inc.	Removed ^{137}Cs; appears to be dragdown.*
	10.0 - 37.0	BE	Ina.	Removed ^{137}Cs; appears to be dragdown.
	37.5 - 44.5	None	Ina.	No man-made contaminants detected.
	45.0 - 67.5	BE	Ina.	Removed ^{137}Cs; appears to be dragdown.*
	68.0 - 85.5	None	Ina.	No man-made contaminants detected.
	86.0 - 116.5	P	Ina.	Included ^{60}Co; repeat logging identified movement; correlates w/30-06-12.
	117.0 - 128.0	None	Ina.	No man-made contaminants detected.
	128.5 - 129.0	BE	Ina.	Removed ^{137}Cs; probably particulate contamination that fell in from the ground surface.
30-06-12	0.0 - 1.5	SS	D	Included ^{137}Cs.
	2.0 - 30.5	BE & P	Inc.	Removed ^{137}Cs; appears to be dragdown.* Included ^{60}Co.

[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 - Plume of contamination.
[e] SFA - Shape Factor Analysis
[f] D - Contamination distributed in formation.
[g] Inc. - Inconclusive, generally due to low or rapidly changing concentrations.
[h] Local - Contamination is confined to the vicinity of the borehole casing.
[i] R - Contamination is remote from the borehole.
[j] Ina. - Inapplicable to apply SFA in this instance.

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Table C-1 (con't.). Summary of Interpreted Data Set for the C Tank Farm

Borehole Number	Depth Interval (ft)	Source[a]	SFA[e]	Disposition/Comments
30-06-12 (con't.)	31.0 - 80.0	BE & P	Ina.	Removed ^{137}Cs; appears to be dragdown.* Included ^{60}Co.
	80.5 - 89.5	None	Ina.	No man-made contaminants detected.
	90.0 - 99.5	BE & P	Ina.	Removed ^{137}Cs; probably particulate contamination that fell in from the ground surface.* Included ^{60}Co; correlates w/30-06-10.
30-07-01	0.0	BE	R	Removed ^{137}Cs; appears to be surface shine.*
	0.5 - 69.5	BE	Inc.	Removed ^{137}Cs; appears to be dragdown.*
	70.0 - 88.0	BE	Ina.	Removed ^{137}Cs; appears to be dragdown.
	88.5 - 100.0	None	Ina.	No man-made contaminants detected.
30-07-02	0.0	BE	R	Removed ^{137}Cs; appears to be surface shine.*
	0.5 - 30.5	BE	Inc.	Removed ^{137}Cs; appears to be dragdown.*
	31.0 - 43.0	BE	Ina.	Removed ^{137}Cs; appears to be dragdown.*
	43.5 - 98.5	None	Ina.	No man-made contaminants detected.
	99.0	BE	Ina.	Removed ^{137}Cs; probably particulate contamination that fell in from the ground surface.
30-07-05	0.0	BE	R	Removed ^{137}Cs; appears to be surface shine.*
	0.5 - 76.5	BE	Ina.	Removed ^{137}Cs; appears to be dragdown.*
	77.0 - 99.5	None	Ina.	No man-made contaminants detected.
30-07-07	0.0 - 15.5	BE	Inc.	Removed ^{137}Cs; appears to be dragdown.*
	16.0 - 58.0	None	Ina.	No man-made contaminants detected.
	58.5 - 72.0	BE	Ina.	Removed ^{137}Cs; appears to be dragdown.*
	72.5 - 98.0	None	Ina.	No man-made contaminants detected.

[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 - Plume of contamination.
[e] SFA - Shape Factor Analysis
[f] D - Contamination distributed in formation.
[g] Inc. - Inconclusive, generally due to low or rapidly changing concentrations.
[h] Local - Contamination is confined to the vicinity of the borehole casing.
[i] R - Contamination is remote from the borehole.
[j] Ina. - Inapplicable to apply SFA in this instance.

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Table C-1 (con't.). Summary of Interpreted Data Set for the C Tank Farm

Borehole Number	Depth Interval (ft)	Source[a]	SFA[e]	Disposition/Comments
30-07-07 (con't.)	98.5	BE	Ina.	Removed ^{137}Cs; probably particulate contamination that fell in from the ground surface.
30-07-08	0.0	BE	R	Removed ^{137}Cs; appears to be surface shine.*
	0.5 - 28.0	BE	Ina.	Removed ^{137}Cs; appears to be dragdown.*
	28.5 - 37.5	None	Ina.	No man-made contaminants detected.
	38.0 - 53.0	BE	Ina.	Removed ^{137}Cs; appears to be dragdown.
	53.5 - 99.0	None	Ina.	No man-made contaminants detected.
30-07-10	0.0 - 1.0	SS	R	Included ^{137}Cs.
	1.5 - 22.0	BE	Inc.	Removed ^{137}Cs; appears to be dragdown.*
	22.5 - 37.0	BE	Ina.	Removed ^{137}Cs; appears to be dragdown.*
	37.5 - 77.5	None	Ina.	No man-made contaminants detected.
	78.0	BE	Ina.	Removed ^{137}Cs; appears to be dragdown.
	78.5 - 98.5	None	Ina.	No man-made contaminants detected.
30-07-11	0.0 - 1.0	SS	Ina.	Included ^{137}Cs and ^{154}Eu; possibly inside a transfer line.
	1.5 - 3.5	SS	Ina.	Used HRLS ^{137}Cs (w/no shield).* Included ^{137}Cs; possibly inside a transfer line.
	4.0 - 4.5	SS	Ina.	Included ^{137}Cs; ^{60}Co and ^{154}Eu; possibly inside a transfer line.
	5.0 - 14.5	SS	D	Included ^{137}Cs; possible transfer line leak.
	15.0 - 16.5	BE	Ina.	Removed ^{137}Cs; appears to be dragdown.*
	17.0 - 36.0	BE	Ina.	Removed ^{137}Cs; appears to be dragdown.
	36.5 - 48.5	None	Ina.	No man-made contaminants detected.
	49.0 - 74.5	BE	Ina.	Removed ^{137}Cs; appears to be dragdown.*

[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 - Plume of contamination.
[e] SFA - Shape Factor Analysis
[f] D - Contamination distributed in formation.
[g] Inc. - Inconclusive, generally due to low or rapidly changing concentrations.
[h] Local - Contamination is confined to the vicinity of the borehole casing.
[i] R - Contamination is remote from the borehole.
[j] Ina. - Inapplicable to apply SFA in this instance.

* - indicates changes to original interpreted data set presented in C Tank Farm Report.

Table C-1 (con't.). Summary of Interpreted Data Set for the C Tank Farm

Borehole Number	Depth Interval (ft)	Source[a]	SFA[e]	Disposition/Comments
30-07-11 (con't.)	75.0 - 94.5	None	Ina.	No man-made contaminants detected.
	95.0 - 97.5	BE	Ina.	Removed ^{137}Cs; probably particulate contamination that fell in from the ground surface.
30-08-02	0.0 - 3.5	SS	D	Included ^{137}Cs and ^{154}Eu; possible transfer line leak.
	4.0 - 18.5	BE	Inc.	Removed ^{137}Cs; appears to be dragdown.*
	19.0 - 23.0	P	R	Included ^{137}Cs and ^{154}Eu; possible transfer line and/or transfer line leak.
	23.5 - 49.0	BE & P	Ina.	Removed ^{137}Cs; appears to be dragdown.* Included ^{60}Co; possible transfer line leak.
	49.5 - 79.5	P	D	Included ^{60}Co; possible transfer line leak.
	80.0 - 98.5	None	Ina.	No man-made contaminants detected.
	99.0	BE	Ina.	Removed ^{137}Cs; probably particulate contamination that fell in from the ground surface.
30-08-03	0.0 - 1.0	SS	Ina.	Included ^{137}Cs. Removed ^{60}Co and ^{154}Eu; appears to be surface shine.*
	1.5 - 50.0	BE	Ina.	Removed ^{137}Cs and ^{152}Eu; appears to be dragdown.*
30-08-12	0.0	BE	R	Removed ^{137}Cs; appears to be surface shine.*
	0.5 - 37.5	BE	Inc.	Removed ^{137}Cs; appears to be dragdown.*
	38.0 - 46.5	None	Ina.	No man-made contaminants detected.
	47.0 - 72.5	BE	Inc.	Removed ^{137}Cs; appears to be dragdown.*
	73.0 - 98.5	BE	Ina.	Removed ^{137}Cs; appears to be dragdown.*
30-09-01	0.0 - 0.5	BE	R	Removed ^{137}Cs; appears to be surface shine.*
	1.0 - 12.5	BE	Local	Removed ^{137}Cs; appears to be dragdown.*
	13.0 - 50.0	BE	Inc.	Removed ^{137}Cs; appears to be dragdown.*

[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 - Plume of contamination.
[e] SFA - Shape Factor Analysis
[f] D - Contamination distributed in formation.
[g] Inc. - Inconclusive, generally due to low or rapidly changing concentrations.
[h] Local - Contamination is confined to the vicinity of the borehole casing.
[i] R - Contamination is remote from the borehole.
[j] Ina. - Inapplicable to apply SFA in this instance.

* - indicates changes to original interpreted data set presented in C Tank Farm Report.

Table C-1 (con't.). Summary of Interpreted Data Set for the C Tank Farm

Borehole Number	Depth Interval (ft)	Source[a]	SFA[e]	Disposition/Comments
30-09-01 (con't.)	50.5 - 88.5	None	Ina.	No man-made contaminants detected.
	89.0 - 99.0	BE & P	Ina.	Removed ^{137}Cs; probably particulate contamination that fell in from the ground surface. Included ^{60}Co; correlates w/30-09-02.
30-09-02	0.0	BE	R	Removed ^{137}Cs; appears to be surface shine.*
	0.5 - 13.5	BE	Inc.	Removed ^{137}Cs; appears to be dragdown.*
	14.0 - 47.5	None	Ina.	No man-made contaminants detected.
	48.0 - 59.0	BE & P	Inc.	Removed ^{137}Cs; appears to be dragdown.* Included ^{60}Co.
	59.5 - 90.5	None	Ina.	No man-made contaminants detected.
	91.0 - 100.0	BE & P	Ina.	Removed ^{137}Cs; probably particulate contamination that fell in from the ground surface. Included ^{60}Co; correlates w/30-09-01.
30-09-06	0.0 - 1.0	SS	R	Included ^{137}Cs. Removed ^{235}U; analytical error.*
	1.5 - 11.0	BE	Inc.	Removed ^{137}Cs; appears to be dragdown.*
	11.5 - 73.5	BE	Ina.	Removed ^{137}Cs; appears to be dragdown.*
	74.0 - 77.5	None	Ina.	No man-made contaminants detected.
	78.0 - 86.0	P	Inc.	Included ^{60}Co; correlates w/30-09-07.
	86.5 - 97.5	None	Ina.	No man-made contaminants detected.
	98.0	BE	Ina.	Removed ^{137}Cs; probably particulate contamination that fell in from the ground surface.
30-09-07	0.0 - 6.0	SS	R	Included ^{137}Cs.
	6.5 - 12.5	BE	Ina.	Removed ^{137}Cs; appears to be dragdown.*

[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 - Plume of contamination.
[e] SFA - Shape Factor Analysis
[f] D - Contamination distributed in formation.
[g] Inc. - Inconclusive, generally due to low or rapidly changing concentrations.
[h] Local - Contamination is confined to the vicinity of the borehole casing.
[i] R - Contamination is remote from the borehole.
[j] Ina. - Inapplicable to apply SFA in this instance.

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Table C-1 (con't.). Summary of Interpreted Data Set for the C Tank Farm

Borehole Number	Depth Interval (ft)	Source[a]	SFA[e]	Disposition/Comments
30-09-07 (con't.)	13.0 - 35.5	BE	Ina.	Removed ^{137}Cs; appears to be dragdown.
	36.0 - 78.5	None	Ina.	No man-made contaminants detected.
	79.0 - 92.0	P	Inc.	Included ^{60}Co; correlates w/30-09-06.
	92.5 - 124.5	None	Ina.	No man-made contaminants detected.
30-09-10	0.0 - 3.5	SS	D	Included ^{137}Cs.
	4.0 - 40.0	BE	Local	Removed ^{137}Cs; appears to be dragdown.*
	40.5 - 67.0	BE & P	Inc.	Removed ^{137}Cs; appears to be dragdown.* Included ^{60}Co.
	67.5 - 98.0	BE & P	Ina.	Removed ^{137}Cs; appears to be dragdown.* Included ^{60}Co.
30-09-11	0.0 - 0.5	BE	R	Removed ^{137}Cs; appears to be surface shine.*
	1.0 - 13.0	BE	Inc.	Removed ^{137}Cs; appears to be dragdown.*
	13.5 - 66.5	BE	Ina.	Removed ^{137}Cs; appears to be dragdown.*
	67.0 - 92.5	None	Ina.	No man-made contaminants detected.
	93.0 - 98.5	BE	Ina.	Removed ^{137}Cs; probably particulate contamination that fell in from the ground surface.
30-10-01	0.0 - 2.0	SS	D	Included ^{137}Cs.
	2.5 - 19.5	BE	Ina.	Removed ^{137}Cs; appears to be dragdown.*
	20.0 - 100.0	None	Ina.	No man-made contaminants detected.
30-10-02	0.0 - 5.5	SS	D	Included ^{137}Cs.
	6.0 - 63.5	BE	Inc.	Removed ^{137}Cs; appears to be dragdown.*
	64.0 - 98.5	None	Ina.	No man-made contaminants detected.

[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 - Plume of contamination.
[e] SFA - Shape Factor Analysis
[f] D - Contamination distributed in formation.
[g] Inc. - Inconclusive, generally due to low or rapidly changing concentrations.
[h] Local - Contamination is confined to the vicinity of the borehole casing.
[i] R - Contamination is remote from the borehole.
[j] Ina. - Inapplicable to apply SFA in this instance.

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Table C-1 (con't.). Summary of Interpreted Data Set for the C Tank Farm

Borehole Number	Depth Interval (ft)	Source[a]	SFA[e]	Disposition/Comments
30-10-02 (con't.)	99.0	BE	Ina.	Removed ^{137}Cs; probably particulate contamination that fell in from the ground surface.
30-00-09	0.0 - 3.5	SS	Ina.	Included ^{137}Cs.
	4.0 - 57.5	None	Ina.	No man-made contaminants detected.
30-10-09	0.0	BE	Ina.	Removed ^{137}Cs; appears to be surface shine.*
	0.5 - 37.5	BE	Ina.	Removed ^{137}Cs; appears to be dragdown.*
	38.0 - 97.5	None	Ina.	No man-made contaminants detected.
30-10-11	0.0 - 3.5	SS	D	Included ^{137}Cs.
	4.0 - 98.5	None	Ina.	No man-made contaminants detected.
30-00-22	0.0 - 6.0	BE	Ina.	Removed ^{137}Cs; appears to be dragdown.*
	6.5 - 9.5	P	Ina.	Included ^{137}Cs; possible transfer line leak near 241-C-151 Diversion Box.
	10.0 - 18.0	BE	Ina.	Removed ^{137}Cs; appears to be dragdown.*
	18.5 - 54.0	None	Ina.	No man-made contaminants detected.
30-00-24	0.0 - 19.5	BE	Ina.	Removed ^{137}Cs; appears to be dragdown.*
	20.0 - 22.0	P	Ina.	Included ^{137}Cs; historical gross gamma anomaly; possible transfer line leak near 241-C-153 Diversion Box.
	22.5 - 58.5	BE	Ina.	Removed ^{137}Cs; appears to be dragdown.*
30-00-11	0.0 - 8.0	BE	Ina.	Removed ^{137}Cs; appears to be dragdown.*
	8.5 - 11.0	P	Ina.	Included ^{137}Cs; historical gross gamma anomaly; possible transfer line leak near 241-C-152 Diversion Box.
	11.5 - 17.5	BE	Ina.	Removed ^{137}Cs; appears to be dragdown.*
	18.0 - 58.5	None	Ina.	No man-made contaminants detected.

[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 - Plume of contamination.
[e] SFA - Shape Factor Analysis
[f] D - Contamination distributed in formation.
[g] Inc. - Inconclusive, generally due to low or rapidly changing concentrations.
[h] Local - Contamination is confined to the vicinity of the borehole casing.
[i] R - Contamination is remote from the borehole.
[j] Ina. - Inapplicable to apply SFA in this instance.

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Table C-1 (con't.). Summary of Interpreted Data Set for the C Tank Farm

Borehole Number	Depth Interval (ft)	Source[a]	SFA[e]	Disposition/Comments
30-11-01	0.0	BE	R	Removed ^{137}Cs; appears to be surface shine.*
	0.5 - 28.0	BE	Ina.	Removed ^{137}Cs; appears to be dragdown.*
	28.5 - 56.0	BE	Ina.	Removed ^{137}Cs; appears to be dragdown.
	56.5 - 97.5	None	Ina.	No man-made contaminants detected.
	98.0	BE	Ina.	Removed ^{137}Cs; probably particulate contamination that fell in from the ground surface.
30-11-05	0.0 - 1.5	SS	Ina.	Included ^{137}Cs.
	2.0 - 4.5	BE	Ina.	Removed ^{137}Cs; appears to be dragdown.*
	5.0 - 10.5	None	Ina.	No man-made contaminants detected.
	11.0 - 12.0	BE	Ina.	Removed ^{137}Cs; appears to be dragdown.
	12.5 - 47.0	None	Ina.	No man-made contaminants detected.
	47.5 - 54.5	BE	Ina.	Removed ^{137}Cs; appears to be dragdown.*
	55.0 - 99.5	None	Ina.	No man-made contaminants detected.
30-11-06	0.0 - 2.5	SS	D	Included ^{137}Cs.
	3.0 - 12.0	BE	Inc.	Removed ^{137}Cs; appears to be dragdown.*
	12.5 - 15.5	BE	Ina.	Removed ^{137}Cs; appears to be dragdown.
	16.0 - 40.5	BE	Inc.	Removed ^{137}Cs; appears to be dragdown.*
	41.0 - 98.5	None	Ina.	No man-made contaminants detected.
	99.0	BE	Ina.	Removed ^{137}Cs; probably particulate contamination that fell in from the ground surface.
30-11-09	0.0	BE	Ina.	Removed ^{137}Cs; appears to be surface shine.*
	1.0 - 15.0	BE	Ina.	Removed ^{137}Cs; appears to be dragdown.*

[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 - Plume of contamination.
[e] SFA - Shape Factor Analysis
[f] D - Contamination distributed in formation.
[g] Inc. - Inconclusive, generally due to low or rapidly changing concentrations.
[h] Local - Contamination is confined to the vicinity of the borehole casing.
[i] R - Contamination is remote from the borehole.
[j] Ina. - Inapplicable to apply SFA in this instance.

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Table C-1 (con't.). Summary of Interpreted Data Set for the C Tank Farm

Borehole Number	Depth Interval (ft)	Source[a]	SFA[e]	Disposition/Comments
30-11-09 (con't.)	15.5 - 99.5	None	Ina.	No man-made contaminants detected.
30-00-10	0.0 - 2.0	SS	Ina.	Included ^{137}Cs.
	2.5 - 12.5	None	Ina.	No man-made contaminants detected.
	13.0	BE	Ina.	Removed ^{137}Cs; appears to be dragdown.*
	13.5 - 52.0	None	Ina.	No man-made contaminants detected.
30-11-11	0.0	BE	Ina.	Removed ^{137}Cs; appears to be surface shine.
	0.5 - 3.5	None	Ina.	No man-made contaminants detected.
	4.0	BE	Ina.	Removed ^{137}Cs; appears to be dragdown.
	4.5 - 99.5	None	Ina.	No man-made contaminants detected.
30-12-13	0.0 - 6.0	SS	D	Included ^{137}Cs.
	6.5 - 14.0	SS	R	Included ^{137}Cs. HRLS did not detect ^{137}Cs in the high rate interval. Possible remote transfer line.
	14.5 - 49.5	BE & P	Ina.	Removed ^{137}Cs; appears to be dragdown.* Included ^{60}Co and ^{154}Eu; possible transfer line leak.
	50.0 - 117.0	None	Ina.	No man-made contaminants detected.
	117.5 - 120.5	BE	Ina.	Removed ^{137}Cs; probably particulate contamination that fell in from the ground surface.
30-12-01	0.0	BE	Ina.	Removed ^{137}Cs; appears to be surface shine.*
	0.5 - 52.5	BE & P	Ina.	Removed ^{137}Cs; appears to be dragdown.* Included ^{60}Co; correlates w/30-12-13.
	53.0 - 99.5	None	Ina.	No man-made contaminants detected.
30-12-03	0.0	BE	Ina.	Removed ^{137}Cs; appears to be surface shine.*
	0.5 - 49.0	BE	Ina.	Removed ^{137}Cs; appears to be dragdown.*

[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 - Plume of contamination.
[e] SFA - Shape Factor Analysis
[f] D - Contamination distributed in formation.
[g] Inc. - Inconclusive, generally due to low or rapidly changing concentrations.
[h] Local - Contamination is confined to the vicinity of the borehole casing.
[i] R - Contamination is remote from the borehole.
[j] Ina. - Inapplicable to apply SFA in this instance.

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Table C-1 (con't.). Summary of Interpreted Data Set for the C Tank Farm

Borehole Number	Depth Interval (ft)	Source[a]	SFA[e]	Disposition/Comments
30-12-03 (con't.)	49.5 - 91.0	None	Ina.	No man-made contaminants detected.
	91.5	BE	Ina.	Removed ^{137}Cs; appears to be dragdown.*
	92.0 - 98.0	None	Ina.	No man-made contaminants detected.
30-00-12	0.0	BE	Ina.	Removed ^{137}Cs; appears to be surface shine.*
	0.5 - 1.5	BE	Ina.	Removed ^{137}Cs; appears to be dragdown.*
	2.0 - 49.5	None	Ina.	No man-made contaminants detected.
	50.0 - 58.5	BE	Ina.	Removed ^{137}Cs; perforated casing.*
	59.0 - 93.5	None	Ina.	No man-made contaminants detected.
	94.0	BE	Ina.	Removed ^{137}Cs; perforated casing.*
	94.5 - 111.0	None	Ina.	No man-made contaminants detected.
	111.5-112.5	BE	Ina.	Removed ^{137}Cs; perforated casing.*
	113.0-136.5	None	Ina.	No man-made contaminants detected.
30-12-09	0.0	BE	Ina.	Removed ^{137}Cs; appears to be surface shine.*
	0.5 - 15.5	BE	Ina.	Removed ^{137}Cs; appears to be dragdown.*
	16.0 - 100.0	None	Ina.	No man-made contaminants detected.
30-00-13	0.0	BE	Ina.	Removed ^{137}Cs; appears to be surface shine.*
	0.5 - 1.5	BE	Ina.	Removed ^{137}Cs; appears to be dragdown.*
	2.0 - 55.0	None	Ina.	No man-made contaminants detected.

[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 - Plume of contamination.
[e] SFA - Shape Factor Analysis
[f] D - Contamination distributed in formation.
[g] Inc. - Inconclusive, generally due to low or rapidly changing concentrations.
[h] Local - Contamination is confined to the vicinity of the borehole casing.
[i] R - Contamination is remote from the borehole.
[j] Ina. - Inapplicable to apply SFA in this instance.

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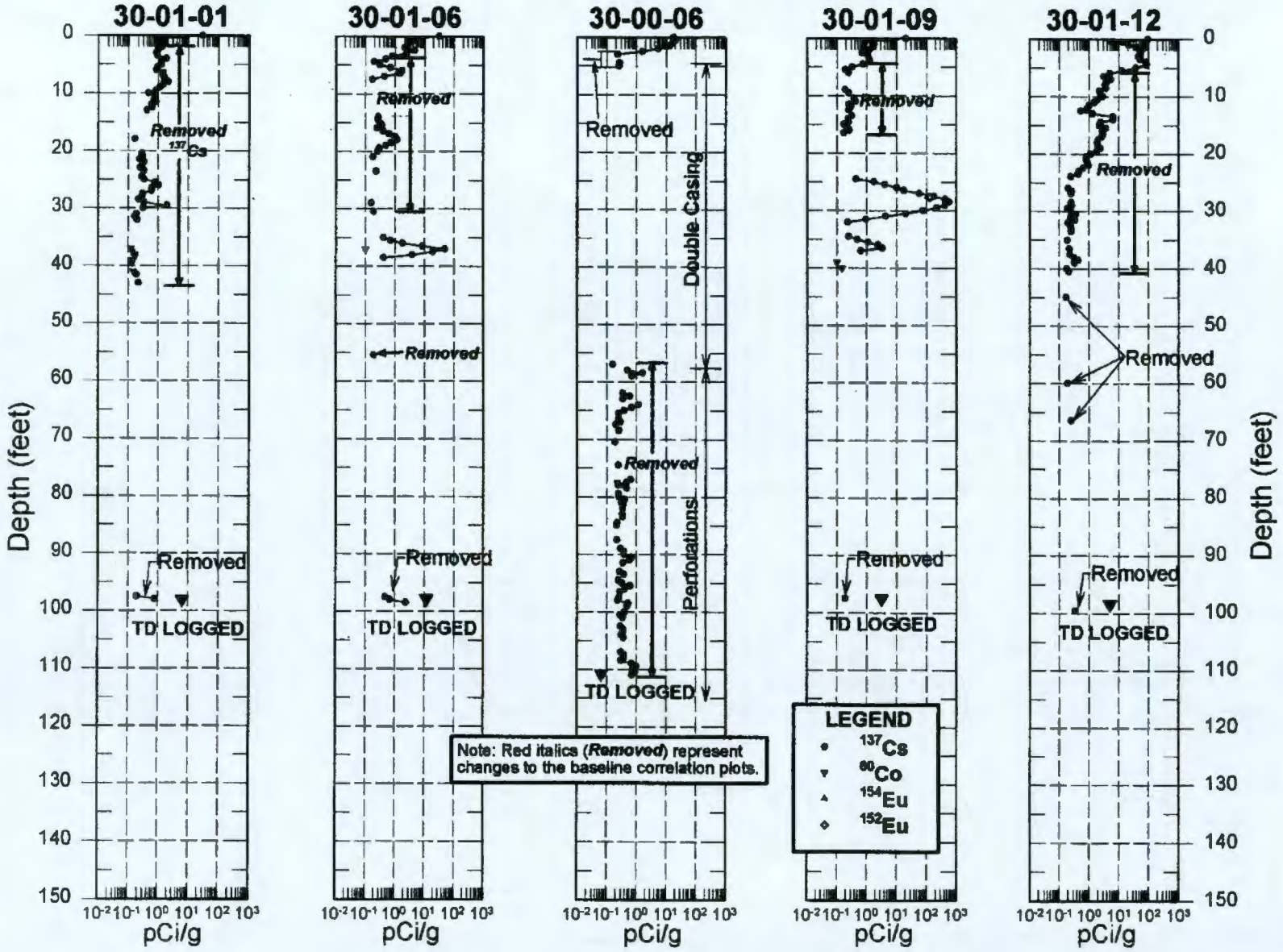


Figure C-1. Summary of Interpreted Data Set for the C Tank Farm

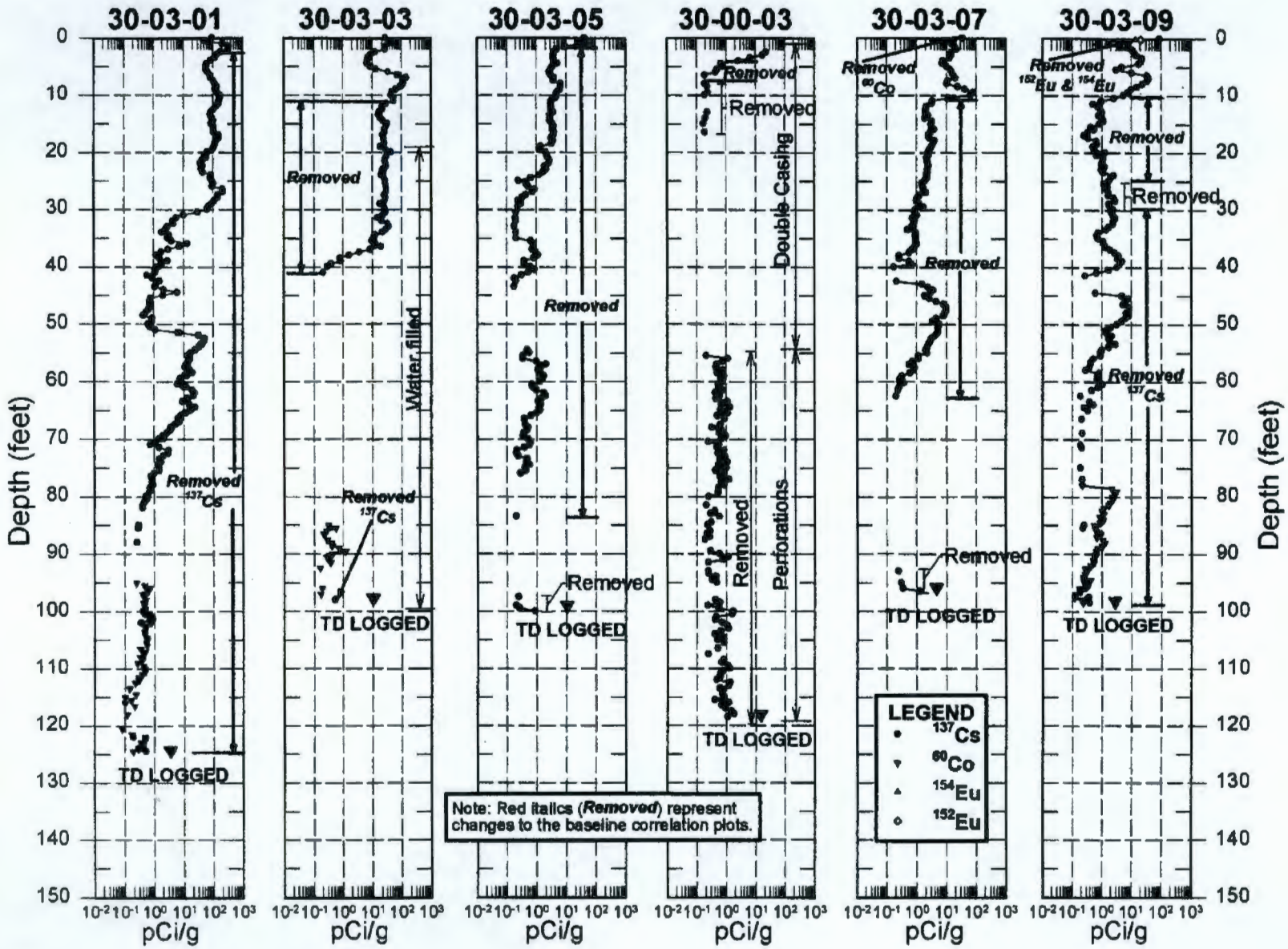


Figure C-2. Summary of Interpreted Data Set for the C Tank Farm

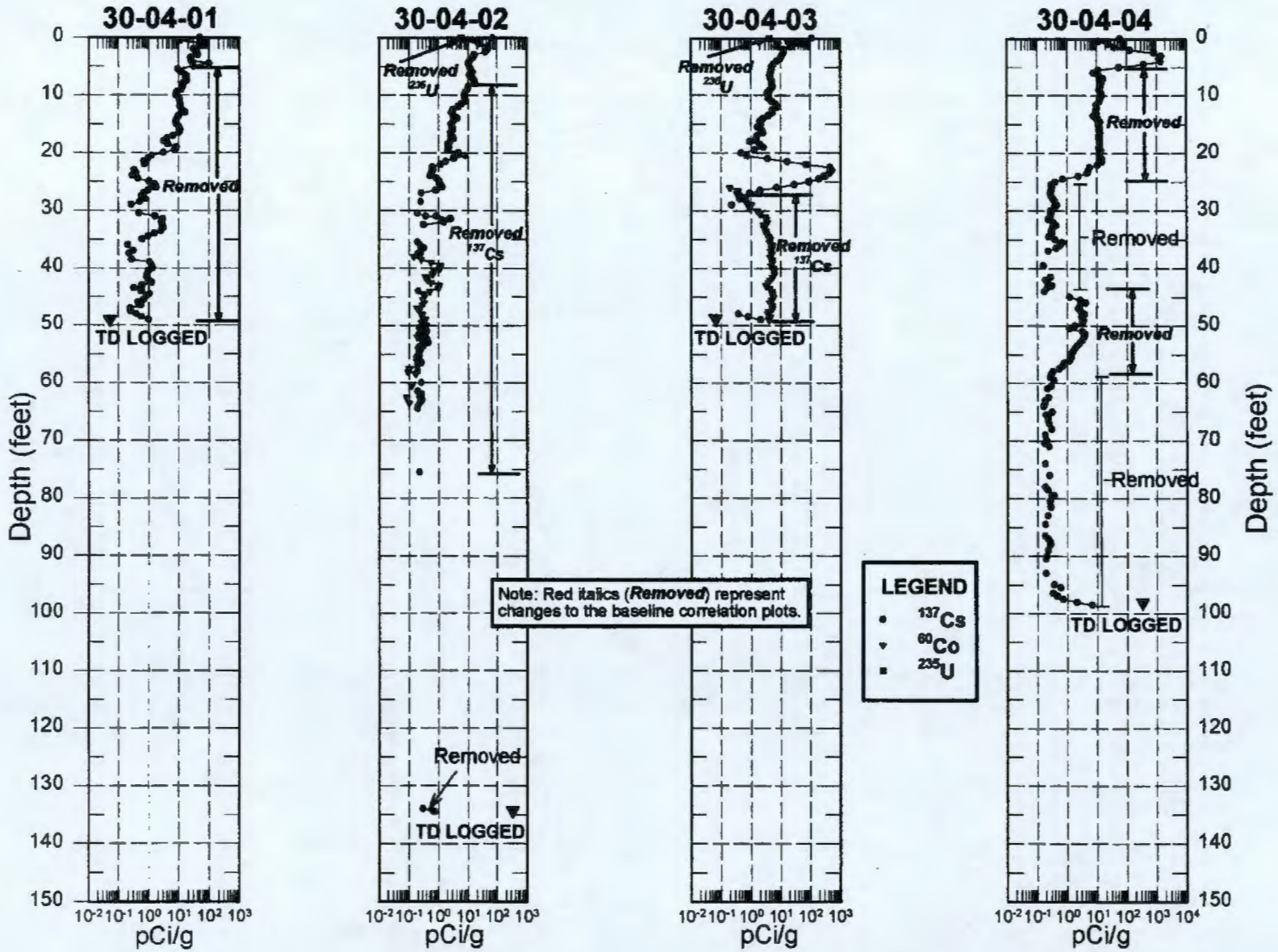


Figure C-3. Summary of Interpreted Data Set for the C Tank Farm

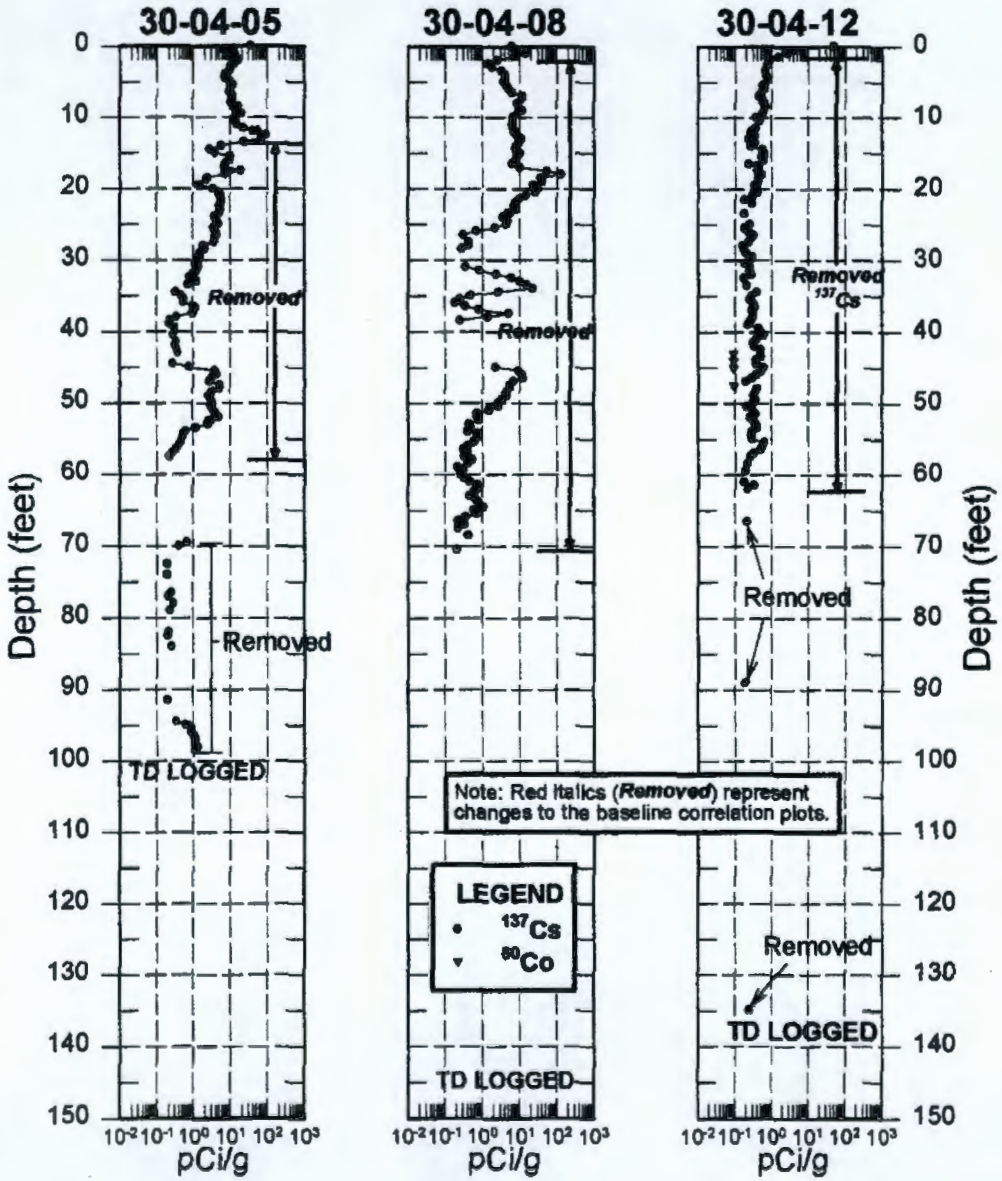


Figure C-4. Summary of Interpreted Data Set for the C Tank Farm

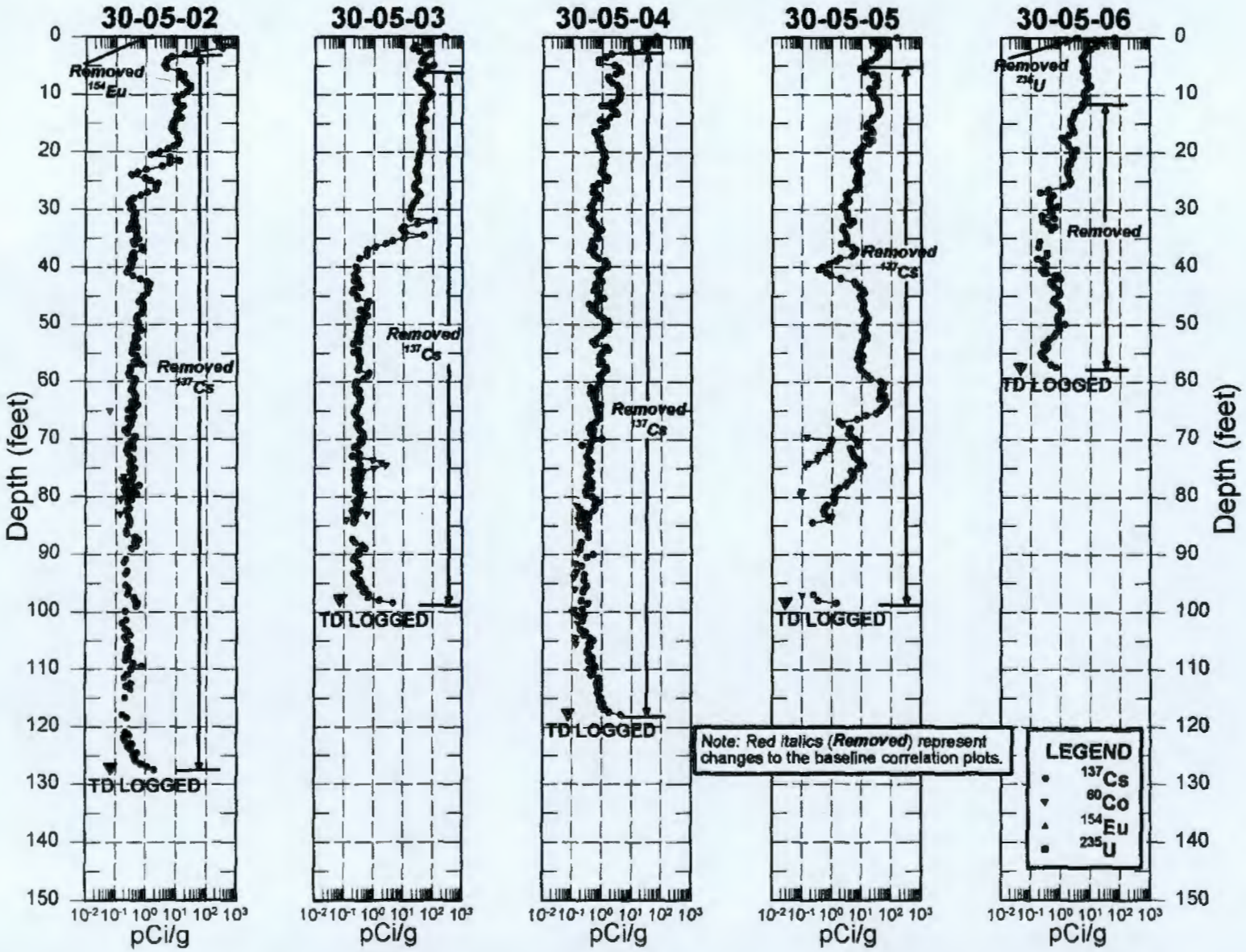


Figure C-5. Summary of Interpreted Data Set for the C Tank Farm

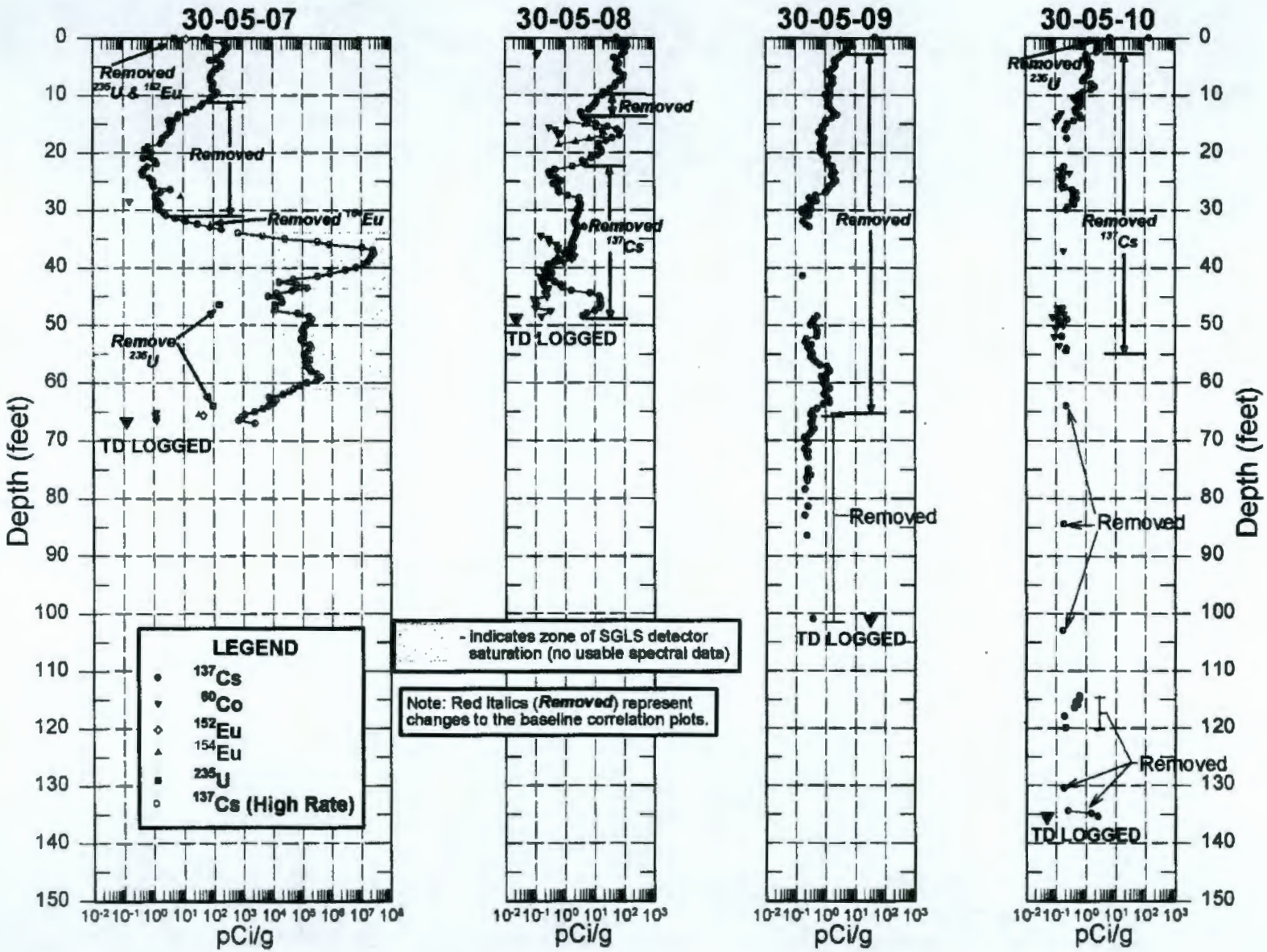


Figure C-6. Summary of Interpreted Data Set for the C Tank Farm

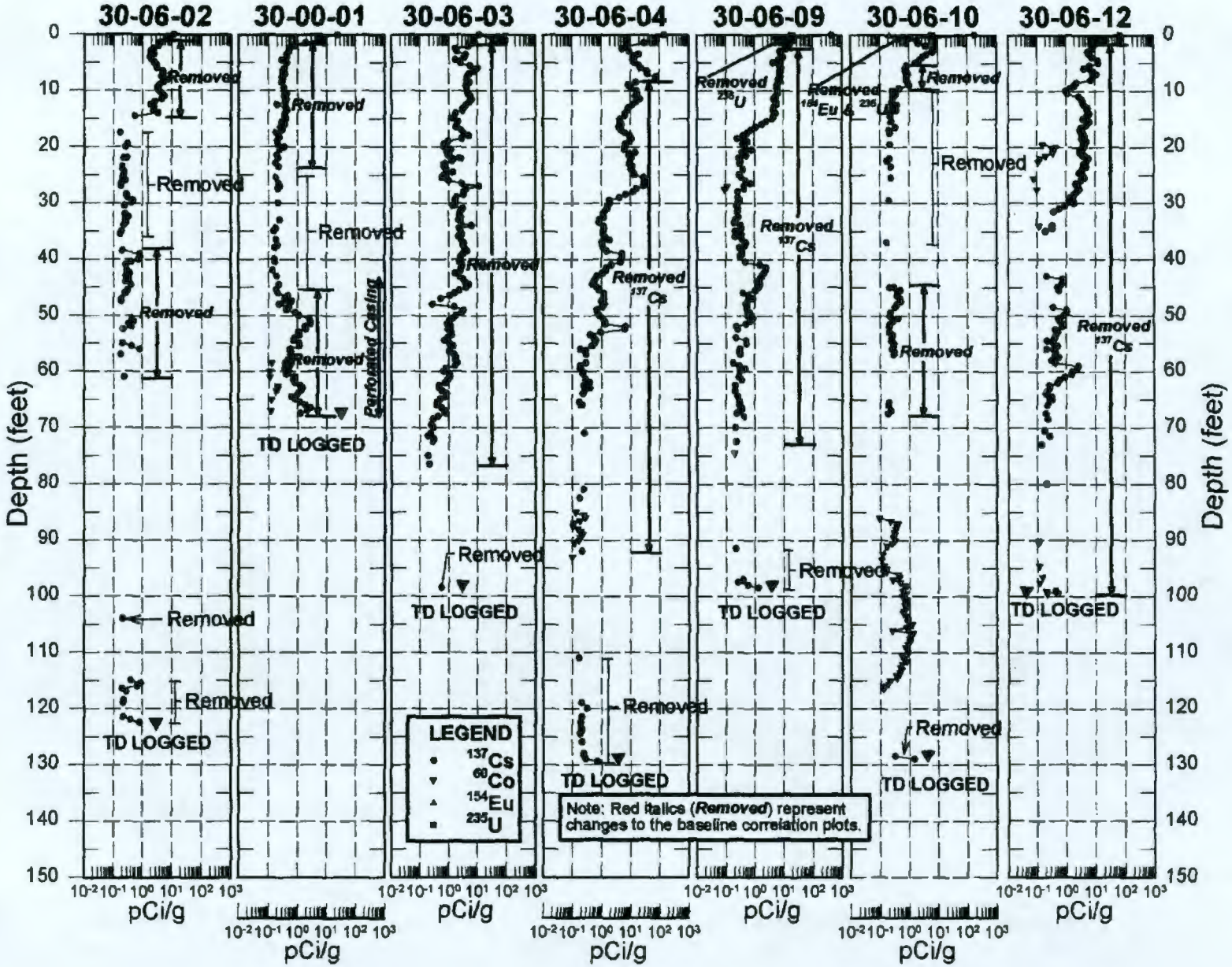


Figure C-7. Summary of Interpreted Data Set for the C Tank Farm

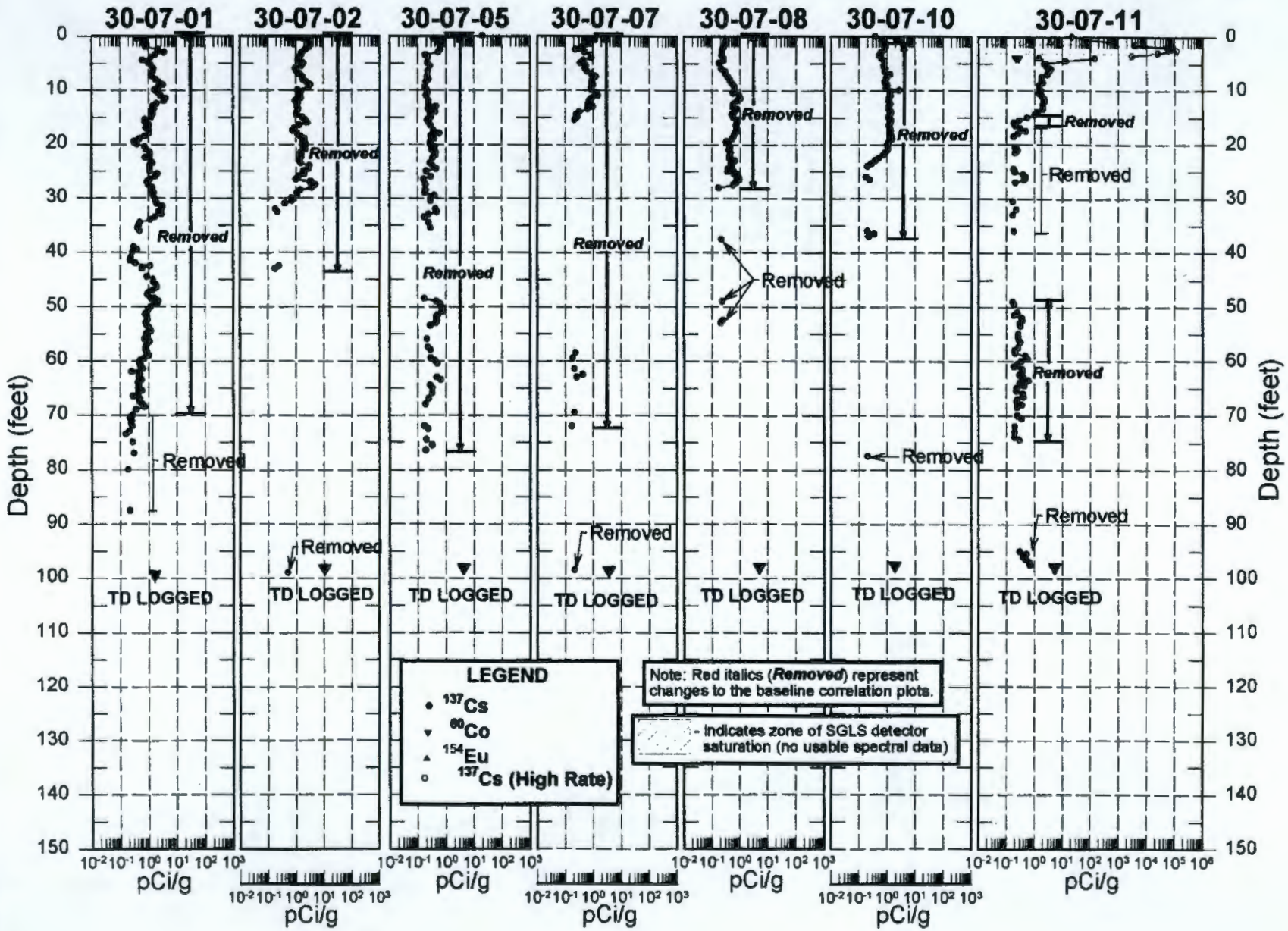


Figure C-8. Summary of Interpreted Data Set for the C Tank Farm

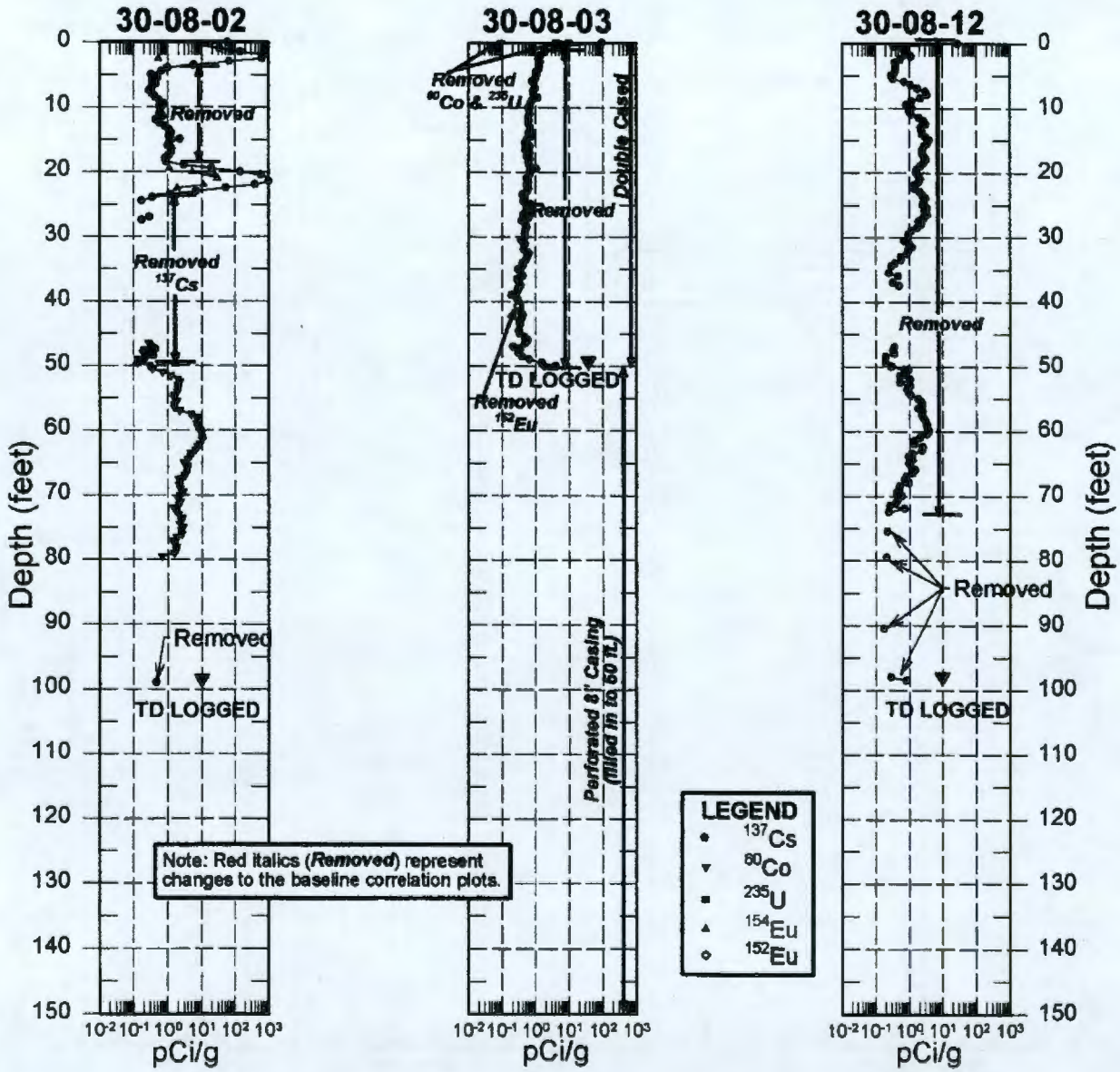


Figure C-9. Summary of Interpreted Data Set for the C Tank Farm

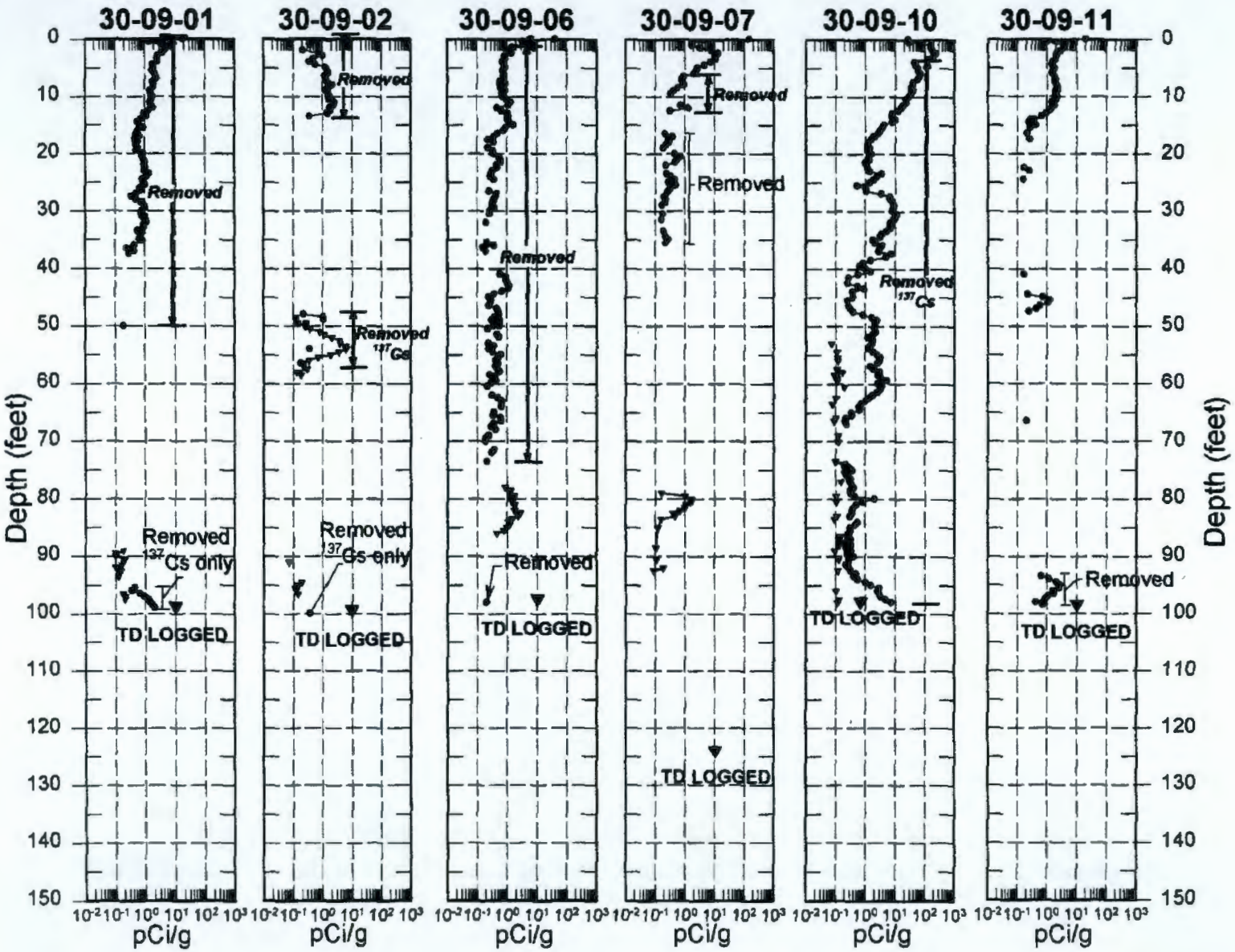


Figure C-10. Summary of Interpreted Data Set for the C Tank Farm

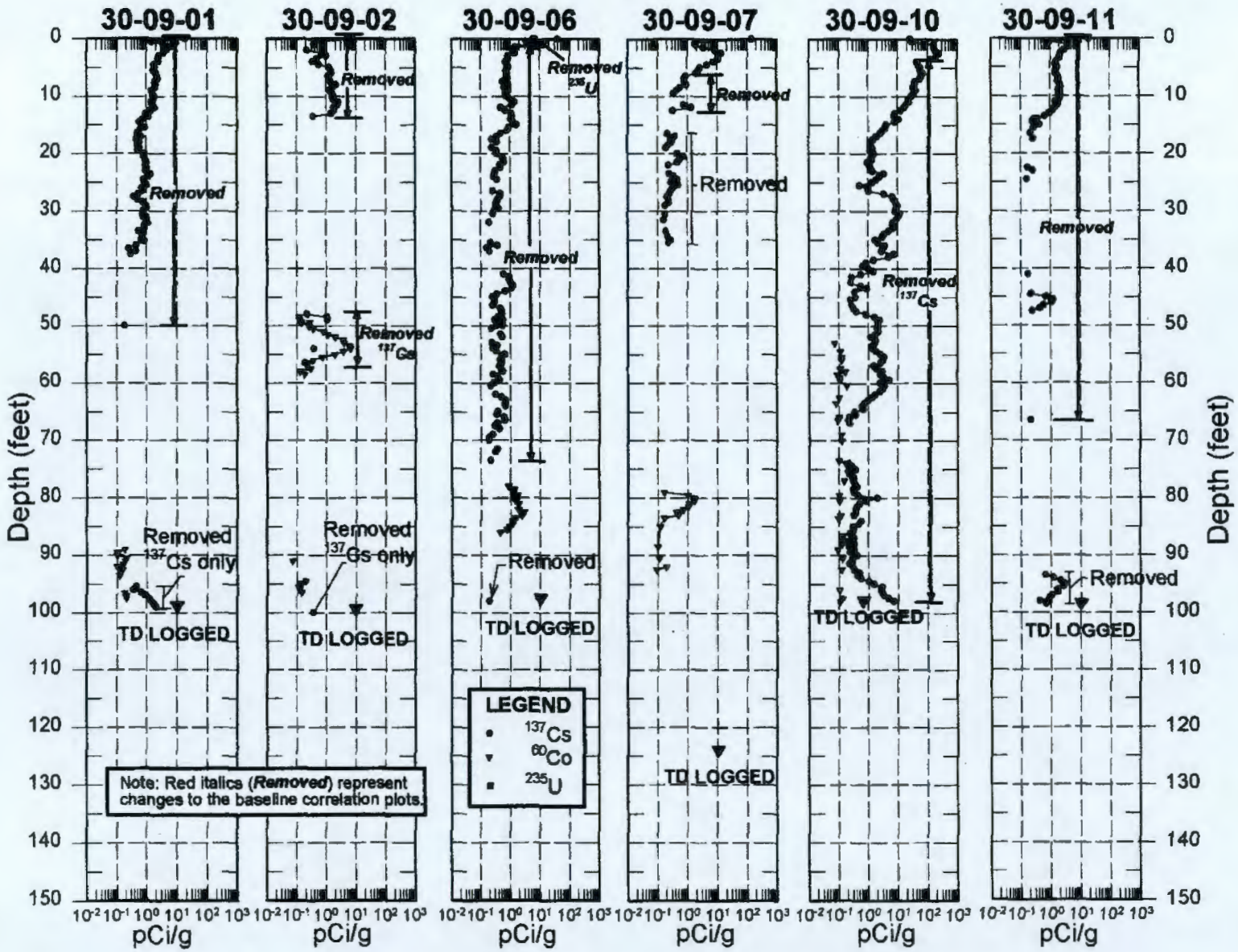


Figure C-11. Summary of Interpreted Data Set for the C Tank Farm

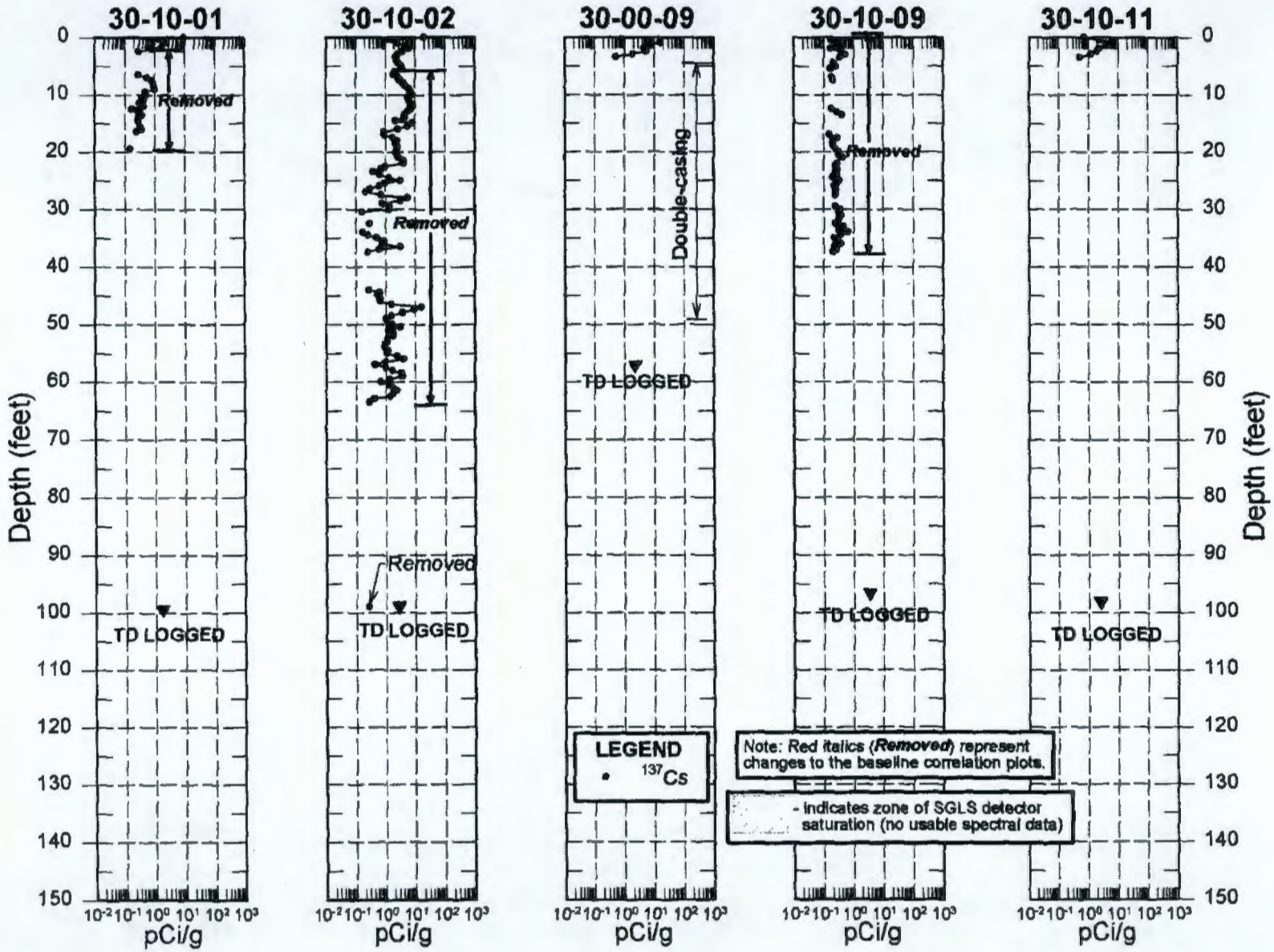


Figure C-12. Summary of Interpreted Data Set for the C Tank Farm

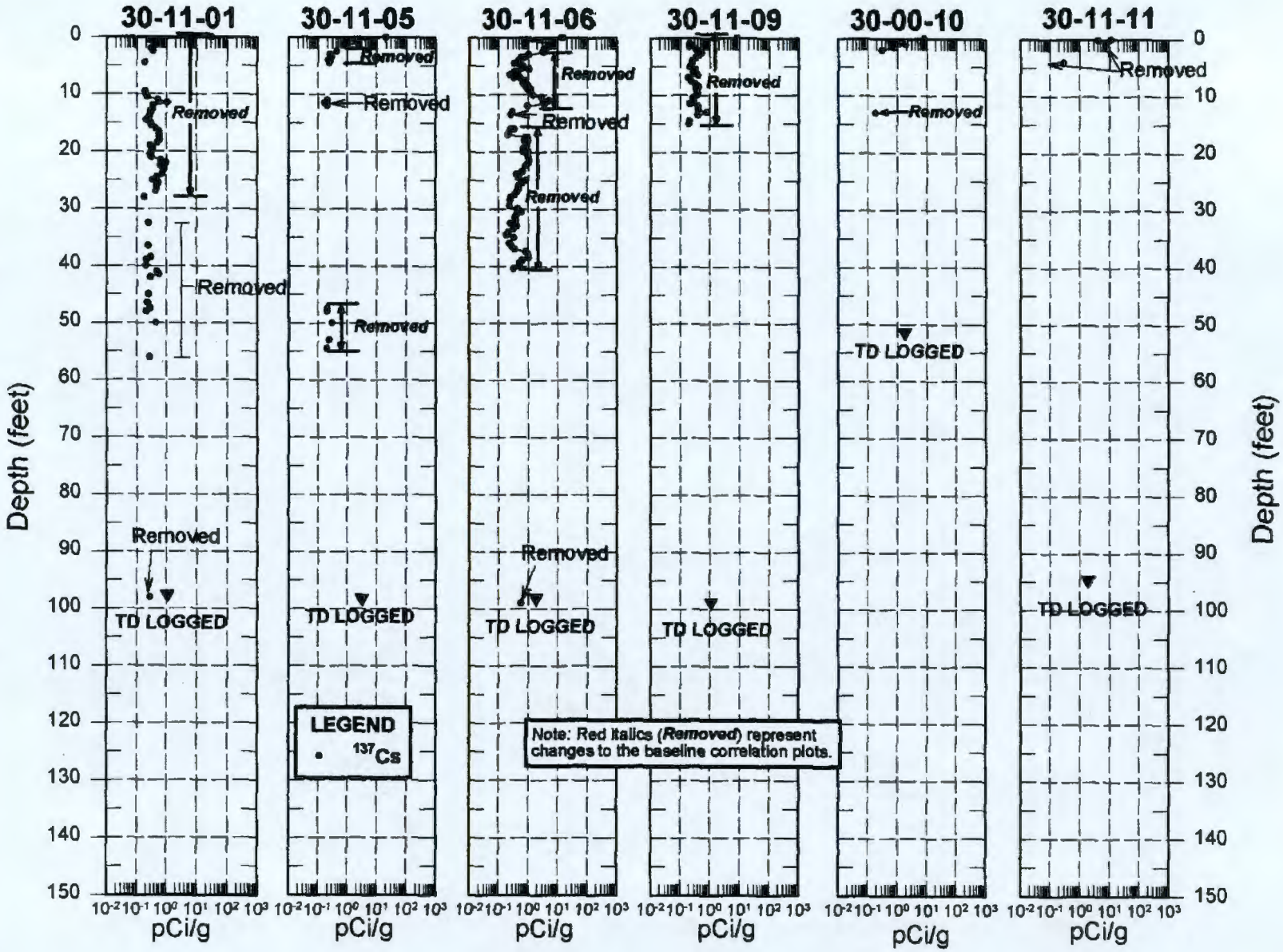


Figure C-13. Summary of Interpreted Data Set for the C Tank Farm

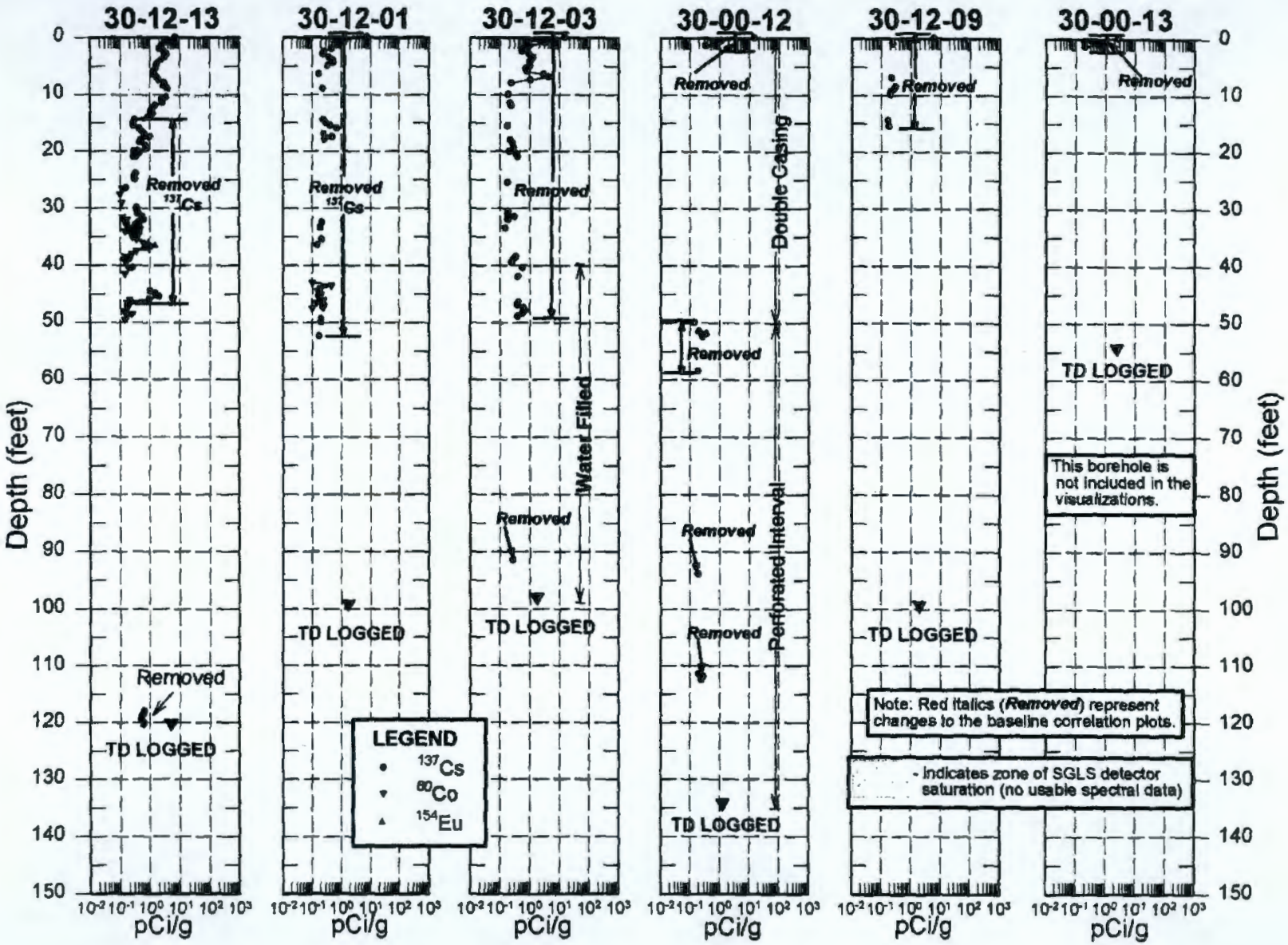


Figure C-14. Summary of Interpreted Data Set for the C Tank Farm

Appendix D
C Tank Farm Visualizations

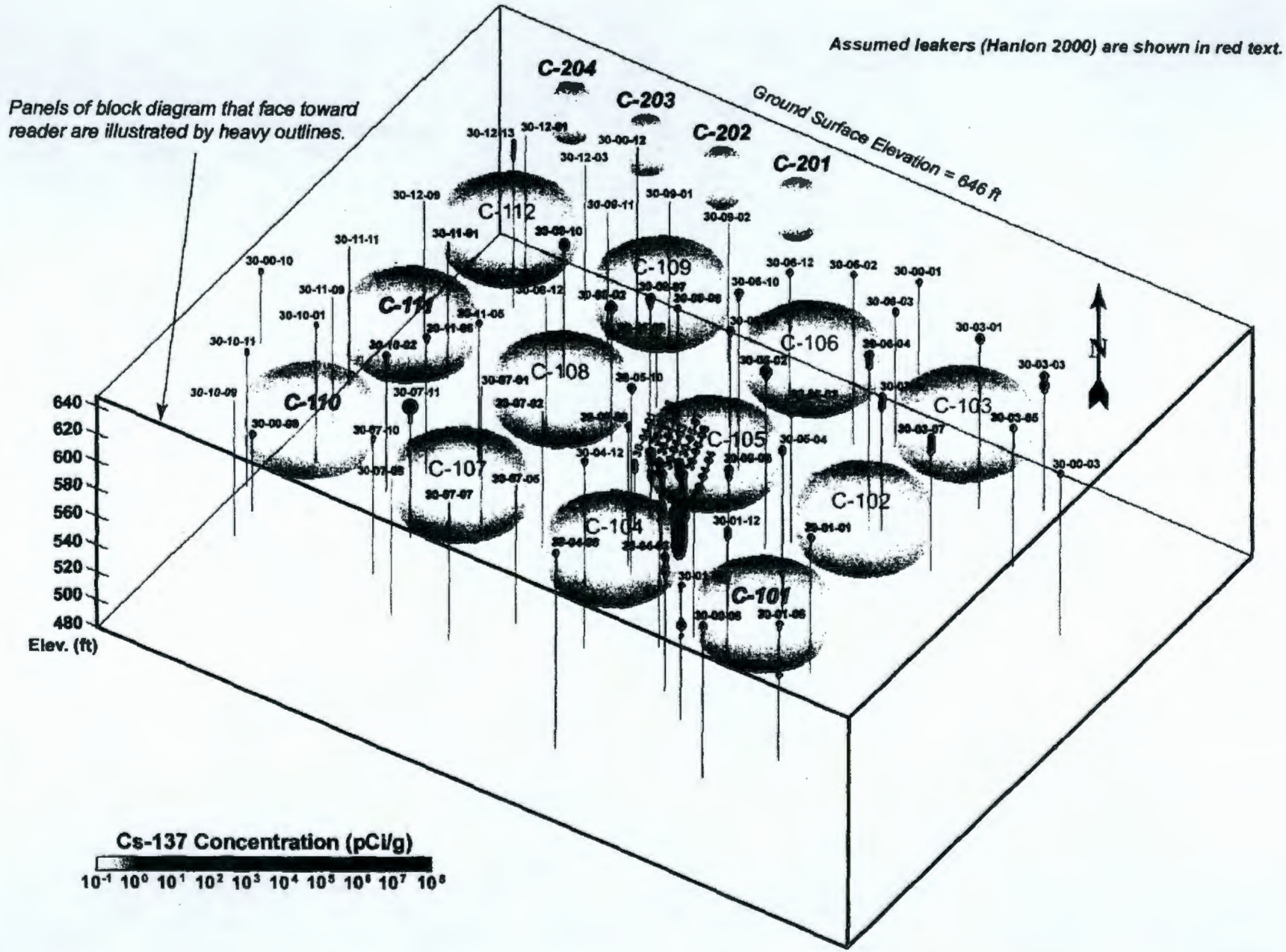


Figure D-1. C Tank Farm Visualization

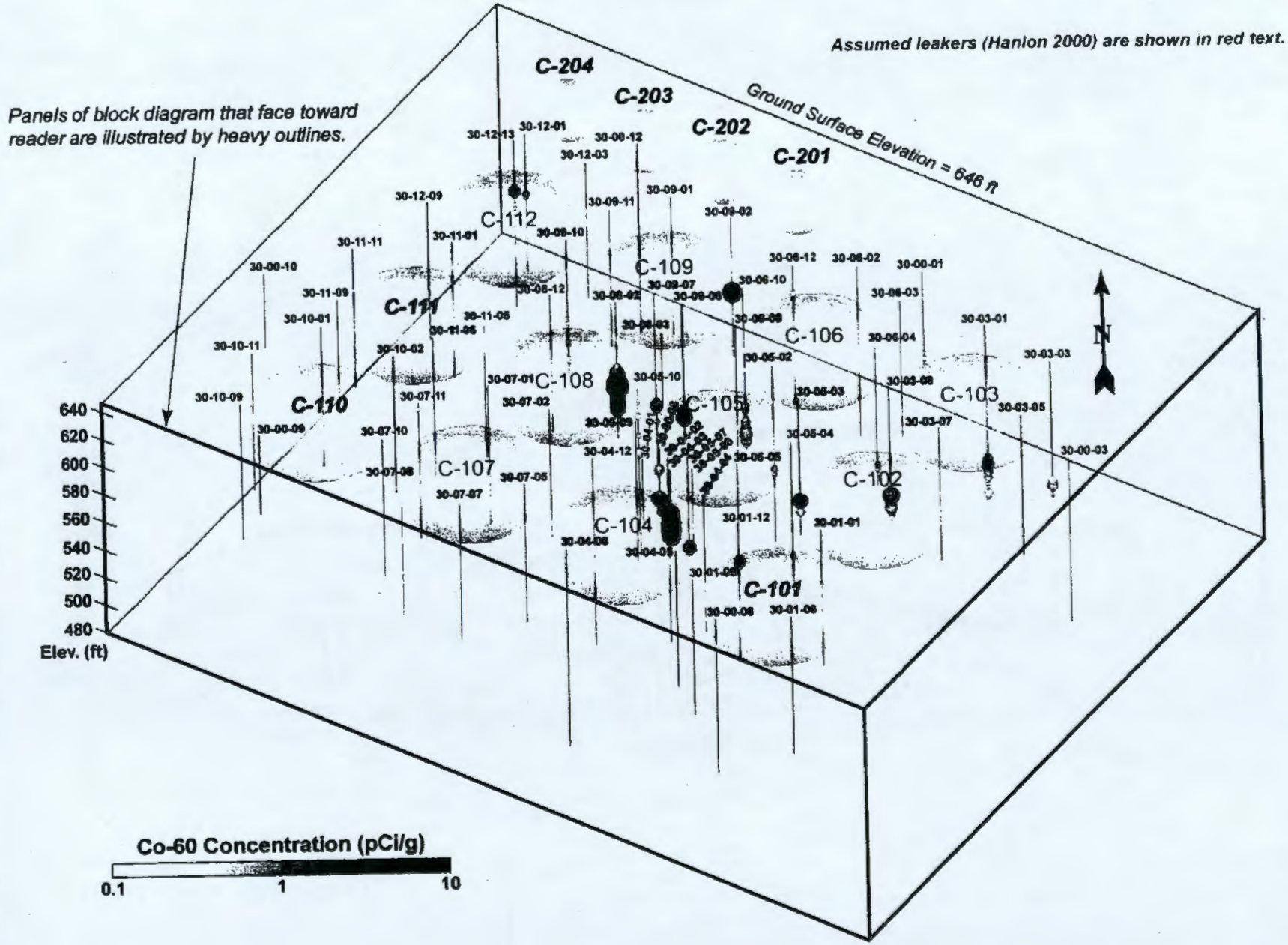


Figure D-2. C Tank Farm Visualization

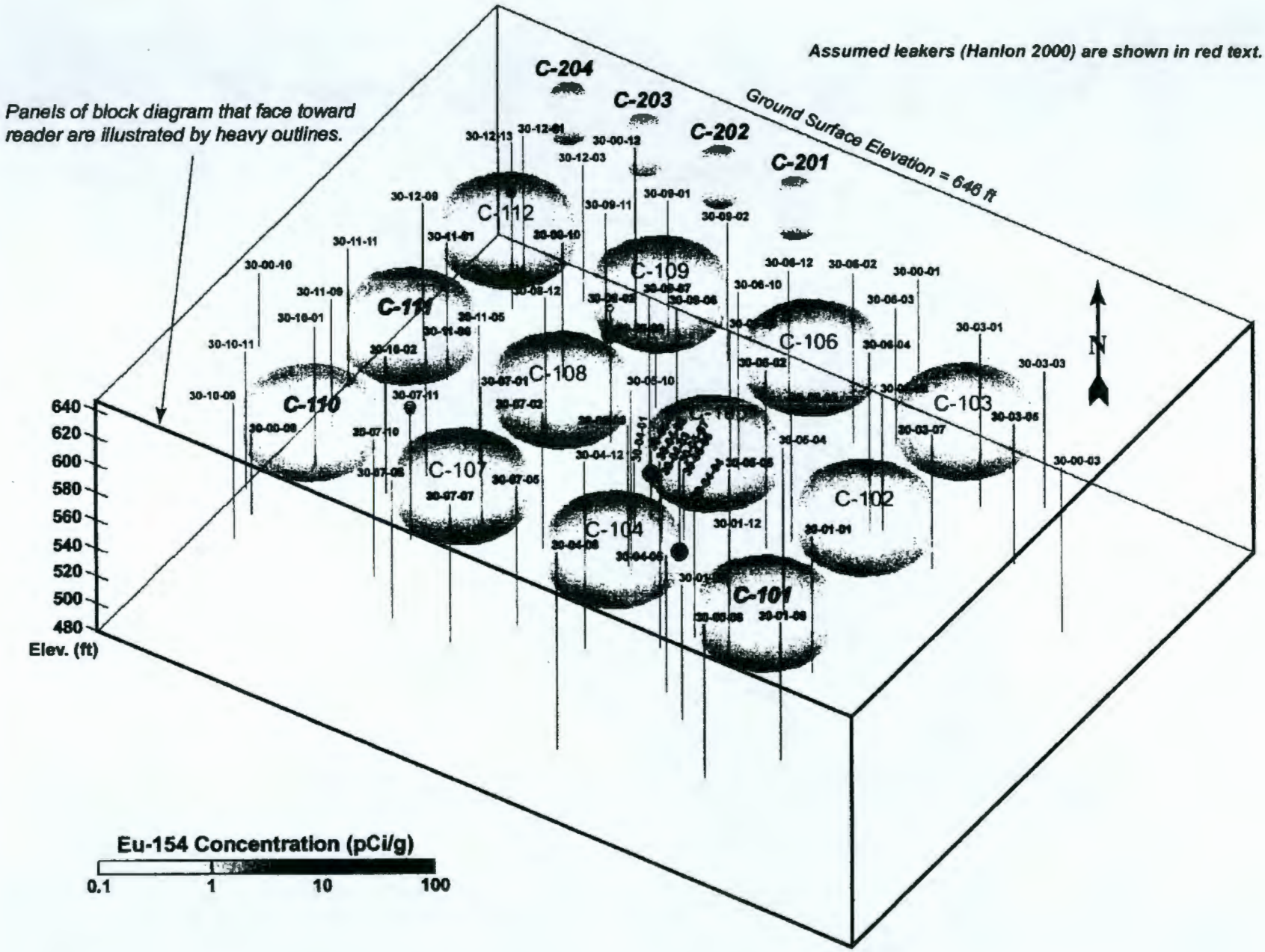


Figure D-3. C Tank Farm Visualization

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

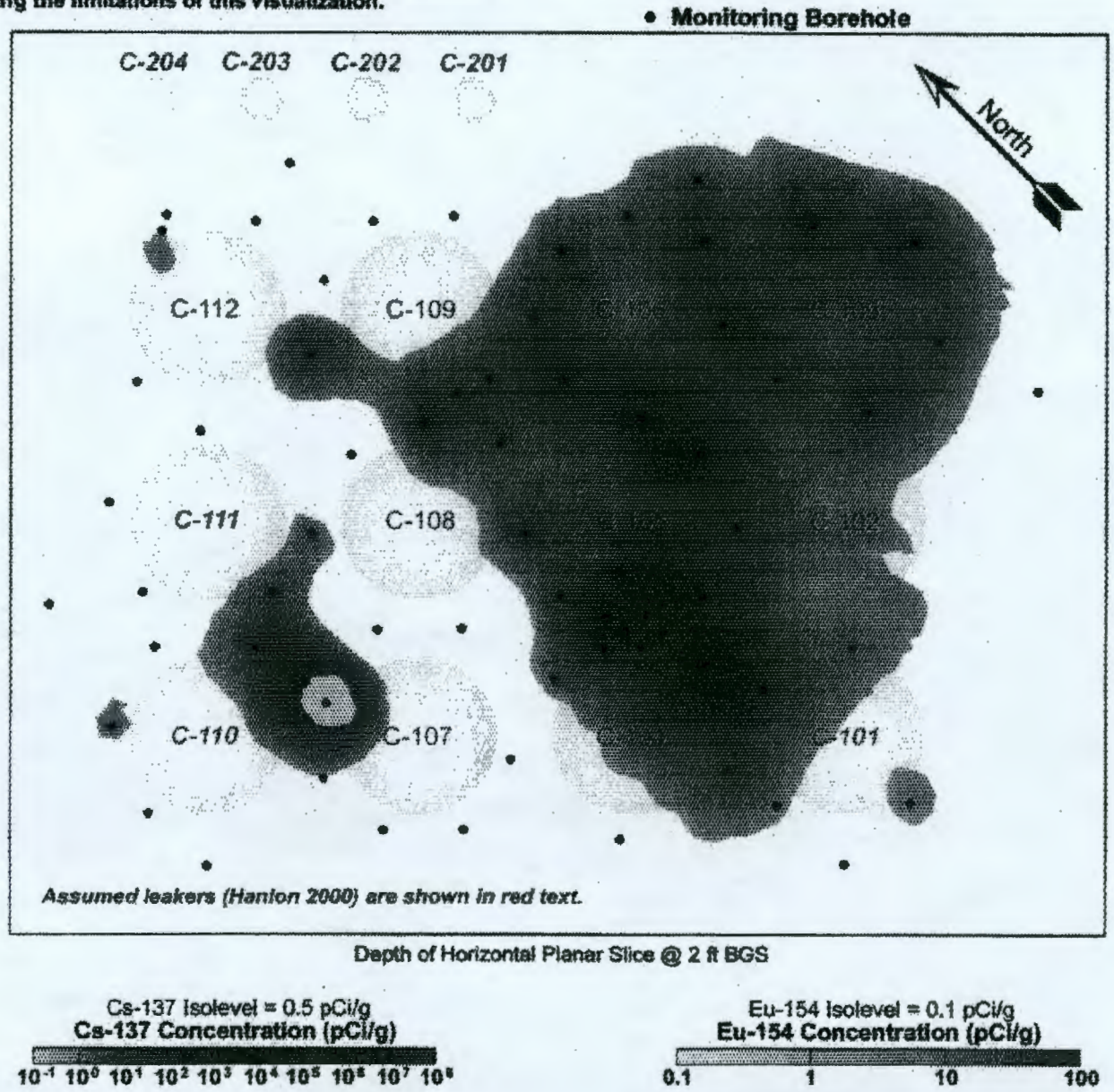


Figure D-4. C Tank Farm Visualization

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

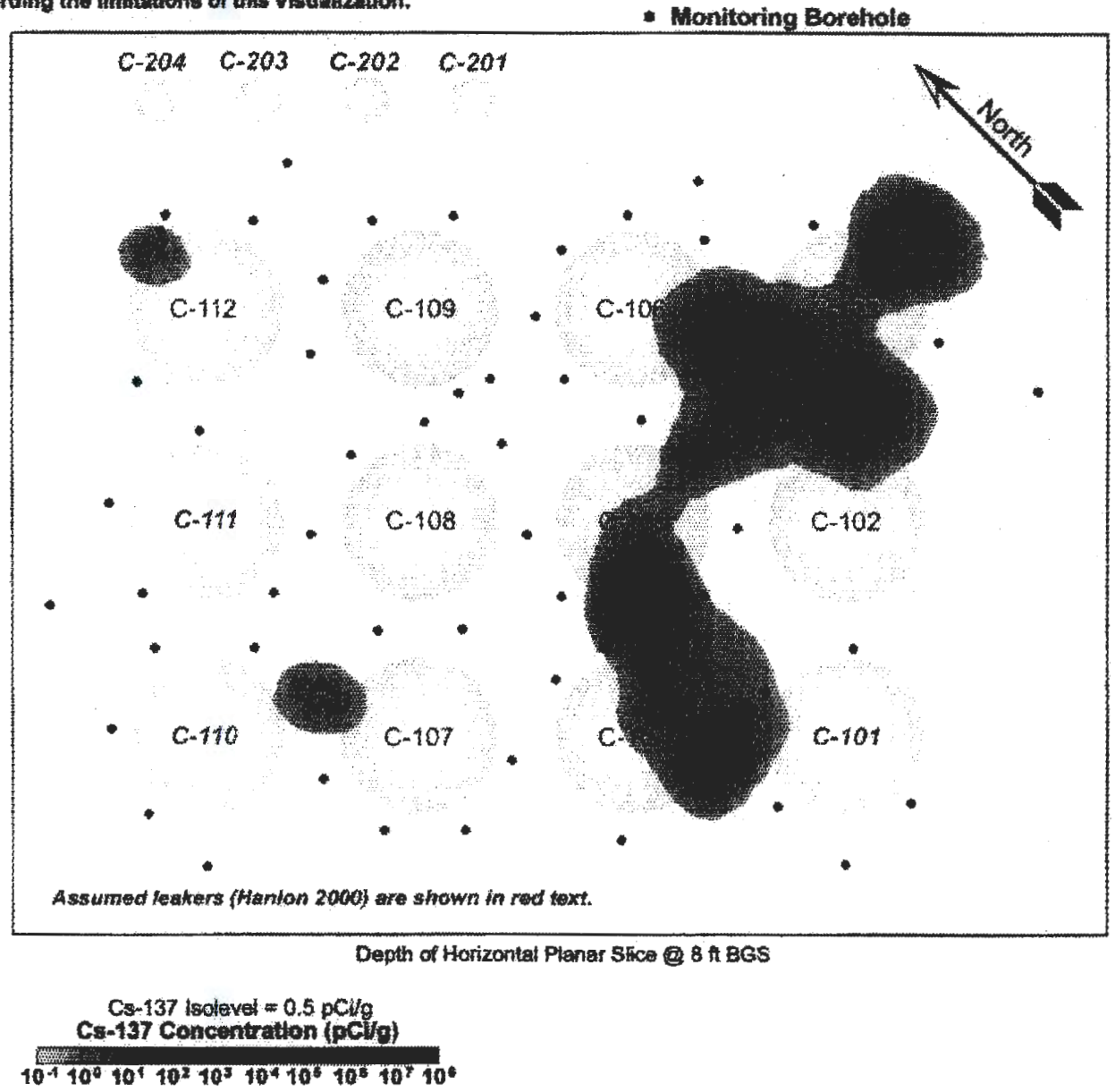


Figure D-5. C Tank Farm Visualization

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

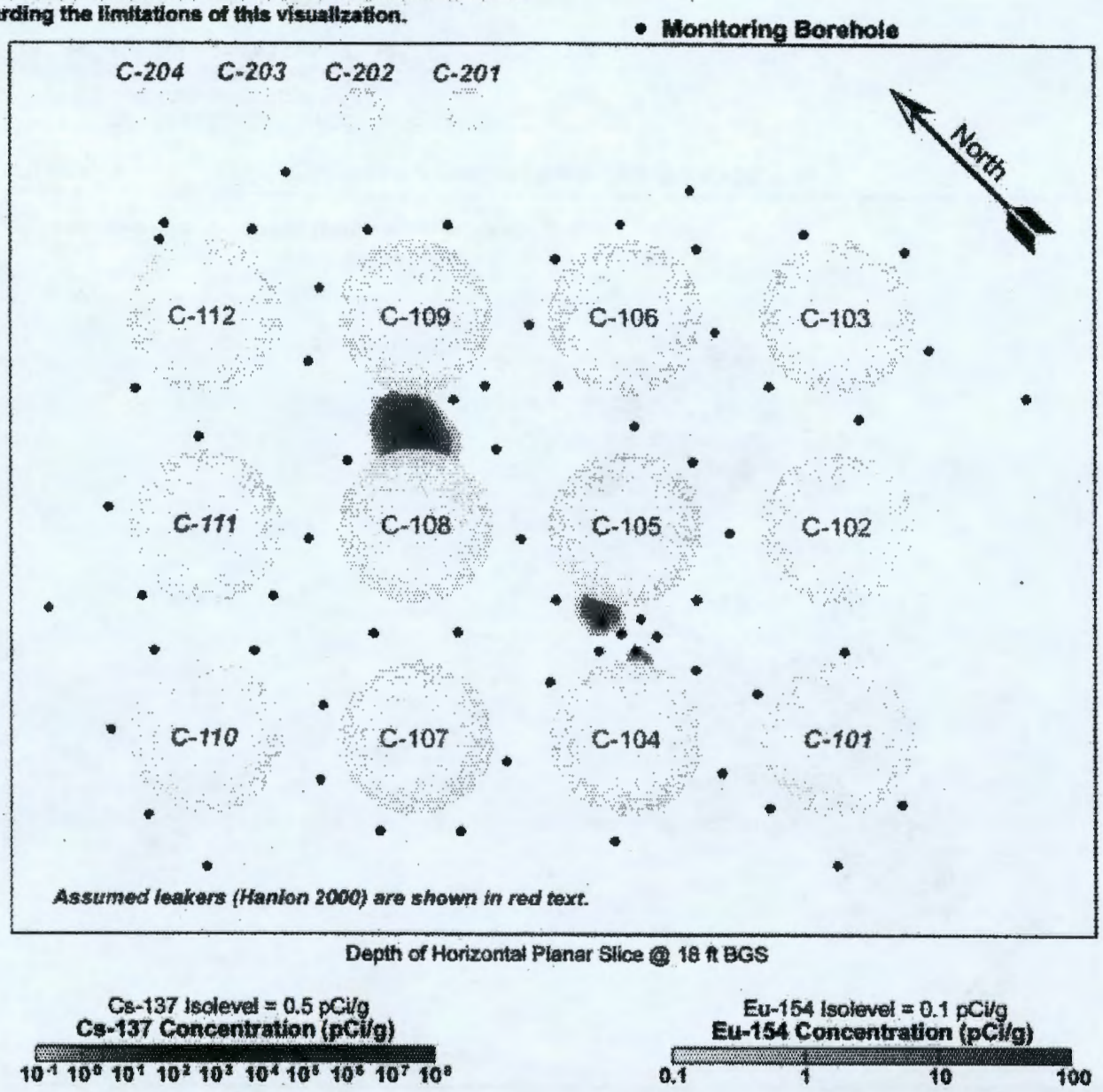


Figure D-6. C Tank Farm Visualization

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

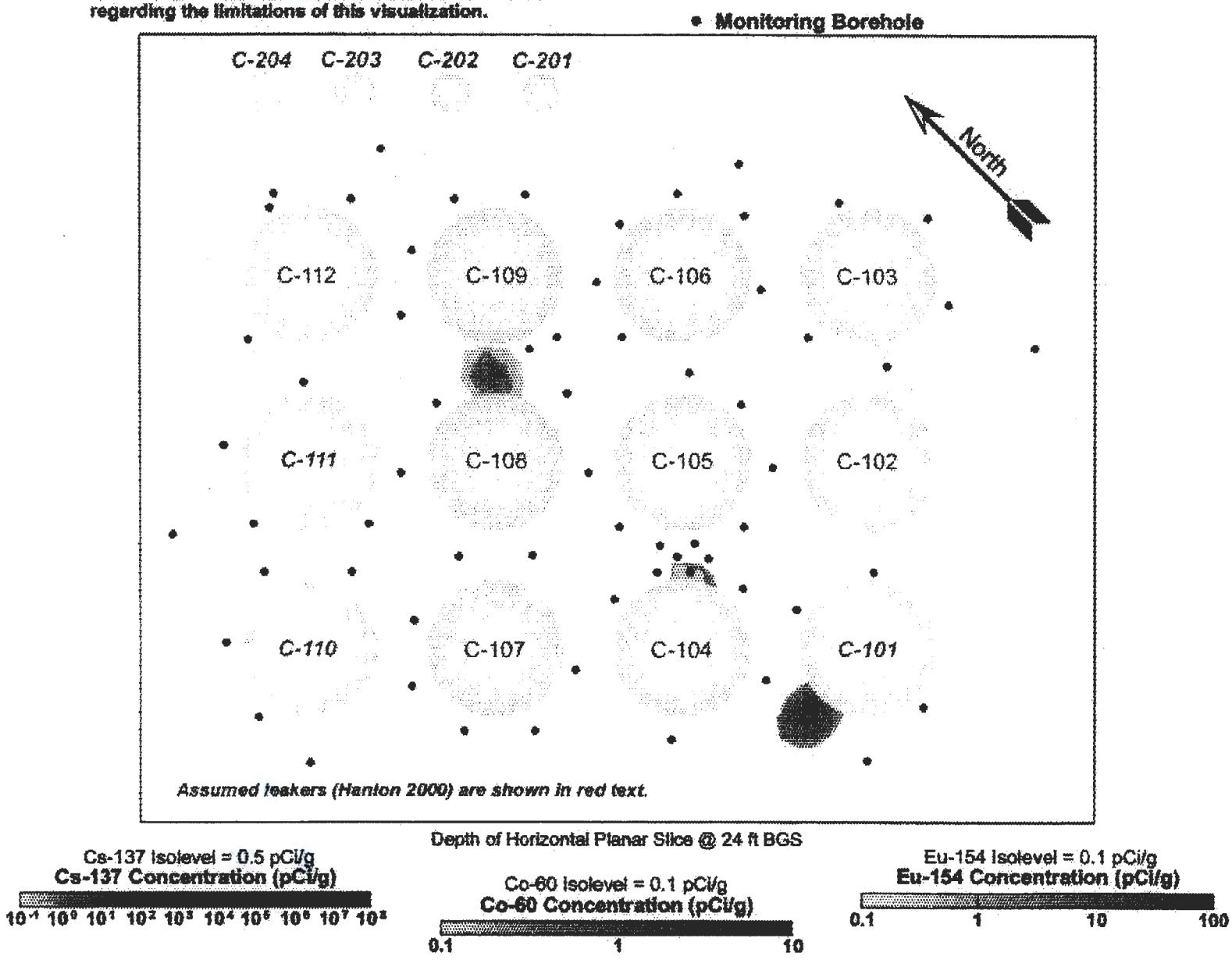


Figure D-7. C Tank Farm Visualization

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

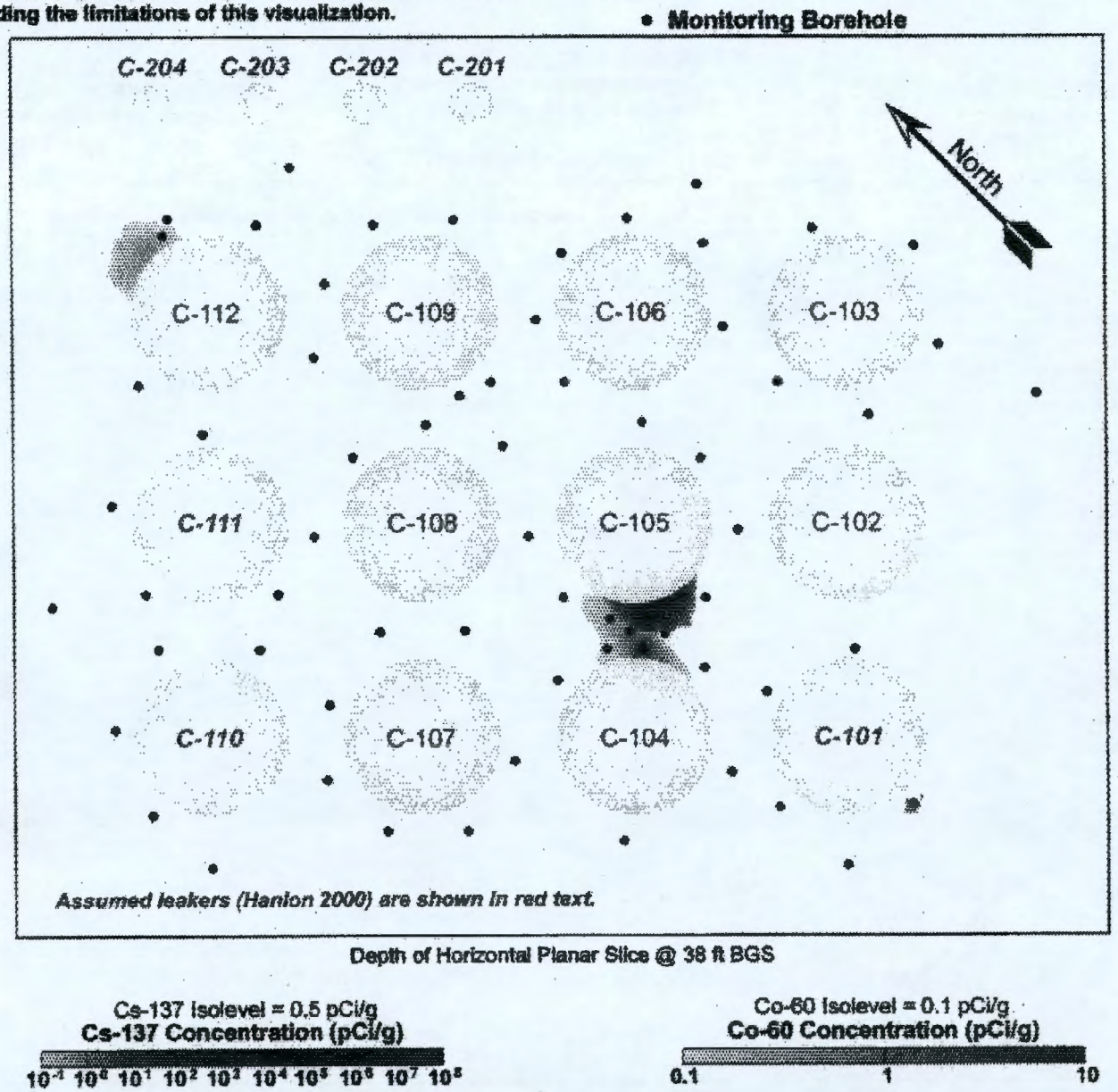


Figure D-8. C Tank Farm Visualization

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

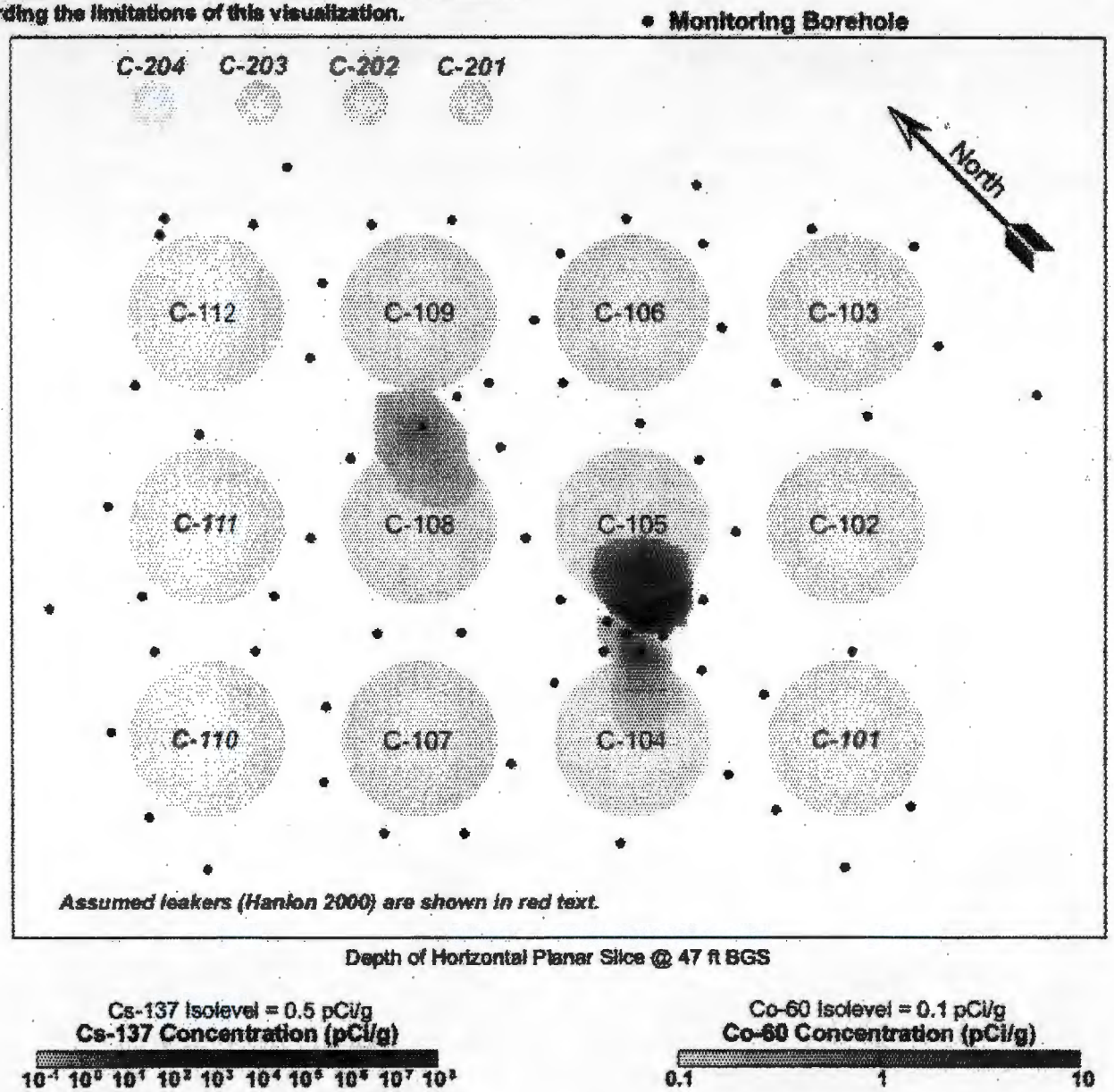


Figure D-9. C Tank Farm Visualization

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

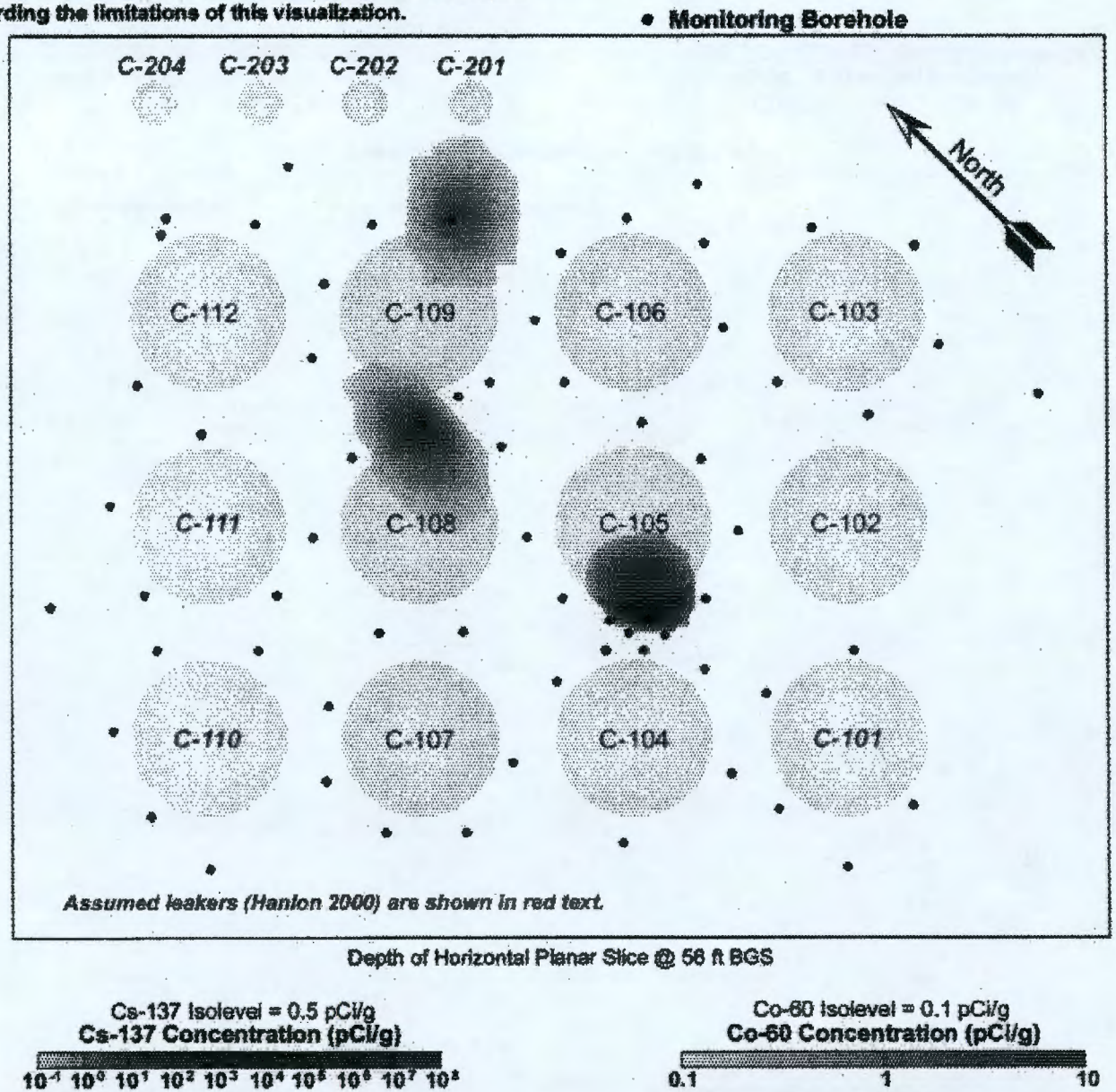


Figure D-10. C Tank Farm Visualization

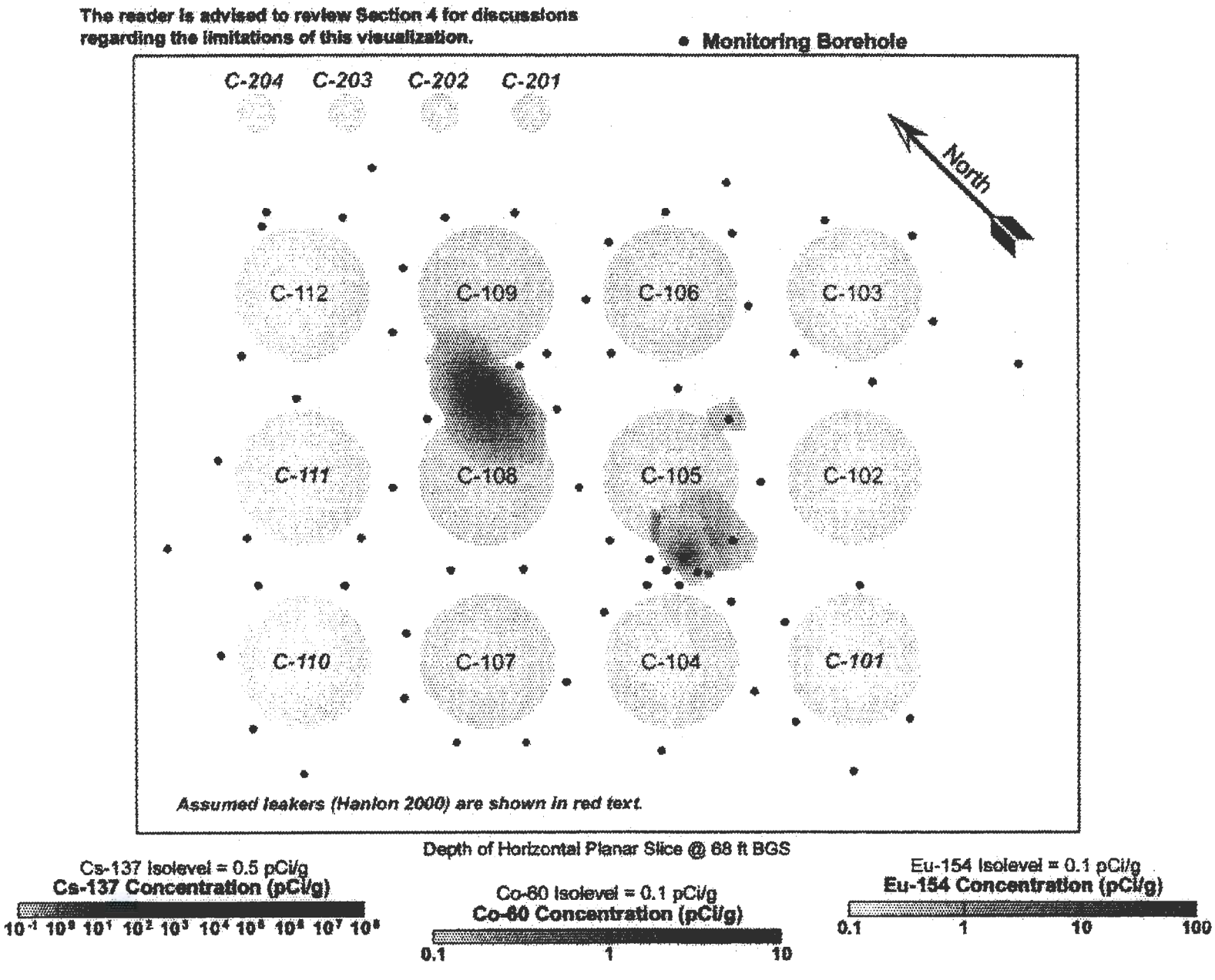


Figure D-11. C Tank Farm Visualization

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

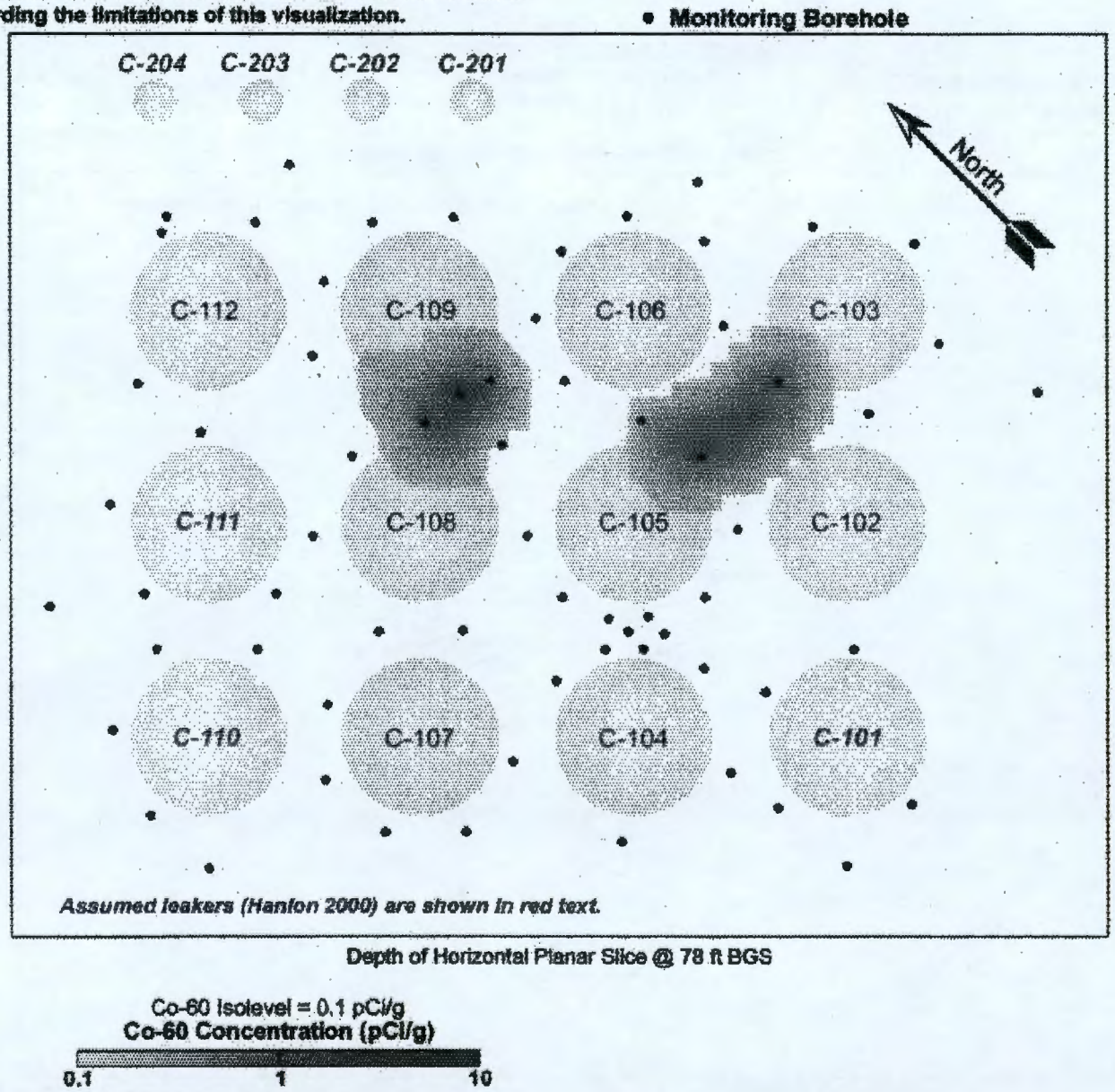


Figure D-12. C Tank Farm Visualization

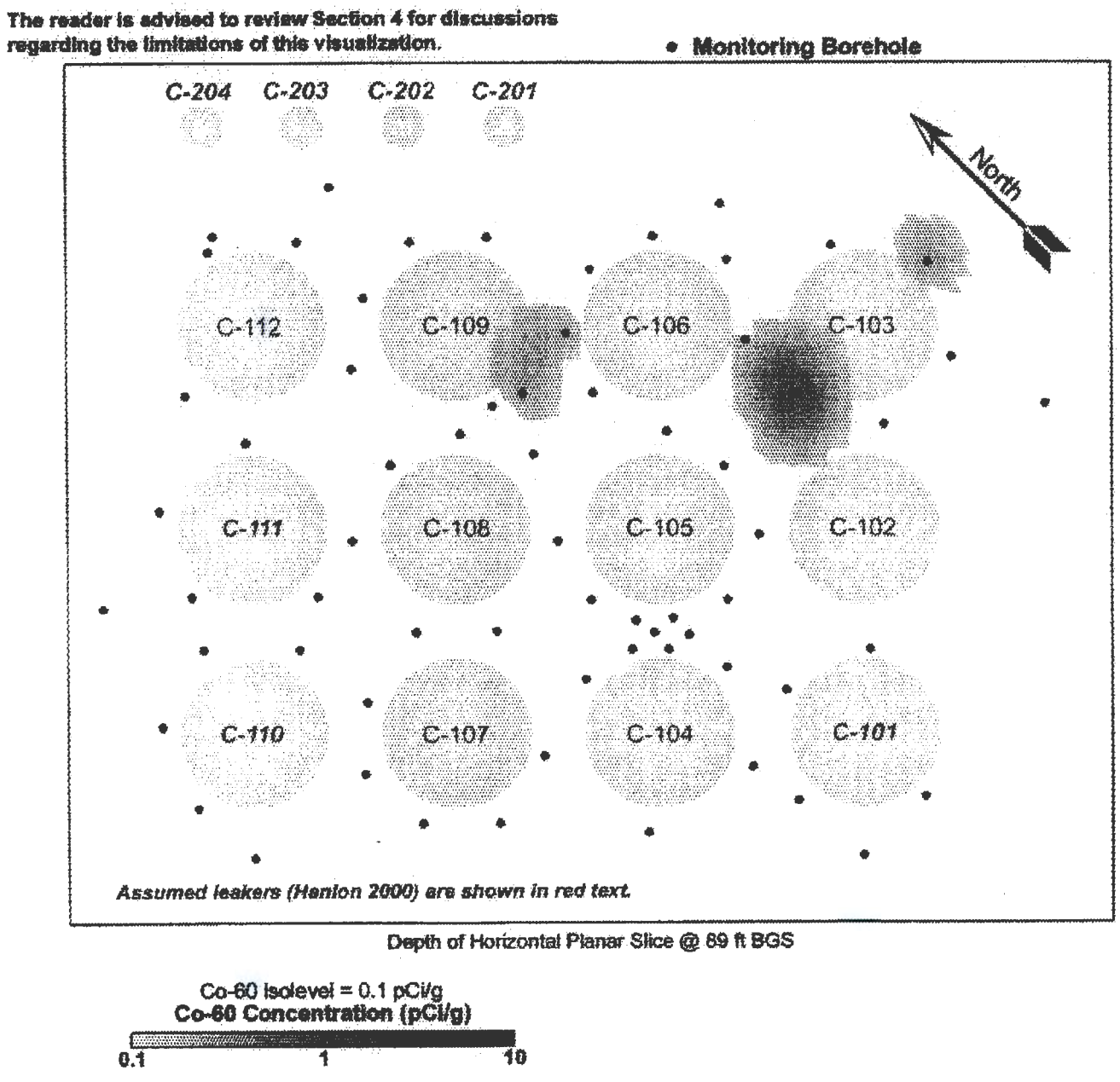
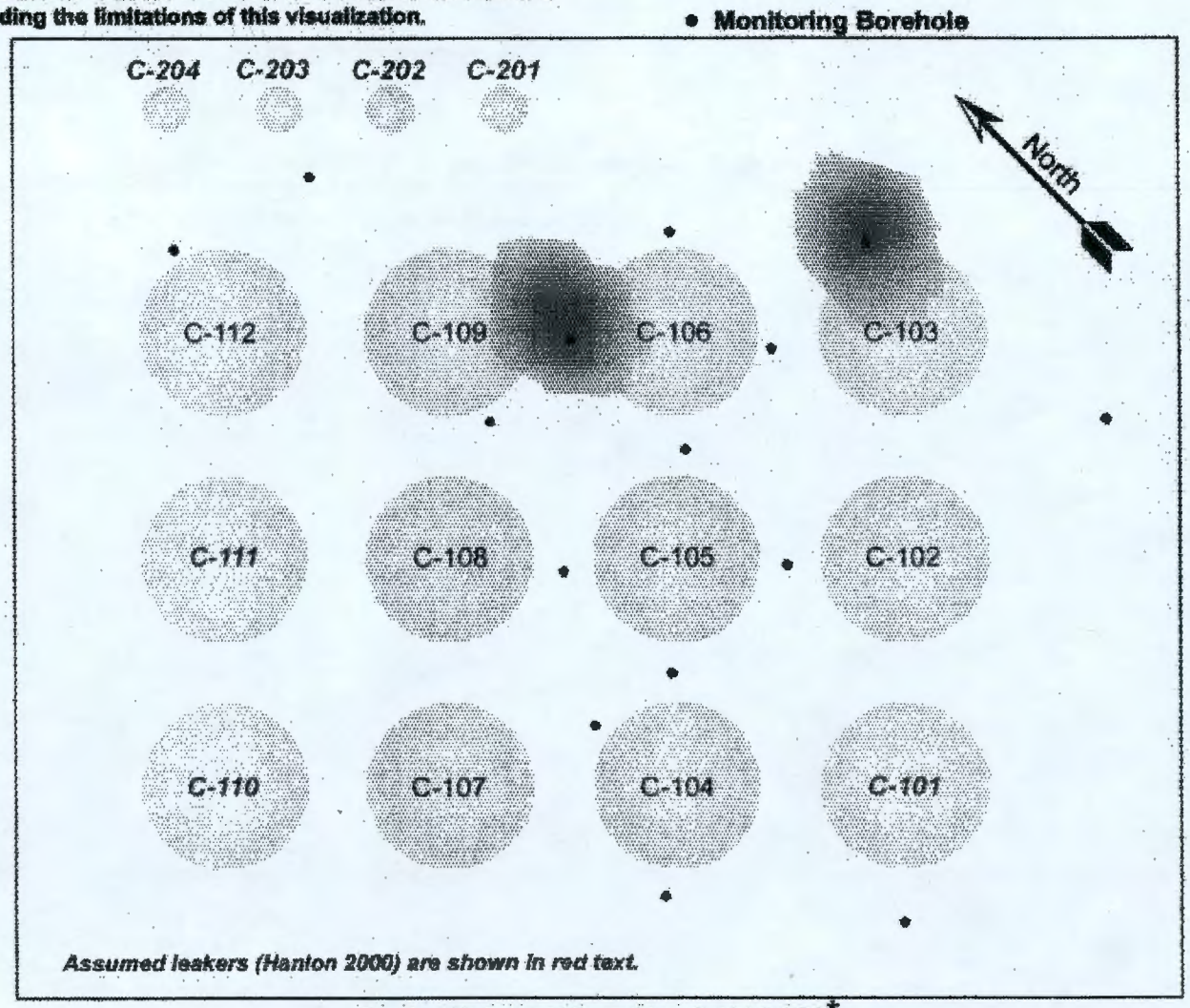


Figure D-13. C Tank Farm Visualization

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



Depth of Horizontal Planar Slice @ 104 ft BGS*

Co-60 Isolevel = 0.1 pCi/g

Co-60 Concentration (pCi/g)

0.1 1 10

*Only boreholes that penetrate beyond this depth are shown on the visualization.

Figure D-14. C Tank Farm Visualization

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

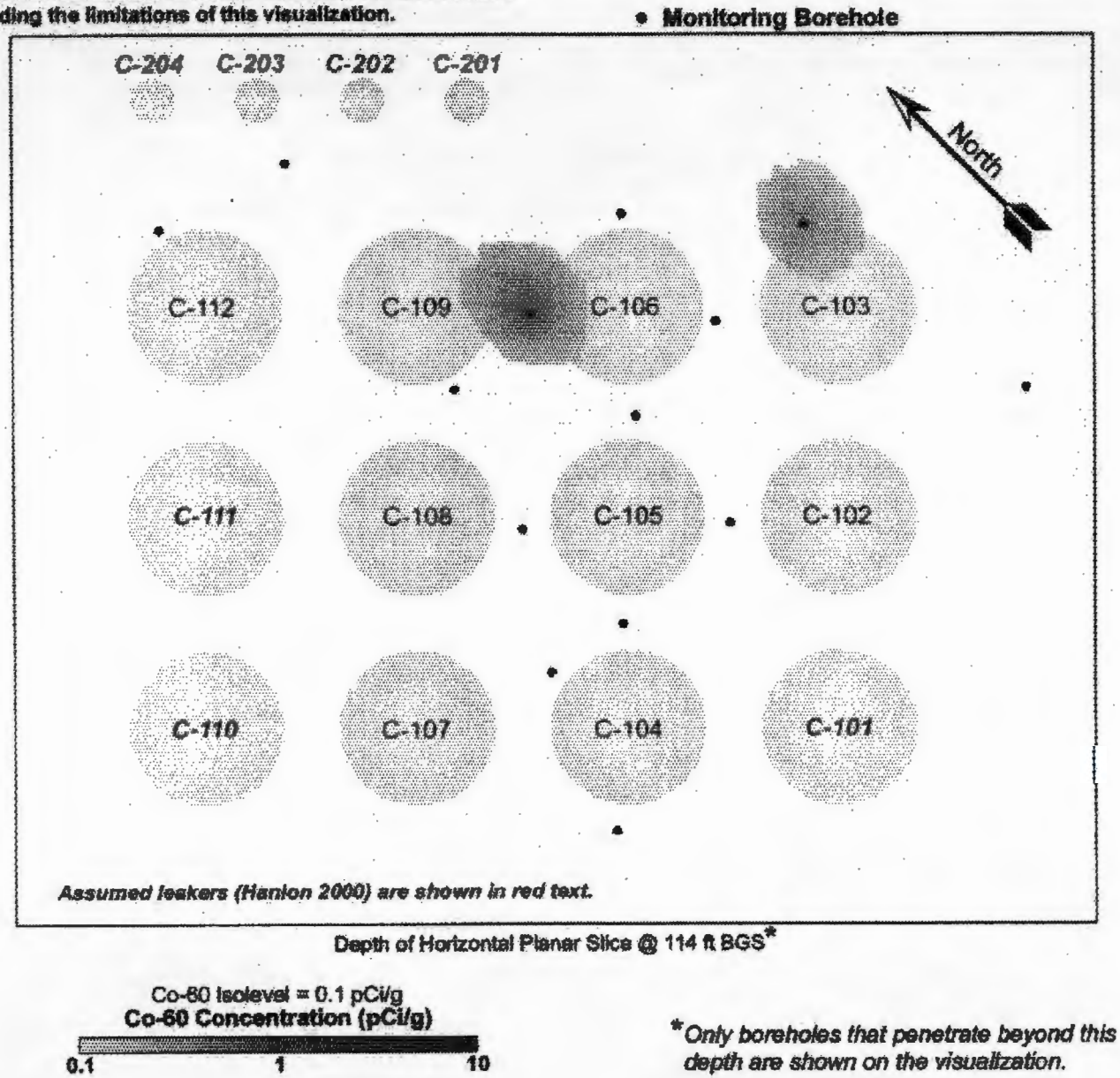
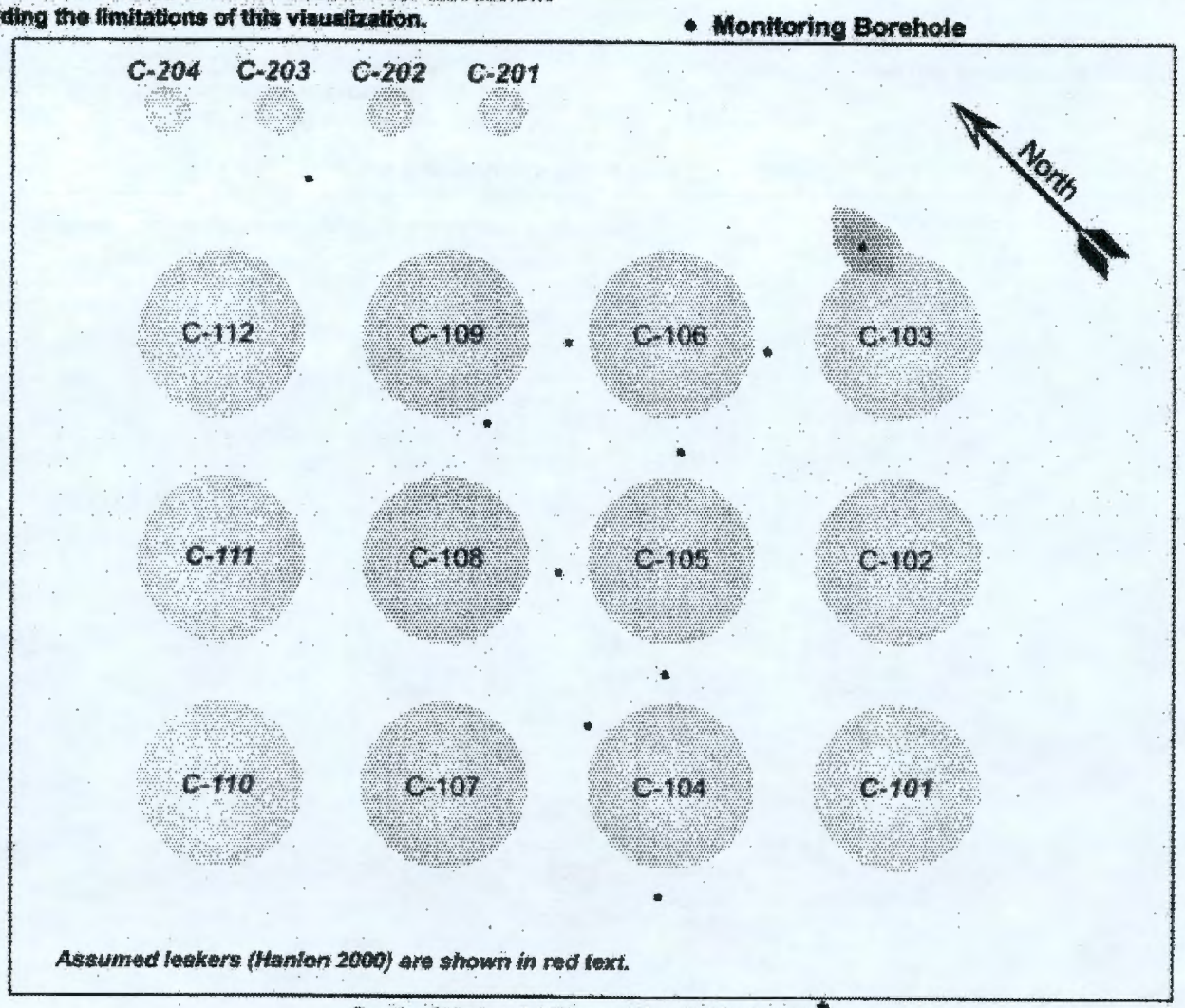


Figure D-15. C Tank Farm Visualization

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



Depth of Horizontal Planar Slice @ 125 ft BGS*

Co-60 Isolevel = 0.1 pCi/g

Co-60 Concentration (pCi/g)

0.1 1 10

*Only boreholes that penetrate to or beyond this depth are shown on the visualization.

Figure D-16. C Tank Farm Visualization

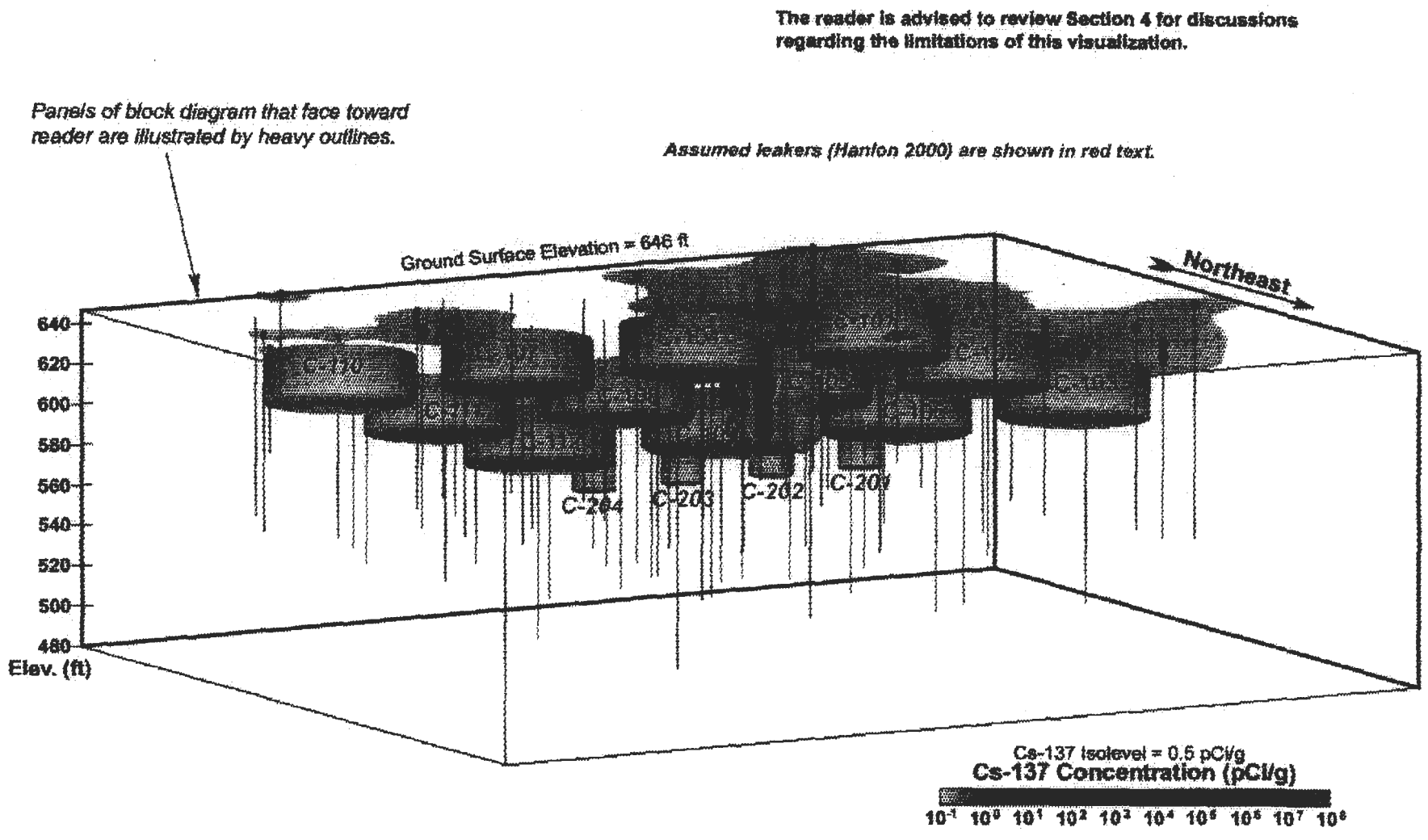


Figure D-17. C Tank Farm Visualization

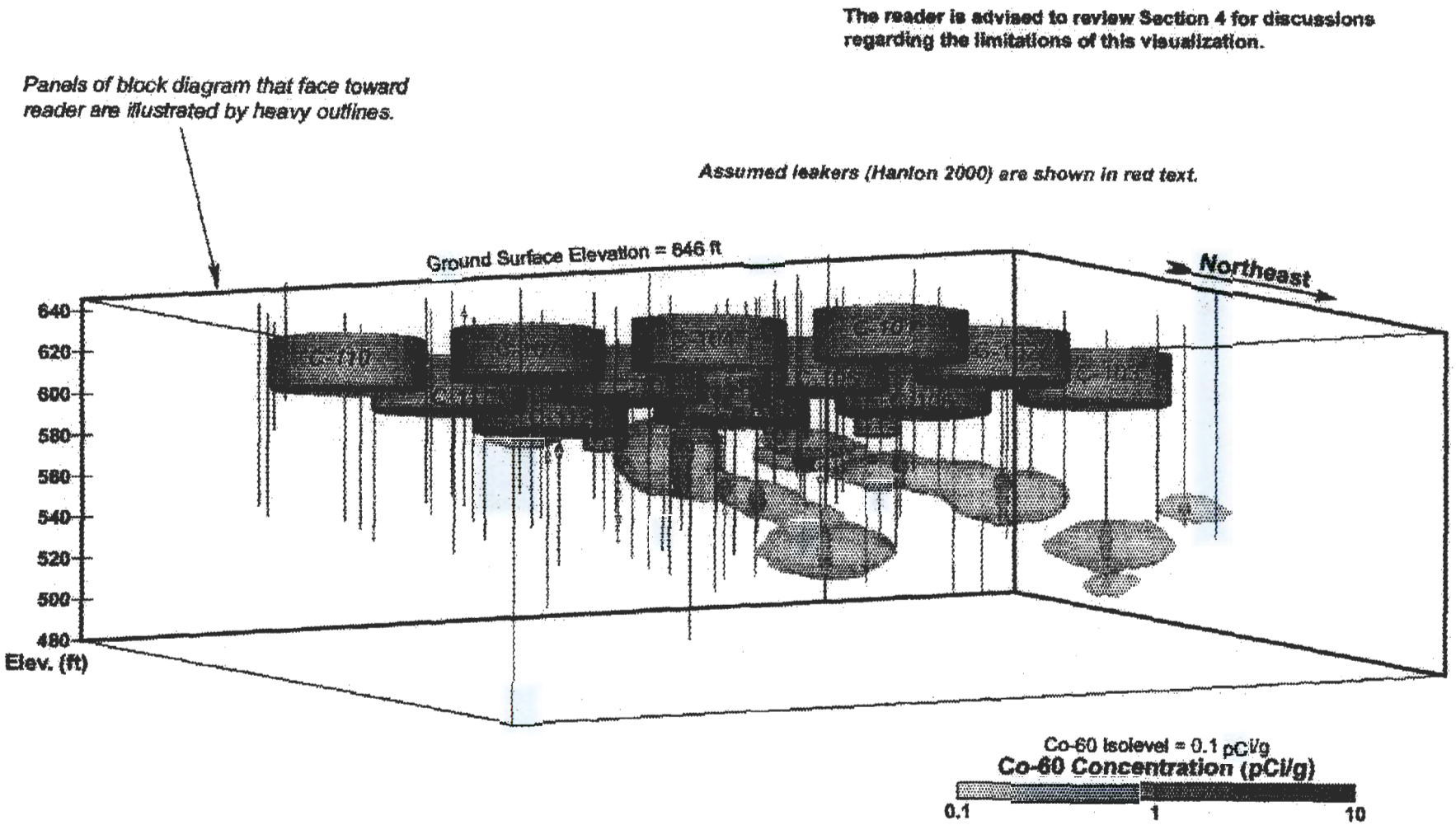


Figure D-18. C Tank Farm Visualization

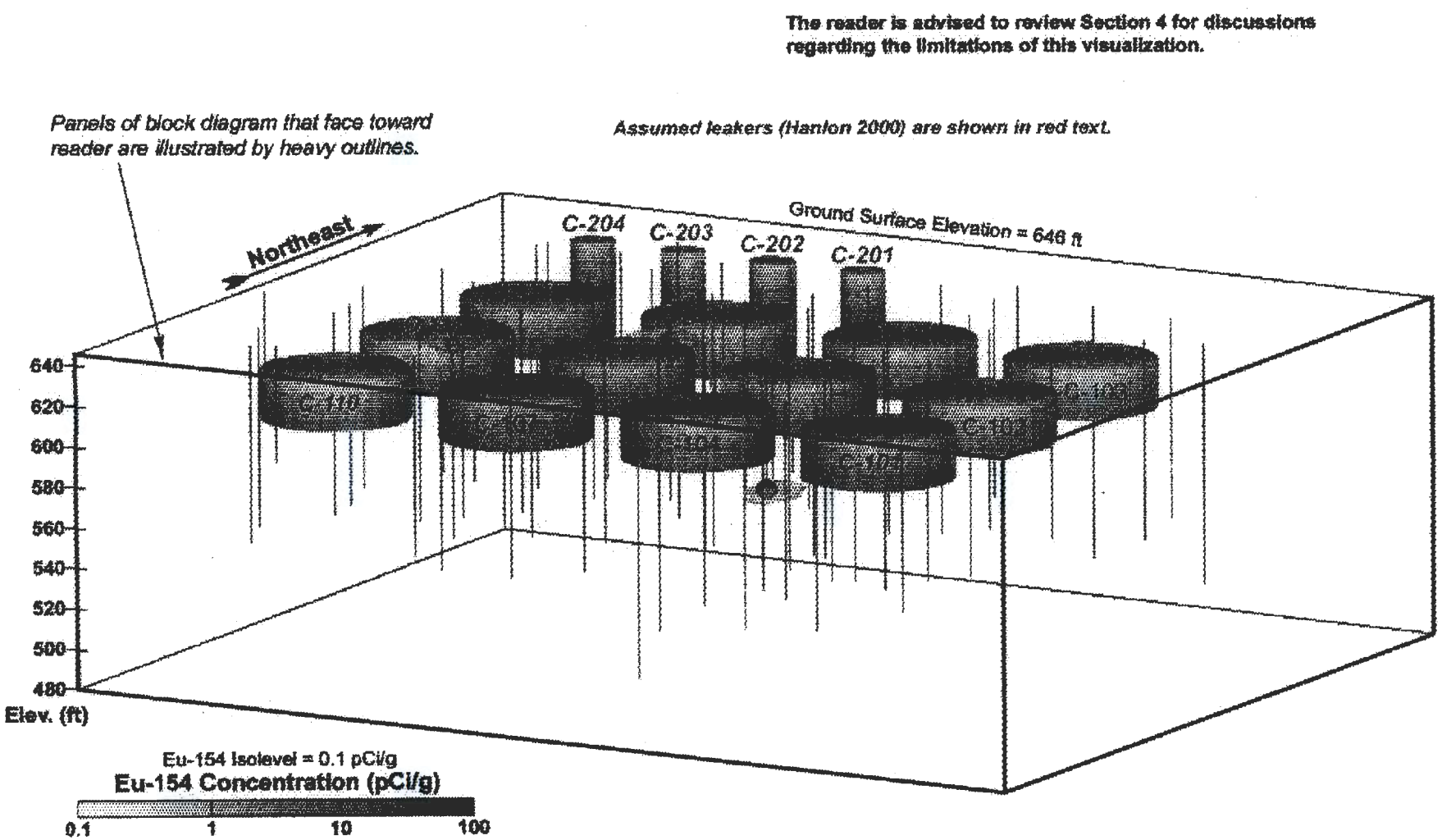


Figure D-19. C Tank Farm Visualization

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.

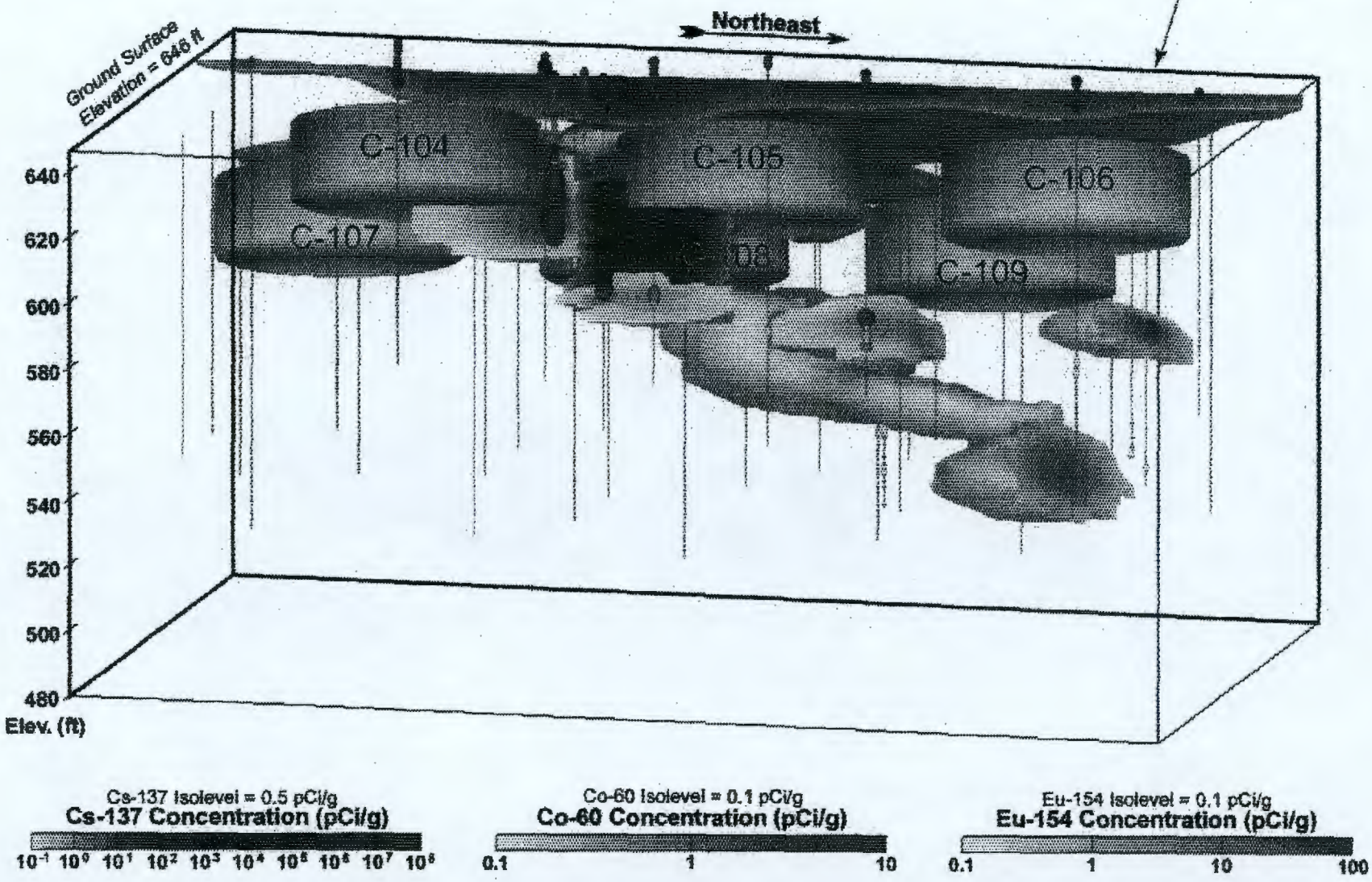


Figure D-20. C Tank Farm Visualization

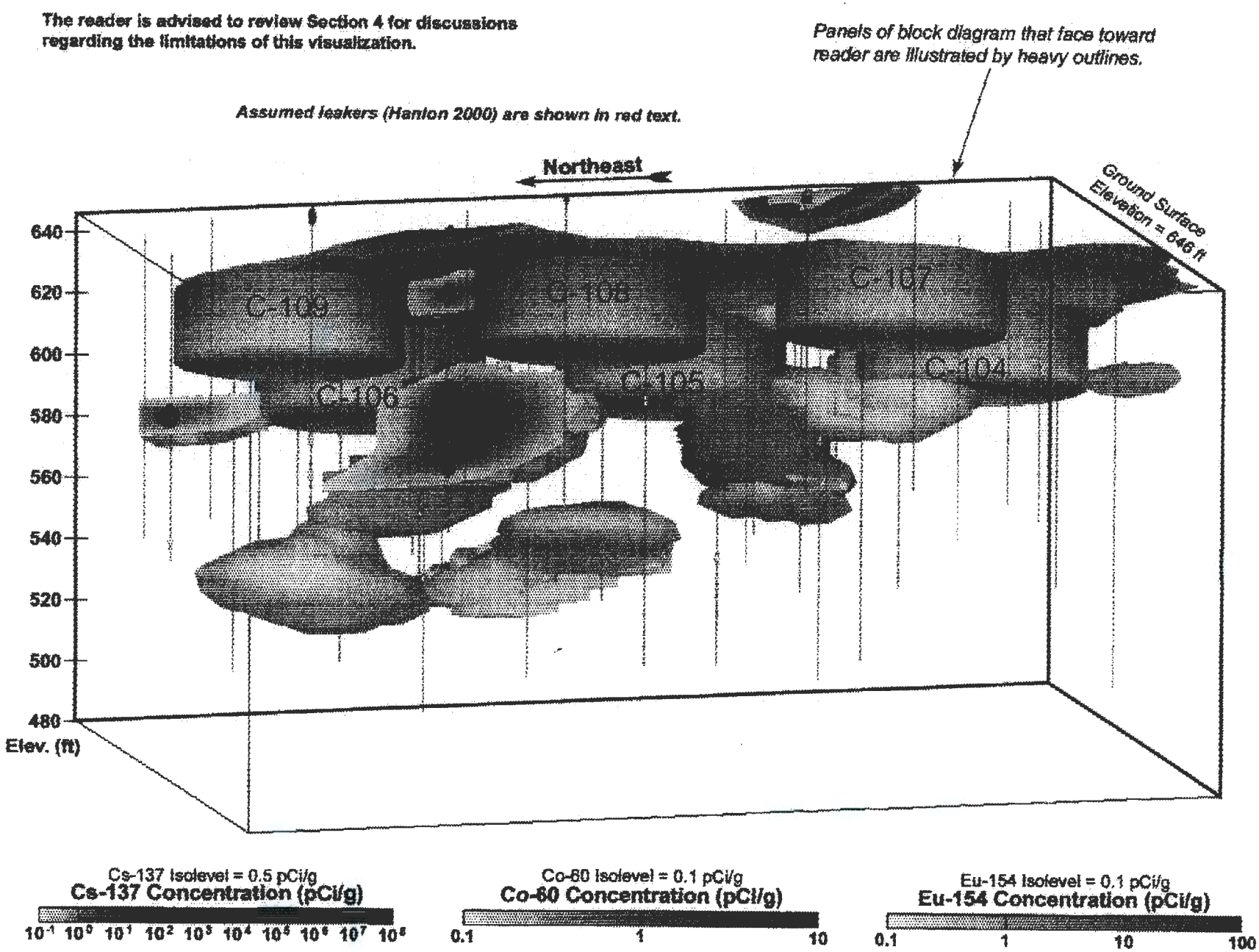


Figure D-21. C Tank Farm Visualization

MACTEC ENVIRONMENTAL RESTORATION SERVICES, LLC

CONTRACT NO.: DE-AC13-96GJ87335
TASK ORDER NO.: MAC-00-09
CONTROL NO.: 3100-T00-0964

MEMO TO: Distribution

FROM: Jim Bertsch, Project Manager

DATE: September 19, 2000

SUBJECT: Addenda to the B and C Tank Farm Reports (Final)

Please find enclosed copies of the subject reports. The C Tank Farm Report (TFR) Addenda incorporates the results of the high-rate and repeat logging activities along with the shape factor analysis. Based upon these results, the 3D visualizations for the C TFR have been revised to reflect the additional data analysis and interpretation. The visualizations in the B TFR have not been changed. In addition, plume volume and contaminate inventory estimates have been calculated for both tank farms.

Should you have any questions or comments, please contact me at (509) 946-3635.

JFB:jmm
Enclosures

cc: Contract File (J. Dearborn)
VZCP 1.1.1.2
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