GJO-97-31-TARA
GJO-HAN-17

RECEIVED
OCT 23 2000
OSTI

Hanford Tank Farms Vadose Zone

Addendum to the S Tank Farm Report

August 2000

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

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

Work performed under DOE Contract No. DE–AC13–96GJ87335.

DISCLAIMER

This report was prepared as an account of work sponsored by an agency of the United States Government. Neither the United States Government nor any agency thereof, nor any of their employees, make any warranty, express or implied, or assumes any legal liability or responsibility for the accuracy, completeness, or usefulness of any information, apparatus, product, or process disclosed, or represents that its use would not infringe privately owned rights. Reference herein to any specific commercial product, process, or service by trade name, trademark, manufacturer, or otherwise does not necessarily constitute or imply its endorsement, recommendation, or favoring by the United States Government or any agency thereof. The views and opinions of authors expressed herein do not necessarily state or reflect those of the United States Government or any agency thereof.

DISCLAIMER

Portions of this document may be illegible in electronic image products. Images are produced from the best available original document.

Contents

Contents (continued)

Figures

Hanford Tank Farms Vadose Zone

Addendum to the S Tank Farm Report

Prepared by:

A.W. Pearson
MACTEC-ERS, Hanford — Date: 8/2/00

Concurrence:

R.G. McCain, Technical Lead
MACTEC-ERS, Hanford — Date: 8/03/00

C.J. Koizumi, Technical Lead
MACTEC-ERS, Grand Junction Office — Date: 08/07/00

Approved by:

J.F. Bertsch, Project Manager
MACTEC-ERS, Hanford — Date: 8/7/00

M.C. Butherus, Task Order Manager
MACTEC-ERS, Grand Junction Office — Date: 8/7/00

J. Berwick, Project Manager
U.S. Department of Energy
Grand Junction Office — Date: 8/14/00

R.M. Yasek, Project Manager
U.S. Department of Energy
Office of River Protection — Date: 8/16/00

Executive Summary

In 1994, the U.S. Department of Energy (DOE) Richland Operations Office (DOE-RL) requested the DOE Grand Junction Office (DOE-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 S Tank Farm Report, which was prepared as part of this characterization project, was issued as document GJO-97-31-TAR, GJO-HAN-17 in February 1998. That document reported the results of the spectral gamma logging characterizations at the S Tank Farm that were originally reported in Tank Summary Data Reports for each individual tank. The S Tank Farm Report provided background information, a history of the farm, geology and hydrology reviews, and a description and review of adjacent waste sites. Data derived from logging existing boreholes in the S Tank Farm were used to develop a three-dimensional model of the distribution of the contamination in the vadose zone in the immediate vicinity of the S Tank Farm.

Since the original S 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 S Tank Farm.

Additional data collected include spectral gamma data acquired from two boreholes that were not logged during the original baseline logging effort. Both of these boreholes, 40-00-04 and 40-10-01, extend to near the top of the water table. The boreholes were not logged previously because the borehole construction consisted of dual casing and grout. At that time, appropriate casing correction factors were not available. The S Tank Farm Report recommended spectral gamma logging in these two boreholes to determine if cesium-137 (^{137}Cs) had migrated deep into the vadose zone. Log data from these boreholes might provide insights into the cause of high technetium to uranium and low tritium to technetium ratios measured in groundwater samples collected from borehole 40-00-04 (Johnson and Chou 1998). Only near-surface contamination, presumably from a surface spill, was detected in these two boreholes.

A high rate logging system (HRLS) was developed and deployed in the S Tank Farm to measure ^{137}Cs concentration levels in high gamma flux zones in two boreholes where the spectral gamma logging system was unable to collect usable data because of high dead times and/or detector saturation. This new system has enabled measurement of ^{137}Cs concentrations up to about

100 million picocuries per gram (pCi/g). ^{137}Cs concentrations of more than 10^6 pCi/g were detected in both boreholes (40-02-03 and 40-04-05) logged with the HRLS.

Other data collected since the S Farm Report was issued include repeat logging measurements from borehole 40-00-02 acquired approximately 2.5 years after the initial baseline data were collected. This borehole was selected for repeat logging to assess the potential effects on the ^{137}Cs contaminant distribution in the sediments near the leak. The ^{137}Cs contamination was apparently not remobilized by the raw water leak (at least in the vicinity of the borehole). No additional boreholes were selected for repeat logging in the S Tank Farm.

A review of historical gross gamma logs provided no evidence of suspected contaminant movement in the S Tank Farm. Independent analysis of historical gross gamma data by Randall and Price (1999) supports this conclusion. However, the repeat logging was limited in scope and the gross gamma logging program was discontinued in 1994; no comprehensive vadose zone monitoring program currently exists.

The interpreted data set presented in the S Tank Farm Report was revised to incorporate the data from the two additional boreholes and the high rate logging. In addition, intervals of relatively low ^{137}Cs contamination, which appeared to be related to borehole effects and/or contaminant dragdown, were removed from the data set. The decision to remove contamination intervals from the data set was based on the results of the previous shape factor analysis, the Randall and Price (1999) data, and the experience of the analysts. These new data sets were used to create the revised three-dimensional visualizations of subsurface contamination for the S Tank Farm 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 S Tank Farm.

This addendum completes the baseline characterization of the S Tank Farm. The purpose of this characterization was to identify the nature and extent of contamination associated with gamma-emitting radionuclides in the S 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 S Tank Farm is located in the southwest portion of the 200 West Area of the Hanford Site (Figure 1). Although the S and SX Tank Farms are included together in the S-SX Waste Management Area, each farm is considered a separate entity for purposes of this report. The S Tank Farm consists of twelve second-generation single-shell tanks (SSTs), each with an individual capacity of 758,000 gallons (gal). These tanks currently store a total of 4,934,000 gal of high-level nuclear waste that was generated primarily from the chemical processing of irradiated uranium fuel. Only one of the tanks (S-104) is listed in Hanlon (2000) as an "assumed leaker." This tank is estimated to have leaked 24,000 gal of high-level radioactive liquid to the vadose zone sediments (Hanlon 2000).

In 1994, the U.S. Department of Energy (DOE) Richland Operations Office (DOE-RL) requested the DOE Grand Junction Office (DOE-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. 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.

Figure 2 shows the location of each borehole in the S Tank Farm. 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 S Tank Farm geophysical logging was completed in 1996, 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, 1997l, and 1997m).

The S Tank Farm Report was completed by the Hanford Tank Farms Vadose Zone Project in February 1998. Since the report 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-97-31-TAR, GJO-HAN-17.

1.1 Background

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

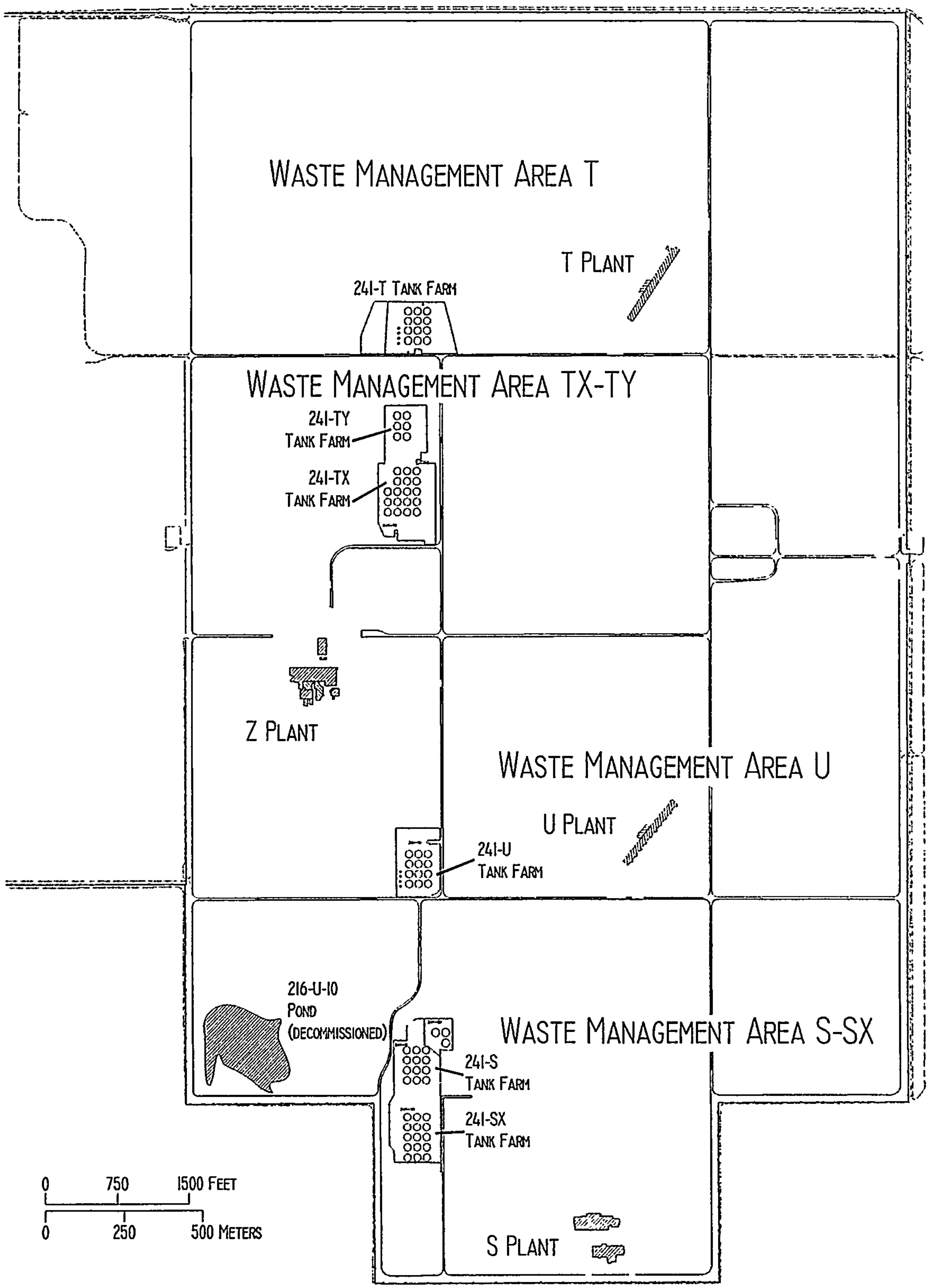

Figure 1. Map of the 200 West Area Showing the Location of the S Tank Farm

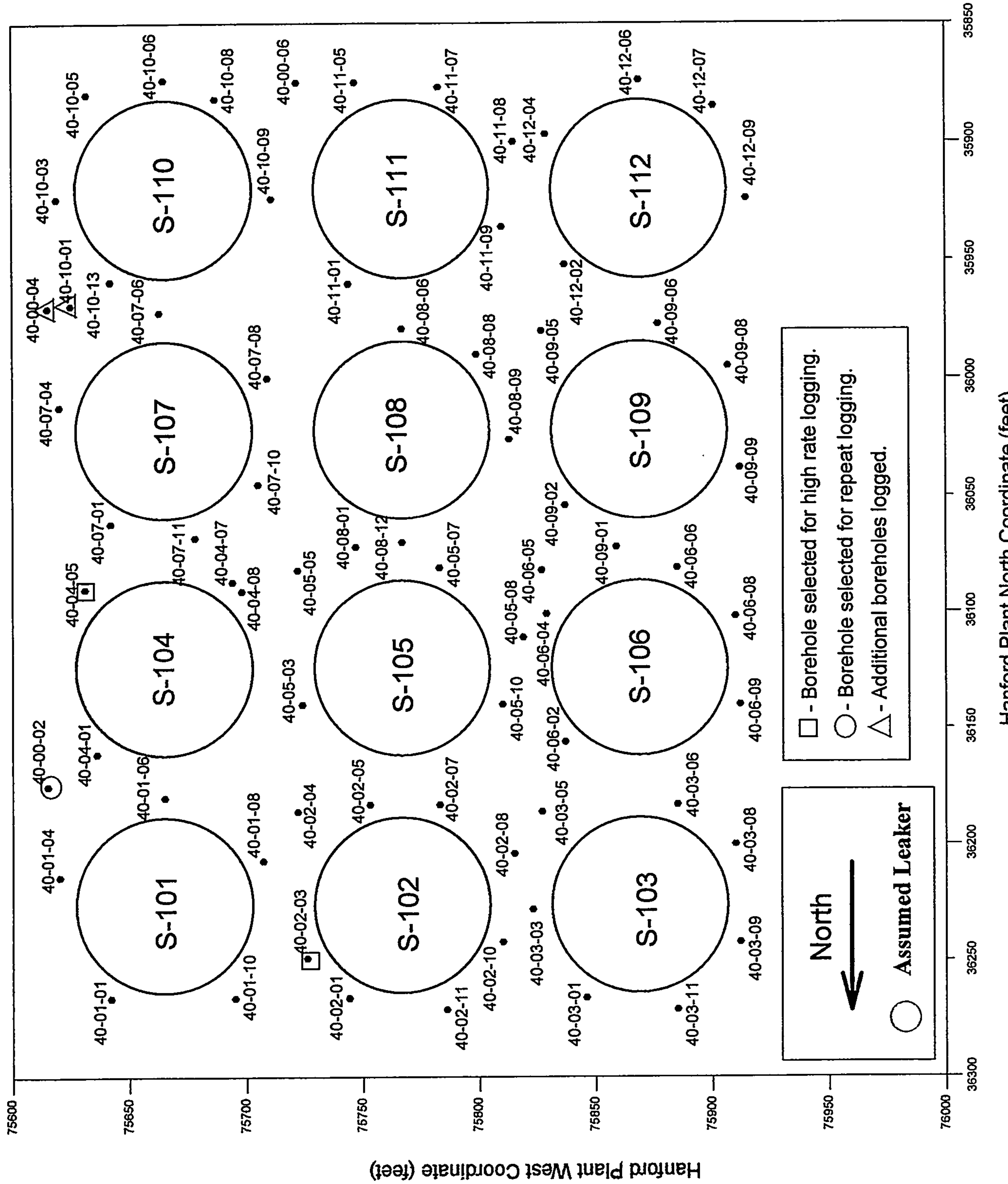

Figure 2. Map of the S Tank Farm Boreholes

In August 1996, a Phase I groundwater quality assessment for the S/SX Waste Management Area (WMA) was initiated in response to a directive from the Washington State Department of Ecology. This action was triggered by increases in specific conductivity and technetium-99 (^{99}Tc) observed in downgradient monitoring wells. Results of the Phase I assessment (Johnson and Chou 1998) indicated that the S/SX WMA had contributed to the groundwater contamination and that multiple source locations within the WMA were required to explain observed spatial and temporal groundwater contamination patterns. This work was carried out independently of the work reported in the S Tank Farm Report.

Since the original S Tank Farm Report was issued in 1998, additional data have been obtained and enhancements have been made in the SGLS data evaluation process. Shape factor analysis had been applied to the original baseline spectral data prior to issuing the S Tank Farm Report to assess contaminant distribution with respect to the borehole axis. However, experience in the shape factor interpretation has led to a more liberal approach when removing contaminant data attributed to borehole effects. This more liberal approach has resulted from the recognition that dragdown of contaminated material to lower depths during drilling is pervasive, particularly when high gamma flux zones are encountered. Other data were obtained from two additional boreholes that were not logged during the original baseline, and repeat logging was performed in one other borehole. 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 S 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 data from two additional boreholes and high rate log data. Tank farm conditions, operational history, current status, and geologic conditions are discussed in the original S Tank Farm Report and in relevant Tank Summary Data Reports (DOE 1997b, 1997c, 1997d, 1997e, 1997f, 1997g, 1997h, 1997i, 1997j, 1997k, 1997l, and 1997m), and will not be restated in this report. The reader is referred to those documents for detailed information.

In general, revisions to the visualizations are based on data from the two additional boreholes and the high rate data. 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. Comparisons between repeat logging and the original logs are discussed in the text. The contaminant plumes shown in the visualizations are based on the original data and the data from the two additional boreholes, as modified by professional judgment, with the HRLS results included in intervals where the SGLS was saturated.

2.0 Summary of Additional Data

Additional data presented in this addendum include data from two boreholes not logged during the original baseline, high rate logging, and repeat logging. Improvements in data analysis and interpretation methods are applied to all borehole data where appropriate. Also referenced in this addendum is work performed by Randall and Price (1999), which provides an analysis of historical gross gamma logging data for the S Tank Farm. This analysis by Randall and Price in addition to SGLS repeat logging evaluated areas of possible contaminant movement within the S Tank Farm vadose zone.

2.1 Additional Boreholes

Two additional boreholes, 40-00-04 (299-W23-01) and 40-10-01 (299-W23-17), were logged with the SGLS after the S Tank Farm Report was issued. These two boreholes were not logged during the original baseline because of their construction configuration (double-cased and grouted). Since that time the decision was made to log boreholes with this type of construction. These two wells were of particular interest because they could provide insights into whether or not ^{137}Cs had migrated deep into the vadose zone. This insight may provide a clue as to the cause of the high technetium/uranium and low tritium/technetium ratios measured in the groundwater downgradient of the waste management area that may be indicative of a tank waste source. Technetium was detected in groundwater samples from borehole 40-00-04 in 1985-86 and again in 1998. The tritium/technetium ratios for both of these samples was near 1 (Johnson and Chou 1999). Both of these boreholes are greater than 200 ft in depth. Other boreholes in the S Tank Farm only reached approximately 150 ft.

2.2 High Rate Logging

During SGLS logging operations in the S Tank Farm in 1996, it soon became apparent that some borehole intervals exhibited very high gamma-ray fluxes, such that the SGLS detectors became saturated, yielding no usable data.

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 SGLS logging systems. 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," that contributes to degradation of spectra (Knoll 1989). "Pulse pileup" occurs when the photon flux at the detector is so great that two or more photons will deposit their energies in the detector within a time interval that is short compared to the time resolution of the system. The electrical charge liberated by the several photons is then processed as if just one photon were involved. Pulse pileup events give output pulses with variable amplitudes because the amplitude of each output pulse depends on the total energy of the several captured photons that contribute to the pulse. The pulses with variable amplitudes add counts to the spectral background continuum, and the photons that participate in pileup are lost, in the sense that they contribute to the spectral background instead of a peak. Consequently, as pileup events increase in frequency, the spectral peaks become more and more obscure. Because peak counts are lost, the peak intensities are no longer proportional to the source concentrations.

Like the SGLSs, the HRLS is essentially nonparalyzable. "Nonparalyzable" and "paralyzable" describe system behavior during "dead periods" of data acquisition (Knoll 1989). In nonparalyzable systems, the deposition of photon energy in the detector is followed by a brief time interval, or dead period, of fixed duration, during which the output electrical pulse is being processed. The system is unresponsive to any additional photons that enter the detector during the dead period. If the gamma-ray flux is intense, a significant number of photons enter the detector during dead periods, and are uncounted. Thus, the count rate rises as the gamma flux increases, but the count rate does not rise as rapidly as the flux. The count rate is non-linear in relation to flux, but linearity is imposed by applying the dead time correction to the recorded count rates (DOE 1995).

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

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). 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 S Tank Farm. Both boreholes logged in the S 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

2.3 Repeat Logging

Repeat logging using the SGLS is useful to evaluate possible contaminant movement over time by comparing concentration data. Analysis of historical gross gamma logging by Randall and Price (1999) has also proved useful for determining potential movement, particularly in zones of high gamma flux. A sufficient amount of time has not passed since the implementation of the HRLS to collect repeat data that would provide meaningful comparisons.

2.3.1 Spectral Gamma Logging System

Repeat logging was performed for one borehole interval in the S Tank Farm using the SGLS. This borehole was selected for repeat logging to assess the impact of a raw water leak near borehole 40-00-02 on the ^{137}Cs distribution in the vadose zone. Approximately 500,000 gal of water were released in a 1 hour period in 1996 from a separated water main near the northeast side of the S Tank Farm. This water pooled in a low area along the east fence line of the farm estimated to be approximately 50 ft from borehole 40-00-02 (Johnson and Chou 1999). It is not possible to determine if this surface water changed the moisture content of the vadose zone in the vicinity of this borehole. The baseline ^{137}Cs concentration profile collected on 6/4/96 was compared to the repeat ^{137}Cs concentration profile collected on 1/21/99. To provide for proper comparison of log data between the original baseline and the repeat logging, the baseline ^{137}Cs was decayed from the date of the baseline logging (6/4/96) to the date of the repeat logging (1/21/99).

2.3.2 Historical Gross Gamma Logging

In 1998, Randall and Price (1999) conducted an analysis of historical gross gamma-ray log data collected in the S Tank Farm between 1975 and 1994. All historical log surveys for individual drywells (boreholes) were evaluated for each interval with elevated gross gamma count rates, allowing observations to be made regarding the stability of any contaminant interval over time. Conclusions from this analysis are provided in this addendum. In general, no areas in the vadose zone were identified as showing contaminant movement. However, the gross gamma logging program was discontinued in 1994 and only limited data are available for the period since 1994.

3.0 Discussion of Results

3.1 Additional Boreholes

Two additional boreholes (40-00-04 and 40-10-01) were logged since the S Tank Farm Report was issued. Both of these boreholes are double cased and grouted. As discussed previously, these boreholes were of particular interest to provide clues to the potential impact of tank waste on the ground water. Combination log plots for these boreholes showing the distribution of naturally occurring and man-made radionuclides, as well as total gamma activity from both the SGLS and the most recent tank farms gross gamma log, are included in Appendix A (Figures A-1 through A-4).

3.1.1 Borehole 40-00-04

Borehole 40-00-04 is located east of tanks S-107 and S-110 and was given the Hanford Site designation 299-W23-01. This borehole was drilled in June of 1952 to a depth of 262 ft with 6-in.-diameter casing. Since then the borehole has been perforated and grouted with a 4-in.-diameter casing set from 0 to 175 ft. This borehole was logged with the SGLS in three log runs from 0 to 219 ft on Jan 21, 1999. Water was encountered in the borehole at about 216 ft. No log data were collected below 219 ft. Both ^{137}Cs and cobalt-60 (^{60}Co) were detected in this borehole. The ^{60}Co was detected from 1.5 to 3.0 ft with a maximum concentration of about 1 pCi/g. The ^{137}Cs was detected from 0.0 to 3.5 ft with a maximum concentration of about 30 pCi/g occurring at the ground surface. Low levels (less than 5 pCi/g) of ^{137}Cs were detected intermittently throughout the borehole to a maximum depth of 214.5 ft. These intermittent occurrences of ^{137}Cs were attributed to borehole effects.

3.1.2 Borehole 40-10-01

Borehole 40-10-01 is located approximately 25 ft northeast of tank S-110 and was given the Hanford Site designation 299-W23-12. This borehole was drilled in September of 1970 to a depth of 238 ft with 6-in.-diameter casing. Since then it has been perforated and grouted with a 4-in.-diameter casing set from 0 to 180 ft. This borehole was logged with the SGLS in three log runs from 0 to 209.5 ft on Jan 20, 1999. Both ^{137}Cs and ^{60}Co were detected in this borehole. The ^{60}Co was detected from 1.5 to 2.0 ft with a maximum concentration of about 0.25 pCi/g. The ^{137}Cs was detected continuously from 0.0 to 54.0 ft at concentrations generally ranging from 1 to 10 pCi/g with a maximum concentration of about 50 pCi/g occurring at the ground surface. Low levels (less than 2 pCi/g) of ^{137}Cs were detected intermittently throughout the remainder of the borehole to a maximum depth of 186 ft. All ^{137}Cs detected below 3.0 ft is thought to be dragdown from a surface spill.

The absence of ^{137}Cs or ^{60}Co at depth in either of these boreholes does not support deep migration of tank waste as a cause of the anomalous ^{99}Tc observed in the groundwater. However, it is not conclusive, because it is also probable that neither borehole intersected the migration pathway. Moreover, contaminants such as ^{99}Tc do not emit a detectable gamma ray and are generally considered to be more mobile than ^{137}Cs.or ^{60}Co. Data from these two boreholes clearly do not provide evidence supporting deep migration of tank waste, but neither can the data refute this possibility.

3.2 High Rate Logging

Logging was conducted using the HRLS in boreholes 40-02-03 and 40-04-05 where the original SGLS logs indicated 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 when an external shield is used. However, zones of more intense radiation were encountered around these two boreholes in which dead times became excessive or the detector became saturated. The HRLS detected ^{137}Cs as the primary radionuclide in both of these intervals.

Table B-1 (Appendix B) summarizes borehole information where high rate logging was conducted in the S 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. 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, the date to which the HRLS data was corrected for decay, and an assessment of relative stability by Randall and Price (1999). 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 is added to the baseline SGLS data.

^{137}Cs concentration values calculated from the high-rate data are presented on plots for each borehole (Figures B-1 and B-2, Appendix B). 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. The legend 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.

3.3 Repeat Logging

Repeat logging was performed in only one borehole (40-00-02) in the S Tank Farm. The purpose was to evaluate possible effects of a surface water spill on the ^{137}Cs distribution in this borehole. This spill, which occurred soon after the baseline logging, pooled in a low area approximately 50 ft from this borehole. The repeat data were collected approximately 2.5 years later. Table C-1 (Appendix C) summarizes the repeat logging performed in the S Tank Farm and includes a comparison log plot for the repeat logging interval in borehole 40-00-02. There does not appear to be a significant change in log values, suggesting that either the water did not reach the contamination in the vicinity of the borehole or that it failed to mobilize the ^{137}Cs.

3.4 Changes to the Interpreted Data Set

The original interpreted data set presented in the S Tank Farm Report was updated by adding spectral data from the two additional boreholes and substituting the high rate data in zones of SGLS detector saturation. Further evaluation of shape factor data and contaminant profiles led to removal of additional zones of contamination that were judged to be primarily associated with contaminant dragdown and/or borehole effects from the original interpreted data set.

Table D-1 (Appendix D) includes a general discussion of the rationale for removing specific depth intervals from the interpreted data set used to create the three-dimensional visualizations. Correlation plots of boreholes surrounding each tank are also included in Appendix D to provide a visual representation of the contaminated intervals. The table and correlation plots constitute the interpreted data set (Section 4.1).

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 S Tank Farm and to present views derived from those visualizations. ^{137}Cs, ^{60}Co, and europium-154 (^{154}Eu) were all detected in the S Tank Farm. Visualizations were created for each of these radionuclides. The development of the visualizations are described in the S Tank Farm Report. The software package from C Tech Development Corporation called "Environmental Visualization System" (EVS) was used to create the visualizations both in the original S Tank Farm Report and in this addendum. However, some improvements to the data input and calculation parameters to the model have been implemented since the original report and will be described in the following sections.

4.1 Interpreted Data Set

The first step in the visualization process is to create an interpreted data set that represents the input to the kriging process. This consists of the original interpreted data set presented in the S Tank Farm Report with the spectral data from the two additional boreholes and the HRLS data added and additional contamination intervals removed that are judged to be localized to the borehole and thus not representative of subsurface contaminant distribution.

All baseline SGLS data collected during 1996 in the S Tank Farm have been updated in this addendum to reflect current analysis practices and procedures. In addition, insights gained during the Expert Panel (a panel of experts appointed by DOE to provide independent oversight of vadose zone technical investigations [DOE 1997a]) discussions have aided in judging the nature of subsurface contaminant distribution as detected by the SGLS and HRLS.

Generally, the borehole radionuclide concentrations have not been corrected for decay, and therefore represent their 1996 baseline values. The HRLS data were adjusted to account for decay between 1996 and 1999.

The final result is an interpreted data set where all contamination intervals judged to be local to the casing and not representative of the surrounding formation are removed and HRLS data have been used to fill in zones of SGLS detector saturation.

4.2 Development of Three-Dimensional Visualizations

The original visualizations utilized an adaptive gridding option that results in estimated values everywhere inside a user-specified rectangular domain. In this addendum a convex hull boundary option is selected. This option produces an irregular boundary that is defined by the distribution of measured data points, effectively restricting the extrapolation of parameters to that volume enclosed by the data points.

The data set derived from the SGLS data consists of measurement data at 0.5-ft intervals in vertical boreholes with a lateral separation generally on the order of tens of feet, resulting in a much greater data density in the vertical direction compared to the horizontal direction. To minimize processing time, search routines in the kriging algorithm utilize a limited number of data points closest to the calculation point, creating a situation in which a contaminated interval in a borehole tends to have an undue effect on nearby points. Because adjacent points in a single borehole are closer than points from another borehole, the data search routine is truncated after collecting all data points from a single hole. To offset this effect, data points in individual boreholes were averaged over 5-ft intervals such that a single average concentration value is assigned to the midpoint of each 5-ft interval (e.g., at 2.5 ft, 7.5 ft, etc.), significantly reducing the size of the input data set and the processing time. More importantly, it "forced" the search algorithm to bring in data from multiple boreholes at most calculation points, which resulted 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 S 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 most accurately honor 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 both ^{137}Cs and ^{60}Co are near 0.1 pCi/g and the MDL for ^{154}Eu is approximately 0.5 pCi/g. In the preprocessing module, a value of 0.01 pCi/g was substituted for non-detects of each radionuclide in the data file. This allowed 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 each contaminant 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, which is discussed in the base calibration report (DOE 1995) and subsequent recalibration reports, 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; the highest HRLS concentrations were about 100 times higher than the 8,000 pCi/g estimate.

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 S 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 above.

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 previously. The visualizations are provided in Appendix E in the order in which they are discussed.

Figure E-1 illustrates the ^{137}Cs contamination derived from the interpreted data set for all boreholes logged in the S 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 million 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 (see Figure 2), and the correlation plots presented in Appendix D.

Figures E-2 and E-3 are similar to Figure E-1 except they portray ^{60}Co and ^{154}Eu, respectively. The logarithmic color scales have also been changed to reflect the concentration range of each radionuclide.

Figures E-4 through E-14 show horizontal planar slices at various depths in the S 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 the highest concentration and maximum extent of plumes that existed between the selected depth intervals. For example, the 3-ft slice probably indicates the best representation of the lateral and average concentration of near-surface contamination that exists between 0 and 3 ft.

Figure E-4, the horizontal slice from 3 ft, provides the best representation of the maximum lateral extent of the near-surface contamination resulting from surface spills. The next slice at 9 ft (Figure E-5), which lies just above the top of the tanks, shows the lateral extent of these spills has greatly decreased. The near-surface contamination near tank S-110 is absent at this depth. The lateral extent of these plumes decreased in the next slice at 18 ft and the ^{60}Co contamination west of tank S-103 is no longer visible.

Figure E-7 is a horizontal slice at 28 ft just below the depth of the cascade lines. The high concentrations of ^{137}Cs on the east side of tank S-102 are likely the result of a cascade line breach. The contamination depicted on the west side of tank S-102 probably represents vertical migration from a large surface spill that occurred near this tank. ^{60}Co contamination west of tank S-103 may also have originated from a surface spill even though it is not shown to be continuous deposition from the ground surface to this depth of 28 ft (i.e., the visualization at 18 ft does not show the ^{60}Co contamination). The next slice at 35 ft shows the top of the plume originating from a leak in tank S-104 and the continued vertical migration of ^{137}Cs from the cascade line breach near tank S-102. The slice at 42 ft shows the maximum concentration and lateral extent of the plume associated with the S-104 tank leak.

Figure E-10 is a horizontal slice at 47 ft, just below the base of the tanks. The tank S-104 plume appears to have migrated to the west under the tank. This figure also shows the vertical extent of the continuous ^{137}Cs contamination from the cascade line breach. ^{137}Cs contamination is again shown on the west side of tank S-102 near boreholes 40-02-07 and 40-02-08. This is thought to be continued vertical migration of the contamination associated with the large surface spill observed in previous slices. Some of the deep ^{137}Cs and ^{60}Co related to this surface spill, between tanks S-102 and S-103 shown in Figures E-10 through E-13, may be due to contaminants migrating along the outside of a borehole casing and pooling near finer grained sediments. The potassium-40 (^{40}K), uranium-238 (^{238}U), and thorium-232 (^{232}Th) (KUT) plots included in the Tank Summary Data Reports for tanks S-102 and S-103 (DOE 1997c, 1997d) show increases in ^{40}K at various depths between 50 and 70 ft that support this theory.

The slice from 55 ft, Figure E-11, shows separate ^{137}Cs and ^{60}Co plumes located between tanks S-102 and S-103 that are probably associated with the large surface spill discussed previously. Figure E-12, the slice from 63 ft, still shows some ^{60}Co between tanks S-102 and S-103. It also shows a plume on the east side of tank S-102 that may be associated with the cascade line breach. This occurrence of an apparently separate plume of ^{137}Cs below a larger plume above may be the result of waste migrating along the borehole casing and pooling on finer grained sediments. The possibility exists that this plume and the deep plumes of ^{137}Cs and ^{60}Co associated with the surface spill may not extend laterally more than a foot or so from the boreholes in which they were detected. The final slice from 69 ft, Figure E-13, shows ^{60}Co between tanks S-102 and S-103 that represents the deepest extent of contamination in the vadose zone near the S Tank Farm and appears to be the result of the large surface spill in the vicinity of tanks S-102 and S-103.

Figures E-14 through E-16 are three-dimensional visualizations that illustrate contamination plumes for ^{137}Cs, ^{60}Co, and ^{154}Eu within the vadose zone at the S 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. Each figure is viewed looking down at the tanks from the northeast. Only one radionuclide was presented on each figure, allowing the reader to more easily view the extent of each plume.

Figure E-17 shows a view from the northeast of the plumes associated with tanks S-101, S-102, S-104, and S-105. These plumes are cut by a southeast-northwest-trending vertical plane that passes through tank S-104 and between tanks S-101 and S-102. This cut exposes the interior of the three major plumes associated with S Tank Farm: 1) S-104 tank leak, 2) cascade line breach near tank S-102, and 3) the large surface spill near tanks S-102 and S-103. The cut was positioned to show the maximum concentrations of these plumes.

4.5 Contaminated Volume and Total Activity Estimate

With completion of the revised visualizations, it became possible to calculate a rough estimate of the volume of contaminated soil and total activity inventory as a function of contaminant threshold level within the plumes shown in the S 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 1996. 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 include any data from historical gross gamma logs or any soil sample data.

The contribution from ^{60}Co and ^{154}Eu may be slightly underestimated because these data are not always measured accurately in zones of high gamma flux by the HRLS. 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.

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	17,180	9.86
	5	5,481	9.81
	50	1,682	9.64
	500	599	9.01
	5,000	211	7.14
	25,000	63.9	4.0
^{60}Co	0.1	2,777	8.67×10^{-4}
	0.5	145	1.7×10^{-4}
^{154}Eu	0.5	267	6.76×10^{-4}
	2	68.8	3.13×10^{-4}

5.0 Conclusions

The purpose of this addendum is to provide an update to the original S Tank Farm Report that was issued more than 2 years ago. The interpretations and conclusions provided in the original report are essentially 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 S 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 a justification for further eliminating many borehole contamination intervals from the interpreted data set, most intervals of significant contamination remain and only relatively low-concentration "ghost" plumes were eliminated from the visualizations.

- Analysis of historical gross gamma logging data provides a qualitative identification of contaminant movement.

- 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 if a monitoring program is implemented. Historical gross gamma logging detectors may have been paralyzed in some cases and the data produced may not be reliable for comparison purposes in the very high concentration zones.

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 S Tank Farm. Conclusions stated in the original S Tank Farm Report remain appropriate and will not be entirely reiterated.

To date there is no evidence of contaminant movement in the vadose zone under the S Tank Farm. The repeat logging from borehole 40-00-02 did not provide evidence of remobilization of ^{137}Cs from the infiltration of a surface water spill. Randall and Price (1999) determined there was no movement observed from the historical gross gamma logging performed from 1975 to 1994. However, routine gross gamma logging was discontinued in 1994, and there has been no comprehensive monitoring effort since that time. A comprehensive routine monitoring program for selected drywells in the S Tank Farm should be implemented to provide data that will substantiate the long-term stability of the observed gamma-emitting contaminants.

Contamination from the tank S-104 plume may not exist as deep as originally thought. ^{137}Cs below 47 ft in borehole 40-04-05 has been determined to be dragdown and was removed from the interpreted data set. The original interpreted data set included ^{137}Cs as deep as 120 ft in borehole 40-04-05.

There is no evidence of deep migration of gamma-emitting radionuclides that may be affecting the groundwater quality beneath the S Tank Farm. Boreholes 40-00-04 and 40-10-01 were both logged to investigate this possibility. Only intermittent occurrences of low concentrations of ^{137}Cs were detected at any significant depth and these were all attributed to borehole effect and removed from the interpreted data set. This does not rule out the possibility that migration pathways were not intersected by existing boreholes or that more mobile contaminants have reached the groundwater at this site.

High rate logging of borehole 40-02-03 detected a maximum ^{137}Cs concentration of 2,240,000 pCi/g at 26.5 ft, supporting the conclusion in the S Tank Farm Report that the cascade line at approximately 22 ft may have been breached during one of the four attempts to drill this borehole. On the basis of drill cuttings measurements, some contamination existed prior to drilling. Therefore, it is not known conclusively if the cascade line was breached, adding additional contamination to the vadose zone, or that all the contamination existed prior to drilling. However, all ^{137}Cs contamination measured from 22 to 47.5 ft and from 57 to 62 ft is believed to be associated with the cascade line. The ^{137}Cs above 22 ft is probably from nearby surface spills.

Significant amounts of ^{137}Cs, once attributed to surface spills in the vicinity of tanks S-101, S-102, S-103, and S-104, have been determined to be dragdown and were removed from the interpreted data set. It still appears, however, some of this ^{137}Cs near boreholes 40-02-07 and 40-02-08 has migrated to approximately 55 ft, perhaps by migrating along the borehole casings and pooling in finer grained sediments. The ^{60}Co associated with this plume appears to have migrated to 72 ft in the vicinity of borehole 40-03-05.

Most of the ^{137}Cs previously attributed to undocumented surface spills near tanks S-107, S-108, S-110, and S-111 has also been attributed to dragdown and removed from the interpreted data set. All ^{137}Cs around tank S-112 was removed.

6.0 Recommendations

Recommendations included in the original S 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 S Tank Farm. The baseline data reported in the S Farm Report and this addendum did not provide any indication of ongoing migration of gamma-emitting radionuclides. An independent assessment of historical data supports this conclusion (Randall and Price 1999). However, the gross gamma logging program was terminated in 1994, and only one borehole was selected for repeat logging. This provides little new data with which to assess any recent (post-1994) migration. Therefore, it is imperative that a routine monitoring program be reinstated within the S Tank Farm as soon as possible. It is not necessary to monitor all boreholes; the S Tank Farm baseline data clearly indicate where monitoring is required. The monitoring program should be based on the use of calibrated detectors with continuing verification measurements to assure detector stability. Both the SGLS and HRLS are complex systems and relatively slow. A faster logging system capable of routine operation by tank farms personnel should be deployed. Preliminary work has been completed on such a system, known as the Radioelement Assessment System (RAS). The SGLS and HRLS should remain available for follow-up investigation of anomalies.

An additional borehole should be drilled and samples collected to further investigate non-gamma-emitting contaminants associated with the tank S-104 plume. Reinterpretation of the

^{137}Cs associated with this plume indicated the maximum depth of contamination was about 48 ft. This fails to explain the reoccurring technetium detected in groundwater in borehole 40-00-04 (299-W23-01).

The Results of Phase I Groundwater Quality Assessment for Single-Shell Tank Waste Management Areas S-SX at the Hanford Site (Johnson and Chou 1998) indicated several driving forces that may be contributing to contaminant migration in S Tank Farm. One such driving force was the main water line leak in 1996. Borehole 40-00-02 was relogged in hopes of determining the impact of this large quantity of surface water infiltrating through the vadose zone on the ^{137}Cs distribution. The ^{137}Cs distribution did not change, but without moisture data it was impossible to determine the amount of water, if any, that actually moved through this zone. Moisture logging in and around this farm would provide valuable data concerning the location of these sources and help quantify the extent to which they may be remobilizing tank waste.

7.0 References

Hanlon, B.M., 2000. *Waste Tank Summary Report for Month Ending March 31, 2000*, HNF-EP-0182-144, CH2M Hill Hanford Group, Inc., Richland, Washington.

Johnson, V.G., and C.J. Chou, 1998. *Results of Phase I Groundwater Quality Assessment for Single-Shell Tank Waste Management Area S-SX at the Hanford Site,* PNNL-12114, Pacific Northwest National Laboratory, Richland, Washington.

__________, 1999. *RCRA Assessment Plan for Single-Shell Tank Waste Management Areas S-SX at the Hanford Site,* PNNL-11810, Pacific Northwest National Laboratory, Richland, Washington.

Knoll, G.F., 1989. *Radiation Detection and Measurement, 2nd Ed.*, John Wiley and Sons, New York.

Randall, R.R., and R.K. Price, 1999. *Analysis and Summary of Historical Dry Well Gamma Logs for S Tank Farm - 200 West,* HNF-4220, Rev. 0, prepared by Waste Management Northwest and Three Rivers Scientific for Lockheed Martin Hanford Corporation, Richland, Washington.

U.S. Department of Energy (DOE), 1995. *Vadose Zone Monitoring Project at the Hanford Tank Farms, Calibration of Two Spectral Gamma-Ray Logging Systems for Baseline Characterization Measurements in the Hanford Tank Farms*, GJPO-HAN-1, prepared by Rust Geotech for the Grand Junction Projects Office, Grand Junction, Colorado, August.

U.S. Department of Energy (DOE), 1997a. *Tank Waste Remediation System Vadose Zone Contamination Issue: Independent Expert Panel Status Report*, DOE/RL-97-49, Rev. 0, Fluor Daniel Hanford Inc., Richland, Washington.

__________, 1997b. *Vadose Zone Characterization Project at the Hanford Tank Farms, Tank Farm Summary Data Report for Tank S-101*, GJ-HAN-70, prepared by MACTEC-ERS for the Grand Junction Projects Office, Grand Junction, Colorado, May.

__________, 1997c. *Vadose Zone Characterization Project at the Hanford Tank Farms, Tank Farm Summary Data Report for Tank S-102*, GJ-HAN-71, prepared by MACTEC-ERS for the Grand Junction Projects Office, Grand Junction, Colorado, May.

__________, 1997d. *Vadose Zone Characterization Project at the Hanford Tank Farms, Tank Farm Summary Data Report for Tank S-103*, GJ-HAN-72, prepared by MACTEC-ERS for the Grand Junction Projects Office, Grand Junction, Colorado, May.

__________, 1997e. *Vadose Zone Characterization Project at the Hanford Tank Farms, Tank Farm Summary Data Report for Tank S-104*, GJ-HAN-73, prepared by MACTEC-ERS for the Grand Junction Projects Office, Grand Junction, Colorado, June.

__________, 1997f. *Vadose Zone Characterization Project at the Hanford Tank Farms, Tank Farm Summary Data Report for Tank S-105*, GJ-HAN-74, prepared by MACTEC-ERS for the Grand Junction Projects Office, Grand Junction, Colorado, July.

__________, 1997g. *Vadose Zone Characterization Project at the Hanford Tank Farms, Tank Farm Summary Data Report for Tank S-106*, GJ-HAN-75, prepared by MACTEC-ERS for the Grand Junction Projects Office, Grand Junction, Colorado, June.

__________, 1997h. *Vadose Zone Characterization Project at the Hanford Tank Farms, Tank Farm Summary Data Report for Tank S-107*, GJ-HAN-76, prepared by MACTEC-ERS for the Grand Junction Projects Office, Grand Junction, Colorado, June.

__________, 1997i. *Vadose Zone Characterization Project at the Hanford Tank Farms, Tank Farm Summary Data Report for Tank S-108*, GJ-HAN-77, prepared by MACTEC-ERS for the Grand Junction Projects Office, Grand Junction, Colorado, June.

__________, 1997j. *Vadose Zone Characterization Project at the Hanford Tank Farms, Tank Farm Summary Data Report for Tank S-109*, GJ-HAN-78, prepared by MACTEC-ERS for the Grand Junction Projects Office, Grand Junction, Colorado, June.

__________, 1997k. *Vadose Zone Characterization Project at the Hanford Tank Farms, Tank Farm Summary Data Report for Tank S-110*, GJ-HAN-79, prepared by MACTEC-ERS for the Grand Junction Projects Office, Grand Junction, Colorado, June.

U.S. Department of Energy (DOE), 1997l. *Vadose Zone Characterization Project at the Hanford Tank Farms, Tank Farm Summary Data Report for Tank S-111*, GJ-HAN-80, prepared by MACTEC-ERS for the Grand Junction Projects Office, Grand Junction, Colorado, June.

__________, 1997m. *Vadose Zone Characterization Project at the Hanford Tank Farms, Tank Farm Summary Data Report for Tank S-112,* GJ-HAN-81, prepared by MACTEC-ERS for the Grand Junction Office, Grand Junction, Colorado, August.

__________, 1999. *Base Calibration of a High Rate Logging System for Characterization of Intense Radiation Zones in the Hanford Tank Farms*, GJO-HAN-29, prepared by MACTEC-ERS for the Grand Junction Office, Grand Junction, Colorado, October.

Appendix A
Additional Borehole Data
for the S Tank Farm

40-10-01 Combination Plot

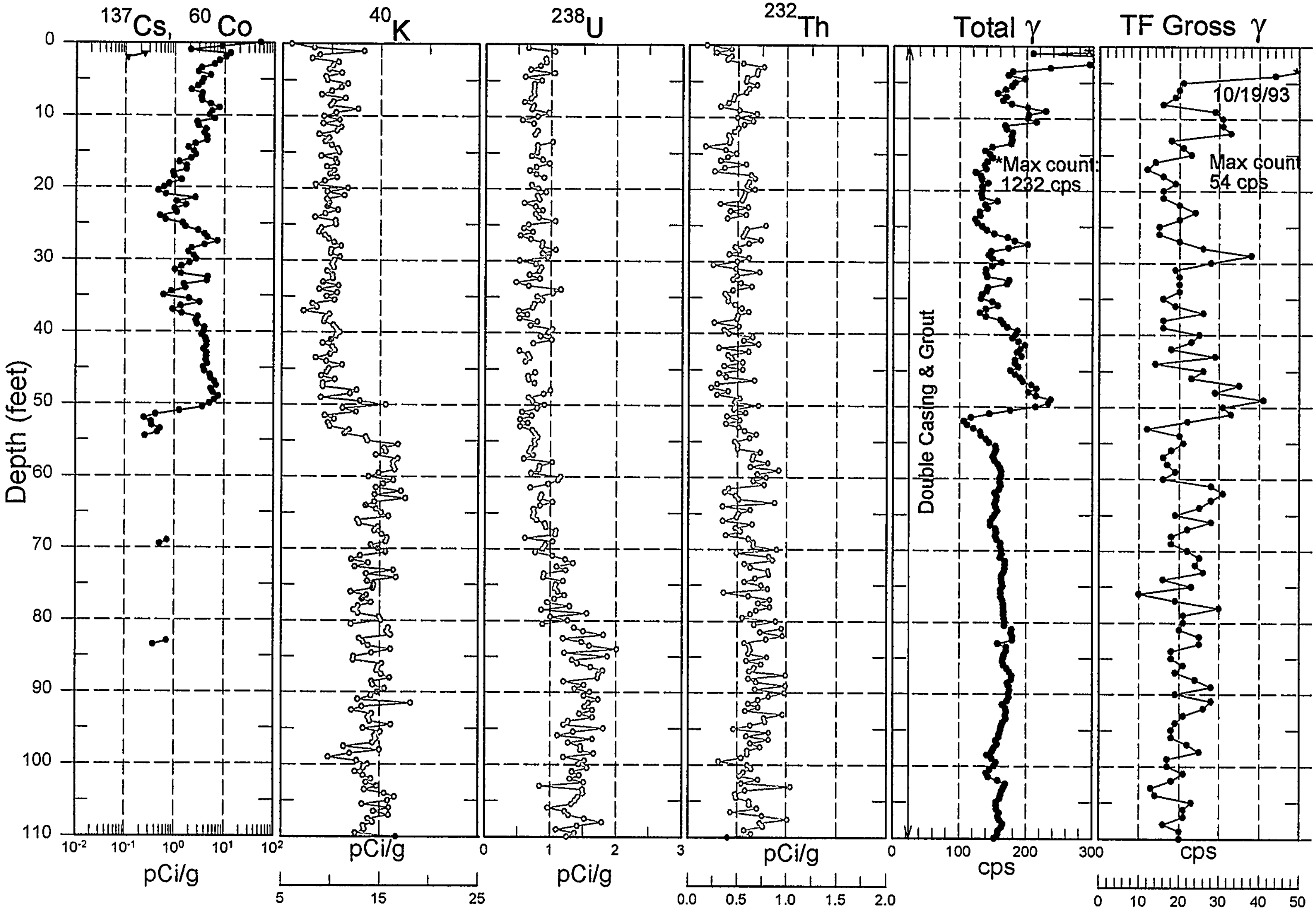

Figure A-1. Additional Borehole Data for the S Tank Farm

40-10-01 Combination Plot

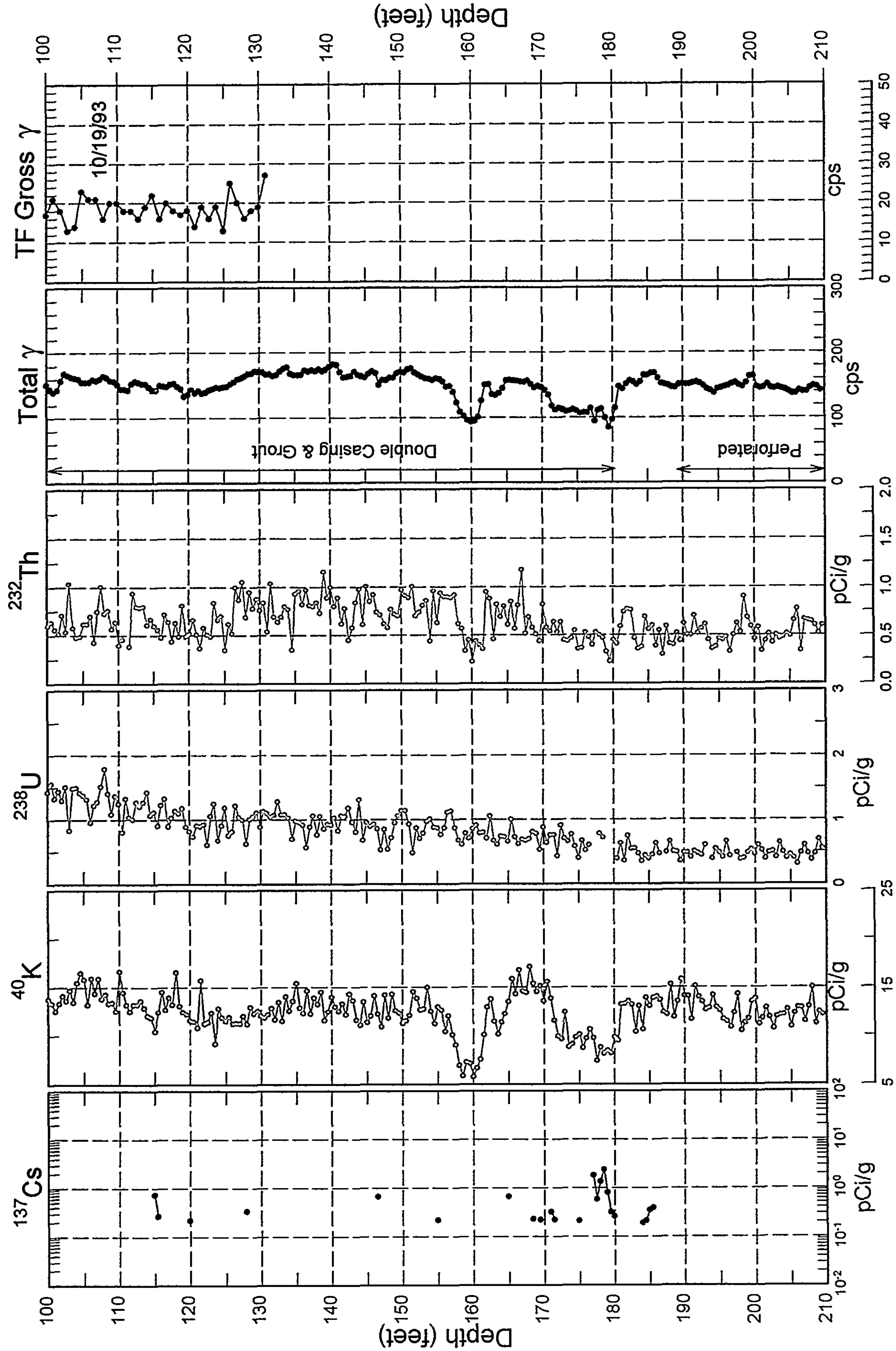

Figure A-2. Additional Borehole Data for the S Tank Farm

40-00-04 Combination Plot

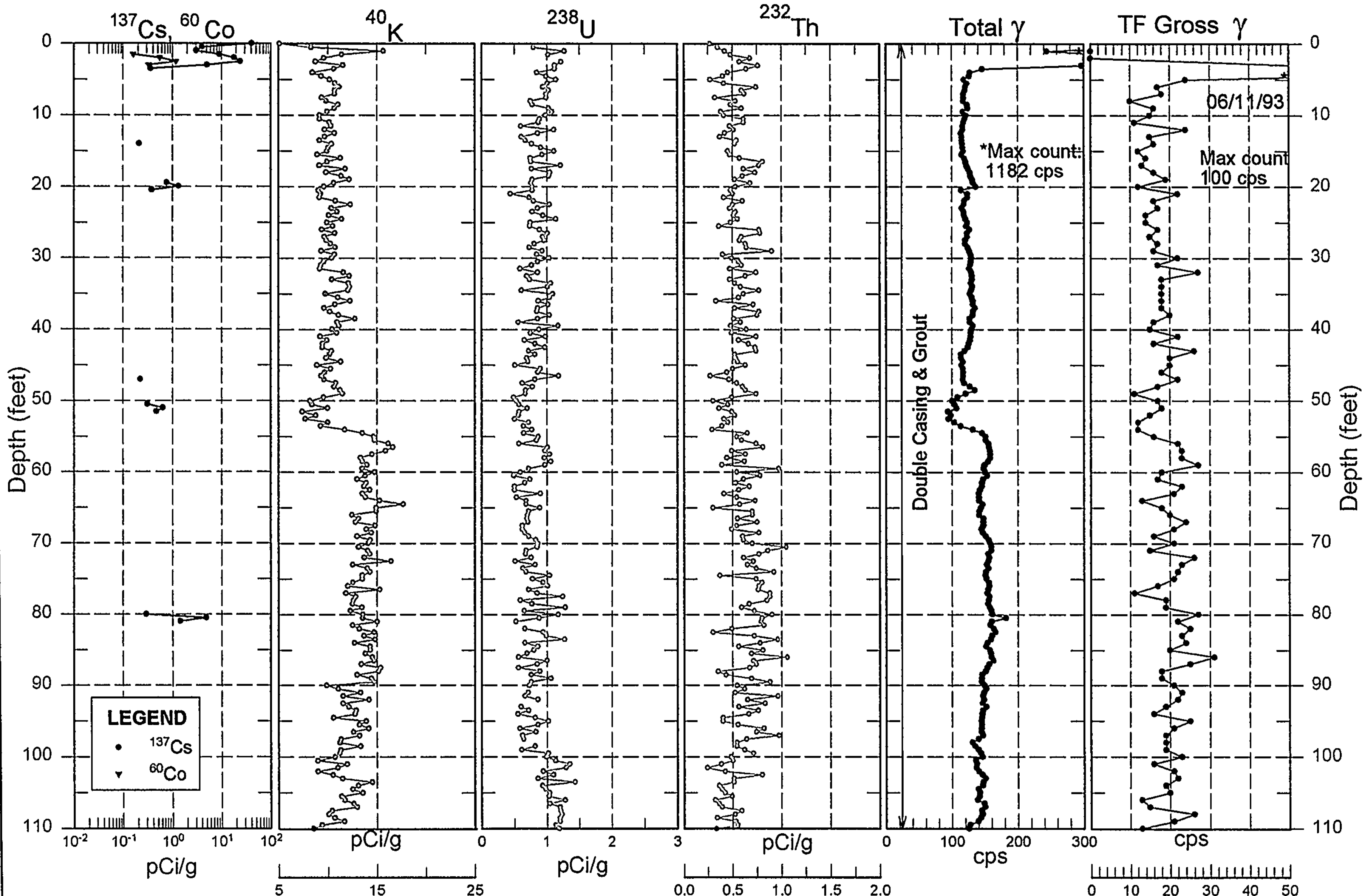

Figure A-3. Additional Borehole Data for the S Tank Farm

40-00-04 Combination Plot

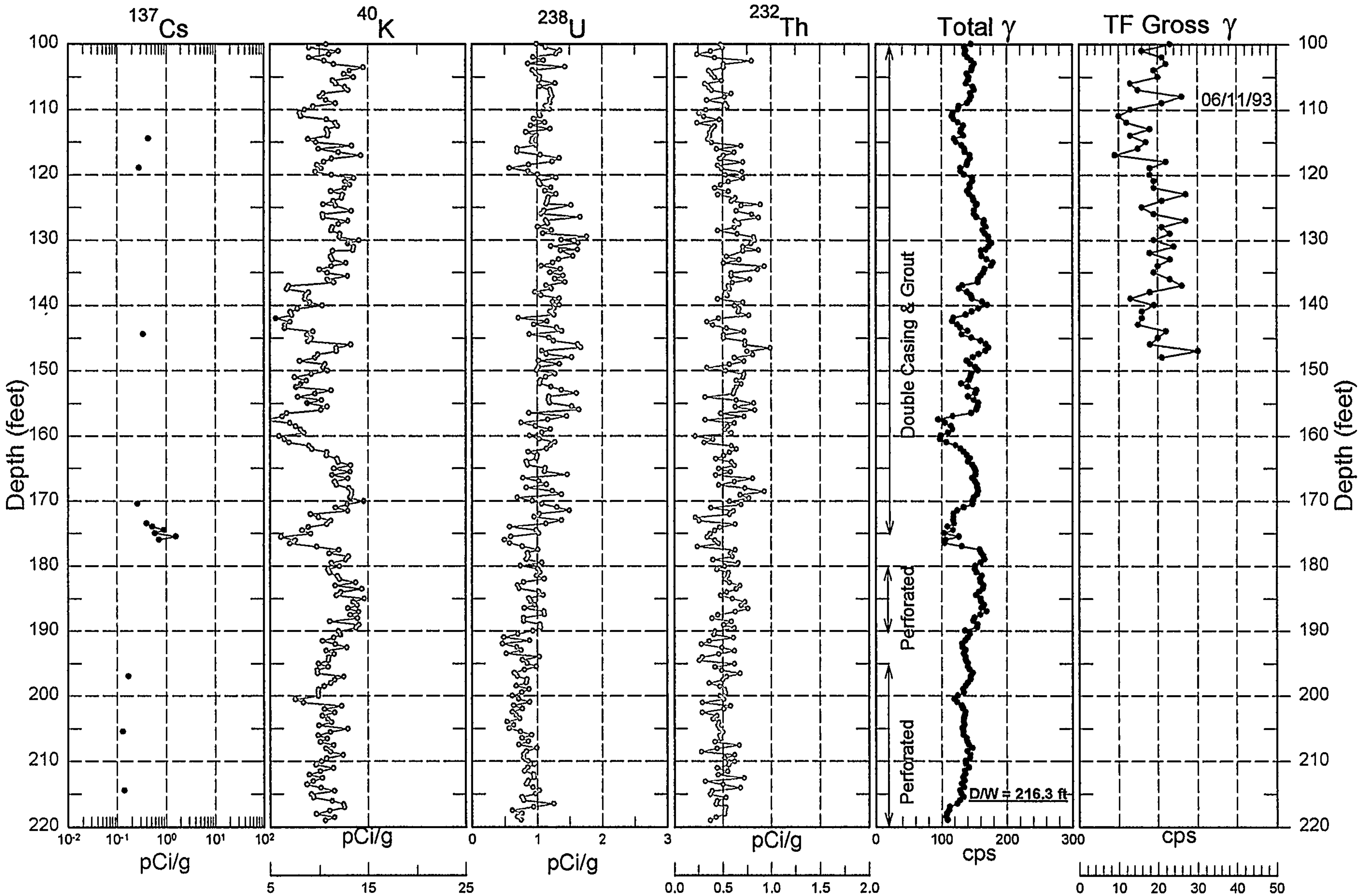

Figure A-4. Additional Borehole Data for the S Tank Farm

Appendix B
Summary of High Rate Logging Results for the S Tank Farm

Table B-1. Summary of High Rate Logging Results for the S Tank Farm

Borehole Number	Log Run Depth Interval (ft)	Shield/ Correction Factor[a]	Comments
40-02-03	20.0 - 29.0	NS/1.00	^{137}Cs was identified from 35.0 to 21.5 ft. The highest concentration (10^6 pCi/g) occurs at 26.5 ft. These data were corrected for decay back to 5/22/96. The HRLS ^{137}Cs data added to the baseline data: 22.0 - 23.5 ft HRLS ^{137}Cs (w/no shield); 24.0 - 27.5 ft HRLS ^{137}Cs (w/external shield); 28.0 - 31.0 ft HRLS ^{137}Cs (w/no shield). R/P[b] state that due to instrument limitations the stability of the interval from 17 - 32 ft was undetermined and there was a possibility of changing ^{137}Cs distribution.
	23.0 - 29.0	ES/3.758	
	28.0 - 35.0	NS/1.00	
40-04-05	37.0 - 43.0	NS/1.00	^{137}Cs was identified from 54.0 to 49.5 ft and from 46.5 to 38.0 ft. The highest concentration (10^6 pCi/g) occurs at 43.5 ft. These data were corrected for decay back to 6/5/96. The HRLS ^{137}Cs data added to the baseline data: 38.5 - 46.0 ft HRLS ^{137}Cs (w/no shield). R/P indicate that the ^{137}Cs from 35 - 55 ft was stable.
	38.0 - 47.0	IS/27.42	
	42.0 - 45.0	NS/1.00	
	44.0 - 55.0	NS/1.00	

[a] Shield configuration options: NS - No shield; ES - External shield; IS - Internal shield; BS - Both shields
[b] R/P - Randall and Price (1999)

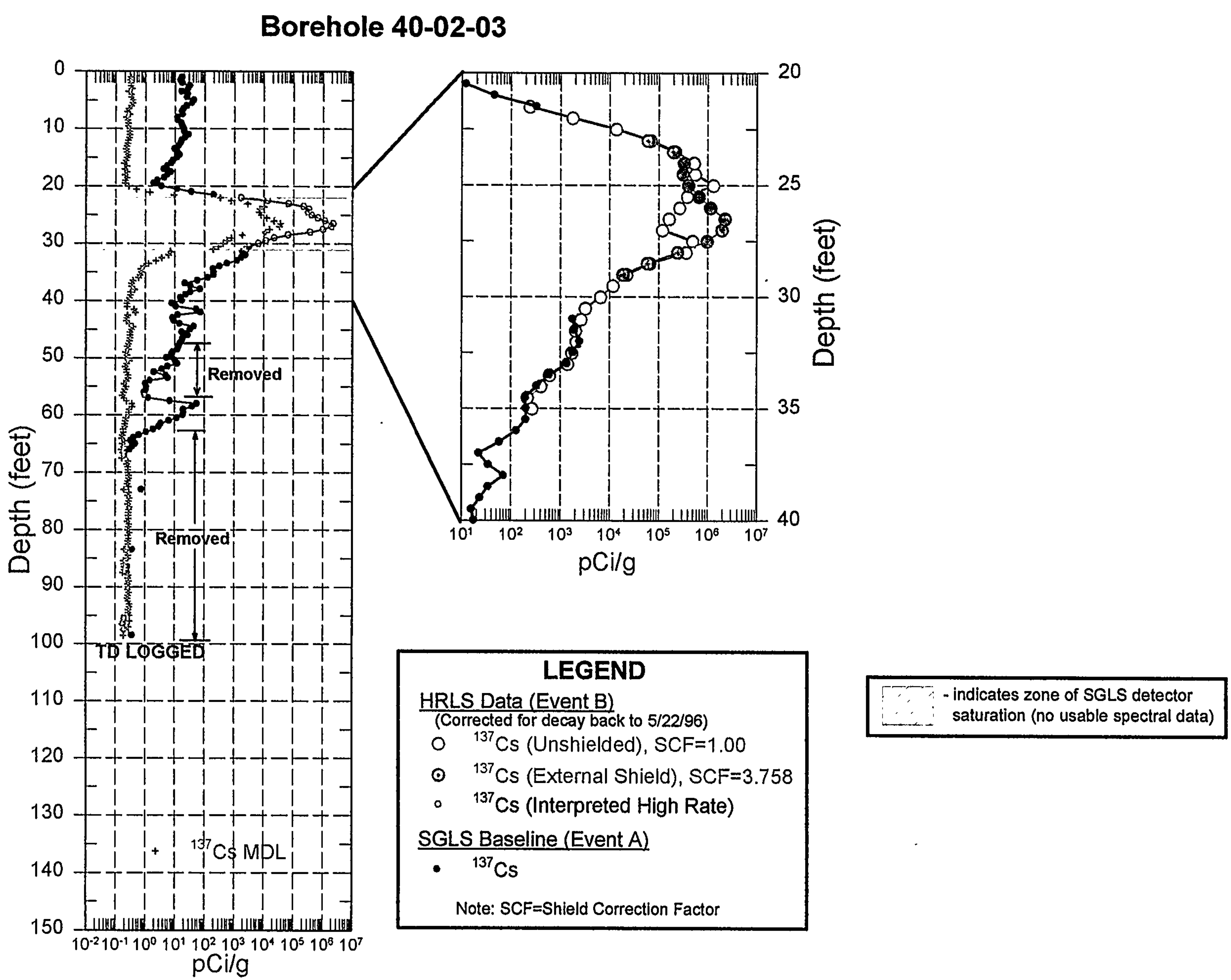

Figure B-1. Summary of High Rate Logging Results for the S Tank Farm

Borehole 40-04-05

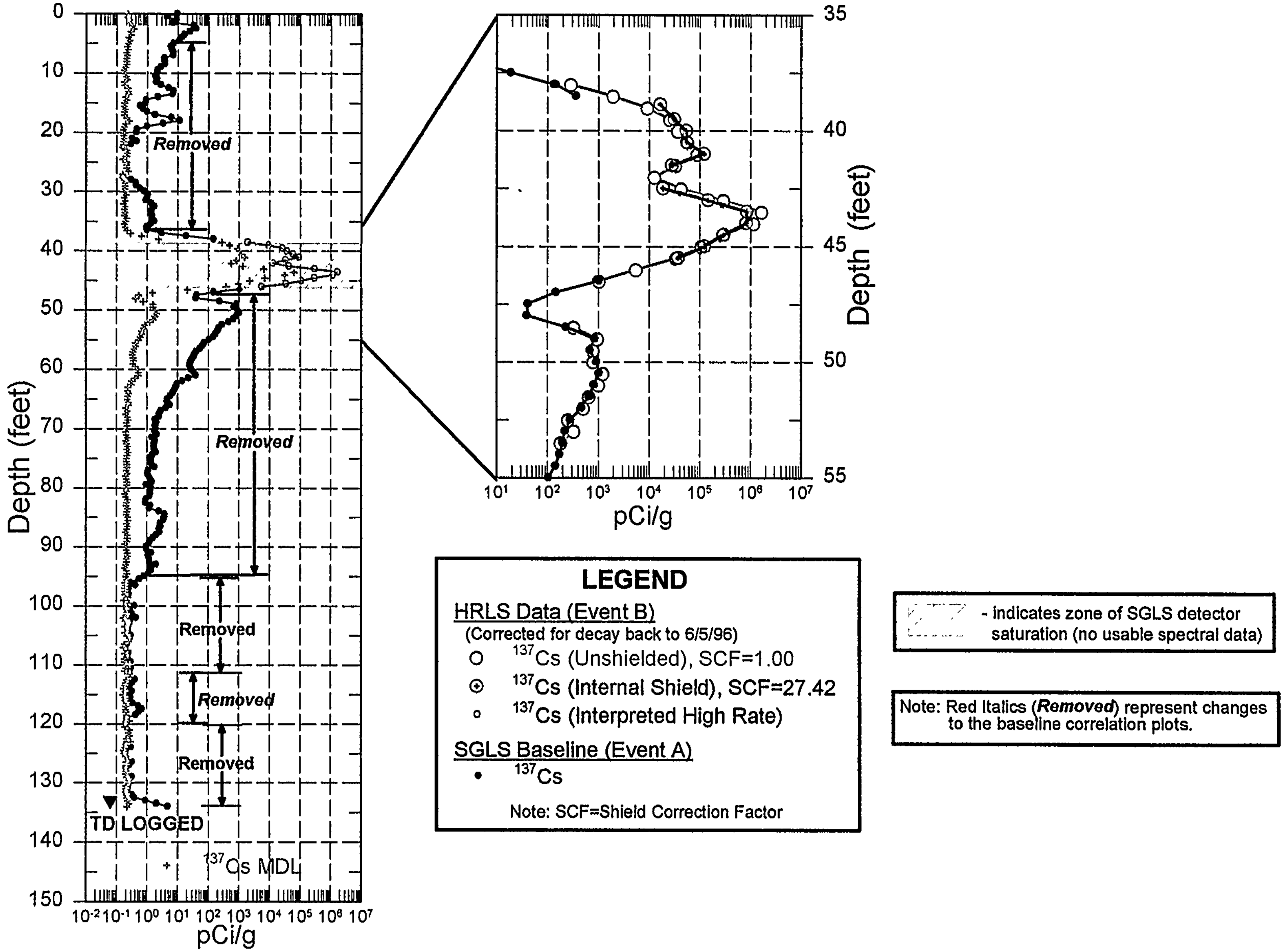

Figure B-2. Summary of High Rate Logging Results for the S Tank Farm

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

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

Borehole Number	Depth Interval (ft)	Reason for Repeat	Logging Unit & (count time)		Evaluation
			Baseline	Repeat	
40-00-02	136.5 - 0.0	IA[a]	G2A (100 s)	G2B (100 s)	No apparent change in contaminant concentration or distribution.

[a] IA - Infiltration assessment

Borehole 40-00-02 Comparison of Baseline and Repeat Logging

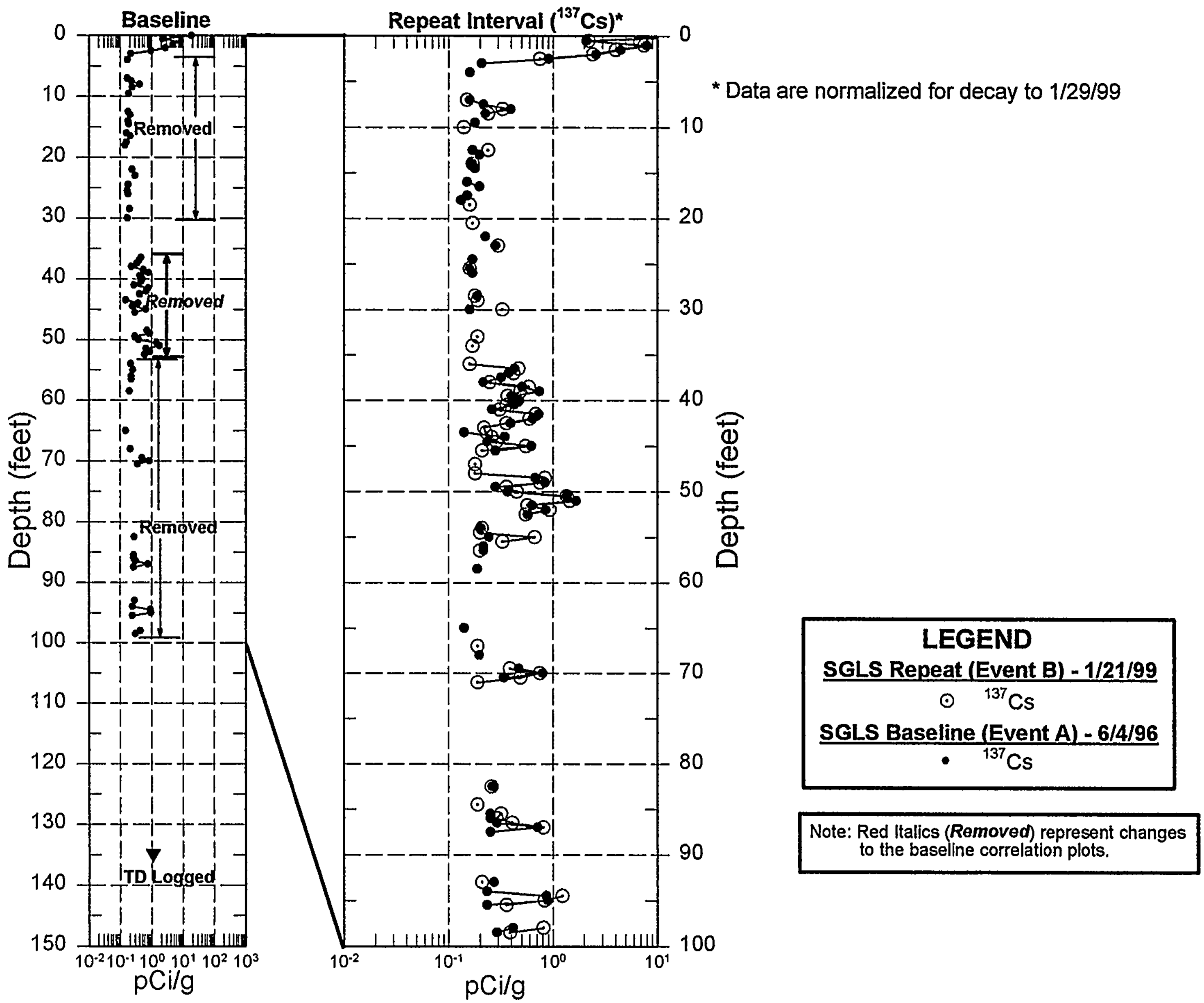

Figure C-1. Summary of Repeat Logging Results for the S Tank Farm

Appendix D
Summary of the Interpreted Data Set for the S Tank Farm

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

Borehole Number	Depth Interval (ft)	Source[a]	SFA[e]	Disposition/Comments
40-01-01	0.0 - 2.5	SS[b]	Ina.[j]	Included ^{137}Cs.
	3.0 - 16.0	BE[c]	Ina.	Removed ^{137}Cs; appears to be dragdown.*
	16.5 - 128.0	None	Ina.	No man-made contaminants detected.
	128.5 - 129.0	BE	Ina.	Removed ^{137}Cs; fell in from the ground surface.
40-01-04	0.0 - 2.0	SS	D[f]	Included ^{137}Cs.
	2.5 - 10.5	BE	Local[h]	Removed ^{137}Cs; appears to be dragdown.
	11.0 - 19.0	None	Ina.	No man-made contaminants detected.
	19.5 - 25.5	BE	Ina.	Removed ^{137}Cs; appears to be dragdown.*
	26.0 - 40.5	BE	Ina.	Removed ^{137}Cs; appears to be dragdown.
	41.0 - 42.0	BE	Ina.	Removed ^{137}Cs; appears to be dragdown.*
	42.5 - 100.0	None	Ina.	No man-made contaminants detected.
	100.5	BE	Ina.	Removed ^{137}Cs; fell in from the ground surface.
40-00-02	0.0 - 3.0	SS	Ina.	Included ^{137}Cs.
	3.5 - 30.0	BE	Ina.	Removed ^{137}Cs; appears to be dragdown.
	30.5 - 36.0	None	Ina.	No man-made contaminants detected.
	36.5 - 52.5	BE	Ina.	Removed ^{137}Cs; appears to be dragdown; perforated casing.*
	53.0 - 99.0	BE	Ina.	Removed ^{137}Cs; appears to be dragdown; perforated casing.
	99.5 - 137.0	None	Ina.	No man-made contaminants detected.
40-01-06	0.0 - 10.0	SS	Ina.	Included ^{137}Cs.
	10.5 - 19.5	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 S Tank Farm Report.

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

Borehole Number	Depth Interval (ft)	Source[a]	SFA[e]	Disposition/Comments
40-01-06 (con't.)	20.0 - 38.5	BE	Ina.	Removed ^{137}Cs; appears to be dragdown.*
	39.0 - 49.5	BE	Ina.	Removed ^{137}Cs; appears to be dragdown.
	50.0 - 96.5	None	Ina.	No man-made contaminants detected.
	97.0 - 97.5	BE	Ina.	Removed ^{137}Cs; fell in from the ground surface.
40-01-08	0.0 - 10.0	SS	Ina.	Included ^{137}Cs, ^{60}Co, and ^{154}Eu; possible transfer line.
	10.5 - 15.0	BE	Ina.	Removed ^{137}Cs; appears to be dragdown.
	15.5 - 102.5	None	Ina.	No man-made contaminants detected.
	103.0	BE	Ina.	Removed ^{137}Cs; fell in from the ground surface.
40-01-10	0.0 - 3.0	SS	Ina.	Included ^{137}Cs.
	3.5 - 29.0	BE	Ina.	Removed ^{137}Cs; appears to be dragdown.*
	29.5 - 36.5	None	Ina.	No man-made contaminants detected.
	37.0 - 48.0	BE	Ina.	Removed ^{137}Cs; appears to be dragdown.
	48.5 - 96.5	None	Ina.	No man-made contaminants detected.
	97.0 - 98.0	BE	Ina.	Removed ^{137}Cs; fell in from the ground surface.
40-02-01	0.0 - 1.5	SS	Ina.	Included ^{137}Cs.
	2.0 - 129.0	None	Ina.	No man-made contaminants detected.
	129.5 - 130.0	BE	Ina.	Removed ^{137}Cs; fell in from the ground surface.
40-02-03	0.0 - 20.0	SS	D	Included ^{137}Cs.
	20.5 - 21.5	P[d]	Inc.[g]	Included ^{137}Cs; possible transfer line leak.
	22.0 - 23.5	P	Ina.	Replaced SGLS ^{137}Cs with HRLS (w/no shield) ^{137}Cs. Included ^{137}Cs; possible transfer line leak.*

[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 S Tank Farm Report.

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

Borehole Number	Depth Interval (ft)	Source[a]	SFA[e]	Disposition/Comments
40-02-03 (con't.)	24.0 - 27.5	P	Ina.	Replaced SGLS ^{137}Cs with HRLS (w/external shield) ^{137}Cs. Included ^{137}Cs; possible transfer line leak.*
	28.0 - 31.0	P	Ina.	Replaced SGLS ^{137}Cs with HRLS (w/no shield) ^{137}Cs. Included ^{137}Cs; possible transfer line leak.*
	31.5 - 47.5	P	Inc.	Included ^{137}Cs; possible transfer line leak.
	48.0 - 56.5	BE	Local	Removed ^{137}Cs; appears to be dragdown.
	57.0 - 62.0	P	Inc.	Included ^{137}Cs; possible transfer line leak.
	62.5 - 98.5	BE	Ina.	Removed ^{137}Cs; appears to be dragdown.
40-02-04	0.0 - 9.0	SS	Ina.	Included ^{137}Cs.
	9.5 - 144.5	None	Ina.	No man-made contaminants detected.
40-02-05	0.0 - 27.0	SS	Inc.	Included ^{137}Cs.
	27.5 - 43.5	BE	Ina.	Removed ^{137}Cs; appears to be dragdown.
	44.0 - 87.5	None	Ina.	No man-made contaminants detected.
	88.0 - 99.0	BE	Ina.	Removed ^{137}Cs; fell in from the ground surface.
40-02-07	0.0 - 2.0	SS	Ina.	Included ^{137}Cs and ^{60}Co.
	2.5 - 45.0	BE & SS	Ina.	Removed ^{137}Cs; appears to be dragdown. Included ^{60}Co.*
	45.5 - 54.5	SS	Ina.	Included ^{137}Cs and ^{60}Co.
	55.0 - 90.0	BE	Ina.	Removed ^{137}Cs; appears to be dragdown.*
	90.5 - 95.5	BE	Ina.	Removed ^{137}Cs; fell in from the ground surface.
40-02-08	0.0 - 30.0	SS	D	Included ^{137}Cs and ^{60}Co.
	30.5 - 41.5	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 S Tank Farm Report.

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

Borehole Number	Depth Interval (ft)	Source[a]	SFA[e]	Disposition/Comments
40-02-08 (con't.)	42.0 - 55.0	SS	D	Included ^{137}Cs and ^{60}Co.
	55.5 - 57.0	BE	Ina.	Removed ^{137}Cs; appears to be dragdown.*
	57.5 - 99.0	None	Ina.	No man-made contaminants detected.
	99.5 - 100.0	BE	Ina.	Removed ^{137}Cs; fell in from the ground surface.
40-02-10	0.0 - 2.0	SS	Ina.	Included ^{137}Cs.
	2.5 - 12.0	None	Ina.	No man-made contaminants detected.
	12.5 - 13.0	BE	Ina.	Removed ^{137}Cs; appears to be dragdown.
	13.5 - 99.5	None	Ina.	No man-made contaminants detected.
	100.0	BE	Ina.	Removed ^{137}Cs; fell in from the ground surface.
40-02-11	0.0 - 2.5	SS	Ina.	Included ^{137}Cs.
	3.0 - 99.5	None	Ina.	No man-made contaminants detected.
	100.0 - 100.5	BE	Ina.	Removed ^{137}Cs; fell in from the ground surface.
40-03-01	0.0 - 0.5	BE	Ina.	Removed ^{137}Cs; appears to be surface shine.
	1.0 - 14.0	None	Ina.	No man-made contaminants detected.
	14.5 - 15.0	BE	Ina.	Removed ^{137}Cs; appears to be dragdown.
	15.5 - 98.5	None	Ina.	No man-made contaminants detected.
40-03-03	0.0 - 5.5	SS	Ina.	Included ^{137}Cs.
	6.0 - 6.5	BE	Ina.	Removed ^{137}Cs; appears to be dragdown.*
	7.0 - 123.5	None	Ina.	No man-made contaminants detected.
40-03-05	0.0 - 1.0	BE	Ina.	Removed ^{137}Cs; appears to be surface shine.

[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 S Tank Farm Report.

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

Borehole Number	Depth Interval (ft)	Source[a]	SFA[e]	Disposition/Comments
40-03-05 (con't.)	1.5 - 48.0	None	Ina.	No man-made contaminants detected.
	48.5 - 72.5	BE & P	Ina.	Removed ^{137}Cs; appears to be dragdown; perforated casing. Included ^{60}Co.*
	73.0 - 148.0	None	Ina.	No man-made contaminants detected.
40-03-06	0.0	BE	Ina.	Removed ^{137}Cs; appears to be surface shine.
	0.5 - 98.5	None	Ina.	No man-made contaminants detected.
40-03-08	0.0 - 5.5	SS	Ina.	Included ^{137}Cs.
	6.0 - 11.0	BE	Ina.	Removed ^{137}Cs; appears to be dragdown.*
	11.5 - 96.0	None	Ina.	No man-made contaminants detected.
40-03-09	0.0 - 2.5	SS	Ina.	Included ^{137}Cs and ^{60}Co.
	3.0 - 50.5	BE & SS	Ina.	Removed ^{137}Cs; appears to be dragdown. Included ^{60}Co.*
	51.0 - 58.0	None	Ina.	No man-made contaminants detected.
	58.5 - 130.0	BE	Ina.	Removed ^{137}Cs; appears to be dragdown; fell in from the ground surface.
40-03-11	0.0	BE	Ina.	Removed ^{137}Cs; appears to be surface shine.
	0.5 - 98.5	None	Ina.	No man-made contaminants detected.
40-04-01	0.0 - 2.0	SS	D	Included ^{137}Cs.
	2.5 - 18.0	BE	Inc.	Removed ^{137}Cs; appears to be dragdown.*
	18.5 - 44.0	BE	Ina.	Removed ^{137}Cs; appears to be dragdown.
	44.5 - 62.5	BE	Ina.	Removed ^{137}Cs; appears to be dragdown.*
	63.0 - 98.0	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.

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

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

Borehole Number	Depth Interval (ft)	Source[a]	SFA[e]	Disposition/Comments
40-04-05	0.0 - 4.5	SS	Inc.	Included ^{137}Cs.
	5.0 - 36.5	BE	Inc.	Removed ^{137}Cs; appears to be dragdown.*
	37.0 - 38.0	P	R[i]	Included ^{137}Cs; probable S-104 tank leak.
	38.5 - 46.0	P	Ina.	Replaced SGLS ^{137}Cs with HRLS (w/no shield) ^{137}Cs. Included ^{137}Cs; probable S-104 tank leak.*
	46.0 - 47.0	P	R	Included ^{137}Cs; probable S-104 tank leak.
	47.5 - 95.0	BE	Inc.	Removed ^{137}Cs; appears to be dragdown.*
	95.5 - 111.0	BE	Ina.	Removed ^{137}Cs; appears to be dragdown.
	111.5 - 120.0	BE	Ina.	Removed ^{137}Cs; appears to be dragdown.*
	120.5 - 134.0	BE	Ina.	Removed ^{137}Cs; appears to be dragdown.
40-04-07	0.0 - 18.0	SS	D	Included ^{137}Cs.
	18.5 - 45.0	BE	Ina.	Removed ^{137}Cs; appears to be dragdown.
	45.5 - 51.0	BE	Ina.	Removed ^{137}Cs; appears to be dragdown.*
	51.5 - 54.0	P	D	Included ^{137}Cs; probable S-104 tank leak.
	54.5 - 97.5	BE	Ina.	Removed ^{137}Cs; appears to be dragdown.
40-04-08	0.0 - 24.5	SS	D	Included ^{137}Cs.
	25.0 - 30.0	BE	Ina.	Removed ^{137}Cs; appears to be dragdown.*
	30.5 - 48.0	BE	Ina.	Removed ^{137}Cs; appears to be dragdown.
40-05-03	0.0 - 2.5	SS	D	Included ^{137}Cs.
	3.0 - 24.0	BE	Ina.	Removed ^{137}Cs; appears to be dragdown.*
	24.5 - 35.0	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 S Tank Farm Report.

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

Borehole Number	Depth Interval (ft)	Source[a]	SFA[e]	Disposition/Comments
40-05-03 (con't.)	35.5 - 36.0	BE	Ina.	Removed ^{137}Cs; appears to be dragdown.
	36.5 - 89.0	None	Ina.	No man-made contaminants detected.
	89.5	BE	Ina.	Removed ^{137}Cs; appears to be dragdown.
	90.0 - 100.0	None	Ina.	No man-made contaminants detected.
	100.5	BE	Ina.	Removed ^{137}Cs; fell in from the ground surface.
40-05-07	0.0 - 19.5	BE	Ina.	Removed ^{137}Cs; appears to be dragdown.*
	20.0 - 56.5	None	Ina.	No man-made contaminants detected.
	57.0	BE	Ina.	Removed ^{137}Cs; appears to be dragdown.
	57.5 - 96.5	None	Ina.	No man-made contaminants detected.
40-05-08	0.0 - 1.5	BE	Ina.	Removed ^{137}Cs; appears to be surface shine.
	2.0 - 9.0	None	Ina.	No man-made contaminants detected.
	9.5 - 12.0	BE	Ina.	Removed ^{137}Cs; appears to be dragdown.*
	12.5 - 98.5	None	Ina.	No man-made contaminants detected.
40-05-10	0.0 - 1.5	BE	Ina.	Removed ^{137}Cs; appears to be surface shine.
	2.0 - 89.5	None	Ina.	No man-made contaminants detected.
40-06-02	0.0 - 8.5	BE	Ina.	Removed ^{137}Cs; appears to be dragdown.
	9.0 - 14.0	BE	Ina.	Removed ^{137}Cs; appears to be dragdown.*
	14.5 - 99.5	None	Ina.	No man-made contaminants detected.
40-06-04	0.0 - 4.5	BE	Ina.	Removed ^{137}Cs; appears to be dragdown.
	5.0 - 125.0	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 S Tank Farm Report.

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

Borehole Number	Depth Interval (ft)	Source[a]	SFA[e]	Disposition/Comments
40-06-05	0.0	BE	Ina.	Removed ^{137}Cs; appears to be surface shine.
	0.5 - 140.5	None	Ina.	No man-made contaminants detected.
40-06-06	0.0	BE	Ina.	Removed ^{137}Cs; appears to be surface shine.
	0.5 - 31.0	BE	Ina.	Removed ^{137}Cs; appears to be dragdown.
	31.5 - 57.5	None	Ina.	No man-made contaminants detected.
	58.0 - 60.0	BE	Ina.	Removed ^{137}Cs; appears to be dragdown.
	60.5 - 96.5	None	Ina.	No man-made contaminants detected.
40-06-08	0.0 - 97.0	None	Ina.	No man-made contaminants detected.
40-06-09	0.0 - 2.5	SS	Ina.	Included ^{137}Cs.
	3.0 - 9.0	None	Ina.	No man-made contaminants detected.
	9.5 - 32.0	BE	Ina.	Removed ^{137}Cs; appears to be dragdown.
	32.5 - 99.0	None	Ina.	No man-made contaminants detected.
40-07-01	0.0 - 6.0	SS	Inc.	Included ^{137}Cs.
	6.5 - 23.0	BE	Ina.	Removed ^{137}Cs; appears to be dragdown.*
	23.5 - 39.0	None	Ina.	No man-made contaminants detected.
	39.5 - 43.5	P	Inc.	Included ^{137}Cs; correlates w/40-04-05; probable S-104 tank leak.
	44.0 - 51.5	None	Ina.	No man-made contaminants detected.
	52.0	BE	Ina.	Removed ^{137}Cs; appears to be dragdown.
	52.5 - 98.5	None	Ina.	No man-made contaminants detected.
	99.0	BE	Ina.	Removed ^{137}Cs; fell in from the ground surface.

[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 S Tank Farm Report.

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

Borehole Number	Depth Interval (ft)	Source[a]	SFA[e]	Disposition/Comments
40-07-04	0.0 - 1.5	SS	Ina.	Included ^{137}Cs.
	2.0 - 101.5	None	Ina.	No man-made contaminants detected.
	102.0	BE	Ina.	Removed ^{137}Cs; fell in from the ground surface.
40-07-06	0.0 - 0.5	SS	Ina.	Included ^{137}Cs.
	1.0 - 4.0	BE	Ina.	Removed ^{137}Cs; appears to be dragdown.*
	4.5 - 98.0	None	Ina.	No man-made contaminants detected.
	98.5	BE	Ina.	Removed ^{137}Cs; fell in from the ground surface.
40-07-08	0.0 - 11.5	SS	Ina.	Included ^{137}Cs.
	12.0 - 20.5	None	Ina.	No man-made contaminants detected.
	21.0	BE	Ina.	Removed ^{137}Cs; appears to be dragdown.
	21.5 - 25.0	None	Ina.	No man-made contaminants detected.
	25.5 - 30.0	BE	Ina.	Removed ^{137}Cs; appears to be dragdown.*
	30.5 - 81.0	None	Ina.	No man-made contaminants detected.
	81.5	BE	Ina.	Removed ^{137}Cs; appears to be dragdown.
	82.0 - 98.5	None	Ina.	No man-made contaminants detected.
	99.0	BE	Ina.	Removed ^{137}Cs; fell in from the ground surface.
40-07-10	0.0 - 16.0	BE	Ina.	Removed ^{137}Cs; appears to be dragdown.*
	16.5 - 98.5	None	Ina.	No man-made contaminants detected.
40-07-11	0.0 - 11.0	SS	D	Included ^{137}Cs.
	11.5 - 57.0	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 S Tank Farm Report.

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

Borehole Number	Depth Interval (ft)	Source[a]	SFA[e]	Disposition/Comments
40-07-11 (con't.)	57.5 - 97.0	None	Ina.	No man-made contaminants detected.
	97.5	BE	Ina.	Removed ^{137}Cs; fell in from the ground surface.
40-08-01	0.0 - 1.0	BE	Ina.	Removed ^{137}Cs; appears to be surface shine.
	1.5 - 97.0	None	Ina.	No man-made contaminants detected.
40-08-06	0.0	BE	Ina.	Removed ^{137}Cs; appears to be surface shine.
	0.5 - 12.5	BE	Ina.	Removed ^{137}Cs; appears to be dragdown.
	13.0 - 99.0	None	Ina.	No man-made contaminants detected.
	99.5	BE	Ina.	Removed ^{137}Cs; fell in from the ground surface.
40-08-08	0.0 - 1.0	BE	Ina.	Removed ^{137}Cs; appears to be surface shine.
	1.5 - 97.5	None	Ina.	No man-made contaminants detected.
40-08-09	0.0	BE	Ina.	Removed ^{137}Cs; appears to be surface shine.
	0.5 - 95.0	None	Ina.	No man-made contaminants detected.
40-08-12	0.0	BE	Ina.	Removed ^{137}Cs; appears to be surface shine.
	0.5 - 4.5	BE	Ina.	Removed ^{137}Cs; appears to be dragdown.
	5.0 - 123.5	None	Ina.	No man-made contaminants detected.
40-09-01	0.0	BE	Ina.	Removed ^{137}Cs; appears to be surface shine.
	0.5 - 96.0	None	Ina.	No man-made contaminants detected.
40-09-02	0.0	BE	Ina.	Removed ^{137}Cs; appears to be surface shine.
	0.5 - 97.5	None	Ina.	No man-made contaminants detected.
	98.0	BE	Ina.	Removed ^{137}Cs; fell in from the ground surface.

[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 S Tank Farm Report.

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

Borehole Number	Depth Interval (ft)	Source[a]	SFA[e]	Disposition/Comments
40-09-05	0.0 - 1.0	BE	Ina.	Removed ^{137}Cs; appears to be surface shine.
	1.5 - 49.0	None	Ina.	No man-made contaminants detected.
	49.5 - 63.5	BE	Ina.	Removed ^{137}Cs; appears to be dragdown; perforated casing.
	64.0 - 108.0	None	Ina.	No man-made contaminants detected.
	108.5	BE	Ina.	Removed ^{137}Cs; appears to be dragdown.
	109.0 - 141.5	None	Ina.	No man-made contaminants detected.
40-09-06	0.0	BE	Ina.	Removed ^{137}Cs; appears to be surface shine.
	0.5 - 98.0	None	Ina.	No man-made contaminants detected.
40-09-08	0.0 - 97.5	BE	Ina.	Removed ^{137}Cs; appears to be surface shine.
	1.5 - 97.5	None	Ina.	No man-made contaminants detected.
40-09-09	0.0	BE	Ina.	Removed ^{137}Cs; appears to be surface shine.
	0.5 - 2.5	BE	Ina.	Removed ^{137}Cs; appears to be dragdown.
	3.0 - 138.0	None	Ina.	No man-made contaminants detected.
40-10-01	0.0 - 3.0	SS	Ina.	Included ^{137}Cs and ^{60}Co. This borehole was not logged during the baseline.*
	3.5 - 185.5	BE	Ina.	Removed ^{137}Cs; appears to be dragdown or ^{137}Cs is in the grout. This borehole was drilled in 1970, possibly after the surface spill had occurred. Borehole 40-00-04, which was drilled in 1952, does not show as extensive dragdown.*
	186.0 - 209.5	None	Ina.	No man-made contaminants identified.*
40-00-04	0.0 - 3.5	SS	Ina.	Included ^{137}Cs and ^{60}Co. This borehole was not logged during the baseline.*

[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 S Tank Farm Report.

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

Borehole Number	Depth Interval (ft)	Source[a]	SFA[e]	Disposition/Comments
40-00-04 (con't.)	4.0 - 214.5	BE	Ina.	Removed ^{137}Cs; appears to be dragdown or ^{137}Cs is in the grout.*
	215.0 - 219.0	None	Ina.	No man-made contaminants identified.*
40-10-03	0.0 - 1.5	SS	Ina.	Included ^{137}Cs.
	2.0 - 16.0	BE	Ina.	Removed ^{137}Cs; appears to be dragdown.*
	16.5 - 97.0	None	Ina.	No man-made contaminants identified.
	97.5	BE	Ina.	Removed ^{137}Cs; fell in from the ground surface.
40-10-05	0.0 - 1.0	BE	Ina.	Removed ^{137}Cs; appears to be surface shine.
	1.5 - 98.0	None	Ina.	No man-made contaminants identified.
40-10-06	0.0 - 3.0	SS	Ina.	Included ^{137}Cs.
	3.5 - 15.0	BE	Ina.	Removed ^{137}Cs; appears to be dragdown.*
	15.5 - 22.0	BE	Ina.	Removed ^{137}Cs; appears to be dragdown.
	22.5 - 49.0	BE	Ina.	Removed ^{137}Cs; appears to be dragdown.*
	49.5 - 144.0	None	Ina.	No man-made contaminants identified.
	137.0 - 144.0	BE	Ina.	Removed ^{137}Cs; fell in from the ground surface.
40-10-08	0.0 - 3.0	SS	Ina.	Included ^{137}Cs.
	3.5 - 17.0	BE	Ina.	Removed ^{137}Cs; appears to be dragdown.*
	17.5 - 28.5	None	Ina.	No man-made contaminants identified.
	29.0	BE	Ina.	Removed ^{137}Cs; appears to be dragdown.
	29.5 - 95.0	None	Ina.	No man-made contaminants identified.
	95.5 - 100.0	BE	Ina.	Removed ^{137}Cs; fell in from the ground surface.

[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 S Tank Farm Report.

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

Borehole Number	Depth Interval (ft)	Source[a]	SFA[e]	Disposition/Comments
40-10-09	0.0 - 2.5	SS	Ina.	Included ^{137}Cs.
	3.0 - 9.5	None	Ina.	No man-made contaminants identified.
	10.0	BE	Ina.	Removed ^{137}Cs; appears to be dragdown.
	10.5 - 99.0	None	Ina.	No man-made contaminants identified.
	99.5 - 100.5	BE	Ina.	Removed ^{137}Cs; fell in from the ground surface.
40-10-13	0.0 - 2.0	SS	Ina.	Included ^{137}Cs.
	2.5 - 7.5	BE	Ina.	Removed ^{137}Cs; appears to be dragdown.*
	8.0 - 122.0	None	Ina.	No man-made contaminants identified.
	122.5 - 124.0	BE	Ina.	Removed ^{137}Cs; fell in from the ground surface.
40-11-01	0.0 - 2.0	SS	Ina.	Included ^{137}Cs.
	2.5 - 7.0	BE	Ina.	Removed ^{137}Cs; appears to be dragdown.*
	7.5 - 143.0	None	Ina.	No man-made contaminants identified.
	143.5 - 144.5	BE	Ina.	Removed ^{137}Cs; fell in from the ground surface.
40-00-06	0.0 - 1.5	SS	Ina.	Included ^{137}Cs.
	2.0 - 7.0	BE	Ina.	Removed ^{137}Cs; appears to be dragdown.*
	7.5 - 47.5	None	Ina.	No man-made contaminants identified.
	48.0 - 50.0	BE	Ina.	Removed ^{137}Cs; appears to be dragdown; perforated casing.*
	50.5 - 97.5	None	Ina.	No man-made contaminants identified.
	98.0	BE	Ina.	Removed ^{137}Cs; appears to be dragdown.
	98.5 - 150.0	None	Ina.	No man-made contaminants identified.

[a] Source - Source of contamination in judgment of analyst.
[b] SS- surface spill
[c] BE - borehole effects (e.g., dragdown, inside/outside casing contamination)
[d] P - 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 S Tank Farm Report.

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

Borehole Number	Depth Interval (ft)	Source[a]	SFA[e]	Disposition/Comments
40-11-05	0.0 - 2.5	BE	Ina.	Removed ^{137}Cs; appears to be dragdown.
	3.0 - 97.5	None	Ina.	No man-made contaminants identified.
40-11-07	0.0	BE	Ina.	Removed ^{137}Cs; appears to be surface shine.
	0.5 - 13.5	BE	Ina.	Removed ^{137}Cs; appears to be dragdown.*
	14.0 - 36.0	None	Ina.	No man-made contaminants identified.
	36.0 - 41.5	BE	Ina.	Removed ^{137}Cs; appears to be dragdown.*
	42.0 - 100.0	None	Ina.	No man-made contaminants identified.
	100.5	BE	Ina.	Removed ^{137}Cs; fell in from the ground surface.
40-11-08	0.0 - 1.0	BE	Ina.	Removed ^{137}Cs; appears to be surface shine.
	1.5 - 97.5	None	Ina.	No man-made contaminants identified.
40-11-09	0.0	BE	Ina.	Removed ^{137}Cs; appears to be surface shine.
	0.5 - 98.5	None	Ina.	No man-made contaminants identified.
40-12-02	0.0	BE	Ina.	Removed ^{137}Cs; appears to be surface shine.
	0.5 - 99.5	None	Ina.	No man-made contaminants identified.
40-12-04	0.0 - 4.5	BE	Ina.	Removed ^{137}Cs; appears to be dragdown.*
	5.0 - 7.0	BE	Ina.	Removed ^{137}Cs; appears to be dragdown.
	7.5 - 125.0	None	Ina.	No man-made contaminants identified.
	125.5 - 126.0	BE	Ina.	Removed ^{137}Cs; fell in from the ground surface.
40-12-06	0.0 - 17.0	BE	Ina.	Removed ^{137}Cs; appears to be dragdown.*
	17.5 - 60.5	None	Ina.	No man-made contaminants identified.

[a] Source - Source of contamination in judgment of analyst.
[b] SS- surface spill
[c] BE - borehole effects (e.g., dragdown, inside/outside casing contamination)
[d] P - 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 S Tank Farm Report.

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

Borehole Number	Depth Interval (ft)	Source[a]	SFA[e]	Disposition/Comments
40-12-06 (con't.)	61.0 - 63.0	BE	Ina.	Removed ^{137}Cs; appears to be dragdown.*
	63.5 - 144.0	None	Ina.	No man-made contaminants identified.
40-12-07	0.0 - 0.5	BE	Ina.	Removed ^{137}Cs; appears to be surface shine.
	1.0 - 98.5	None	Ina.	No man-made contaminants identified.
40-12-09	0.0	BE	Ina.	Removed ^{137}Cs; appears to be surface shine.
	0.5 - 8.5	None	Ina.	No man-made contaminants identified.
	9.0	BE	Ina.	Removed ^{137}Cs; appears to be dragdown.
	9.5 - 15.0	None	Ina.	No man-made contaminants identified.
	15.5 - 25.5	BE	Ina.	Removed ^{137}Cs; appears to be dragdown.*
	26.0 - 29.0	None	Ina.	No man-made contaminants identified.
	29.5	BE	Ina.	Removed ^{137}Cs; appears to be dragdown.
	30.0 - 99.0	None	Ina.	No man-made contaminants identified.

[a] Source - Source of contamination in judgment of analyst.
[b] SS- surface spill
[c] BE - borehole effects (e.g., dragdown, inside/outside casing contamination)
[d] P - 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 S Tank Farm Report.

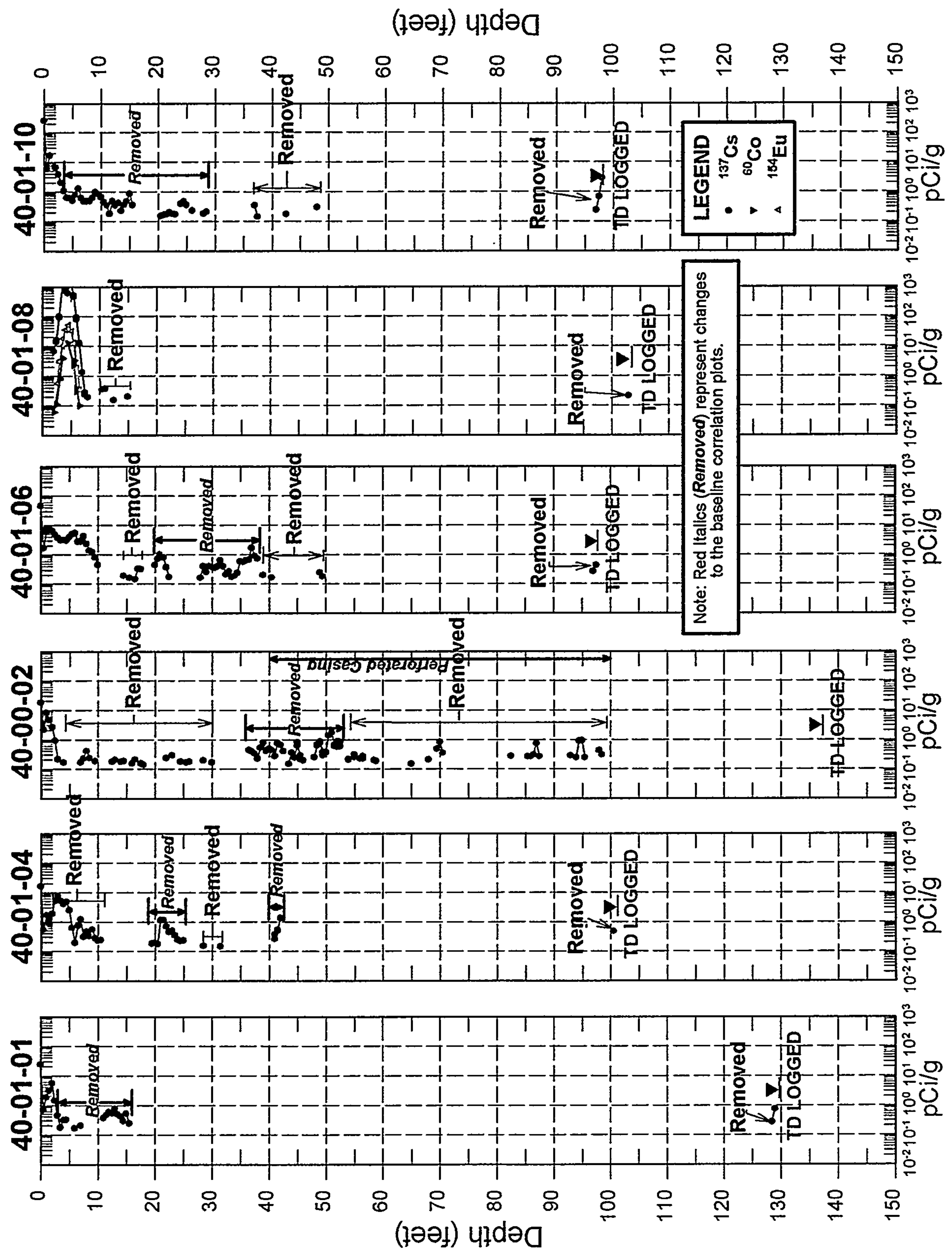

Figure D-1. Summary of Interpreted Data Set for the S Tank Farm

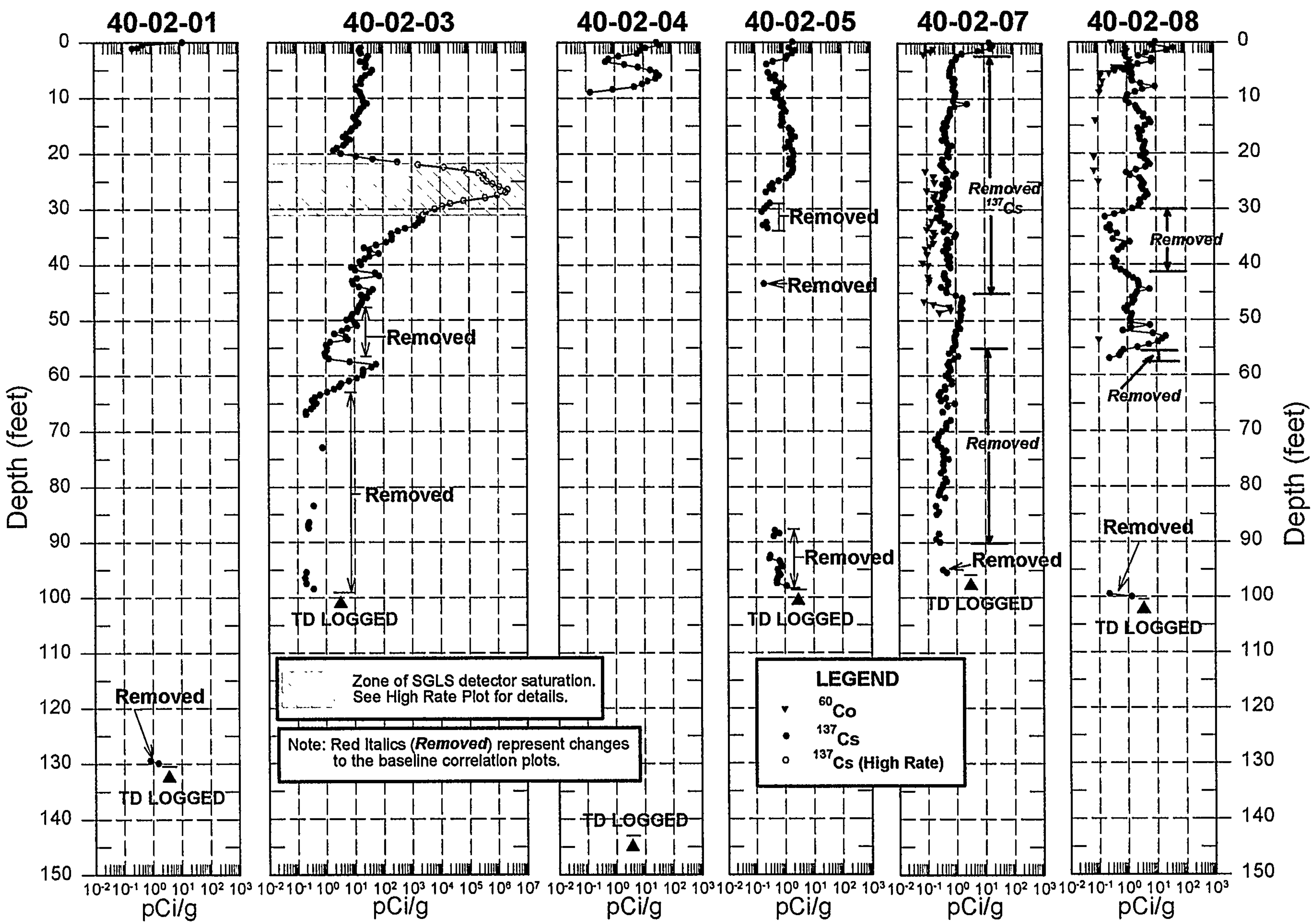

Figure D-2. Summary of Interpreted Data Set for the S Tank Farm

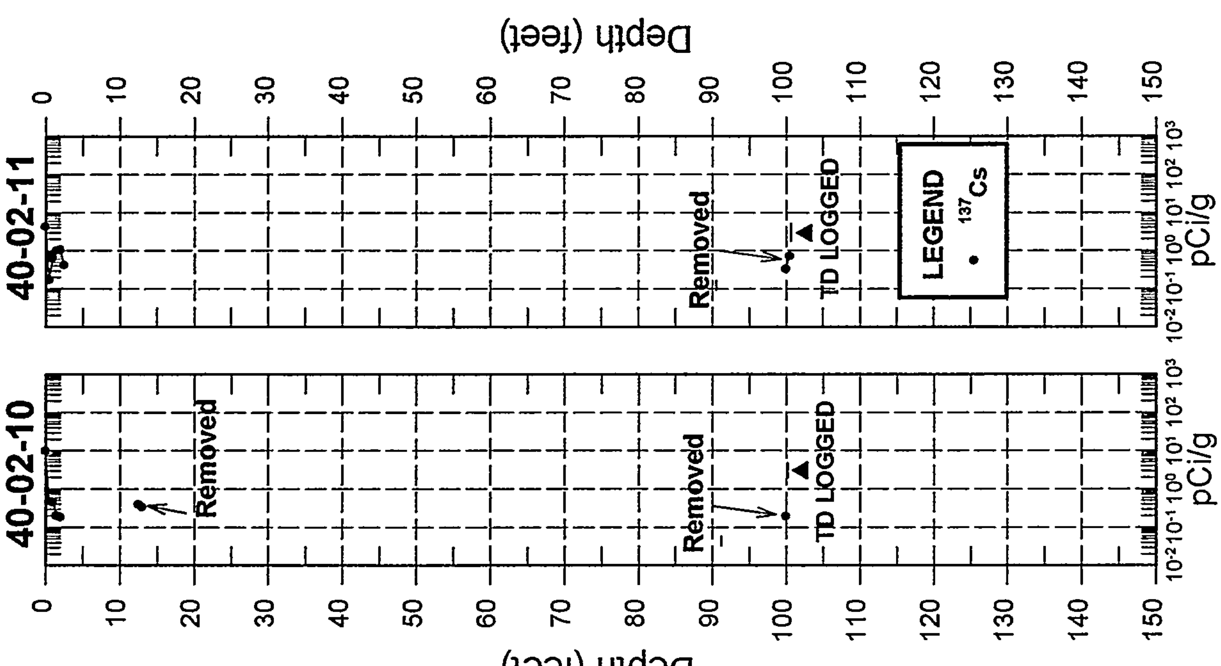

Figure D-3. Summary of Interpreted Data Set for the S Tank Farm

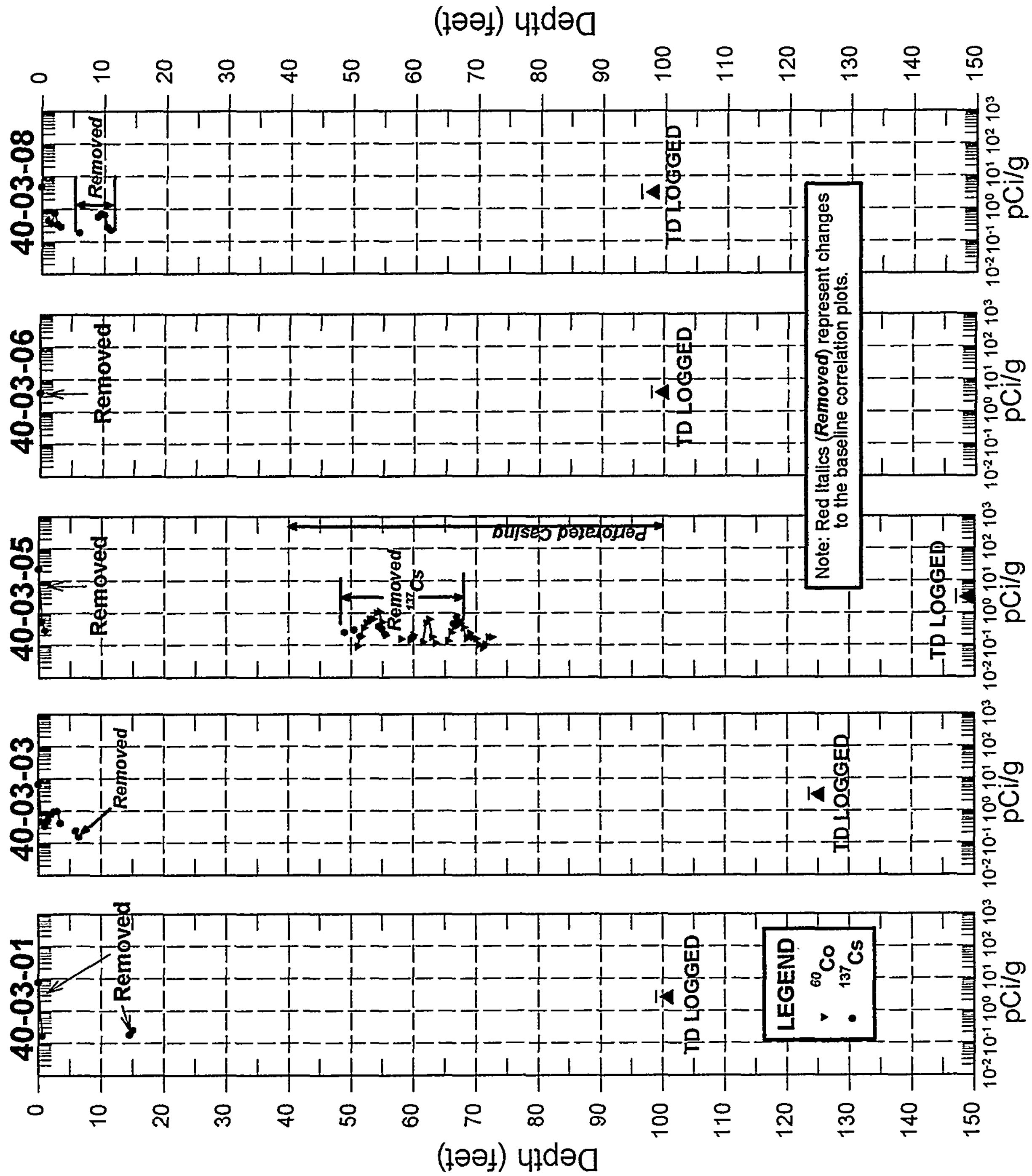

Figure D-4. Summary of Interpreted Data Set for the S Tank Farm

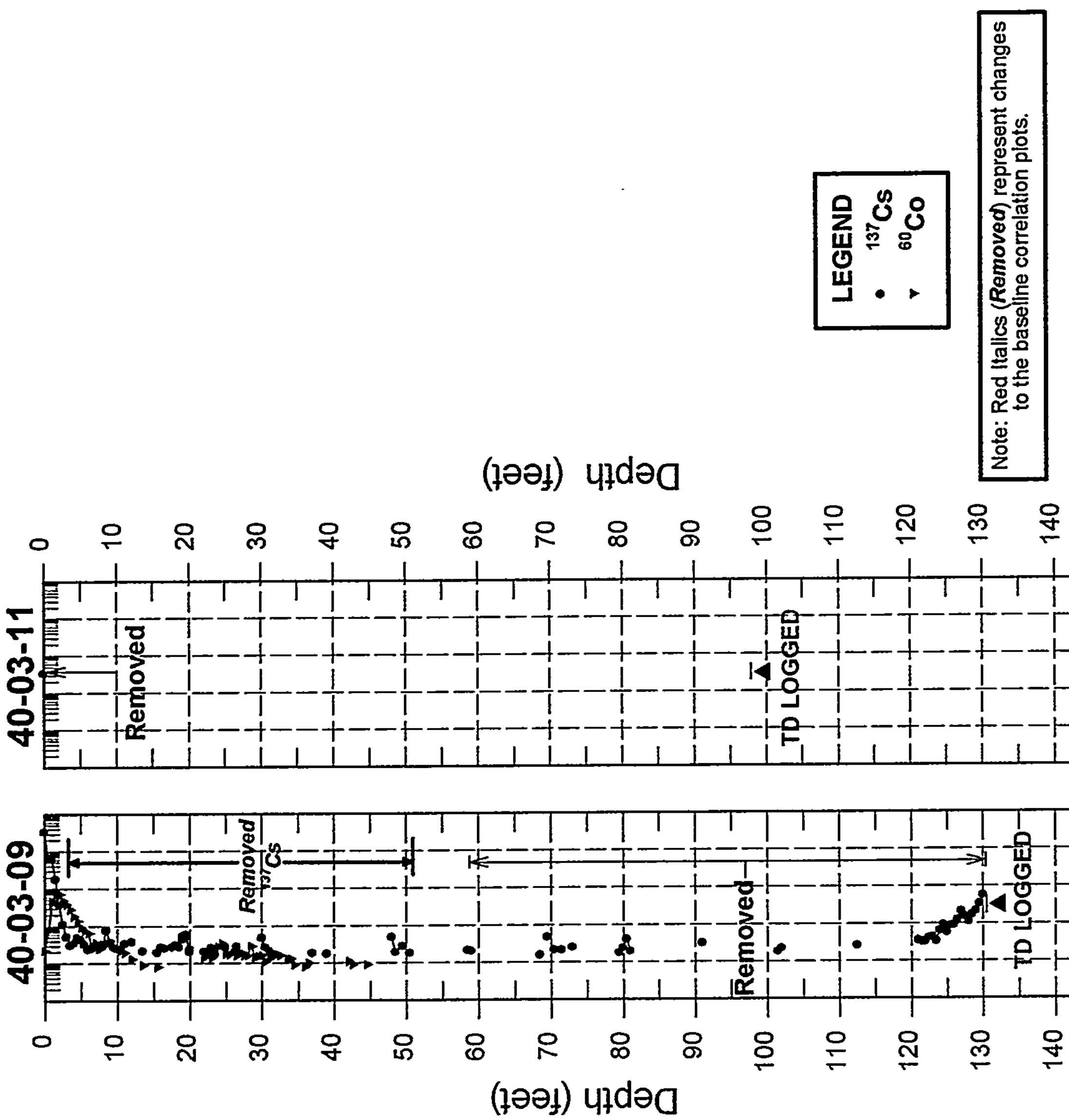

Figure D-5. Summary of Interpreted Data Set for the S Tank Farm

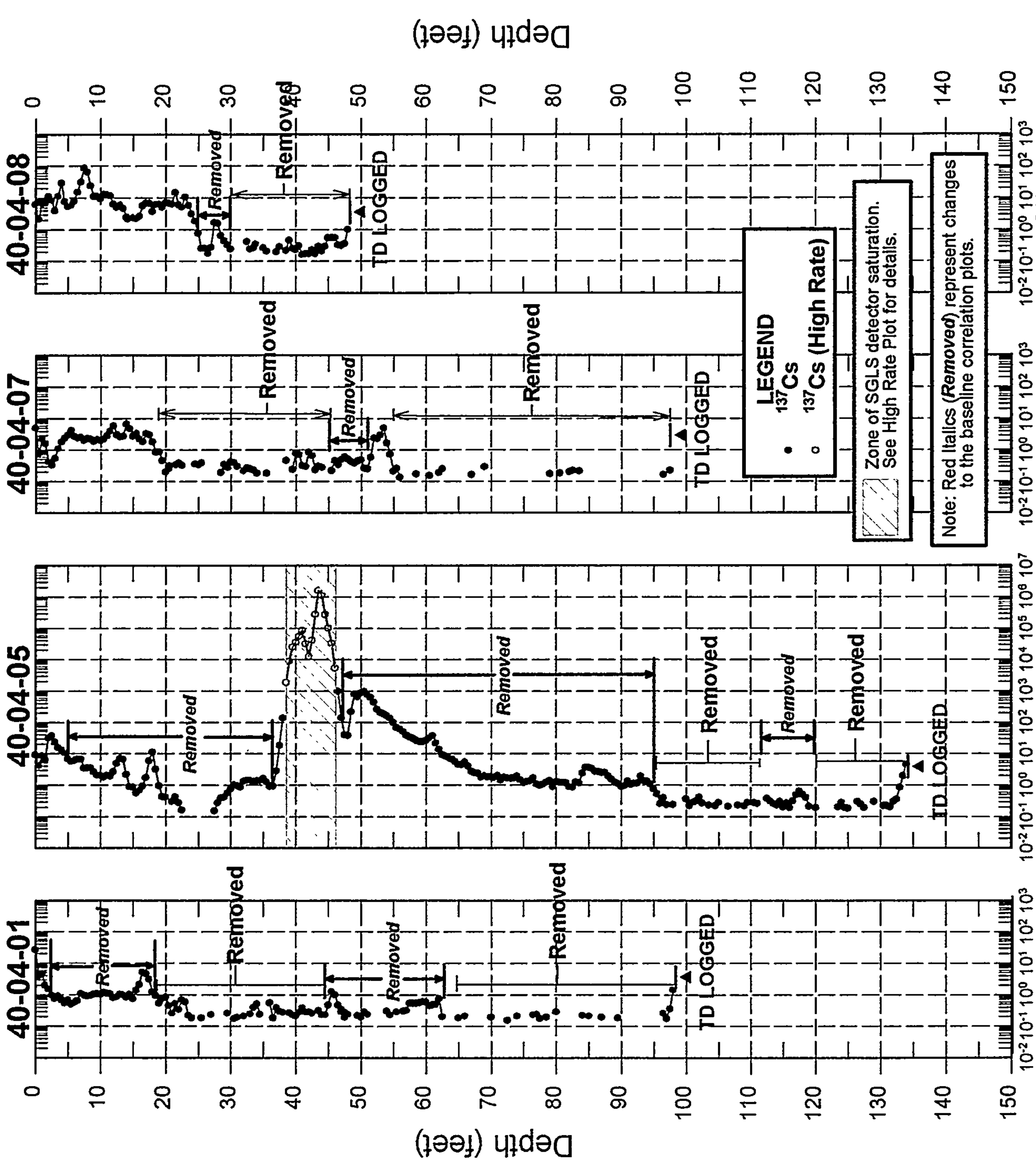

Figure D-6. Summary of Interpreted Data Set for the S Tank Farm

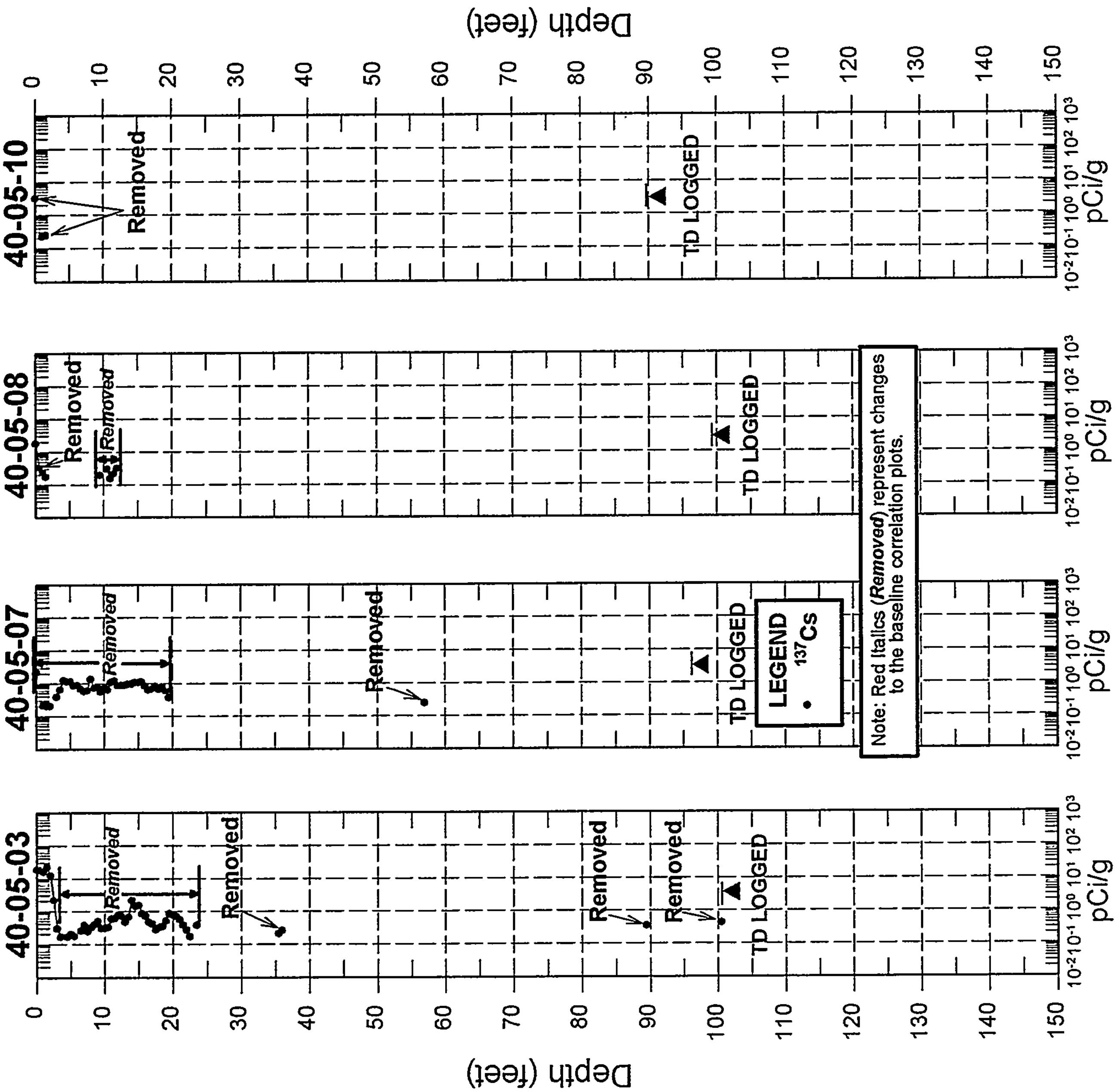

Figure D-7. Summary of Interpreted Data Set for the S Tank Farm

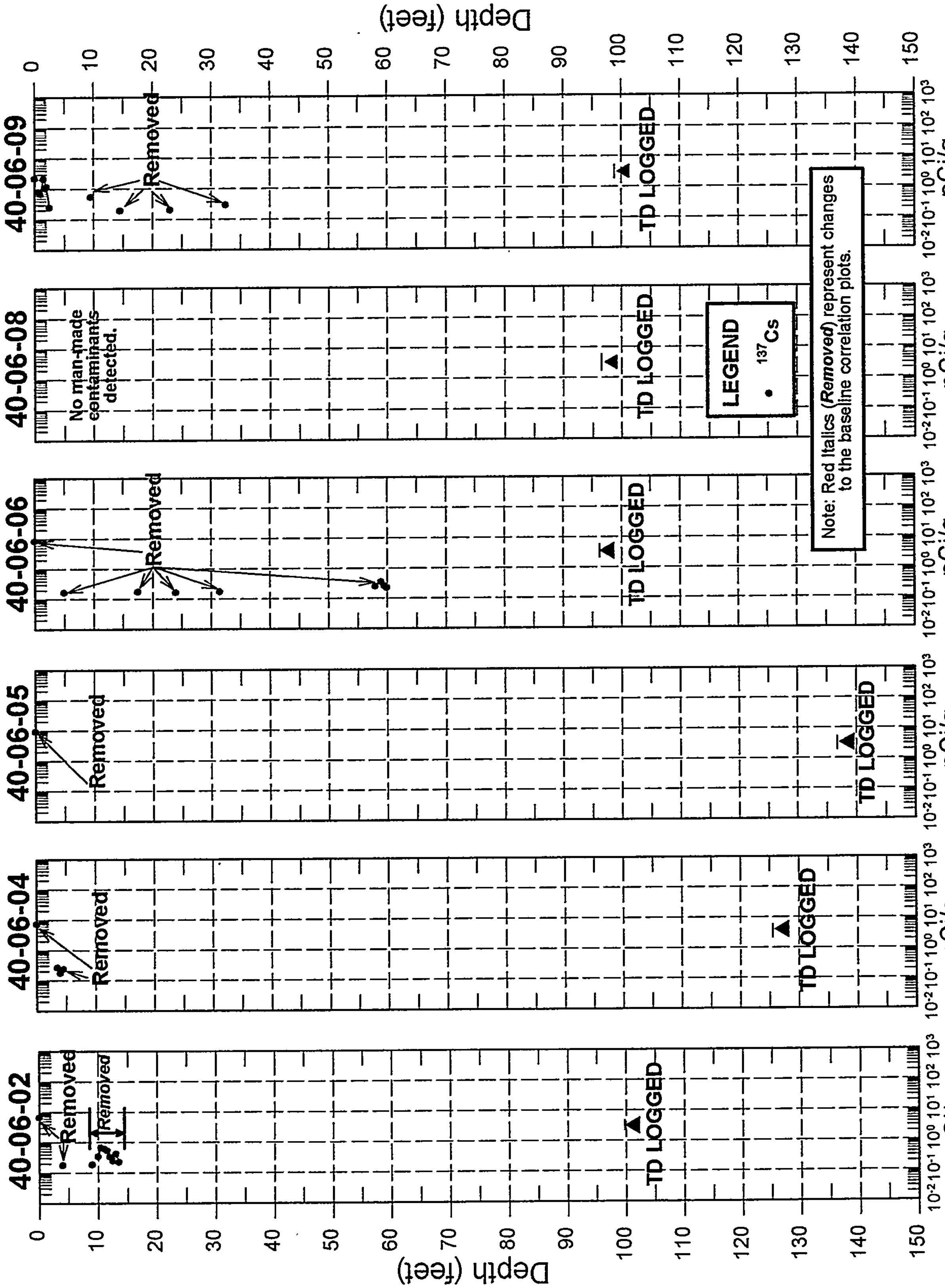

Figure D-8. Summary of Interpreted Data Set for the S Tank Farm

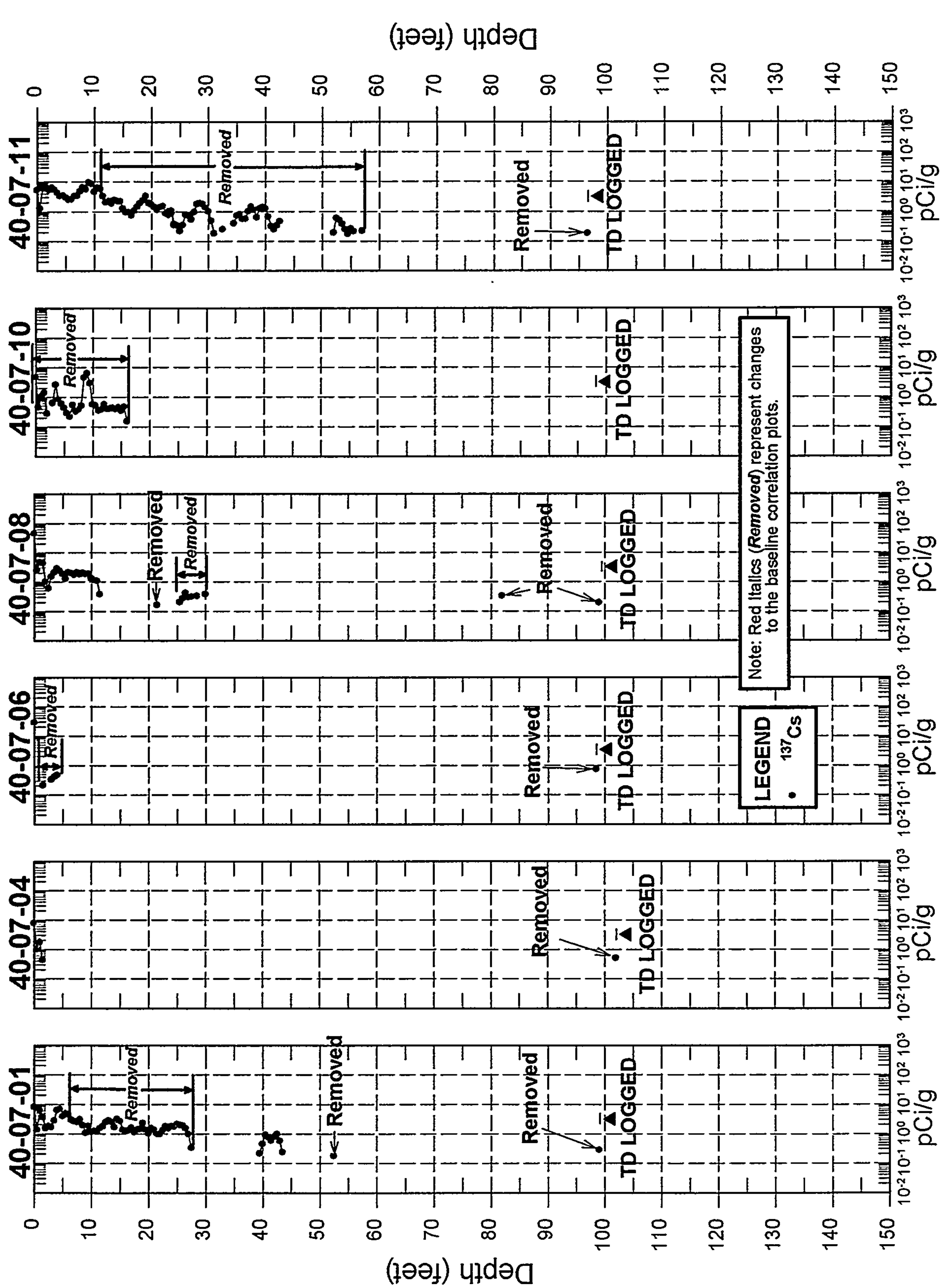

Figure D-9. Summary of Interpreted Data Set for the S Tank Farm

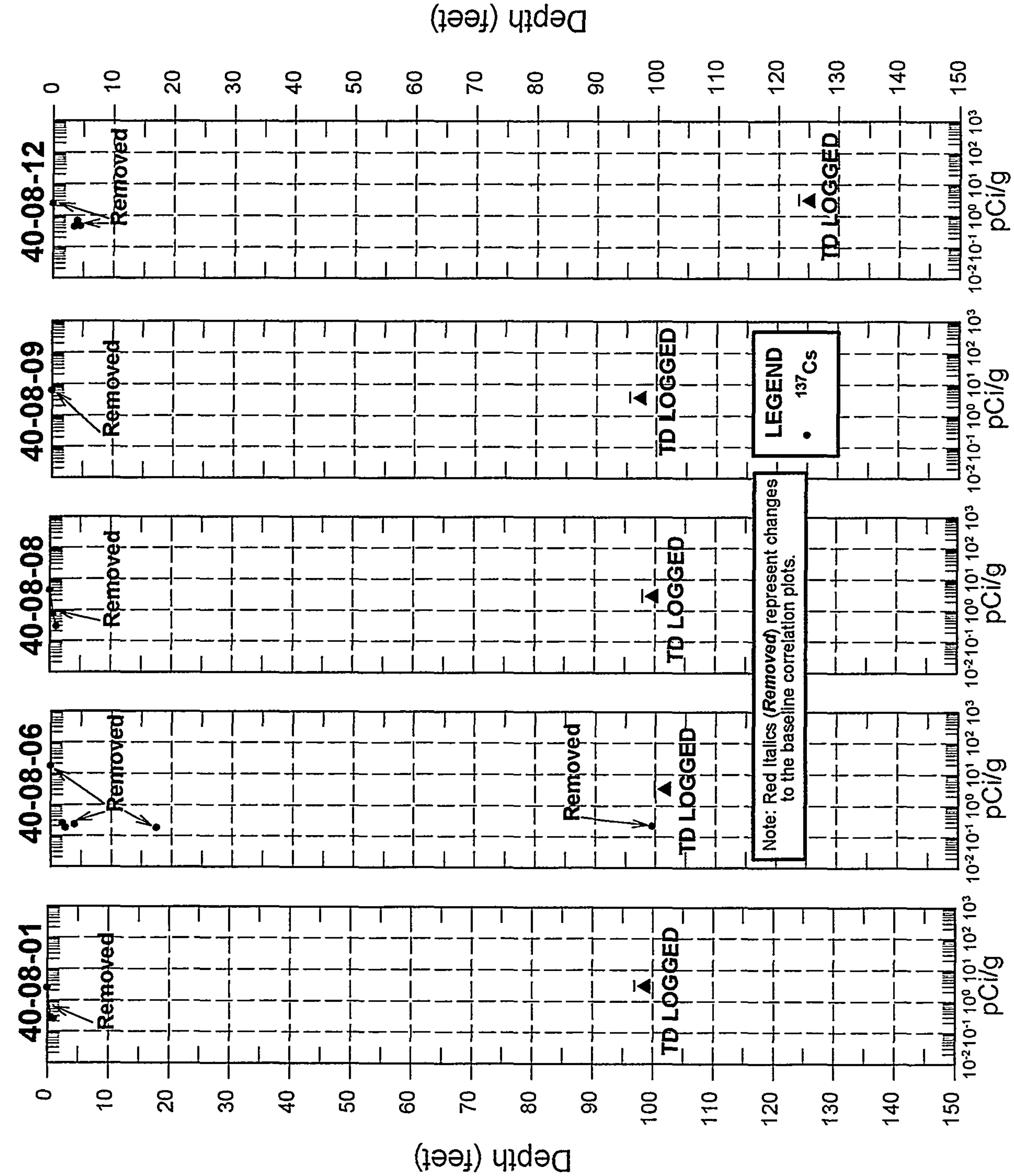

Figure D-10. Summary of Interpreted Data Set for the S Tank Farm

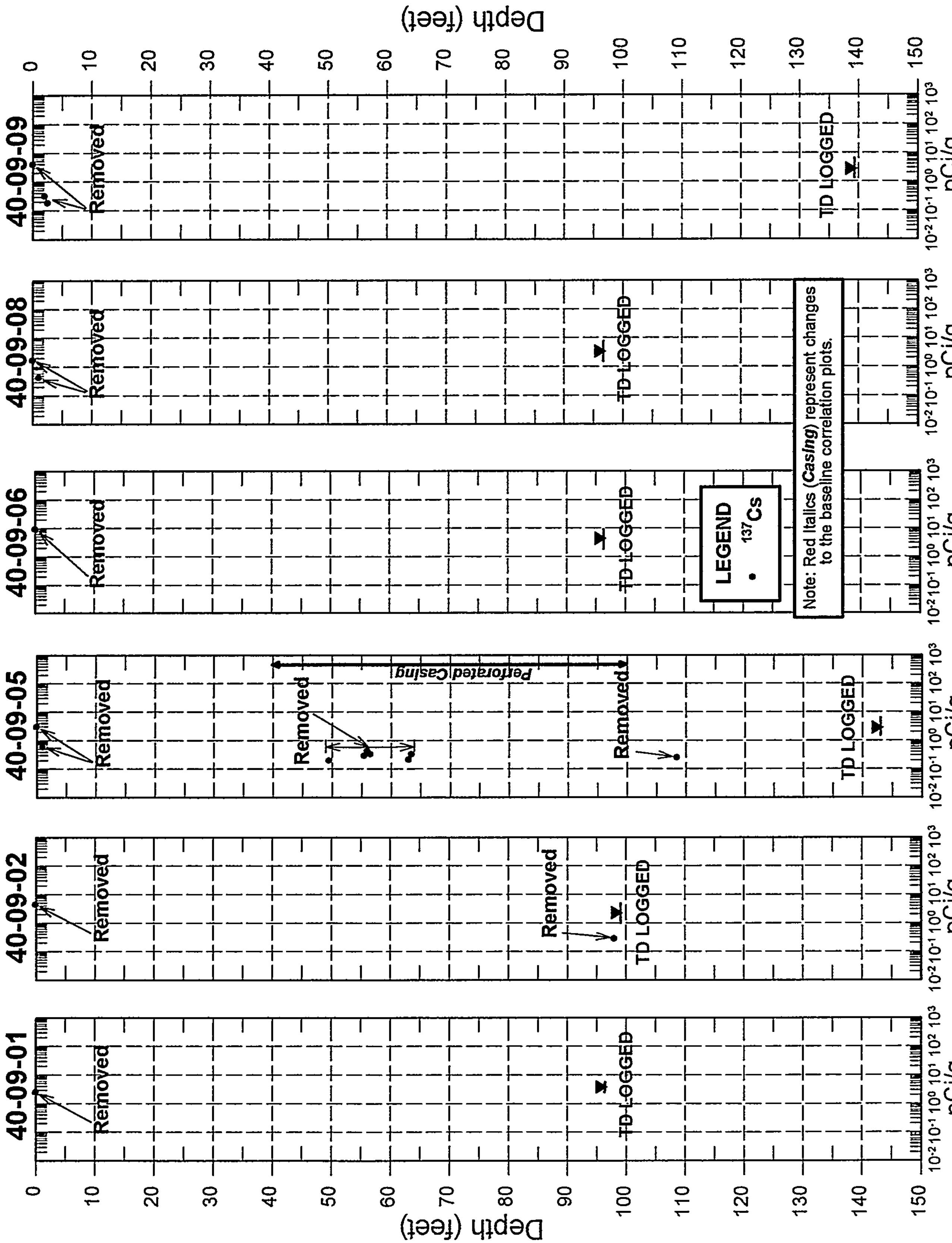

Figure D-11. Summary of Interpreted Data Set for the S Tank Farm

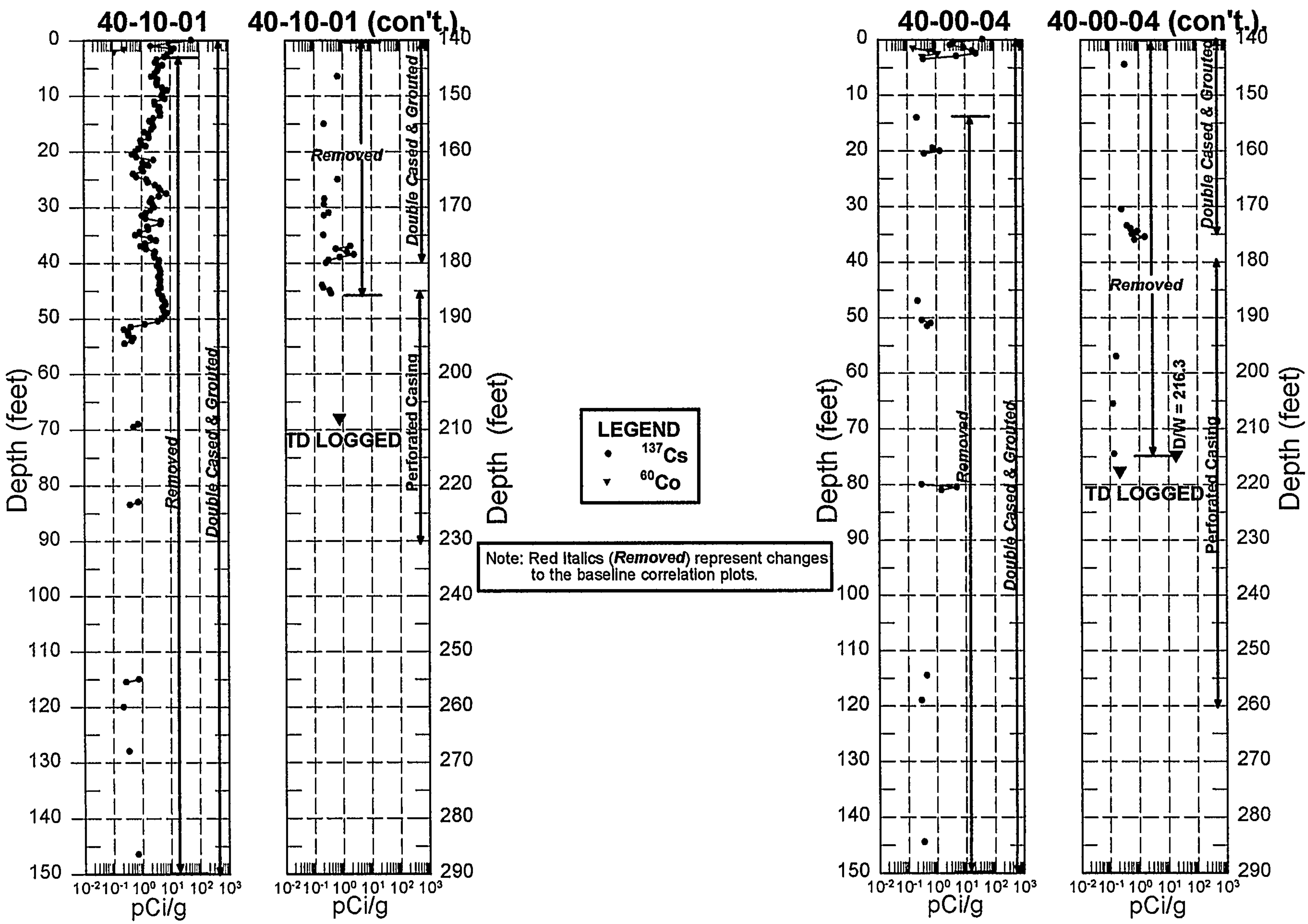

Figure D-12. Summary of Interpreted Data Set for the S Tank Farm

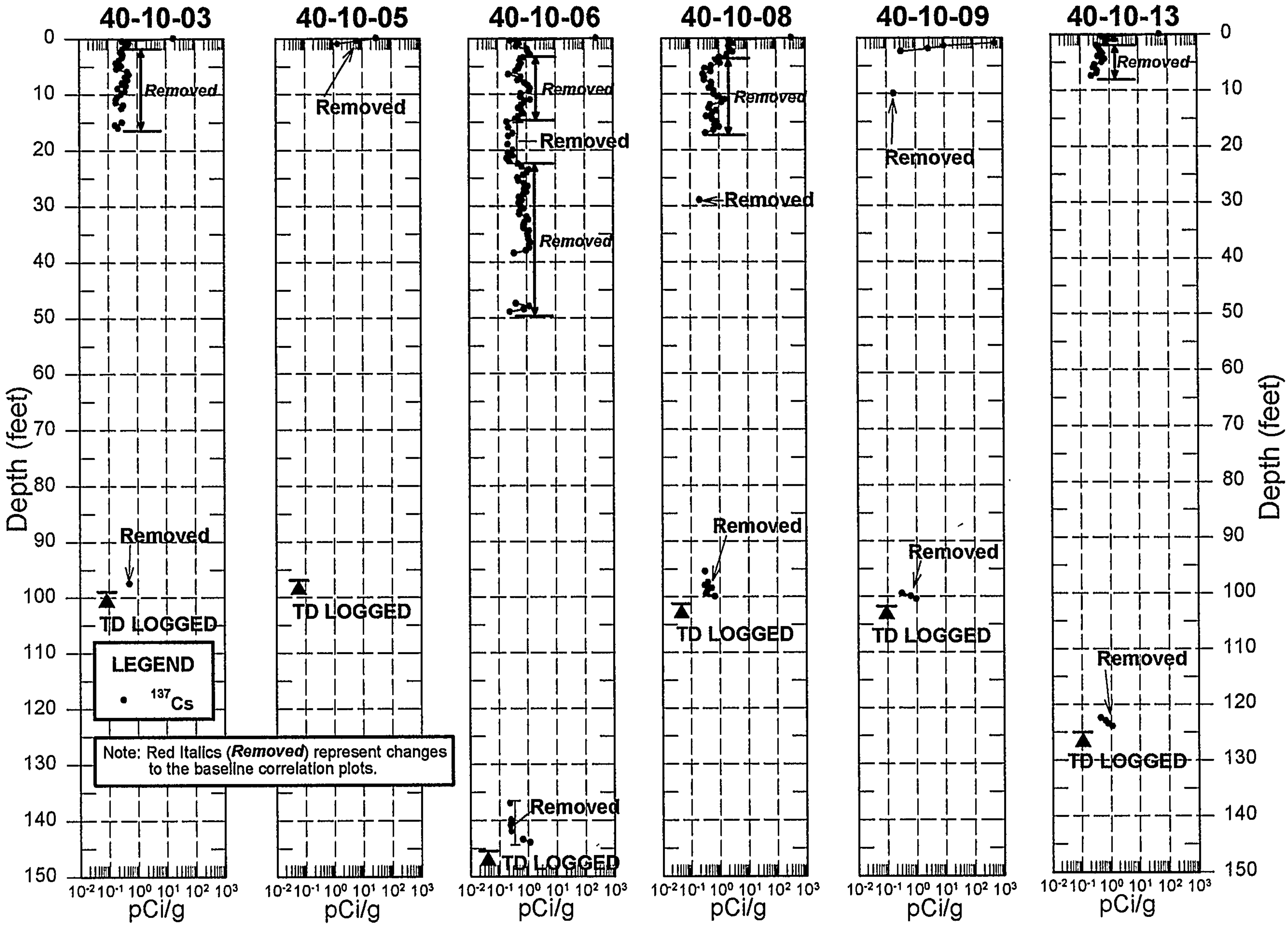

Figure D-13. Summary of Interpreted Data Set for the S Tank Farm

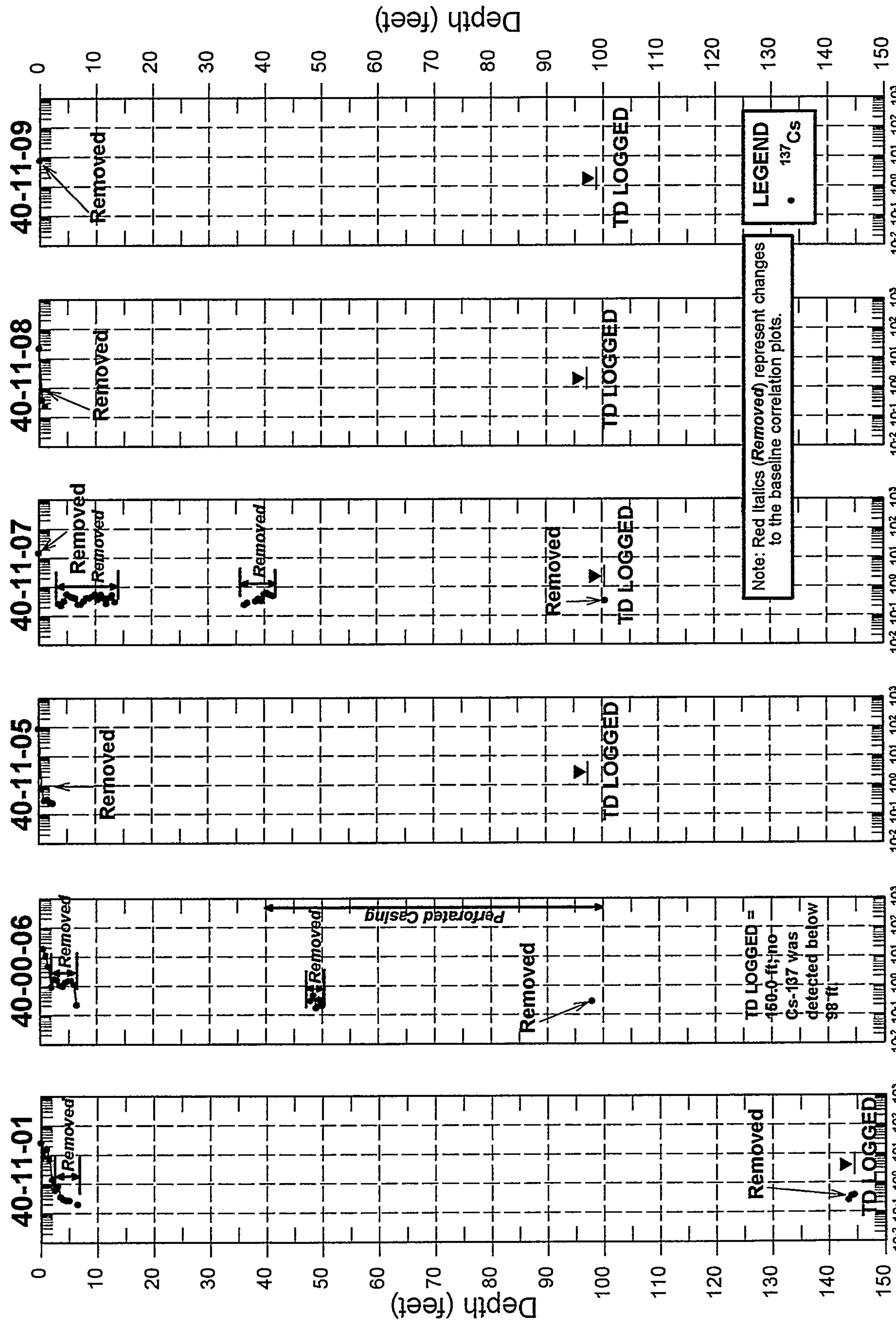

Figure D-14. Summary of Interpreted Data Set for the S Tank Farm

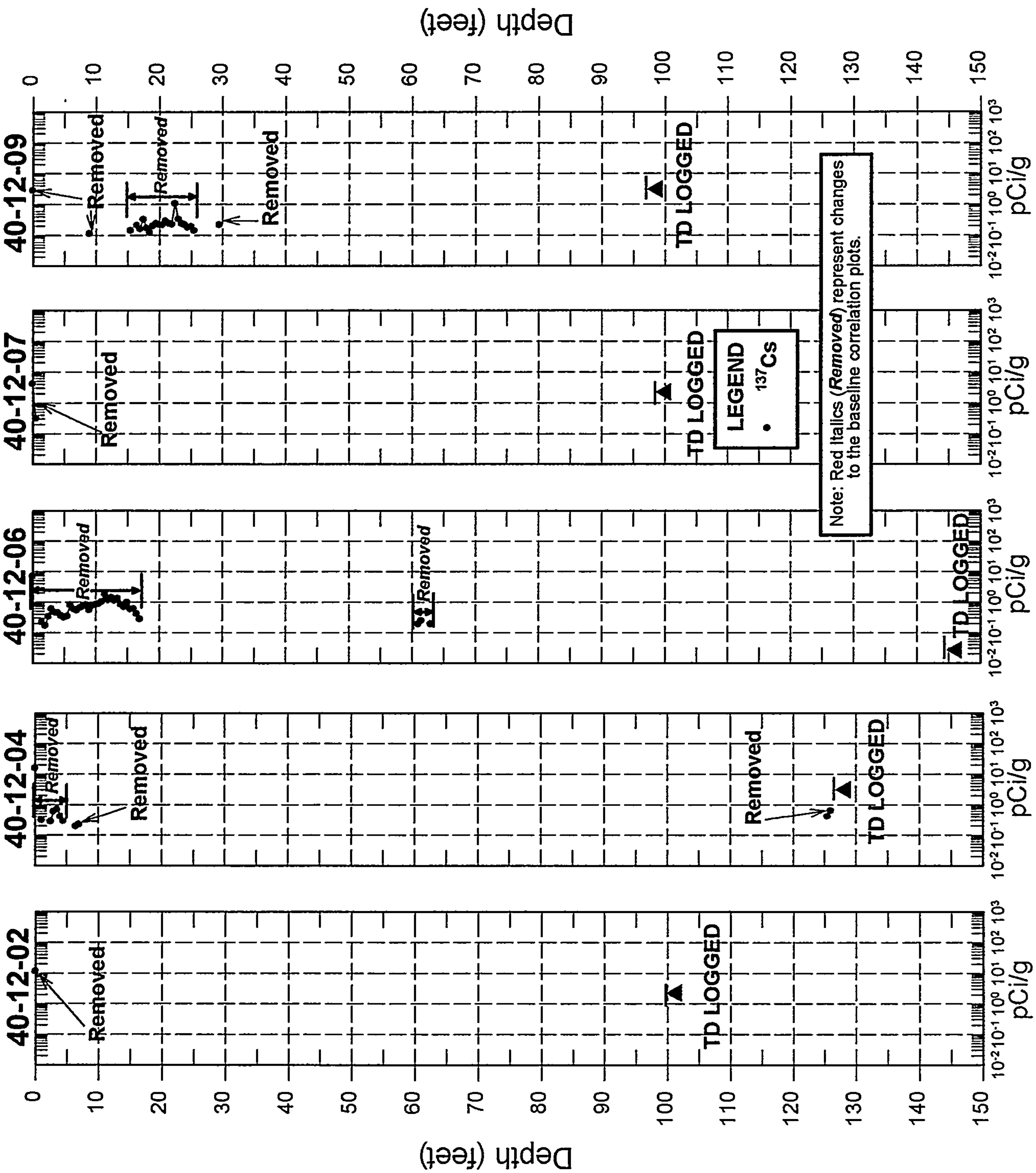

Figure D-15. Summary of Interpreted Data Set for the S Tank Farm

Appendix E
S Tank Farm Visualizations

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

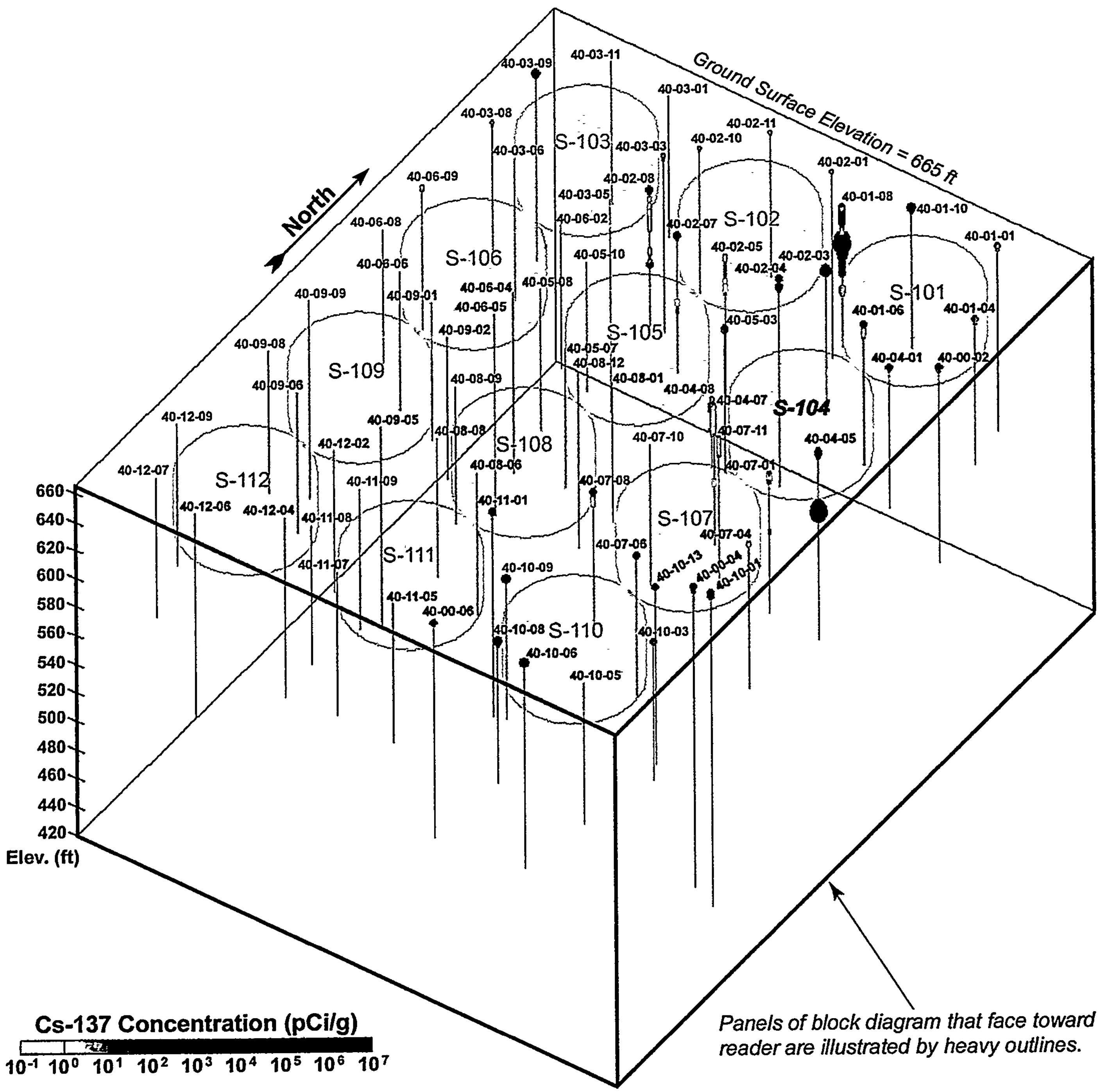

Figure E-1. S Tank Farm Visualization

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

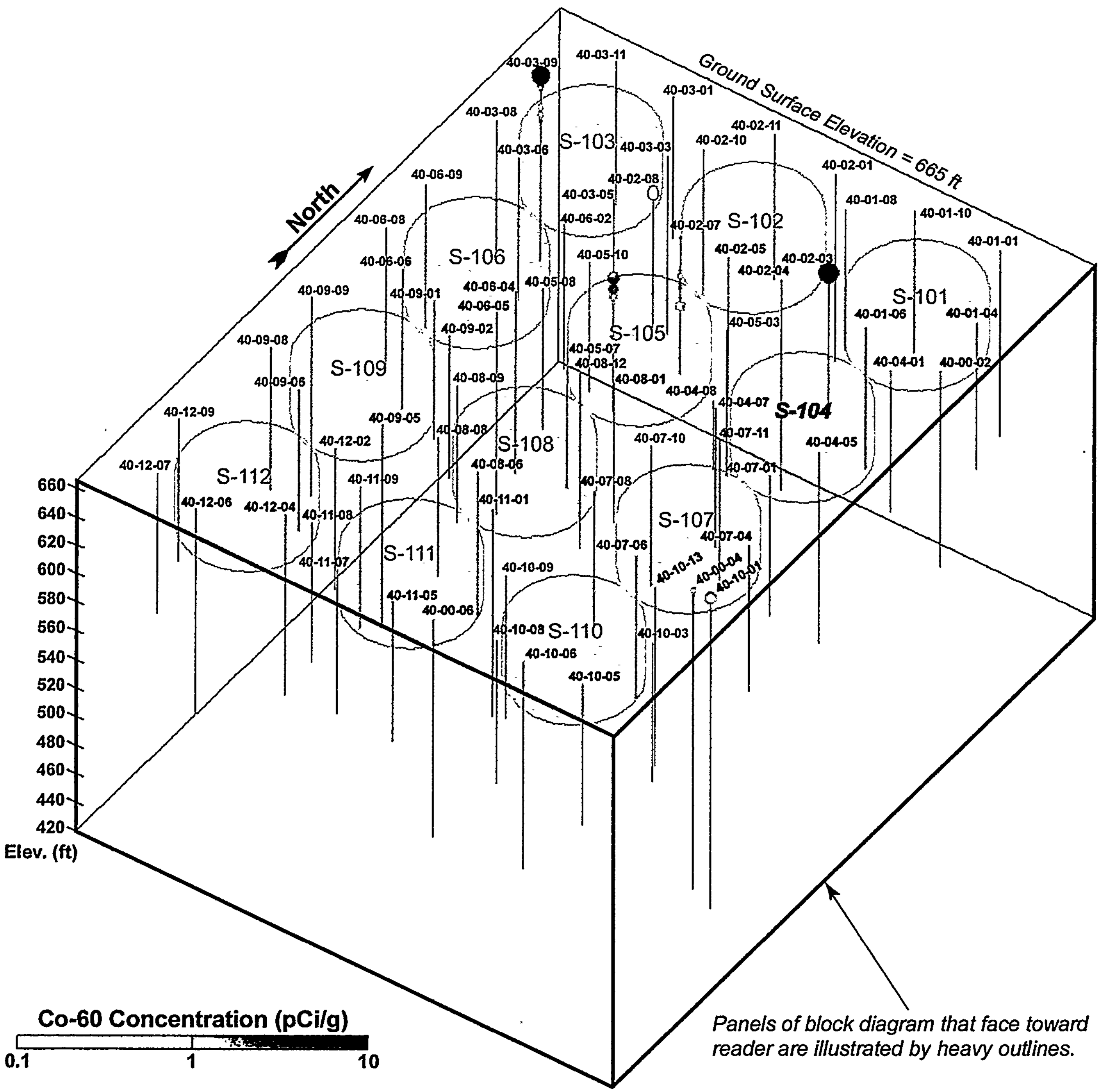

Figure E-2. S Tank Farm Visualization

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

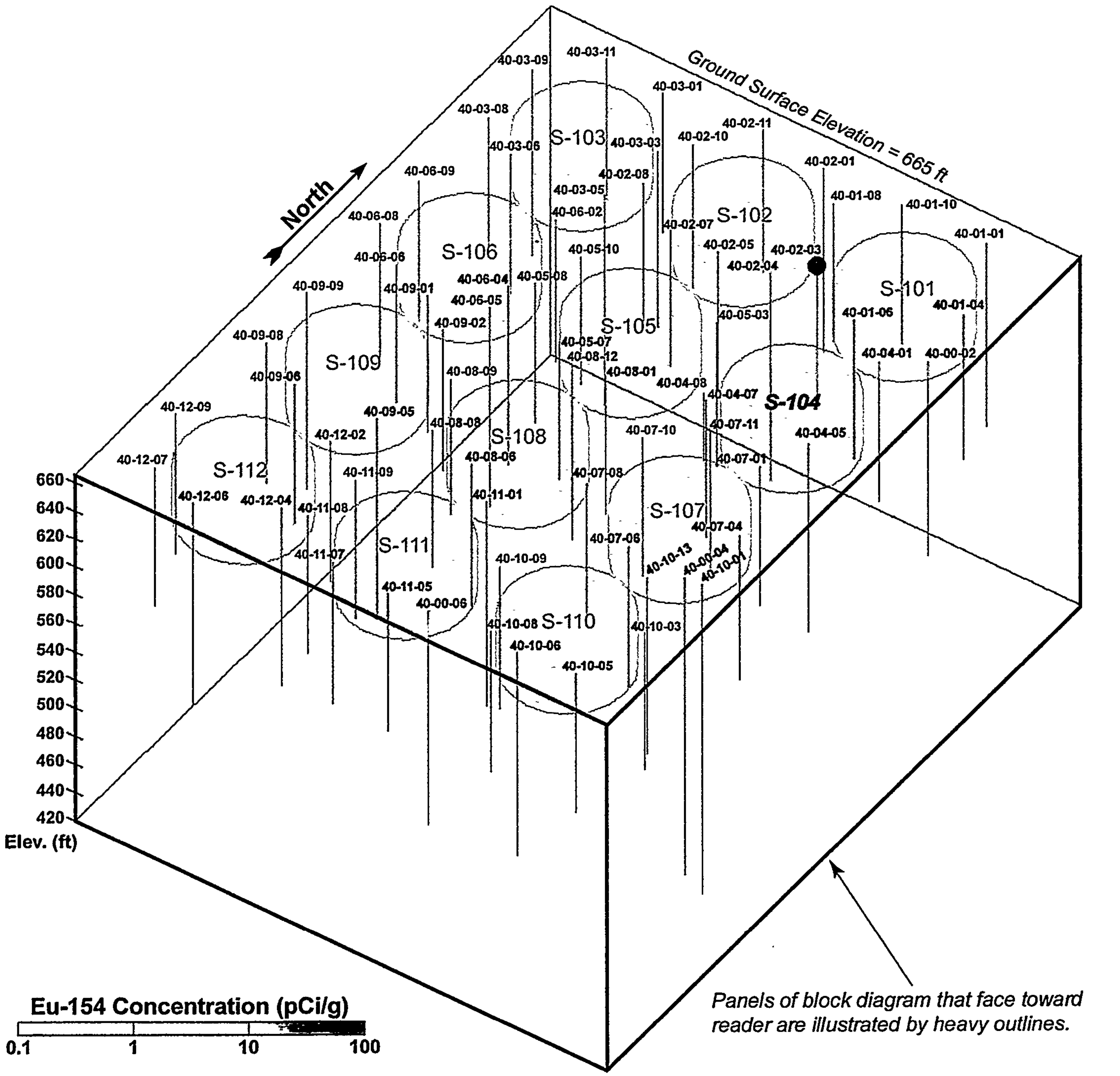

Figure E-3. S Tank Farm Visualization

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

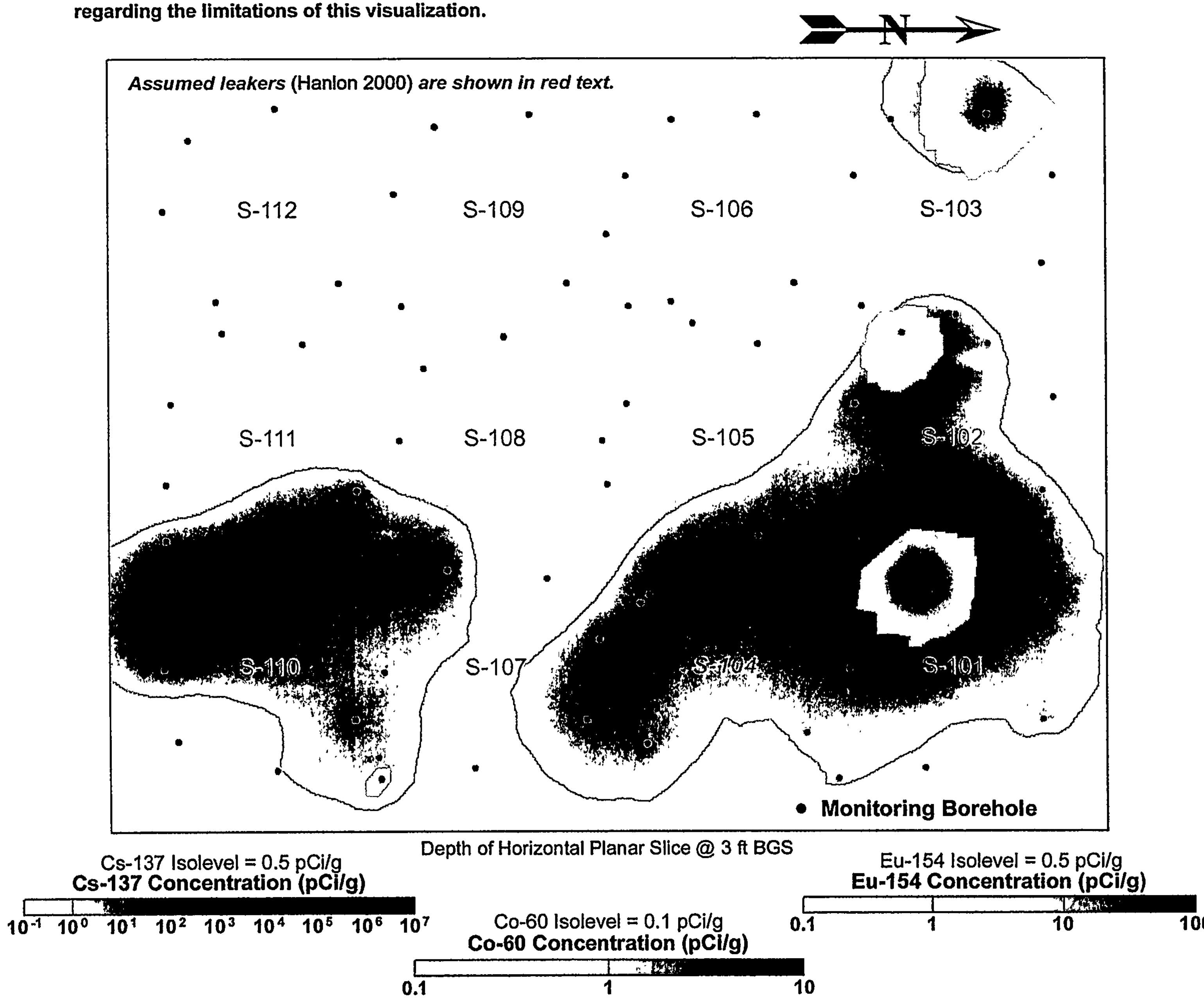

Figure E-4. S Tank Farm Visualization

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

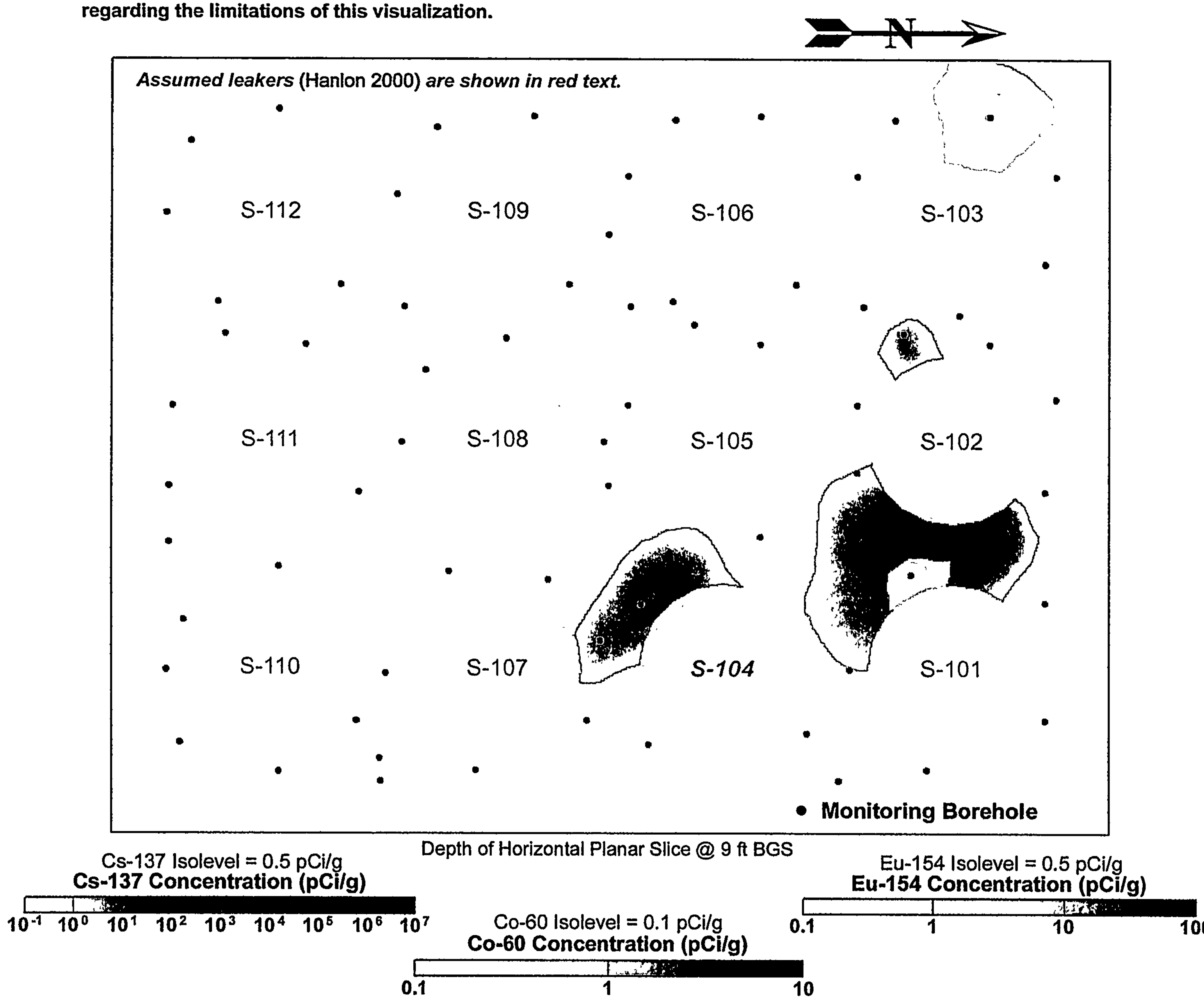

Figure E-5. S Tank Farm Visualization

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

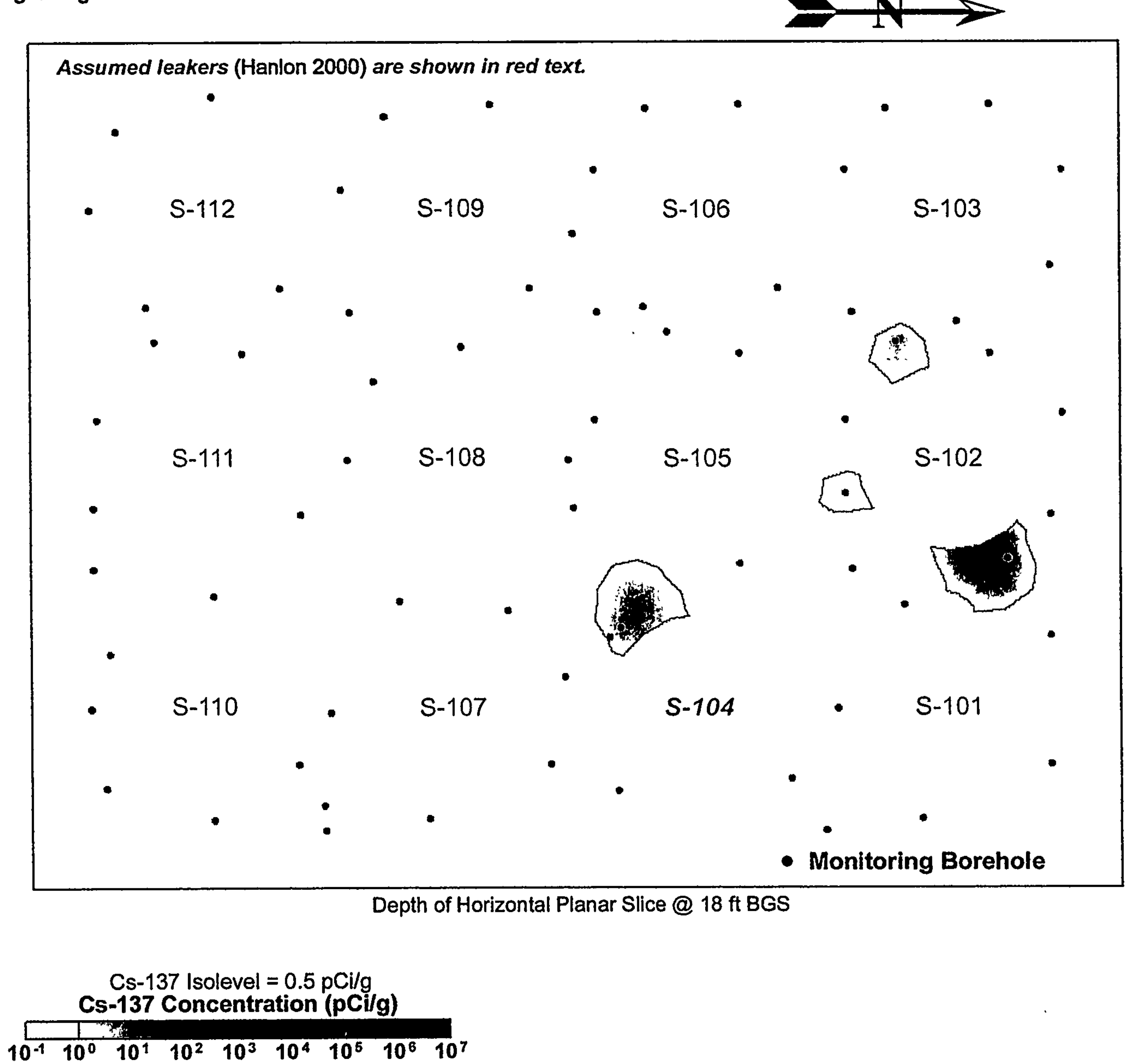

Figure E-6. S Tank Farm Visualization

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

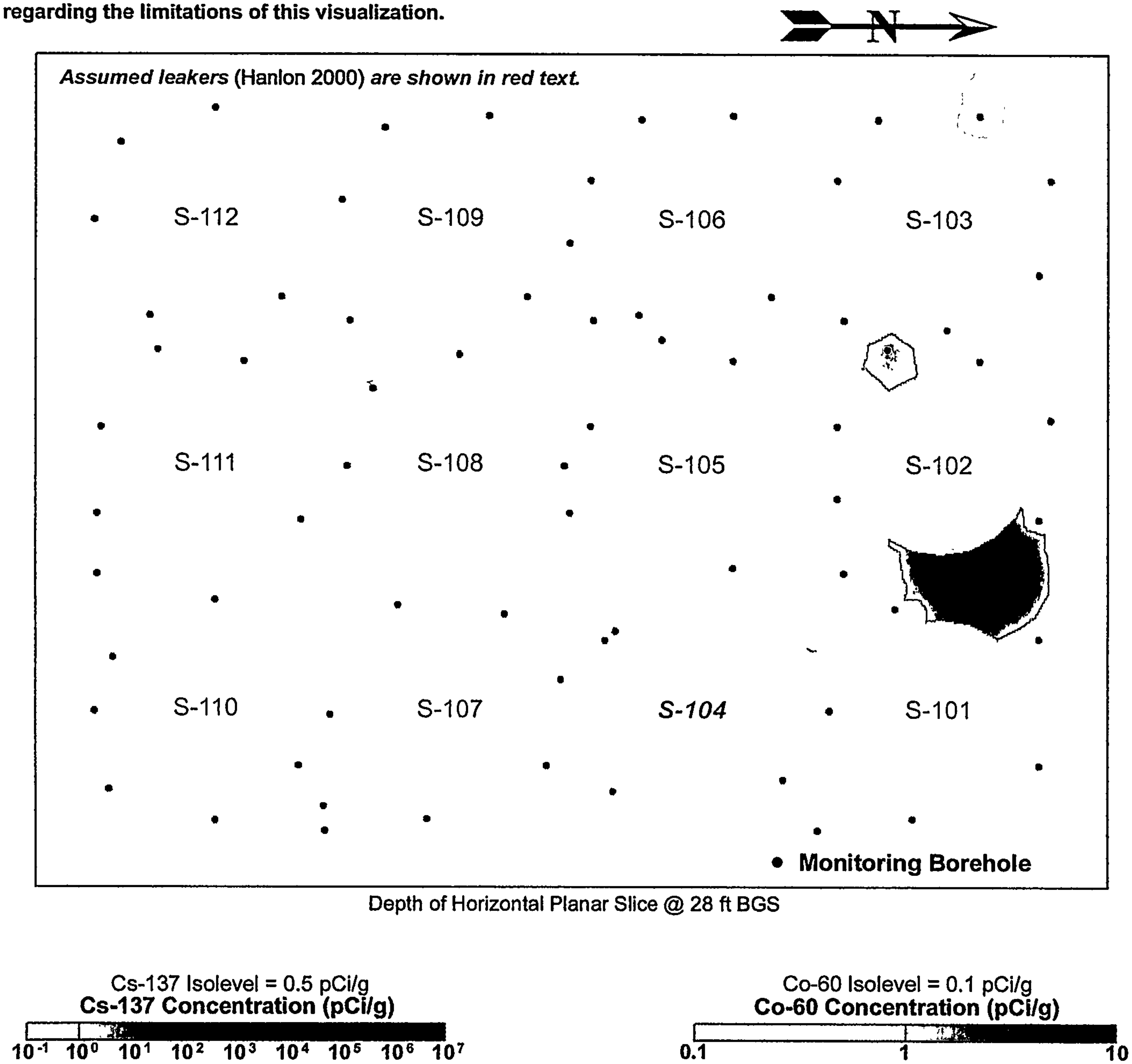

Figure E-7. S Tank Farm Visualization

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

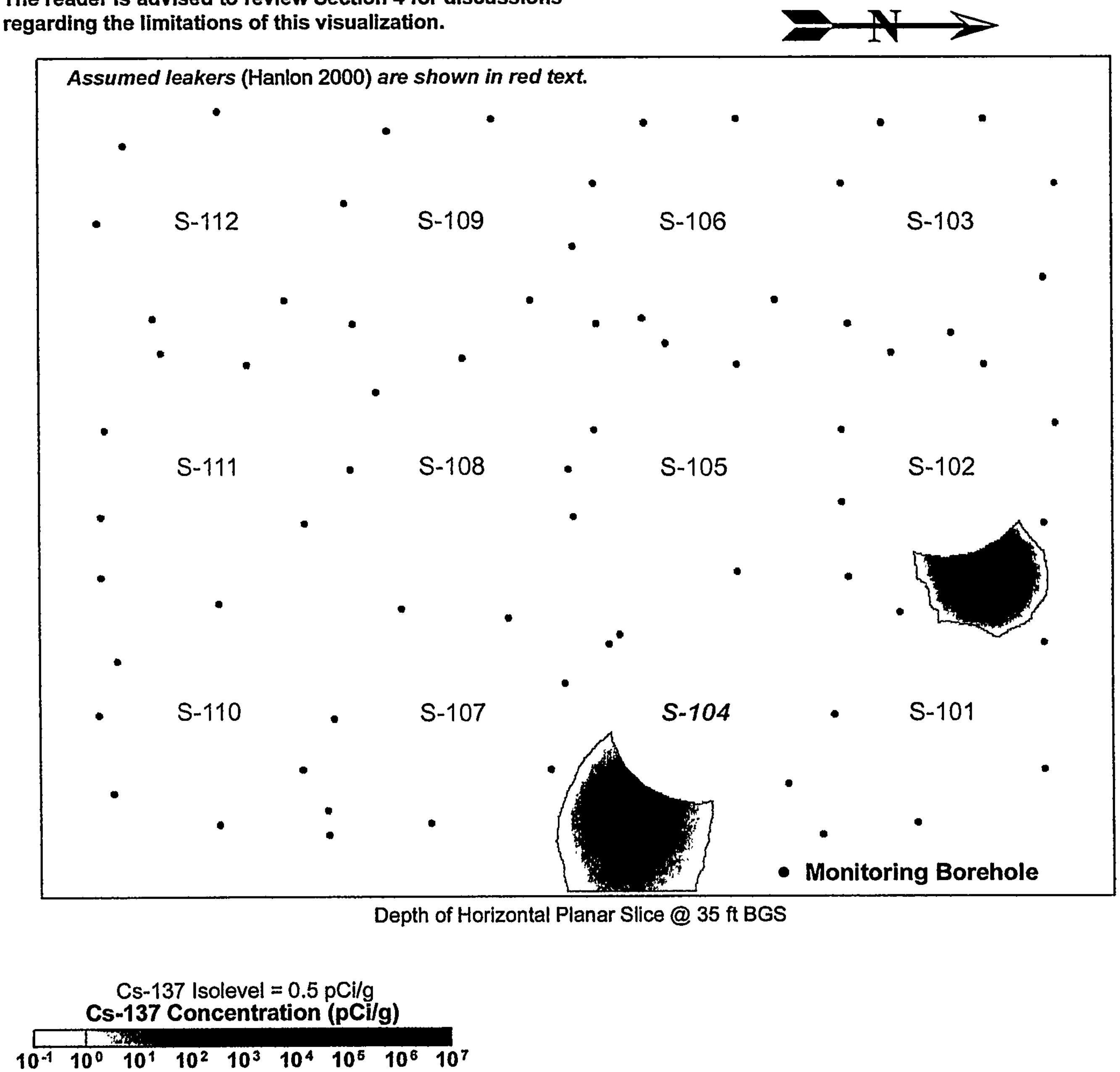

Figure E-8. S Tank Farm Visualization

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

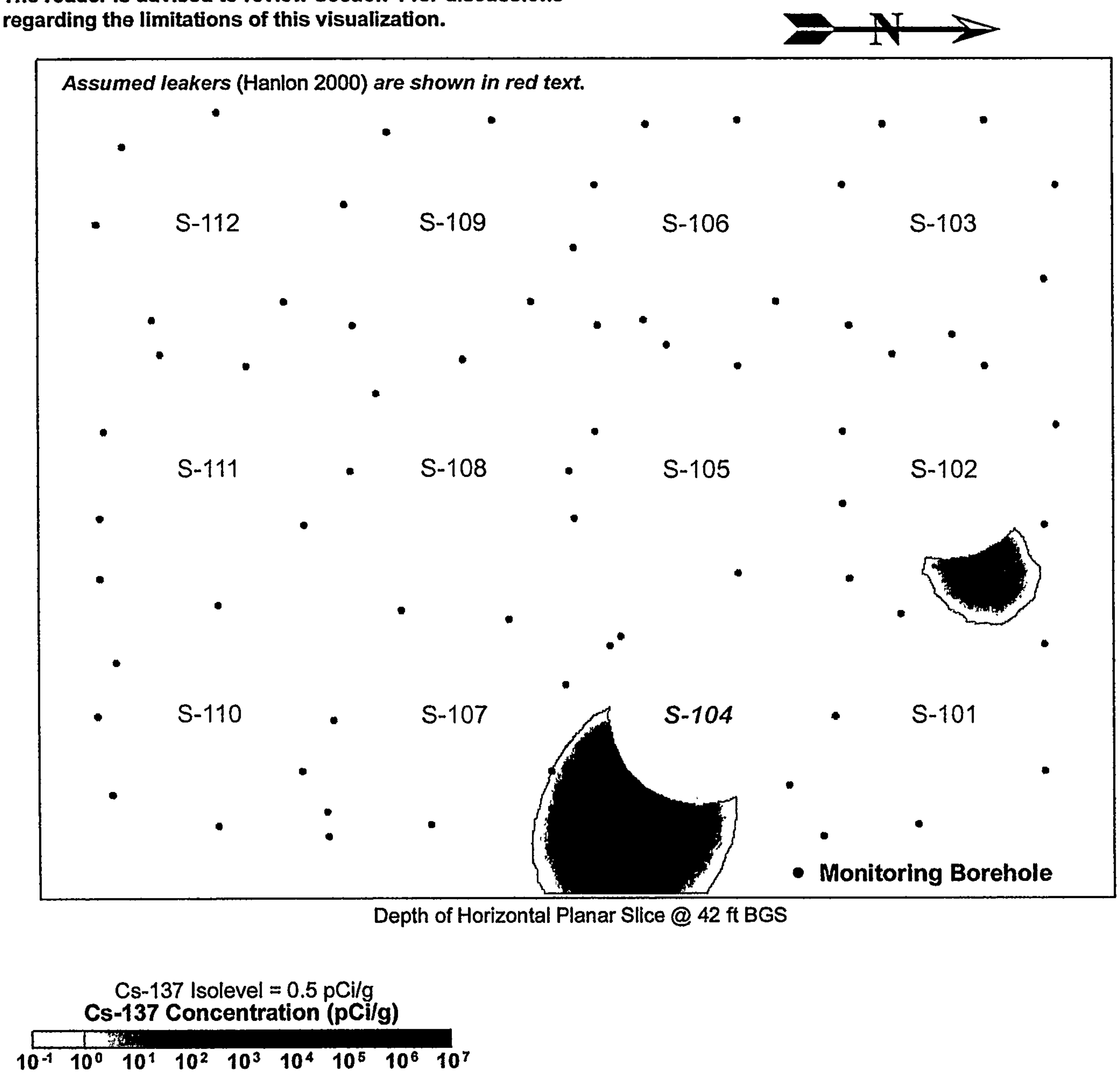

Figure E-9. S Tank Farm Visualization

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

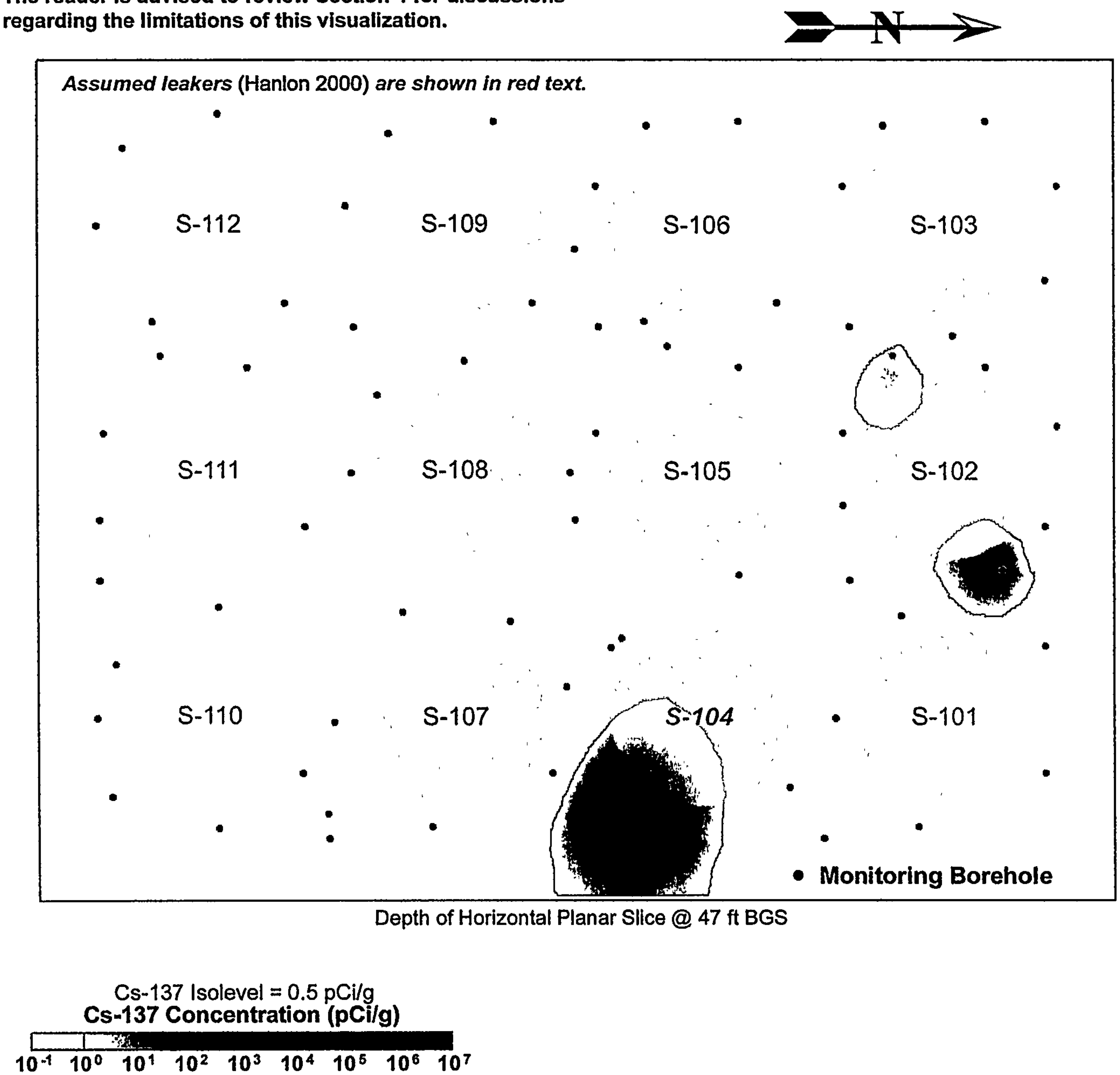

Figure E-10. S Tank Farm Visualization

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

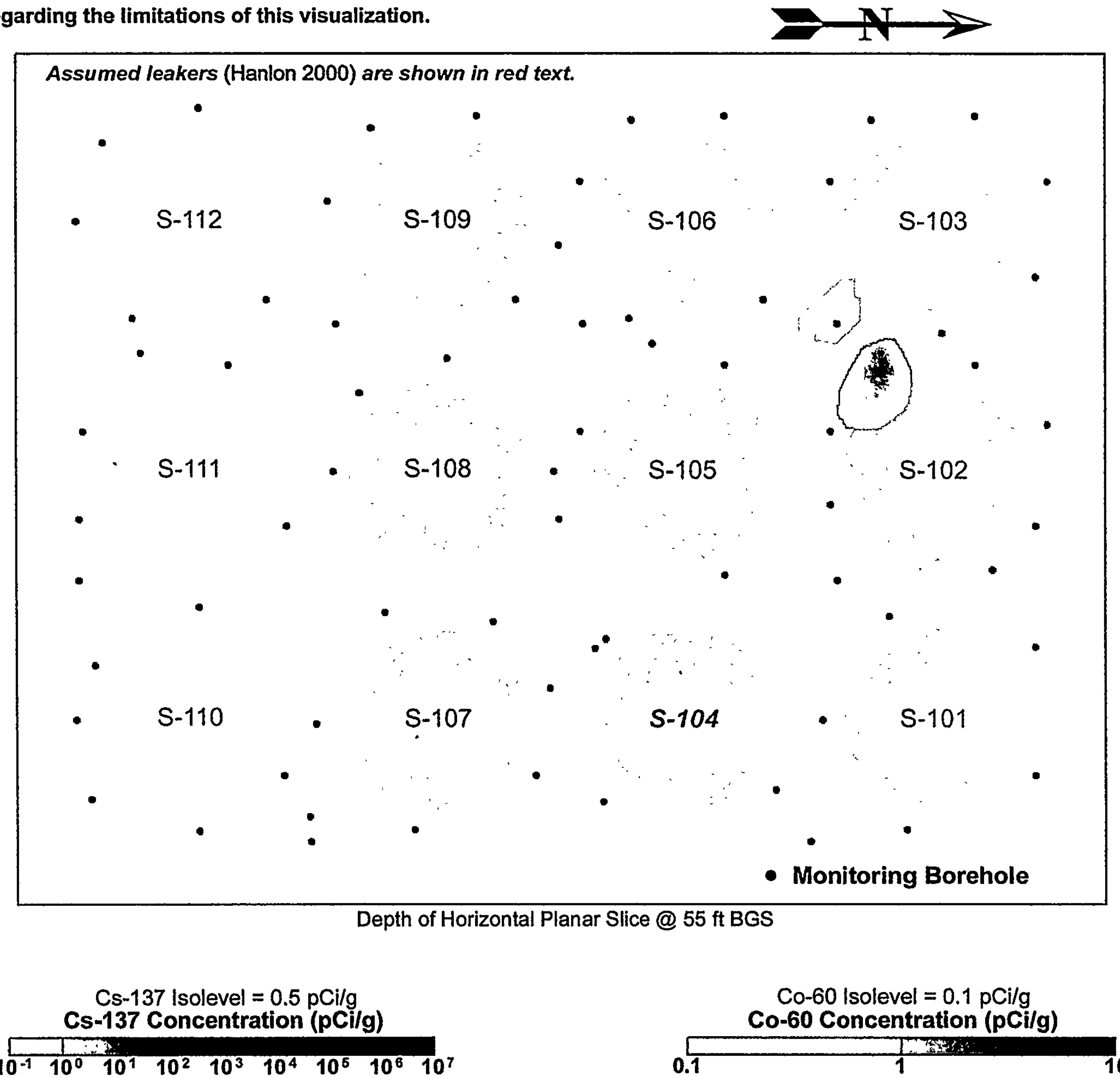

Figure E-11. S Tank Farm Visualization

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

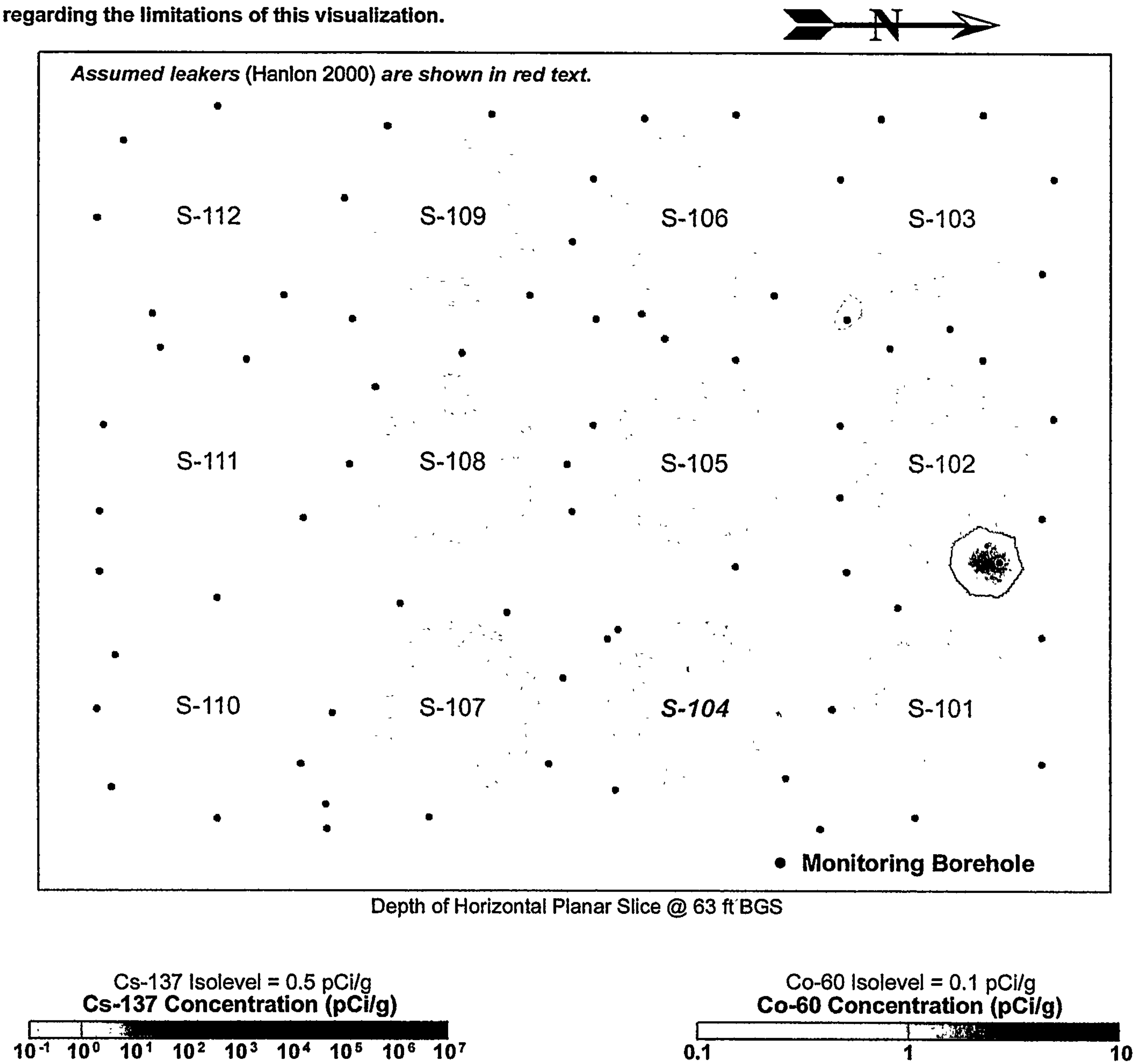

Figure E-12. S Tank Farm Visualizations

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

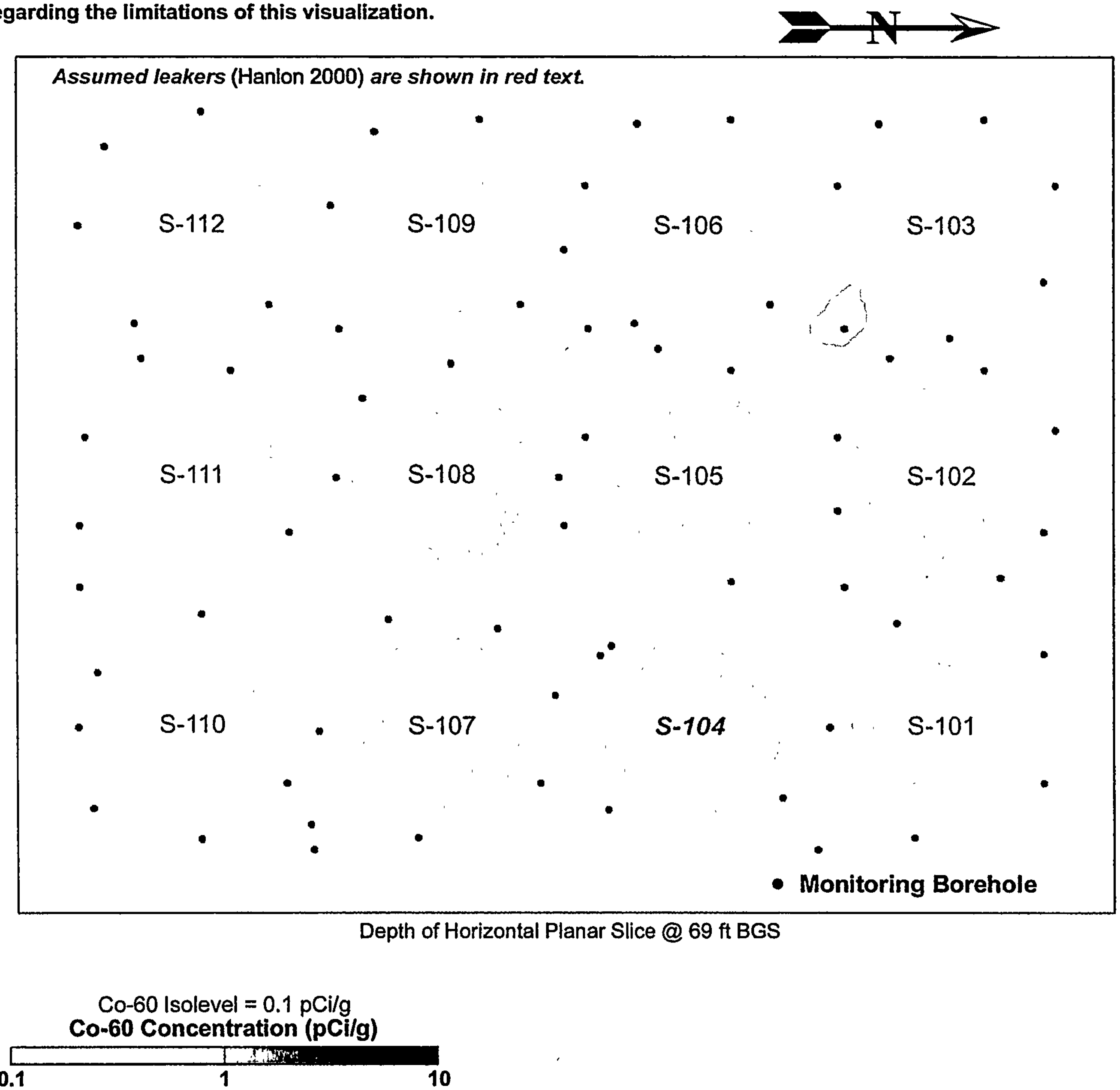

Figure E-13. S Tank Farm Visualization

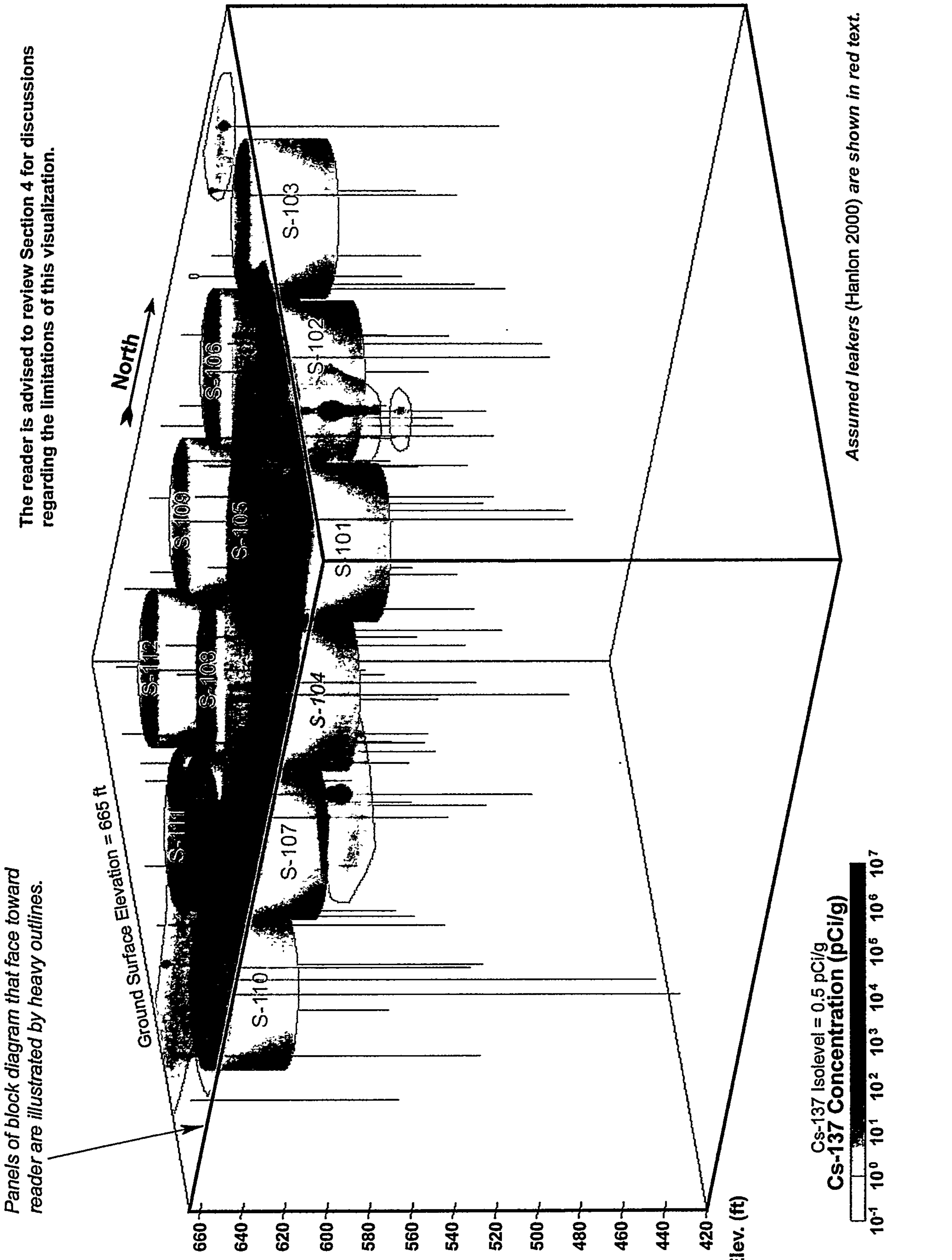

Figure E-14. S Tank Farm Visualization

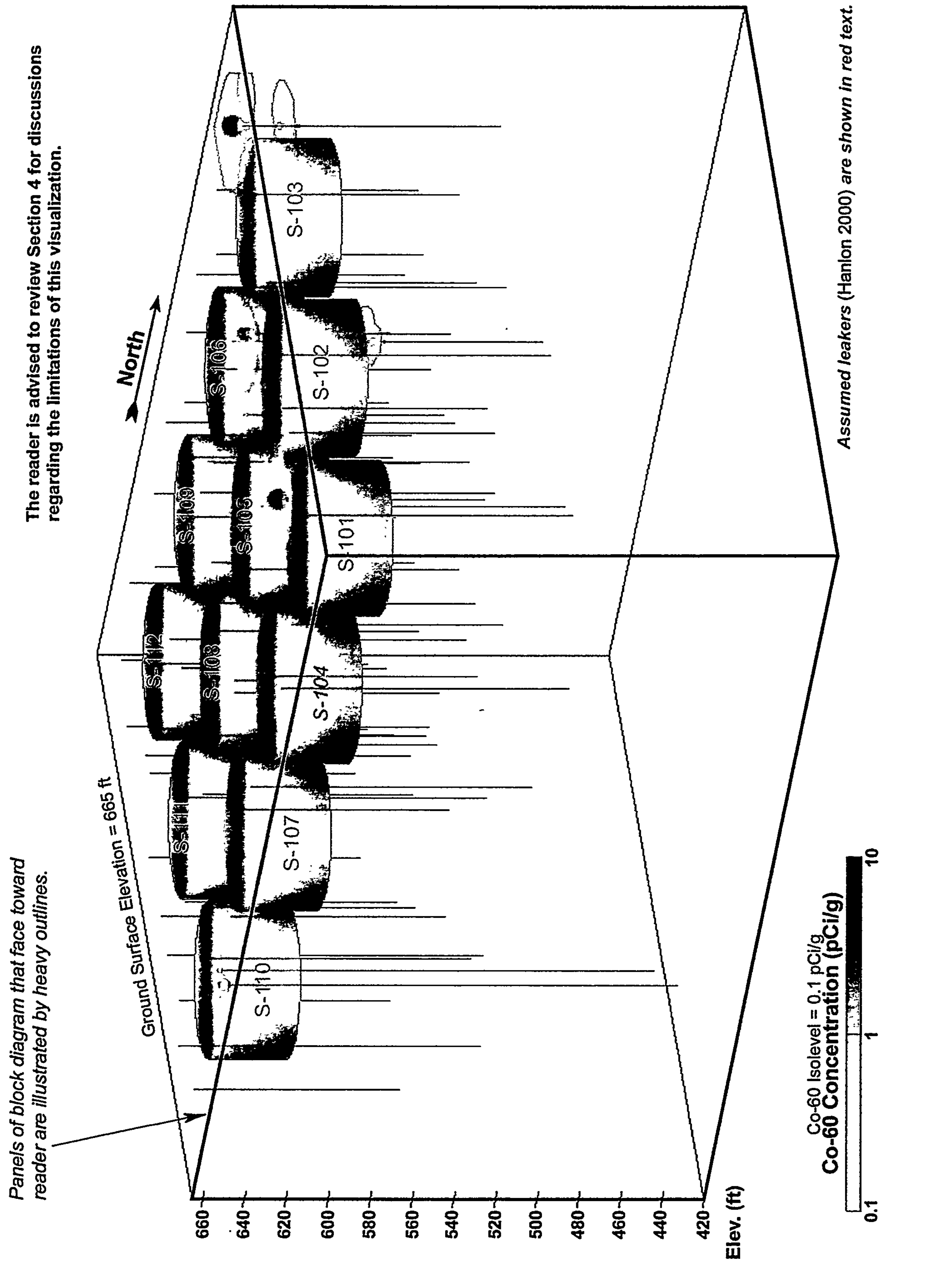

Figure E-15. S Tank Farm Visualization

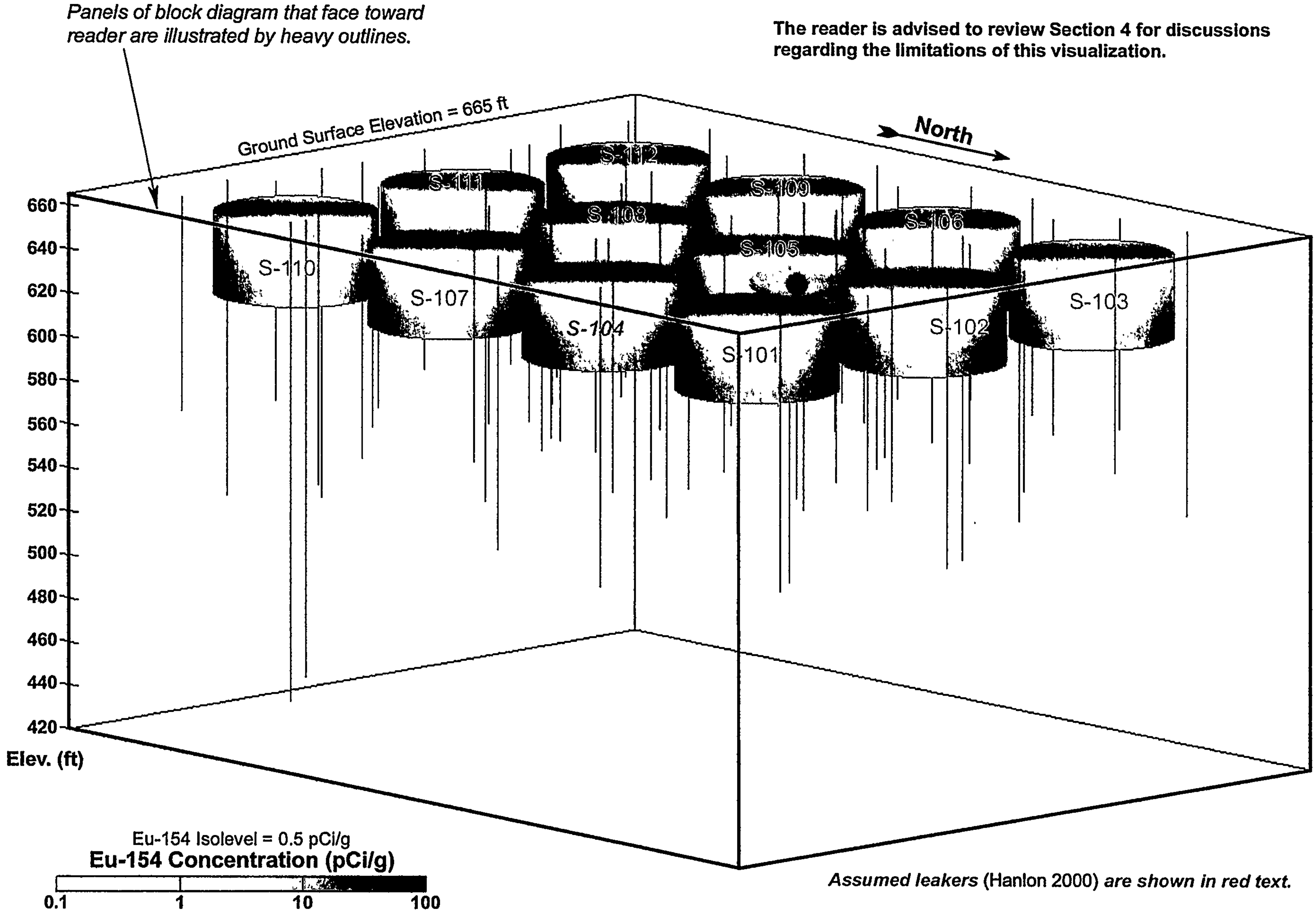

Figure E-16. S Tank Farm Visualization

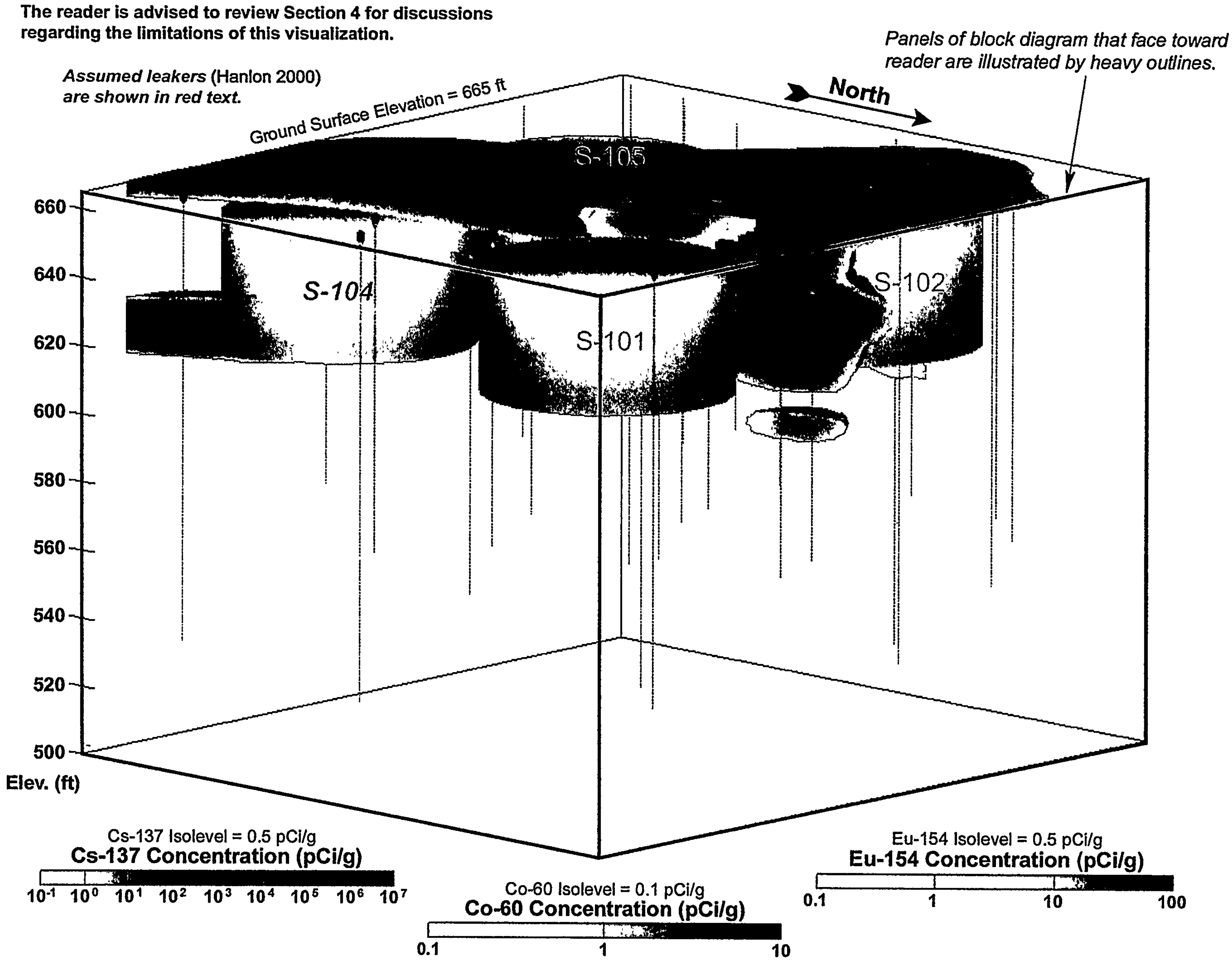

Figure E-17. S Tank Farm Visualization