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Hanford Tank Farms Vadose Zone

Addendum to the TX Tank Farm Report

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Office of River Protection
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Hanford Tank Farms Vadose Zone

Addendum to the TX Tank Farm Report

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Executive Summary

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

The TX Tank Farm Report, which was prepared as part of this characterization project, was issued in September 1997 as document number GJO-97-13-TAR, GJO-HAN-11. The TX Tank Farm Report summarized the results of the spectral gamma logging at the TX Tank Farm that were originally reported in Tank Summary Data Reports for each individual tank and 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 TX Tank Farm were used to develop a three-dimensional model of the distribution of the contamination in the vadose zone.

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

A high rate logging system (HRLS) was developed and deployed in the TX Tank Farm to measure cesium-137 (^{137}Cs) concentration levels in high gamma flux zones where the spectral gamma logging system was unable to collect usable data because of high dead times and detector saturation. This new system can measure ^{137}Cs concentrations up to about 100 million picocuries per gram (pCi/g). ^{137}Cs concentrations of more than 10^4 pCi/g were detected in one borehole (51-04-04) logged with the HRLS.

Since the TX Tank Farm Report was issued, the technique of shape factor analysis has been developed to provide information regarding the distribution of observed contamination with respect to the borehole. Shape factor analysis of data from the TX Tank Farm, combined with a careful evaluation of contaminant profiles, has resulted in identification of many contaminated intervals in which the contamination is judged to be localized to the borehole or otherwise non-representative of subsurface contamination.

Since the TX Tank Farm Report was issued, repeat logging measurements were collected in selected borehole intervals approximately 3 years after the initial baseline data. Four boreholes

(51-03-09, 51-04-05, 51-05-05, and 51-05-07) exhibit possible concentration increases that may indicate migration of contaminants through the vadose zone. However, the repeat logging was limited in scope, and interpretations based on limited data are not conclusive. An independent evaluation of historical tank farms gross gamma data collected between 1975 and 1994 has recently been completed, but results were not available for use in this document. The gross gamma logging program was discontinued in 1994 and no comprehensive vadose zone monitoring program currently exists.

The interpreted data set presented in the TX Tank Farm Report was revised to incorporate the data from 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 and the experience of the analysts. These new data sets were used to create the revised three-dimensional visualizations of subsurface contamination for the TX 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 TX Tank Farm.

This addendum completes the baseline characterization of the TX Tank Farm. The purpose of this characterization was to identify the nature and extent of contamination associated with gamma-emitting radionuclides in the TX Tank Farm using existing boreholes. The TX Tank Farm Report supplemented by this addendum serves as a baseline against which future measurements can be compared to identify changes in the vadose zone, track contaminant movement, and identify or verify future tank leaks. The visualizations represent a "snapshot" of the nature and extent of contamination associated with gamma-emitting radionuclides present in the vadose zone at the time of baseline logging. Baseline logging for the TX Tank Farm was performed in early 1996.

1.0 Introduction

The TX Tank Farm is located in the northern portion of the 200 West Area of the Hanford Site and consists of eighteen second-generation single-shell tanks (SSTs), each with a capacity of 758,000 gallons (gal) (Figure 1). These tanks were constructed between 1947 and 1948 to store high-level radioactive waste generated during chemical processing of irradiated uranium reactor fuel. This waste was generated primarily at the T Plant, which is located about 3,000 feet (ft) northeast of the TX Tank Farm. These tanks currently store a total of 7,009,000 gal of waste. Eight of the eighteen 758,000-gal tanks are designated as "assumed leakers." A total volume of 58,500 gal of liquid waste is estimated to have leaked from these tanks into the vadose zone sediments. The remaining ten tanks are currently classified as sound (Hanlon 2000). Gross gamma logging was discontinued in the leak detection boreholes in 1994 and leak detection monitoring has since been based on internal tank measurements.

In 1994, the U.S. Department of Energy (DOE) Richland Operations Office (DOE-RL) requested the DOE Grand Junction Office (GJO), Grand Junction, Colorado, to perform a baseline characterization of gamma-emitting radionuclides in the vadose zone at all Hanford SST farms using high resolution spectral gamma-ray logging methods in existing boreholes surrounding the tanks. The DOE-GJO developed the Spectral Gamma Logging System (SGLS), which consists of a downhole sonde and surface support system (cable, winch, and electronic systems mounted in a custom-built truck). The downhole sonde contains a detector made from an n-type high purity germanium (HPGe) crystal with an approximate system efficiency of 35 percent. Using the SGLS, the baseline characterization of the TX Tank Farm was completed between December 1995 and May 1996. The results of the geophysical logging and radionuclide concentration log plots for individual boreholes were compiled and presented in 18 individual Tank Summary Data Reports (1996a, 1996b, 1996c, 1996d, 1996e, 1996f, 1997a, 1997b, 1997c, 1997d, 1997e, 1997f, 1997g, 1997h, 1997i, 1997j, 1997k, 1997l).

The TX Tank Farm Report was the fifth tank farm report to be completed by the Hanford Tank Farms Vadose Zone Project. Since that report was completed, additional work has been performed and modifications to the original report and visualizations are warranted. This document will discuss those modifications and serves as an addendum to the original report. The original report was issued as document number GJO-97-13-TAR, GJO-HAN-11.

1.1 Background

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

RCRA groundwater monitoring at the T and TX/TY waste management areas (WMAs) moved from interim status detection monitoring to assessment monitoring in 1993 because of exceedances in specific conductance in downgradient wells 299-W10-17 and 299-W14-12.

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

Specific conductance values in well 299-W10-17 have shown some variability, but have remained well above the critical mean established from four quarters of groundwater monitoring data from upgradient wells. Specific conductance values in well 299-W14-12 dropped significantly between 1993 and mid-1996, but they appear to have stabilized at values above the critical mean during late 1996 and 1997. Although not a direct indication of contamination, higher values of specific conductance appear to be associated with elevated activities of technetium-99 (^{99}Tc), tritium, iodine-129 (^{129}I), and cobalt-60 (^{60}Co). Results of a Phase I Groundwater Quality Assessment published in January 1998 suggest that elevated ^{99}Tc and associated co-contaminants (e.g. chromium, tritium, nitrate, ^{129}I , and ^{60}Co) are consistent with a small volume tank waste source within the WMA (Hodges 1998).

Since the original TX Tank Farm Report was issued in 1997, additional data have been obtained and enhancements have been made to the data evaluation process. In particular, shape factor analysis has allowed identification of intervals where contaminant dragdown is a dominant factor, additional spectral data have been collected from repeat logging of selected borehole intervals, and a high rate logging system (HRLS) has been developed to investigate intervals of high gamma flux where the SGLS was unable to collect usable spectral data.

1.2 Purpose and Scope

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

Results of shape factor analysis, HRLS logging, and SGLS repeat logging are summarized in tables included in appendices to this report. The revised three-dimensional visualizations have been developed from an interpreted data set that incorporates the results of high rate logging and shape factor analysis. In the interest of brevity, only repeat and high rate plots are included. Shape factor plots are not included.

In general, the results of shape factor analysis and HRLS data have been incorporated into the interpreted data set used to create the visualizations. Repeat logging data are generally not incorporated into the interpreted data set, unless the data clarify ambiguities in the original log data. The primary justification for excluding SGLS repeat data is that only a small fraction of the total logging footage was re-logged. The purpose of the baseline characterization project is to provide a "snapshot" of the nature and extent of gamma-emitting contamination. To routinely insert repeat logging data would thus distort the original baseline. Contaminant plumes shown in the visualizations included in this addendum are based on the original baseline characterization data, but have been modified as a result of shape factor analysis and the application of professional judgment to the determination of the contaminant distribution.

Areas of potential contaminant movement are identified on the basis of comparison of repeat logging data and original baseline logging data. However, it is difficult to draw firm conclusions regarding recent contaminant movement because only limited repeat logging data are available and routine borehole monitoring was discontinued in 1994. An independent evaluation of historical tank farms gross gamma data collected between 1975 and 1994 has recently been completed, but results were not available for use in this document.

2.0 Summary of Additional Data

Additional data presented in this addendum include HRLS logging and SGLS repeat logging. All borehole data have been reviewed in light of improvements in data analysis and interpretation methodology. Application of new interpretive techniques such as the shape factor method to analysis of spectral gamma-ray logs enables an assessment of the distribution of the contaminants with respect to the borehole so that intervals of localized borehole contamination can be identified and eliminated from the visualizations.

2.1 High Rate Logging System (HRLS)

During SGLS logging operations in the TX Tank Farm, one subsurface interval exhibited a field of very high gamma-ray flux, such that the SGLS detector experienced high system dead time, yielding no usable spectral data.

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

The HRLS operates normally in gamma-ray fluxes intense enough to "saturate" the SGLS. Saturation refers to the circumstance in which the detector records spectra in which the peaks (full energy peaks) are tiny or even absent. This situation is an extreme manifestation of "pileup," which contributes to degradation of spectra (Knoll 1989). "Pulse pileup" occurs when the photon flux at the detector is so great that the probability is high that two or more photons will deposit their energies in the detector within a time interval that is short compared to the time resolution of the system. The electrical charge liberated by the several photons is then processed as if just one photon were involved. Pulse pileup events give output pulses with variable amplitudes because the amplitude of each output pulse depends on the total energy of the several captured photons that contribute to the pulse. The pulses with variable amplitudes add counts to the spectral background continuum, and the photons that participate in pileup are lost, in the sense that they contribute to the spectral background instead of a peak. Consequently, as pileup

events increase in frequency, the spectral peaks become more and more obscure. Because peak counts are lost, the peak intensities are no longer proportional to the source concentrations.

Like the SGLSs, the HRLS is essentially nonparalyzable. "Nonparalyzable" and "paralyzable" describe system behavior during "dead periods" of data acquisition (Knoll 1989). In nonparalyzable systems, the deposition of photon energy in the detector is followed by a brief time interval, or dead period, of fixed duration, during which the output electrical pulse is being processed. The system is unresponsive to any additional photons that enter the detector during the dead period. If the gamma-ray flux is intense, a significant number of photons may 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 count rates from paralyzable systems may be ambiguous in high gamma-ray fluxes and may significantly underestimate contaminant concentrations.

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

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

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

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

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

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

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

Nuclide	6-in. Casing	4- & 6-in. Casing	6-, 8-, & 10-in. Casing	Internal Shield	External Shield	Both Shields
^{137}Cs	1.000	1.41	2.71	27.42	3.758	96.40

2.2 Repeat Logging

Repeat logging using the SGLS can be used to evaluate the possibility of contaminant movement over time by comparing the concentrations measured at different times. Analysis of historical total gamma-ray logs acquired between 1975 and 1994 can also provide some insights into the possible movement of contaminants, especially in zones of high gamma-ray flux. A sufficient amount of time has not passed since the implementation of the HRLS to collect repeat data that would provide meaningful comparisons.

2.2.1 Spectral Gamma Logging System (SGLS)

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

interest. To provide for proper comparison of spectral log data between the original baseline and the repeat logging, baseline data were adjusted for decay and compared to the repeat logging results. To maintain consistency of the baseline data, repeat logging results were not included in the interpreted data set used in the development of the TX Tank Farm contaminant visualizations.

2.2.2 Historical Total Gamma-Ray Logging

Total gamma-ray logs were acquired in all of the boreholes in the TX Tank Farm on a regular but variable schedule from 1975 to 1994. Although a comprehensive review of the historical total gamma-ray logs is beyond the scope of this addendum, results of the historical logging can be useful for the purpose of identifying areas in the vadose zone where contaminant movement has occurred in the past. Boreholes that showed historical total gamma-ray activity were reviewed and used as a tool when needed to support an interpretation as to the disposition of contaminant plumes presented in this addendum. Comments regarding an interval of historical total gamma-ray activity were noted in the appendices as such.

An independent assessment of historical gross gamma data from 1975 to 1994 has recently been completed, but the results were not available for use in preparing this addendum. It is anticipated that a report describing these results will be available in the near future.

2.3 Shape Factor Analysis

Experience with SGLS logging results in the TX Tank Farm and elsewhere indicated that observed contamination in many intervals appeared to be localized to the borehole casing. This may be caused by "drag down" or contaminants adhering to the outside surface of the casing that are carried downward as the casing advances through a contaminated zone. Another possible mechanism is contaminant movement along the outside of the casing or in the annular void space between the casing and the surrounding formation. However, this type of movement is considered to be relatively unlikely because the physics of flow through the vadose zone require that the formation pore space be saturated before significant movement into the annular void space can occur. Localized contamination on the inside of the casing can occur when particulate contamination enters the well from the surface or during drilling. For purposes of this report, contamination local to the borehole casing is referred to as "borehole effects" regardless of the mechanism of deposition.

In addition to localized contamination, the SGLS may also detect gamma activity associated with a discrete source remote from the borehole, such as contaminants contained within a buried pipeline that passes close to the borehole.

Some indication that gamma radiation within a particular interval originates from the inside or outside of the casing, or from within the earth surrounding the casing, can be provided by an interpretive technique known as shape factor analysis. The technique of shape factor analysis is

described in detail in Wilson (1997, 1998). In general, shape factor analysis relies on ratios of certain intervals of the Compton continuum to discriminate between contamination that is localized to the casing, uniformly distributed in the formation, or that occurs as a discrete source at a distance from the borehole. At present, the method is only applicable to ^{137}Cs and ^{60}Co , but the principles can be extended to other radionuclides as well. In some cases, shape factor analysis can also identify a characteristic distortion of the low energy portion of a spectrum that may be caused by bremsstrahlung associated with the presence of a high-energy beta emitter such as strontium-90 (^{90}Sr) in the vicinity of the borehole.

Shape factor analysis was applied to the SGLS baseline data acquired in boreholes of the TX Tank Farm to identify zones of localized contamination that were not representative of subsurface contaminant plumes in the vadose zone. The results of this analysis have been incorporated into the visualizations presented in this addendum.

3.0 Discussion of Results

Borehole log events are referred to by letters A, B, C, etc. Each log event is a separate episode of data collection. Thus, Event A is the initial logging event and referred to as the baseline, while Events B or C are subsequent events that could refer to either repeat SGLS data or HRLS logging data. A log run refers to a single sequential set of log data collected during an event. Multiple log runs may occur with the same log event, for example, when using different shield configurations or when logging is terminated at the end of a day requiring a second day of logging to complete the borehole survey. Depth overlaps (1 ft) occur between log runs.

3.1 High Rate Logging

Logging was conducted using the HRLS in two boreholes within the TX Tank Farm. One borehole (51-14-04) represents an interval where SGLS baseline results yielded unusable data resulting from high system dead times. The second borehole (51-07-07) represents an interval of continuous ^{60}Co contamination that was thought to be of sufficient gamma intensity to test the sensitivity and range of the HRLS. Figure 2 shows the locations of these boreholes within the TX Tank Farm.

The results indicate that the ^{60}Co concentration in borehole 51-07-07 was probably not of sufficient intensity to continuously measure using the HRLS. The few spectra in which ^{60}Co was detected displayed only the 1173-keV peak, with little or no evidence of a peak at 1333 keV. The maximum ^{60}Co concentration in this zone is about 400 pCi/g. There is good agreement between SGLS and HRLS data. The HRLS responds primarily to ^{137}Cs at 662 keV, because this is the most abundant gamma-emitting radionuclide remaining in tank waste plumes. In addition, the sensitivity of the HRLS detector decreases rapidly with increasing gamma energy. The net effect is that detector sensitivity to ^{60}Co or $^{152/154}\text{Eu}$ is significantly less than for ^{137}Cs . In addition, pulse pileup effects at high count rates contribute to an elevated background, and peaks

become less distinct. ^{60}Co and ^{154}Eu are frequently observed above and below zones of high gamma intensity, but are not detected by the HRLS. The presence of these nuclides in the high intensity zone is inferred, but they cannot be quantified.

^{137}Cs and ^{60}Co concentration values calculated using the HRLS data are shown on log plots for each borehole presented in Appendix A. A table in Appendix A summarizes borehole information where HRLS logging was conducted in the TX Tank Farm. Included in the table are the depth intervals logged with the system, correction factors for the different shield configurations, if any, and comments concerning any relevant observations.

3.2 Repeat Logging

SGLS repeat logging in the TX Tank Farm was performed for selected depth intervals in nine boreholes. Repeat logging data were collected approximately 3 years after the SGLS baseline data. A table included in Appendix B summarizes SGLS repeat logging performed in the TX Tank Farm and indicates the zones of investigation in each borehole, the reason for repeat logging, and an evaluation of the results. Appendix B also includes comparison log plots between baseline and repeat logging events. To provide a meaningful comparison, baseline contaminant concentrations were adjusted for decay to match the repeat logging dates. Figure 2 shows the locations of these boreholes and denotes any changes.

On the basis of comparison of baseline and repeat logging, four boreholes (51-03-09, 51-04-05, 51-05-05, and 51-05-07) appear to exhibit increases in contaminant concentration that may indicate contaminant movement. However, the changes in concentration values were within the uncertainty of their respective measurement and therefore no definitive conclusion can be drawn. Each of these boreholes should be considered a candidate for additional logging as part of any future monitoring program.

An independent assessment of historical gross gamma data from 1975 to 1994 for TX Tank Farm has recently been completed, but a copy of the report was not available when this addendum was prepared. Because the routine gross gamma monitoring program was discontinued in 1994, there is little with which to assess the possibility of continued contaminant migration.

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 TX Tank Farm and to present views derived from those visualizations. The software package from C Tech Development Corporation called "Environmental Visualization System" (EVS) was used to create the visualizations in both the original TX Tank Farm Report and in this addendum. One of the greatest concerns that resulted from the preparation of the original visualizations presented in the TX Tank Farm Report was the possibility that some of the contamination may be either on the

inside or outside of the borehole casing and not representative of subsurface conditions. At the beginning of model development, the assumption was made that all contamination detected was distributed within the formation. Since development of the original visualizations, efforts have been made to identify and eliminate intervals of contamination associated with "borehole effects" such as casing contamination and/or contaminant drag down. Improvements to the data input and calculation parameters in 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. Construction of the interpreted data set begins by creating a single text file that contains all the spectral gamma-ray data collected from both the SGLS baseline and HRLS logging activities. This data set includes the horizontal coordinates and depth of each data point and the calculated concentration value at that point for each contaminant of interest. The data set is manually edited to remove intervals of contamination judged to be localized to the borehole and thus not representative of the subsurface contaminant distribution.

A table included in Appendix C lists all of the boreholes in the TX Tank Farm that were included in the interpreted data set. The table summarizes borehole contamination information from both SGLS and HRLS logging activities, the results of shape factor analysis, and the disposition of that data relative to the three-dimensional visualizations. Appendix C also includes log plots of each borehole showing the SGLS and HRLS data used to create the visualizations in this addendum.

Concentration values in the interpreted data set for TX Tank Farm have not been corrected for decay. In the addendum to the SX Tank Farm Report (DOE 2000), data were corrected for decay to January 1, 2000. However, as work progressed in other tank farms, it was found that decay corrections would lead to significant loss of data, particularly for ^{60}Co , which has a half life of about 5 years. In several cases, correction for decay to January 1, 2000 would lead to situations where the maximum ^{60}Co value for a specific plume would fall below the minimum detectable level for the SGLS. Either the values would have to be portrayed below the minimum detection level (MDL), or the plume would be lost. Therefore, the decision was made to report data in terms of the time at which the baseline logging was performed.

For the TX Tank Farm, the time span for the baseline is early 1996. HRLS data were collected about 3 years later. Adjustments for decay (extrapolated backward) were made to the HRLS data for consistency with the interpreted data set. This had minimal effect on the TX Tank Farm data set because there was only one zone in borehole 51-14-04 with ^{137}Cs concentrations high enough to collect data using the HRLS.

4.2 Development of Three-Dimensional Visualizations

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

The 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 borehole. To offset this effect, data points in individual boreholes were averaged over 5-ft intervals, significantly reducing the size of the input data set and the processing time. More importantly, it “forced” the search algorithm to bring in data from multiple boreholes at most calculation points, resulting in a more realistic extrapolation of concentration values into the region between boreholes. To maintain fidelity to the original data, sphere plots and other representations of measurement data are based on the interpreted data set, which contains actual values at 0.5-ft vertical increments.

4.2.1 Geostatistical Model

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

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

4.2.2 Three-Dimensional Plume Calculation and Visualizations

Kriging was used to estimate the contaminant concentration values at points on a three-dimensional grid. Once this concentration grid was developed, visualizations of the estimated contaminant concentrations could be produced in the form of a solid surface model. The visualization can be moved, rotated, and viewed from any angle or direction; color printouts can also be produced.

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

The kriging software applies a horizontal-to-vertical anisotropy ratio that allows the user to influence the "fabric" of the data set. The anisotropy ratio applies a biased weighting to data points in horizontal and vertical directions from a given data node. The program default is 10, which means that data points a given distance in the horizontal direction from a node will have an influence 10 times greater than data points at the same distance in a vertical direction. Kriging analyses were performed using several anisotropy values and the value that yielded results that appeared to best represent the measured distributions of contaminants was determined through trial and error. The primary criteria controlling selection of an appropriate anisotropy value was the appearance of the resulting plume. Higher anisotropy values tend to produce more lateral exaggeration, which may result in a "stringy" appearance. Lower anisotropy values tend to increase the influence of contaminant values in the vertical direction, resulting in a more "bulbous" appearance. An anisotropy value of 4 was applied during the kriging of the ^{137}Cs , ^{60}Co , ^{154}Eu , uranium-235/238 ($^{235/238}\text{U}$), and antimony-125 (^{125}Sb) visualizations presented in this addendum.

For the contaminants of interest (^{137}Cs , ^{60}Co , ^{154}Eu , and ^{125}Sb), the MDL for the SGLS was generally on the order of 0.1 pCi/g. In the preprocessing module, a value of 0.01 pCi/g was substituted for non-detects in the data file, allowing the presence of non-detects in the data set to have an impact on computation of nodal values during the kriging process, because data analysis is based on the logarithm of contaminant values. During post-processing, values less than 0.1 pCi/g were ignored.

The processed uranium contaminants, ^{235}U and ^{238}U , have much higher MDLs of 1.0 and 10 pCi/g, respectively. In the preprocessing module, values of 0.1 and 1.0 pCi/g were substituted for non-detects in the ^{235}U and ^{238}U data files, respectively. During post-processing, values less than 1.0 pCi/g for ^{235}U and 10 pCi/g for ^{238}U were ignored.

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

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

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

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

4.3 Potential Uncertainties and Inaccuracies

The visualizations presented in this report are based on estimated ^{137}Cs , ^{60}Co , ^{154}Eu , processed ^{235}U , and ^{238}U values as determined by geostatistical estimation (kriging) procedures applied to an interpreted data set that has been averaged over 5-ft depth intervals. In addition to the uncertainties associated with geostatistical estimation applied to an interpreted and averaged data set, there are other sources of uncertainty that must be considered, including uncertainties in the assay calculation process as well as counting error. The uncertainty in assay calculation is discussed in the base calibration report (DOE 1995) and subsequent re-calibration reports. It is estimated by combining errors associated with the calibration efficiency determination, counting statistics of the calibration measurements, and uncertainties in the model concentration values. The counting error is associated with the random nature of the radioactive decay process.

Potential model inaccuracies associated with zones of high ^{137}Cs concentrations are not significant in the TX Tank Farm because of the limited occurrence of these zones. Where SGLS detector saturation occurred in the original baseline, no concentration values could be calculated, or they were highly suspect. Therefore, a value of 10,000 pCi/g was placed in the database for kriging operations. This setup had minimal effect on the TX Tank Farm data set because there was only one zone in borehole 51-14-04 with ^{137}Cs concentrations high enough to saturate the SGLS detector. In this addendum, ^{137}Cs concentration values computed from HRLS data were substituted in that interval where the SGLS was saturated. HRLS data from borehole 51-07-07 were analyzed for the purpose of testing the sensitivity and range of the HRLS with respect to ^{60}Co and the data were not used in the development of the TX Tank Farm visualizations.

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 TX 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. As discussed previously, specific borehole intervals suspected to be primarily borehole contamination have been removed from the interpreted data set.

A major potential source of error in the visualizations for the TX Tank Farm is the lack of any data from under the tanks. Significant levels of contamination could exist under some tanks, in particular under tanks TX-105, -107, and -114; however, no data are available from this volume. If such data were to be included, it is likely that the plumes portrayed in the visualizations would extend further into the volume underneath the tanks.

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

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

4.4 Discussion of Visualizations

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

Appendix Figures D-1 through D-6 illustrate the man-made radionuclides (^{137}Cs , ^{60}Co , ^{154}Eu , ^{235}U , ^{238}U , and ^{125}Sb) that were derived from the interpreted data set for all boreholes logged in the TX Tank Farm. These figures portray the data values at 0.5-ft intervals as spheres that are colored and sized to show the relative radionuclide concentration. The concentration values are presented with logarithmic color scales that range from 0.1 to as high as 100,000 pCi/g. The borehole numbers are indicated on the figures to facilitate correlation of the three-dimensional representation of the data in the remaining figures and the interpreted data set plots presented in Appendix C.

Figures D-7 through D-17 show horizontal planar slices at various depths in the TX Tank Farm. These slices illustrate the distribution of the major contaminants ^{137}Cs , ^{60}Co , ^{154}Eu , ^{235}U , ^{238}U , and ^{125}Sb that occur at concentrations greater than their listed isolevels in picocuries per gram. The depths of these slices were selected to indicate a balance of the highest concentration and maximum extent of plumes that existed between the selected depth intervals.

The horizontal slice from the 3-ft depth (Figure D-7) provides the best representation of the lateral extent of contamination that exists between the ground surface and 3 ft. In general, the slice at the 3-ft depth shows two large areas of ^{137}Cs . Unspecified surface sources, including unplanned releases or surface spills, are probably the sources of this contamination. The highest ^{137}Cs concentration values are located toward the north portion of the tank farm along the northeast quadrant of tank TX-114 and between tanks TX-117 and TX-118.

There is good correlation with ^{137}Cs contamination between depths of 3 and 6 ft (Figures D-7 and D-8). The slice at the 6-ft depth represents the area just above the tank dome. ^{154}Eu was detected along the northwest quadrant of tank TX-117 and probably represents a buried pipeline or contamination from a pipeline leak. The highest ^{137}Cs concentration values are still located toward the north portion of the tank farm along the east quadrant of tank TX-114 and between tanks TX-117 and TX-118.

The slice at the 13-ft depth (Figure D-9) shows the maximum depth extent of ^{137}Cs contamination originating from surface sources. Between tanks TX-117 and TX-118 are the highest ^{137}Cs concentration values, which extend to the southeast past tank TX-114. ^{137}Cs contamination is also located along the east quadrant of tank TX-116.

Figures D-10 and D-11 show slices at depths of 23 and 27 ft, respectively. These slices represent the approximate highest waste level of the tanks. The ^{137}Cs plume at the southeast quadrant of tank TX-109 may be associated with a leak from a spare inlet. In addition, a ^{137}Cs and ^{60}Co plume between tanks TX-117 and TX-118 may be associated with a near-surface source or with a leak from the cascade overflow line that connects tanks TX-117 and TX-118.

At the 27-ft depth, (Figure D-11) there is a small area of ^{137}Cs along the east side of tank TX-105. Repeat logging was performed in borehole 51-05-03 to investigate a total gamma-ray anomaly observed in the absence of significant ^{137}Cs contamination. Results of the repeat logging were inconclusive because neither the ^{137}Cs nor other radionuclides appear to be present at levels sufficient to account for the anomaly. The most likely explanation appears to be either remote ^{137}Cs contamination or possibly ^{90}Sr . The Tank Summary Data Report for tank TX-105 (DOE 1996e) presented the possibility of ^{90}Sr after rigorous analysis of the SGLS data. The source may possibly be a leak from inlet lines at tank TX-105.

Figure D-12 shows a slice at the 48-ft depth, which represents approximately the base of the tanks. Several new contaminant plumes are evident around tanks TX-104, -105, -107, and -114, which may be the result of tank leaks. A ^{125}Sb plume is shown along the northeast quadrant of tank TX-104 and a ^{154}Eu plume is shown along the south quadrant of tank TX-107. Processed $^{235/238}\text{U}$ were detected along the northeast and southeast quadrants of tank TX-105. Tank TX-114 shows a ^{137}Cs plume along the tank's east side. The highest ^{137}Cs concentration value (62,700 pCi/g) in the TX Tank Farm was measured in this area. ^{60}Co continues to be present along the east side of tank TX-118, correlating with contamination from the 3- and 23-ft depths. The presence of contamination at the 48-ft depth infers that tank TX-104, although not classified as a leaker, may have leaked in the past. In addition to the ^{125}Sb contamination, processed $^{235/238}\text{U}$

were also detected at this depth along the northeast and southeast quadrants of tank TX-104 but not plotted on the visualization because concentration values averaged over the 5-ft interval fell below the minimum isopleth necessary to be plotted.

The slice at the 53-ft depth (Figure D-13) represents the interface between the tank farm's excavation surface and the undistributed sediments of the Hanford formation. The three plumes associated with tanks TX-105, -107, and -118 correlate with the plumes at the 48-ft depth. The exception is the ^{137}Cs plume from tank TX-114, which did not extend to the 53-ft depth and appears to have no other contaminants associated with it (e.g., ^{60}Co or ^{154}Eu). The ^{154}Eu plume on the south side of tank TX-107 includes ^{60}Co at this depth and occupies the area between tanks TX-103 and TX-107. It also appears to extend under both tanks. The $^{235/238}\text{U}$ plume from tank TX-105 is also larger and the ^{137}Cs and ^{60}Co plume is still present along the east quadrant of tank TX-118. $^{235/238}\text{U}$ was also detected along the south side of tank TX-104 at this depth but is not shown in the visualization because the average concentration values are too low.

The 61-ft slice (Figure D-14) represents the maximum lateral extent of the $^{235/238}\text{U}$ plume from tank TX-105. Analysis of SGLS repeat logging data indicates that $^{235/238}\text{U}$ concentration values between tanks TX-101 and -105 may be increasing. Note that on this and the following slice, the $^{235/238}\text{U}$ contamination east of TX-105 appears to terminate abruptly along a north-south-trending line along the eastern margin of the tank farm. This is a consequence of the convex hull option, which limits the portrayal of contamination to the volume enclosing the boreholes.

The 68-ft slice (Figure D-15) represents the maximum lateral extent of the ^{60}Co plume extending from tank TX-107 in a southwest direction. Processed ^{238}U is shown at both depths located along the south quadrant of tank TX-104. This ^{238}U is part of the contaminant plume first discussed at the 48-ft depth. In addition, at about this depth, more processed $^{235/238}\text{U}$ was detected toward the southwest but was not plotted on the visualization because the averaged values were relatively low.

The final two slices, at the 78- and 92-ft depths (Figures D-16 and D-17), indicate that all but one of the plumes have reached their maximum depth above 78 ft. At these depths the visualization indicates that the ^{60}Co plume from tank TX-107 has moved away from the tank toward the southwest. Below 92 ft, the vertical extent of the contaminant plume is poorly defined because no boreholes in the vicinity extend through the bottom of the plume. Evaluation of SGLS repeat logging data shows that ^{60}Co values appear to be increasing, indicating that migration may be continuing.

Figures D-18 through D-21 are three-dimensional visualizations that illustrate the major contamination plumes within the vadose zone at the TX Tank Farm. These visualizations show the plumes created with the EVS software superimposed over the SGLS and HRLS data; the plumes of interest are presented with a degree of transparency to view the data that define the plumes. The distribution of the ^{137}Cs , ^{60}Co , ^{235}U , and ^{238}U contamination, respectively, is shown viewed from below and looking toward the southwest; all views are from a common vantage

point. These figures portray the distribution of the four major contaminants in the vadose zone immediately below the TX Tank Farm.

Figure D-22 shows a view from above the TX Tank Farm looking toward the northwest through a portion of the ^{137}Cs , ^{60}Co , ^{154}Eu , and ^{238}U plumes cut by an east-west-trending vertical plane that lies at the southern edge of tanks TX-105, -106, and -107.

Figure D-23 shows tanks TX-114, -115, and -118 viewed from above and looking toward the southwest through a portion of the ^{137}Cs and ^{60}Co plumes cut by a northwest-southeast-trending vertical plane that lies at the northeastern edge of tanks TX-114 and TX-118. This cut exposes the interior of the ^{137}Cs plume showing the highest concentration values in the tank farm along the east quadrant of tank TX-114.

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 TX 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 activity 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 kriged values extrapolated from the interpreted data set, where concentration values have been averaged over 5-ft intervals, and represent the volumes of the contaminated formation and total radioactivity for ^{137}Cs , ^{60}Co , ^{154}Eu , and $^{235/238}\text{U}$. The total activities represent values at the time of the baseline logging in 1996, and have not been corrected for decay. These estimates are based entirely on the data from the baseline spectral gamma characterization program, with HRLS data included in zones of detector saturation. The data sets used for the volume and total activity inventory estimates do not include any data from historical gross gamma logs or any soil sample data.

The contribution from ^{60}Co , ^{154}Eu , ^{125}Sb , ^{235}U , and ^{238}U may be slightly underestimated because these data are not always measured accurately in zones of high gamma flux. A further limitation of this inventory is that no data are available from directly under the tanks, where the highest concentrations of radionuclides are presumed to exist. In addition, EVS extrapolates the contaminant plumes through the volume occupied by the tanks. This may result in a minor error in the volume of contaminated soil in the upper portion of the plumes. However, given the nature of the estimates and the relatively sparse data set, these errors are not likely to significantly affect the estimates.

The tables below list the contaminated soil volumes and total activities that occur at or above each threshold level for ^{137}Cs , ^{60}Co , ^{154}Eu , ^{125}Sb , ^{235}U , and ^{238}U , respectively.

Contaminant Threshold (pCi/g)	^{137}Cs	Total Activity (Curies)
	Contaminated Volume (Cubic Meters)	
0.5	33,550	0.45
5	7,609	0.36
50	831	0.19
500	36.8	4.00e-02

Contaminant Threshold (pCi/g)	^{60}Co	Total Activity (Curies)
	Contaminated Volume (Cubic Meters)	
0.1	761,600	0.22
0.3	6,865	7.86e-02
0.5	5,197	7.73e-02
1	3,495	7.48e-02
5	1,258	6.43e-02
50	225	3.63e-02
100	95	2.12e-02

Contaminant Threshold (pCi/g)	^{154}Eu	Total Activity (Curies)
	Contaminated Volume (Cubic Meters)	
0.5	698	7.07e-03
1	465	6.67e-03
5	177	5.12e-03
10	111	4.16e-03
25	47.6	2.68e-03

Contaminant Threshold (pCi/g)	¹²⁵ Sb	Total Activity (Curies)
	Contaminated Volume (Cubic Meters)	
0.1	90	2.08e-05

Contaminant Threshold (pCi/g)	²³⁵ U	Total Activity (Curies)
	Contaminated Volume (Cubic Meters)	
1	3,000	7.19e-03
2	351	1.51e-03

Contaminant Threshold (pCi/g)	²³⁸ U	Total Activity (Curies)
	Contaminated Volume (Cubic Meters)	
10	5,819	0.18
20	1,324	8.21e-02
30	704	5.67e-02
40	437	4.17e-02
50	282	3.04e-02
60	180	2.12e-02

5.0 Conclusions

The purpose of this addendum is to provide an update to the original TX Tank Farm Report that was issued in 1997. The interpretations and conclusions in the original report are unchanged. However, since the original report was issued, knowledge has been gained that provides a more complete framework by which the contaminant distribution can be viewed. In addition, enhancements to the data collection have been made since the TX Tank Farm Report was issued. Some of the more important improvements in the understanding of the log data have resulted from the following:

- Shape factor analysis was developed as a method to discriminate between contamination that is restricted to the vicinity of the casing (borehole effects) and that which occurs in the formation enclosing the casing. Although shape factor analysis leads to the elimination of many intervals of contamination from the interpreted data

set, the most significant contaminated intervals were generally not affected. The major improvement in the visualizations achieved by shape factor analysis was the removal of zones of low level "ghost" plumes from the visualizations, which allows the remaining zones of contamination to be shown with greater clarity.

- Repeat SGLS logging has allowed for evaluation of possible concentration increases between 1995 and 1999. Historical gross gamma-ray logging data have provided a qualitative indication of contaminant movement. However, there has been no comprehensive effort to monitor changes in vadose zone contamination since 1994.
- High rate logging has allowed determination of maximum concentration values in borehole intervals where the SGLS was saturated. ^{137}Cs concentrations as high as 62,700 pCi/g were detected in the TX Tank Farm.

Integration of the HRLS 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 TX Tank Farm. Conclusions stated in the original TX Tank Farm Report generally remain valid and will not be reiterated. However, evaluation of the SGLS repeat data suggests that the level of ^{60}Co contamination south of tank TX-107 and west of tank TX-103 and the $^{235/238}\text{U}$ contamination south of tank TX-105 both appear to be increasing since the 1996 SGLS baseline logging event, suggesting the possibility of continuing contaminant movement through the vadose zone. Figure 2 shows borehole locations of all repeat and HRLS logging and indicates where contamination increases have occurred. Log plots presented in Appendix C show indications of contaminant movement where the original baseline data were adjusted for decay and compared to repeat data.

In addition, results of SGLS baseline and repeat logging indicate that remote ^{137}Cs or ^{90}Sr contamination may be present along the east side of tank TX-105. The appearance of the anomalous response in the baseline and repeat data at about the 30-ft depth can not be attributed to the ^{137}Cs or other identified radionuclides. Additional investigations, including sample collection and analysis, may be required to prove or disprove the presence of the ^{90}Sr contaminant.

6.0 Recommendations

Recommendations included in the original TX Tank Farm Report remain valid. The baseline data reported in the TX Tank Farm Report and this addendum have provided an indication of the nature and extent of contamination associated with gamma-emitting radionuclides. Evaluation of selected historical and relogging data suggests that contaminant migration appears to be continuing. However, the gross gamma logging program was terminated in 1994, and little new data are available to assess continuing migration from 1994 to the present. Therefore, it is important that a routine vadose zone monitoring program be reinstated within the TX Tank Farm as soon as possible. It is not necessary to monitor all boreholes; the TX baseline data clearly

indicate where monitoring data are required. In addition to routine gamma monitoring, consideration should be given to implementation of a moisture logging program to detect and monitor changes in vadose zone moisture conditions.

Drilling of additional boreholes is warranted to test the groundwater for contamination and to sample the vadose zone sediments to further investigate the contaminant plumes identified by the SGLS baseline and repeat study. This is particularly important for the area immediately to the south of tank TX-107 and west of tank TX-103, where ^{60}Co contamination in the vadose zone appears to have moved toward the southwest against the generalized direction of groundwater flow to the northeast.

The total gamma-ray anomaly located along the east quadrant of tank TX-105 should be evaluated further to determine if ^{90}Sr is present. The location of the anomaly indicates that inlet pipelines entering tank TX-105 from the east may be the source of the contamination.

7.0 References

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

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

Borehole	Depth (ft) for Each Log Run	Shield/ Correction Factor ^a	Comment
51-07-07	57-65	NS/1.00	The highest calculated ⁶⁰ Co concentration value was 391 pCi/g detected at the 58.5-ft depth. This interval was logged by the HRLS to test the sensitivity of the detector in a mostly ⁶⁰ Co environment.
	53-58		The log plot shows that the HRLS concentration values from 57 to 60 ft are slightly higher than the calculated decay of baseline data but the differences are within the estimated uncertainty measurements. The data indicate that the ⁶⁰ Co concentrations were probably at or below the MDL of the detector and below the MDL of the detector for ¹⁵⁴ Eu.
51-14-04	43-49	NS/1.00	<p>The highest calculated ¹³⁷Cs concentration value was 62,700 pCi/g detected at the 46-ft depth. Other contaminants such as ⁶⁰Co and ^{152/154}Eu were not detected by either SGLS baseline or HRLS spectral data. This interval was identified as a historical total gamma-ray anomaly.</p> <p>The log plot showing the HRLS interpreted data set includes the interval of no-shield data from 44.5 to 47.5 ft. The HRLS data were extrapolated backward to the baseline date (02/07/96) for consistency with the interpreted data set (the highest extrapolated ¹³⁷Cs concentration was 68,500 pCi/g).</p>

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

Borehole 51-07-07

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

Borehole 51-14-04

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

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

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

Borehole	Depth (ft)	Logging Unit/ Counting Time		Reason for Repeat	Evaluation
		Baseline	Repeat		
51-01-02	60-80	G1 (100 s)	G2B (100 s)	CM ^a	SGLS repeat data suggest that ^{235/238} U concentrations appear to be stable.
51-03-09	60-97.5	G2 (100 s)	G2B (100 s)	CM	SGLS repeat data suggest that ⁶⁰ Co concentrations from 60 to 74 ft appear to be stable.
					From 74 to 97.5 ft, SGLS repeat data show that ⁶⁰ Co concentrations tend to be higher than the calculated decay of the baseline data, suggesting that ⁶⁰ Co concentrations are unstable, but the differences are within the estimated measurement uncertainty. ⁶⁰ Co contamination is also present at the bottom of the logged interval. This borehole is recommended for additional monitoring.
51-04-02	40-60	G1 (100 s)	G2B (100 s)	CM	SGLS repeat data indicate ^{235/238} U and ¹²⁵ Sb concentrations from 40 to 60 ft appear to be stable. Repeat values for ¹²⁵ Sb show good repeatability and depth control when compared to baseline values adjusted for decay (T1/2=2.77y).
51-04-05	45-85	G1 (100 s)	G2B (100 s)	CM ^a	SGLS repeat data from 50 to 53 ft and 71.5 to 75.5 ft indicate that ^{235/238} U and ⁶⁰ Co concentrations appear to be stable.
					Between 69 and 71 ft and 76 to 80 ft, SGLS repeat data indicate ⁶⁰ Co concentrations may be higher than baseline values, but the differences are within measurement uncertainty. The interval from 80 to 94 ft shows that ⁶⁰ Co contamination was detected below the depth previously reported by baseline data. This borehole is recommended for additional monitoring.

^a CM - Contaminant movement^b TG - Elevated total gamma count rate in the absence of significant ¹³⁷Cs contamination

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

Borehole	Depth (ft)	Logging Unit/ Counting Time		Reason for Repeat	Evaluation
		Baseline	Repeat		
51-04-06	60-80	G1 (100 s)	G2B (100 s)	CM	SGLS repeat data indicate $^{235/238}\text{U}$ concentrations from 63 to 77 ft appear to be stable.
51-05-01	45-65	G2 (100 s)	G2B (100 s)	CM	SGLS repeat data indicate $^{235/238}\text{U}$ concentrations from 45.5 to 60.5 ft appear to be stable and show good repeatability and depth control. The ^{137}Cs contamination from 45 to 52 ft is probably localized to the borehole casing.
51-05-03	25-35	G2 (100 s)	G2B (100 s)	TG ^b	Between 28 and 32 ft, SGLS baseline and repeat data indicate anomalous total gamma-ray activity that cannot be definitively attributed to ^{137}Cs contamination or other radionuclides. The possibility that ^{90}Sr may be present was reported in the Tank Summary Data Report for tank TX-105 (DOE 1996e). Shape factor analysis indicates that the ^{137}Cs contamination is remote from the detector and does not confirm the presence of ^{90}Sr (remote is considered to be contamination greater than 12 in. from the borehole and in the formation). Two inlet lines enter tank TX-105 from the east (3 o'clock position) and may have leaked in the past. The anomaly may also correlate with ^{137}Cs contamination in borehole 51-09-04 at the 26-ft depth; however, two other boreholes (51-05-01 and 51-00-03) that are positioned closer to borehole 51-09-04 show no total gamma-ray anomalies.
	60-80	G2 (100 s)	G2B (100 s)	CM ^a	SGLS repeat data from 61 to 77.5 ft show mostly continuous $^{235/238}\text{U}$ contamination where concentration values illustrate good repeatability and depth control, indicating the interval is stable.

^a CM - Contaminant movement^b TG - Elevated total gamma count rate in the absence of significant ^{137}Cs contamination

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

Borehole	Depth (ft)	Logging Unit/ Counting Time		Reason for Repeat	Evaluation
		Baseline	Repeat		
51-05-05	50-80	G2 (100 s)	G2B (100 s)	CM ^a	Stable ^{235/238} U concentrations are indicated from SGLS repeat data calculated between the 50.5- and 71-ft depths. Data show good repeatability and depth control.
					SGLS repeat data from 71.5 to 75 ft show continuous ^{235/238} U contamination with increasing concentration values, suggesting the interval is unstable. Repeat data measured peak concentration values for ²³⁵ U and ²³⁸ U at 16 and 256 pCi/g, respectively, at the 74.5-ft depth. The differences are within the estimated uncertainty measurements. This borehole is recommended for additional monitoring.
51-05-07	60-70	G2 (100 s)	G2B (100 s)	CM	Stable ^{235/238} U concentrations are indicated from SGLS repeat data between 60.5 and 65 ft, which shows good repeatability and depth control.
					SGLS repeat data from 65.5 to 67 ft show continuous ^{235/238} U contamination at concentrations near the MDL where baseline concentrations were intermittent. This suggests that concentration values may be increasing, and that the interval may be unstable. This borehole is recommended for additional monitoring.

^a CM - Contaminant movement^b TG - Elevated total gamma count rate in the absence of significant ¹³⁷Cs contamination

SGLS Baseline (Event A) and SGLS Repeat (Event B) Plots **Borehole 51-01-02**

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

SGLS Baseline (Event A) and SGLS Repeat (Event B) Plots **Borehole 51-03-09**

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

SGLS Baseline (Event A) and SGLS Repeat (Event B) Plots **Borehole 51-04-02**

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

SGLS Baseline (Event A) and SGLS Repeat (Event B) Plots **Borehole 51-04-05**

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

SGLS Baseline (Event A) and SGLS Repeat (Event B) Plots **Borehole 51-04-06**

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

SGLS Baseline (Event A) and SGLS Repeat (Event B) Plots **Borehole 51-05-01**

Figure B-6. Summary of Repeat Logging Results for the TX Tank Farm

SGLS Baseline (Event A) and SGLS Repeat (Event B) Plots **Borehole 51-05-03**

Figure B-7. Summary of Repeat Logging Results for the TX Tank Farm

SGLS Baseline (Event A) and SGLS Repeat (Event B) Plots **Borehole 51-05-05**

LEGEND			
SGLS Baseline (Event A)			
04/08/96			
◇	^{238}U	■	^{235}U
●	^{137}Cs	▲	^{125}Sb
SGLS Repeat (Event B)			
01/29/99			
◇	^{238}U	□	^{235}U
△	^{125}Sb		
Decayed Baseline Data			
decayed to 01/29/99			
◇	^{125}Sb		

Figure B-8. Summary of Repeat Logging Results for the TX Tank Farm

SGLS Baseline (Event A) and SGLS Repeat (Event B) Plots **Borehole 51-05-07**

Figure B-9. Summary of Repeat Logging Results for the TX Tank Farm

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

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

Borehole	Depth Interval (ft)	Source ^a	SFA ^c	Disposition/Comments
51-00-03	0-3	SS ^b	D ^f	¹³⁷ Cs included.
	3.5-10	Pipeline	Ina. ^j	¹³⁷ Cs and ¹⁵⁴ Eu included; possible pipeline.
	10.5-15	BE ^c	Local ^g	¹³⁷ Cs removed.
	15.5-70		Inc. ⁱ	¹³⁷ Cs removed; perforated casing from 40-100 ft.
	70.5-95		Local	Continuous ¹³⁷ Cs removed.
	95.5-102		Inc.	¹³⁷ Cs removed.
51-00-06	0-2	SS	R ^h	¹³⁷ Cs included.
	2.5-146.5	BE	Inc.	Intermittent ¹³⁷ Cs removed; perforated casing from 40-100 ft.
51-00-07	0-1	SS	D	¹³⁷ Cs included.
	45.5-134	BE	Inc.	Intermittent ¹³⁷ Cs removed; perforated casing from 40-100 ft.
	69-98	P ^d	Ina.	^{235/238} U included; may correlate with boreholes 51-04-05 and 51-04-06.
51-00-09	0-109.5	BE	Inc.	Intermittent ¹³⁷ Cs removed; perforated casing from 40-100 ft.
51-00-10	0-2.5	SS	Local	¹³⁷ Cs included.
	38-109	BE	Inc.	Intermittent ¹³⁷ Cs removed; perforated casing from 40-100 ft.

^a Source - Source of contamination in judgment of analyst

^b SS - Surface spill

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

^d P - Probable contamination plume

^e SFA - Shape Factor Analysis

^f D - Contamination distributed in formation

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

^h R - Contamination is remote from borehole

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

^j Ina. - Inapplicable to apply shape factor method to this radionuclide

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

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

Borehole	Depth Interval (ft)	Source ^a	SFA ^e	Disposition/Comments
51-01-02	0-4	SS ^b	D ^f	¹³⁷ Cs included.
	4.5-40.5	BE ^c	Local ^g	¹³⁷ Cs removed.
	51, 61.5-63.5		Inc. ⁱ	Isolated ¹³⁷ Cs removed.
	61.5-67.5	P ^d	Ina. ^j	Intermittent ^{235/238} U included; may correlate with boreholes 51-01-06, 51-01-08, and 51-01-09.
	80-108	BE	Local	Isolated ¹³⁷ Cs removed.
51-01-04	0-2	SS	R ^h	¹³⁷ Cs included.
	2.5-23	BE	Local	¹³⁷ Cs removed.
	23.5-107.5		Inc.	
51-01-06	0-3	SS	D	¹³⁷ Cs included.
	3.5-47 and 72.5-98.5	BE	Inc.	¹³⁷ Cs removed.
	77	P	Ina.	Isolated ²³⁵ U included; may correlate with boreholes 51-01-02, 51-01-08, and 51-01-09.
51-01-08	0-22.5	BE	Local	¹³⁷ Cs removed.
	23-40.5		Inc.	
	75-75.5	P	Ina.	Isolated ^{235/238} U included; may correlate with boreholes 51-01-02, 51-01-06, and 51-01-09.
	97-98	BE	Local	Isolated ¹³⁷ Cs removed.

^a Source - Source of contamination in judgment of analyst

^b SS - Surface spill

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

^d P - Probable contamination plume

^e SFA - Shape Factor Analysis

^f D - Contamination distributed in formation

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

^h R - Contamination is remote from borehole

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

^j Ina. - Inapplicable to apply shape factor method to this radionuclide

Table C-2 (con't.). Summary of Interpreted Data Set for TX-101 Boreholes

Borehole	Depth Interval (ft)	Source ^a	SFA ^c	Disposition/Comments
51-01-09	0-2	SS	D	¹³⁷ Cs included.
	2.5-57.5	BE	Inc.	¹³⁷ Cs removed.
	67.5-68	P	Ina.	Isolated ^{235/238} U included; may correlate with boreholes 51-01-02, 51-01-06, and 51-01-08.
	111-112.5	BE	Inc.	¹³⁷ Cs removed.

^a Source - Source of contamination in judgment of analyst

^b SS - Surface spill

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

^d P - Probable contamination plume

^e SFA - Shape Factor Analysis

^f D - Contamination distributed in formation

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

^h R - Contamination is remote from borehole

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

^j Ina. - Inapplicable to apply shape factor method to this radionuclide

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

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

Borehole	Depth Interval (ft)	Source ^a	SFA ^e	Disposition/Comments
51-02-02	0-1.5	SS ^b	D ^f	¹³⁷ Cs included.
	2-10	BE ^c	Inc. ⁱ	¹³⁷ Cs removed.
	10.5-16		Local ^g	
	16.5-24.5, 98		Inc.	
51-02-05	0-1.5	SS	R ^h	¹³⁷ Cs included.
	10.5-11, 26, and 99-101	BE	Inc.	Isolated ¹³⁷ Cs removed.
51-02-07	0-2	SS	R	¹³⁷ Cs included.
	2.5-9	BE	Inc.	¹³⁷ Cs removed.
	9.5-19		Local	
	19.5-28		Inc.	
51-02-09	0-7	SS	D	¹³⁷ Cs included.
	7.5-35, 97	BE	Inc.	¹³⁷ Cs removed.
51-02-12	0-3	SS	R	¹³⁷ Cs included.
	3.5-28 and 99.5	BE	Inc.	¹³⁷ Cs removed.

^a Source - Source of contamination in judgment of analyst

^b SS - Surface spill

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

^d P - Probable contamination plume

^e SFA - Shape Factor Analysis

^f D - Contamination distributed in formation

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

^h R - Contamination is remote from borehole

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

^j Ina. - Inapplicable to apply shape factor method to this radionuclide

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

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

Borehole	Depth Interval (ft)	Source ^a	SFA ^e	Disposition/Comments
51-03-01	0-8	SS ^b	D ^f	¹³⁷ Cs included.
	8.5-22, and 42-49	BE ^c	Inc. ⁱ	Intermittent ¹³⁷ Cs removed.
	51-74.5	P ^d	D	⁶⁰ Co included; may correlate with boreholes 51-03-09, 51-03-11, and 51-03-12.
	52-54		Ina. ^j	¹⁵⁴ Eu included; may correlate with boreholes 51-03-11 and 51-03-12.
51-03-02	0-5.5	SS	D	¹³⁷ Cs included.
	6-39	BE	Inc.	¹³⁷ Cs removed.
	39-40.5		Local ^g	
	41-144		Inc.	Intermittent ¹³⁷ Cs removed.
51-03-06	0-3	SS	D	¹³⁷ Cs included.
	4-9	BE	Inc.	¹³⁷ Cs removed.
	10-16		Local	
	17-26		Inc.	
	99.5-100		Local	
51-03-09	0-3	SS	R ^h	¹³⁷ Cs included.
	3.5-12	BE	Local	¹³⁷ Cs removed.
	12.5-19.5		Inc.	
	20-23		Local	
	23.5-29		Inc.	

^a Source - Source of contamination in judgment of analyst

^b SS - Surface spill

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

^d P - Probable contamination plume

^e SFA - Shape Factor Analysis

^f D - Contamination distributed in formation

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

^h R - Contamination is remote from borehole

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

^j Ina. - Inapplicable to apply shape factor method to this radionuclide

Table C-4 (con't.). Summary of Interpreted Data Set for Tank TX-103 Boreholes

Borehole	Depth Interval (ft)	Source ^a	SFA ^e	Disposition/Comments
51-03-09 (con't.)	60.5-87	P	D	Continuous ⁶⁰ Co included. This interval also showed a historical total gamma anomaly. The activity at this depth has decreased at a rate that is consistent with ⁶⁰ Co. Contamination may correlate with boreholes 51-03-01, 51-03-11, and 51-03-12.
	87-97.5		Inc.	Continuous ⁶⁰ Co included; may correlate with boreholes 51-03-11 and 51-03-12.
51-03-11	0-3	SS	D	¹³⁷ Cs included.
	3.5-23	BE	Local	¹³⁷ Cs removed.
	50.5-75	P	D	⁶⁰ Co included; may correlate with boreholes 51-03-01, 51-03-09, and 51-03-12.
	51-60.5		Ina.	¹⁵⁴ Eu included; may correlate with boreholes 51-03-01 and 51-03-12.
	75.5-89		Inc.	Intermittent ⁶⁰ Co included.
	89.5-95		D	⁶⁰ Co included; may correlate with boreholes 51-03-09 and 51-03-12.
	95.5-101		Inc.	⁶⁰ Co included; contamination is present at the bottom of the logged interval, indicating that the bottom of the contaminant plume has not been determined.

^a Source - Source of contamination in judgment of analyst

^b SS - Surface spill

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

^d P - Probable contamination plume

^e SFA - Shape Factor Analysis

^f D - Contamination distributed in formation

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

^h R - Contamination is remote from borehole

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

^j Ina. - Inapplicable to apply shape factor method to this radionuclide

Table C-4 (con't.). Summary of Interpreted Data Set for Tank TX-103 Boreholes

Borehole	Depth Interval (ft)	Source ^a	SFA ^c	Disposition/Comments
51-03-12	0-2	SS	R	¹³⁷ Cs included.
	2.5-9	BE	Local	¹³⁷ Cs removed.
	9.5-36		Inc.	
	51-68	P	D	⁶⁰ Co included; may correlate with boreholes 51-03-01, 51-03-09, and 51-03-11.
	51-59.5		Ina.	¹⁵⁴ Eu included; may correlate with boreholes 51-03-01 and 51-03-11.
	53.5			Isolated ¹⁵² Eu included.
	68-75		Inc.	⁶⁰ Co included.
	69-100	BE		Isolated ¹³⁷ Cs removed.
	92-94.5 and 100	P		Isolated ⁶⁰ Co included; may correlate with boreholes 51-03-09 and 51-03-11.

^a Source - Source of contamination in judgment of analyst

^b SS - Surface spill

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

^d P - Probable contamination plume

^e SFA - Shape Factor Analysis

^f D - Contamination distributed in formation

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

^h R - Contamination is remote from borehole

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

^j Ina. - Inapplicable to apply shape factor method to this radionuclide

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

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

Borehole	Depth Interval (ft)	Source ^a	SFA ^c	Disposition/Comments
51-04-02	0-2	SS ^b	D ^f	¹³⁷ Cs included.
	2.5-7.5	BE ^e	Inc. ⁱ	¹³⁷ Cs removed.
	8-10.5	SS	D	¹³⁷ Cs included.
	11-16.5	BE	Inc.	¹³⁷ Cs removed.
	42.5-53.5	P ^d	Ina. ^j	Intermittent ^{235/238} U and ¹²⁵ Sb included; may correlate with boreholes 51-04-05 and 51-04-06.
	74.5-76		Inc.	⁶⁰ Co included; may correlate with borehole 51-04-05.
51-04-05	0-2	SS	D	¹³⁷ Cs included.
	2.5-22.5	BE	Inc.	¹³⁷ Cs removed.
	46-51.5	P	Ina.	Intermittent ^{235/238} U included; may correlate with boreholes 51-04-02 and 51-04-06.
	60-62.5	P	Inc.	⁶⁰ Co included.
	67.5-75		D	⁶⁰ Co included; may correlate with borehole 51-03-09.
	75.5-78.5		Inc.	⁶⁰ Co included.
	97.5	BE		¹³⁷ Cs removed.
51-04-06	0-1.5	SS	D	¹³⁷ Cs included.
	2-34	BE	Inc.	¹³⁷ Cs removed.
	63-76.5	P	Ina.	Intermittent ^{235/238} U included; may correlate with boreholes 51-04-02 and 51-04-05.

^a Source - Source of contamination in judgment of analyst

^b SS - Surface spill

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

^d P - Probable contamination plume

^e SFA - Shape Factor Analysis

^f D - Contamination distributed in formation

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

^h R - Contamination is remote from borehole

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

^j Ina. - Inapplicable to apply shape factor method to this radionuclide

Table C-5 (con't.). Summary of Interpreted Data Set for Tank TX-104 Boreholes

Borehole	Depth Interval (ft)	Source	SFA	Disposition/Comments
51-04-08	0-1.5	SS	R ^b	¹³⁷ Cs included.
	2-6	BE	Inc.	¹³⁷ Cs removed.
	6.5-23.5	SS	Local	
51-04-10	0-4	SS	D	¹³⁷ Cs included.
	4.5-12.5	BE	Inc.	¹³⁷ Cs removed.
51-04-12	0.5-7.5	SS	D	¹³⁷ Cs included.
	8-11	BE	Local	¹³⁷ Cs removed.
	11.5-22, 31, and 100.5		Inc.	

^a Source - Source of contamination in judgment of analyst

^b SS - Surface spill

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

^d P - Probable contamination plume

^e SFA - Shape Factor Analysis

^f D - Contamination distributed in formation

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

^h R - Contamination is remote from borehole

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

^j Ina. - Inapplicable to apply shape factor method to this radionuclide

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

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

Borehole	Depth Interval (ft)	Source ^a	SFA ^c	Disposition/Comments
51-05-01	0-1	SS ^b	D ^f	¹³⁷ Cs included.
	1.5-12.5	BE ^c	Local ^g	¹³⁷ Cs removed.
	13-40.5 and 45.5-52.5		Inc. ⁱ	
	47-60.5	P ^d	Ina. ^j	Processed ^{235/238} U included. This interval also showed a historical total gamma anomaly. Contaminants may correlate with boreholes 51-05-03, 51-05-05, and 51-05-07.
	70.5, 97.5-99	BE	Inc.	¹³⁷ Cs removed.
51-05-03	0-5	SS	D	¹³⁷ Cs included.
	5.5-28.5	BE	Local	¹³⁷ Cs removed.
	29.5-37	SS	R ^h	¹³⁷ Cs included. ⁹⁰ Sr is indicated from 28 to 32 ft by an anomalous total gamma activity with no identifiable energy peaks. This interval may correlate with ¹³⁷ Cs contamination detected in borehole 51-09-04. See the Repeat Data presented in Appendix B.
	37.5-44	BE	Inc.	¹³⁷ Cs removed.
	60.5-77	P	Ina.	Intermittent processed ^{235/238} U included, contaminants may correlate with boreholes 51-05-01, 51-05-05, and 51-05-07.
	102-113	BE	Inc.	Isolated ¹³⁷ Cs removed.

^a Source - Source of contamination in judgment of analyst

^b SS - Surface spill

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

^d P - Probable contamination plume

^e SFA - Shape Factor Analysis

^f D - Contamination distributed in formation

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

^h R - Contamination is remote from borehole

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

^j Ina. - Inapplicable to apply shape factor method to this radionuclide

Table C-6 (con't.). Summary of Interpreted Data Set for Tank TX-105 Boreholes

Borehole	Depth Interval (ft)	Source	SFA	Disposition/Comments
51-05-05	0-1	SS	R	¹³⁷ Cs included.
	1.5-25	BE	Inc.	¹³⁷ Cs removed.
	50.5-74.5	P	Ina.	Processed ^{235/238} U and ¹²⁵ Sb included. This interval also showed a historical total gamma anomaly. Contaminants may correlate with boreholes 51-05-01, 51-05-03, 51-05-07, and 51-01-02.
	97.5-98	BE	Inc.	Isolated ¹³⁷ Cs removed.
51-05-07	0-2	SS	D	¹³⁷ Cs included.
	2.5-22.5	BE	Local	¹³⁷ Cs removed.
	23-50	BE	Inc.	
	60.5-67	P	Ina.	Intermittent processed ^{235/238} U included. This interval also showed a historical total gamma anomaly. Contaminants may correlate with boreholes 51-05-01, 51-05-03, and 51-05-05.
	105.5-106.5	BE	Inc.	¹³⁷ Cs removed.
51-05-08	0-1	SS	D	¹³⁷ Cs included.
	1.5-10.5, 15-61, and 99	BE	Inc.	Intermittent ¹³⁷ Cs removed.
51-05-10	0-1	SS	R	¹³⁷ Cs included.
	1.5-99.5	BE	Inc.	Intermittent ¹³⁷ Cs removed.

^a Source - Source of contamination in judgment of analyst

^b SS - Surface spill

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

^d P - Probable contamination plume

^e SFA - Shape Factor Analysis

^f D - Contamination distributed in formation

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

^h R - Contamination is remote from borehole

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

^j Ina. - Inapplicable to apply shape factor method to this radionuclide

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

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

Borehole	Depth Interval (ft)	Source ^a	SFA ^c	Disposition/Comments
51-06-02	0-2	SS ^b	D ^f	¹³⁷ Cs included.
	2.5-18	BE ^c	Local ^g	¹³⁷ Cs removed.
	18.5-39.5 and 99.5-100		Inc. ⁱ	
51-06-04	0-1	SS	R ^h	¹³⁷ Cs included.
	1.5-14	BE	Local	¹³⁷ Cs removed.
	14.5-32 and 100-100.5		Inc.	
51-06-08	0-5	SS	R	¹³⁷ Cs included.
	5.5-7	Pipeline	Local	¹³⁷ Cs, ⁶⁰ Co, and ¹⁵⁴ Eu included; probable pipeline.
	7.5-38.5 and 83.5-98	BE	Inc.	¹³⁷ Cs removed.
51-06-10	0-1	SS	D	¹³⁷ Cs included.
	1.5-27 and 97.5-98	BE	Inc.	Intermittent ¹³⁷ Cs removed.
51-06-12	0-5.5	SS	R	¹³⁷ Cs included.
	6-9.5 and 18	BE	Inc.	¹³⁷ Cs removed.
	10-13.5		Local	

^a Source - Source of contamination in judgment of analyst

^b SS - Surface spill

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

^d P - Probable contamination plume

^e SFA - Shape Factor Analysis

^f D - Contamination distributed in formation

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

^h R - Contamination is remote from borehole

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

^j Ina. - Inapplicable to apply shape factor method to this radionuclide

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

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

Borehole	Depth Interval (ft)	Source ^a	SFA ^c	Disposition/Comments
51-07-01	0-4	SS ^b	R ^h	¹³⁷ Cs included.
	4.5-22	BE ^c	Local ^g	¹³⁷ Cs removed.
	22.5-41.5 and 69.5-108		Inc. ⁱ	
51-07-03	0-13.5	SS	D ^f	¹³⁷ Cs included.
	23-24.5, 96	BE	Inc.	Isolated ¹³⁷ Cs removed.
51-07-04	0-2	SS	R	¹³⁷ Cs included.
	2.5-9	BE	Local	¹³⁷ Cs removed.
	9.5-28, 47-71, and 95.5-96	BE	Inc.	
51-07-18	0-5.5	SS	D	¹³⁷ Cs included.
	6-22	BE	Inc.	¹³⁷ Cs removed.
	50-67.5	P ^d	D	⁶⁰ Co included. This interval also showed a historical total gamma anomaly. Contamination may correlate with boreholes 51-07-07, 51-03-11, and 51-03-12.
	68-74.5		Inc.	⁶⁰ Co included.
	49.5-60		Ina. ^j	¹⁵⁴ Eu included.

^a Source - Source of contamination in judgment of analyst

^b SS - Surface spill

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

^d P - Probable contamination plume

^e SFA - Shape Factor Analysis

^f D - Contamination distributed in formation

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

^h R - Contamination is remote from borehole

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

^j Ina. - Inapplicable to apply shape factor method to this radionuclide

Table C-8 (con't.). Summary of Interpreted Data Set for Tank TX-107 Boreholes

Borehole	Depth Interval (ft)	Source	SFA	Disposition/Comments
51-07-07	0-9.5	SS	D	¹³⁷ Cs included.
	10-17.5	BE	Local	Continuous ¹³⁷ Cs removed.
	18-29.5, 46	BE	Inc.	Isolated ¹³⁷ Cs removed.
	50-77	P	D	⁶⁰ Co included. This interval also showed a historical total gamma anomaly. Contamination may correlate with boreholes 51-07-18, 51-03-11, and 51-03-12.
	51-57		Ina.	¹⁵⁴ Eu included.
51-07-09	0-4	SS	D	¹³⁷ Cs included.
	4.5-12.5	BE	Local	¹³⁷ Cs removed.
	23-22.5, 64		Inc.	Isolated ¹³⁷ Cs removed.
	68.5-99.5			¹³⁷ Cs removed.
	84.5	P	Inc.	Isolated ⁶⁰ Co contamination included; may correlate with boreholes 51-07-07 and 51-07-18.
51-07-11	0-0.5	SS	R	¹³⁷ Cs included.
	1-7	BE	Local	¹³⁷ Cs removed.
	7.5-40.5, 97		Inc.	

^a Source - Source of contamination in judgment of analyst

^b SS - Surface spill

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

^d P - Probable contamination plume

^e SFA - Shape Factor Analysis

^f D - Contamination distributed in formation

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

^h R - Contamination is remote from borehole

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

^j Ina. - Inapplicable to apply shape factor method to this radionuclide

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

Borehole	Depth Interval (ft)	Source ^a	SFA ^c	Disposition/Comments
51-08-05	0-5.5	SS ^b	R ^h	¹³⁷ Cs included.
	6-13 and 45-47	BE ^c	Local ^g	¹³⁷ Cs removed.
	13.5-21.5 and 90.5		Inc. ⁱ	
51-08-09	0-3	SS	D ^f	¹³⁷ Cs included.
	3.5-8	BE	Local	¹³⁷ Cs removed.
	8.5-18		Inc.	
51-08-11	0-3	SS	D	¹³⁷ Cs included.
	3.5-10	BE	Inc.	Isolated ¹³⁷ Cs removed.

^a Source - Source of contamination in judgment of analyst

^b SS - Surface spill

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

^d P - Probable contamination plume

^e SFA - Shape Factor Analysis

^f D - Contamination distributed in formation

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

^h R - Contamination is remote from borehole

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

^j Ina. - Inapplicable to apply shape factor method to this radionuclide

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

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

Borehole	Depth Interval (ft)	Source ^a	SFA ^e	Disposition/Comments
51-09-03	0-1.5	SS ^b	R ^h	¹³⁷ Cs included.
	2-7	BE ^c	Local ^g	¹³⁷ Cs removed.
	7.5-98.5		Inc. ⁱ	
51-09-04	0-1	SS	R	¹³⁷ Cs included.
	1.5-6	SS	D ^f	
	6.5-18	BE	Inc.	¹³⁷ Cs removed.
	23-27.5	P ^d	R	¹³⁷ Cs included. This interval also showed a historical total gamma anomaly.
	29.5-44.5 and 84.5-98.5	BE	Inc.	Intermittent ¹³⁷ Cs removed.
51-09-08	0-1.5	SS	R	¹³⁷ Cs included.
	2-13 and 18.5-25	BE	Local	¹³⁷ Cs removed.
	13.5-18, 25.5-37.5, and 98-99		Inc.	
51-09-10	1-6	SS	D	¹³⁷ Cs included.
	6.5-12	BE	Local	¹³⁷ Cs removed.
	12.8-48		Inc.	

^a Source - Source of contamination in judgment of analyst

^b SS - Surface spill

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

^d P - Probable contamination plume

^e SFA - Shape Factor Analysis

^f D - Contamination distributed in formation

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

^h R - Contamination is remote from borehole

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

^j Ina. - Inapplicable to apply shape factor method to this radionuclide

Table C-10 (con't.). Summary of Interpreted Data Set for Tank TX-109 Boreholes

Borehole	Depth Interval (ft)	Source	SFA	Disposition/Comments
51-09-12	0-4.5	SS	D	¹³⁷ Cs included.
	5-10 and 15.5-20	BE	Local	¹³⁷ Cs removed.
	10.5-15, 20.5-34.5, and 80-98.5		Inc.	

^a Source - Source of contamination in judgment of analyst

^b SS - Surface spill

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

^d P - Probable contamination plume

^e SFA - Shape Factor Analysis

^f D - Contamination distributed in formation

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

^h R - Contamination is remote from borehole

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

^j Ina. - Inapplicable to apply shape factor method to this radionuclide

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

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

Borehole	Depth Interval (ft)	Source ^a	SFA ^e	Disposition/Comments
51-10-01	0-2	SS ^b	R ^h	¹³⁷ Cs included.
	2.5-36	BE ^c	Local ^g	¹³⁷ Cs removed.
	36.5-43.2 and 97-98.5		Inc. ⁱ	¹³⁷ Cs removed. At about 54 ft, a historical total gamma-ray anomaly was reported that does not correlate with contamination detected by the SGLS. Contaminants probably have decayed to levels below the MDL of the SGLS detector. This is the zone that led to the classification of tank TX-110 as questionable integrity. Historical total gamma-ray anomalies are also reported at this depth in nearby boreholes 51-10-13, 51-10-25, and 51-13-08.
	86		Inc.	Isolated ⁶⁰ Co included.
51-10-04	0-3	SS	R	¹³⁷ Cs included.
	3.5-23	BE	Local	¹³⁷ Cs removed.
	23.5-40.5, 95, and 99.5		Inc.	
51-10-08	0-5.5	SS	R	¹³⁷ Cs included.
	6-20.5	BE	Local	¹³⁷ Cs removed.
	21-40.5 and 98-99		Inc.	
51-10-12	0-1	SS	R	¹³⁷ Cs included.
	1.5-14 and 98-99.5	BE	Local	¹³⁷ Cs removed.
	14.5-97.5		Inc.	

^a Source - Source of contamination in judgment of analyst

^b SS - Surface spill

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

^d P - Probable contamination plume

^e SFA - Shape Factor Analysis

^f D - Contamination distributed in formation

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

^h R - Contamination is remote from borehole

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

^j Ina. - Inapplicable to apply shape factor method to this radionuclide

Table C-11 (con't.). Summary of Interpreted Data Set for Tank TX-110 Boreholes

Borehole	Depth Interval (ft)	Source	SFA	Disposition/Comments
51-10-13	1-6	SS	D	¹³⁷ Cs included.
	6.5-11.5	BE	Local	¹³⁷ Cs removed.
	12-26.5		Inc.	
	29 and 95.5	P	Inc.	Isolated ⁶⁰ Co included.
	47 and 95-96.5	BE	Inc.	¹³⁷ Cs removed. At about 54 ft, a historical total gamma-ray anomaly was reported that does not correlate with contamination detected by the SGLS. Historical total gamma-ray anomalies are also reported at this depth in boreholes 51-10-01, 51-10-25, and 51-13-08.
51-10-25	0-4.5	SS	R	¹³⁷ Cs included.
	5-13	BE	Local	¹³⁷ Cs removed.
	62 and 95.5	P	Inc.	Isolated ⁶⁰ Co included. At about 54 ft, a historical total gamma-ray anomaly was reported that does not correlate with present contamination detected by the SGLS. Historical total gamma-ray anomalies are also reported at this depth in boreholes 51-10-01, 51-10-13, and 51-13-08.
	98.5	BE	Inc.	Isolated ¹³⁷ Cs removed.

^a Source - Source of contamination in judgment of analyst

^b SS - Surface spill

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

^d P - Probable contamination plume

^e SFA - Shape Factor Analysis

^f D - Contamination distributed in formation

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

^h R - Contamination is remote from borehole

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

^j Ina. - Inapplicable to apply shape factor method to this radionuclide

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

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

Borehole	Depth Interval (ft)	Source ^a	SFA ^e	Disposition/Comments
51-11-01	0-3.5	SS ^b	D ^f	¹³⁷ Cs included.
	3.5-5 and 109-111	BE ^c	Local ^g	¹³⁷ Cs removed.
	5.5-30.5		Inc. ⁱ	
51-11-02	0-2.5	SS	D	¹³⁷ Cs included.
	3-31 and 113.5	BE	Inc.	Isolated ¹³⁷ Cs removed.
	40-98.5 and 146.5-147		Local	¹³⁷ Cs removed; casing perforations from 40-95 ft.
51-11-03	0-1.5	SS	R ^h	¹³⁷ Cs included.
	2-30.5 and 96.5-99	BE	Local	¹³⁷ Cs removed.
	31-56.5 and 78.5-96		Inc.	
51-11-07	0-1.5	SS	R	¹³⁷ Cs included.
	2-8	BE	Local	¹³⁷ Cs removed.
	8.5-22, 41.5, and 98-98.5		Inc.	
51-11-10	0-1.5	SS	R	¹³⁷ Cs included.
	2-22.5 and 99	BE	Local	¹³⁷ Cs removed.
	23-98.5		Inc.	

^a Source - Source of contamination in judgment of analyst

^b SS - Surface spill

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

^d P - Probable contamination plume

^e SFA - Shape Factor Analysis

^f D - Contamination distributed in formation

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

^h R - Contamination is remote from borehole

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

^j Ina. - Inapplicable to apply shape factor method to this radionuclide

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

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

Borehole	Depth Interval (ft)	Source ^a	SFA ^e	Disposition/Comments
51-12-01	0-1.5	SS ^b	R ^h	¹³⁷ Cs included.
	2-22.5	BE ^c	Inc. ⁱ	Intermittent ¹³⁷ Cs removed.
51-12-04	0-2.5	SS	D ^f	¹³⁷ Cs included.
	3-6.5	BE	Local ^g	¹³⁷ Cs removed.
	7-23.5 and 100-100.5		Inc.	
51-12-05	0-3	SS	D	¹³⁷ Cs included.
	3.5-21.5	BE	Local	¹³⁷ Cs removed.
	22-33 and 99.5		Inc.	
51-12-07	0-1	SS	D	¹³⁷ Cs included.
	1.5-16, 79, and 98.5	BE	Inc.	Intermittent ¹³⁷ Cs removed.
51-12-10	0-4.5	SS	D	¹³⁷ Cs included.
	5-31.5	BE	Inc.	¹³⁷ Cs removed.
51-12-11	0-2.5	SS	D	¹³⁷ Cs included.
	3-13, 38.5, 69.5, and 87-92.5	BE	Inc.	¹³⁷ Cs removed.

^a Source - Source of contamination in judgment of analyst

^b SS - Surface spill

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

^d P - Probable contamination plume

^e SFA - Shape Factor Analysis

^f D - Contamination distributed in formation

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

^h R - Contamination is remote from borehole

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

^j Ina. - Inapplicable to apply shape factor method to this radionuclide

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

Table C-14. Summary of Interpreted Data Set for Tank TX-113 Boreholes

Borehole	Depth Interval (ft)	Source ^a	SFA ^c	Disposition/Comments
51-13-05	0-1.5	SS ^b	R ^h	¹³⁷ Cs included.
	2-10	BE ^c	Local ^g	¹³⁷ Cs removed.
	10.5-13.5	SS	D ^f	¹³⁷ Cs included.
	14-17.5 and 97.5-99	BE	Local	¹³⁷ Cs removed.
	18-33, 47, 61, 63.5, and 75-97		Inc. ⁱ	
51-13-08	0-1.5	SS	R	¹³⁷ Cs included.
	2-24	BE	Local	¹³⁷ Cs removed. At about 54 ft, a historical total gamma-ray anomaly was reported that does not correlate with contamination detected by the SGLS. Contaminants probably have decayed to levels below the MDL of the SGLS detector. Historical total gamma-ray anomalies were also reported at this depth in nearby boreholes 51-10-01, 51-10-13, and 51-10-25 that were not detected by SGLS baseline logging.
	24.5-98.5		Inc.	
51-13-12	0-7	SS	D	¹³⁷ Cs included.
	7.5-37.5 and 96.5-99	BE	Local	¹³⁷ Cs removed.
	38-96	BE	Inc.	¹³⁷ Cs removed.

^a Source - Source of contamination in judgment of analyst

^b SS - Surface spill

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

^d P - Probable contamination plume

^e SFA - Shape Factor Analysis

^f D - Contamination distributed in formation

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

^h R - Contamination is remote from borehole

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

^j Ina. - Inapplicable to apply shape factor method to this radionuclide

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

Table C-15. Summary of Interpreted Data Set for Tank TX-114 Boreholes

Borehole	Depth Interval (ft)	Source ^a	SFA ^e	Disposition/Comments
51-14-04	0-12	SS ^b	D ^f	¹³⁷ Cs included.
	12.5-27 and 91.5-97.5	BE ^c	Local ^g	¹³⁷ Cs removed.
	27.5-42.5 and 51-91		Inc. ⁱ	
	43-50	P ^d	D	¹³⁷ Cs included. The highest calculated ¹³⁷ Cs concentration value was 62,700 pCi/g detected at the 46-ft depth. Contamination may correlate with boreholes 51-14-08 and 51-14-11.
51-14-08	0-2	SS	R ^h	¹³⁷ Cs included.
	2.5-19	BE	Local	¹³⁷ Cs removed.
	19.5-42.5 and 46-98		Inc.	
	43-45.5	P	D	¹³⁷ Cs included. Historical total gamma-ray anomaly; may correlate with boreholes 51-14-04 and 51-14-11.
51-14-11	0-11.5	SS	D	¹³⁷ Cs included.
	12-35 and 98.5-99.5	BE	Local	¹³⁷ Cs removed.
	35.5-42.5 and 46-98		Inc.	
	43-45.5	P	D	¹³⁷ Cs included. Historical total gamma-ray anomaly; may correlate with boreholes 51-14-04 and 51-14-08.

^a Source - Source of contamination in judgment of analyst

^b SS - Surface spill

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

^d P - Probable contamination plume

^e SFA - Shape Factor Analysis

^f D - Contamination distributed in formation

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

^h R - Contamination is remote from borehole

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

^j Ina. - Inapplicable to apply shape factor method to this radionuclide

Figure C-15. Summary of Interpreted Data Set for the TX Tank Farm

Table C-16. Summary of Interpreted Data Set for Tank TX-115 Boreholes

Borehole	Depth Interval (ft)	Source ^a	SFA ^c	Disposition/Comments
51-15-04	0-1.5	SS ^b	D ^f	¹³⁷ Cs included.
	2-29	BE ^c	Local ^g	¹³⁷ Cs removed.
	29.5-52	P ^d	D	Isolated ⁶⁰ Co included. A historical total gamma-ray anomaly is indicated between 17 and 48 ft.
	30.5-94.5	BE	Inc. ⁱ	¹³⁷ Cs removed.
51-15-07	0-3	SS	D	¹³⁷ Cs included.
	3.5-11	BE	Local	Intermittent ¹³⁷ Cs removed.
	11.5-99		Inc.	
51-15-09	0-5, 19-21.5, and 99	BE	Inc.	Intermittent ¹³⁷ Cs removed.
51-15-11	0-9	SS	D	¹³⁷ Cs included.
	9.5-23	BE	Local	¹³⁷ Cs removed. A historical total gamma-ray anomaly is indicated between 31 and 38 ft that does not correlate with present contamination detected by the SGLS.
	23.5-39.5 and 98-98.5		Inc.	

^a Source - Source of contamination in judgment of analyst

^b SS - Surface spill

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

^d P - Probable contamination plume

^e SFA - Shape Factor Analysis

^f D - Contamination distributed in formation

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

^h R - Contamination is remote from borehole

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

^j Ina. - Inapplicable to apply shape factor method to this radionuclide

Figure C-16. Summary of Interpreted Data Set for the TX Tank Farm

Table C-17. Summary of Interpreted Data Set for Tank TX-116 Boreholes

Borehole	Depth Interval (ft)	Source ^a	SFA ^c	Disposition/Comments
51-16-04	0-13	SS ^b	D ^f	¹³⁷ Cs included.
	13.5-30.5 and 98.5	BE ^c	Local ^g	¹³⁷ Cs removed.
	31-40.5 and 44.5-98		Inc. ⁱ	¹³⁷ Cs removed.
	40.5-43	P ^d	D	¹³⁷ Cs included. A historical gross gamma-ray anomaly is indicated between 40 and 45 ft.
51-16-07	0-3.5	SS	D	¹³⁷ Cs included.
	4-22 and 100-101.5	BE	Local	¹³⁷ Cs removed.
	22.5-99.5		Inc.	¹³⁷ Cs removed. A historical total gamma-ray anomaly was reported between 65 and 74 ft that does not correlate with present contamination detected by the SGLS. A short-lived radionuclide such as ¹⁰⁶ Ru is indicated from the decay of historical logs.
51-16-11	0-8	SS	D	¹³⁷ Cs included.
	8.5-18	BE	Local	¹³⁷ Cs removed.
	18.5-40.5, 82.5, and 97.5-99		Inc.	¹³⁷ Cs removed. A historical total gamma-ray anomaly was reported between 47 and 55 ft that does not correlate with present contamination detected by the SGLS. A short-lived radionuclide such as ¹⁰⁶ Ru is indicated from the decay of historical logs.

^a Source - Source of contamination in judgment of analyst

^b SS - Surface spill

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

^d P - Probable contamination plume

^e SFA - Shape Factor Analysis

^f D - Contamination distributed in formation

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

^h R - Contamination is remote from borehole

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

^j Ina. - Inapplicable to apply shape factor method to this radionuclide

Figure C-17. Summary of Interpreted Data Set for the TX Tank Farm

Table C-18. Summary of Interpreted Data Set for Tank TX-117 Boreholes

Borehole	Depth Interval (ft)	Source ^a	SFA ^c	Disposition/Comments
51-17-02	0-2	SS ^b	R ^h	¹³⁷ Cs included.
	2.5-26.5 and 98.5-99	BE ^c	Local ^g	¹³⁷ Cs removed.
	27-98		Inc. ⁱ	
51-17-03	0-4	SS	D ^f	¹³⁷ Cs included.
	4.5-9 and 41.5-94	BE	Local	¹³⁷ Cs removed; perforated casing from 38-92 ft.
	9.5-41 and 95.5-142.5		Inc.	¹³⁷ Cs removed.
51-17-10	0-9	SS	R	¹³⁷ Cs included.
	4.5-8.5	pipeline	Ina. ^j	⁶⁰ Co and ¹⁵⁴ Eu included; probable pipeline.
	9.5-21 and 25.5-45	BE	Local	¹³⁷ Cs removed.
	21.5-25	SS	R	¹³⁷ Cs included. A historical total gamma-ray anomaly was reported between 18 and 25 ft that may correlate with borehole 51-18-03.
	45.5-97.5	BE	Inc.	¹³⁷ Cs removed.
51-17-11	0-8.5	SS	R	¹³⁷ Cs included.
	8.5-33	BE	Local	¹³⁷ Cs removed.
	33.5-63 and 95-101.5		Inc.	

^a Source - Source of contamination in judgment of analyst

^b SS - Surface spill

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

^d P - Probable contamination plume

^e SFA - Shape Factor Analysis

^f D - Contamination distributed in formation

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

^h R - Contamination is remote from borehole

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

^j Ina. - Inapplicable to apply shape factor method to this radionuclide

Figure C-18. Summary of Interpreted Data Set for the TX Tank Farm

Table C-19. Summary of Interpreted Data Set for Tank TX-118 Boreholes

Borehole	Depth Interval (ft)	Source ^a	SFA ^c	Disposition/Comments
51-18-01	0-4	SS ^b	D ^f	¹³⁷ Cs included.
	4.5-12 and 19-27.5	BE ^c	Local ^g	¹³⁷ Cs removed.
	12.5-18.5, 28-36, and 99.5		Inc. ⁱ	
	39 and 50.5	P ^d	Inc.	Isolated ⁶⁰ Co included. These intervals also showed a historical total gamma-ray anomaly.
51-18-03	0-60	P	D	¹³⁷ Cs included. This interval showed a historical total gamma-ray anomaly.
	11.5-36.5 and 42.5-59.5			⁶⁰ Co included.
	60.5-79	BE	Inc.	¹³⁷ Cs removed.
51-18-05	0-7	SS	D	¹³⁷ Cs included.
	7.5-41	BE	Local	¹³⁷ Cs removed.
	41.5-101.5		Inc.	
	96	P	Inc.	Isolated ⁶⁰ Co included.
51-18-07	0-1.5	SS	R ^h	¹³⁷ Cs included.
	2-33.5 and 99	BE	Local	¹³⁷ Cs removed.
51-18-09	0-3.5	SS	D	¹³⁷ Cs included.
	4-10	BE	Local	Intermittent ¹³⁷ Cs removed.
	10.5-28 and 99		Inc.	

^a Source - Source of contamination in judgment of analyst

^b SS - Surface spill

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

^d P - Probable contamination plume

^e SFA - Shape Factor Analysis

^f D - Contamination distributed in formation

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

^h R - Contamination is remote from borehole

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

^j Ina. - Inapplicable to apply shape factor method to this radionuclide

Table C-19 (con't.). Summary of Interpreted Data Set for Tank TX-118 Boreholes

Borehole	Depth Interval (ft)	Source	SFA	Disposition/Comments
51-18-10	0-1.5	SS	D	¹³⁷ Cs included.
	2-17.5	BE	Local	Intermittent ¹³⁷ Cs removed.
	18-33.5		Inc.	
51-18-11	0-3.5	SS	D	¹³⁷ Cs included.
	5-14	BE	Local	¹³⁷ Cs removed.
	14.5-25	SS	D	¹³⁷ Cs included.
	25.5-101	BE	Inc.	¹³⁷ Cs removed.
	45	P	Inc.	Isolated ⁶⁰ Co included; may correlate with boreholes 51-18-01 and 51-18-03.

^a Source - Source of contamination in judgment of analyst

^b SS - Surface spill

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

^d P - Probable contamination plume

^e SFA - Shape Factor Analysis

^f D - Contamination distributed in formation

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

^h R - Contamination is remote from borehole

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

^j Ina. - Inapplicable to apply shape factor method to this radionuclide

Figure C-19. Summary of Interpreted Data Set for the TX Tank Farm

Appendix D
TX Tank Farm Visualizations

Figure D-1. TX Tank Farm Visualization

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

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

Figure D-2. TX Tank Farm Visualization

Figure D-3. TX Tank Farm Visualization

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

Figure D-4. TX Tank Farm Visualization

Figure D-5. TX Tank Farm Visualization

Figure D-6. TX Tank Farm Visualization

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

• Monitoring Borehole

Figure D-7. TX Tank Farm Visualization

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

• Monitoring Borehole

Figure D-8. TX Tank Farm Visualization

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

• Monitoring Borehole

Figure D-9. TX Tank Farm Visualization

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

• Monitoring Borehole

Figure D-10. TX Tank Farm Visualization

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

• Monitoring Borehole

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

Depth of Horizontal Planar Slice @ 27 ft BGS

Cs-137 Isolevel = 0.5 pCi/g
Cs-137 Concentration (pCi/g)

Co-60 Isolevel = 0.3 pCi/g
Co-60 Concentration (pCi/g)

Figure D-11. TX Tank Farm Visualization

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

Figure D-12. TX Tank Farm Visualization

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

• Monitoring Borehole

Depth of Horizontal Planar Slice @ 53 ft BGS

Figure D-13. TX Tank Farm Visualization

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

• Monitoring Borehole

Depth of Horizontal Planar Slice @ 61 ft BGS

Figure D-14. TX Tank Farm Visualization

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

• Monitoring Borehole

Figure D-15. TX Tank Farm Visualization

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

• Monitoring Borehole

Figure D-16. TX Tank Farm Visualization

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

• Monitoring Borehole

Depth of Horizontal Planar Slice @ 92 ft BGS

Figure D-17. TX Tank Farm Visualization

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

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

Figure D-18. TX Tank Farm Visualization

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

Figure D-19. TX Tank Farm Visualization

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

Figure D-20. TX Tank Farm Visualization

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

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

Figure D-21. TX Tank Farm Visualization

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

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

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

Figure D-22. TX Tank Farm Visualization

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

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

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

Figure D-23. TX Tank Farm Visualization