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Analysis and Summary Report of Historical Dry Well Gamma Logs for the 241-B Tank Farm - 200 East

Prepared for the U.S. Department of Energy
Assistant Secretary for Environmental Management

Project Hanford Management Contractor for the
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Fluor Hanford

P.O. Box 1000
Richland, Washington

Analysis and Summary Report of Historical Dry Well Gamma Logs for the 241-B Tank Farm - 200 East

H. A. Sydnor
CH2M HILL Hanford Group, Inc.

A. J. Knepp
CH2M HILL Hanford Group, Inc.

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Fluor Hanford
P.O. Box 1000
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Analysis and Summary Report of Historical Dry Well Gamma Logs for the 241-B Tank Farm - 200 East

Keywords:

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Abstract:

This report provides a summary of the gross gamma ray data for the 241-B Tank Farm and is intended to identify changes in the gamma activity of gamma-emitting radionuclide contaminants around each accessible borehole, and is not intended to provide interpretation of the data relative to vadose zone mechanics. Trends in data, as well as areas where additional information would be helpful in evaluating the unusual nature of some of the data, are discussed.

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Title Page

**Analysis and Summary Report of Historical Dry Well
Gamma Logs for B Tank Farm – 200 East**

March 1, 2000

Russel Randall, Ph.D
Randall Price
Joseph Caggiano, Ph.D

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Analysis and Summary Report of Historical Dry Well Gamma Logs for the 241-B Tank Farm – 200 East

1 Introduction

The single shell tank farm dry well surveillance program was established as one of several methods used to identify leaking tanks. Until 1975, gross gamma ray data were collected in a non-digital format. In 1975, the surveillance program was upgraded to a digital logging system. Under the upgraded system, gross gamma ray logs were captured in digital form utilizing several types of logging detectors. These logs were then reviewed immediately after collection to identify or confirm leaks of radioactive liquid from suspect underground tanks. Suspect tanks were identified by sudden drops of in-tank liquid level measurements. The system was not intended to identify the specific radionuclides contributing to the total gross gamma ray activity. However, digital gross gamma ray logs acquired from January 1975 through mid-year 1994 can and have been re-analyzed to determine contaminant distribution in the subsurface around boreholes within this period of data collection. Data acquired prior to 1975 require reformatting to be useful for this analysis. Details of the analysis procedure is in "Analysis Techniques and Monitoring Results, 241-SX Dry Well Surveillance Logs," (Randall and Price, 1999).

Integral to the analysis of the gross gamma ray data is the use of information provided from the spectral gamma logging analysis implemented from 1995 to 1999 for all single-shell tank farms. Preliminary log data for B Tank Farm were supplied to Three Rivers Scientific by MACTEC-ERS (Grand Junction, CO) to facilitate this analysis. The spectral gamma analysis for B Tank Farm is scheduled to be released early in 2000 by MACTEC-ERS of Grand Junction, Colorado for the U.S. Department of Energy (DOE) under contract #DE-AC04-94AL96907 (MACTEC-ERS, 1998). The spectral gamma logging system (SGLS) employs a high-purity germanium (HPGe) detector to obtain data leading to the identification and depth of gamma ray emitting radioactive isotopes. The identity of gamma-emitting isotopes that are present in the subsurface is required for interpretation of the tank farm gross gamma ray dry well surveillance logs. By integrating SGLS data with historical dry well surveillance data, some knowledge is gained concerning the tank leak history, and the historical mobility and decay of man-made gamma-emitting radionuclides in the vadose zone. The observations made in this report concern gamma-emitting contaminant mobility (or lack of mobility) that has occurred over the time period spanned by the available data.

This report provides a summary of the gross gamma ray data for the B Tank Farm and is intended to identify changes in the gamma activity of contamination around the borehole, and is not intended to provide interpretation of the data relative to vadose zone mechanics. Trends in the data, as well as areas where additional information would be helpful in evaluating the unusual nature of some of the data, are discussed. In general, the data analysis resulted in the identification of two types of subsurface conditions (i.e. clean dry wells and dry wells with contaminated intervals). Within the dry wells with contaminated intervals (discrete depth zones) four categories of contamination were identified. They are defined as follows:

- **CLEAN:** no gamma-emitting contaminants detected for the survey speeds and sensitivities of the gross gamma ray probes used; specifically no systematic trend above the naturally occurring radionuclide background in the soils is indicated by the data.
- **STABLE:** gamma activity follows a decay curve of HPGe identified or hypothesized radionuclides; specifically the decay rate of the isotope(s) identified in the zone matches the change over time in the gross gamma log response, and no noticeable deviation from the radionuclide decay is apparent within the time period of the data.

- **UNSTABLE:** evidence of contaminant migration exists within the period of data collection; specifically, in logs with proper depth control, a peak migrates with passage of time, or there is a sudden increase in GTP (Grade Thickness Product) that does not correlate with any change of logging tools or procedure, this is reflective of the addition of a gamma-emitting contaminant.

Some contamination zones were identified as unstable early in the time period and as stable at the end of the time period.

Note: Nomenclature for the classification of subsurface contamination categories has evolved beyond those presented in the Analysis Techniques report (Randall and Price, 1998). The contaminate category of "changing" has been replaced by more descriptive terms of "unstable early" and "unstable"

- **TANK FARM ACTIVITY:** erratic log data response values at the bottom of drywells or at shallow depths resulting from logging procedure changes, radioactive waste transfer operations, surface or near surface leaks/spills, and clean up of surface contamination; specifically the irregular change in gross gamma-ray log data values between successive surveys at or near the surface and at the bottom of the drywell. These rapid and inconsistent log changes suggest that contamination may be the result of tank farm operation activities (e.g., waste transfers) or logging procedure changes, and are not related to vadose zone mechanics.
- **UNDETERMINED:** no specific conclusion can be reached with the available data; specifically stability cannot be determined due to insufficient data, exceeding the system design criteria (both upper and lower limits) for recording gross gamma ray data, or possible effects of depth shift or surface activities.

Stable vs. unstable is an apparent condition limited by the time interval over which data were collected, the sensitivity of the tools, and the level of contamination; it is not a statement concerning the fixed or mobile nature of a given isotope in the vadose zone.

Radio-isotopes identified reported in this report are either identified by the HPGe data or are hypothesized to exist presently or existed in the past. Radio-isotopes cannot be identified from a gross gamma ray log alone. The presence of hypothesized isotopes generally have a rapid rate of decay (e.g., Ru-106) which may not be identified by the HPGe tool if the level of radioactivity falls below detection limits at the time the SGLS data were obtained (mid 1990's). The earlier presence of such isotopes is be speculated based on the fit of a decay curve of the isotope to the change over time of the gross gamma ray data.

It is beyond the scope of this project to identify the contaminant source, rate of movement, or migration pathway and their ultimate impact to the environment. It is also noted that where boreholes do not exist, gamma-emitting isotopes may be present and movement can occur without detection. This investigation is limited to the immediate area (approximately 20 inches) around each borehole from which gamma rays are readily detected, and is not rigorous enough to interpret the condition of the space between boreholes and outside of the investigated area. Contaminants which do not emit gamma rays or where decay products do not emit gamma rays, are not detected by gross or spectral gamma logging and are therefore not discussed in this report. While such isotopes may be present, they are beyond the scope of this report.

1.1 Background

A series of sixteen tanks were constructed at the B Tank Farm (one of four original tank farms at the Hanford Site) in 1943-44 to receive high-level liquid mixed waste resulting from chemical processing activities (Brevick, et. al., 1996). Twelve of these tanks held 550,000 gallons and were constructed on 100-foot centers and are 75 feet in diameter, leaving 25 feet between the sides of each tank. Four smaller 55,000 gallon tanks were also constructed in B Farm. No historical gross gamma surveillance logs were available for the four smaller tanks. The large tanks are connected in a variety of ways, such as by cascade and transfer lines, the details of which can be obtained from the engineering construction diagrams for this tank farm. A network of vadose monitoring wells (dry wells) was installed throughout the B Tank Farm as part of a leak detection and surveillance system. Borehole locations (centered on the borehole name) and the depth of logging, (listed below borehole name) are presented in Figure 1. The boreholes range in depth from 60 to 145 feet, with the majority being 100 or more feet deep. The 1975 to 1995 digital gross gamma ray data were analyzed by Three Rivers Scientific (under subcontract to Waste Management Technical Services, Richland, Washington) and the results are the subject of this report.

1.2 Data Analysis Description

The dry well data analysis procedure used for the B Tank Farm gross gamma historical logs is discussed in detail in the Analysis Techniques report (Randall and Price, 1999).

Data from the dry well logs were compiled to maximize trend identification. This process does not add or delete data, but merely compiles the data into a more useful format. This data set is used to create a depth vs. time plot (stack plot) to identify trends over time and zones of contamination. All historical log surveys for a single dry well (borehole) are analyzed as a whole for each radioactive zone above background in the well, allowing statements to be made about the apparent condition or rate of change of any given radioactive interval. For clarity of presentation, all logs are not plotted, but a specific frequency selection (i.e., quarterly) is used to render the stack plot readable without affecting the integrity of the data.

Review of the historical gross gamma ray data revealed that limits in the system design for collecting data prior to 1983 created a situation where the zero-depth reference point for the start of data collection was inconsistent. This difference in zero-depth point makes evaluating trends in the data difficult. Several methods can be employed to overcome varying zero points and to essentially create a common starting point from which to view the data, making trend identification easier. One method applies a depth shift to the data, which is simply adjusting data up or down so that certain identifiable features in the logs can be aligned and evaluated. No depth shifting was required to analyze the B Tank Farm, thus maintaining maximum data integrity.

A second method to analyze changes between successive gross gamma logs utilizes a calculation called the Grade Thickness Product (GTP) which can be applied over a depth interval broad enough to include all depth variances so as not to require depth shifting. The GTP is a summation of the values of logging instrument readings over the depth interval of interest (minus background activity), multiplied by the distance between sample point depths. This calculation yields a constant that is independent of the log depth increment and the specific depth interval starting/ending point. When the calculation is applied over the entire contamination interval, the result is a more accurate representation of the condition of the zone over time.

Note: Gross gamma ray data were collected using a variety of probe types. The count rates generated by these probe types do not directly correlate, as discussed in the Analysis Techniques report (Randall and Price, 1998). Caution must therefore be used when relating GTP values in zones recorded with different probe types (e.g., the NaI probe type 04 does not record values that relate to those recorded with the Green or Red GM probe types 01 and 02). Scaling factors between the different probe types are presented in "Dry Well Probe Calibrations" (Randall, 1999).

Figure 1. B Tank Farm Borehole Locations and Total Depth

Gross gamma ray log surveys were recorded over the length of the borehole at sampling intervals of one foot, starting at the maximum depth to which the logging detector was positioned (near or at the bottom of the dry well). In thin radioactive zones, these differences between successive logs in the depth locations of the one foot sample intervals will cause variations in the apparent shape of the log in the thin contamination zone and changes in the maximum count rate in the apparent center of the zone. The GTP calculation is used to eliminate this apparent problem.

The average background activity for the GTP calculation and "Average Background" plots, which are provided, is the gamma radiation from naturally occurring potassium, uranium, and thorium (i.e. natural background). The average background is computed and reviewed for each survey and provided a level of confidence that the instrumentation worked consistently and that the gross gamma ray data are valid. The average background is calculated either between a lower and upper count rate limit or for a depth range. The lower count rate limit is generally set at zero (0) c/s; a value defined as indicating a data gap. The upper count rate limit is generally set at 50 c/s for probe type 04 (NaI), a conservative value near what is considered background activity. In perspective, the original leak detection program, responsible for collecting the log data, considered a 200 c/s count rate for the probe type 04 (NaI) a reportable occurrence.

The percentage of data values for each survey that are considered as representing the natural background (i.e. not contaminated interval) is also calculated and presented on the summary plots as "Frequency Clean".

Zones of gamma-emitting contamination are examined for historical character using the GTP calculation. The average background activity is subtracted from peak values so that only the contaminated levels above background are included in the analysis. A graph is generated with GTP plotted against time for each depth interval analyzed. One or more decay lines are then superimposed on the graph based on isotopes identified by the SGLS data, knowledge of tank constituents, and the known presence of isotopes in other boreholes. Sometimes decay lines can be fit through the data a number of ways with none of them fitting perfectly. When two or more isotopes are identified, a least squares fit analysis for a multi-component decay is performed. A detailed discussion of how two or more curves are combined is provided in the Appendix to the Data Analysis Results for the BX Single Shell Tank Farm Dry Well Gross Gamma Ray Surveillance Log Surveys (Randall & Price, 1999). Gamma-emitting isotopes that are known to exist in the inventory of the tank farm, or are identified in nearby wells, may not be identified by the SGLS because they were at or below detection levels for the HPGe when the logs were recorded. Such isotopes are hypothesized to have been present when the gross gamma logs were recorded and are therefore included in the least squares fit analysis. The decay rates for each of the components are held fixed in the fitting process and the relative intensities of the components are calculated and reported in the data analysis when appropriate. The relative contribution of gross gamma rays from one component to another depends on the nature of the isotopes and the detector design.

Note: Spurious data were generated during normal data collecting activities. Spurious zero values are called data gaps and are considered as unrealistically low natural background activity when recorded with the sodium-iodide probes. Between 1975 and 1982, the equipment would occasionally record a spurious data value of minus one (-1) or zero (0). A value of minus one represents an invalid count rate. Data gaps occur at various locations in the surveys, including in the background or in the middle of a high contamination zone within a borehole. Data gaps are not included in the calculation of average background, grade thickness product, or

Comparing the GTP data and the decay line(s) reveals information about the rate of change of contamination within a zone over the period that data were collected. When appropriate, multiple plots are generated to show the results for different zones within a borehole. The details for the use of GTP data are described in the Analysis Techniques Report (Randall and Price, 1999).

The objective of the analysis is to assure that a consistent and thorough examination of dry well surveillance logs is performed and to determine if contamination abruptly entered the region of the borehole and quickly migrated out. All digital surveys within the time interval analyzed are examined to minimize undetected problems or conditions. Table 1 contains a list of the dry wells located in the B Tank Farm as well as information concerning the identity, level, and depth of contamination.

The data available for this analysis are limited. Some of the limitations are the:

- Inability to identify when down-hole contamination is a result of vadose zone transport or drag down during casing installation
- Insufficient gross gamma ray data to establish a statistical trend or rigorous statistical analysis
- Lack of HPGe data (eg. 20-00-23 was not logged with the HPGe)
- Incomplete time interval over which data are available
- Insufficient borehole depth
- Inability to identify isotopes that have decayed to levels below the detection limits of the SGLS HPGe detector.

Table 1. B Tank Farm Borehole Contaminate Zones

Borehole Number	Survey Depth (feet)	Number of Surveys	Probe Type	Category	Zone Top (feet)	Zone Base (feet)	Max GTP (ftxc/s)	Year Max GTP	Isotopes Present
20-00-01	100'	164	4	^a Undetermined	34	44	50	1980	Cs ¹³⁷
				^a Undetermined	50	63	400	1975	Cs ¹³⁷
				^a Undetermined	90	98	50	1980	Cs ¹³⁷
20-00-02	130'	298	4	^b Clean	-	-	-	-	-
20-00-05	145'	163	4	^c Stable	45	60	300	1975	Cs ¹³⁷ , Co ⁶⁰
20-00-07	77'	190	4	^b Clean	-	-	-	-	-
20-00-09	140'	191	4	^b Clean	-	-	-	-	-
20-00-11	160'	182	4	^c Stable	45	54	120	1975	Cs ¹³⁷
20-00-23	60'	154	4	^b Clean	-	-	-	-	-
20-01-01	110'	258	4	^c Stable	35	46	4000	1975	Cs ¹³⁷ , Co ⁶⁰
				Unstable Early	48	65	2000	1976	Co ⁶⁰
20-01-03	135'	265	4	^b Clean	-	-	-	-	-
20-01-05	100'	247	4	Unstable Early	46	60	450	1975	^a Ru ¹⁰⁶
20-01-06	60'	266	4	Unstable Early	17	40	3500	1976	Cs ¹³⁷ , Eu ¹⁵⁴
				Unstable Early	48	63	2800	1976	Cs ¹³⁷ , Co ⁶⁰
20-01-07	100'	260	4	^c Stable	17	26	150	1975	Cs ¹³⁷ , ^a Ru ¹⁰⁶
				Unstable Early	46	58	800	1975	^a Ru ¹⁰⁶
20-01-11	100'	258	4	^c TF Activity	0	12	150K	1976	Cs ¹³⁷
20-02-03	100'	310	4	^b Clean	-	-	-	-	-
20-02-05	140'	307	4	^b Clean	-	-	-	-	-
20-02-07	100'	307	4	^b Clean	-	-	-	-	-
20-02-09	100'	362	4	^b Clean	-	-	-	-	-
20-02-11	100'	302	4	^c TF Activity	0	16	250K	1977	Cs ¹³⁷
20-03-02	110'	404	4	^c TF Activity	0	10	175	1985	Cs ¹³⁷

20-03-03	100'	407	4	*Stable	0	10	180	1975	Cs ¹³⁷
				*Stable	48	62	325	1975	*Ru ¹⁰⁶
20-03-06	135'	456	4	*TF Activity	0	12	500	1984	Cs ¹³⁷
				*Stable	28	42	900	1975	*Ru ¹⁰⁶
20-03-09	100'	400	4	*TF Activity	0	10	100	1975	Cs ¹³⁷
20-03-11	100'	399	4	*TF Activity	0	12	6K	1978	Cs ¹³⁷ ; Co ⁶⁰
20-04-03	100'	384	4	*TF Activity	0	10	2000	1975	Cs ¹³⁷
				*TF Activity	10	22	800	1975	Cs ¹³⁷
20-04-06	135'	444	4	*TF Activity	0	10	3500	1975	Cs ¹³⁷
20-05-06	120'	190	14	*Stable	40	60	* 32K	1980	Cs ¹³⁷
				*Undetermined	70	120	* 1200	1980	Cs ¹³⁷
20-06-02	100'	316	4	*TF Activity	0	8	7K	1975	Cs ¹³⁷
20-06-03	140'	321	4	*Clean	-	-	-	-	-
20-06-06	100'	117	4	*TF Activity	0	6	200	1981	Cs ¹³⁷
				*Stable	6	20	400	1981	Cs ¹³⁷
				*Stable	40	60	200K	1981	Cs ¹³⁷
				*Stable	60	100	8K	1981	Cs ¹³⁷
20-06-11	125'	322	4	*Clean	-	-	-	-	-
20-07-02	100'	342	4	*Stable	31	62	70K	1975	Cs ¹³⁷ ; Eu ¹⁵⁴
				*Stable	74	99	1300	1975	Cs ¹³⁷ ; Eu ¹⁵⁴
20-07-05	100'	260	4	*Clean	-	-	-	-	-
20-07-08	135'	264	4	*Clean	-	-	-	-	-
20-07-11	100'	329	4	Stable	68	80	80	1975	*Sr ⁹⁰ /RemoteCs
20-08-02	110'	397	4	Stable	50	65	100	1975	Cs ¹³⁷
				*Undetermined	85	110	300	1975	Co ⁶⁰
20-08-03	130'	451	4	*TF Activity	0	10	2000	1978	Cs ¹³⁷
20-08-05	100'	454	4	*Clean	-	-	-	-	-
20-08-07	100'	409	4	*Undetermined	64	76	60	1975	*Sr ⁹⁰ /RemoteCs
20-08-09	130'	401	4	*Undetermined	120	132	100	1980	Co ⁶⁰
20-09-02	101'	425	4	*Clean	-	-	-	-	-
20-09-06	102'	467	4	Unstable Early	72	92	100	1984	Co ⁶⁰
20-09-11	100'	476	4	*TF Activity	0	15	50K	1979	Cs ¹³⁷
20-10-02	100'	255	4	Unstable	65	90	3000	1980	Co; *Sr ⁹⁰ /RemoteCs
20-10-07	100'	265	4	Unstable	15	26	10K	1976	Cs ¹³⁷ ; Eu ¹⁵⁴
				*Stable	46	56	900	1975	Cs ¹³⁷
20-10-09	135'	257	4	*Clean	-	-	-	-	-
20-10-12	120'	267	2	*Stable	18	80	*25K	1980	Cs ¹³⁷
				*Stable	80	100	* 800	1980	Cs ¹³⁷
20-11-09	120'	343	4	*Stable	32	42	150	1977	Cs ¹³⁷
20-12-02	125'	314	4	*Clean	-	-	-	-	-
20-12-03	100'	408	4	*Stable	60	90	4000	1975	Co ⁶⁰ ; *Ru ¹⁰⁶
20-12-06	105'	331	4	*Stable	28	54	2500	1975	*Ru, Sr/RemoteCs
20-12-07	100'	309	4	*Undetermined	5	20	200	1975	Cs ¹³⁷
20-12-11	100'	308	4	*Stable	5	18	200	1975	Cs ¹³⁷

*Probe type: 2 = Red GM, least sensitive; reads highest level of gamma ray activity and therefore used in zone of high activity

4 = NaI, most sensitive, reads lowest level of gamma ray activity and therefore used in zones of limited activity

14 = Shielded NaI, moderate sensitivity, reads about ten times lower than the NaI probe

Caution must be used when relating GTP values in zones recorded with different probe types.

^bNo systematic trend above the detection threshold for the gross gamma ray logs is indicated by the data.

^cAn irregular change in the intensity of gross gamma rays between successive surveys at or near the surface suggests that contamination may be the result of tank farm activities or logging procedure changes and not vadose zone transport.

^dStability cannot be determined due to insufficient data, exceeding the system design criteria (both upper and lower limits) for recording gross gamma ray data, or possible effects of depth shift or surface activities.

^eThe decay rate of the isotope(s) identified in the zone matches the change in concentration of the isotope(s) as measured over time, and no noticeable deviation from the match is apparent within the period that gross gamma ray data were collected.

^fCurrently, isotopes cannot be identified from gross gamma ray data alone; therefore, if the period of instability is prior to the collection of SGLS data, isotopes with a rapid rate of decay (e.g., Ru-106), or at levels that decay below detection limits, may not be identified. Also, beta-emitting isotopes such as Sr-90 cannot be directly detected by the SGLS. The presence of such isotopes is hypothesized.

^gStable vs. unstable is an apparent condition limited by the time interval over which data were collected and the level of contamination, and is not a statement concerning the fixed or mobile nature of a given isotope.

2 Subsurface Condition Categories

2.1 Clean

A clean well is one that exhibits no observable change in the character of the activity over the logging history of the well, and does not have any isotopes identified by the SGLS greater than the average background levels of naturally occurring gamma ray emitting isotopes. Non-gamma emitting radionuclides or other contaminant species might be present but are not detected by either HPGe or gross gamma logging. Although spurious surveys (those readings that do not repeat over time) may exist in the frequency clean and the average background plots, the trend of the data is clear. Seventeen of 52 wells in the B Tank Farm are considered clean (Figure 2) and are listed in Table 2. The remaining 34 wells are considered contaminated and are further categorized and discussed in the following sections.

Table 2. B Tank Farm Clean Wells

Borehole Number	Survey Depth	Category
20-00-02	130'	Clean
20-00-07	77'	Clean
20-00-09	140'	Clean
20-00-23	60'	Clean
20-01-03	135'	Clean
20-02-03	100'	Clean
20-02-05	140'	Clean
20-02-07	100'	Clean
20-02-09	100'	Clean
20-06-03	140'	Clean
20-06-11	125'	Clean
20-07-05	100'	Clean
20-07-08	135'	Clean

20-08-05	100'	Clean
20-09-02	101'	Clean
20-10-09	135'	Clean
20-12-02	125'	Clean

2.2 Contaminated

Specific gamma-emitting isotopes that are in the subsurface are identified from data acquired by the SGLS. Integration of the decay rate of the radionuclide species identified by the SGLS with the gross gamma ray data collected during the dry well surveillance program provides insight as to the rate of change, if any, of radionuclides in the subsurface. During the analysis of B Tank Farm data, five gamma-emitting isotopes were identified or hypothesized to have occurred in radioactive contamination zones. They are cesium-137 (Cs-137), cobalt-60 (Co-60), europium-154 (Eu-154), strontium-90 (Sr-90), and ruthenium-106 (Ru-106). Cesium-137 is the most commonly identified isotope and is often not associated with other isotopes, although it is found with one or more of the other isotopes in eight wells. Remote Cs-137 (i.e. at some distance from the borehole) or Sr-90 is hypothesized to occur near four wells to account for a rise in total gamma energy incompatible with the levels of isotopes detected by the HPGe.

Ruthenium-106 is not currently present above the detection threshold in any of the wells examined by the SGLS. This is due to the very rapid exponential decay of Ru-106 over a short half-life of 1.02 years. Ruthenium-106 is hypothesized to have been present in six wells in 1975 on the basis of the gross gamma ray data and the resulting GTP calculations that mimic the decay rate of Ru-106, coupled with the inventory list of radionuclides known to be in the tanks during that time. Ruthenium-106 is assumed to be present if the decay curve for Ru-106 matches the GTP plot. If a decay curve does not match, then the contaminants cannot be identified without additional information.

Strontium-90 is indirectly indicated by the SGLS since it emits beta particles and not gamma rays. However, a high gross gamma ray response that is not associated with a specific source isotope (as detected or not detected by the SGLS) is hypothesized to result from the presence of Sr-90 in four wells in the B Tank Farm. Gross gamma ray data provide information about rates of decay for the isotopes present provided subsurface conditions are stable, (i.e. no net addition, subtraction or movement, of contaminant). Other beta-emitting isotopes can cause an elevated gross gamma ray response; isotopes with half-lives similar to that for Sr-90 are hypothesized to be present. In the four cases, the half-life for Sr-90 fits with the gross gamma ray data and the calculated decay rate. In order for instruments to detect an elevated gross gamma ray response due to beta particles, a large amount of source material such as Sr-90 needs to be present. An alternative possible cause of elevated gross gamma with no visible photo peaks associated with a specific gamma emitting radionuclide (identified by HPGe) is a strong gamma source located remotely from the detection point (eg. Remote Cs-137).

The isotopes identified in B Farm with the SGLS exist primarily under four categories of subsurface conditions: tank farm activity, undetermined, stable, and unstable. Two unstable conditions and several "unstable early" conditions are also present in B Tank Farm. Dry well locations (centered beneath the borehole name on the map) are labeled with the conditions of subsurface zones and are shown in Figure 2. A different condition can be indicated for each contaminated zone within a well that exhibits multiple zones of contamination.

2.2.1 Tank Farm Activity

A sudden, significant change in the intensity of gross gamma rays between successive gross gamma surveys at or near the ground surface suggests that contamination may have resulted from tank farm

activities or logging procedure changes. Vadose zone transport is expected to occur with slower and a monotonic change and is not indicated by these surveys. Radioactive contamination occurs near the surface in twelve wells, apparently as the result of tank farm activities (i.e., logging procedure changes, transfer line operations, valve box and conduit leaks, surface spills, etc.). These wells are listed in Table 3.

Figure 2. B Tank Farm Radiation Zone Categories

Table 3. B Tank Farm Activity Zones

Borehole Number	Survey Depth (feet)	Category	Zone Depth (feet)	Max GTP (fxc/s)	Year Max GTP	Isotopes Present	Comments
20-01-11	100'	TF Activity	0-12	150K	1976	Cs ¹³⁷	
20-02-11	100'	TF Activity	0-16	250K	1977	Cs ¹³⁷	
20-03-02	110'	TF Activity	0-10	175	1985	Cs ¹³⁷	
20-03-06	135'	TF Activity	0-12	500	1984	Cs ¹³⁷	
20-03-09	100'	TF Activity	0-10	100	1975	Cs ¹³⁷	
20-03-11	100'	TF Activity	0-12	6K	1978	Cs ¹³⁷ ; Co ⁶⁰	
20-04-03	100'	TF Activity	0-10 10-22	2000 800	1975 1975	Cs ¹³⁷ Cs ¹³⁷	
20-04-06	135'	TF Activity	0-10	3500	1975	Cs ¹³⁷	
20-06-02	100'	TF Activity	0-8	7K	1975	Cs ¹³⁷	
20-06-06	100'	TF Activity	0-6	200	1981	Cs ¹³⁷	
20-08-03	130'	TF Activity	0-10	2000	1978	Cs ¹³⁷	
20-09-11	100'	TF Activity	0-15	50K	1979	Cs ¹³⁷	

2.2.2 Undetermined

Infrequently, stability cannot be determined due to: gross gamma energy levels exceeding the system design criteria (both upper and lower limits), insufficient data, possible effects of depth shift, and surface activities. Eight zones out of the 52 wells examined are undetermined: These zones are listed in Table 4.

Table 4. B Tank Farm Undetermined Zones

Borehole Number	Survey Depth (feet)	Category	Zone Depth (feet)	Max GTP (fxc/s)	Year Max GTP	Isotopes Present	Comments
20-00-01	100'	Undetermined	34-44 90-98	50 50	1980 1980	Cs ¹³⁷ Cs ¹³⁷	GTP results are scattered on the plot and show higher values and high variability before 1983. After 1983, the few data points (because of infrequent logging) follow a Cs-137 decay curve. The activity is low level, (10 pCi/g or less).
20-00-01	100'	Undetermined	50-63	400	1975	Cs ¹³⁷	After 1983, GTP follows decay curve of Cs-137, but infrequent logging generated too few data points.
20-05-06	120'	Undetermined	70-120	1200	1980	Cs ¹³⁷	Shielded NaI Probe type. GTP values follow Cs-137 decay curve, but infrequent logging generated too few data points.
20-08-02	110'	Undetermined	85-110	300	1975	Co ⁶⁰	GTP declines markedly in 1980, then follows the decay curve of Co-60. Abrupt changes could be attributed to either formation changes or logging conditions at the base of the borehole.
20-08-07	100'	Undetermined	64-76	60	1975	Sr ⁹⁰ /Re-moteCs ¹³⁷	GTP is low level with high statistical uncertainty.
20-08-09	130'	Undetermined	120-132	100	1980	Co ⁶⁰	GTP is low level and erratic and the zone is at the base of borehole. Therefore, this

							zone is characterized undetermined. HPGe showed low levels of Co-60 at base of borehole
20-12-07	100'	Undetermined	5-20	200	1975	Cs ¹³⁷	GTP is erratic and low level before 1984; there are too few scattered points after 1984.

2.2.3 Stable

The subsurface condition of a zone with radioactive contamination is considered stable when:

- The decay rate of the isotope(s) identified with SGLS matches the trend observed in the GTP of the gross gamma ray data
- Contaminants continue to decay at a rate consistent with the hypothesized isotope(s) half-life
- No noticeable change in concentration is apparent over the short time interval that data were collected.

Twenty two zones are considered stable and are listed in Table 5.

Table 5. B Tank Farm Stable Zones

Borehole Number	Survey Depth (feet)	Category	Zone Depth (feet)	Max GTP (flux/s)	Year Max GTP	Isotopes Present	Comments
20-00-05	145'	Stable	45-60	300	1975	Cs ¹³⁷ , Co ⁶⁰	
20-00-11	160'	Stable	45-54	120	1975	Cs ¹³⁷	
20-01-01	110'	Stable	35-46	4000	1975	Cs ¹³⁷	
20-01-07	100'	Stable	17-26	150	1975	Cs ¹³⁷ , Ru ¹⁰⁶	
20-03-03	100'	Stable	0-10	180	1975	Cs ¹³⁷	
20-03-03	100'	Stable	48-62	325	1975	Ru ¹⁰⁶	
20-03-06	135'	Stable	28-42	900	1975	Ru ¹⁰⁶	
20-05-06	120'	Stable	40-60	32K	1980	Cs ¹³⁷	Shielded Nal
20-06-06	100'	Stable	40-60	400	1981	Cs ¹³⁷	
20-06-06	100'	Stable	60-100	200K	1981	Cs ¹³⁷	
20-06-06	100'	Stable	6-20	8K	1981	Cs ¹³⁷	
20-07-02	100'	Stable	31-62	70K	1975	Cs ¹³⁷ , Eu ¹⁵⁴	
20-07-02	100'	Stable	74-99	1300	1975	Cs ¹³⁷ , Eu ¹⁵⁴	
20-07-11	100'	Stable	68-80	80	1975	Sr ⁹⁰ /RemoteCs ¹³⁷	
20-08-02	110'	Stable	50-65	100	1975	Cs ¹³⁷	
20-10-07	100'	Stable	46-56	900	1975	Cs ¹³⁷	
20-10-12	120'	Stable	18-80	25K	1980	Cs ¹³⁷	Red GM
20-10-12	120'	Stable	80-100	800	1980	Cs ¹³⁷	Red GM
20-11-09	120'	Stable	32-42	150	1977	Cs ¹³⁷	
20-12-03	100'	Stable	60-90	4000	1975	Co ⁶⁰ , Ru ¹⁰⁶	
20-12-06	105'	Stable	28-54	2500	1975	Ru ¹⁰⁶ , Sr ⁹⁰ /RemoteCs ¹³⁷	

20-12-11	100'	Stable	5-18	200	1975	Cs ¹³⁷	
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*Currently, isotopes cannot be identified from gross gamma ray data alone; therefore, if the period of instability is prior to the collection of SGLS data, isotopes with a rapid rate of decay (e.g., Ru-106), or at levels that decay below detection limits, may not be identified.

The mobility of the radioactive contaminants in the subsurface soils before or after the gross gamma ray and SGLS data collection period is undetermined. If a new driver were introduced, such as the influx of a large volume of liquid, contaminants could be remobilized. Similarly, a change in geochemical conditions in the soil could also affect mobility. Given the current gross gamma and SGLS data, it cannot be determined if remobilization will or will not occur.

2.2.4 Unstable

The subsurface condition of a zone with radioactive contamination is considered unstable when, at some point within the time interval of data collection, contamination was not decreasing at the decay rate of the isotope(s) identified with SGLS. In this case, the decay curve does not match the trend observed in the GTP of the identified or hypothesized isotope. In the B Tank Farm, two zones are identified which exhibited instability within the time period that gross gamma ray data were collected. In another six zones, instability occurs during the earlier years of data collection for certain depth intervals. A discussion of unstable and "unstable early" zones is presented in Table 6.

Table 6. B Tank Farm Unstable and Unstable Early Zones

Borehole Number	Survey Depth (feet)	Category	Zone Depth (feet)	Max GTP (Rxc/s)	Year Max GTP	Isotopes Present	Comments
20-10-02	100'	Unstable	65-90	3000	1980	Co ⁶⁰ , Sr ⁹⁰ /Re moteCs ¹³⁷	The stack plot demonstrates downward movement of gamma-emitting contaminants. GTP increases from 1975 to 1981, then decreases with a minor increase in 1985. The total gamma energy on the SGLS log exceeds that produced by the Co-60 and Cs-137 (HPGe identified). There are too few points to confirm the decay is from Co-60 or an unidentified isotope with a 30 year half life (Sr-90 is hypothesized).
20-10-07	100'	Unstable	15-26	10K	1976	Cs ¹³⁷ , Eu ¹⁵⁴	GTP has multiple time intervals of rapid increases and decreases, which clearly show an unstable period from 1975 to 1984. A fit for the last few years of the grade thickness product for Cs-137 and Eu-154 could not be established.
20-01-01	110'	Unstable Early	48-65	2000	1976	Cs ¹³⁷ , Co ⁶⁰	GTP increases from 1975 to 1976-77, then decreases steeply until 1982. After 1982, curve approximates Co-60 decay but with few data points. Therefore, this zone is characterized Unstable Early

20-01-05	100'	Unstable Early	46-60	450	1975	Ru ¹⁰⁶	GTP increases sharply in 1975-76 and then declines markedly after 1976—approximating but not exactly following Ru-106 decay (other isotope(s) may be present). Therefore, Unstable Early
20-01-06	60'	Unstable Early	17-40	3500	1976	Cs ¹³⁷ ; Eu ¹⁵⁴	GTP decreases after 1982 consistent with decay of Eu-154 and Cs-137, but decays pre-1982 at a more rapid rate caused by an unknown isotope.
20-01-06	60'	Unstable Early	48-63	2800	1976	Cs ¹³⁷ ; Co ⁶⁰	Rapid increases in GTP show influx of contamination in 1976 and 1979, with subsequent rapid declines showing the effect of a short-lived isotope. Data for 1983 through 1994 matches combined decay curve for Co-60 and Cs-137.
20-01-07	100'	Unstable Early	46-58	800	1975	Ru ¹⁰⁶	GTP after 1975 does not follow the decay of Ru-106 and is caused by an unknown isotope(s).
20-09-06	102'	Unstable Early	72-92	100	1984	Co ⁶⁰	GTP increases from 1975 to 1984, then decays consistent with decay curve of Co-60 (HPGe identified).

3 Details of Contaminated Conditions

3.1 Stable Zones

Several zones within a number of wells exhibit gross gamma ray activity above natural background. Many of these radioactive intervals are observed to be stable as verified by the change in GTP over time which coincides with the decay rate of the isotope(s) identified or hypothesized to have been present in the well during the time interval data were collected. The isotopes present in these stable zones vary and are presented in Table 5. In general, they occur as follows:

- Cs-137 is present in all but eight (of 51) zones, sometimes with other isotopes. In 19 of these zones, it is stable.
- Sr-90 and/or Remote Cs-137 (i.e. at some distance from the borehole) is hypothesized in four zones, two of which are stable.
- Co-60 is present in ten zones, sometimes with other isotopes. Three of these zones are stable.
- Ru-106 is hypothesized to have existed early in the history of seven zones, sometimes with other isotopes. Five of these zones are stable.
- Eu-154 is present in four zones, usually with Cs-137. Two of these zones are stable.

The fixed decay rate of the isotope(s) present is used to calculate the decay line (Figure 3). Table 7 lists the half-life of the isotopes encountered in the B Tank Farm.

When a contaminated interval contains multiple isotopes, the intensity of the slowest decay component is plotted to match the data over the most recent time period for which data exist. Faster decay isotopes are then clearly indicated as necessary to match the trend of the GTP values. When the decay curve fits the GTP plot, a stable condition is said to exist. When the decay curve does not fit any portion of the GTP plot, stability cannot be established. The factors responsible for this instability are beyond the scope of this report.

Figure 3. Radionuclide Half-life Decay Rates

Table 7. Half-life of Isotopes Identified in the B Tank Farm Boreholes

Isotope	Half-life Years
Ru ¹⁰⁶	1.02
Co ⁶⁰	5.27

Eu ¹⁵⁴	8.5
Sr ⁹⁰	28.5
Cs ¹³⁷	30.17

3.2 Depth of Contamination

Most of the dry wells within the B Tank Farm show some contamination, with contamination spread throughout the farm and not concentrated within a limited geographic area. Only 17 of 52 wells (33%) are categorized as Clean. Another twelve wells show surface contamination (categorized as Tank Farm Activity). Figures 4, 5, and 6 depict borehole locations (centered beneath the borehole name) and depth to top of contamination and the isotope(s) present at that depth (Figure 4), depth to bottom of contamination and the isotope(s) present at that depth (Figure 5); and locations where GTP values are greater than 1,000 ft*c/s (Figure 6). In general, the contaminated intervals are less than 20 feet thick, but are as much as 80 continuous feet in some areas (e.g., 18 to 100 ft. in borehole 20-10-12). One borehole (20-06-06) contains four distinct zones, with contamination essentially continuous from ground surface to 100 ft., the total depth of the borehole. Several boreholes exhibit contamination at or very close to the bottom of the borehole, but contamination is not continuous throughout the entire borehole as it is in borehole 20-06-06.

The observable maximum depth of contamination (Figure 5) is dependent on the depth to which detectors penetrated the subsurface. Depth control issues related to logging make much of the data at the surface prior to 1983 unusable for evaluating contaminant conditions. Depth control issues also inhibit the ability to identify any downward movement of contamination during this time interval, prior to 1983. However, where inconsistent depth control is not an issue, data analysis can identify movement of contamination by the changes in the gross gamma ray activity occurring at a rate that is faster than the decay rate of the isotope(s) present in the zone. Downward migration of a peak over time in a borehole with good depth control also indicates contaminant transport. The stack plot for borehole 20-10-02 shows contamination to have migrated 75 ft. downward from 1982 to 1987. If contamination continues to move away from the well, whether downward or laterally, it is reasonable to assume that movement would continue in the same manner beyond the confines of the well, provided subsurface conditions have not changed. There is verifiable contamination at the bottom of only four wells (20-05-06, 20-06-06, 20-07-02, and 20-10-12). In one well (20-05-06), the condition of Cs-137 is undetermined, and there is not enough evidence to indicate if this Cs-137 contamination went deeper than the bottom of the well. During some logging operations prior to 1984, there may have been a few to several seconds of delay between when the operator activated the detector and when the hoist was activated. Such an occurrence increases the counting time at the bottom of the hole and leads to artificially high counts that do not reflect actual conditions.

Wells that have high contaminant levels below the surface may indicate proximity to infiltration or a leak event. Figure 6 depicts zones where the GTP is greater than 1,000 ft*c/s. GTP exceeds 1,000 in 18 wells, with values ranging as high as 250,000 for the NaI detector (25,000 for the Red GM detector). Caution must be used when relating GTP values in zones recorded with different probe types (Randall 1999) since they were designed to read different intensities of contamination. GTP values for the shielded NaI probe and for the Red Gm are reported for two wells (20-05-06 and 20-10-12, respectively). These values are lower than those reported for the unshielded NaI probe because of different detection efficiencies. The shielded NaI and Red GM probes are used where the activity levels in the soil are high and would saturate the unshielded NaI probe. In addition, the GTP values for intervals of different thickness are not directly comparable. Since GTP incorporates both the depth interval and the intensity of gross gamma ray activity, possible differences in interval thickness must be accounted for before comparing the GTP values between intervals. The distribution of GTP values with depth range (in order of depth range) and contributing isotope(s) is shown in Table 8.

Figure 4. B Tank Farm Top of Contamination

Figure 6. B Tank Farm Grade Thickness Product Greater Than 1,000 ft*c/s

Table 8: B Tank Farm GTP Depth Range and Contributing Isotopes

Borehole Number	Zone Depth (feet)	*Probe Type	Max GTP (fxc/s)	Year Max GTP	Isotopes Present
20-06-02	0-8	4	7K	1975	Cs ¹³⁷
20-03-02	0-10	4	175	1985	Cs ¹³⁷
20-03-03	0-10	4	180	1975	Cs ¹³⁷
20-03-09	0-10	4	100	1975	Cs ¹³⁷
20-04-06	0-10	4	3500	1975	Cs ¹³⁷
20-08-03	0-10	4	2000	1978	Cs ¹³⁷
20-06-06	0-100	4	200K	1981	Cs ¹³⁷
20-01-11	0-12	4	150K	1976	Cs ¹³⁷
20-03-11	0-12	4	6K	1978	Cs ¹³⁷ , Co ⁶⁰
20-09-11	0-15	4	50K	1979	Cs ¹³⁷
20-02-11	0-16	4	250K	1977	Cs ¹³⁷
20-04-03	0-22	4	2000	1975	Cs ¹³⁷
20-03-06	0-42	4	900	1984	Cs ¹³⁷ , Ru ¹⁰⁶
20-12-11	5-18	4	200	1975	Cs ¹³⁷
20-12-07	5-20	4	200	1975	Cs ¹³⁷
20-10-07	15-56	4	10K	1976	Cs ¹³⁷ , Eu ¹⁵⁴
20-01-07	17-58	4	800	1975	Cs ¹³⁷ , Ru ¹⁰⁶
20-01-06	17-63	4	3500	1976	Cs ¹³⁷ , Eu ¹⁵⁴ , Co ⁶⁰
20-10-12	18-100	2	*25K	1980	Cs ¹³⁷
20-12-06	28-54	4	2500	1975	*Ru ¹⁰⁶ , Sr ⁹⁰ /RemoteCs ¹³⁷
20-07-02	31-99	4	70K	1975	Cs ¹³⁷ , Eu ¹⁵⁴
20-11-09	32-42	4	150	1977	Cs ¹³⁷
20-00-01	34-98	4	400	1975	Cs ¹³⁷
20-01-01	35-65	4	4000	1975	Cs ¹³⁷ , Co ⁶⁰
20-05-06	40-120	14	*32K	1980	Cs ¹³⁷
20-00-11	45-54	4	120	1975	Cs ¹³⁷
20-00-05	45-60	4	300	1975	Cs ¹³⁷ , Co ⁶⁰
20-01-05	46-60	4	450	1975	*Ru ¹⁰⁶
20-03-03	48-62	4	325	1975	*Ru ¹⁰⁶
20-08-02	50-110	4	300	1975	Cs ¹³⁷ , Co ⁶⁰
20-12-03	60-90	4	4000	1975	Co ⁶⁰ , Ru ¹⁰⁶
20-08-07	64-76	4	60	1975	Sr ⁹⁰ /RemoteCs ¹³⁷
20-10-02	65-90	4	3000	1980	Co ⁶⁰ , Sr ⁹⁰ /RemoteCs ¹³⁷
20-07-11	68-80	4	80	1975	Sr ⁹⁰ /RemoteCs ¹³⁷
20-09-06	72-92	4	100	1984	Co ⁶⁰
20-08-09	120-132	4	100	1980	Co ⁶⁰

*Probe type: 2 = Red GM, least sensitive; used in zones of highest level of gamma ray activity.

4 = NaI, most sensitive, reads and is used in lowest level of gamma ray activity.

14 = Shielded NaI probe

Caution must be used when relating GTP values in zones recorded with different probe types.

*Hypothesized isotopes; currently cannot be identified from gross gamma ray data alone; therefore, if the period of instability is prior to the collection of SGLS data, isotopes with a rapid rate of decay (e.g., Ru-106), or at levels that decay below detection limits, may not be identified. Also, beta-emitting isotopes such as Sr-90 cannot be directly detected by the SGLS.

3.3 Isotopes Identified

Five man-made isotopes are known to be, or hypothesized to have been present, in the B Tank Farm at or above the detection limit based on the gross gamma ray log analysis. They are listed in Table 7 along with their half-life. Cesium-137 is the most common isotope found in the B Tank Farm and occurs in several places in the farm at varying depths and intensities. It most often is found alone, occurring with other isotopes in only nine zones, and is hypothesized to be present remotely (i.e. at some distance from

the borehole) in four wells. Strontium-90 is hypothesized to be present in four wells in the western part of the B Tank Farm. The SGLS log analysis often indicated the possibility of Strontium-90 due to elevated gross gamma with no observable increases in the identified radionuclides. Note that a strong remote source of Cesium-137 can also generate an elevated gross gamma response without observing elevations in photo peaks identified. The half-life of Ru-106 is short (1.02 years) and it is no longer detectable by the HPGe detector (HPGe surveys were performed in the mid-1990s). However, it is an isotope known to be in the tank waste inventory at the time when early logging was conducted, and the decay line calculated for Ru-106 matches well with the GTP calculations in the wells where it occurs. Both Co-60 and Eu-154 were detected by the HPGe tool. Co-60 was present in nine wells, and sometimes occurs with other isotopes. Eu-154 was present in three dry wells, usually also with Cs-137. The distribution and depth to top of the zones that occur in the B Tank Farm are shown in Figure 4.

3.4 Time Interval

Data evaluation is limited to the period when digital data were first captured in 1975 to the last digital data collection in 1994. Five general conditions are observed concerning the life cycle of contamination events over the time interval during which digital data were acquired:

- The middle or end of a period (i.e., contamination entered the soil around the borehole prior to initial digital data acquisition) where subsurface conditions were unstable at the beginning of digital logging and then apparently became stable,
- Stable subsurface conditions at the beginning of data collection, followed by the development of an unstable condition (indicated by a rate of change that is inconsistent with the decay rate of known isotopes in the well), followed by apparent stability,
- Stable subsurface conditions at the beginning of data collection, followed by an unstable condition (indicated by a rate of change that is inconsistent with the decay rate of known isotopes in the well) that does not become stable within the period of data collection,
- Unstable--Gamma-emitting isotopes entering the zone during some time interval and the GTP decay curve for that time does not match the decay curve of the hypothesized or known (causative) isotopes. Two zones are unsatable; six are unstable early in the period of the data recording.
- Insufficient digitally recorded data (i.e., too few data points resulting from infrequent logging), or there is so much scatter in the GTP that no definitive conclusion can be reached (i.e., the zone is classified as Undetermined)

For some near surface contaminant distribution profiles, the lack of depth control prior to 1986 results in data that cannot be used to determine the stability. After 1983 the upgraded logging system has excellent depth control and even complex distributions can be analyzed for stability.

There is insufficient information available for this report to determine if contamination at depth may be the result of well installation, e.g. drag down of preexisting contaminated soil during drilling.

3.5 Unstable Zones

There are two unstable zones identified in B Tank Farm. One zone extends from 65 to 90 feet in borehole 20-10-02 and the other zone extends from 15 to 26 feet in borehole 20-10-07.

4 Summary

By integrating SGLS data with historical dry well surveillance data, some knowledge is gained concerning the behavior of gamma-emitting radionuclides in the vadose zone over time. The SGLS and gross gamma ray data allow a rigorous analysis about the identity, character, and decay trends of isotopes present in contaminated intervals that were identified during the twenty-year period that the digital dry well data were collected.

Five subsurface conditions were identified during the analysis of the historical dry well data; and they are designated: clean, tank farm activity, undetermined, stable, and unstable. (Note that the category of unstable is further subdivided into 1) unstable, meaning changing other than decay at end of data collection; and 2) unstable early, meaning stability was reached before end of data collection.) This classification reflects the conditions in which contamination is present (or not present) within the period gross gamma ray data were collected electronically. It does not represent the conditions within the subsurface after 1994. However, an assumption that the trend of the data might continue unaltered seems reasonable, barring any event that changes the hydrogeologic or geochemical conditions in the subsurface.

There are seventeen wells that are classified as Clean. These wells occur throughout the farm and are not restricted to one geographic area of the B Farm.

The contaminated boreholes occur throughout the farm and are not restricted to one geographic area. One quarter (25%) of the contaminated zones are designated as having resulted from tank farm activities. Eight zones scattered throughout B Farm are classified as Undetermined. The levels of contamination in these zones are generally near the detection threshold; improved monitoring equipment and analysis techniques might be used to establish stability. Twenty-two zones are designated as Stable. Six zones are designated as Unstable Early (five of these surround tank B-101). Only two zones are considered Unstable; one zone extends from 65 to 90 feet in borehole 20-10-02 and shows some downward migration of contaminants. The other is from 15 to 26 feet in borehole 20-10-07, which shows lack of stability at the end of the data collection.

The most common gamma-emitting isotope present in the subsurface of the B Tank Farm is Cs-137, which was detected in almost all of the dry wells with contamination. The depth range of detection of Cs-137 is 0 to the bottom of a drywell (120 feet). Remote Cs-137 or Sr-90 is hypothesized to be present in four wells. The depth range of detection of Co-60 is also 0 to the bottom of a drywell (132 feet, in 20-08-09); the isotope occurs in nine wells. Europium-154 was detected with the HPGe in three wells at very low levels. Ruthenium-106 is hypothesized to have existed in the subsurface down as deep as 100 feet in six wells throughout the farm, although it is no longer at detectable levels.

There are 18 wells with contamination greater than 1,000 ft*c/s (equivalent NaI) GTP that is not due to tank farm activities. The wells are scattered throughout the B Tank Farm and are not concentrated in one geographic area. It is not known if contamination exists beneath the bottom of any given well.

According to the current understanding of chemistry, Ru-106 is very mobile in Hanford soils. It is unlikely to be identified using the analysis methods employed for this project since it should be unstable (i.e., moving). However, Ru-106 sometimes exists under stable conditions, as apparent by its identification in wells 20-01-07, 20-03-03, 20-03-06, 20-12-03 and 20-12-06. It is also present in some other boreholes in which there is instability early, followed by stability. Ru-106 appears in zones close to and beyond the depth of the tanks in B Tank Farm.

In order for the gross gamma logging equipment to identify an elevated gross gamma ray response due to Sr-90, the amount of Sr-90 has to be very high and near the borehole. Zones with high total gamma detected by SGLS with no causative isotopes identified with the HPGe are suspected to contain either

remote (i.e., several feet from the borehole) Cs-137 or Sr-90. This condition was noted in four boreholes: 20-07-11, 20-08-07, 20-10-02 and 20-12-06.

Information on how or whether geology and/or geochemistry affect the direction, rate and extent of isotope migration in the subsurface is not considered in this report. However, it is noted in several boreholes that total gamma due to natural potassium 40, uranium and thorium shows a marked increase at about the base of backfill (i.e., the top of the natural, in-place strata) in the B Tank Farm. This interface between materials of apparently different compaction may have influenced the mobility and distribution of contaminant isotopes. The base of backfill occurs at a depth of about 35-40 feet

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Brief Listing of General Observations and Special Data Presentation Conditions

General Observations

Several re-occurring features are listed in the following:

- Depth control after 1984 is excellent and detailed survey features can be analyzed in complex contaminant structures after this date.
- Around 1985 the frequency clean plot often shows a drop to a value slightly less than 100%. This effect is caused by the zero readings at the surface (i.e., a change in logging procedure).
- The first 2 to 5 surveys in 1975 often show an average (natural) background that is higher than the remaining surveys.
- Occasionally, different files with different dates show the exact same data indicating electronic copying errors.
- Before the onset of depth control (around 1984), the bottom reading for surveys varies between low and high count-rates for successive surveys. The pattern between surveys is apparently random.
- The KJT signature shows a pronounced lithology change between 45 and 50 feet for most of the wells in this tank farm, refer to the HPGe data.

Special Presentation Conditions

Several analysis processing and presentation methods are listed in the following:

- No data are deleted from the presentation plots; thus spurious surveys are often viewed.
- Stack plots are generated from a selected frequency (most common is quarterly). There is no selection based upon interpreted validity of the survey.
- During analysis each survey is processed and analyzed, even when some surveys are not viewed in a specific plot, such as the stack plot. A few spurious surveys can be presented on the stack plot that have valid data (generally due to tool failure). And the following survey, generally the next day is consistent with the surveys prior to the anomalous survey.
- The oldest and latest survey plots on a grade thickness plot are not necessarily the first and last in the electronic data set. The oldest and latest surveys that represent the true vadose zone condition are shown in the GTP and Clean plots. Thus the dates on the log plots may not match the dates listed in the table on the header page preceding each dry well presentation.
- The random readings at the bottom of surveys before 1984 are judged not valid unless the SGLS data indicates a measurable quantity at the bottom of a dry well.
- While other probe data exists in the set analyzed, these data are not processed in this work scope unless they affect the conclusion for the stability of the dry well. However, the presence of these data may be useful to the reader, and thus are listed in the table of the header page.

Two methods may be used to calculate the average background for grade thickness product. One is a threshold method, where all reading between 0 and 50 c/s are averaged to obtain an average background. The second is the use of an analyst selected depth interval. If the SGLS indicates multiple zones of average background in a dry well the second method is used to select the appropriate background for the GTP zone.

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B Tank Farm Peripheral (00) Wells

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This section contains the analysis results for vadose zone boreholes (dry wells) associated with the “B” Tank Farm in general, and are not associated with a specific tank.

Special Note:

Borehole 20-00-23 has historical gross gamma data, but HPGe log data are not available.

Borehole 20-00-01

Contamination (Cs-137) from 34-44 feet is Undetermined

Contamination (Cs-137) from 50-63 feet is Undetermined

Contamination (Cs-137) from 90-98 feet is Undetermined

The grade thickness products from 34 to 44 feet and between the depths of 90 and 98 feet are decreasing consistent with Cs-137 (HPGe identified) decay after 1983. From 1979 to 1983 the grade thickness products read higher than before and after this time period. Since the contamination is at such low levels, no clear classification can be made, and these intervals are designated undetermined.

The grade thickness product from 50 to 63 feet is decreasing consistent with Cs-137 (HPGe identified) decay after 1983. This depth interval has high enough levels of contamination that the deviation is not caused by background subtraction errors or depth shifting errors. After 1983 the frequency of logging is low and no clear classification is possible; therefore, this interval is designated undetermined.

Gross Gamma Survey Information

Probe Type Processed :	04: NaI
Other Probe Types :	02: Red GM; 03: Neutron
Survey Depth :	100 ft
First Survey Date :	1/14/1975
Last Survey Date :	6/14/1993
Number Surveys Processed :	164

Analysis Notes

Method Used to Compute Background :	Threshold 0<val<50 for 50-63 ft Fixed bkg (over 5-34 ft) for 34-44 ft Fixed bkg (over 65-90 ft) for 90-98 ft
Depth(s) where Contamination Identified in Gross Gamma Surveys :	34-44, 50-63, & 90-98 ft Undetermined
Analyst Name :	R.R. Randall
Company Name :	Three Rivers Scientific

20-00-01 Combination Plot

Analysis by: Three Rivers Scientific

Borehole 20-00-02**No Gamma Ray Emitting Contamination Identified**

Based upon gross gamma log data acquired between 1975 and 1993, there are no significant levels of gamma ray emitting contamination in the vadose zone between the depths of 2 and 130 feet. The HPGe logging system detected Cs-137 at 3 pCi/g or less from 2 to 130 feet, which is below detection threshold for the gross gamma data.

The stack plot shows an increase in the interval between 45 and 50 feet. This is the depth of KUT increase, refer to HPGe data.

Gross Gamma Survey Information

Probe Type Processed :	04: NaI
Other Probe Types :	03: Neutron
Survey Depth :	130 ft
First Survey Date :	1/13/1975
Last Survey Date :	6/14/1993
Number Surveys Processed :	298

Analysis Notes

Method Used to Compute Background :	Threshold 0<val<50
Depth(s) where Contamination Identified in Gross Gamma Surveys :	NONE
Analyst Name :	R.R. Randall
Company Name :	Three Rivers Scientific

20-00-02 Combination Plot

20-00-02 Combination Plot

Borehole 20-00-02

**No Gamma-Ray Emitting Contamination
 Above Survey Detection Threshold**

Analysis by: Three Rivers Scientific

Borehole 20-00-05**Contamination (Co-60 & Cs-137) from 45-60 feet is Stable**

The grade thickness product from 45 to 60 feet is decreasing consistent with a least square fit of Cs-137 & Co-60 (HPGe identified) decay. The least square fit yields a relative gross contribution from Co-60 to Cs-137 of 0.14 as of 6/15/1993.

Gross Gamma Survey Information

Probe Type Processed :	04: NaI
Other Probe Types :	03: Neutron
Survey Depth :	145 ft
First Survey Date :	1/13/1975
Last Survey Date :	6/15/1993
Number Surveys Processed :	163

Analysis Notes

Method Used to Compute Background :	Threshold 0<val<50
Depth(s) where Contamination Identified in Gross Gamma Surveys :	45-60 ft Stable
Analyst Name :	R.R. Randall
Company Name :	Three Rivers Scientific

20-00-05 Combination Plot

20-00-05 Combination Plot

Borehole 20-00-07**No Gamma Ray Emitting Contamination Identified**

Based upon gross gamma log data acquired between 1975 and 1993, there are no significant levels of gamma ray emitting contamination in the vadose zone between depths of 2 to 77 feet. The HPGe logging system detected Cs-137 at 3 pCi/g or less from 2 to 77 feet.

Gross Gamma Survey Information

Probe Type Processed :	04: NaI
Other Probe Types :	02: Red GM; 03: Neutron
Survey Depth :	77 ft
First Survey Date :	1/14/1975
Last Survey Date :	6/15/1993
Number Surveys Processed :	190

Analysis Notes

Method Used to Compute Background :	Threshold 0<val<50
Depth(s) where Contamination Identified in Gross Gamma Surveys :	NONE
Analyst Name :	R.R. Randall
Company Name :	Three Rivers Scientific

20-00-07 Combination Plot

Borehole 20-00-07

**No Gamma-Ray Emitting Contamination
 Above Survey Detection Threshold**

Analysis by: Three Rivers Scientific

Borehole 20-00-09**No Gamma Ray Emitting Contamination Identified**

Based upon gross gamma log data acquired between 1975 and 1994, there are no significant levels of gamma ray emitting contamination between depths of 2 and 123 feet. The HPGe logging system detected Cs-137 at 1 pCi/g or less from 2 to 123 feet. The stack plot shows that the borehole was logged from 0 to 140 feet until near 1986 when the log depth interval was changed to 0 to 123 feet.

Gross Gamma Survey Information

Probe Type Processed :	04: NaI
Other Probe Types :	02: Red GM; 03: Neutron
Survey Depth :	140 ft
First Survey Date :	1/14/1975
Last Survey Date :	6/14/1993
Number Surveys Processed :	191

Analysis Notes

Method Used to Compute Background :	Threshold 0<val<50
Depth(s) where Contamination Identified in Gross Gamma Surveys :	NONE
Analyst Name :	R.R. Randall
Company Name :	Three Rivers Scientific

20-00-09 Combination Plot

Borehole 20-00-09

**No Gamma-Ray Emitting Contamination
 Above Survey Detection Threshold**

Analysis by: Three Rivers Scientific

Borehole 20-00-11**Contamination (Cs-137) from 45-54 feet is Stable**

The grade thickness product from 45 to 54 feet is decreasing consistent with Cs-137 (HPGe identified) decay.

Gross Gamma Survey Information

Probe Type Processed :	04: NaI
Other Probe Types :	02: Red GM; 03: Neutron
Survey Depth :	160 ft
First Survey Date :	1/14/1975
Last Survey Date :	6/14/1993
Number Surveys Processed :	182

Analysis Notes

Method Used to Compute Background :	Fixed Bkg (over 10-40 ft) for 45-54 ft
Depth(s) where Contamination Identified in Gross Gamma Surveys :	45-54 ft Stable
Analyst Name :	R.R. Randall
Company Name :	Three Rivers Scientific

20-00-11 Combination Plot

20-00-11 Combination Plot

Borehole 20-00-23**No Gamma Ray Emitting Contamination Identified**

Based upon gross gamma log data acquired between 1977 and 1994, there are no significant levels of gamma ray emitting contamination in the vadose zone between depths of 2 and 60 feet. HPGe logging data are not available for this well.

Gross Gamma Survey Information

Probe Type Processed :	04: NaI
Other Probe Types :	03: Neutron
Survey Depth :	60 ft
First Survey Date :	8/3/1977
Last Survey Date :	6/14/1993
Number Surveys Processed :	154

Analysis Notes

Method Used to Compute Background :	Threshold 0<val<50
Depth(s) where Contamination Identified in Gross Gamma Surveys :	NONE
Analyst Name :	R.R. Randall
Company Name :	Three Rivers Scientific

Borehole 20-00-23

**No Gamma-Ray Emitting Contamination
 Above Survey Detection Threshold**

Analysis by: Three Rivers Scientific

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Tank B-101 Wells

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This section contains the analysis results for vadose zone boreholes (dry wells) associated with Tank 101 in the "B" Tank Farm.

Special Note: (none)

Borehole 20-01-01

Contamination (Cs-137 & Co-60) from 35-46 feet is Stable
Contamination (Co-60) from 48-65 feet is Unstable Early

The grade thickness product from 35 to 46 feet is decreasing consistent with a least square fit for Cs-137 and Co-60 (HPGe identified) decay. The relative gross gamma contribution of Co-60 to Cs-137 is 0.03 as of 6/7/94.

The grade thickness product from 48 to 65 feet is not decreasing consistent with Co-60 (HPGe identified) decay. Clearly, influx of Co-60 occurs before 1975 until 1976; after 1976 a linear (non-decay) decline is observed until 1980; therefore, this contamination interval is designated unstable early. The possibility of downward movement after 1982 cannot be judged due to the low intensity of the gross gamma. Thus, the grade thickness product was computed over a depth from 48 to 65 feet that is wide enough to cover possible downward movement if present.

Gross Gamma Survey Information

Probe Type Processed :	04: NaI
Other Probe Types :	02: Red GM; 03: Neutron
Survey Depth :	100 ft
First Survey Date :	1/13/1975
Last Survey Date :	6/7/1994
Number Surveys Processed :	258

Analysis Notes

Method Used to Compute Background :	Threshold 0<val<50 for 35-46 ft Fixed Bkg (over 65-95 ft) for 48-65 ft
Depth(s) where Contamination Identified in Gross Gamma Surveys :	35-46 ft Stable 48-65 ft Unstable Early
Analyst Name :	R.R. Randall
Company Name :	Three Rivers Scientific

20-01-01 Combination Plot

Borehole 20-01-03**No Gamma Ray Emitting Contamination Identified**

Based upon gross gamma log data acquired between 1975 and 1995, there are no significant levels of gamma ray emitting contamination in the vadose zone between depths of 2 and 135 feet.. The HPGe logging system detected Cs-137 at a depth of 2 feet at a concentration of 0.2 pCi/g.

Gross Gamma Survey Information

Probe Type Processed :	04: NaI
Other Probe Types :	02: Red GM; 03: Neutron
Survey Depth :	135 ft
First Survey Date :	1/13/1975
Last Survey Date :	6/07/1994
Number Surveys Processed :	265

Analysis Notes

Method Used to Compute Background :	Threshold 0<val<50
Depth(s) where Contamination Identified in Gross Gamma Surveys :	NONE
Analyst Name :	R.R. Randall
Company Name :	Three Rivers Scientific

20-01-03 Combination Plot

20-01-03 Combination Plot

Borehole 20-01-03

**No Gamma-Ray Emitting Contamination
Above Survey Detection Threshold**

Analysis by: Three Rivers Scientific

Borehole 20-01-05**Contamination (unknown) from 46-60 feet is Unstable Early**

The grade thickness product from 46 to 60 feet increases from before 1975 until 1976, and is rapidly decreasing after 1976. Ru-106 decay is plotted for reference only. The specific contaminant isotopes are unknown, but the early movement is indicated. No radionuclide is identified for this interval in 1994.

Gross Gamma Survey Information

Probe Type Processed :	04: NaI
Other Probe Types :	02: Red GM; 03: Neutron
Survey Depth :	100 ft
First Survey Date :	1/13/1975
Last Survey Date :	6/7/1994
Number Surveys Processed :	247

Analysis Notes

Method Used to Compute Background :	60-90 ft
Depth(s) where Contamination Identified in Gross Gamma Surveys :	46-60 ft Unstable Early
Analyst Name :	R.R. Randall
Company Name :	Three Rivers Scientific

20-01-05 Combination Plot

Borehole 20-01-06

Contamination (Eu-154 & Cs-137) from 17-40 feet is Unstable Early
Contamination (Co-60 & Cs-137) from 48-63 feet is Unstable Early

The grade thickness product from 17 to 40 feet is decreasing consistent with a least square fit of Eu-154 and Cs-137 (both HPGe identified) decay after 1982. A faster component of decay is possibly indicated from the gross gamma historical data, but such an isotope, as Co-60, is not detected by the HPGe log data. The least square fit for Eu-154 and Cs-137 yields a relative contribution of the gross from Eu-154 to Cs-137 of 0.54 as of 6/7/94. Note that this ratio is higher than would be expected from the HPGe data.

The grade thickness product from 48 to 63 feet exhibits two periods of contaminant influx, once in 1975 and again in 1979. The grade thickness product shows a faster decline than Cs-137 plus Co-60 (both HPGe identified). Co-60 and Cs-137 decay was least square fit for the time period from mid 1983 to 1994; resulting in a good match of the data over this time period. The least square fit for Co-60 and Cs-137 yields a relative contribution of the gross from Co-60 to Cs-137 of 2.7 as of 6/7/94. The stack plot indicates some evidence for downward movement, or lateral influx in a lower zone. The possible downward movement can also be below the bottom of the borehole; however, low levels of contaminant prohibit a clear conclusion.

Gross Gamma Survey Information

Probe Type Processed :	04: NaI
Other Probe Types :	02: Red GM; 03: Neutron
Survey Depth :	60 ft
First Survey Date :	5/21/1975
Last Survey Date :	6/7/1994
Number Surveys Processed :	246

Analysis Notes

Method Used to Compute Background :	Threshold 0<val<50
Depth(s) where Contamination Identified in Gross Gamma Surveys :	17-40 & 48-63 ft Unstable Early
Analyst Name :	R.R. Randall
Company Name :	Three Rivers Scientific

20-01-06 Combination Plot

Analysis by: Three Rivers Scientific

Borehole 20-01-07

Contamination (Ru-106) from 17-26 feet is Stable*
Contamination (unknown) from 46-58 feet is Unstable Early

The grade thickness product from 17 to 26 feet is decreasing consistent with a least square fit for Ru-106 (hypothesized) & Cs-137 (HPGe identified) decay. The relative gross gamma contribution of Ru-106 to Cs-137 is 8.3 as of 1/13/1975. *Both the scatter in the early data and the short time period for the decay of the possible Ru-106 component make the classification of stable uncertain. Also, the HPGe observed level of Cs-137 is typically below the gross gamma threshold.

The grade thickness product from 46 to 58 feet is not decreasing consistent with Ru-106 (hypothesized) decay. An Ru-106 decay curve is added for reference only. Since there is no good match with Ru-106 decay, the specific isotope is unknown. The rapid decline from 1975 to 1980 appears linear and not the character of decay.

Gross Gamma Survey Information

Probe Type Processed :	04: NaI
Other Probe Types :	02: Red GM; 03: Neutron
Survey Depth :	100 ft
First Survey Date :	1/13/1975
Last Survey Date :	6/7/1994
Number Surveys Processed :	260

Analysis Notes

Method Used to Compute Background :	Threshold 0<val<50 for 17-26 ft Fixed Bkg(over 60-90 ft) for 46-58 ft
Depth(s) where Contamination Identified in Gross Gamma Surveys :	17-26 ft Stable * 46-58 ft Unstable Early
Analyst Name :	R.R. Randall
Company Name :	Three Rivers Scientific

20-01-07 Combination Plot

Borehole 20-01-11**Contamination (Cs-137) from 0-12 feet is Tank Farm Activity**

The grade thickness product from 0 to 12 feet is decreasing consistent with Cs-137 (HPGe identified) decay after 1984. The stack plot shows the depth reference difference before and after 1984.

Gross Gamma Survey Information

Probe Type Processed :	04: NaI
Other Probe Types :	02: Red GM; 03: Neutron
Survey Depth :	100 ft
First Survey Date :	1/13/1975
Last Survey Date :	6/7/1994
Number Surveys Processed :	258

Analysis Notes

Method Used to Compute Background :	Threshold 0<val<50
Depth(s) where Contamination Identified in Gross Gamma Surveys :	0-12 ft Tank Farm Activity
Analyst Name :	R.R. Randall
Company Name :	Three Rivers Scientific

20-01-11 Combination Plot

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Tank B-102 Wells

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This section contains the analysis results for vadose zone boreholes (dry wells) associated with Tank 102 in the "B" Tank Farm.

Special Note: (none)

Borehole 20-02-03**No Gamma Ray Emitting Contamination Identified**

Based upon gross gamma data acquired between 1975 and 1994, there are no significant levels of gamma ray emitting contamination in the vadose zone between depths of 2 and 100 feet. The HPGe logging system detected Cs-137 at 0.4 pCi/g or less from 2 to 100 feet.

Gross Gamma Survey Information

Probe Type Processed :	04: NaI
Other Probe Types :	03: Neutron
Survey Depth :	100 ft
First Survey Date :	1/13/1975
Last Survey Date :	6/14/1993
Number Surveys Processed :	310

Analysis Notes

Method Used to Compute Background :	Threshold 0<val<50
Depth(s) where Contamination Identified in Gross Gamma Surveys :	NONE
Analyst Name :	R.R. Randall
Company Name :	Three Rivers Scientific

20-02-03 Combination Plot

Borehole 20-02-03

**No Gamma-Ray Emitting Contamination
 Above Survey Detection Threshold**

Analysis by: Three Rivers Scientific

Borehole 20-02-05**No Gamma Ray Emitting Contamination Identified**

Based upon gross gamma log data acquired between 1975 and 1994, there are no significant levels of gamma ray emitting contamination in the vadose zone between depths of 2 and 145 feet. The HPGe logging system detected Cs-137 at 2 pCi/g or less from 2 to 16 feet.

Gross Gamma Survey Information

Probe Type Processed :	04: NaI
Other Probe Types :	03: Neutron
Survey Depth :	145 ft
First Survey Date :	1/14/1975
Last Survey Date :	6/14/1993
Number Surveys Processed :	345

Analysis Notes

Method Used to Compute Background :	Threshold 0<val<50
Depth(s) where Contamination Identified in Gross Gamma Surveys :	NONE
Analyst Name :	R.R. Randall
Company Name :	Three Rivers Scientific

20-02-05 Combination Plot

20-02-05 Combination Plot

Borehole 20-02-05

**No Gamma-Ray Emitting Contamination
 Above Survey Detection Threshold**

Analysis by: Three Rivers Scientific

Borehole 20-02-07**No Gamma Ray Emitting Contamination Identified**

Based upon gross gamma log data acquired between 1975 and 1994, there are no significant levels of gamma ray emitting contamination in the vadose zone between depths of 2 and 100 feet. The HPGe logging system detected Cs-137 at 1 pCi/g or less from 2 to 30 feet.

Gross Gamma Survey Information

Probe Type Processed :	04: NaI
Other Probe Types :	03: Neutron
Survey Depth :	100 ft
First Survey Date :	1/14/1975
Last Survey Date :	6/14/1993
Number Surveys Processed :	307

Analysis Notes

Method Used to Compute Background :	Threshold 0<val<50
Depth(s) where Contamination Identified in Gross Gamma Surveys :	NONE
Analyst Name :	R.R. Randall
Company Name :	Three Rivers Scientific

20-02-07 Combination Plot

Borehole 20-02-07

**No Gamma-Ray Emitting Contamination
 Above Survey Detection Threshold**

Analysis by: Three Rivers Scientific

Borehole 20-02-09**No Gamma Ray Emitting Contamination Identified**

Based upon gross gamma log data acquired between 1975 and 1994, there are no significant levels of gamma ray emitting contamination in the vadose zone between depths of 2 and 100 feet. The HPGe logging system detected Cs-137 at 2 pCi/g or less and Co-60 at 0.2 pCi/g or less between depths of 2 and 100 feet.

Gross Gamma Survey Information

Probe Type Processed :	04: NaI
Other Probe Types :	03: Neutron
Survey Depth :	100 ft
First Survey Date :	1/14/1975
Last Survey Date :	6/14/1993
Number Surveys Processed :	362

Analysis Notes

Method Used to Compute Background :	Threshold 0<val<50
Depth(s) where Contamination Identified in Gross Gamma Surveys :	NONE
Analyst Name :	R.R. Randall
Company Name :	Three Rivers Scientific

20-02-09 Combination Plot

Borehole 20-02-09

**No Gamma-Ray Emitting Contamination
Above Survey Detection Threshold**

Analysis by: Three Rivers Scientific

Borehole 20-02-11**Contamination (Cs-137) from 0-16 feet is Tank Farm Activity**

The grade thickness product from 0 to 16 feet is erratic and not consistent with Cs-137 (HPGe identified) decay. Before 1977, the low readings could be caused by either depth reference errors or changes in contaminants. The gross gamma detectors used may be near saturation over the depth interval from 0 to 16 feet.

Gross Gamma Survey Information

Probe Type Processed :	04: NaI
Other Probe Types :	03: Neutron
Survey Depth :	100 ft
First Survey Date :	1/14/1975
Last Survey Date :	6/14/1993
Number Surveys Processed :	302

Analysis Notes

Method Used to Compute Background :	Threshold 0<val<50
Depth(s) where Contamination Identified in Gross Gamma Surveys :	0-16 ft Tank Farm Activity
Analyst Name :	R.R. Randall
Company Name :	Three Rivers Scientific

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Tank B-103 Wells

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This section contains the analysis results for vadose zone boreholes (dry wells) associated with Tank 103 in the "B" Tank Farm.

Special Note: (none)

Borehole 20-03-02**Contamination (Cs-137) from 0-10 feet is Tank Farm Activity**

The grade thickness product from 0 to 10 feet is erratic and not decreasing consistent with Cs-137 (HPGe identified) decay. The level of contamination is also very low and there is scatter in the data.

Gross Gamma Survey Information

Probe Type Processed :	04: NaI
Other Probe Types :	02: Red GM; 03: Neutron
Survey Depth :	110 ft
First Survey Date :	1/14/1975
Last Survey Date :	6/07/1994
Number Surveys Processed :	404

Analysis Notes

Method Used to Compute Background :	Threshold 0<val<50
Depth(s) where Contamination Identified in Gross Gamma Surveys :	0-10 ft Tank Farm Activity
Analyst Name :	R.R. Randall
Company Name :	Three Rivers Scientific

20-03-02 Combination Plot

20-03-02 Combination Plot

Borehole 20-03-03

Contamination (Cs-137) from 0-10 feet is Stable
Contamination (Ru-106) from 48-62 ft is Stable

The grade thickness product from 0 to 10 feet is decreasing consistent with Cs-137 (HPGe identified) decay. The match of the grade thickness product and the decay curve is very good considering depth reference errors near the surface.

The grade thickness product from 48 to 62 feet is decreasing consistent with Ru-106 (hypothesized) decay. The time during which the decay curve matches the data is short and the results are not totally conclusive; however, the contamination appears stable.

Gross Gamma Survey Information

Probe Type Processed :	04: NaI
Other Probe Types :	02: Red GM; 03: Neutron
Survey Depth :	100 ft
First Survey Date :	1/14/1975
Last Survey Date :	6/7/1994
Number Surveys Processed :	407

Analysis Notes

Method Used to Compute Background :	Threshold $0 < \text{val} < 50$ for 0-10 ft Fixed Bkg (over 65-90 ft) for 48-62 ft
Depth(s) where Contamination Identified in Gross Gamma Surveys :	0-10 & 48-62 ft Stable
Analyst Name :	R.R. Randall
Company Name :	Three Rivers Scientific

20-03-03 Combination Plot

Analysis by: Three Rivers Scientific

Borehole 20-03-06

Contamination (Cs-137) from 0-12 feet is Tank Farm Activity
Contamination (Ru-106) from 28-42 feet is Stable

The grade thickness product from 0 to 12 feet is erratic and is indicative of tank farm activities. Since 1986 the grade thickness product is consistent with Cs-137 (HPGe identified) decay.

The grade thickness product from 28 to 42 feet is decreasing consistent with Ru-106 (hypothesized) decay. Co-60 is detected with the HPGe over this depth interval, but at levels that are too low to detect with the gross gamma logging systems. The Ru-106 decays to zero by 1982, and no new influx of any contaminant occurs from 1982 until 1995.

Gross Gamma Survey Information

Probe Type Processed :	04: NaI
Other Probe Types :	02: Red GM; 03: Neutron
Survey Depth :	135 ft
First Survey Date :	1/14/1975
Last Survey Date :	6/7/1994
Number Surveys Processed :	456

Analysis Notes

Method Used to Compute Background :	Threshold 0<val<50
Depth(s) where Contamination Identified in Gross Gamma Surveys :	0-12 Tank Farm Activity 28-42 ft Stable
Analyst Name :	R.R. Randall
Company Name :	Three Rivers Scientific

20-03-06 Combination Plot

20-03-06 Combination Plot

Borehole 20-03-09**Contamination (Cs-137) from 0-10 feet is Tank Farm Activity**

The grade thickness product from 0 to 10 feet is erratic indicative of tank farm activities. After 1986, the grade thickness is decreasing consistent with Cs-137 (HPGe identified) decay.

Gross Gamma Survey Information

Probe Type Processed :	04: NaI
Other Probe Types :	02: Red GM; 03: Neutron
Survey Depth :	100 ft
First Survey Date :	1/14/1975
Last Survey Date :	6/7/1994
Number Surveys Processed :	400

Analysis Notes

Method Used to Compute Background :	Threshold 0<val<50
Depth(s) where Contamination Identified in Gross Gamma Surveys :	0-10 ft Tank Farm Activity
Analyst Name :	R.R. Randall
Company Name :	Three Rivers Scientific

20-03-09 Combination Plot

Borehole 20-03-11

Contamination (Co-60 & Cs-137) from 0-12 feet is Tank Farm Activity

The grade thickness product from 0 to 12 feet is decreasing consistent with a least square fit of Co-60 (hypothesized) & Cs-137 (HPGe identified) decay after mid 1977. Prior to mid 1977, the magnitude of change is beyond depth reference errors. Depth reference errors occurred before the upgraded logging system in about 1980. The relative contribution of the gross gamma from Co-60 to Cs-137 is 0.06 as of 6/7/1994. This level of Co-60 would not be detectable with the HPGe logging system. It is possible that no Co-60 was present between 1978 and 1995 and the grade thickness product only appears to decline consistent with the least square fit and the identity of other contaminant isotope(s) is masked by the erratic nature of the tank farm activities

Gross Gamma Survey Information

Probe Type Processed :	04: NaI
Other Probe Types :	02: Red GM; 03: Neutron
Survey Depth :	100 ft
First Survey Date :	1/14/1975
Last Survey Date :	6/7/1994
Number Surveys Processed :	399

Analysis Notes

Method Used to Compute Background :	Threshold 0<val<50
Depth(s) where Contamination Identified in Gross Gamma Surveys :	0-12 ft Tank Farm Activity
Analyst Name :	R.R. Randall
Company Name :	Three Rivers Scientific

20-03-11 Combination Plot

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Tank B-104 Wells

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This section contains the analysis results for vadose zone boreholes (dry wells) associated with Tank 104 in the "B" Tank Farm.

Special Note: (none)

Borehole 20-04-03

Contamination (Cs-137) from 0-10 feet is Tank Farm Activity
 Contamination (Cs-137) from 10-22 feet is Tank Farm Activity

The grade thickness products from 0 to 10 and 10 to 20 feet are erratic and indicative of tank farm activity. The levels of change are sufficiently high that depth reference errors alone cannot result in the observed erratic nature. The grade thickness product is decreasing consistent with Cs-137 (HPGe identified) decay after 1986.

Gross Gamma Survey Information

Probe Type Processed :	04: NaI
Other Probe Types :	03: Neutron
Survey Depth :	100 ft
First Survey Date :	1/14/1975
Last Survey Date :	6/15/1993
Number Surveys Processed :	384

Analysis Notes

Method Used to Compute Background :	Threshold 0<val<50
Depth(s) where Contamination Identified in Gross Gamma Surveys :	0-10 & 10-22 ft Tank Farm Activity
Analyst Name :	R.R. Randall
Company Name :	Three Rivers Scientific

20-04-03 Combination Plot

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Borehole 20-04-06**Contamination (Cs-137) from 0-10 feet is Tank Farm Activity**

The grade thickness product from 0 to 10 feet is erratic and indicative of tank farm activity. The gross gamma zone is so close to the surface, that depth reference errors may impact the classification. Slight errors in depth zero reference affect the grade thickness product for a thin zone near the surface. After 1984, the grade thickness product is decreasing consistent with Cs-137 (HPGe identified) decay.

Gross Gamma Survey Information

Probe Type Processed :	04: NaI
Other Probe Types :	02: Red GM; 03: Neutron
Survey Depth :	135 ft
First Survey Date :	1/9/1975
Last Survey Date :	6/15/1993
Number Surveys Processed :	444

Analysis Notes

Method Used to Compute Background :	Threshold 0<val<50
Depth(s) where Contamination Identified in Gross Gamma Surveys :	0-10 ft Tank Farm Activity
Analyst Name :	R.R. Randall
Company Name :	Three Rivers Scientific

20-04-06 Combination Plot

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Tank B-105 Wells

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This section contains the analysis results for vadose zone boreholes (dry wells) associated with Tank 105 in the "B" Tank Farm.

Special Note: (none)

Borehole 20-05-06

Contamination (Cs-137) from 40-60 feet is Stable
Contamination (Cs-137) from 70-120 feet is Undetermined

The grade thickness product from 40 to 60 feet is decreasing consistent with Cs-137 (HPGe identified) decay. This classification is based on the shielded NaI (probe type 14) logging detector since the contamination levels are so high. (Note probe type 04 is invalid over this depth interval.)

The grade thickness product from 70 to 120 feet is decreasing consistent with Cs-137 (HPGe identified) decay for the non-zero readings of the probe type 04. Several readings yield very low values (for unknown reasons) and the frequency of log data is low; thus the classification of undetermined.

Gross Gamma Survey Information

Probe Type Processed :	14: Shielded NaI (190); 04: NaI (29)
Other Probe Types :	None
Survey Depth :	120 ft
First Survey Date :	5/6/1980 (probe 14); 1/15/1980 (probe 04)
Last Survey Date :	9/20/1989 (probe 14); 7/19/1989 (probe 04)
Number Surveys Processed :	190 (probe 14); 29 (probe 04)

Analysis Notes

Method Used to Compute Background :	Threshold 0<val<50 (probe 04) Threshold 0<val<10 (probe 14)
Depth(s) where Contamination Identified in Gross Gamma Surveys :	40-60 ft Stable 70-120 ft Undetermined
Analyst Name :	R.R. Randall
Company Name :	Three Rivers Scientific

20-05-06 Combination Plot

Borehole 20-05-06 Shielded NaI Probe-14

Analysis by: Three Rivers Scientific

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Borehole 20-06-11	171

This section contains the analysis results for vadose zone boreholes (dry wells) associated with Tank 106 in the "B" Tank Farm.

Special Note: (none)

Borehole 20-06-02**Contamination (Cs-137) from 0-8 feet is Tank Farm Activity**

The grade thickness product over 0-8 feet is erratic with no clear trend. A Cs-137 (HPGe identified) decay line is plotted along the upper portion of the data values.

Gross Gamma Survey Information

Probe Type Processed :	04: NaI
Other Probe Types :	14: Shielded (9); 03: Neutron (2)
Survey Depth :	100 ft
First Survey Date :	1/14/1975
Last Survey Date :	6/14/1993
Number Surveys Processed :	316

Analysis Notes

Method Used to Compute Background :	10-40 ft
Depth(s) where Contamination Identified in Gross Gamma Surveys :	0-8 ft Tank Farm Activity
Analyst Name :	R. K. Price
Company Name :	Three Rivers Scientific

20-06-02 Combination Plot

Analysis by: Three Rivers Scientific

Borehole 20-06-03**No Gamma Ray Emitting Contamination Identified**

Based upon gross gamma log data acquired between 1975 and 1994, there are no significant levels of gamma ray emitting contamination in the vadose zone between depths of 2 and 140 feet. The maximum Cs-137 concentrations are 5 pCi/g or less from 0 to 17 feet and at 39 feet, then less than 0.6 pCi/g for the rest of the borehole.

Gross Gamma Survey Information

Probe Type Processed :	04: NaI
Other Probe Types :	03: Neutron
Survey Depth :	140 ft
First Survey Date :	1/14/1975
Last Survey Date :	6/14/1993
Number Surveys Processed :	321

Analysis Notes

Method Used to Compute Background :	Threshold 0<val<50
Depth(s) where Contamination Identified in Gross Gamma Surveys :	NONE
Analyst Name :	R. K. Price
Company Name :	Three Rivers Scientific

20-06-03 Combination Plot

Borehole 20-06-03

**No Gamma-Ray Emitting Contamination
Above Survey Detection Threshold**

Analysis by: Three Rivers Scientific

Borehole 20-06-06

Contamination (Cs-137) from 0-6 feet is Tank Farm Activity

Contamination (Cs-137) from 6-20 feet is Stable

Contamination (Cs-137) from 40-60 feet Stable

Contamination (Cs-137) from 60-100 feet Stable

The grade thickness product over 0-6 feet is erratic and is indicative of tank farm activities. A Cs-137 (HPGe identified) decay line is plotted.

The grade thickness product over 6-20 feet is decreasing consistent with the decay of Cs-137 (HPGe identified) from 1981 to 1994. The grade thickness product from the initial surveys (1980) to 1983 is erratic with lower than average readings, and may be due to depth shift errors.

The Cs-137 contamination from 51 to 55 feet was high enough to prevent processing of the HPGe spectral data and may be beyond the linear region of the tank farm NaI detector. The grade thickness product is decreasing consistent with the decay of Cs-137 (HPGe identified) from 1982 to 1994.

The grade thickness product over 60-100 feet is decreasing consistent with the decay of Cs-137 (HPGe identified) from 1983 to 1994.

Gross Gamma Survey Information

Probe Type Processed :	04: NaI
Other Probe Types :	14: Shielded (34); 03: Neutron (2)
Survey Depth :	100 ft
First Survey Date :	7/24/1980
Last Survey Date :	6/14/1993
Number Surveys Processed :	117

Analysis Notes

Method Used to Compute Background :	20-40ft
Depth(s) where Contamination Identified in Gross Gamma Surveys :	0-6 ft Tank Farm Activity; 6-20, 40-60 & 60-100 ft Stable
Analyst Name :	R. K. Price
Company Name :	Three Rivers Scientific

20-06-06 Combination Plot

Analysis by: Three Rivers Scientific

Borehole 20-06-11

No Gamma Ray Emitting Contamination Identified

Based upon gross gamma log data acquired between 1975 and 1994, there are no significant levels of gamma ray emitting contamination in the vadose zone between depths of 2 and 125 feet. The maximum Cs-137 concentrations are 3 pCi/g or less from 0 to 25 feet and less than 0.2 pCi/g for the rest of the borehole.

Gross Gamma Survey Information

Probe Type Processed :	04: NaI
Other Probe Types :	14: Shielded (9); 03: Neutron (2)
Survey Depth :	125 ft
First Survey Date :	1/14/1975
Last Survey Date :	6/14/1993
Number Surveys Processed :	322

Analysis Notes

Method Used to Compute Background :	Threshold 0<val<50
Depth(s) where Contamination Identified in Gross Gamma Surveys :	NONE
Analyst Name :	R. K. Price
Company Name :	Three Rivers Scientific

20-06-11 Combination Plot

Borehole 20-06-11

**No Gamma-Ray Emitting Contamination
 Above Survey Detection Threshold**

Analysis by: Three Rivers Scientific

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Tank B-107 Wells

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This section contains the analysis results for vadose zone boreholes (dry wells) associated with Tank 107 in the "B" Tank Farm.

Special Note:

The borehole 20-07-11 has high total gamma with no KUT or gamma-emitting radionuclides. Such high gross response with no radionuclide identification is indicative of either Sr-90 or a strong remote source that has excessive photo peak attenuation with significant Compton downscatter. Borehole 20-07-11 has a stable radioactive contaminant with about a 30 year half life. The decay of both Sr-90 and remote Cs-137 would nearly match the 30 year half life.

Borehole 20-07-02

Contamination (Cs-137 & Eu-154) from 31-62 feet Stable
Contamination (Cs-137 & Eu-154) from 74-99 feet Stable

The grade thickness product over 31-62 feet is decreasing consistent with a least square fit for Cs-137 & Eu-154 (both HPGe identified) from 1975 to 1995. The ratio of gross gamma from Cs-137 to gross gamma from Eu-154 is 33.8 as of 6-7-1994. The HPGe logging system detected Cs-137 at 1000 pCi/g and Eu-154 at 5 pCi/g in the interval. Low concentrations of Co-60 and Eu-152 contamination were also detected by the HPGe logging system at concentrations less than 0.5 pCi/g intermittently through the interval, thus these isotopes were not included in the fitting.

The grade thickness product over 74-99 feet is decreasing consistent with a least square fit for Cs-137 & Eu-154 (both HPGe identified) from 1975 to 1994. The ratio of gross gamma from Cs-137 to gross gamma from Eu-154 is 17.1 as of 6-7-1994. The HPGe logging system detected Cs-137 at 30 pCi/g and Eu-154 at less than 1 pCi/g in the interval.

Gross Gamma Survey Information

Probe Type Processed :	04: NaI
Other Probe Types :	03: Neutron
Survey Depth :	100 ft
First Survey Date :	1/14/1975
Last Survey Date :	6/07/1994
Number Surveys Processed :	342

Analysis Notes

Method Used to Compute Background :	10-30 ft
Depth(s) where Contamination Identified in Gross Gamma Surveys :	31-62 ft Stable 74-99 ft Stable
Analyst Name :	R. K. Price
Company Name :	Three Rivers Scientific

20-07-02 Combination Plot

Borehole 20-07-05**No Gamma Ray Emitting Contamination Identified**

Based upon gross gamma log data acquired between 1975 and 1994, there are no significant levels of gamma ray emitting contamination between the depths of 2 and 100 feet. The maximum Cs-137 concentrations are 2 pCi/g or less from 0 to 5 feet and less than 0.5 pCi/g for the rest of the borehole.

Gross Gamma Survey Information

Probe Type Processed :	04: NaI
Other Probe Types :	03: Neutron
Survey Depth :	100 ft
First Survey Date :	1/14/1975
Last Survey Date :	6/7/1994
Number Surveys Processed :	260

Analysis Notes

Method Used to Compute Background :	Threshold 0<val<50
Depth(s) where Contamination Identified in Gross Gamma Surveys :	NONE
Analyst Name :	R. K. Price
Company Name :	Three Rivers Scientific

20-07-05 Combination Plot

Borehole 20-07-05

Borehole 20-07-05

**No Gamma-Ray Emitting Contamination
Above Survey Detection Threshold**

Analysis by: Three Rivers Scientific

Borehole 20-07-08**No Gamma Ray Emitting Contamination Identified**

Based upon gross gamma log data acquired between 1975 and 1994, there are no significant levels of gamma ray emitting contamination between the depths of 2 and 135 feet. The maximum Cs-137 concentrations are 2 pCi/g or less from 0 to 8 feet and none for the rest of the borehole. Increased natural radionuclides (i.e. thorium and uranium) caused the elevated HPGe total gamma activity at 52 feet.

Gross Gamma Survey Information

Probe Type Processed :	04: NaI
Other Probe Types :	03: Neutron
Survey Depth :	135 ft
First Survey Date :	1/09/1975
Last Survey Date :	6/07/1994
Number Surveys Processed :	264

Analysis Notes

Method Used to Compute Background :	Threshold 0<val<50
Depth(s) where Contamination Identified in Gross Gamma Surveys :	NONE
Analyst Name :	R. K. Price
Company Name :	Three Rivers Scientific

20-07-08 Combination Plot

Borehole 20-07-08

**No Gamma-Ray Emitting Contamination
Above Survey Detection Threshold**

Analysis by: Three Rivers Scientific

Borehole 20-07-11**Contamination (Sr-90 or Remote Cs-137) from 68-80 feet Stable**

The grade thickness product over 68-80 feet is decreasing consistent with the decay of Sr-90 or remote Cs-137 (both hypothesis) from 1975 to 1994. The HPGe logging system did not detect any gamma emitting contaminants in the interval of slightly higher gross gamma. This character is indicative of either a strong beta emitter (such as Sr-90) or a strong remote source (such as Cs-137). Both radionuclides speculated have a half life close to 30 years and thus the decay line plotted.

Gross Gamma Survey Information

Probe Type Processed :	04: NaI
Other Probe Types :	03: Neutron
Survey Depth :	100 ft
First Survey Date :	1/14/1975
Last Survey Date :	6/07/1994
Number Surveys Processed :	329

Analysis Notes

Method Used to Compute Background :	40-65 ft
Depth(s) where Contamination Identified in Gross Gamma Surveys :	68-80 ft Stable
Analyst Name :	R. K. Price
Company Name :	Three Rivers Scientific

20-07-11 Combination Plot

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Tank B-108 Wells

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This section contains the analysis results for vadose zone boreholes (dry wells) associated with Tank 108 in the "B" Tank Farm.

Special Note:

The borehole 20-08-07 has high total gamma with no elevated KUT or gamma-emitting radionuclide from 64 to 76 feet. Such high gross response with no radionuclide identification is indicative of either Sr-90 or a strong remote source that has excessive photo peak attenuation with significant Compton downscatter. Borehole 20-08-07 has a stable radioactive contaminant with about a 30 year half life. The decay of both Sr-90 and remote Cs-137 would nearly match the 30 year half life.

Borehole 20-08-02

Contamination (Cs-137) from 50-65 feet is Stable
Contamination (Co-60) from 85-110 feet is Undetermined

The grade thickness product over 50-65 feet is low level and is decreasing, consistent with the decay of Cs-137 (HPGe identified) from 1975 to 1994. The HPGe logging system detected Cs-137 at less than 10 pCi/g at 58.

The grade thickness product over 85-110 feet has an abrupt step decrease in 1980 then continues with to decrease consistent with the decay of Co-60 (HPGe identified) from 1980 to 1994. The HPGe logging system detected Cs-137 and Co-60 at less than 1 pCi/g in the interval for both radionuclides. These levels are typically below detection with the tank farm gross gamma response, and thus the classification of undetermined.

Gross Gamma Survey Information

Probe Type Processed :	04: NaI
Other Probe Types :	03: Neutron
Survey Depth :	110 ft
First Survey Date :	1/14/1975
Last Survey Date :	6/07/1994
Number Surveys Processed :	397

Analysis Notes

Method Used to Compute Background :	65-80 ft
Depth(s) where Contamination Identified in Gross Gamma Surveys :	50-65 ft Stable; 85-110 ft Undetermined
Analyst Name :	R. K. Price
Company Name :	Three Rivers Scientific

20-08-02 Combination Plot

Analysis by: Three Rivers Scientific

Analysis by: Three Rivers Scientific

Borehole 20-08-03**Contamination (Cs-137) from 0-10 feet is Tank Farm Activity**

The grade thickness product over 0-10 feet is erratic from 1975 to 1978, then from 1978 to 1995 is decreasing consistent with the decay of Cs-137 (HPGe identified). The erratic and abrupt changes in the grade thickness product in this shallow depth interval are characteristic of tank farm activities.

Gross Gamma Survey Information

Probe Type Processed :	04: NaI
Other Probe Types :	02: Red GM (2); 03: Neutron (2)
Survey Depth :	130 ft
First Survey Date :	1/14/1975
Last Survey Date :	6/07/1994
Number Surveys Processed :	451

Analysis Notes

Method Used to Compute Background :	10-40 ft
Depth(s) where Contamination Identified in Gross Gamma Surveys :	0-10 ft Tank Farm Activity
Analyst Name :	R. K. Price
Company Name :	Three Rivers Scientific

20-08-03 Combination Plot

Analysis by: Three Rivers Scientific

Borehole 20-08-05

No Gamma Ray Emitting Contamination Identified

Based upon gross gamma log data acquired between 1975 and 1995, there are no significant levels of gamma emitting contamination in the vadose zone between depths of 2 and 100 feet. The HPGe logging system detected Cs-137 at 3 pCi/g at 0 feet and less than 0.5 pCi/g for the rest of the borehole.

Gross Gamma Survey Information

Probe Type Processed :	04: NaI
Other Probe Types :	03: Neutron
Survey Depth :	100 ft
First Survey Date :	1/14/1975
Last Survey Date :	6/07/1994
Number Surveys Processed :	454

Analysis Notes

Method Used to Compute Background :	Threshold 0<val<50
Depth(s) where Contamination Identified in Gross Gamma Surveys :	NONE
Analyst Name :	R. K. Price
Company Name :	Three Rivers Scientific

20-08-05 Combination Plot

Borehole 20-08-05

**No Gamma-Ray Emitting Contamination
 Above Survey Detection Threshold**

Analysis by: Three Rivers Scientific

Borehole 20-08-07**Contamination (Sr-90 or Remote Cs-137) from 64-76 feet Undetermined**

The HPGe logging system recorded a significant increase in total gamma activity between 69 and 75 feet, with no man made gamma emitting contaminants identified and only a nominal increase in the natural thorium concentration. Therefore, a grade thickness product over 64-76 feet was examined. The result is highly statistical due to the low levels. Therefore, the category of undetermined is assigned. The grade thickness product plot uses a 30 year decay line for reference, which would be the case for either Sr-90 or remote Cs-137.

Gross Gamma Survey Information

Probe Type Processed :	04: NaI
Other Probe Types :	03: Neutron
Survey Depth :	100 ft
First Survey Date :	1/14/1975
Last Survey Date :	6/07/1994
Number Surveys Processed :	409

Analysis Notes

Method Used to Compute Background :	40-60 ft
Depth(s) where Contamination Identified in Gross Gamma Surveys :	64-76 ft Undetermined
Analyst Name :	R. K. Price
Company Name :	Three Rivers Scientific

20-08-07 Combination Plot

Borehole 20-08-07

Analysis by: Three Rivers Scientific

Borehole 20-08-09**Contamination (Co-60) from 122-132 feet Undetermined**

The HPGe logging system detected Co-60 at concentrations less than 2 pCi/g at 130 feet in the borehole. The grade thickness product over 122-132 feet is low level and appears to be increasing from 1975 to 1983, then shows a decreasing trend from 1983 to 1994. The low level probe response with the interval being at the bottom of the borehole complicates analysis; thus the category of undetermined is assigned. The grade thickness product plot has a Co-60 decay line for reference.

Gross Gamma Survey Information

Probe Type Processed :	04: NaI
Other Probe Types :	03: Neutron
Survey Depth :	130 ft
First Survey Date :	1/14/1975
Last Survey Date :	6/07/1994
Number Surveys Processed :	401

Analysis Notes

Method Used to Compute Background :	110-120 ft
Depth(s) where Contamination Identified in Gross Gamma Surveys :	122-132 ft Undetermined
Analyst Name :	R. K. Price
Company Name :	Three Rivers Scientific

20-08-09 Combination Plot

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Tank B-109 Wells

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This section contains the analysis results for vadose zone boreholes (dry wells) associated with Tank 109 in the "B" Tank Farm.

Special Note: (none)

Borehole 20-09-02**No Gamma Ray Emitting Contamination Identified**

Based upon gross gamma log data acquired between 1975 and 1994, there are no significant levels of gamma ray emitting contamination in the vadose zone between depths of 2 and 100 feet. The HPGe logging system detected Cs-137 at 4 pCi/g at a depth of 1 foot, and less than 1 pCi/g to the depth of 30 feet.

Gross Gamma Survey Information

Probe Type Processed :	04: NaI
Other Probe Types :	03: Neutron
Survey Depth :	101 ft
First Survey Date :	1/14/1975
Last Survey Date :	6/07/1994
Number Surveys Processed :	425

Analysis Notes

Method Used to Compute Background :	Threshold 0<val<50
Depth(s) where Contamination Identified in Gross Gamma Surveys :	NONE
Analyst Name :	R. K. Price
Company Name :	Three Rivers Scientific

20-09-02 Combination Plot

Borehole 20-09-02

**No Gamma-Ray Emitting Contamination
 Above Survey Detection Threshold**

Analysis by: Three Rivers Scientific

Borehole 20-09-06**Contamination (Co-60) from 72-92 feet is Unstable Early**

The grade thickness product over 72-92 feet increased from 1975 to 1984 then began to decrease (within counting statistics), consistent with the decay of Co-60 (HPGe identified) from 1984 to 1994. The HPGe logging system detected Co-60 at less than 0.3 pCi/g.

Gross Gamma Survey Information

Probe Type Processed :	04: NaI
Other Probe Types :	02: Red GM (1); 03: Neutron (2)
Survey Depth :	102 ft
First Survey Date :	1/14/1975
Last Survey Date :	6/07/1994
Number Surveys Processed :	467

Analysis Notes

Method Used to Compute Background :	50-70 ft
Depth(s) where Contamination Identified in Gross Gamma Surveys :	72-92 ft Unstable Early
Analyst Name :	R. K. Price
Company Name :	Three Rivers Scientific

20-09-06 Combination Plot

Borehole 20-09-11**Contamination (Cs-137) from 0-15 feet is Tank Farm Activity**

The grade thickness product over 0-15 feet is erratic from 1975 to 1979 then from 1979 to 1994 is decreasing consistent with the decay of Cs-137 (HPGe identified).

Gross Gamma Survey Information

Probe Type Processed :	04: NaI
Other Probe Types :	02: Red GM (1); 03: Neutron (2)
Survey Depth :	100 ft
First Survey Date :	1/14/1975
Last Survey Date :	6/07/1994
Number Surveys Processed :	476

Analysis Notes

Method Used to Compute Background :	15-35 ft
Depth(s) where Contamination Identified in Gross Gamma Surveys :	0-15 ft Tank Farm Activity
Analyst Name :	R. K. Price
Company Name :	Three Rivers Scientific

20-09-11 Combination Plot

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Tank B-110 Wells

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This section contains the analysis results for vadose zone boreholes (dry wells) associated with Tank 110 in the "B" Tank Farm.

Special Note:

The borehole 20-10-02 has high total gamma with no elevated KUT or gamma-emitting radionuclide. Such high gross response with no radionuclide identification is indicative of either Sr-90 or a strong remote source that has excessive photo peak attenuation with significant Compton downscatter. Borehole 20-10-02 has a stable radioactive contaminant with about a 30 year half life. The decay of both Sr-90 and remote Cs-137 would nearly match the 30 year half life.

Borehole 20-10-02

Contamination (Co-60 & Sr-90) from 65-90 feet Unstable

The stack plot shows downward movement of the contaminants from 1982 to 1987 at 75 feet. The grade thickness product plot of the interval from 65 to 90 feet shows an increase in the gamma activity from 1975 to 1981, then it begins to decrease, and has another minor increase in 1985. The total gamma detected by the HPGe logging system in this interval is several times greater than is expected from the concentrations of the gamma emitting contaminants of Co-60 and Cs-137 (both HPGe identified). Sr-90 and/or remote Cs-137 is hypothesized. The grade thickness product is least square fit to Co-60 (HPGe identified) and a 30 year radionuclide (Sr-90 or remote Cs-137 hypothesized) from 1986 to 1994. The stability between 1986 and 1995 can not be confirmed by the fit and is thus categorized is Unstable. The ratio of gross gamma from Co-60 to gross gamma from a 30 year decay radionuclide is 0.173 as of 6/7/1994.

Gross Gamma Survey Information

Probe Type Processed :	04: NaI
Other Probe Types :	02: Red GM (1); 03: Neutron (6)
Survey Depth :	100 ft
First Survey Date :	1/14/1975
Last Survey Date :	6/07/1994
Number Surveys Processed :	255

Analysis Notes

Method Used to Compute Background :	40-64 ft for 65-90 ft interval
Depth(s) where Contamination Identified in Gross Gamma Surveys :	65-90 ft Unstable
Analyst Name :	R. K. Price
Company Name :	Three Rivers Scientific

20-10-02 Combination Plot

Borehole 20-10-07

Contamination (Cs-137 & Eu-154) from 15-26 feet Unstable Contamination (Ru-106 & Co-60) from 46-56 feet Stable

The grade thickness product over 15-26 feet has multiple time intervals of rapid increases and decreases, which clearly show an unstable period from 1975 to 1984. A least square fit for the last few years of the grade thickness product for Cs-137 and Eu-154 (both HPGe identified) could not be established, thus this interval is classified Unstable. The grade thickness plot has both Eu-154 and Cs-137 decay lines for reference.

The grade thickness product over 46-56 feet is decreasing consistent with a least square fit for Co-60 (HPGe identified) and Ru-106 (hypothesized) from 1975 to 1994, and this interval is classified stable. The ratio of gross gamma from Ru-106 to gross gamma from Co-60 is 10.9 as of 1/14/1975.

Gross Gamma Survey Information

Probe Type Processed :	04: NaI
Other Probe Types :	02: Red GM (2); 03: Neutron (5)
Survey Depth :	100 ft
First Survey Date :	1/14/1975
Last Survey Date :	6/07/1994
Number Surveys Processed :	265

Analysis Notes

Method Used to Compute Background :	28-45 ft
Depth(s) where Contamination Identified in Gross Gamma Surveys :	15-26 ft Unstable; 46-56 ft Stable
Analyst Name :	R. K. Price
Company Name :	Three Rivers Scientific

20-10-07 Combination Plot

* Apparent Concentration

Borehole 20-10-09**No Gamma Ray Emitting Contamination Identified**

Based upon gross gamma data acquired between 1975 and 1994, there are no significant levels of gamma ray emitting contamination between the depths of 2 and 135 feet. The maximum Cs-137 concentrations are less than 2 pCi/g from 0 to 20 feet, and none for the rest of the borehole.

Gross Gamma Survey Information

Probe Type Processed :	04: NaI
Other Probe Types :	02: Red GM (4); 03: Neutron (5)
Survey Depth :	135
First Survey Date :	1/14/1975
Last Survey Date :	6/07/1994
Number Surveys Processed :	257

Analysis Notes

Method Used to Compute Background :	Threshold 0<val<50
Depth(s) where Contamination Identified in Gross Gamma Surveys :	NONE
Analyst Name :	R. K. Price
Company Name :	Three Rivers Scientific

20-10-09 Combination Plot

Borehole 20-10-09

**No Gamma-Ray Emitting Contamination
 Above Survey Detection Threshold**

Analysis by: Three Rivers Scientific

Borehole 20-10-12

Contamination (Cs-137) from 18-80 feet Stable. Contamination (Cs-137) from 80-100 feet Stable.

The Red GM probe was modified from 1975 to 1980 and these detector changes resulted in abrupt changes in the grade thickness product values. This is also confirmed by changes in average background and frequency clean values. Stability analysis of contamination zones is therefore limited between 1980 and 1995 when the Red GM probe configuration was constant.

The grade thickness products over 18-80 and 80-100 feet are decreasing consistent with the decay of Cs-137 (HPGe identified) from 1980 to 1994, and these intervals are designated stable. The HPGe logging system identified Cs-137 as the dominant contaminant adjacent to the zone where detector saturation occurred.

Gross Gamma Survey Information

Probe Type Processed :	02: Red GM
Other Probe Types :	01: Green GM (3); 03: Neutron (8); 04 NaI (27); 14: Shielded (1)
Survey Depth :	120
First Survey Date :	1/15/1975
Last Survey Date :	6/07/1994
Number Surveys Processed :	267

Analysis Notes

Method Used to Compute Background :	106-120 ft
Depth(s) where Contamination Identified in Gross Gamma Surveys :	18-80 and 80-100 ft Stable
Analyst Name :	R. K. Price
Company Name :	Three Rivers Scientific

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Tank B-111 Wells

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This section contains the analysis results for vadose zone boreholes (dry wells) associated with Tank 111 in the "B" Tank Farm.

Special Note:

The borehole 20-11-09 has high total gamma with no elevated KUT or gamma emitting radionuclide. Such high gross response with no radionuclide identification is indicative of either Sr-90 or a strong remote source that has much photo peak attenuation with more Compton downscatter. Borehole 20-11-09 has a stable radioactive contaminant with about a 30 year half life. The decay of both Sr-90 and remote Cs-137 would nearly match the 30 year half life.

Borehole 20-11-09

Contamination (Cs-137) from 32-42 feet Stable

The grade thickness product over 32-42 feet is low level and is decreasing, within counting statistics, consistent with the decay of Cs-137 (HPGe identified) from 1975 to 1994. The HPGe logging system detected Cs-137 at concentrations of less than 2 pCi/g at 37 feet and recorded higher total gamma activity in this zone than would be expected from only Cs-137 and the natural KUT concentrations.

Gross Gamma Survey Information

Probe Type Processed :	04: NaI
Other Probe Types :	02: Red GM (13); 03: Neutron (3)
Survey Depth :	120
First Survey Date :	1/14/1975
Last Survey Date :	6/07/1994
Number Surveys Processed :	343

Analysis Notes

Method Used to Compute Background :	15-30 ft
Depth(s) where Contamination Identified in Gross Gamma Surveys :	32-42 ft Stable
Analyst Name :	R. K. Price
Company Name :	Three Rivers Scientific

20-11-09 Combination Plot

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Tank B-112 Wells

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This section contains the analysis results for vadose zone boreholes (dry wells) associated with Tank 112 in the "B" Tank Farm.

Special Note: (none)

Borehole 20-12-02

No Gamma Ray Emitting Contamination Identified

Based upon gross gamma log data acquired between 1975 and 1994, there are no significant levels of gamma ray emitting contamination in the vadose zone between the depths of 2 and 100 feet. The HPGe logging system detected Cs-137 at less than the minimum detectable level for the tank farm gross gamma surveys. The maximum Cs-137 concentration is less than 3 pCi/g from 0 to 10 feet and less than 0.6 pCi/g for the rest of the borehole.

Gross Gamma Survey Information

Probe Type Processed :	04: NaI
Other Probe Types :	03: Neutron
Survey Depth :	125
First Survey Date :	1/14/1975
Last Survey Date :	3/17/1994
Number Surveys Processed :	317

Analysis Notes

Method Used to Compute Background :	Threshold 0<val<50
Depth(s) where Contamination Identified in Gross Gamma Surveys :	NONE
Analyst Name :	R. K. Price
Company Name :	Three Rivers Scientific

20-12-02 Combination Plot

Borehole 20-12-02

**No Gamma-Ray Emitting Contamination
Above Survey Detection Threshold**

Analysis by: Three Rivers Scientific

Borehole 20-12-03

Contamination (Co-60 & Ru-106) from 60-90 feet Stable

The grade thickness product over 60-90 feet is decreasing consistent with a least square fit for Co-60 (HPGe identified) and Ru-106 (hypothesized) from 1975 to 1994. The ratio of gross gamma from Co-60 to gross gamma from Ru-106 is 0.07 as of 1-14-1975. The HPGe logging system detected Co-60 at less than 0.5 pCi/g at 68 feet.

Gross Gamma Survey Information

Probe Type Processed :	04: NaI
Other Probe Types :	03: Neutron
Survey Depth :	100
First Survey Date :	1/14/1975
Last Survey Date :	3/17/1994
Number Surveys Processed :	408

Analysis Notes

Method Used to Compute Background :	40-60 ft
Depth(s) where Contamination Identified in Gross Gamma Surveys :	60-90 ft Stable
Analyst Name :	R. K. Price
Company Name :	Three Rivers Scientific

20-12-03 Combination Plot

Analysis by: Three Rivers Scientific

Borehole 20-12-06

Contamination (Ru-106 & Sr-90) from 28-54 feet Stable

The HPGe logging system recorded elevated total gamma with no gamma emitting contaminant or increased natural radionuclides in the interval from 40 to 48 feet. The grade thickness product over 28-54 feet is decreasing consistent with a least square fit for Ru-106 (hypothesized) and Sr-90 or remote Cs-137 (hypothesized) from 1975 to 1994, and is assigned the category of stable. The ratio of gross gamma from Ru-106 to gross gamma from a 30 year half life radionuclide is 6.9 as of 1/14/1975. The HPGe logging system detected Co-60 at less than 0.2 pCi/g at 52 feet.

The HPGe logging system detected Cs-137 between 0 and 20 feet at 4 pCi/g or less.

Gross Gamma Survey Information

Probe Type Processed :	04: NaI
Other Probe Types :	03: Neutron
Survey Depth :	105
First Survey Date :	1/14/1975
Last Survey Date :	3/23/1994
Number Surveys Processed :	331

Analysis Notes

Method Used to Compute Background :	10-28 ft
Depth(s) where Contamination Identified in Gross Gamma Surveys :	28-54 ft Stable
Analyst Name :	R. K. Price
Company Name :	Three Rivers Scientific

20-12-06 Combination Plot

Borehole 20-12-07**Contamination (Cs-137) from 5-20 feet Undetermined**

The grade thickness product over 5-20 feet is low level. Inconsistent logging practices at the zero depth location prior to 1984 prevented accurate monitoring of shallow contamination. The apparent increase in the grade thickness product in 1984 may be the result of logging operations upgrades. A Cs-137 decay line is plotted for reference. The contamination interval is categorized as Undetermined.

Gross Gamma Survey Information

Probe Type Processed :	04: NaI
Other Probe Types :	03: Neutron
Survey Depth :	100
First Survey Date :	1/14/1975
Last Survey Date :	3/23/1994
Number Surveys Processed :	309

Analysis Notes

Method Used to Compute Background :	25-38 ft
Depth(s) where Contamination Identified in Gross Gamma Surveys :	5-20 ft Undetermined
Analyst Name :	R. K. Price
Company Name :	Three Rivers Scientific

20-12-07 Combination Plot

Borehole 20-12-11

Contamination (Cs-137) from 5-18 feet Stable

The grade thickness product over 5-18 feet is low level and is decreasing, within counting statistics, consistent with the decay of Cs-137 (HPGe identified) from 1975 to 1994. The HPGe logging system detected Cs-137 at less than 10 pCi/g at 10 feet.

Gross Gamma Survey Information

Probe Type Processed :	04: NaI
Other Probe Types :	03: Neutron
Survey Depth :	100
First Survey Date :	1/14/1975
Last Survey Date :	3/17/1994
Number Surveys Processed :	308

Analysis Notes

Method Used to Compute Background :	20-35 ft
Depth(s) where Contamination Identified in Gross Gamma Surveys :	5-18 ft Stable
Analyst Name :	R. K. Price
Company Name :	Three Rivers Scientific

20-12-11 Combination Plot