Hanford Single-Shell Tank Leak Causes and Locations - 241-T Farm

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Abstract: This document identifies 241-T Tank Farm (T Farm) leak causes and locations for the 100 series leaking tanks (241-T-106 and 241-T-111) identified in RPP-RPT-55084, Rev. 0, Hanford 241-T Farm Leak Inventory Assessment Report. This document satisfies the T Farm portion of the target (T04) in the Hanford Federal Facility Agreement and Consent Order milestone M-045-91F.

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EXECUTIVE SUMMARY

This document identifies 241-T Tank Farm (T Farm) leak causes and locations for the 100-series leaking tanks in T Farm. The leak causes and locations report for all of the 100-series single-shell leaking tanks is one of the targets, M-045-91-T04 (T04), in the Hanford Federal Facility Agreement and Consent Order milestone M-045-91F. The T04 target requires that the DOE provide to State of Washington, Department of Ecology (Ecology) a report on the 100-series single-shell tanks which have been or will be identified as having leaked in RPP-32681, Rev. 0 (Rev. 1), *Process to Assess Tank Farm Leaks in Support of Retrieval and Closure Planning,* leak assessment reports.

The leak assessment report for T Farm, RPP-RPT-55084, Rev. 0, *Hanford 241-T Farm Leak Inventory Assessment Report*, identified two 100-series leaking tanks in T Farm, 241-T-106 (T-106 and 241-T-111 (T-111). All of the other ten 100-series tanks in T Farm are classified as "sound" or are identified in RPP-RPT-55084 as requiring re-assessment of their classification per TFC-ENG-CHEM-D-42, *Tank Leak Assessment Process.* The TFC-ENG-CHEM-D-42 assessments are not part of the M-045-91-T04 target.

This T Farm leak causes and locations document is part of a series of tank farm reports that identify leak causes and locations for 100-series leaking tanks. A summary and conclusions document will be issued, RPP-RPT-54909, *Hanford Single-Shell Tank Leak Causes and Locations – Summary*, that compiles the results from all of the leak causes and locations tank farm reports when they have been issued which will fulfill the T04 target requirements.

The liner failures in tank T-106 and tank T-111 were first detected by liquid level decreases, and in the case of tank T-106, subsequently confirmed by the detection of drywell radioactivity. The tank T-111 liquid level decreases both in 1974 and after 1994 were apparently not large enough to be detected with the existing drywells up to drywell relogging in 1998.

The identification of T Farm tank leak locations focused on the possible vertical indication of a liner leak from liquid level decreases, radial transport in the soil indicated by radiation detected in drywells, and other factors such as liner bulging. The tank T-106 liner leaks probably occurred at or near the base of tank with a possible sidewall leak indication. The location of the tank T-111 liner leak could not be determined from the available data; however, the T Farm bottom liners were required to be replaced during construction, therefore, the bottom liner may be a possible tank T-111 leak location.

The likely causes of liner leaks were examined including tank design, construction conditions and activities, waste storage thermal conditions, and chemistry-corrosion. No one single condition stood out as the likely cause of either of the T Farm tank leaks. The leaks may have been influenced by the T Farm bottom liner replacement prompted by the buckling of the bottom liners and evidence of subsequent repair of at least one of the replaced bottom liners. Some or all of the factors may have been acting serially or together to contribute to tank liner failure.

Basic information on the leaking and sound T Farm tanks was reviewed to try and identify any differences between leaking and sound tanks related to liner failure. Both of the leaking T Farm tanks as well as three of the sound tanks stored second cycle Bismuth Phosphate process waste (2C) which at elevated temperatures increases the propensity for stress corrosion cracking and/or pitting. However, both the leaking and sound tanks stored 2C waste at temperatures below 100°F, which would have had little effect on corrosion. No single available parameter seems to stand out as a possible difference between leaking and sound tanks. Unknown differences either acting serially or together with known conditions may be the difference which also includes the possibility of undetected failure.

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Acronyms and Abbreviations

221-T	T Plant
241-BX	BX Farm
241-SX	SX Farm
241-T	T Farm
241-U	U Farm
AEC	Atomic Energy Commission
ALC	air lift circulator
ASME	American Society of Mechanical Engineers
ASTM	American Society for Testing and Materials
BPF	Blue Print File
BGS	below grade surface
$BiPO_4$	bismuth phosphate
cpm	counts per minute
c/s, cps	counts per second
DST(s)	double-shell tank(s)
ECOLOGY	State of Washington, Department of Ecology
FIC	Food Instrument Corporation
GM	Geiger-Mueller probe
LL	liquid level
MT	manual tape
NaI	sodium-iodide
NO_2^-	nitrite
NO_3^-	nitrate
OCP	open circuit potential
OH^-	hydroxide
ORP	Office of River Protection
PCSACS	PC Surveillance Analysis Computer System
QI	questionable integrity
REDOX	Reduction Oxidation Plant
RLS	Radionuclide Logging System
SCC	stress corrosion cracking
SGLS	Spectral Gamma Logging System
SP	scintillation probe
SST(s)	single-shell tank(s)
WRPS	Washington River Protection Solutions, LLC

Units

°C	degrees Centigrade
Ci	curie
°F	degrees Fahrenheit
ft	feet
gal	gallon
K	1000
kgal	kilogallon (10^3 gallons)

in	inches
M	moles per liter
mm	millimeter
mR/hr	milliRoentgen Per Hour
pCi	picocurie (10^{-12} curies)
pCi/g	picocurie per gram
ppm	parts per million

Waste Type Abbreviations

224	lanthanum fluoride finishing process waste in 221-T
1C	first cycle decontamination waste (from fuels reprocessing plant)
2C	second cycle decontamination waste (from fuels reprocessing plant)
CPLX	complexed waste
CW	coating waste
DW	decontamination waste
EB	Evaporator Bottoms
Evap	Evaporator feed (post 1976)
HLW	high-level waste
IX	ion exchange waste
LW	222-S Laboratory waste
MW	Metal waste
NCPLX	non-complexed waste
R	REDOX HLW
TBP	Tri-butyl phosphate waste

1.0 INTRODUCTION

The Hanford Federal Facility Agreement and Consent Order target M-045-91F-T04 indicated that part of the RPP-32681, *Process to Assess Tank Farm Leaks in Support of Retrieval and Closure Planning*, reporting would include leak causes and locations reports for all of the 100-series single-shell leaking tanks. This document is part of a series of documents that identifies leak causes and locations of 100-series single-shell leaking tanks that have been identified in the individual RPP-32681 tank farm leak assessments. An overall leak causes and locations summary and conclusions document will be prepared along with background and common tank farm information when all of the 100-series single-shell leaking tanks have been addressed (RPP-RPT-54909, *Hanford Single-Shell Tank Leak Causes and Locations – Summary and Conclusion*, to be issued). The information from RPP-RPT-54909 will be incorporated into the summary conclusions report on leak integrity for the Hanford Federal Facility Agreement and Consent Order milestone M-045-91F.

The 241-T Tank Farm (T Farm) tanks with a leak loss are addressed in this document. The T Farm assessment in RPP-RPT-55084, Rev. 0 (*Hanford 241-T Farm Leak Inventory Assessment Report*) reported a leak loss for tanks 241-T-106 (T-106) and 241-T-111 (T-111) and recommended that tanks 241-T-101 (T-101), 241-T-102 (T-102), 241-T-103 (T-103), 241-T-107 (T-107), 241-T-108 (T-108), and 241-T-109 (T-109) be further assessed using TFC-ENG-CHEM-D-42 (*Tank Leak Assessment Process*). The TFC-ENG-CHEM-D-42 assessments are not part of the M-045-91-T04 target.

The identification of T Farm tank leak locations focused on the first indication of radiation detected in drywells as well as liquid level decreases as appropriate. Leak detection laterals were not installed underneath the T Farm tanks.

The T Farm leak causes were examined: design, thermal conditions, chemistry and corrosion construction conditions. However, no one individual condition stands out as the likely cause of either the tank T-106 or tank T-111 leaks. The tank leaks could have been influenced by tank construction activities such as the T Farm tank bottom liner replacement. Some or all of the factors can act serially or together to contribute to tank liner failure.

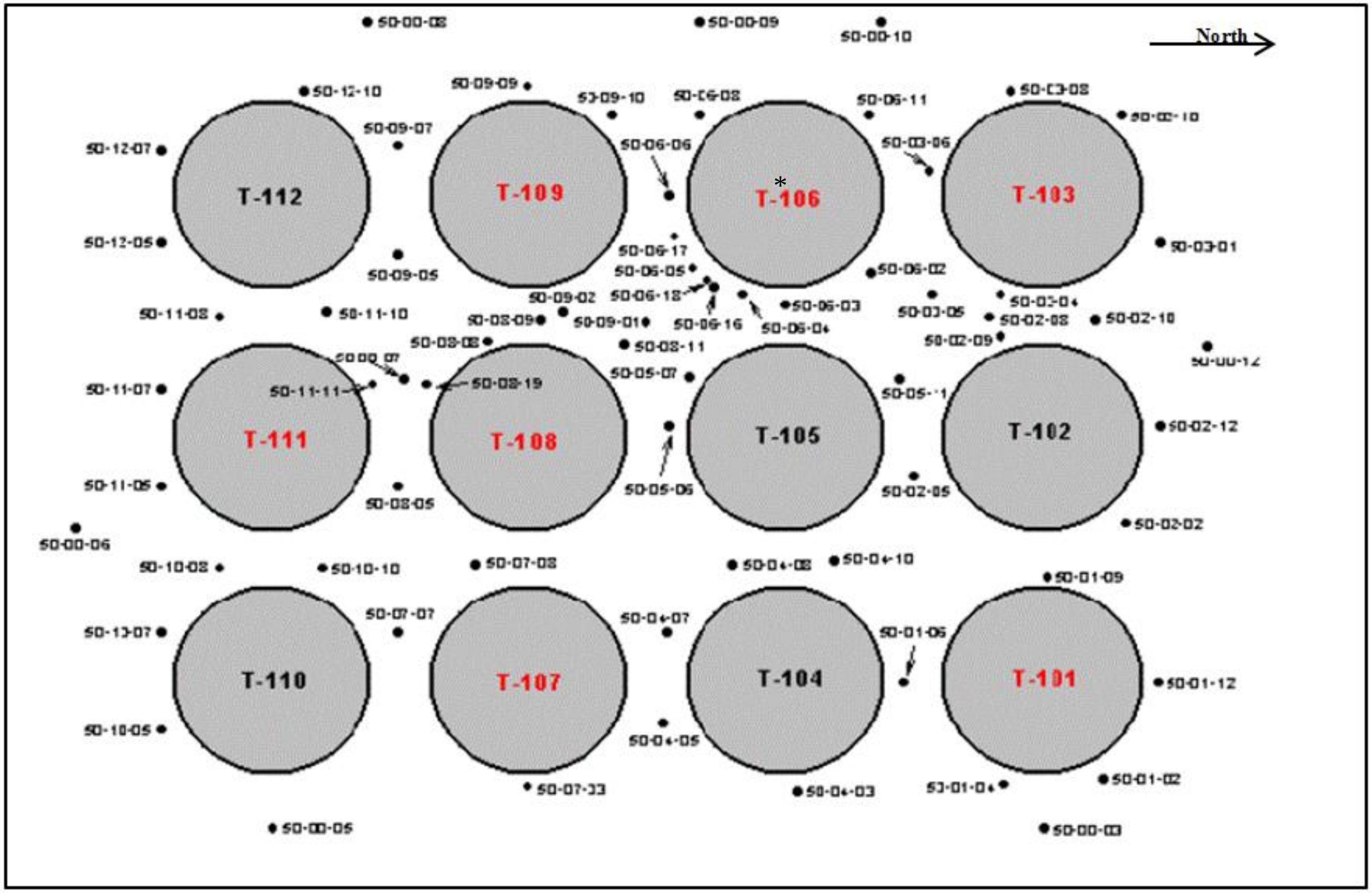
Two meetings were held to review status of tanks T-106 and T-111 with the Office of River Protection (ORP) and the State of Washington, Department of Ecology (Ecology) personnel. A review on January 7, 2014, covered the information that had been generated on the location of the tank T-106 leak and supporting data. A second meeting on March 11, 2014, provided a review of the tank T-111 leak causes and locations document along with a comparison of the available information on the other T Farm tanks. Comments were received, responses developed, and additions/revisions were made to the document (see Appendix A).

2.0 T FARM BACKGROUND

The T Farm was constructed between 1943 and 1944 and is located at the intersection of Camden Avenue and 23rd Street in the 200 West Area. The farm includes twelve 100-series dish bottom design SSTs. The tanks are 75-ft in diameter with an operating capacity of 530,000 gallons (HNF-SD-WM-ER-320, Rev. 1, *Supporting Document for the Historical Tank Content Estimate for T-Tank Farm*). A typical 100 series tank in T Farm contains 10 to 12 risers ranging in size from 4-in to 42-in in diameter that provide grade-level access to the underground tank. Normally, there is one riser in the center of the tank dome and four or five each on opposite sides of the dome. The tanks are arranged in four rows of three tanks forming a cascade. The cascade overflow height is ~15.9-ft from the tank knuckle bottom and 2.0-ft below the top of the steel liner.

Figure 2-1 shows a schematic of the T Farm tanks with location of the drywells.

Figure 2-1. T Farm 100-Series Tanks and Associated Drywells (RPP-RPT-55048, Rev. 0)



* Tanks T101, T-103, T-107, T-108, and T-109 were recommended to be assessed using the TFC-ENG-CHEM-D-42 procedure as identified in RPP- RPT-55048. Therefore, these tanks were not evaluated in this document.

Tanks T-106 and T-111 contained various waste types throughout operation which are listed in Table 2-1. The following sections describe some of the important common tank features and conditions that could affect tank leak causes and locations. This is followed by the individual tank analyses of the possible leak locations and causes and a comparison of leaking and non-leaking tanks in the conclusion section. The sections contain excerpts from RPP-RPT-55084, Rev. 0.

Table 2-1. Leaking T Farm Tanks with Waste Type

Tank	Waste Type
T-106	1C, 2C, REDOX CW, IX
T-111	2C, 224

Note: Waste types are listed in the List of Terms

3.0 T FARM COMMONALITIES

3.1 TANK DESIGN/CONSTRUCTION

3.1.1 Tank Design

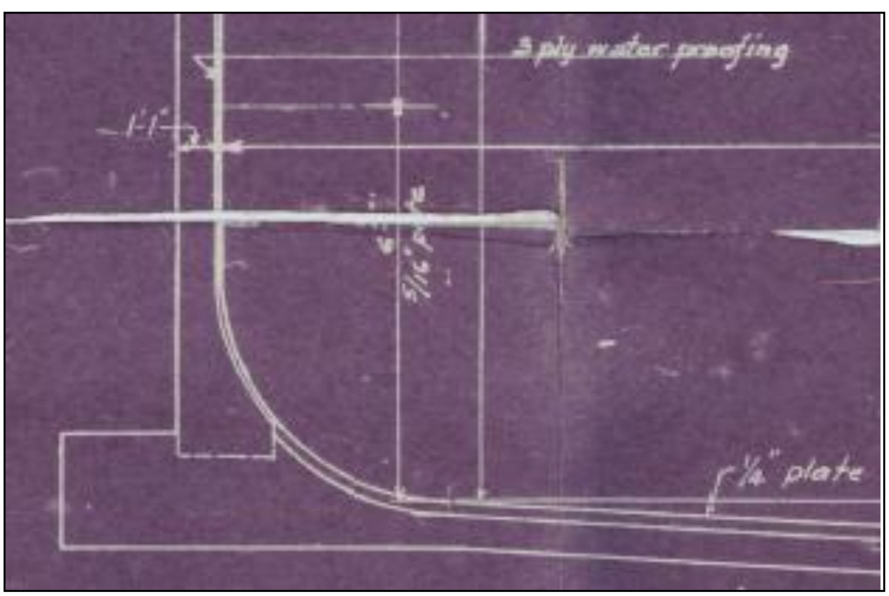
The T Farm SSTs are constructed of 1-ft thick reinforced concrete with a 0.25-in mild carbon steel liner (ASTM A7-39) on the bottom and sides with knuckle plates at 0.3125-in and a 1.25-ft thick domed concrete top. The tanks have a dished bottom with a 4-ft radius knuckle and a 15-ft operating depth from the tank knuckle bottom.

The tanks are set on a reinforced concrete foundation. A three-ply fabric waterproofing was applied over the foundation. Four coats of primer paint were sprayed on all exposed interior tank surfaces. Tank ceiling domes were covered with three applications of magnesium zincfluorosilicate wash. Lead flashing was used to protect the joint where the steel liner meets the concrete dome. Asbestos gaskets were used to seal the access holes in the tank dome. The tanks were waterproofed on the sides and top on the outside of the steel liners with tar and a cement-like sealant. Each tank was covered with ~5.6 to 7.2-ft of overburden.

The tanks have four process spare inlet nozzles located ~16.5-ft from the tank knuckle bottom, ~0.6-ft above the cascade overflow line and 1.4-ft below the top of the steel liner. The steel bottom of the T Farm tanks intersects the sidewall on a 4-ft radius (BPF-73550, Drawings D-2 and D-3, *Specification for Construction of Composite Storage Tanks (B, C, T, and U Tank Farms)*).

Figure 3-1 shows the detail of the knuckle liner to the grout, and three-ply asphaltic waterproof membranes between the bottom and sidewall intersection (BPF-73550, Sheet D5).

Figure 3-1. B C T U Tank Farm Knuckle Configuration with Three Ply Waterproofing (BPF-73550, Sheet D5)

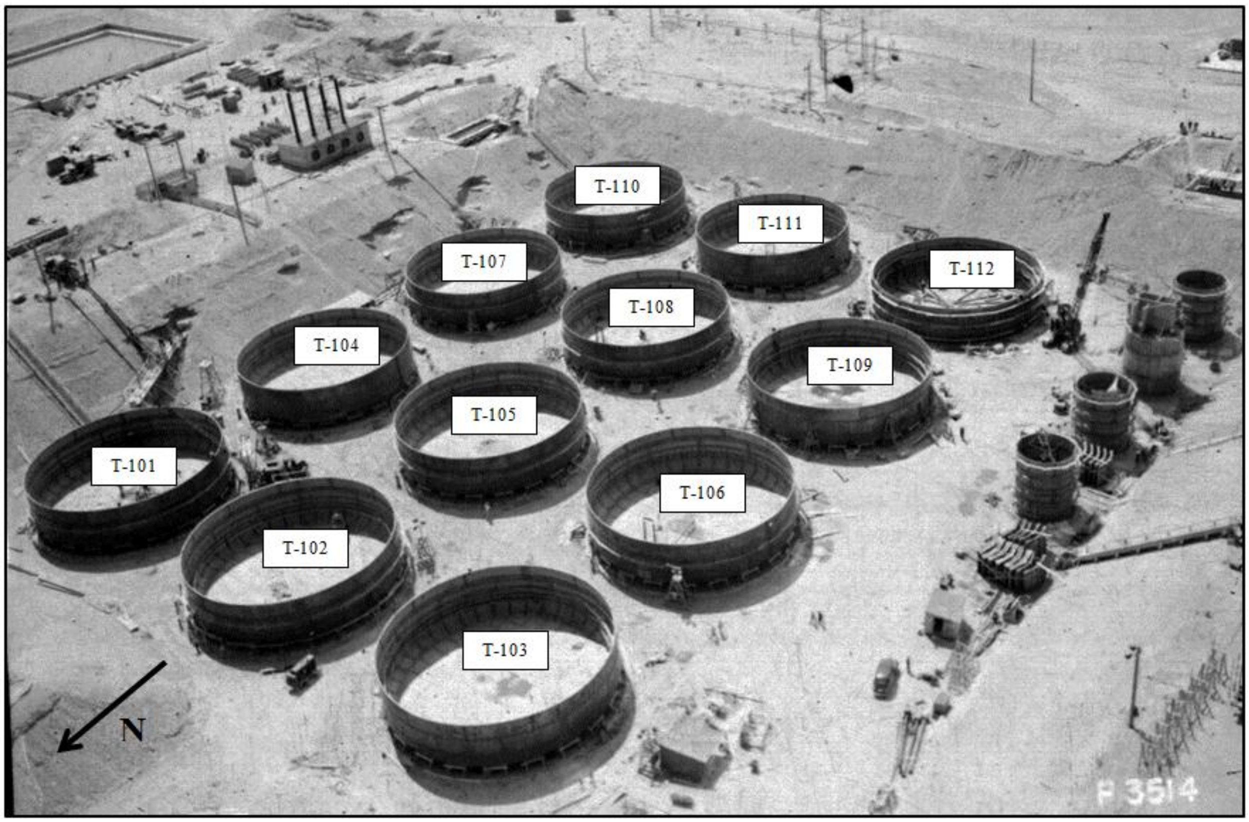


3.1.2 Tank Construction

Tank Construction Conditions

The T Farm construction temperatures were examined to determine if the tank liner fabrication occurred at or below the metal ductile-to-brittle temperature transition. The photograph in Figure 3-2 shows the T Farm under construction on June 22, 1944.

Figure 3-2. T Farm Construction Photograph June 22, 1944 (P3514 N1585575)



The four small 200 series to the right of the photo are not part of the Leak Causes and Locations report per M-045-91F-T04.

The metallurgical factors that limited carbon steel's ability to resist impact at low temperature were perhaps not well understood when T Farm was constructed and were not specified for the 0.25-in thick ASTM A7-39, *American Society for Testing and Materials, Standard Specifications for Steel for Bridges and Buildings*, mild carbon steel liner at the time. Current standards for construction of pressure vessels, ASME Boiler & Pressure Vessel Code (B&PVC), Section VIII, *Rules for Construction of Pressure Vessels,* provide requirements for vessels constructed of carbon and low alloy steels with respect to minimum design metal temperatures. That standard does not identify ASTM A7-39, as a material type but it does identify ASTM A283, *Standard Specification for Low and Intermediate Tensile Strength Carbon Steel Plates*. Early versions of ASTM A283 were similar to ASTM A7-39 because they identified the same chemical composition requirements as ASTM A7-39, and ASTM A283 steel plate and ASTM A7-39 steel plate had the same required tensile strength range, minimum yield point, and bending properties.

Current B&PVC Section VIII requirements specify, for ASTM A283 material of nominal thickness ≤10-mm (0.394-in), a minimum design metal temperature of 18°F. For the purposes of this report, it will be assumed that the 18°F design temperature is applicable to the fabrication of ASTM A7-39 carbon steel.

Boxes from the list of Vendor Information Reports for T Farm were searched for any Chemical and Physical Test Reports for the tank steel plates used in the farm but none were found. No other construction information for T Farm was found during the search.

A review of toughness and the ductile-to-brittle transition temperature for carbon steels (designated as "impact transition temperature") in Mark's Standard Handbook for Mechanical Engineers, Tenth Edition, indicates that carbon content can have a significant effect. Decreased carbon content not only raises the propagation energy needed for crack growth but also lowers the temperature for transition from ductile-to-brittle behavior (reference Fig 6.2.11 in Marks), suggesting that the B&PVC Section VIII low temperature service limit may be lower than what could be expected for steel of the vintage used in T Farm construction. The concentrations of carbon and trace impurities and their effect on this property are not specifically known, and low temperature impact resistance could only be determined reliably by impact testing of actual tank specimens.

Below the transition temperature, the metal loses its ability to absorb forces such as induced loads, or the impact of falling objects without fracturing. In this circumstance it is possible for micro-fissures or hairline cracks to be created. Later, when the metal is subjected to high stress, it might be possible for the cracks to propagate through the metal, or possibly subject the weakened areas to increased corrosion.

Any low temperatures experienced during construction at or less than the 18°F allowable temperature where impact loading (e.g. a dropped tool or piece of equipment from scaffolding) had the potential for creating micro-fissures may have triggered fissures in the steel liner (see Sections 4.3.2 and 5.3.2).

Design, fabrication, and erection of the tank steel lining were required to be in accordance with current "Standards Specifications for Elevated Steel Water Tanks, Standpipes and Reservoirs" as promulgated by the "American Water Works Association" (BPF-73550). Welding and inspection requirements were to conform to the American Welding Society's "Code for Arc and Gas Welding in Building Construction", Section 4.

The possible variability of liner steel from either different runs from the same supplier, or because of multiple suppliers could affect the resistance to low temperatures.

<u>Construction Activities</u>

The T Farm tanks experienced a reported buckling of the bottom liners during construction of the tanks and all of the T Farm tank bottom liners required replacement (HW-7-103, *Hanford Engineering Works Monthly Report April 1944*, page 14).

> *"The extensive buckling of 75' liner bottoms at Bldg. 241-T received considerable attention, and it was decided that all twelve of the bottoms would require replacement. The subcontractor is proceeding with this work."*

The following photographs (see Figure 3-3 and Figure 3-4) indicate the buckling of the T Farm bottom liners identified in the HW-7-103 monthly report.

Figure 3-3. T Farm Tank Buckled Liner April 15, 1944 (Specific Tank Not Identified)

Figure 3-4. Tank T-111 Tank Buckled Liner April 15, 1944

The Hanford Engineering Works Monthly Reports for May, June, and July 1944 (HW-7-189, HW-7-273, HW-7-384) provide information on the T Farm bottom liner replacement progress and testing in the following excerpts.

May, 1944 (HW-7-189)

> *"Work has progressed at a more rapid pace on the fabrication of steel tanks at Building 241-T. Most of the sheets of steel are in place and welding is well underway. The first concrete should be poured around a finished tank early next month."*

June, 1944 (HW-7-273)

> *"Welding on all tanks in Building 241-T is essentially complete. Several tanks have passed X-ray tests. Concrete has been poured around one 20-ft. tank, including dome cover and condenser base. Two 75-ft. tanks have membrane lining in place and one of those has the wood forms in place preparatory to pouring concrete around sides and pouring dome. Base slabs have been poured for all diversion boxes and some of the piping installed and buried in concrete."*

July, 1944 (HW-7-384)

> *"The subcontractor has made excellent progress during the month on Building 241-T. All steel tanks are completely welded and have passed X-ray tests. Concrete has been poured complete on seven of the twelve large tanks. All others are being formed in and reinforcing steel is being placed. Diversion boxes are nearly complete."*

The April and May monthly reports indicate that all of the bottom liners were to be replaced in all of the twelve 100-series T Farm tanks. The June and July 1944 monthly reports state that all welding was complete and passed X-ray tests.

The ripples identified in previous reports (e.g., RPP-RPT-54912, Rev. 0, *Hanford Single-Shell Tank Leak Causes and Locations – 241-A Farm*) probably refer to the visual effects of either the support structure for the bottom liner during construction or the overall stress inherent in the welding of multiple steel plates making up the bottom liner. The small discontinuous ripples of probably less than a few inches in height observed during construction in previous reports differ from bottom liner bulging and the degree of what has been called warping of T Farm bottom liners. Bulging is typically indicated by the degree of bottom liner uplift of more than several inches over a relatively larger area after the tank is being or has been filled. The warping of T Farm bottom liners deformed (warped) after being welded into place during construction of the tank liners possibly as a result of being raised three feet off the ground on wooden braces to allow welding of the underside of the tank bottoms. The warping of T Farm bottom liners appears to be much more than a few inches describing ripples. No information has been found that indicates how this may have been solved in the other original tank farms (B Farm, C Farm, and U Farm).

Construction photographs (see Appendix B) were reviewed to identify any possible individual tank details and provide a chronology of the original construction time frame compared to the time required for bottom liner replacement. Replacement consisted of lowering the bottom liner/knuckle assembly, removing the buckled bottom liner and in the case of tank T-112 the knuckle. Then the new bottom liner was installed along with the knuckle or the new bottom liner was welded to the original knuckle. There is no indication from the available photographs that any of the knuckle plates were removed except for tank T-112. The time frames involved would indicate the other knuckles were not removed.

Individual tank details related to tank integrity following bottom liner replacement were not found. The T Farm photographs, Figure B-1 and Figure B-2, indicate that all of the T Farm original bottom liners and knuckles were fabricated in about 30 days (see Table 3-1). The bottom liner replacement included lowering the bottom liner/knuckle assembly, removal of the bottom liner, assembly and welding of the new bottom liner presumably to the existing knuckle (except for tank T-112), raising the bottom liner/knuckle assembly to complete welding and weld X-ray, then lowering the bottom liner/knuckle assembly. The photographs, Figure B-3 through Figure B-7, indicate that most of the T Farm bottom liner replacement was accomplished in about 60 days including the fabrication of most of the T Farm tank sidewalls. However, tank T-110 collapsed and fell off of the supporting wooden braces on June 6, 1944. The opinion of the investigation committee indicated that vibration from chipping defective welds caused the tank to shift and drop (Accident at 241-T Area, 200 West Area, June 14, 1944, Memorandum for the Officer in Charge, Accession Number D475700). Therefore, bottom liner weld repair was still in progress June 6, 1944 and after resumption of work June 15, 1944. It is unclear if this was repair on a replaced bottom liner or the original bottom liner or whether weld repair was needed on other tanks. A photograph taken June 22, 1944 indicates all T Farm tanks lowered to the concrete pads indicating no further work on the bottom liners.

Table 3-1. T Farm Construction Chronology from Photographs

Date	Description	Photograph
February 10, 1944	T Farm initial tank liner construction.	P-1421 (B-1)
March 6, 1944	All T Farm 100 Series tank bottom liner and knuckles fabricated.	P-1697 (B-2)
April 4, 1944	Start of bottom liner replacement - tank T-112 tank lowered and bottom liner removed, knuckle in place.	P-2130 (B-3)
April 19, 1944	Tank T-112, started welding replacement bottom liner, two knuckle plates positioned. Tank T-109 lowered and bottom liner removed, knuckle to be removed?	P-2373 (B-4)
May 3, 1944	Tank T-112 bottom liner and knuckle replaced. Several tanks lowered with bottom liners removed, knuckles in place.	P-2569 (B-5)
May 18, 1944	T Farm bottom liner replacements in place. Eight tanks with at least one tier of sidewalls in place.	P-2760 (B-6)
June 5, 1944	T Farm bottom liner replacements continue to be worked, as some tanks remain elevated. Eleven tanks with most sidewalls in place.	P-3036 (B-7)
June 22, 1944	T Farm tank bottom liner replacement/repair complete, all tanks lowered to concrete pad indicating no further work on the bottom liner.	P-3495 (B-8)

The T Farm tanks as well as the B, C, and U Farm tanks were built in war time when materials were scarce-possibly affecting quality, design and construction standards were less rigorous than currently in use, and time was of the essence to support the war effort. The scarcity of relevant construction information may have been affected by some of the above as well as procedural and security requirements at the time.

3.2 IN-TANK DATA FOR LEAKING T FARM TANKS

The general information in this section is further developed and applied to the leaking tanks in Sections 4.4 and 5.4 for tanks T-106 and T-111, respectively, to understand implications of the conditions that could affect liner leaks and identify possible liner leak locations.

3.2.1 Liquid Level

The following is an excerpt from RPP-ENV-39658 (*Hanford SX-Farm Leak Assessments Report*):

> "Originally liquid levels were measured using pneumatic dip tubes (HW-10475-C, *Hanford Technical Manual Section C*, page 908). This practice was later replaced and a manual tape with a conductivity electrode was used to detect the liquid surface (H-2-2257, *Conductor Reel for Liquid Level Measurement*). The biggest limitations of

> the manual tape measurements were failures of the electrodes, solids forming on the electrode and measurement precision. The statistical accuracy of the manual tape and electrode measurement technique was 0.75 in. (~2,060 gal), as determined in July 1955 (HW-51026, *Leak Detection – Underground Storage Tanks,* page 4). Later, liquid-level determinations were automated in many of the SSTs to provide more accurate and reliable measurements".

It was stated in RPP-RPT-43704 (*Hanford BY-Farm Leak Assessments Report*) that the accuracy for the manual tape can vary from 0.25-in to 2-in for different tanks depending on surface conditions (liquid/solids), boiling, air lift circulator (ALC) operation, and conductivity.

The in-tank repeatability limits for FIC liquid level gauges are ± 0.25-in (Letter 72730-80-097, "Review of Classification of Six Hanford Single-Shell "Questionable Integrity (QI)" Tanks").

Transfer discrepancies of greater than 1.5-in (4,125 gal) measured at the first hour and every two hours thereafter with an FIC, manual tape, or flowmeter required an orderly and immediate shutdown, investigation, and notification. The 1.5-in discrepancy requirement was a specification limit in ARH-1601, Section D, *Specifications and Standards for the Operation of Radioactive Waste Tank Farms and Associated Facilities.*

Liquid level measured by manual tape (MT) is calculated for B, C, T, and U Farm tanks with the formula: volume = (MT Reading X 2750 gal/in) + 12,500 gal (LET-082172, H.N. Raymond to C.J. Francis, August 21, 1972, *Maximum Operating Levels and Cascade Levels in 200-West area Tank Farms* [IDMS Accession D196208887]). Even though the letter title indicates only west area, the above formula for the B, C, T, and U Farm tanks is found on the last page of the letter. The formula was confirmed to have been used as late as 1980 in RHO-CD-896, *Review of Classification of Nine Hanford Single-Shell "Questionable Integrity" Tanks*, page 76, for the then current tank T-111 volume (488,000 gal) and MT reading (173-in) which verified use of the formula. All half yearly and quarterly report ending volumes in this document were calculated with this formula. Original MT readings and the MT readings in PCSACS are all measured from the lower knuckle of the above tanks which is 12-in above the bottom inside center of the tanks. The ENRAF liquid level readings in PCSACS have been converted to read from the bottom inside center of the tank. Therefore, for the same reported liquid level the ENRAF reading is 12-in greater than the MT reading.

3.2.2 Temperature

Limited temperature data is available for the T Farm tanks until the 1970s. Available waste temperatures starting in the 1970s can be found in HNF-SD-WM-ER-320, Rev. 1, *Supporting Document for the Historical Tank Content Estimate for T-Tank Farm*, and in PCSACS. Historical documents in the following two paragraphs can be used to infer probable tank temperatures for the storage of waste in the T Farm tanks (see Sections 4.4.2 and 5.4.2 for individual tank waste temperature).

The T Farm tank construction specifications indicated the temperature of the liquid contents would be (up to) 220°F (HW-1946, *Specifications for Composite Storage Tanks – Buildings #241 at Hanford Engineering Works*). The condensers on the B, C, T, and U Farm tanks 101 through 106 were reported to be adequate for the waste temperatures and vapor loads for the original operations at approximately 180°F for supernatant and sludge (WHC-MR-0132, *A History of the 200 Area Tank Farms*).

The earliest operation limitations found for T Farm are addressed in ARH-951, *Limitations for Use of Underground Waste Tanks*. The ARH-951 document was issued December 18, 1969 and indicated that tank temperatures for should be held below 230°F with a 5°F per day rise for liquid temperatures below 180°F and a 3°F per day rise for liquid temperatures above 180°F during waste addition to the tank.

3.2.3 Liner Observations

A bulge, typically caused by rapid vaporization of moisture under the tank liner, may result in the direct failure of the liner or cause enough stress or thinning on the steel liner plates and welds that they become more susceptible to the effects of corrosion without producing a permanent bulge. Experience indicates that bulging tends to be a dynamic phenomenon, and it is possible that a tank with no measured bulge at one point in time may actually have had a displaced liner that was not detected at another time.

3.2.4 Chemistry-Corrosion

The types of corrosion that may occur in the Hanford Site SSTs include uniform corrosion, stress corrosion cracking (SCC), pitting, crevice, and liquid-air interface corrosion which were identified in PNNL-13571, *Expert Panel Recommendations for Hanford Double-Shell Tank Life Extension*.

Uniform corrosion rates for SSTs are reported to be generally less than 1 mil/year (HNF-3018, Rev. 0, *Single-Shell Tank Sluicing History and Failure Frequency*) for the SSTs. Carbon steel exposed to alkaline solutions has a low general corrosion rate (PNL-5488, *Prediction Equations for Corrosion Rates of A-537 and A-516 Steels in Double Shell Slurry*). However, the presence of the nitrate ion may induce various forms of localized attack (i.e., SCC, pitting, etc.).

Nitrate Ion-Induced Stress Corrosion Cracking

Stress corrosion cracking is the growth of cracks in a corrosive environment. It can lead to unexpected sudden failure of normally ductile metals subjected to a tensile stress, especially at elevated temperatures. Stress corrosion cracking is highly chemically specific in that certain alloys are likely to undergo SCC only when exposed to a small number of chemical environments. The chemical environment that causes SCC for a given alloy is often one which is only mildly corrosive to the metal otherwise.

Nitrate ion-induced SCC is the predominant threat to the integrity of the steel liners in the SSTs and DSTs at the Hanford Site and many investigations have been performed to establish the parameters under which the tanks can be protected from this threat. This work, together with the efforts of many others, led to the adoption of the waste chemistry control limits for SCC prevention in 1983 (OSD-T-151-00017, *Operating Specifications for the Aging Waste Operations in Tank Farms 241-AY and 241-AZ*).

The factors governing the rates of nitrate ion-induced SCC cracking by Hanford Site DST wastes were recently reviewed (RPP-RPT-47337, *Specifications for the Minimization of the Stress Corrosion Cracking Threat in Double-Shell Tank Wastes*). In brief, the test results led to the conclusion that the rates of nitrate ion-induced SCC depended on the properties of the steel, the applied potential versus the open circuit potential (OCP), the temperature and the concentrations of aggressive substances such as nitrate ion, and the potential inhibitors such as hydroxide and nitrite ion.

The technical work has shown that SCC is promoted by high temperatures, high nitrate ion concentrations, low hydroxide ion concentrations, low nitrite ion concentrations, and low nitrite ion/nitrate ion concentration ratios. Tanks with maximum temperatures less than 122°F would not be expected to experience significant SCC damage regardless of waste types (HNF-3018, Rev. 0). Tanks with the maximum temperatures above 122°F and a ratio of nitrate concentration to the sum of nitrite and hydroxide concentrations greater than 2.5 would be expected to suffer SCC-related damage (HNF-3018, Rev. 0). The concentration of nitrate and temperature are parameters that have the most effect on SCC. However, the pH (hydroxide) and nitrite can inhibit SCC. The current double-shell tank operating specifications for chemistry are reported in OSD-T-151-00007, Rev. 10, *Operating Specifications for the Double-Shell Storage Tanks*. While the chemistry specifications stated in this document were prepared for the DSTs, corrosion mechanisms and corrosion protection mechanisms applicable to DST primary tank metal liners are equally applicable to the older SST metal liners.

Localized Corrosion: Crevice, Pitting, and Liquid-Air Interface Corrosion

Crevice corrosion can occur in regions where a small volume of solution cannot readily mix with the bulk solution such as under deposits, between metal flanges, and other confined areas. Once initiated, crevice corrosion proceeds by the same mechanism as pitting corrosion (RPP-RPT-33306, *IQRPE Integrity Assessment Report for the 242-A Evaporator Tank System*).

Pitting corrosion is the localized corrosion of a metal surface confined to a point or small area that takes the form of cavities. Pitting corrosion in dilute solutions ($NO_3^- < 1M$) of waste has been studied at the Savannah River Site (SRS). Pitting has been determined to not be a problem at hydroxide concentrations greater than 1M for any of the diluted waste solutions tested (WSRC-TR-90-512, *Effect of Temperature on the Nitrite Requirement to Inhibit Washed Sludge*, Oblath and Congdon 1987, *Inhibiting Localized Corrosion during Storage of Dilute Waste*). Nitrate ion was determined to be the usual controlling aggressive species when its concentrations ranged between 0.01M and 1M (WSRC-TR-90-512). The presence of hydroxide ion and nitrite ion has shown to inhibit pitting corrosion due to the aggressive nitrate ion. This work led to the conservative recommendation that the concentration of nitrite ion be greater than 0.033M for the avoidance of pitting in dilute solutions of nitrate ion at pH 10 and 40°C (104°F) (RPP-ASMT-53793, Rev. 0, *Tank 241-AY-102 Leak Assessment Report*).

The chemical compositions required for prevention of pitting corrosion can also be applied as limits for prevention of liquid-air interface corrosion at the surface of the supernatant.

Crevice, pitting, and liquid-air interface corrosion are types of localized corrosion possible in the SSTs; however, historically SCC is the more predominant type of corrosion of concern.

Historical Corrosion Control

The earliest chemical specifications for SSTs addressing pH, nitrite, nitrate, and hydroxide are listed in Table 3-2 (ARH-1601, Section D).

Table 3-2. ARH-1601 Specifications 1973

Waste Tank Farms and Associated Facilities Specifications	
Variable	**Specification**
pH	Minimum 8.0
NO_2^-	500 ppm
NO_3^-	< 6M
OH^-	< 7M

There was no similar specification found that addressed all of these parameters during the operation of T Farm prior to 1973. However, if the ARH-1601 specifications were in effect during prior T Farm waste storage, the storage of undesirable concentrations of NO_2^-, NO_3^-, and OH^- could result in vulnerability to SCC and/or localized corrosion.

Historical waste sample data as well as temperatures are typically not available for the SSTs and no sample data were recovered for tanks T-106 and T-111. Thus, the concentrations of NO_2^-, NO_3^-, and OH^- listed in Sections 4.4.4 and 5.4.4 are typical concentrations that were found in reports and other sources for the waste types listed. The reports may be based on limited data and/or values or were obtained from process flowsheets. Therefore, waste chemistry concentrations may not reflect the actual conditions when specific tank sample and temperature data is unavailable especially when multiple waste types are present in the tank. Individual tank sections provide information on the waste types stored in the tank.

The caustic (sodium hydroxide) requirements for waste neutralization (HW-10475-C-DEL, *Hanford Technical Manual Section C)* were calculated on the basis of 10% excess over the theoretical amounts. The quantity of 50% sodium hydroxide required to neutralize each of the process solutions to a pH of 7 was determined experimentally. Samples were not required but could be taken and pH measured on an ad hoc basis.

3.2.5 Photographs

Available photographs of the T Farm leaking tanks T-106 and T-111 were reviewed. Photographs were reviewed to identify beachlines possibly indicating previous operations of overfilling the tank, damaged equipment, possible liner bulges, and any other anomalies that could be indicative of a tank liner leak, and/or possible leak location. See Sections 4.4.5 and 5.4.5 for details for tanks T-106 and T-111, respectively. The photographs do not indicate a liner bulge for tanks T-106 and T-111. Construction photographs were also reviewed and are addressed in Section 3.1.2.

3.3 EX-TANK DATA FOR LEAKING T FARM TANKS

The general information in this section is further developed and applied to the leaking tanks in Sections 4.5 and 5.5 for tanks T-106 and T-111, respectively, to understand implications of the conditions that could affect liner leaks and identify possible liner leak locations.

3.3.1 Laterals

Leak detection laterals were installed approximately 10-ft underneath some of the tanks containing self-boiling waste in 241-A and 241-SX Farms. Each lateral is a 3-in pneumatic stainless steel tubing enclosed in 4-in carbon steel pipe. Probes were driven to the end of the lateral with compressed air then slowly withdrawn to gather a radiation profile below the bottom of the tank. Lateral leak detection systems were not installed under the T Farm tanks.

3.3.2 Drywells

Fourteen drywells are located around tank T-106 and ten drywells are located around tank T-111. The earliest tank specific drywells were installed between 1973 and 1975 with three later in 1977, 1979, and 1993; later, two direct pushes were installed in 2003. All of the radiation readings in drywells are assumed to be maximum or peak readings unless otherwise noted. Drywells were drilled vertically from the surface and drywell coordinates and detailed drywell information, e.g., pipe dimensions and configuration, for tanks T-106 and T-111 are addressed in references sited in the individual tank segments. Drywells will not be useful to detect releases that enter the soil from the tank unless the volume released is sufficiently large to facilitate lateral transport to a drywell typically to within ~1-ft of the drywell. The vertical height of a tank liner leak may not be directly related to the point of detection in the drywell. This is especially true for small leaks that may flow downward some distance before encountering a drywell.

The “00” series drywells (drywell 50-00-10, T Farm) were installed shortly after tank construction, usually around the periphery of the farm and most extend to 150-ft below grade surface (BGS). Others with tank numbers embedded in the drywell number (50-06-02, tank T-106) were constructed later, sometimes after tank operations had ceased and generally to 100-ft BGS, with a few deeper than 100-ft BGS. The usual number of drywells surrounding a tank is one to four. If there are more, then there likely was some concern regarding a release which was being investigated. The last number corresponds to the clocked position of the drywell with respect to due north.

Four gamma ray probe types were used to monitor gamma in drywells to detect leaks (RPP-6088, *Analysis and Summary Report of Historical Dry Well Gamma Logs for the 241-T Tank Farm 200 East Area*). The most widely used probe was the unshielded gross gamma sodium-iodide (NaI) probe (or probe 04; the shielded NaI probe was referred to as probe 14). The NaI probe (04) is very sensitive and able to record gamma ray activity from 30 counts per second (cps) up to about 40,000 cps (15mR/hr) before the data becomes unreliable (RHO-RE-EV-4P, *Supporting Information for the Scientific Basis for Establishing Dry Well Monitoring Frequencies*. The next most commonly used probe was the Red-GM (or probe 02) which is less sensitive but can reliably record gross gamma at much higher levels of activity (up to ~500R/hr).

Operation of these and other probes are discussed in HNF-3136, *Analysis Techniques and Monitoring Results, 241-SX Drywell Surveillance Logs*. A scintillation probe (SP) was also used to measure low levels of radiation in the drywells. Leak location identification is primarily focused on the first indication of a leak and is therefore typically concerned with the lower levels of gross gamma detection and initial migration.

Drywell sections (see Sections 4.5.1 and 5.5.1) contain gross gamma figures taken from RPP-6088, *Analysis & Summary Report of Historical Drywell Gamma Logs for 241-T Tank Farm - 200 West*, showing continuing or new contamination in the drywells based on BGS depth from 1975 to 1994. Some of these gross gamma figures show anomalous data that appear to be unexplained detections that do not reflect radioactivity in the soil. In 1999, a baseline characterization of the gamma-ray-emitting radionuclides distributed in the vadose zone sediments beneath and around T Farm was performed using spectral gamma logs (SGLS) and documented in GJO-HAN-27, *Vadose Zone Characterization Project at the Hanford Tank Farms T Tank Farm Report*. Individual vadose zone characterization summary data reports were issued in 1998-1999 for the T Farm tanks with results reported in the leaking tank segments. The gross gamma figure detection sensitivity is lower than SGLS (~10 pCi/g versus ~0.1 pCi/g equivalent Cs-137). Therefore, radioactivity $\leq$ 10 pCi/g does not appear on the gross gamma figures (GJO-HAN-27). SGLS logging can confirm both Cs-137 and/or Co-60 radioactivity which can assist in the leak location analysis, and the SGLS data is weighted more heavily on interpreting drywells. The criteria for drywell monitoring are defined in RHO-ST-34, *A Scientific Basis for Establishing Drywell-Monitoring Frequencies*, with the monitoring frequency found in SD-WM-TI-356, *Waste Storage Tank Status and Leak Detection Criteria*.

All of the radiation readings in drywells are assumed to be maximum or peak readings unless otherwise noted and are from the Red-GM probe unless otherwise indicated. The individual tank segments report the available drywell data in the drywell section and in some cases the more recent direct pushes installed to locate detailed soil radioactivity. The drywell summary section provides the analyses of the associated drywells and any direct pushes with the tank that is of concern.

3.4 LINER LEAK LOCATIONS

Drywell radioactivity when first detected can indicate a radial or depth location of a tank leak, migration of the tank leak, or the possible migration of an adjacent tank leak. The radial drywell radioactivity is also dependent on any possible flow paths from the actual tank liner leak location to the drywell itself as well as the waste viscosity and distance to the drywell. Drywells can also indicate the tank liner sidewall leak vertical location but the indication needs to be analyzed relative to non-tank liner leaks associated with pipe lines or other sources.

Liquid level decreases can be used for sidewall as well as bottom liner leaks but need to be analyzed in relationship with the vertical level of the tank drywell radioactivity, evaporation, and drywell contamination from pipe line leaks and other non-tank sources.

A liner leak may have penetrated the waterproof membrane at any location and followed concrete cracks or construction joints to a different location including the top of the tank footing. Therefore, the point of waste egress from the tank liner may not be the point of entry of the leaking waste to the soil. Later indications of radioactivity in the drywells with improved detector capabilities could indicate additional leakage but the location of the leak could not be pinpointed without some additional information.

The lack of radioactivity above background in a drywell indicates that if there was a liner leak it either occurred at another location, the leak flow was insufficient to reach the effective radius of the probes used in the drywell, or was not able to adequately detect the specific radioisotope with the gamma probe. When there is no radioactivity detected in a drywell or no recoverable data for a drywell it is not included as part of the leak location analysis.

3.5 POSSIBLE LINER LEAK CAUSE(S)

Analysis of the T Farm commonalities which centered on tank design/construction, in-tank data, and ex-tank data indicates that there appears to be no one individual condition that stands out as the cause of the T Farm tank leaks. The evidence that T Farm tank bottom liners required replacement causes concern with the quality of the replacement bottom liners. The following sections provide a tank T-106 and T-111 review of these conditions as they relate to liner leak causes.

Other general tank construction factors such as the quality of materials and general fabrication could also contribute to tank liner failure. No definitive evidence has been found to substantiate quality defects.

4.0 TANK 241-T-106 SEGMENT

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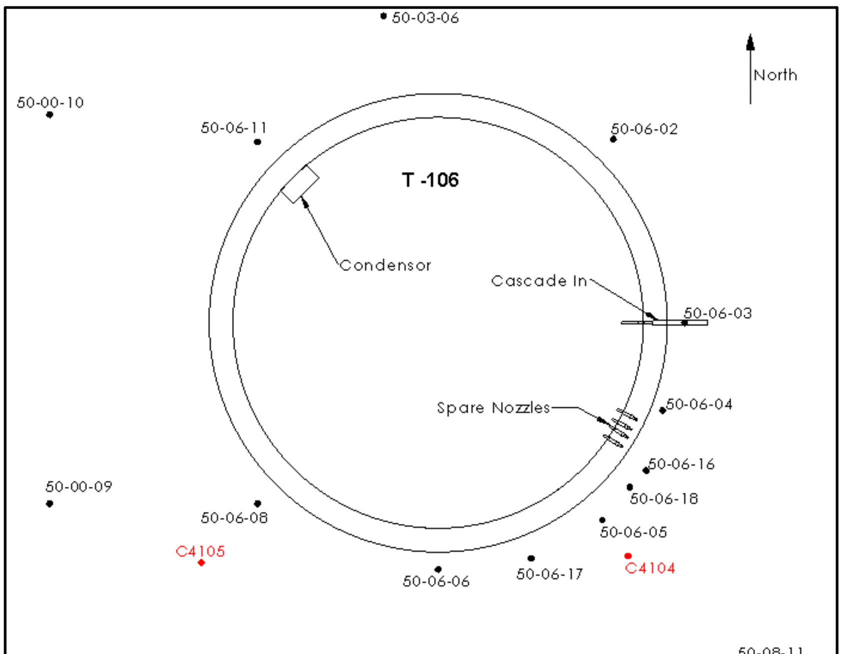
4.1 TANK T-106 BACKGROUND HISTORY

This section provides information on the historical waste loss event associated with Single-Shell Tank (SST) 241-T-106 (T-106). There are 14 drywells located around tank T-106 with specified distances from the drywell to the tank footing shown in Figure 4-1: 50-00-10 and 50-08-11, installed in 1944, 50-06-02, 50-06-03, 50-06-04, 50-06-05, 50-06-06, 50-06-08, and 50-06-11, installed in 1973, 50-06-17, 50-03-06, and 50-06-16, installed in 1975, 50-00-09 installed in 1977, and 50-06-18 installed in 1993. In addition, two nearby direct pushes, C4104 and C4105, were installed in 2003.

The bottom of the tank footing is ~38-ft 1-in Below Grade Surface (BGS) with ~6.2-ft soil cover over the dome (WHC-SD-WM-TI-665, Rev. 0D, *Soil Load above Hanford Waste Storage Tanks*; BPF-73550).

Figure 4-1. Tank T-106 Associated Drywells

Tank inner ring is steel liner; outer ring is outer edge of tank footing



Drywell	Distance to Footing (ft)*	Date Installed
50-06-02	~4.5	7/1973
50-06-03	~3.1	6/1973
50-06-04	~2.2	7/1973
50-06-16	~4.8	7/1975
50-06-18	~4.2	4/13/1993
50-08-11	~45	10/31/1944
50-06-05	~5.0	8/1973
C4104	~13	2003
50-06-17	~4.4	7/1975
50-06-06	~3.1	7/1973
C4105	~20	2003
50-06-08	~4.8	7/1973
50-00-09	~36	2/28/1977
50-00-10	~39	10/31/1944
50-06-11	~4.8	7/1973
50-03-06	~15	1/1975

*Assumes perfect vertical alignment

Reference: H-2-36948
BPF 73550
RPP-35968
RPP-23752

TJ Barnes
11-14-2013

4.2 TANK T-106 OPERATIONS SUMMARY

Tank T-106 was placed into service in June 1947 and began receiving second-cycle decontamination waste from the Bismuth Phosphate process (2C waste type) at T Plant (BHI-00061, Rev. 0). In the third quarter of 1948, tank T-106 was emptied and refilled with first cycle waste (1C) from the Bismuth Phosphate process at T Plant. The tank remained full through the fourth quarter of 1953.

In early 1954, the contents from tank T-106 were pumped out of the tank to a crib. On June 17, 1954, tank T-106 was again filled with 1C waste from T Plant and remained full until late 1954. Beginning in the first quarter of 1955, the supernatant was removed from tank T-106 leaving approximately 10 kgal of solids in the tank.

In the second quarter of 1956, tank T-106 received approximately 221 kgal of waste from tank U-110 which contained 1C and REDOX coating waste (CW). No additional transfers occurred until the second quarter of 1965 when approximately 221 kgal of REDOX CW from tank S-107 was pumped to tank T-106. An additional 90 kgal of REDOX CW from tank S-107 was pumped to the tank in the first quarter of 1966 and tank T-106 was declared full.

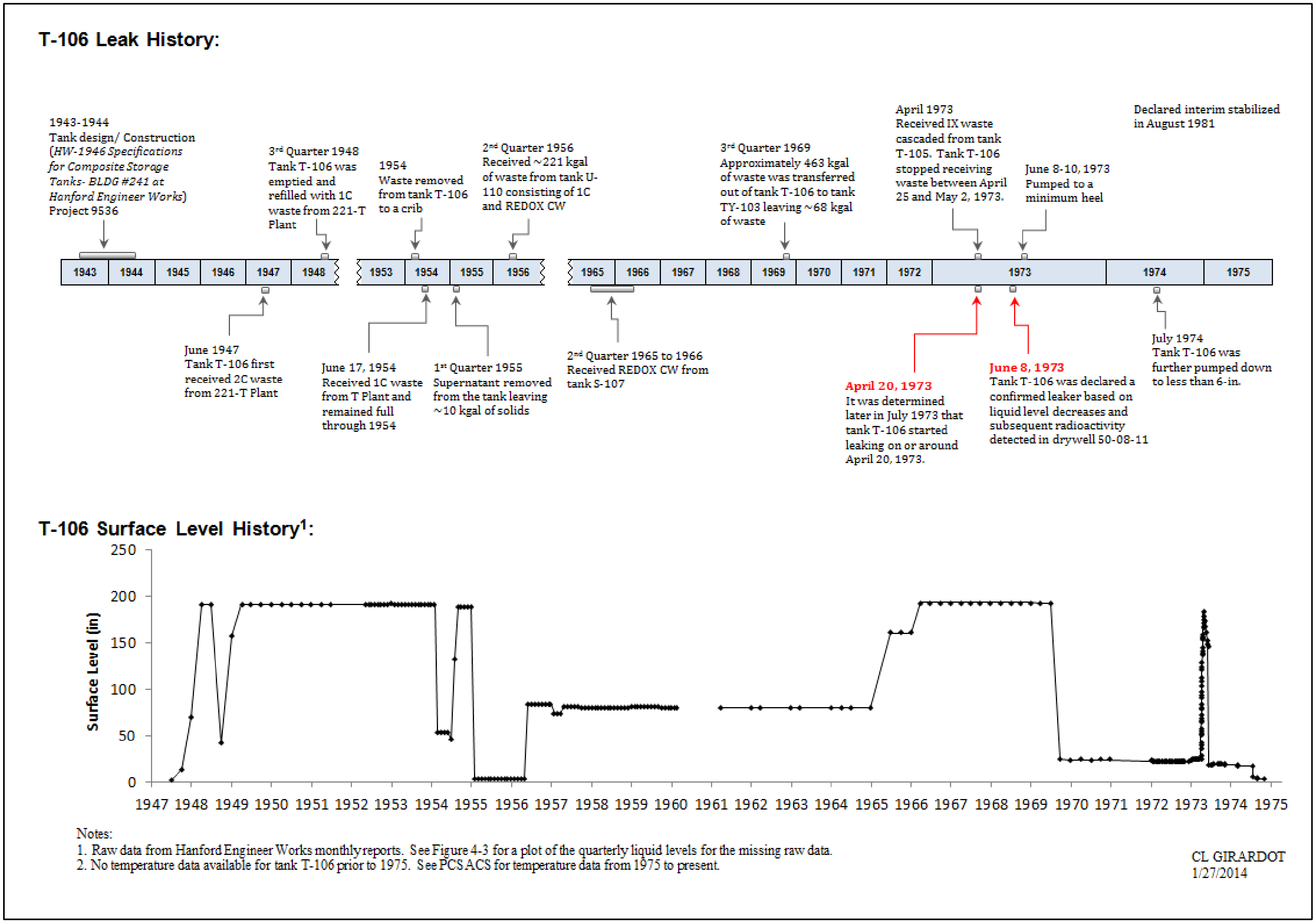
Beginning in the third quarter of 1969, approximately 463 kgal of waste was transferred out of tank T-106 to tank TY-103. At the end of this transfer, tank T-106 contained approximately 68 kgal of waste, including 26 kgal of solids. No additional transfers occurred until the first quarter of 1973 when waste was cascaded from tank T-105 to tank T-106. This waste consisted of decontamination waste (DW), low level waste, and ion exchange waste from B Plant Fission Product Recovery operations. By the end of March 1973, tank T-106 contained approximately 78 kgal of waste which consisted of REDOX CW, B plant low-level waste and ion exchange (IX) waste. Beginning on April 4, 1973, the planned fill of tank T-106 with IX waste was started.

On June 8, 1973, tank T-106 was declared a confirmed leaker based on liquid level decreases as well as increased radioactivity in drywell 50-08-11 in May and June 1973. It was later discovered that the tank T-106 leak began on or around April 20, 1973 (*Report on the Investigation of the 106 T Tank Leak at the Hanford Reservation* [AEC Report 1973, Exhibit G]). The tank was removed from service and pumped to a minimum heel from June 8-10, 1973 to tank T-112 (AEC Report 1973). In July 1974, the tank was further pumped down to a residual layer of less than 6-in. Approximately 115 kgal of liquid waste was estimated to have leaked from tank T-106 (RPP-RPT-55084, Rev. 0).

Tank T-106 was declared administratively interim stabilized in August 1981. As of July 31, 2013, tank T-106 contains 22 kgal of sludge (HNF-EP-0182, Rev. 304).

The operational history of tank T-106 leak related details including liquid level is charted in Figure 4-2.

Figure 4-2. Operational Leak History of Tank T-106



4.3 TANK DESIGN/CONSTRUCTION

4.3.1 Tank Design

The steel bottoms of the T Farm tanks intersect the sidewall on a 4-ft radius knuckle transition (BPF-73550, Drawings D-2 and D-3). The rounded knuckle transition, the three-ply asphaltic membrane waterproofing between the liner and the concrete, a notched footing construction joint, and the concrete shell are features common to all T Farm tanks (see Section 3.1.1).

4.3.2 Tank Construction

Construction Conditions

The T Farm tanks were constructed between January 1944 and September 1944. Temperatures are not available for 1944 between May 18 and December 1. From the start of T Farm tank construction through May 18, 1944 there were two minimum temperatures of 12°F with day time temperatures of 44°F and 57°F, one at 18°F, and four at 20°F with day time temperatures between 41°F and 56°F.

As described in Section 3.1.2, cold weather affects the ductile-to-brittle steel transition temperature, with 18°F being the assumed design temperature for the carbon steel liner, which could result in a fracture upon impact. However, in general, the temperatures during the T Farm construction time frame were much milder than those experienced during 241-SX Farm construction where ductile-to-brittle steel transition temperatures were exceeded.

Design, fabrication, and erection of the tank steel lining were required to be in accordance with current "Standard Specifications for Elevated Steel Water Tanks, Standpipes and Reservoirs" as promulgated by the "American Water Works Association" (BPF-73550). Welding requirements were required to conform to the American Welding Society's "Code for Arc and Gas Welding in Building Construction", Section 4.

Construction Activities

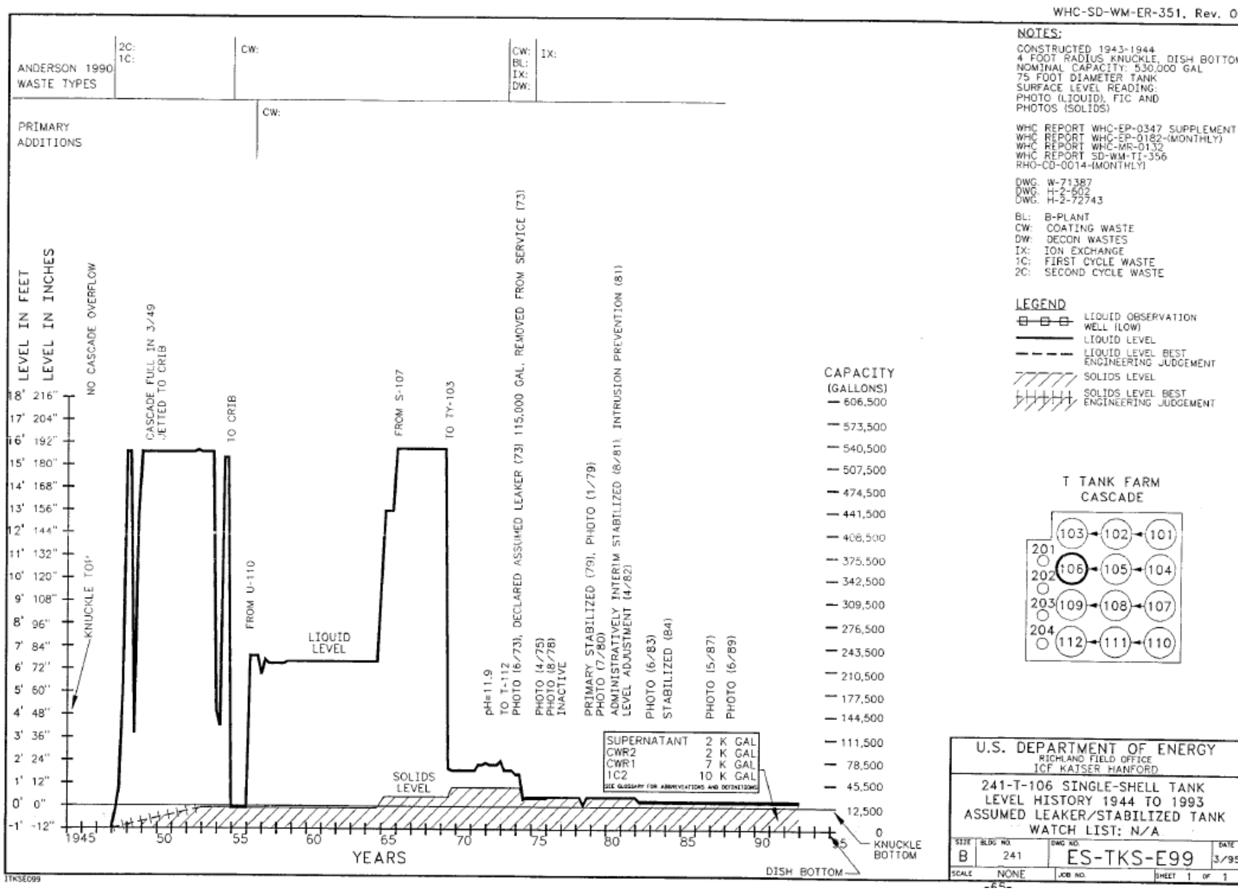
The T Farm tanks experienced a reported warping of the bottom liners during construction of the tanks and all of the T Farm tank bottom liners required replacement (HW-7-103, *Hanford Engineering Works Monthly Report April 1944*, page 14). No specific references were recovered documenting replacement of the tank T-106 bottom liner. The original construction time frame of the T Farm 100-series tank bottom liners and knuckle was about 30 days. Photographs indicate about 60 days were required to replace most of the warped T Farm bottom liners which also included construction of most of the tank sidewalls. Monthly reports indicated all tanks passed X-ray tests. The number of concurrent construction activities in T Farm during the bottom liner replacement opens the possibility of quality issues that may not have been identified by X-ray testing. See Section 3.1.2, Construction Activities, for additional details.

4.4 TANK T-106 IN-TANK DATA

4.4.1 Liquid Level

The liquid level plot in Figure 4-3 indicates the transfer activity into and out of tank T-106. The liquid levels are end of quarter levels so this figure may not reflect all transfers into and out of the tank that occurred during the operational history. See Figure 4-2 for historical monthly liquid level readings.

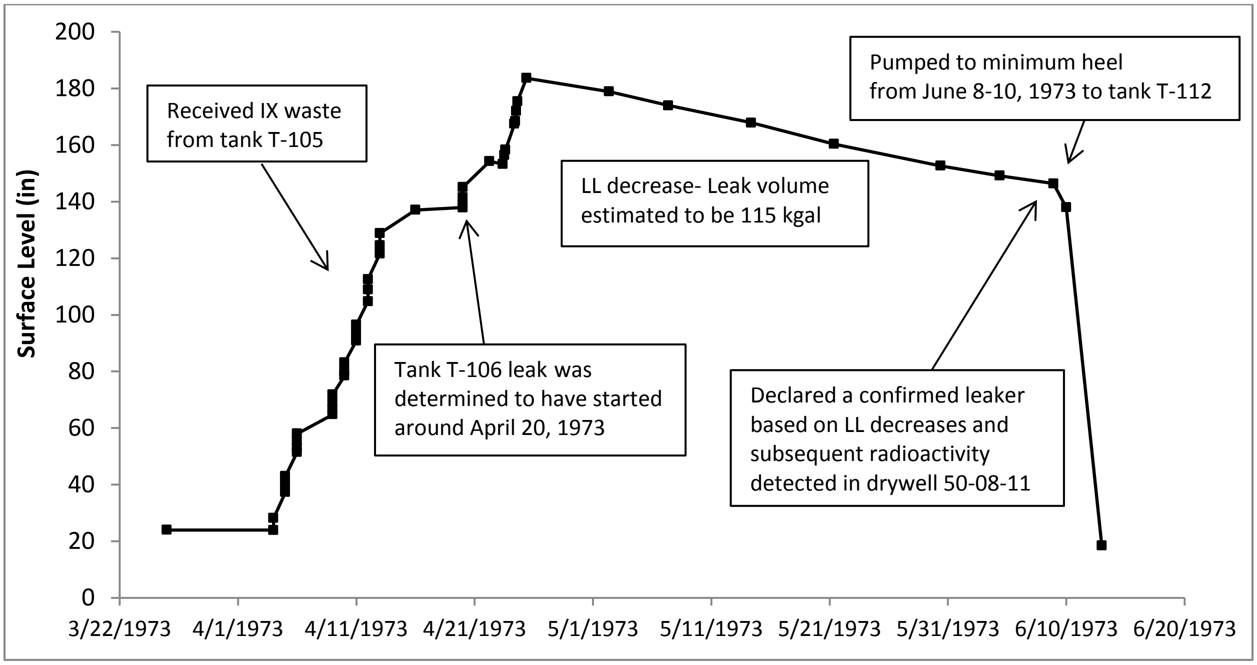
Figure 4-3. Tank T-106 End of Quarter Surface Level



HNF-SD-WM-ER-320, Rev. 1, 1997, *Supporting Document for the Historical Tank Content Estimate for T-Tank Farm.*

The tank T-106 leak was determined to have started on or around April 20, 1973 (AEC Report 1973). The tank was declared a confirmed leaker June 8, 1973 based on liquid level decreases and subsequent radioactivity detected in drywell 50-08-11. A plot of the tank T-106 liquid level from March 26, 1973 through June 13, 1973 (see Figure 4-4) shows the transfer of ion exchange (IX) waste from tank T-107 to tank T-105 and cascaded to T-106 and subsequent liquid level decrease from a leak. The total leak volume of waste from the tank, 115 kgal, occurred during the transfer of waste into tank T-106 through pumping the waste to tank T-112 starting June 8, 1973.

Figure 4-4. Tank T-106 Liquid Level March 26, 1973 through June 10, 1973

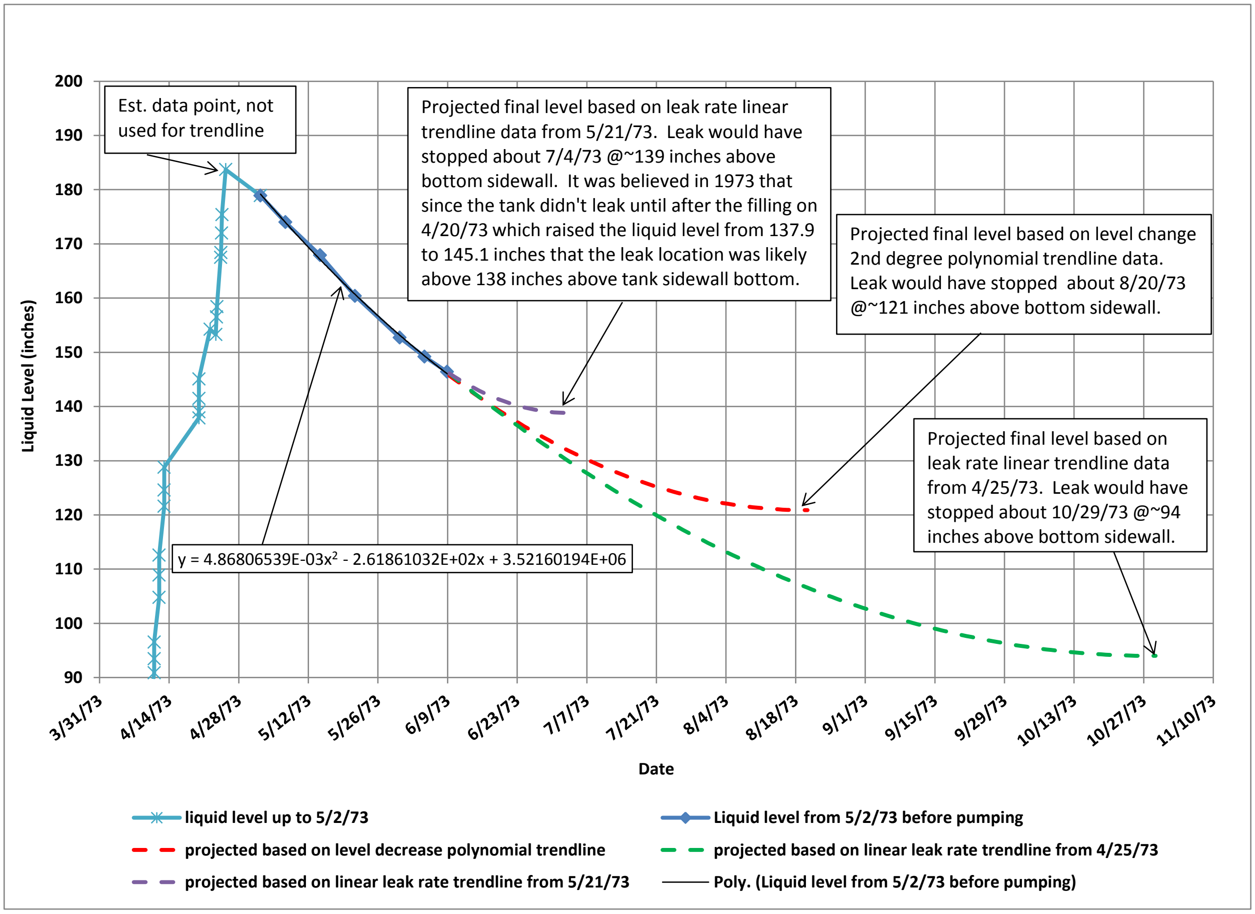


Reference: AEC Report 1973, Exhibit G

It was originally assumed that the tank T-106 leak occurred at approximately the 138-in liquid level indicating a sidewall leak based on a discrepancy in the material balance during the transfer of IX waste cascaded from tank T-105 (IDMS Accession #1009270335, page 223). A material balance discrepancy of greater than 1.2-in was determined sometime between April 4 and April 24, 1973, when pumping from tank T-107 to tank T-105 occurred. Tank T-106 stopped receiving IX waste cascaded from tank T-105 between April 25 and May 2, 1973.

Figure 4-5 shows the projected final liquid level (or potential sidewall leak location) based on a linear leak rate trend line and a polynomial leak rate trend line using data from various start dates in May 1973 to right before pumping on June 8, 1973. Three projected final liquid levels were determined ranging from 94-in to 139-in above the tank sidewall bottom, supporting a possible sidewall leak. See RPP-RPT-54921, *Estimation of Past Leak Rates for Selected Hanford Single-Shell Tanks* (To be issued), for additional information. The surrounding tank T-106 drywells (see Section 4.5.1) support a leak location at or near the tank bottom. However, a sidewall leak could be possible since the leak may have penetrated the waterproof membrane at any location (possibly near the bottom of the tank) for egress to the soil which could have been detected at a lower BGS level in the nearby drywells.

Figure 4-5. Tank T-106 Estimated Level Change if Tank Not Pumped



Note: The purple and green dotted projections were determined through back calculations of liquid level using a decreasing rate with time which was projected into the future.

4.4.2 Temperature

No temperature data were recovered for tank T-106 from June 1947 when the tank was first put into service until June 1975. Tank T-106 waste temperature plots from September 1975 to 2013 can be found in SACS (PCSACS). Average temperatures ranged from approximately 65°F to 75°F from 1975 to present with the maximum temperature reported at 87°F in September 1979 (see PCSACS).

Seven tanks in the B, C, T, and U Farms that contained metal waste (MW) ranged in temperature from 84°F to 174°F between 1945 and 1947 (HW-14946, *A Survey of Corrosion Data and Construction Details, 200 Area Waste Storage Tanks*). The temperature of T Farm tanks (tank T-101 and T-102) that contained MW waste ranged from 99°F to 165°F between 1945 and 1947 (HW-14946). Document HW-20742, *Loss of Depleted Metal Waste Supernatant to Soil*, reports MW from the $BiPO_4$ process was cascaded into a 241-BX Farm series of tanks with temperatures recorded in the first tank of ~180°F, which contained the bulk of the uranium and fission products, and ~70°F in the last tank of the cascade. Tank T-106, the third tank in the tank T-104 through tank T-106 cascade would also experience the lowest temperatures with cooling time and less fission product containing solids accumulation. The MW contains approximately 90%, of the fission products from the $BiPO_4$ process, 1C approximately 10%, and 2C 1% or less. This provides a point of comparison to infer low tank waste temperatures in tank T-106 probably 100°F or less for the storage of 1C and 2C wastes.

The rate of temperature rise can result in increased vapor pressure under the bottom tank liner from moisture in the underlying grout and vapor from the asphalt membrane below the grout. Temperatures are not available so an actual rate of temperature rise is not available but the above temperature scenario would not likely result in bulging. There were no reports of bulging in tank T-106.

4.4.3 Liner Observations

A review of the available photographs taken June 12, 1973 and April 16, 1975 did not contain any evidence of a tank bottom liner bulge. There is no documentation available indicating a liner bulge was present in tank T-106.

4.4.4 Chemistry-Corrosion

Tank T-106 began receiving 2C waste from 221-T Plant in June 1947 and stored various waste types as shown in Table 4-1. The typical concentration for nitrite, nitrate, and hydroxide for these waste types are shown in Table 4-2. Nitrite and hydroxide are known as nitrate induced SCC inhibitors. One key characteristic for inhibiting SCC is to maintain a high nitrite concentration to nitrate concentration ratio (see Section 3.2.4).

Table 4-1. Tank T-106 Waste Storage Chronology

Date	Waste Type	Length of Storage
June 1947 to 1948	2C	~ 1 year
1948 to 1955	1C	~ 7 years
1956 to 1969	1C/REDOX CW	~ 13 years
1973	IX	~ 3 months

Note: Tank T-106 received a small amount of undefined B Plant low level waste in 1973.

Table 4-2. Waste Chemistries for Waste Types Stored in Tank T-106

Waste Type[1]	[NO_3^-]	[NO_2^-]	[OH^-]	Meets Current DST Specification[2]
CW	0.6	0.9	1.0	Yes
1C	1.54	0.26	0.28	No[3]
IX	1.97	0.27	0.69	Yes
2C	1.27	Not Reported	Not Reported	No[4]

1. Reference WHC-EP-0449, 1991, *The Sort on Radioactive Waste Type Model: A Method to Sort Single-Shell Tanks into Characteristic Groups.*
2. Reference OSD-T-151-00007, Rev. 12, 2013, *Operating Specification for the Double-Shell Storage Tanks*.
3. Reference WHC-EP-0772, 1994, *Characterization of the Corrosion Behavior of the Carbon Steel Liner in Hanford Site Single-Shell Tanks*.
4. According to the assumption from reference WHC-EP-0772, *Characterization of the Corrosion Behavior of the Carbon Steel Liner in Hanford Site Single-Shell Tanks*.

The first waste type stored in tank T-106 was 2C waste from 221-T Plant. The 2C waste was stored in the tank for approximately one year at unknown temperatures. Waste type 2C is assumed to not meet the current DST specifications (WHC-EP-0772) based on possibly high nitrate and low hydroxide. One of the recommendations in the report, HW-3-3220, *SE-PC-#82 A Study of Decontamination Cycle Waste Solutions and Methods of Preparing Them for Disposal*, states neutralizing 2C waste to pH 7 was adopted at 221-T Plant beginning in October 1945. The 2C waste is potentially a concern for pitting and/or SCC but it is not conclusive as the storage temperatures were low.

Tank T-106 stored 1C waste type for approximately seven years on top of a heel of 2C waste and then stored 1C mixed with REDOX CW for 13 years, for a total of 20 years. Waste type 1C does not meet the current DST specification for waste chemistry due to low concentrations of nitrite and hydroxide and would create an environment conducive to SCC and/or pitting. However, the REDOX CW would have reduced the corrosiveness of the 1C waste. Tank T-106 received IX waste prior to the tank leak, which should not be a concern for either pitting and/or SCC.

4.4.5 Photographs

The available photographs for tank T-106, taken June 12, 1973 and April 16, 1975, were reviewed and no anomalies were indicated that relate to a liner failure.

4.5 TANK T-106 EX-TANK DATA

4.5.1 Drywells

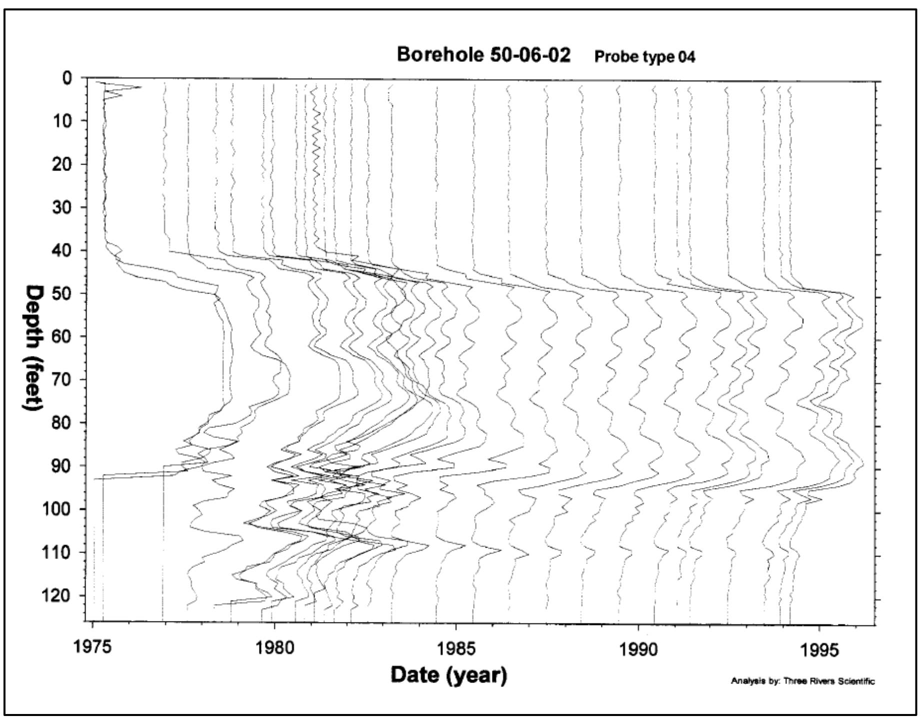
There are 14 drywells located around tank T-106 with specified distances from the drywell to the tank footing shown in Figure 4-1. Drywells 50-00-10 and 50-08-11 were installed in 1944 and were the only drywells near tank T-106 when the leak was detected. The following were all installed after the leak was detected: 50-06-02, 50-06-03, 50-06-04, 50-06-05, 50-06-06, 50-06-08, and 50-06-11, installed in 1973, 50-06-17, 50-03-06, and 50-06-16, installed in 1975, 50-00-09 installed in 1977, and 50-06-18 installed in 1993. In addition, two direct pushes, C4104 and C4105, were installed in 2003. All of the radiation readings in drywells are assumed to be maximum or peak readings unless otherwise noted (see Section 3.3.2). The following subsections report the available drywell information and the drywell summary section provides the analyses of the associated drywells with tank T-106 leak location.

4.5.1.1 Drywell 50-06-02

Drywell 50-06-02 is located approximately 4.5-ft from the tank T-106 footing. Drywell 50-06-02 was drilled in July 1973 with the first recoverable reading on July 10, 1973 reporting a peak of 300K cpm at approximately 55-ft BGS. Readings continued to be reported through June 1987 at depths ranging from 55 to 86-ft BGS and readings ranged between 200K cpm and 1400K cpm. See Appendix A1 for the drywell data.

In June 1999, Cs-137, Co-60, Eu-154, Eu-152, U-238, and U-235 were the only man-made gamma-emitting radionuclides detected in this drywell (GJ-HAN-120, *Vadose Zone Characterization Project at the Hanford Tank Farms Tank Summary Data Report for Tank T-106*). Document GJ-HAN-120 reports, "*The interval of Co-60, Eu-154, Eu-152, and processed uranium (U-235 and U-238) contamination detected below 45 ft is interpreted to demarcate a contaminant plume that resulted from the T-106 tank leak. The highest concentrations of Co-60 contamination occur within the central portion of the plume (75 to 102 ft), suggesting that the Co-60 contamination traveled primarily through the formation and was not dragged down during drilling. Historical gross gamma log data suggest that the Co-60 contamination within the plume continued to migrate downward from 1973 to 1992.*" Figure 4-6 shows the depths of radioactivity from 1975 to 1995 (RPP-6088).

Figure 4-6. Tank T-106 Drywell 50-06-02 (RPP-6088)



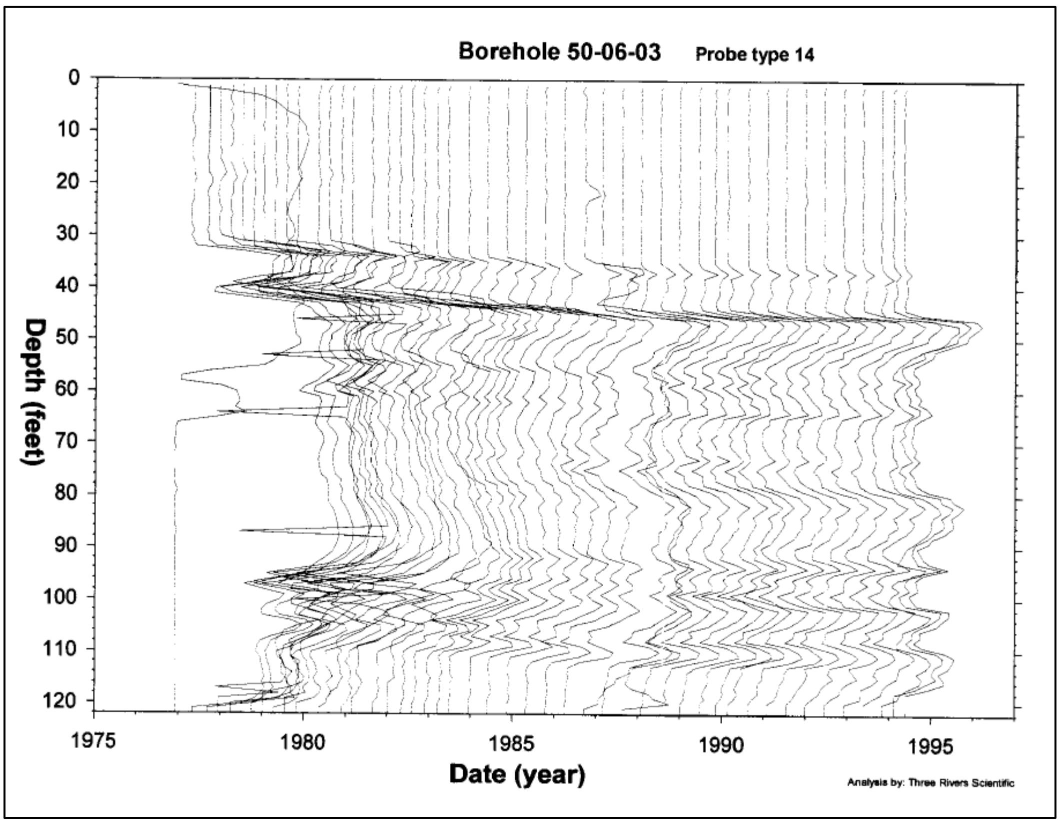
Note: Bottom of the tank footing is ~38-ft 1-in BGS

4.5.1.2 Drywell 50-06-03

Drywell 50-06-03 is located approximately 3.1-ft from the tank T-106 footing. Drywell 50-06-03 was drilled in June 1973 with the first recoverable reading on June 27, 1973 with two peaks, 350K cpm at ~46-ft BGS and 500K cpm at ~82-ft BGS (see Appendix A1). The next reading on July 24, 1973 reported two peaks, 337K cpm at 43-ft BGS and 257K cpm at 77-ft BGS, both peaks at a higher BGS level. Radioactivity continued to be detected through August 1987 at about the 82 to 92-ft BGS level. The peaks were reported at the higher BGS level (~45-ft BGS) later from 1984 to 1987.

In June 1999, Cs-137, Co-60, Eu-154, Eu-152, and Sn-126 were the only man-made radionuclides detected in this drywell (GJ-HAN-120). Document GJ-HAN-120 states, "*The Cs-137, Co-60, Eu-154, and Eu-152 contamination detected between 33 and 42 ft most likely originated from the T-106 tank leak. It appears that the contamination migrated laterally from the leak source along the base of the tank to this borehole.*" This document also states that the contamination detected below 43-ft BGS originated from the tank T-106 leak. Figure 4-7 shows the depths of radioactivity from 1975 to 1995 (RPP-6088).

Figure 4-7. Tank T-106 Drywell 50-06-03 (RPP-6088)



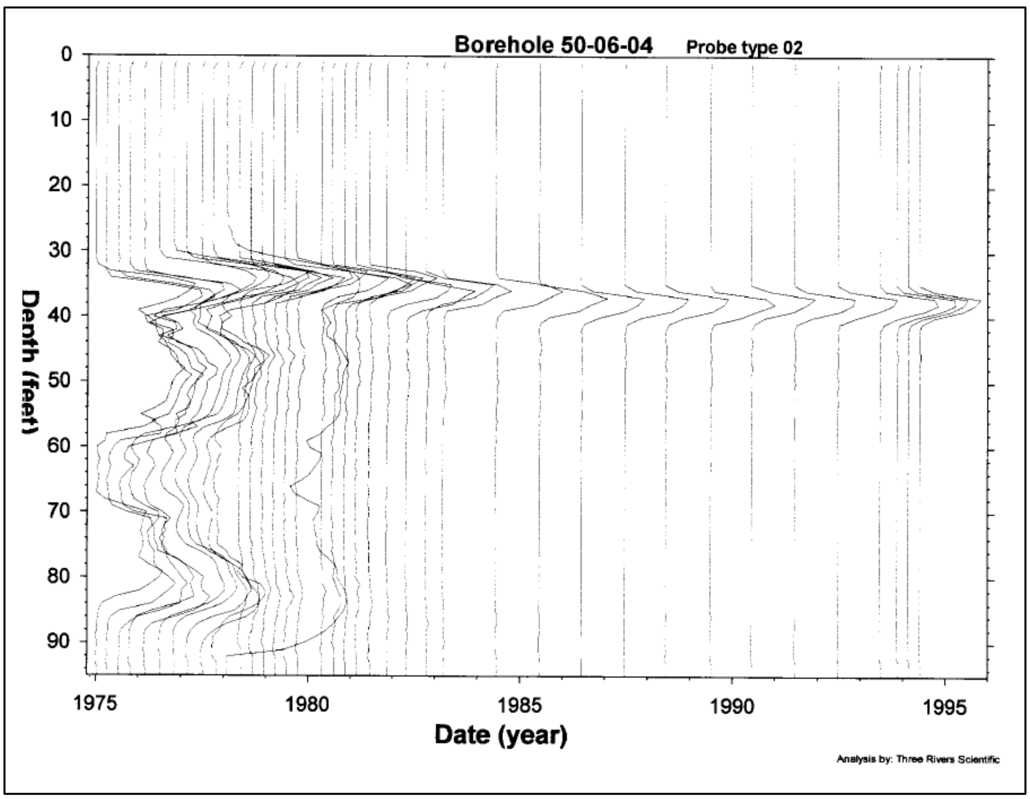
Note: Bottom of the tank footing is ~38-ft 1-in BGS

4.5.1.3 Drywell 50-06-04

Drywell 50-06-04 is located approximately 2.2-ft from the tank T-106 footing. Drywell 50-06-04 was drilled in July 1973 with the first recoverable readings reported on July 24, 1973 with two peaks, 387K cpm at 33-ft BGS and 290K cpm at 45-ft BGS (see Appendix A1). Radioactivity levels gradually declined through June 1987 but the peak continued to be reported at the higher BGS depth (33-37-ft BGS).

In June 1999, Cs-137, Co-60, Eu-154, Eu-152, and Sn-126 decay product were the only man-made gamma and beta-emitting radionuclides detected in this drywell (GJ-HAN-120). Document GJ-HAN-120 states, "*Cs-137 appears to be the predominant radionuclide present within the zone of extremely high gamma radiation detected from 35 to 41 ft. Significant concentrations of Co-60 and Eu-154/152 may also occur within this contamination zone. This contamination originated from the T-106 tank leak, accumulated at the base of the tank farm excavation, and migrated laterally along the perimeter of the tank to this borehole.*" Figure 4-8 shows the depths of radioactivity from 1975 to 1995 (RPP-6088).

Figure 4-8. Tank T-106 Drywell 50-06-04 (RPP-6088)



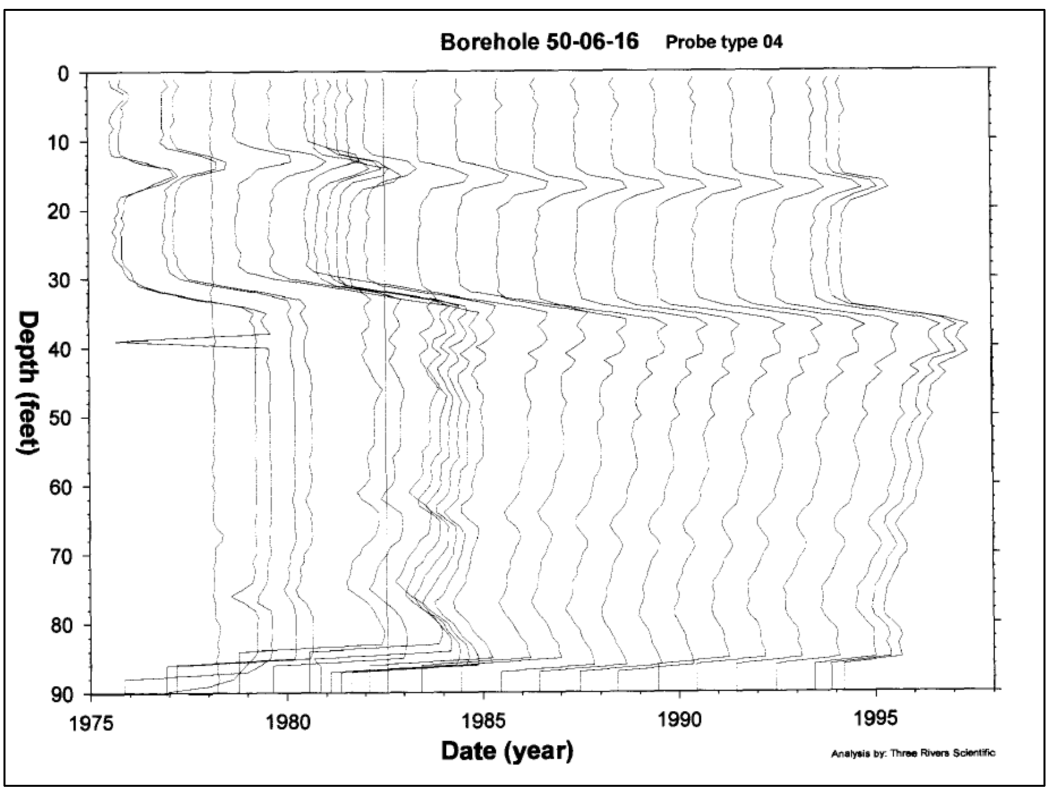
Note: Bottom of the tank footing is ~38-ft 1-in BGS

4.5.1.4 Drywell 50-06-16

Drywell 50-06-16 is located approximately 4.8-ft from the tank T-106 footing. Drywell 50-06-16 was drilled on July 1975 with the first recoverable reading on July 16, 1975 with a peak of 33.9K cpm at 49-ft BGS (see Appendix A1). The next reading reported on July 25, 1975 reported the peak at 65-ft BGS (36.7K cpm). Radioactivity gradually declined at this BGS level through January 18, 1977. Beginning on January 21, 1977, radioactivity increased to 1362.7K cpm at 47-ft BGS and by September 17, 1980 a peak of 2707.4K cpm was recorded at 33-ft BGS. See Appendix A1 for drywell 50-06-16 data through June 1987.

In June 1999, Cs-137, Co-60, Eu-154, and Eu-152 were the only man-made gamma-emitting radionuclides detected in drywell 50-06-16 (GJ-HAN-120). Document GJ-HAN-120 reports, "*The zone of very high Cs-137 contamination and the less concentrated zone of Eu-154 detected between 33 and 42 ft originated from the T-106 tank leak. Other radionuclides may be present within this zone that were not detected by the SGLS because of the high dead time in the region. It appears that the waste accumulated and spread along the base of the tank farm excavation to this borehole.*" Figure 4-9 shows the depths of radioactivity from 1975 to 1995 (RPP-6008). Radioactivity at ~15-ft BGS shown in Figure 4-9 is probably due to a pipeline or other near surface source.

Figure 4-9. Tank T-106 Drywell 50-06-16 (RPP-6008)



Note: Bottom of the tank footing is ~38-ft 1-in BGS

4.5.1.5 Drywell 50-06-18

Drywell 50-06-18 is located approximately 4.2-ft from the tank T-106 footing. Drywell 50-06-18 was drilling to total depth was completed on April 13, 1993. Between November 1992 and April 1993, logging with the Radionuclide Logging System (RLS) was performed several times to progressively log the drywell as it was gradually drilled to total depth. The counting system of the shielded RLS was saturated from 35 to 44-ft BGS; however, at 0.5-ft above the saturation zone, the radioactivity measured greater than 6,000 pCi/g of Cs-137 (GJ-HAN-120). It was stated in GJ-HAN-120, "*The fact that the detection capability of the shielded RLS was exceeded along this interval indicates that this zone of very high radiation probably contains Cs-137 concentrations in excess of 33,000 pCi/g.*"

In June 1999, Cs-137, Co-60, Eu-154, and Eu-152 were the only man-made gamma-emitting radionuclides detected in drywell 50-06-18 (GJ-HAN-120). The 1998 RLS data was compared to the 1999 SGLS data it was determined that the Cs-137, Co-60, Eu-154, Eu-152, and Sn-126 detected below 45-ft BGS resulted from the T-106 tank leak (GJ-HAN-120). Also, the data indicated that no influx or movement of the Cs-137, Eu-154, and Eu-152 contamination has occurred since 1994 and that these contaminants appear to be stable within the plume.

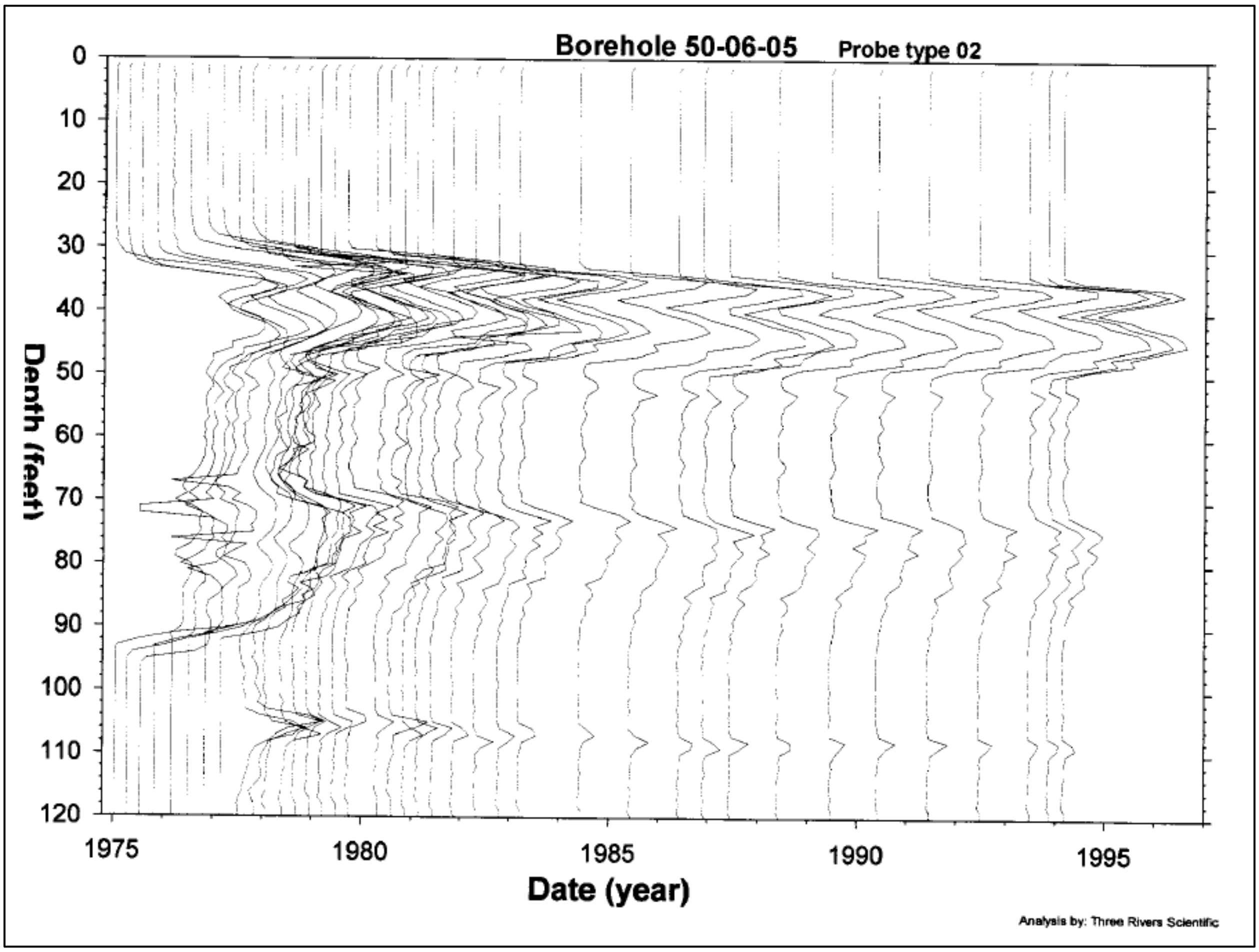
Drywell 50-06-18 was drilled about 20 years after tank T-106 started leaking. This data only indicates the spread of the contamination plume from 1973 and does not help in identifying the initial leak location of the tank T-106 leak. Therefore, drywell 50-06-18 is not included as part of the determination of the leak location for tank T-106.

4.5.1.6 Drywell 50-06-05

Drywell 50-06-05 is located approximately 5-ft from the tank T-106 footing. Drywell 50-06-05 was drilled in August 1975 with the first recoverable reading on August 27, 1973 reported two peaks at 700K cpm, one at 29-ft BGS and the other at 39-ft BGS (see Appendix A1). Subsequent readings only reported one peak at approximately the 40-ft BGS level. Readings gradually increased to 1334.9K cpm at 44-ft BGS by December 1974 and then gradually declined to 365.5K cpm at 44-ft BGS by June 1987.

In June 1999, Cs-137 and Co-60 were the only man-made gamma-emitting radionuclides detected in drywell 50-06-05 (GJ-HAN-120). Document GJ-HAN-120 reports, "*On the basis of the rate of decrease of the historical gross gamma activity, it was determined that Cs-137 is the primary radionuclide present within the zone of extremely high gamma radiation detected from 33 to 93 ft. The magnitude of the Cs-137 within this region of the vadose zone indicates that the contamination originated from the T-106 tank leak and that this borehole is very close to the leak source.*" Figure 4-10 shows the depths of radioactivity from 1975 to 1995 (RPP-6008).

Figure 4-10. Tank T-106 Drywell 50-06-05 (RPP-6008)



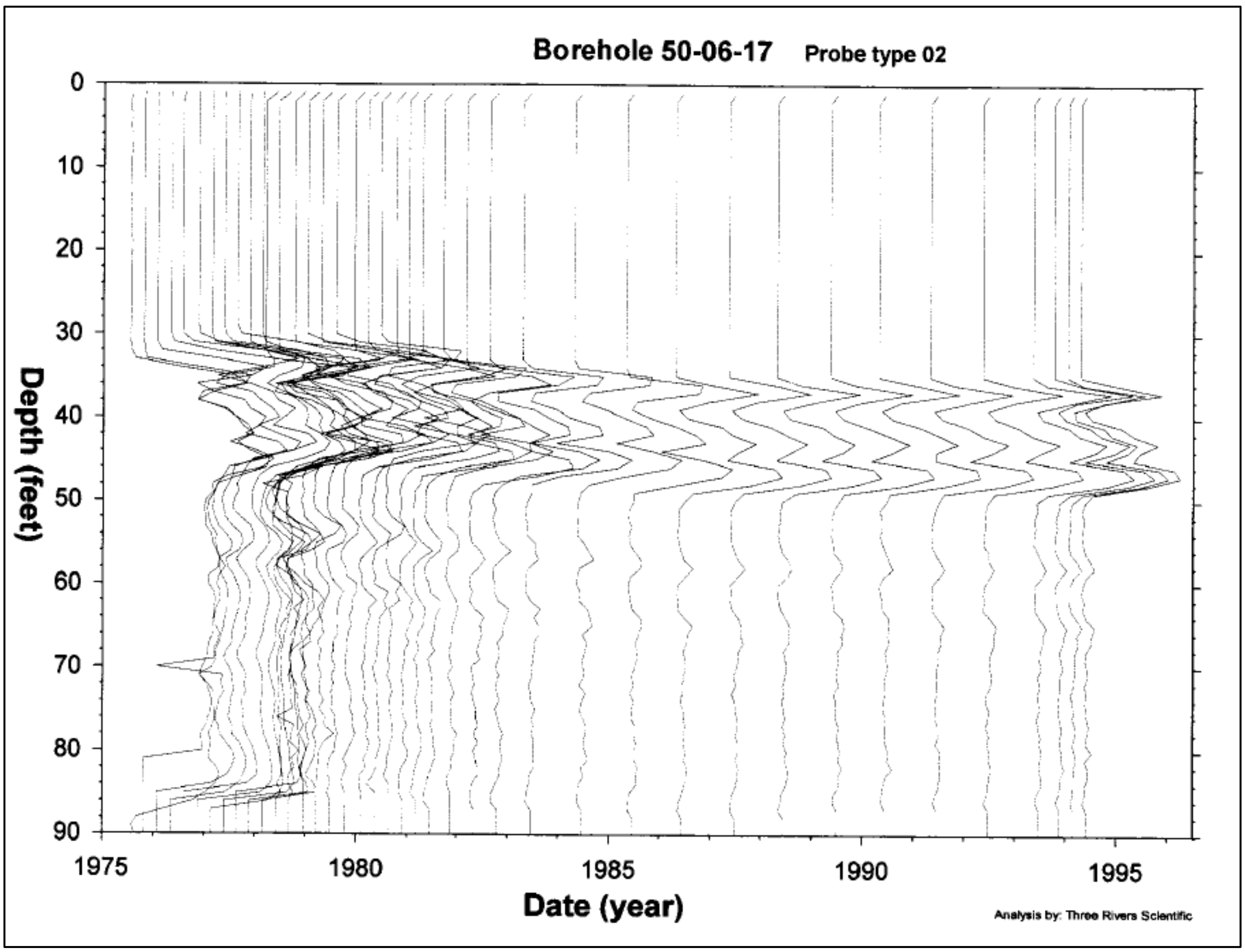
Note: Bottom of the tank footing is ~38-ft 1-in BGS

4.5.1.7 Drywell 50-06-17

Drywell 50-06-17 is located approximately 4.4-ft from the tank T-106 footing. Drywell 50-06-17 was drilled in July 1975 with the first recoverable reading on July 16, 1975 reported a peak of 312.2K cpm at 46-ft BGS (see Appendix A1). Readings doubled at this BGS level by July 25, 1975 and remained relatively stable to March 7, 1978. Beginning March 14, 1978 through June 1987, the peak was recorded at approximately 100K cpm ranging from 43 to 47-ft BGS.

In June 1999, Cs-137 and Eu-154 were the only man-made gamma-emitting radionuclides detected in drywell 50-06-17 (GJ-HAN-120). Document GJ-HAN-120 reports, "*The rate of decrease of historical gross gamma activity within the zone of extremely high gamma radiation indicates that Cs-137 is the predominant radionuclide present within the interval from 33 to 50 ft and in the lower portion of the logged interval. Similar to borehole 50-06-05, the potential magnitude of the Cs-137 within these regions of the vadose zone indicates that this contamination originated from the T-106 tank leak and that this borehole is very close to the leak source.*" Figure 4-11 shows the depths of radioactivity from 1975 to 1995 (RPP-6008).

Figure 4-11. Tank T-106 Drywell 50-06-17 (RPP-6008)



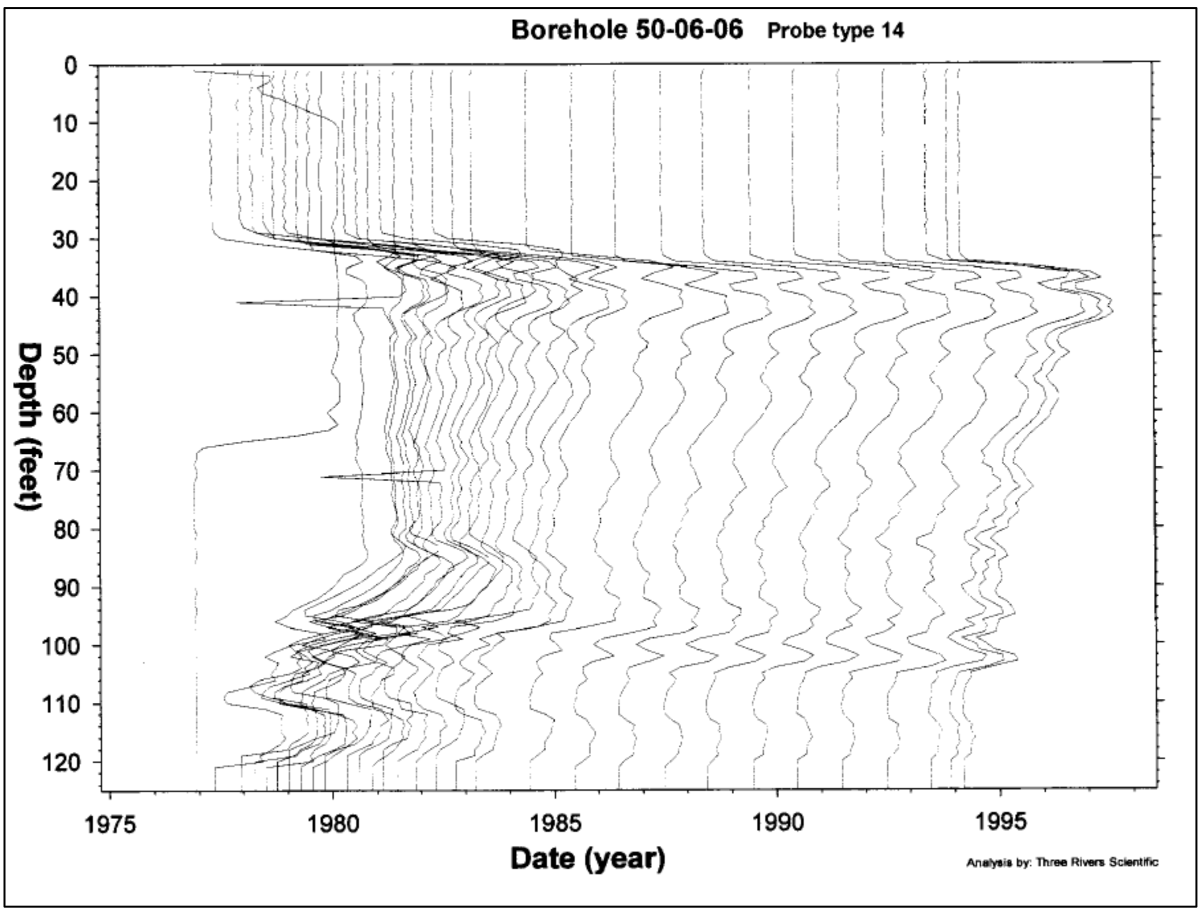
Note: Bottom of the tank footing is ~38-ft 1-in BGS

4.5.1.8 Drywell 50-06-06

Drywell 50-06-06 is located approximately 3.1-ft from the tank T-106 footing. Drywell 50-06-06 was drilled in July 1973 with the first recoverable reading on July 3, 1973 reported a broad peak at ~400K cpm from 42 to 66-ft BGS (see Appendix A1). Subsequent readings remained relatively stable. Beginning July 25, 1975 through November 30, 1976, the peak radioactivity was reported at the 82-ft BGS level. The peak was then reported at 39-ft BGS beginning January 4, 1977 and readings continued to be detected through June 1987 at roughly this BGS level.

In June 1999, Cs-137, Co-60, Eu-154, Eu-152, Sn-126, and Sb-125 were the only man-made gamma and beta emitting radionuclides detected in drywell 50-06-06 (GJ-HAN-120). Document GJ-HAN-120 reports, "*The rate of decrease of the historical gross gamma activity suggests that Cs-137 is the predominant radionuclide present within the zone of extremely high gamma radiation detected from 35 to 46 ft. The Cs-137 contamination originated from the T-106 tank leak, accumulated at the base of the tank farm excavation, and migrated laterally along the perimeter of the tank to this borehole.*" Figure 4-12 shows the depths of radioactivity from 1975 to 1995 (RPP-6008).

Figure 4-12. Tank T-106 Drywell 50-06-06 (RPP-6008)



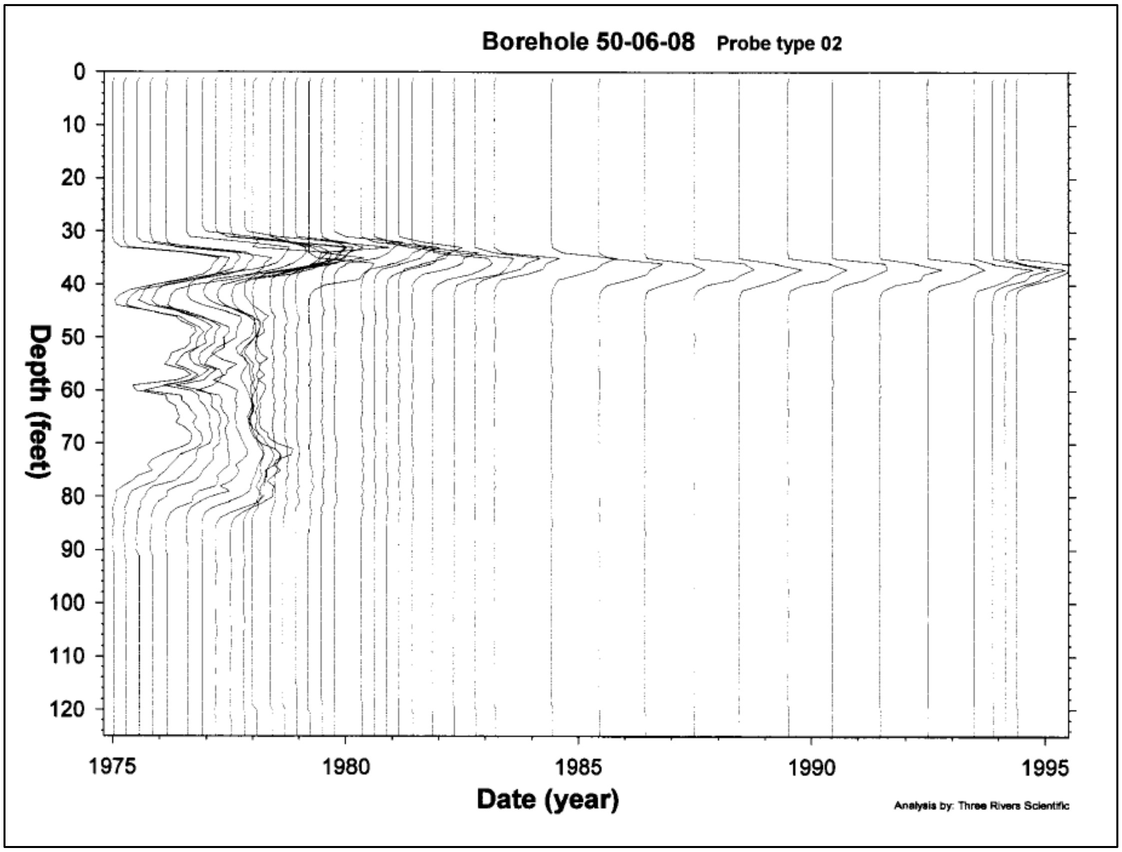
Note: Bottom of the tank footing is ~38-ft 1-in BGS

4.5.1.9 Drywell 50-06-08

Drywell 50-06-08 is located approximately 4.8-ft from the tank T-106 footing. Drywell 50-06-08 was drilled in July 1973 with the first recoverable reading on July 11, 1973 with two peak reported, 450K cpm from 32 to 39-ft BGS and 350K cpm at ~49-ft BGS (see Appendix A1). The next recoverable reading on July 24, 1973 reported only one peak at 34-ft BGS. Readings gradually declined to 22.9K cpm by June 1987 at this BGS level.

In June 1999, Cs-137, Co-60, Eu-154, Eu-152, and Sn-126 were the only man-made gamma and beta-emitting radionuclides detected in drywell 50-06-08 (GJ-HAN-120). Document GJ-HAN-120 reports, "*On the basis of the rate of decrease of the historical gross gamma activity, it was determined that Cs-137 is the predominant radionuclide present within the zone of extremely high gamma radiation detected from 35 to 41 ft. A large zone of moderate to high Cs-137 contamination extends from 46 ft to the bottom of the logged interval around this borehole. No deep Cs-137 contamination was detected below 41 ft around adjacent borehole 50-06-06, which lies between this borehole and the suspected source of the contamination, suggesting that the Cs-137 did not migrate through the vadose zone sediments from the contaminant source. The data indicate that the Cs-137 contamination originated from the T-106 tank leak, accumulated at the base of the tank farm excavation, and migrated laterally along the bottom of the tank farm excavation to this borehole.*" Figure 4-13 shows the depths of radioactivity from 1975 to 1995 (RPP-7729).

Figure 4-13. Tank T-106 Drywell 50-06-08 (RPP-6008)



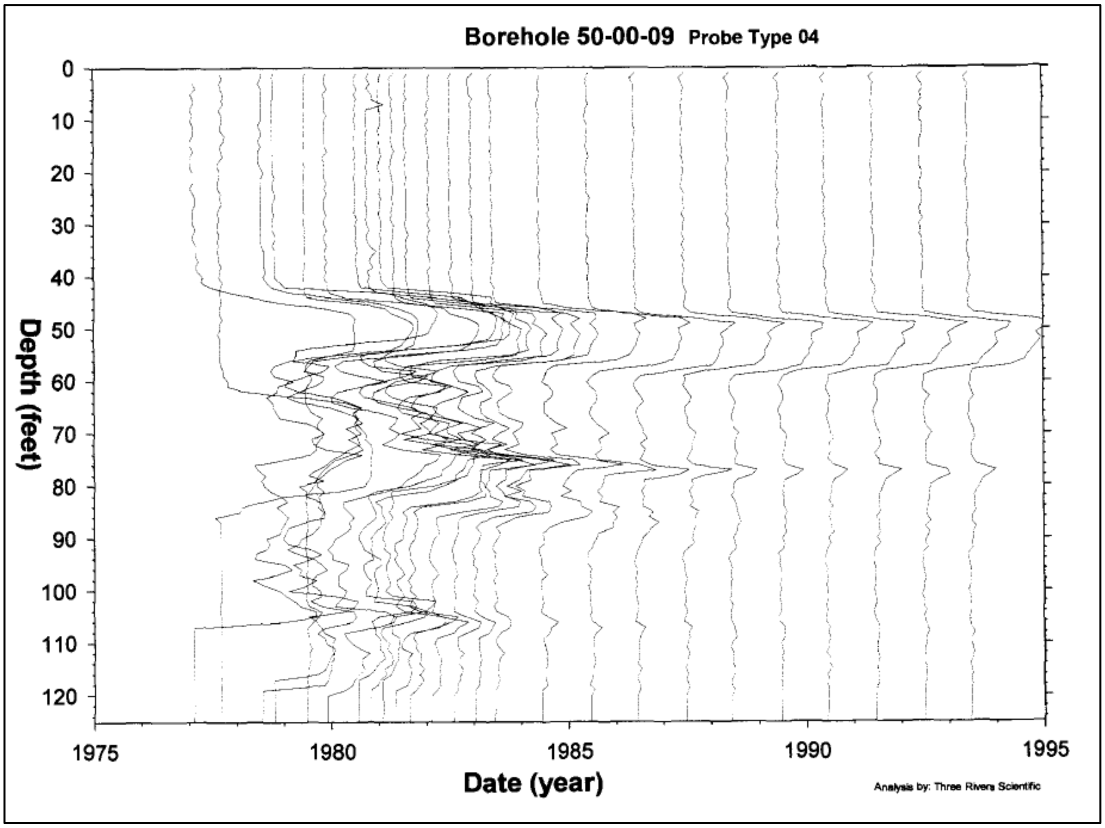
Note: Bottom of the tank footing is ~38-ft 1-in BGS

4.5.1.10 Drywell 50-00-09

Drywell 50-00-09 is located approximately 36-ft from the tank T-106 footing. Drywell 50-00-09 was drilled on February 28, 1977. No historical drywell data were recovered for drywell 50-00-09 except for Figure 4-14 which shows the depths of radioactivity from 1975 to 1995 (RPP-6008).

In June 1999, Cs-137, Co-60, Eu-154, and Eu-152 were the only man-made gamma-emitting radionuclides detected in drywell 50-00-09 (GJ-HAN-120). Document GJ-HAN-120 reports, "*The radionuclide contaminants Co-60, Eu-154, and Eu-152 detected below 46 ft occur within a plume that resulted from the T-106 tank leak. This plume has been identified in all the boreholes located adjacent to the east and southeast sides of the tank between this borehole and borehole 50-06-02.*"

Figure 4-14. Tank T-106 Drywell 50-00-09 Probe 04 (RPP-6088)



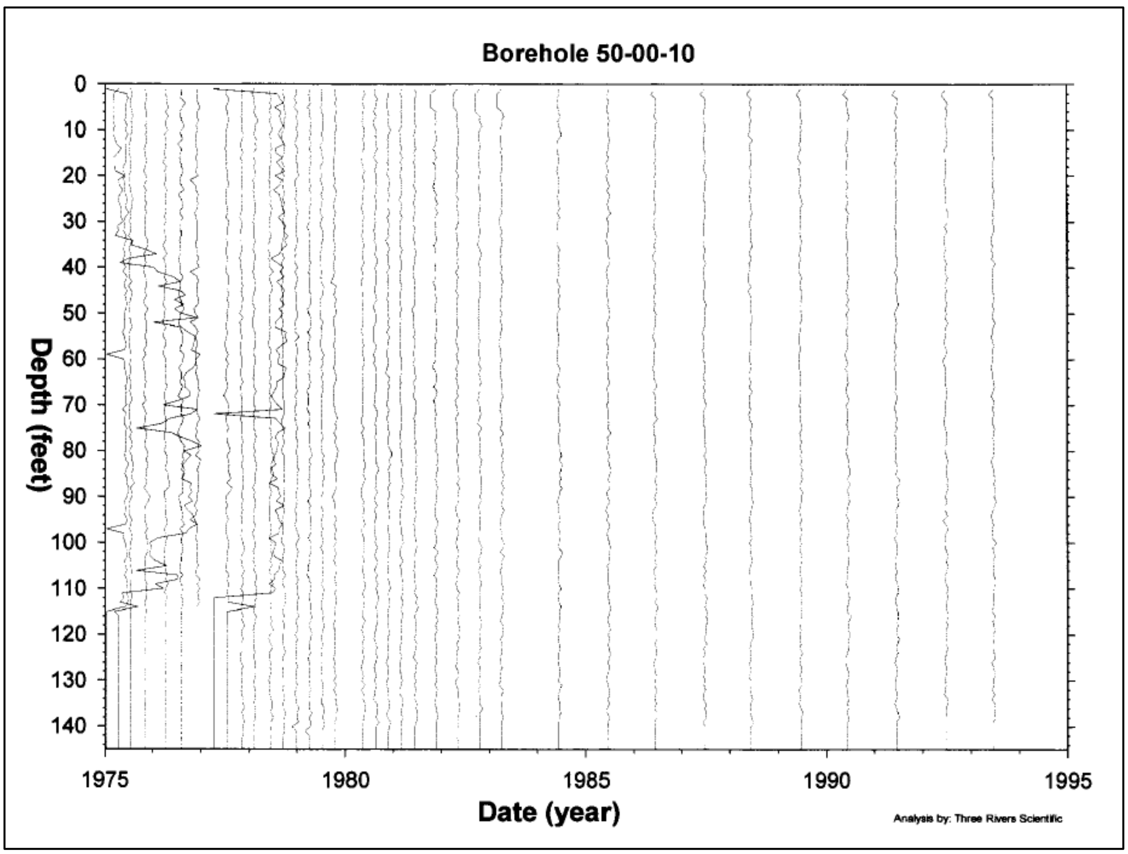
Note: Bottom of the tank footing is ~38-ft 1-in BGS

4.5.1.11 Drywell 50-00-10

Drywell 50-00-10 is located approximately 39-ft from the tank T-106 footing. Drywell 50-00-10 was drilled in 1944 with the first recoverable reading in 1973 reported as less than values (see Figure A1-1). No other drywell data were recovered except for Figure 4-15 which shows the depths of radioactivity from 1975 to 1995 (RPP-6088).

In June 1999, Cs-137 was the only man-made gamma-emitting radionuclides detected in drywell 50-00-10 (GJ-HAN-120). Cs-137 was detected continuously from the ground surface to 17-ft BGS at low concentrations ranging from 0.1 to 0.5 pCi/g. Isolated Cs-137 contamination was detected at 115.5 and 116-ft BGS at concentrations of 0.11 and 0.22 pCi/g, respectively. Document GJ-HAN-120 reports, "*It appears that this borehole is located outside the region of vadose zone contamination resulting from tank or pipeline leaks.*" Since historical radioactivity in this drywell is very low, and the 1999 SGLS report low levels of radioactivity, drywell 50-00-10 is not being included as part of the leak location for tank T-106.

Figure 4-15. Tank T-106 Drywell 50-00-10 (RPP-6088)



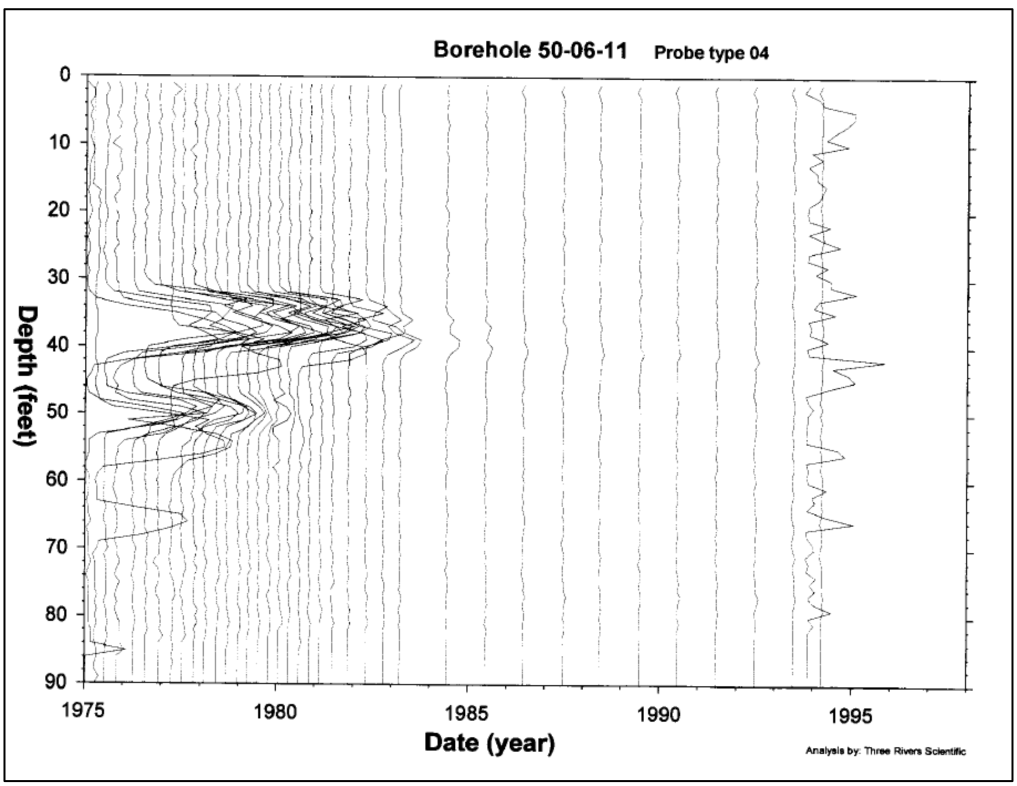
Note: Bottom of the tank footing is ~38-ft 1-in BGS

4.5.1.12 Drywell 50-06-11

Drywell 50-06-11 is located approximately 4.8-ft from the tank T-106 footing. Drywell 50-06-11 was drilled in July 1973 with the first recoverable reading on July 18, 1973 with a peak of 0.4K cpm at ~36-ft BGS (see Appendix A1). Readings remained relatively stable until November 29, 1974 when a peak of 285.8K cpm was reported at 39-ft BGS. The peak remained relatively stable through 1979 and then slowly declined to 2K cpm by June 1987 at 40-ft BGS.

In June 1999, Cs-137 and Co-60 were the only man-made gamma-emitting radionuclides detected in drywell
50-06-11 (GJ-HAN-120). Cs-137 was detected at the ground surface, 0.5-ft, and 10.5-ft BGS at concentrations of less than 0.5 pCi/g. Small zones of nearly continuous Co-60 contamination were detected from 36 to 41-ft BGS, 76.5 to 78.5-ft BGS, and from 81-ft BGS to the bottom of the logged interval (82.5-ft BGS) ranging from 0.05 to 0.25 pCi/g. Document GJ-HAN-120 reports, "*The Co-60 contamination detected from 38 to 41 ft and 76.5 to 82.5 ft may have originated from the T-106 tank leak or possibly a leak from tank T-103. The upper zone of Co-60 contamination appears to have accumulated at the base of the tank farm excavation along the bottom periphery of the tank and could have migrated from either leak source. The lower zone of Co-60 contamination correlates approximately with the depth of the Co-60 plume detected in borehole 50-03-06, suggesting that tank T-103 is a more likely source.*" Figure 4-16 shows the depths of radioactivity from 1975 to 1995 (RPP-6008).

Figure 4-16. Tank T-106 Drywell 50-06-11 (RPP-6008)



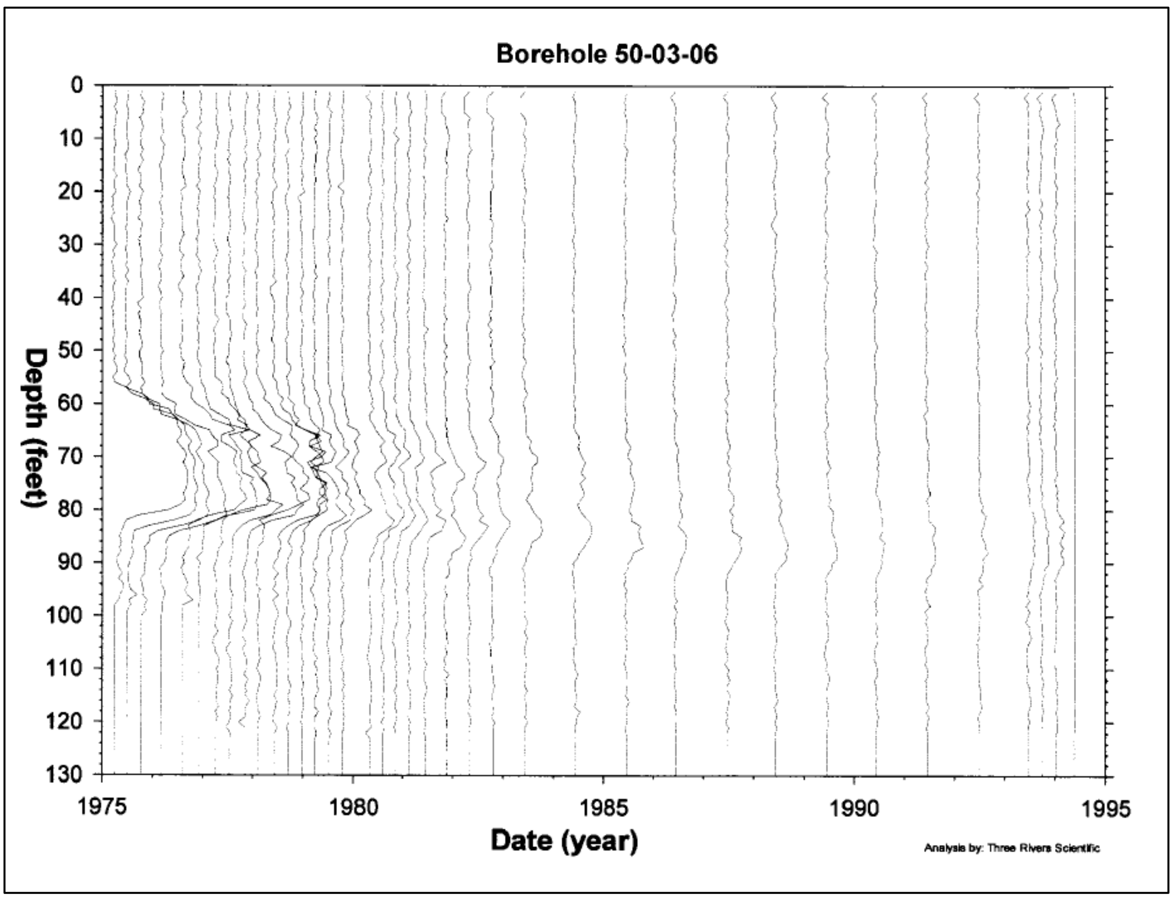
Note: Bottom of the tank footing is ~38-ft 1-in BGS

4.5.1.13 Drywell 50-03-06

Drywell 50-03-06 is located approximately 15-ft from the tank T-106 footing. Drywell 50-03-06 was drilled in January 1975 with the first recoverable reading on April 2, 1975 with a peak of 33.1K cpm reported at 75-ft BGS (see Appendix A1). The peak gradually declined into 1987 to a peak of 4.2K cpm at 87-ft BGS.

In June 1999, Cs-137, Co-60 and Eu-154 were the only man-made gamma-emitting radionuclides detected in drywell 50-03-06 (GJ-HAN-120). Cs-137 was detected at the ground surface with lower concentrations detected below this zone probably from carry down during drilling. Document GJ-HAN-120 reports, "*The plume containing Co-60 and Eu-154 contamination detected between 66 and 95 ft most likely originated from a leak from tank T-103.*" Therefore, drywell 50-03-06 is not included as part of the leak location for tank T-106. Figure 4-17 shows the depths of radioactivity from 1975 to 1995 (RPP-6088).

Figure 4-17. Tank T-106 Drywell 50-03-06 (RPP-6008)



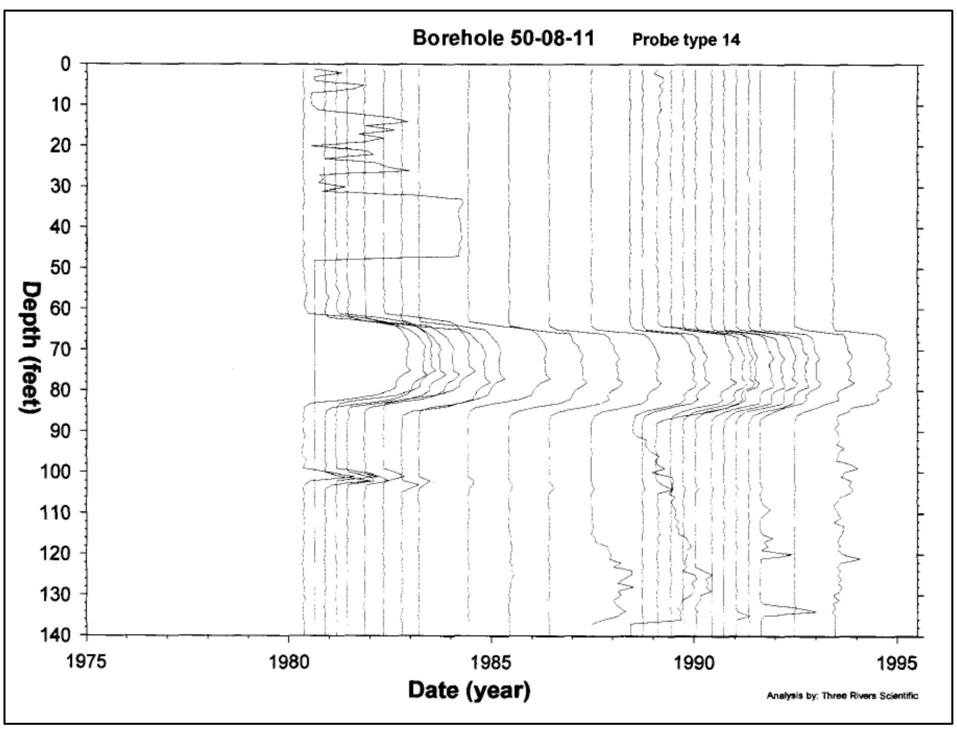
Note: Bottom of the tank footing is ~38-ft 1-in BGS

4.5.1.14 Drywell 50-08-11

Drywell 50-08-11 is located approximately 45-ft from the tank T-106 footing. Drywell 50-08-11 was drilled in 1944 and was one of two drywells near tank T-106 when the leak occurred. The first recoverable reading was on May 31, 1973 reported at 10K cpm with a scintillation probe at an indeterminate BGS (see Appendix A1). The reading increased by a factor of 10 and more over the next few days (AEC Report 1973). The next recoverable readings started July 24, 1973 at 310K cpm at ~65-ft BGS. Readings gradually decreased to 1.3K cpm at 76-ft BGS in August 1978 then were reported as 972.2K cpm at 76-ft BGS in January 1979. The January 1979 peak gradually decreased to 64.5K cpm at 78-ft BGS.

In June 1999, Cs-137, Co-60, Eu-154, and Eu-152 were the only man-made gamma-emitting radionuclides detected in drywell 50-08-11 (GJ-HAN-120). Cs-137 was detected almost continuously from the ground surface to 63.5-ft BGS, almost continuously from 85.5 to 97.5-ft BGS, intermittently from 102.5 to 105-ft BGS, and intermittently from 118-ft BGS to the bottom of the borehole (135.5-ft BGS). Co-60 contamination was detected almost continuously from 54.5 to 112.5-ft BGS. A thick zone of Co-60 contamination occurs from about 65 to 86-ft BGS. The maximum Co-60 concentration was 90.5 pCi/g at 70.5-ft BGS. Eu-152 and Eu-154 were detected continuously from ~64 to ~83-ft BGS with peaks at 4.7 pCi/g and 173.3 pCi/g, respectively. Document GJ-HAN-120 reports, "*The Co-60, Eu-154, and Eu-152 contamination detected below about 54.5 ft is probably the result of a tank leak. On the basis of data from historical gross gamma logs, contamination has been present in this interval since at least 1973. A likely source of the Co-60, Eu-154, and Eu-152 contamination is nearby tank T-106, a known leaker.*" Figure 4-18 shows the depths of radioactivity from 1980 to 1995 (RPP-6088).

Figure 4-18. Tank T-106 Drywell 50-08-11 (RPP-6008)



Note: Bottom of the tank footing is ~38-ft 1-in BGS

4.5.1.15 2003 Direct Push C4104 and C4105

In 2003, direct pushes C4104 and C4105 were installed near tank T-106 as shown in Figure 4-1. These direct pushes were intended to investigate movement of contaminants since the early 1990's when a nearby drywell was drilled (RPP-23752, Rev. 0-A, *Field Investigation Report for Waste Management Areas T and TX-TY*). The results provide confirmation of the initial leak detected in 1973 but are not included in the determination of the initial leak location for tank T-106 as these were installed 30 years after the tank was first suspected of leaking.

4.5.1.16 Drywell Summary

The tank T-106 leak was determined to have started on or around April 20, 1973. The tank was declared a confirmed leaker June 8, 1973 based on liquid level decreases and subsequent radioactivity detected in drywell 50-08-11. Only two drywells (drywells 50-08-11 and 50-00-10) were near tank T-106 when the leak occurred.

Tank T-106 drywells 50-00-10 and 50-03-06 do not indicate any radioactivity associated with a tank T-106 leak and are therefore not included in the leak location for tank T-106.

Only drywell 50-08-11 supported the tank T-106 leak in April 1973 as this was the only drywell reporting radioactivity during this time. Drywell 50-08-11 first reported radioactivity with a peak of 10K cpm at an undetermined BGS level on May 31, 1973 which continued to increase over the next couple of days. The next reading recovered that reported the BGS depth of the peak was in July 1973 at 65-ft BGS.

Drywells 50-06-02, 50-06-03, 50-06-04, 50-06-05, 50-06-06, 50-06-08, and 50-06-11 were all drilled in June-July 1973 after the initial tank T-106 leak. All these drywells report radioactivity that support a tank T-106 leak. Drywell 50-06-11 reported a peak at 36-ft BGS which was reported to be related to a tank T-103 leak versus tank T-106; however, it remains inconclusive. The peak radioactivity reported in these drywells was reported at various BGS depths. Drywells 50-06-04, 50-06-05, and 50-06-08 all had peak readings that were above the BGS level of the top of the tank footing (36-ft 1-in) which could imply a sidewall leak. Drywells 50-06-04 and 50-06-05 also had another peak recorded at a lower BGS level. Drywells 50-06-02, 50-06-03, and 50-06-06 all reported radioactivity at or below the bottom of the tank. Drywells 50-06-16 and 50-06-17, drilled in 1975, and drywell 50-00-09, drilled in 1977, first recoverable readings report radioactivity associated with the initial tank T-106 leak. Drywell 50-06-16 (see Figure 4-9) shows radioactivity at ~15-ft BGS which is probably due to a pipeline or other near surface source.

Drywell 50-06-18, drilled in 1993, also reported radioactivity associated with the tank T-106 leak. Radioactivity detected in this drywell just provides confirmation of the leak but not necessarily the location of the initial leak site as it was drilled years after the tank was first suspected of leaking. Therefore, drywell 50-06-18 is not included as part of the leak location for tank T-106.

Two direct pushes C4104 and C4105 were installed in 2003 to determine the extent of the tank T-106 leak. Since this direct pushes were installed 30 years after the leak was initially detected, direct push C4104 and C4105 are not included as part of the initial leak location for tank T-106. No leak detection laterals were installed near tank T-106.

4.6 POSSIBLE TANK T-106 LINER LEAK LOCATION(S)

A liner leak may have penetrated the waterproof membrane at any location or pooled on the waterproof membrane and followed concrete cracks or construction joints to a different location for egress to the soil, including the top of the tank footing.

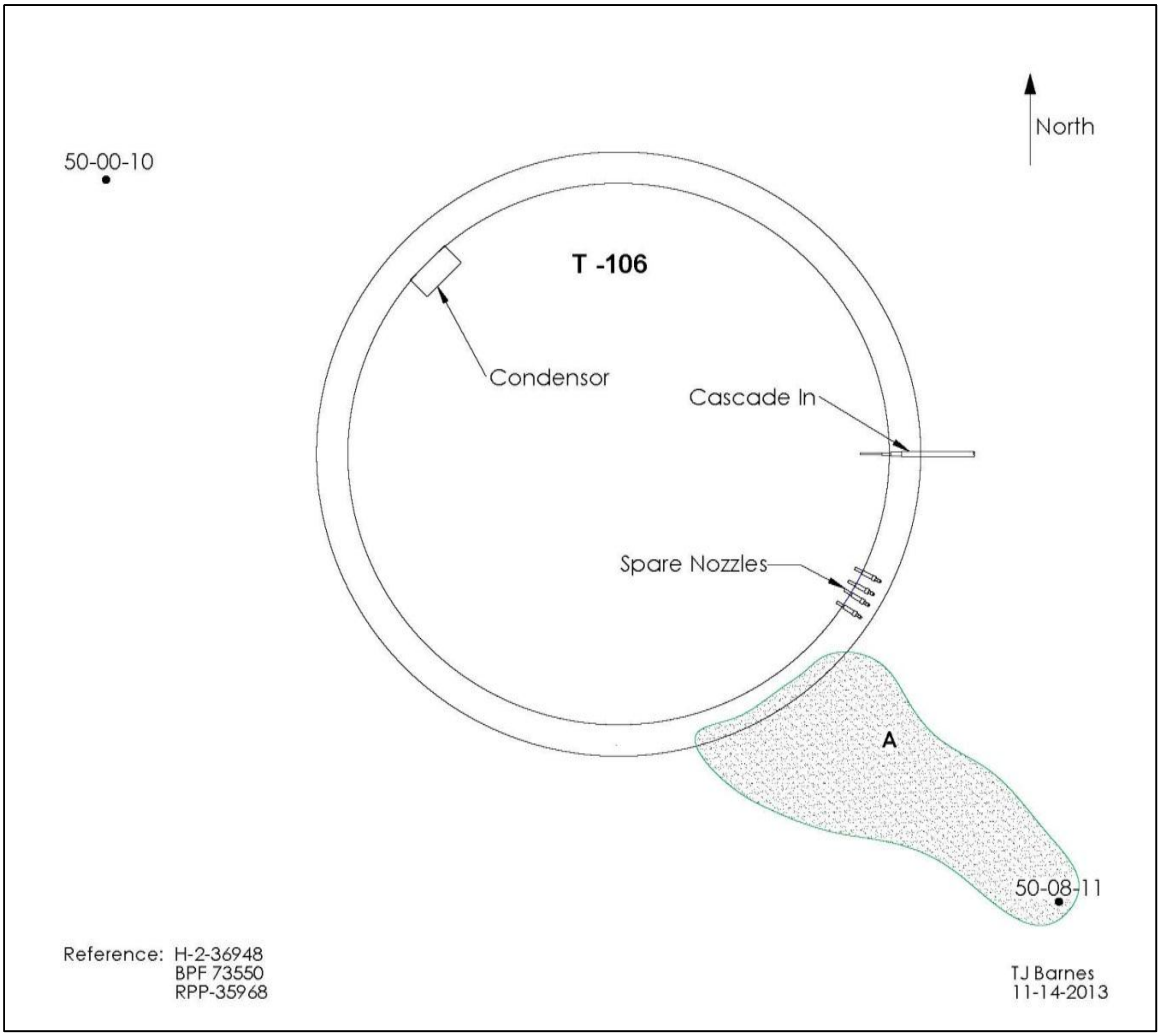
The tank T-106 leak was determined to have started on or around April 20, 1973. The tank was declared a confirmed leaker June 8, 1973 based on liquid level decreases and subsequent radioactivity detected in drywell 50-08-11 (one of only two drywells located near the tank during this time). Tank T-106 had at least one liner leak site based on radioactivity initially detected in one drywell. Other drywells were installed starting in June 1973 after the leak started and two direct pushes in 2003. Liquid level data indicates a possible sidewall leak which may have penetrated the waterproof membrane at any location below. Three drywells, installed after June 1973, report peaks that support a sidewall leak. The other drywells that indicate radioactivity report peaks at or below the bottom of the tank. Thus, a sidewall leak seems plausible as well as a leak at or near the bottom of the tank.

Drywell data that were obtained after the initial leak date is difficult to use to interpret initial leak locations due to variables such as uncertainty of the migration of contaminants once they reach the soil, the rate of contaminant movement in the soil, and how these are affected by the possible lithology changes.

4.6.1 Leak Detected in May-June 1973

The tank T-106 leak was determined to have started on or around April 20, 1973 (see Section 4.2). There were only two drywells (50-08-11 and 50-00-10) near tank T-106 during this time frame. The first recoverable reading for drywell 50-08-11 on May 31, 1973 indicated radioactivity with a peak of 10K cpm at an unspecified BGS depth. Radioactivity continued to increase significantly over the next couple of days (see site A in Figure 4-19). Drywell 50-08-11 radioactivity was coupled with a significant drop in the liquid level confirming the tank T-106 leak.

Figure 4-19. Tank T-106 Possible Leak Location (May-June 1973)
Tank inner ring is steel liner; outer ring is outer edge of tank footing

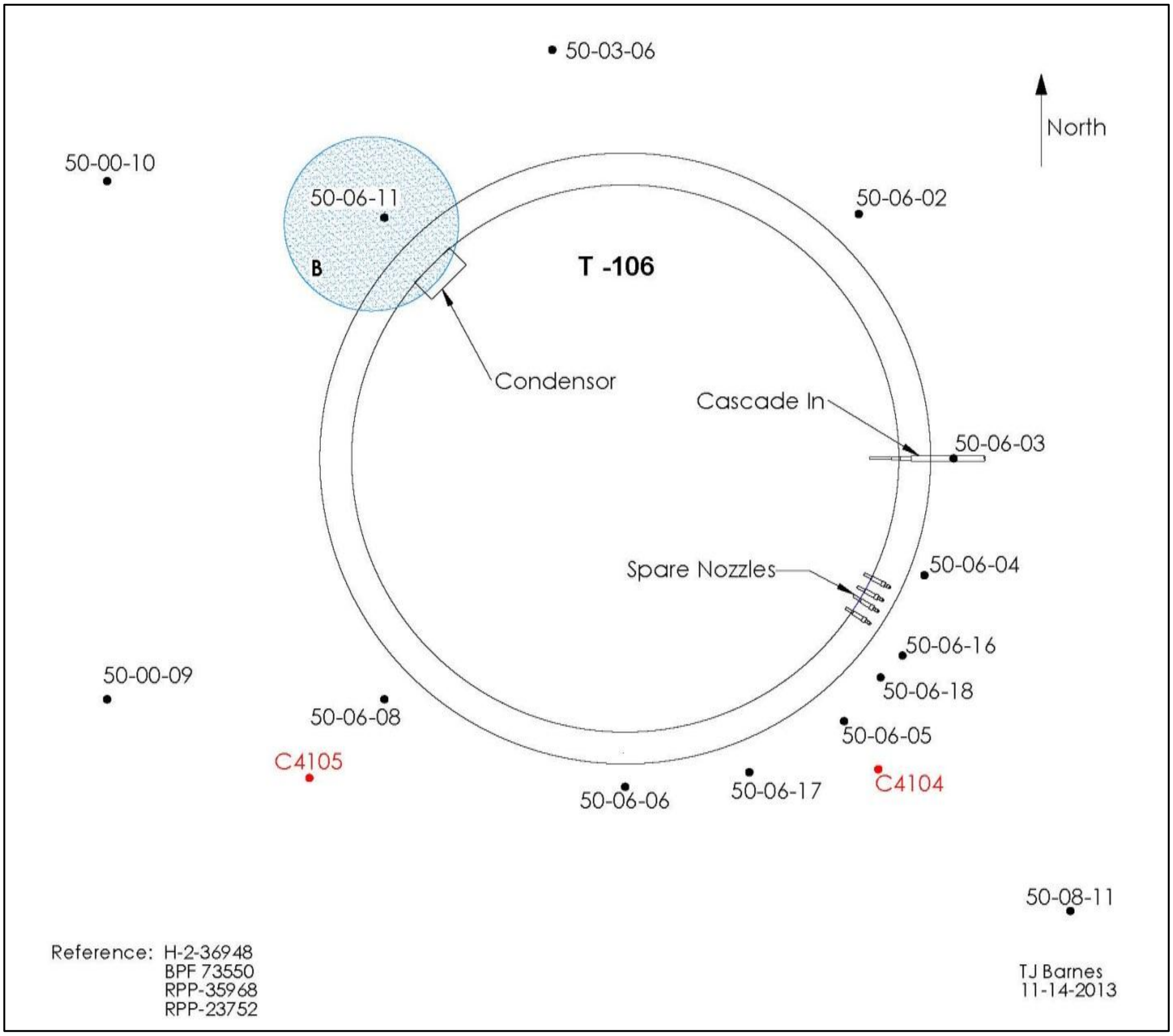


The tank T-106 was determined to have started on or around April 20, 1973 (see Section 4.4.1). Only two drywells were located near the tank at this time. Additional drywells were installed near tank T-106 beginning in June 1973 and were used to estimate the shape of the leak plume to the likely tank leak location.

4.6.2 Leak Detected in July 1973

Drywell 50-06-11 was installed in July 1973 in the northwestern portion of tank T-106. The first recoverable reading reported a peak in July 1973 at 36-ft BGS (see site B in Figure 4-20). Drywell 50-00-10 did not indicate any radioactivity associated with a tank leak and this was the only drywell near drywell 50-06-11 during this time. It was reported that radioactivity detected in this drywell is likely associated with a tank T-103 leak versus tank T-106. However, since the source of this radioactivity remains unknown, a tank T-106 leak source cannot be ruled out which would be unrelated to the initial leak in the southeastern portion of the tank.

Figure 4-20. Tank T-106 Possible Leak Location (July 1973)
Tank inner ring is steel liner; outer ring is outer edge of tank footing



The tank T-106 was determined to have started on or around April 20, 1973 (see Section 4.4.1). Only two drywells (50-08-11 and 50-00-10) were located near the tank when the tank was first suspected of leaking. Additional drywells were installed near tank T-106 beginning in June 1973.

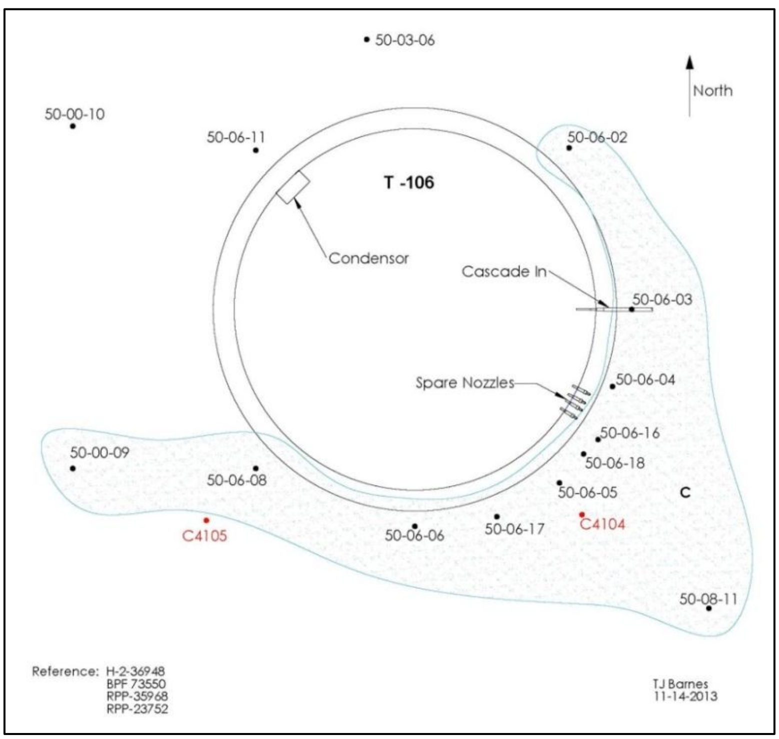
4.6.3 Leak Detected in June 1973 to 1977

Drywells 50-06-08, 50-06-06, 50-06-05, 50-06-04, and 50-06-03 were drilled in June-July 1973 and all reported radioactivity indicating a tank T-106 leak with the first recoverable readings. Drywells 50-06-16 and 50-06-17 were drilled in July 1975 and both report radioactivity that support a tank T-106 leak in the southeastern portion of the tank. Drywell 50-00-09 was drilled in February 1977 which reported radioactivity, likely due to migration from the earlier leak. Due to the extent of the tank T-106 leak, peaks were reported in all these drywells at various BGS depths. Three drywells (50-06-04, 50-06-05, and 50-06-08) reported peaks at a higher BGS level that supports a sidewall leak. The liquid level review indicated a possible sidewall leak near 139-in which is ~28-ft BGS. The other drywells that indicate radioactivity report peaks at or below the bottom of the tank.

It was reported that the initial leak site was located near drywells 50-06-05 and 50-06-17 based on the concentrations detected by SGLS (GJ-HAN-120) with migration to the adjacent drywells (see site C in Figure 4-21). There is a possibility that there are multiple leak sites in this area; however, since these drywells were installed later and data wasn't recovered until months after the tank leak, the number of leak sites in this area remains speculative. Drywell 50-16-18 was installed in 1993 and direct pushes C4104 and C4105 were installed in 2003; these are not included as part of the leak location for tank T-106 since these seem to only confirm the extent of the initial leak.

Figure 4-21. Tank T-106 Possible Leak Location (June 1973 to 1977)

Tank inner ring is steel liner; outer ring is outer edge of tank footing



The tank T-106 was determined to have started on or around April 20, 1973 (see Section 4.4.1). Only two drywells (50-08-11 and 50-00-10) were located near the tank when the tank was first suspected of leaking. Additional drywells shown above were drilled in June 1973 through 1977. Drywell 50-16-18 was drilled in 1993 and direct pushes C4104 and C4105 were installed in 2003.

4.6.4 Leak Location Summary

The tank T-106 leak was determined to have started on or around April 20, 1973. There were only two drywells (50-08-11 and 50-00-10) near tank T-106 during this time frame. The first recoverable reading for drywell 50-08-11 on May 31, 1973 indicated radioactivity with a peak of 10K cpm at an unspecified BGS depth. Radioactivity continued to increase significantly over the next couple of days (see site A in Figure 4-22). Drywell 50-08-11 radioactivity was also coupled with a significant drop in the liquid level confirming the tank T-106 leak.

Drywell 50-06-11 was installed in July 1973 in the northwestern portion of tank T-106. The first recoverable reading reported a peak in July 1973 at 36-ft BGS (see site B in Figure 4-22). Drywell 50-00-10 did not indicate any radioactivity associated with a tank leak and this was the only drywell near drywell 50-06-11 during this time. It was reported that radioactivity detected in this drywell is likely associated with a tank T-103 leak versus tank T-106. However, since the source of this radioactivity remains unknown, a tank T-106 leak source cannot be ruled out.

Drywells 50-06-08, 50-06-06, 50-06-05, 50-06-04, and 50-06-03 were drilled in June-July 1973 and all reported radioactivity indicating a tank T-106 leak. Drywells 50-06-16 and 50-06-17 (drilled in July 1975) and 50-06-18 (drilled in 1977) all report radioactivity that support a tank T-106 leak in the southeastern portion of the tank. Due to the extent of the tank T-106 leak, peaks were reported in all these drywells at various BGS depths. Three drywells (50-06-04, 50-06-05, and 50-06-08) reported peaks at a higher BGS level that supports a sidewall leak. The liquid level review indicated a possible sidewall leak ranging from 94-in to 139-in which corresponds to ~28 to 32-ft BGS. The other drywells that indicate radioactivity report peaks at or below the bottom of the tank. Thus, a sidewall leak seems plausible as well as a leak at or near the bottom of the tank.

It was reported that the initial leak site was located near drywells 50-06-05 and 50-06-17 based on the concentrations detected by SGLS with migration to the adjacent drywells (see site C in Figure 4-22). There is a possibility that there are multiple leak sites in this area; however, since these drywells were installed later and data wasn't recovered until months after the tank leak, the number of leak sites in this area remains speculative.

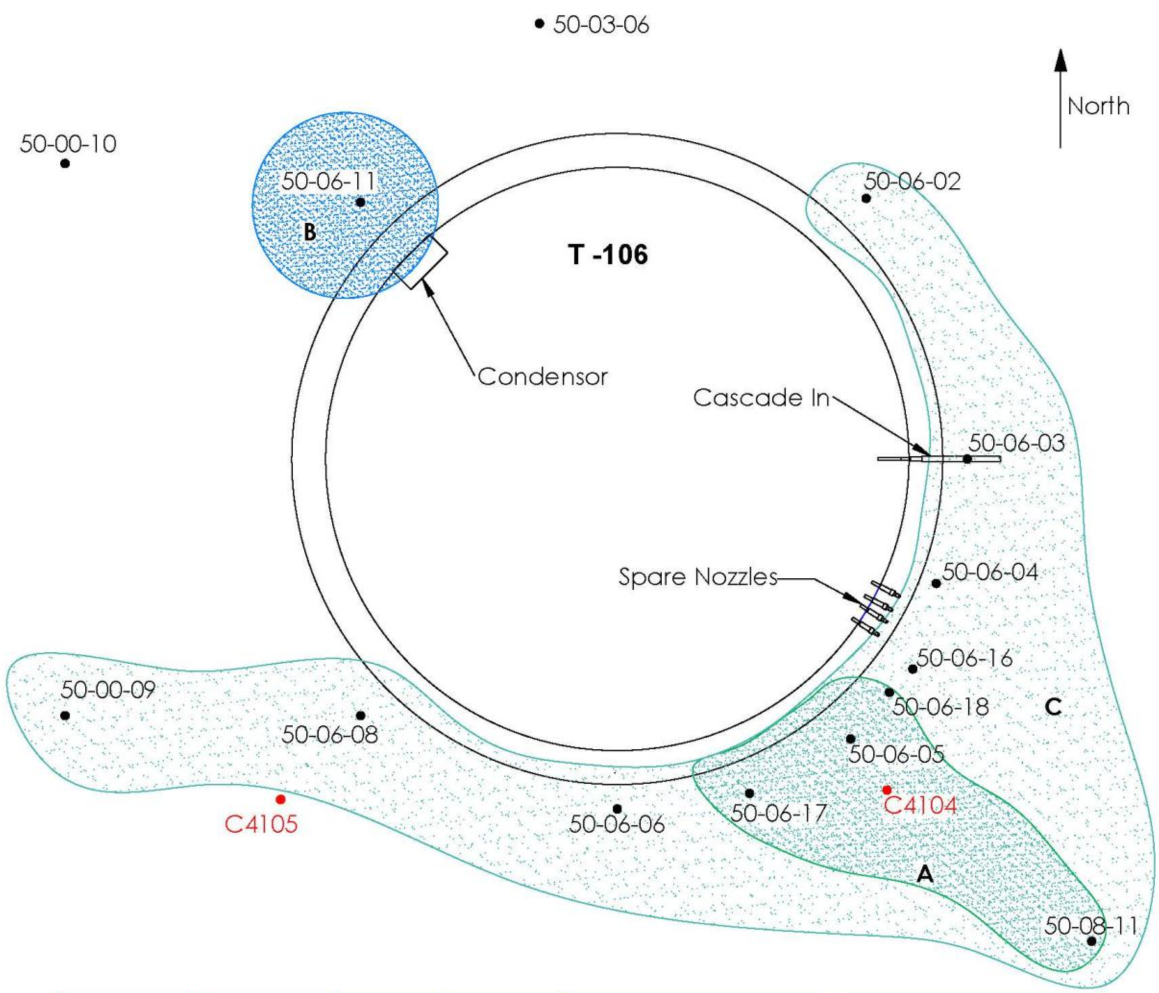
Drywell 50-06-18 and direct pushes C4104 and C4105 were installed later in 1993 and 2003, respectively, more than 20 years after the tank was first suspected of leaking. Data obtained from this drywell and direct pushes confirm the extent of the tank T-106 leak. Therefore, this later information is not included in the determination of the leak location.

Leak locations in Figure 4-22 are based on peak readings and are a representation of possible initial boundaries of radioactivity.

No evidence was found for a liner bulge occurring in tank T-106, and it remains unclear if a liner bulge once existed in the tank during its operation. However, tank T-106 non-boiling temperatures are not likely to be a factor in causing a liner bulge.

Figure 4-22. Tank T-106 Possible Radial Leak Locations

Tank inner ring is steel liner, outer ring is outer edge of tank footing



A	B	C
May - June 1973	July 1973	June 1973 - 1977
Tank T-106 was determined to have started leaking around April 20, 1973 based on liquid level decreases and subsequent drywell radioactivity. Only two drywells (50-08-11 and 50-00-10) were located near the tank during this time. Drywell 50-08-11 reported radioactivity in May 1973 at an unspecified BGS depth which increased significantly over the next couple of days. Supernatant was removed from tank T-106 starting June 8, 1973.	Drywell 50-06-11 was installed in July 1973. The first recoverable reading reported a peak in September 1973 at 36-ft BGS. It was reported that radioactivity detected in this drywell is likely associated with tank T-103 verus tank T-106. However, it remains unknown and a tank T-106 leak source cannot be ruled out. This appears to be separate from the initial leak site.	Additional drywells were drilled in June-July 1973, 1975, and 1977. These drywells support a tank T-106 leak and are likely related to the initial April 1973 leak. Concentrations detected by SGLS were highest in drywells 50-06-05 and 50-06-17 indicating the initial leak site was closest to these drywells. Three drywells (50-06-04, 50-06-05, and 50-06-08) reported peaks at a higher BGS level that supports a sidewall leak. Liquid level analysis indicates a possible sidewall leak ranging from 94 to 139-in which corresponds to ~28 to 32-ft BGS. The other drywells that indicate radioactivity report peaks at or below the bottom of the tank. Thus, a sidewall leak seems plausible but not conclusive.Drywell 50-06-18 was installed in 1993 and direct pushes C4104 and C4105 were installed in 2003; these are not included as part of the leak location for tank T-106 since these only confirm the extent of the initial leak.

Reference: H-2-36948
BPF 73550
RPP-35968
RPP-23752

TJ Barnes
11-14-2013

4.7 POSSIBLE TANK T-106 LINER LEAK CAUSE(S)

Tank T-106 was evaluated for five conditions known to contribute to a failed liner.

4.7.1 Tank Design

The T Farm tank design does not appear to be a factor contributing to a failed liner (see Section 3.1.1).

4.7.2 Thermal Conditions

No temperature data are available for tank T-106 prior to 1975, however, tank T-106 held only non-boiling waste. Thermal shock creates stress both from rapid temperature rise as well as waste-induced high temperatures. Since no records are available, it is uncertain what the maximum temperature was in tank T-106 during operation as well as the rate of temperature rise when waste was added. The thermal attributes of the waste and other information (see Section 4.4.2) would indicate that thermal stresses were likely minimal and should not have challenged the tank storage limits.

Temperature requirements in ARH-951 issued December 18, 1969 indicated that tank temperatures should be held below 230°F.

4.7.3 Chemistry-Corrosion

Tank T-106 initially received 2C waste and stored only this waste type for approximately one year. Tank T-106 was then emptied and received 1C waste which was stored for about seven years. The tank was then emptied and refilled with 1C and REDOX CW which was stored for approximately 13 years. Waste types 1C and 2C do not meet the current DST specifications for waste chemistry and would therefore create an environment conducive to pitting and/or SCC especially in the first eight years of service when in contact with only 1C or 2C waste. However, the 1C and 2C waste temperatures were probably close to or below 100°F and therefore would have little effect on corrosion. With the addition of REDOX CW, this would likely reduce the corrosiveness of the 1C waste. Other waste types stored in tank T-106 should not have resulted in pitting or SCC.

4.7.4 Liner Observations

A review of the available photographs for tank T-106 does not contain any evidence pointing to a tank leak. There is no documentation available indicating a liner bulge was present in the tank.

4.7.5 Tank Construction

The T Farm tank liners were constructed between January 1944 and September 1944. Only isolated minimum temperatures were experienced during tank construction at or below 18°F with day time temperatures between 41°F and 56°F (see Section 4.3.2). Impact occurrences could have occurred during cold temperatures that may have triggered fissures in the steel liner; however, the possibility seems much less than that which might have occurred during construction in other tank farms.

The T Farm tanks experienced warping of the bottom liner during construction of the tanks and all of the T Farm tank bottom liners required replacement (see Section 4.3.2). The July monthly report (HW-7-384) reported that all tanks passed X-ray test; however, there may have been quality issues that were not identified by X-ray testing.

4.8 TANK T-106 CONCLUSIONS

Most of higher level peak drywell radioactivity indicated that the tank T-106 liner leaked in at least one location in the southeast portion of the tank with a spread of radioactivity from the north east to the south west portion of the tank. An isolated location of radioactivity occurred to the northwest. A liquid level analysis indicated a possible sidewall leak. Three drywells indicated radioactivity data points between 29-ft and 35-ft BGS pointing to a possible sidewall leak. However, the other drywells report radioactivity at or below the tank bottom. Thus, a sidewall leak seems plausible as well as a leak at or near the bottom of the tank.

There are several liner leak cause conditions that were examined however no one individual condition stands out as the likely cause of the tank T-106 leak. Storage of 1C and 2C wastes would be a possible cause except the likely storage temperature of 100°F or less should not have caused a corrosion problem. There may have been anomalies in the bottom liner after replacement, and storage of 1C and 2C wastes may have increased the propensity for corrosion in a stressed liner.

There appears to be very little contribution from storage of waste, thermal conditions, tank design, or construction temperatures. The evidence that T Farm tank bottom liners required replacement causes concern with the quality of the replacement especially on any one tank. The tank T-106 leak could have been influenced by the T Farm tank bottom liner replacement effort. Some or all of the factors can act serially or together to contribute to tank liner failure.

APPENDIX A1

TANK T-106 GROSS GAMMA DRYWELL DATA

Table A1-1. Tank T-106 Drywell Radioactivity (K counts per minute) (July 1973 through June 1987) (SD-WM-TI-356 and Figure A1-2) (Sheet 1 of 2)

50-06-02			50-06-03			50-06-04			50-06-05			50-06-06			50-06-08		
Drilled July 1973			Drilled June 1973			Drilled July 1973			Drilled August 1973			Drilled July 1973			Drilled July 1973		
Date	Peak (K cpm)	Depth (ft)	Date	Peak (K cpm)	Depth (ft)	Date	Peak (K cpm)	Depth (ft)	Date	Peak (K cpm)	Depth (ft)	Date	Peak (K cpm)	Depth (ft)	Date	Peak (K cpm)	Depth (ft)
7/10/1973[2]	300	~55	6/27/1973[2]	350 500	~46 ~82	7/24/1973	387 290	33 45	8/27/1973[2]	700 700	~29 ~39	7/3/1973[2]	400	42-66	7/11/1973[2]	450 350	32-39 ~49
7/24/1973	300	50.0	7/24/1973	337 257	43 77	N/A[1]			N/A[1]			7/24/1973	380	31-64	7/24/1973	445	34
9/21/1973	274.8 139.8	50.0 59.0	9/30/1973	387.5	77	9/20/1973	378	33	9/20/1973	814.8	38	9/20/1973	379.8	46	9/20/1973	480	34
11/7/1973	226.8 145.2	53.0 61.0	11/23/1973	282.6	45	N/A[1]			N/A[1]			N/A[1]			N/A[1]		
N/A[1]			12/28/1973	320.0	82	N/A[1]			N/A[1]			N/A[1]			N/A[1]		
1/3/1974	167.4 147.0	55.0 62.0	N/A[1]			N/A[1]			2/2/1974	910.2	40	N/A[1]			N/A[1]		
4/4/1974	190.2	63.0	N/A[1]			4/4/1974	364.8	36	4/17/1974	1000.2	40	5/17/1974	391.8	49	4/17/1974	400.2	35
6/27/1974	170.2	62.0	N/A[1]			7/16/1974	320	35	9/12/1974	1308.4	45	9/12/1974	105.7	59	7/3/1974	429.6	35
8/15/1974	79.0	67.0	8/10/1974	360.0	88	10/11/1974	249	37	12/11/1974	1334.9	44	12/11/1974	96.0	58	8/15/1974	214.0	36
N/A[1]			8/15/1974	185.5	85	N/A[1]			N/A[1]			N/A[1]			N/A[1]		
N/A[1]			9/26/1974	182.0	83	N/A[1]			N/A[1]			N/A[1]			N/A[1]		
2/27/1975	42.1	69.0	2/13/1975	143.9	86	2/13/1975	212	37	2/13/1975	1042.5	35	1/29/1975	84.0	58	2/13/1975	180.9	36
7/16/1975	32.2	68.0	7/16/1975	115.1	85	7/23/1975	197	37	7/23/1975	1013.1	44	7/25/1975	90.6	82	7/25/1975	173.6	35
4/6/1976	16.3	70.0	4/6/1976	82.3	87	4/6/1976	224	36	4/6/1976	1426.3	43	4/6/1976	59.3	83	4/6/1976	211.3	34
N/A[1]			N/A[1]			10/5/1976	211	35	8/31/1976	1118.6	42	11/30/1976	56.6	83	11/2/1976	214.3	34
1/4/1977	10.0	69.0	1/4/1977	61.4	86	N/A[1]			N/A[1]			1/4/1977	55.6	39	N/A[1]		
2/4/1977	1335.4	69.0	2/4/1977	3624.1	86	3/1/1977	216	34	3/1/1977	1655.2	42	N/A[1]			N/A[1]		
6/10/1977	1010.9	70.0	5/6/1977	3551.8	87	N/A[1]			N/A[1]			N/A[1]			5/3/1977	219.8	36
10/7/1977	931.7	70.0	10/7/1977	3629.9	87	9/13/1977	203	34	9/13/1977	1675.9	41	9/13/1977	53.2	39	9/13/1977	204.9	33

Table A1-1. Tank T-106 Drywell Radioactivity (K counts per minute) (July 1973 through June 1987) (SD-WM-TI-356 and Figure A1-2) (Sheet 2 of 2)

50-06-02			50-06-03			50-06-04			50-06-05			50-06-06			50-06-08		
Date	Peak (K cpm)	Depth (ft)	Date	Peak (K cpm)	Depth (ft)	Date	Peak (K cpm)	Depth (ft)	Date	Peak (K cpm)	Depth (ft)	Date	Peak (K cpm)	Depth (ft)	Date	Peak (K cpm)	Depth (ft)
3/10/1978	795.7	73	2/10/1978	3414.7	87	3/7/1978	176	33	3/7/1978	1515.7	41	3/7/1978	38.8	40	3/7/1978	177.1	33
8/11/1978	595.9	73.0	7/7/1978	3853.0	86	4/4/1978	39	34	4/4/1978	542.9	41	4/4/1978	9.2	40	4/4/1978	45.3	35
9/14/1978	434.8	73.0	10/6/1978	1627.8	88	8/4/1978	46	34	8/8/1978	549.8	41	8/8/1978	9.8	40	8/8/1978	37.7	35
8/8/1979	288.1	73.0	8/8/1979	1299.3	91	8/13/1979	53	35	8/13/1979	392.6	42	8/13/1979	6.9	40	8/13/1979	32.8	34
3/4/1980	199.0	73.0	3/4/1980	872.2	86	8/13/1980	48.5	34	6/13/1980	426.7	41	8/13/1980	7.2	40	8/13/1980	30.0	33
8/19/1980	132.6	74.0	8/19/1980	608.5	86	N/A[1]			N/A[1]			8/25/1980	5.8	40	N/A[1]		
9/3/1980	132.5	79	N/A[1]			N/A[1]			N/A[1]			9/3/1980	3709.5	40	N/A[1]		
9/16/1980	1377.6	75.0	N/A[1]			N/A[1]			N/A[1]			N/A[1]			N/A[1]		
6/17/1981	1072.4	77.0	6/16/1981	410.8	92	6/15/1981	46.3	34	6/15/1981	372.7	42	6/16/1981	4245.1	41	6/15/1981	31.0	34
8/10/1982	569.0	82.0	8/10/1982	295.3	92	7/26/1982	57.1	34	7/26/1982	511.2	43	7/28/1982	3534.2	40	7/26/1982	34.9	34
6/5/1983	452.4	82.0	6/28/1983	209.7	92	6/14/1983	41.6	36	6/14/1983	431.8	43	6/15/1983	3865.5	42	6/14/1983	28.9	35
6/13/1984	292.4	84.0	5/31/1984	172.3	45	6/11/1984	43.4	36	6/11/1984	440.2	43	6/13/1984	3887.0	41	6/11/1984	28.1	35
6/18/1985	246.5	86	N/A[1]			6/19/1985	46.2	37	6/19/1985	423.2	44	6/20/1985	3774.2	43	6/19/1985	26.2	36
6/10/1986	223.9	55	6/24/1986	149.5	47	6/11/1986	36.4	37	6/11/1986	368.4	44	6/10/1986	3747.7	43	6/11/1986	22.3	37
6/24/1987	206.0	86.0	8/19/1987	137.2	47	6/25/1987	34.5	37	6/25/1987	365.5	44	6/25/1987	3197.1	43	6/25/1987	22.9	37

Note: [1]N/A: Data not available
[2]Reference RHO-ST-1, *Status of Liquid Waste Leaked from the 241-T-106 Tank*, 1979.
No raw data was recovered for drywells 50-00-09 (drilled in February 1977) and 50-06-18 (drilled in April 1993).

Table A1-2. Tank T-106 Drywell Radioactivity (K counts per minute) (May 1973 through June 1987) (SD-WM-TI-356) (Sheet 1 of 2)

50-06-11			50-06-16			50-06-17			50-03-06			50-08-11		
Drilled July 1973			**Drilled July 1975**			**Drilled July 1975**			**Drilled January 1975**			**Drilled 1944**		
Date	**Peak (K cpm)**	**Depth (ft)**	**Date**	**Peak (K cpm)**	**Depth (ft)**	**Date**	**Peak (K cpm)**	**Depth (ft)**	**Date**	**Peak (K cpm)**	**Depth (ft)**	**Date**	**Peak (K cpm)**	**Depth (ft)**
Drywell drilled in July 1973			Drywell drilled in July 1975			Drywell drilled in July 1975			Drywell drilled in January 1975			5/31/1973	10	N/A[1]
												6/1/1973	1,000	N/A[1]
												6/4/1973	300[2]	N/A[1]
												6/5/1973	290[2]	N/A[1]
												6/6/1973	310[2]	N/A[1]
												6/7/1973	290[2]	N/A[1]
7/18/1973	0.4	~36										7/24/1973[3]	310[2]	65
9/20/1973	0.9	35										9/20/1973	292.2	68
3/20/1974	0.9	35										4/4/1974	274.8	77
7/31/1974	0.9	35										8/15/1974	109.6	77
11/29/1974	285.8	39										N/A[1]		
2/13/1975	171.3	41							4/2/1975	33.1	75	2/13/1975	82.0	77
7/25/1975	315.7	39	7/16/1975	33.9	49	7/16/1975	312.2	46	7/25/1975	28.7	76	7/23/1975	66.7	79
N/A[1]			7/25/1975	36.7	65	7/25/1975	695.8	45	N/A[1]			N/A[1]		
4/9/1976	206.0	38	4/6/1976	14.8	67	4/6/1976	442.7	45	4/9/1976	21.2	76	4/6/1976	23.2	77
N/A[1]			N/A[1]			11/23/1976	461.3	44	9/3/1976	20.8	79	10/19/1976	20.6	74
1/7/1977	101.6	39	1/18/1977	10.4	65	N/A[1]			N/A[1]			N/A[1]		
1/7/1977	1035.8	37	1/21/1977	1362.7	47	N/A[1]			N/A[1]			N/A[1]		
N/A[1]			N/A[1]			5/3/1977	471.8	44	5/6/1977	16.9	79	4/5/1977	15.7	75
10/7/1977	735.3	38	10/20/1977	1146.0	46	10/18/1977	538.9	44	10/7/1977	16.4	79	10/18/1977	12.7	75
2/10/1978	521.5	38	3/3/1978	1006.1	47	3/7/1978	457.5	43	N/A[1]			3/7/1978	8.5	75
N/A[1]			N/A[1]			3/14/1978	122.1	43	N/A[1]			3/14/1978	2.3	75
8/11/1978	372.2	38	8/11/1978	845.0	47	8/8/1978	116.5	44	8/11/1978	13.2	76	8/8/1978	1.3	76
N/A[1]			N/A[1]			N/A[1]			N/A[1]			1/15/1979	0.0	N/A[1]

Table A1-2. Tank T-106 Drywell Radioactivity (K counts per minute) (May 1973 through June 1987) (SD-WM-TI-356) (Sheet 2 of 2)

50-06-11			50-06-16			50-06-17			50-03-06			50-08-11		
Date	Peak (K cpm)	Depth (ft)	Date	Peak (K cpm)	Depth (ft)	Date	Peak (K cpm)	Depth (ft)	Date	Peak (K cpm)	Depth (ft)	Date	Peak (K cpm)	Depth (ft)
2/6/1979	244.0	37	N/A[1]			N/A[1]			N/A[1]			1/18/1979	972.2	76
N/A[1]			N/A[1]			N/A[1]			N/A[1]			4/17/1979	823.5	75
8/8/1979	185.8	37	8/21/1979	546.8	47	8/13/1979	134.4	44	8/7/1979	7.4	80	8/9/1979	771.8	75
N/A[1]			2/5/1980	439.6	46	N/A[1]			N/A[1]			2/5/1980	561.1	74
7/22/1980	70.2	36	8/19/1980	322.2	46	8/13/1980	125.2	43	8/19/1980	6.4	81	8/19/1980	418.3	75
N/A[1]			9/3/1980	334.3	47	N/A[1]			N/A[1]			N/A[1]		
N/A[1]			9/17/1980	2707.4	33	N/A[1]			N/A[1]			N/A[1]		
6/16/1981	23.7	39	6/16/1981	2957.6	35	6/15/1981	121.0	44	6/16/1981	5.7	82	6/16/1981	322.0	76
7/28/1982	12.0	39	7/29/1982	2166.4	34	7/26/1982	137.5	44	7/28/1982	4.9	83	7/28/1982	211.7	77
6/15/1983	6.2	39	6/15/1983	2248.4	35	6/14/1983	118.3	45	6/15/1983	4.7	84	6/15/1983	152.4	77
6/13/1984	4.6	39	6/13/1984	2431.7	35	6/11/1984	115.9	45	6/13/1984	4.7	84	6/13/1984	123.8	77
6/18/1985	2.8	40	6/18/1985	2110.0	36	6/19/1985	109.9	46	6/18/1985	4.7	87	6/18/1985	98.7	78
6/10/1986	2.0	41	6/10/1986	2595.4	37	6/11/1986	109.0	47	6/10/1986	3.6	85	6/10/1986	80.4	78
6/24/1987	2.0	40	6/24/1987	2521.0	37	6/25/1987	95.0	47	6/24/1987	4.2	87	6/29/1987	64.5	78

Note: [1]N/A: Data not available
[2]Readings obtained using a geiger-muller (GM) probe was used
[3]Referenced from Figure A1-2
No raw data was recovered for drywells 50-00-09 (drilled in February 1977) and 50-06-18 (drilled in April 1993).

Figure A1-1. Tank T-106 Drywell 50-00-10 Historical Data September 1973 through January 1974

10³x1

DRY WELL RADIATION LEVELS - T FARM

Dry Well No. 500010
Old Well No. W-10-54

SP Probe Type; Well Depth 150

Date	Peak c/m	Depth Ft.	Comments	Date	Peak	Depth Ft.	Comments
9-21-73	NONE		8500 to 15,000 Bottom 8500 110'	11-1	<100		40 @ 89' 5
10-18	NONE 9000	Bottom 111		11-8	<100		59 @ 103'
11-27	NONE 9500	Bottom		11-15	<100		Rechecked 37364 44' 5
12-27	1100	Bottom 112'		11-21	<100		21 @ 17' 5
1-19-74	9,000	Bottom 111		11-29	<25		51 @ 28' 4
3-5	10,750	112		12-4	<100		38 @ 90' 2
3-23	10,000	111		12-13	<50		58 @ 102' 5
4-19	12,000 11,000	84 to 94 Btm 112		12-20	<100		96 @ 81 3
6-1	NONE <10,500			12-28	<25		42 @ 83 4
6-22	NONE <100		38 at 65' [illegible] 3	1-3	<100		3
6-26	9750	Btm	7500 to 11,500	1-13	<80 130		94 @ 88' noise 3
7-4	10,000 8000	82' to 91' BTM		1-17	<35		4
7-11	12000	BTM	<10,000	1-22	<30.		1
7-19	<10,000		SP	2-20			
7-29	<5000		SP	2-27			
8-8	<100		41 @ 108' 2	3-7			
8-16	<100		33 @ 84' 2	3-14			
8-21	<100		35 @ 86' 2	3-19			
8-29	<100		3	3-26			
9-5	<100		4	4-2			
9-10	<100		Plot changed 2	4-11			
9-18	<100		4	4-18	(?)	Re Run	
9-26	<100		41 @ 91. 1	4-22			
10-2	<100		38 @ 101 5	4-25			
10-9	<100		2	5-2			
10-16	<100		40 @ 87' 3	5-9	(R) [illegible]		ReRun
10-23	<100		3	5-12			

BWA:jas
8/31/73

Note: No other historical raw data was recovered for drywell 50-00-10. Drywell 50-00-10 was drilled October 1944.

Figure A1-2. T Farm Drywell Data July 24, 1973

The following ~~[struck through]~~ radiation readings were measured with a G.M. probe 7-24-73 in the dry wells surrounding 106 T tank:

Well No.	Well No	Reading (counts/minute)	Depth below Ground
50-08-11	W-10-51	310,000	65'
50-06-06	W-10-106	380,000	31' thru 64'
50-06-03	W-10-107	337,000	43'
		257,000	77'
50-06-02	W-10-108	300,000	50'
50-06-08	W-10-109	445,000	34'
50-06-04	W-10-110	387,000	33'
		390,000	45'
50-08-09	W-10-112	no meaningful readings (too low)	
50-05-06	W-10-113	35	85'
50-02-08	W-10-116	2600	38'

114 cold
115 "

40'

113	116
35 cpm	2600
85'	38'

mike metz 22817

Benedict 22385

R. Smith 22690

LARKIN 22836

Schmidt 22951

5.0 TANK 241-T-111 SEGMENT

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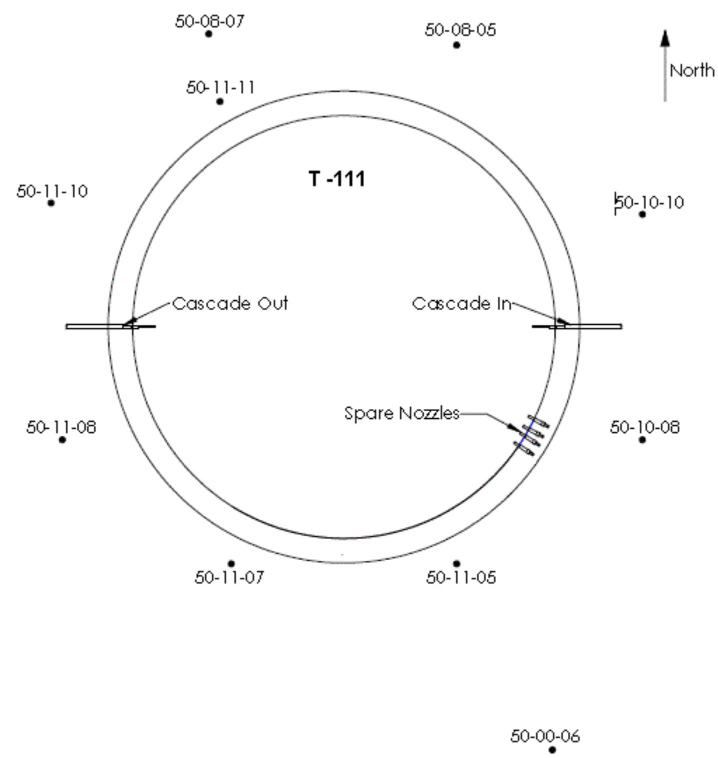
5.1 TANK T-111 BACKGROUND HISTORY

This section provides information on the historical waste loss event associated with SST 241-T-111 (T-111). There are ten drywells located around tank T-111 with specified distances from the drywell to the tank footing shown in Figure 5-1: 50-00-06 installed in 1944, 50-08-05, 50-10-10, 50-11-05, 50-11-08, and 50-08-07 installed in 1974, 50-10-08, 50-11-07, and 50-11-10, installed in 1975, and 50-11-11, installed in 1979.

The bottom of the tank footing is ~38-ft 1-in BGS with ~6.2-ft soil cover over the dome (WHC-SD-WM-TI-665, Rev. 0D; BPF-73550).

Figure 5-1. Tank T-111 Associated Drywells

Tank inner ring is steel liner; outer ring is outer edge of tank footing



Drywell	Distance to Footing (ft)*	Date Installed
50-08-05	~12	3/31/1974
50-10-10	~15	2/28/1974
50-10-08	~15	3/31/1975
50-00-06	~42	9/30/1944
50-11-05	~4.7	2/28/1974
50-11-07	~4.7	2/28/1975
50-11-08	~12	2/28/1974
50-11-10	~15	1/31/1975
50-11-11	~3.8	7/31/1979
50-08-07	~15	2/28/1974

*Assumes perfect vertical alignment

Reference: H-2-36948
BPF 73550
RPP-35968
RPP-23752

TJ Barnes
2-21-2014

5.2 TANK T-111 OPERATIONS SUMMARY

Tank T-111 was brought into service during the fourth quarter of 1945 and first received second cycle decontamination (2C) waste cascaded from tank T-110. The tank was filled with 2C waste, at which time the waste was cascaded to tank T-112. Cascading continued until the third quarter of 1946, when tank T-112 was filled. During the third and fourth quarters of 1947, nearly all of the supernatant of tank T-111 was transferred to crib T-006. The cascading of 2C waste to tank T-111 resumed in the first quarter of 1948. When the entire three tank cascade became full, waste from tank T-112 was transferred to a crib. This cycle continued until the fourth quarter of 1952. From 1952 to 1956, tank T-111 was used to cascade 2C and 224 Building lanthanum fluoride waste (224) from the lanthanum fluoride finishing process in 221-T Plant to a crib. The last waste transfer into tank T-111 was in 1956.

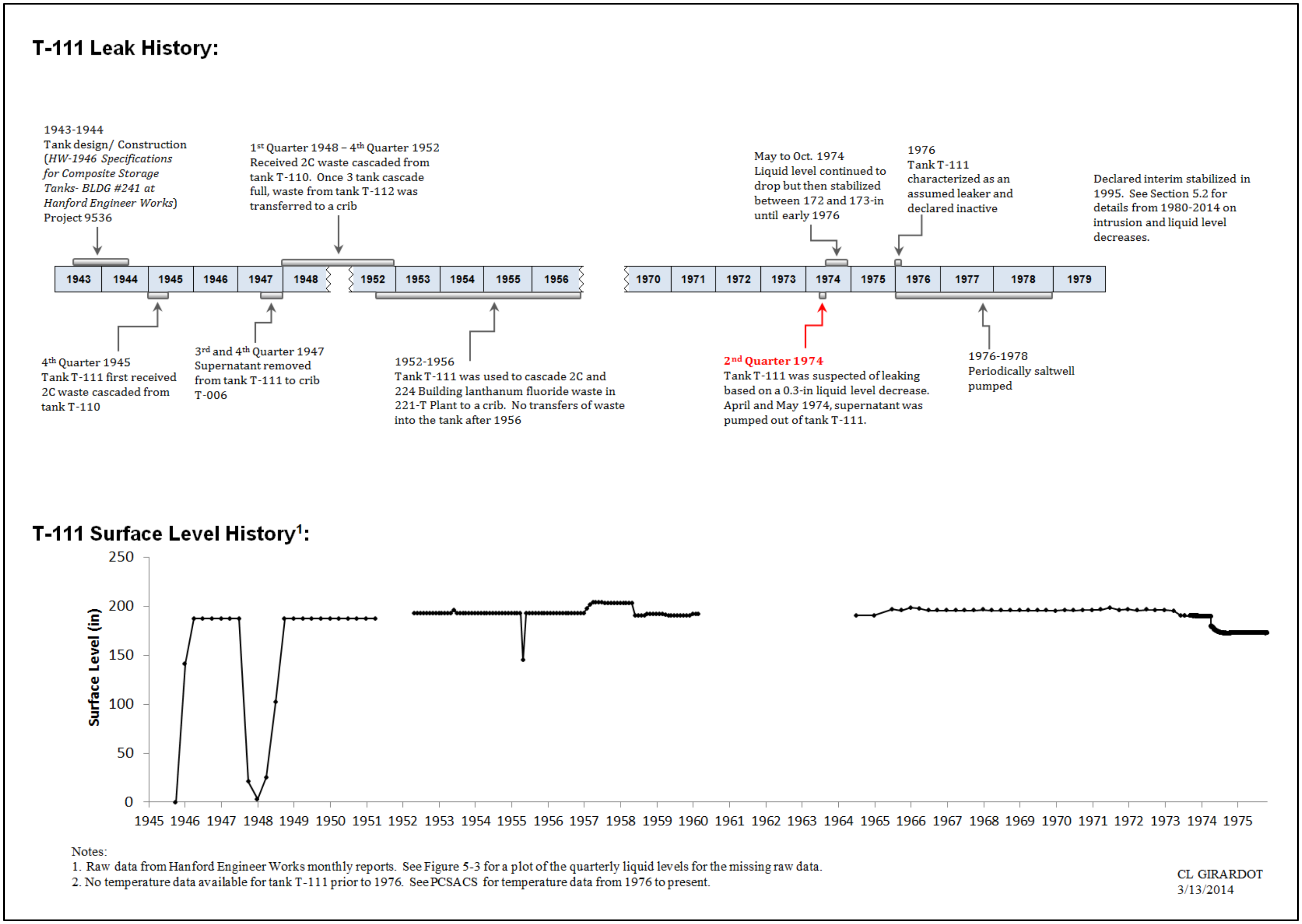
The tank T-111 contents remained unchanged from 1956 until April 1974 when a liquid level decrease of 0.3-in was observed over a period of nine months (see Section 5.4.1 for details). The tank was suspected of leaking and most of the supernatant was pumped from tank T-111 starting April 14, 1974 and continuing into May 1974 to tanks S-110, T-101, T-109, and TX-109. Tank T-111 was characterized as an assumed leaker and was declared inactive in 1976.

Saltwell pumping using a turbine pump began in 1976 and continued periodically until 1978 when pumping was discontinued. Shortly after pumping was halted the waste level began to rise slowly. The increase continued from 1979 until 1993 at a fairly linear rate indicative of a water intrusion. In 1993, the level began to decrease and it appeared that the tank was leaking again so a saltwell jet pump was installed and operated. Interim stabilization using the jet pump was complete in 1995 (HNF-EP-0182, Rev. 305). A tank T-111 waste tank Integrity Investigation was conducted in 1995 (reported in RPP-RPT-54964, Rev. 2, *Evaluation of Tank 241-T-111 Level Data and In-Tank Video Inspection*) that concluded "the level changes in tank T-111 are due to a combination of intrusion and leaking."

From 1995 to 2006 the tank liquid level had a nominal 1-in increase before the liquid level began to drop again. The liquid level has been decreasing since 2006 with the decrease rate accelerating with time. The volume of liquid leaked from the tank from 1995 to April 2013 is calculated to be ~2,600 gal. The leak rate from tank T-111 reached a maximum of slightly over -3 gal/day in June 2013 and as of January 1, 2014 was approximately -1.8 gal/day (RPP-RPT-54964, Rev. 2). Tank T-111 is estimated to contain 447 kgal of sludge at the end of August 2013 (HNF-EP-0182, Rev. 305).

The operational history of tank T-111 leak related details including liquid level is charted in Figure 5-2.

Figure 5-2. Operational Leak History of Tank T-111



5.3 TANK DESIGN/CONSTRUCTION

5.3.1 Tank Design

The steel bottoms of the T Farm tanks intersect the sidewall on a 4-ft radius knuckle transition (BPF-73550, Drawings D-2 and D-3). The rounded knuckle transition, the three-ply asphaltic membrane waterproofing between the liner and the concrete, a notched footing construction joint, and the concrete shell are features common to all T Farm tanks (see Section 3.1.1).

5.3.2 Tank Construction

Construction Conditions

The T Farm tanks were constructed between January 1944 and September 1944. Temperatures are not available for 1944 between May 18 and December 1. From the start of T Farm tank construction through May 18, 1944 there were two minimum temperatures of 12°F with day time temperatures of 44°F and 57°F, one at 18°F, and four at 20°F with day time temperatures between 41°F and 56°F.

As described in Section 3.1.2, cold weather affects the ductile-to-brittle steel transition temperature, with 18°F being the assumed design temperature for the carbon steel liner, which could result in a fracture upon impact. However, in general, the temperatures during the T Farm construction time frame were much milder than those experienced during 241-SX Farm construction where ductile-to-brittle steel transition temperatures were exceeded.

Design, fabrication, and erection of the tank steel lining were required to be in accordance with current "Standard Specifications for Elevated Steel Water Tanks, Standpipes and Reservoirs" as promulgated by the "American Water Works Association" (BPF-73550). Welding requirements were required to conform to the American Welding Society's "Code for Arc and Gas Welding in Building Construction", Section 4.

Construction Activities

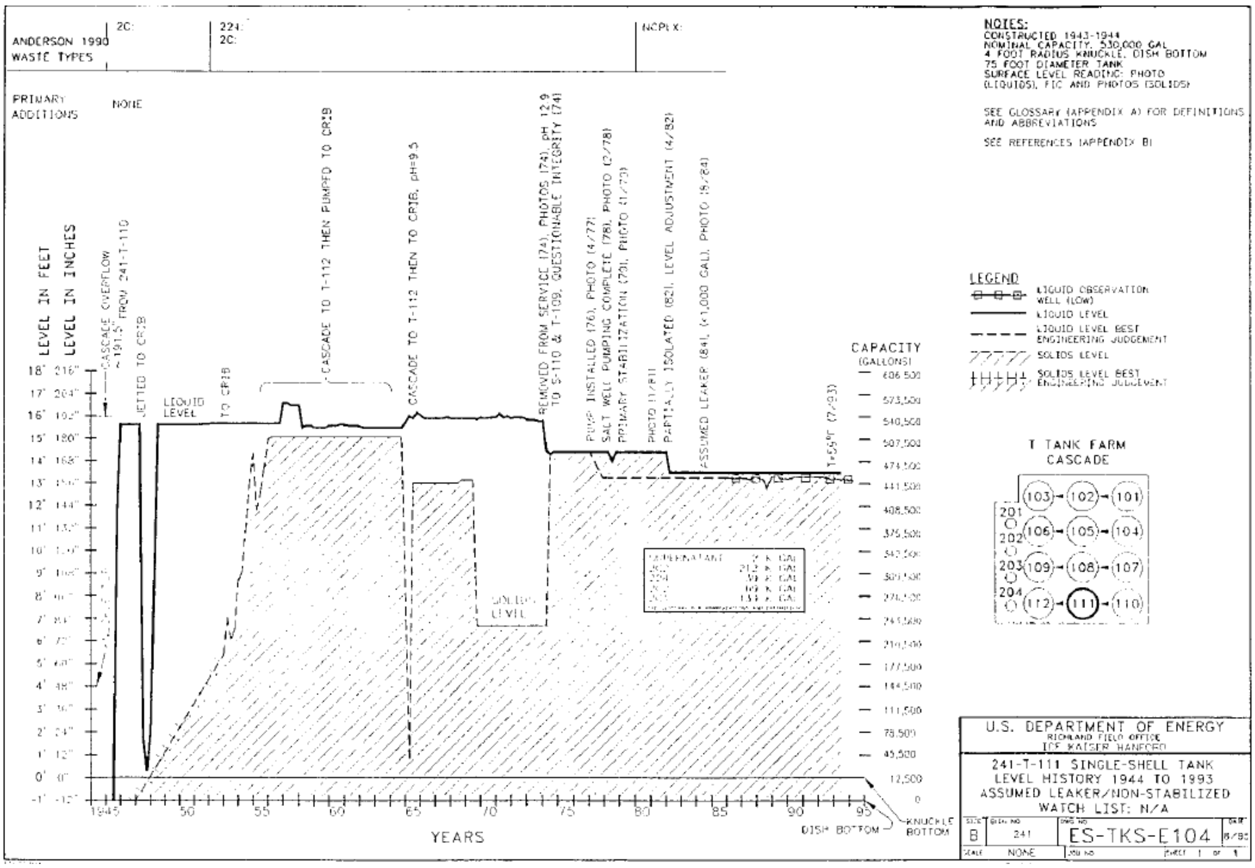
The T Farm tanks experienced a reported warping of the bottom liners during construction of the tanks and all of the T Farm tank bottom liners required replacement (HW-7-103, *Hanford Engineering Works Monthly Report April 1944*, page 14). No specific references were recovered documenting replacement of the tank T-111 bottom liner. The original construction time frame of the T Farm 100-series tank bottom liners and knuckle was about 30 days. About 60 days was required to replace most of the warped T Farm bottom liners which also included construction of most of the tank sidewalls. Monthly reports indicated all tanks passed X-ray tests. The number of concurrent construction activities in T Farm during the bottom liner replacement opens the possibility of quality issues that may not have been identified by X-ray testing. See Section 3.1.2, Construction Activities, for additional details.

5.4 TANK T-111 IN-TANK DATA

5.4.1 Liquid Level

The liquid level plot in Figure 5-3 indicates the transfer activity into and out of tank T-111. The liquid levels are end of quarter levels so this figure may not reflect all transfers into and out of the tank that occurred during the operational history. See Figure 5-2 for historical monthly liquid level readings.

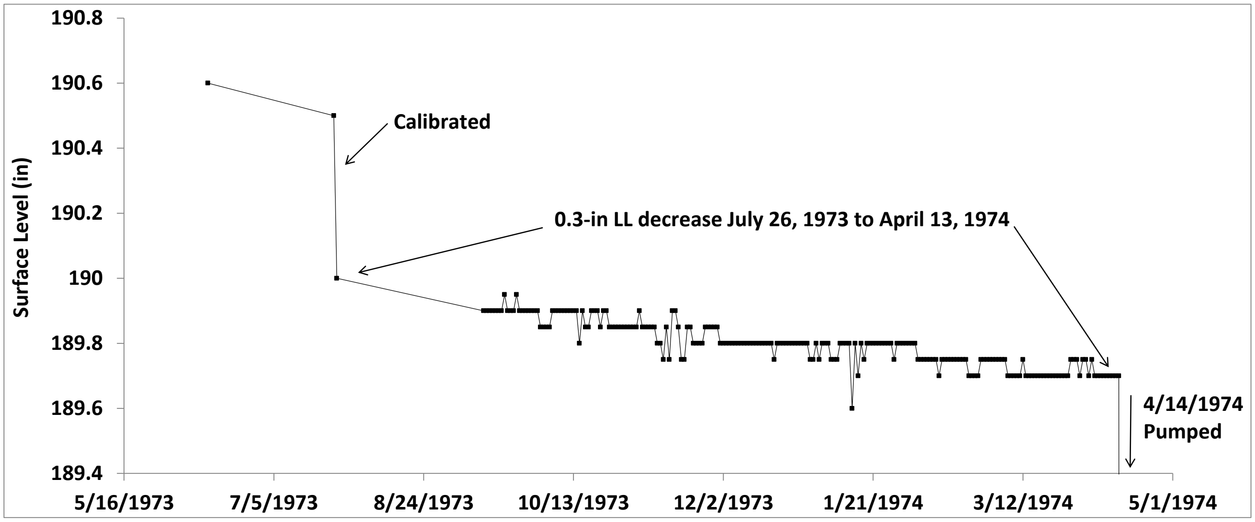
Figure 5-3. Tank T-111 End of Quarter Surface Level



HNF-SD-WM-ER-320, Rev. 1, 1997, *Supporting Document for the Historical Tank Content Estimate for T-Tank Farm.*

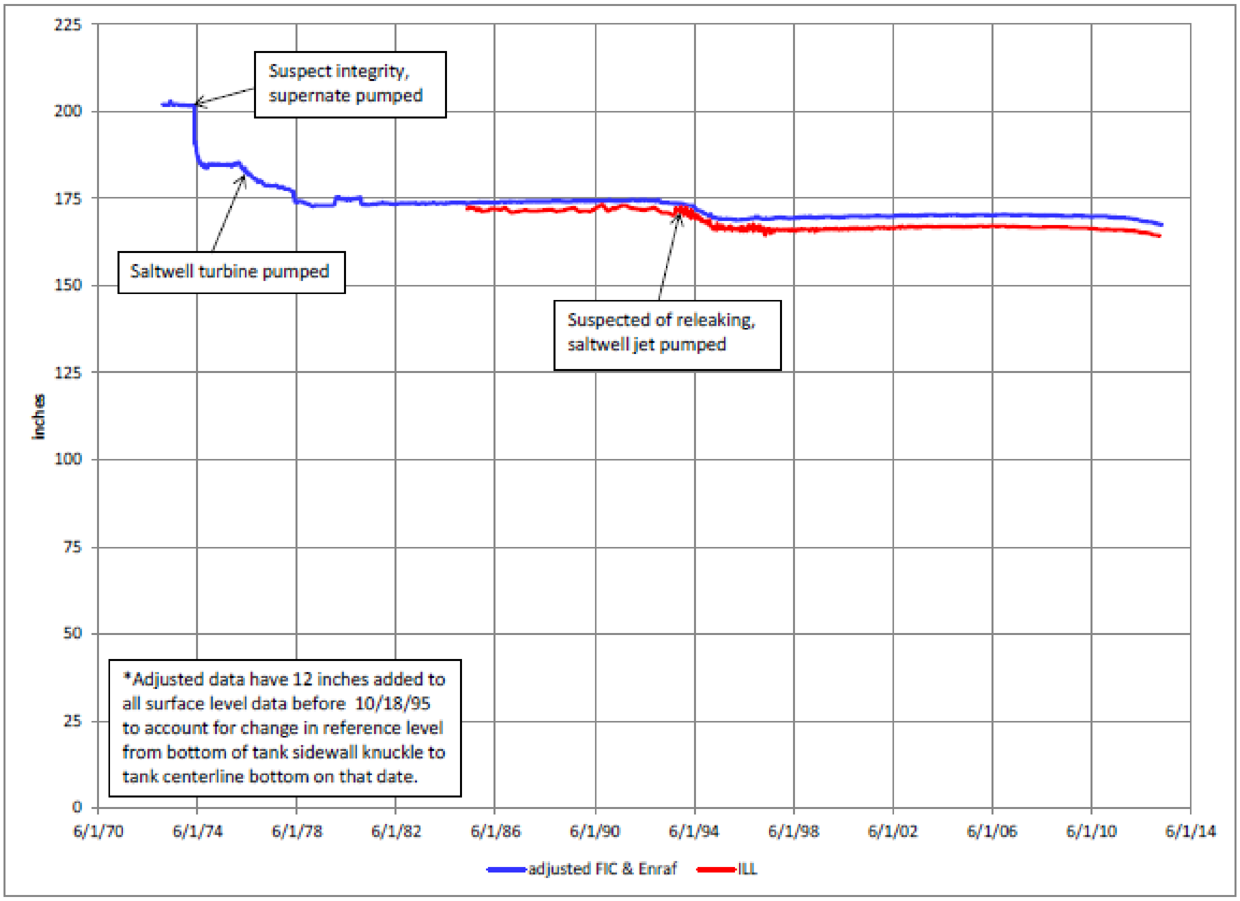
Tank T-111 was first suspected of leaking due to a 0.3-in liquid level decrease (~700 gal) in April 1974. The liquid level decrease was reported to have occurred starting July 26, 1973 (190-in) to April 13, 1974 (189.7-in), a period of nine months (see Figure 5-4). Supernatant was removed from tank T-111 to tank S-110 starting April 14, 1974. The leak volume was estimated to be less than 1,000 gal (HNF-EP-0182, *Waste Tank Summary Report for Month Ending February 28, 2013*).

Figure 5-4. Tank T-111 Liquid Level June 13, 1973 to April 14, 1974



From 1978 to 1993, tank T-111 had an apparent water intrusion of over 1.5-in as shown in Figure 5-5 (RPP-RPT-54964, Rev. 1). However, in 1993 the liquid level began to decrease and the tank was suspected of leaking again. A jet pump was installed and additional liquid was removed to the extent practical in 1994 and 1995. From 1995 to 2006, the tank liquid level increased 1-in before the liquid level began to drop again. Since 2006, the liquid level has been decreasing with the decrease rate accelerating with time. The volume of tank T-111 liquid leaked from 1995 to January 2014 is calculated at ~2,600 gal (RPP-RPT-54964, Rev. 2) after analysis of possible contributing factors including gas accumulation.

Figure 5-5. Tank T-111 Interstitial Liquid Level and Adjusted* Surface Level Data (RPP-RPT-54964, Rev. 1)



5.4.2 Temperature

Tank T-111 temperature ranged between 93°F (17% full 10/28/45) to 88°F (100% full 2/25/46), HW-7-450 *Plant Assistance Report-200 Areas- Weekly (2-27-46 thru 4-3-46*. No other temperature data were recovered for tank T-111 from 1946 until February 1976. Tank T-111 waste temperature plots from February 1976 to 2013 can be found in SACS (PCSACS). Average temperatures ranged from approximately 55°F to 75°F from 1976 to present with the maximum temperature reported at 87°F in August 1976 (see PCSACS).

Seven tanks in the B, C, T, and U Farms that contained metal waste (MW) ranged in temperature from 84°F to 174°F between 1945 and 1947 (HW-14946, *A Survey of Corrosion Data and Construction Details, 200 Area Waste Storage Tanks*). The temperature of T Farm tanks (tank T-101 and T-102) that contained MW waste ranged from 99°F to 165°F between 1945 and 1947 (HW-14946). Document HW-20742, *Loss of Depleted Metal Waste Supernatant to Soil*, reports MW from the $BiPO_4$ process was cascaded into a 241-BX Farm series of tanks with temperatures recorded in the first tank of ~180°F, which contained the bulk of the uranium and fission products, and ~70°F in the last tank of the cascade. Tank T-111, the second tank in the tank T-110 through tank T-112 cascade would experience lower temperatures with cooling time and less fission product containing solids accumulation. The MW contains approximately 90%, of the fission products from the $BiPO_4$ process, 1C approximately 10%, and 2C 1% or less. This provides a point of comparison to infer low tank waste temperatures in tank T-111, probably less than 100 °F for the storage of 2C wastes.

The rate of temperature rise can result in increased vapor pressure under the bottom tank liner from moisture in the underlying grout and vapor from the asphalt membrane below the grout. Temperatures are not available to calculate rate of rise therefore an actual rate of temperature rise is not available but the above temperatures would not likely result in bulging. There were no reports of bulging in tank T-111.

5.4.3 Liner Observations

A review of the available photographs taken April 11, 1974 and June 3, 1974 did not contain any evidence pointing to a tank leak. There is no documentation available indicating a liner bulge was present in tank T-111.

5.4.4 Chemistry-Corrosion

Tank T-111 began receiving waste in 1945 and received various waste types throughout operation as shown in Table 5-1. The typical concentration for nitrite, nitrate, and hydroxide for waste is shown in Table 5-2. Nitrite and hydroxide are known as nitrate induced SCC inhibitors. One key characteristic for inhibiting SCC is to maintain a high nitrite concentration to nitrate concentration ratio (see Section 3.2.4).

Table 5-1. Tank T-111 Waste Storage Chronology

Date	Waste Type	Length of Storage
1945 to 1952*	2C	~ 7 years
1952-1974	2C/224	~ 22 years

*Tank T-111 was emptied starting in the 3rd quarter of 1947 and filled full with 2C waste by the 3rd quarter of 1948

Table 5-2. Waste Chemistries for Waste Types Stored in Tank T-111

Waste Type[1]	$[NO_3^-]$	$[NO_2^-]$	$[OH^-]$	Meets Current DST Specification[2]
2C	1.27	Not Reported	Not Reported	No[3]
224	1.06	Not Reported	0.59	Yes[4]

1. Reference WHC-EP-0449, 1991, *The Sort on Radioactive Waste Type Model: A Method to Sort Single-Shell Tanks into Characteristic Groups.*
2. Reference OSD-T-151-00007, Rev. 12, 2013, *Operating Specification for the Double-Shell Storage Tanks*.
3. According to the assumption from reference WHC-EP-0772, *Characterization of the Corrosion Behavior of the Carbon Steel Liner in Hanford Site Single-Shell Tanks*.
4. Regardless of the concentration of nitrite, the hydroxide plus nitrite is greater than or equal to 0.4 times the nitrate concentration.

The first waste type stored in tank T-111 was 2C waste cascaded from tank T-110. The 2C waste was stored in the tank for approximately two years at unknown temperatures. Tank T-111 was emptied and refilled with 2C waste from 1947-1948, then stored this waste for an additional four years. Waste type 2C is assumed to not meet the current DST specifications (WHC-EP-0772) based on possibly high nitrate and low hydroxide. However, the 2C waste temperatures were less than 100°F and therefore would have little effect on corrosion. One of the recommendations in the report, HW-3-3220, *SE-PC-#82 A Study of Decontamination Cycle Waste Solutions and Methods of Preparing Them for Disposal*, states neutralizing 2C waste to pH 7 was adopted at 221-T Plant beginning in October 1945. The 2C waste is potentially a concern for pitting and/or SCC but it is not conclusive.

Tank T-111 also received 224 waste mixed with 2C waste at unknown ratios. Waste type 224 should not be a concern for pitting and/or SCC. When mixed with 2C waste, 224 wastes should have decreased the propensity of corrosion of the 2C waste; however, since the ratios of these waste types are unknown it remains inconclusive. Samples of tank T-111 taken June 7, 1974 and September 24, 1974 listed a pH of 13.25 and 12.9 respectively with corresponding OH^- of 0.254 M and 0.206 M (Accession # 1007130273, *Analytical Chemistry Report for 241-T-111*, June 7, 1974, Pages 1 and 2). Subsequent interstitial samples recorded pH ranging from 9.8 to 10.2. Temperatures less than 100°F would not result in pitting and/or SCC.

5.4.5 Photographs

A review of the available photographs taken April 11, 1974 and April 6, 1977 did not contain any evidence of a tank liner problem. There is no documentation available indicating a liner bulge was present in tank T-111.

5.5 TANK T-111 EX-TANK DATA

5.5.1 Drywells

There are ten drywells located around tank T-111: 50-00-06 installed in 1944, 50-08-05, 50-10-10, 50-11-05, 50-11-08, and 50-08-07 installed in 1974, 50-10-08, 50-11-07, and 50-11-10, installed in 1975, and 50-11-11, installed in 1979. All of the radiation readings in drywells are assumed to be maximum or peak readings unless otherwise noted (see Section 3.3.2). The following subsections report the available drywell information and the drywell summary section provides the analyses of the associated drywells with tank T-111.

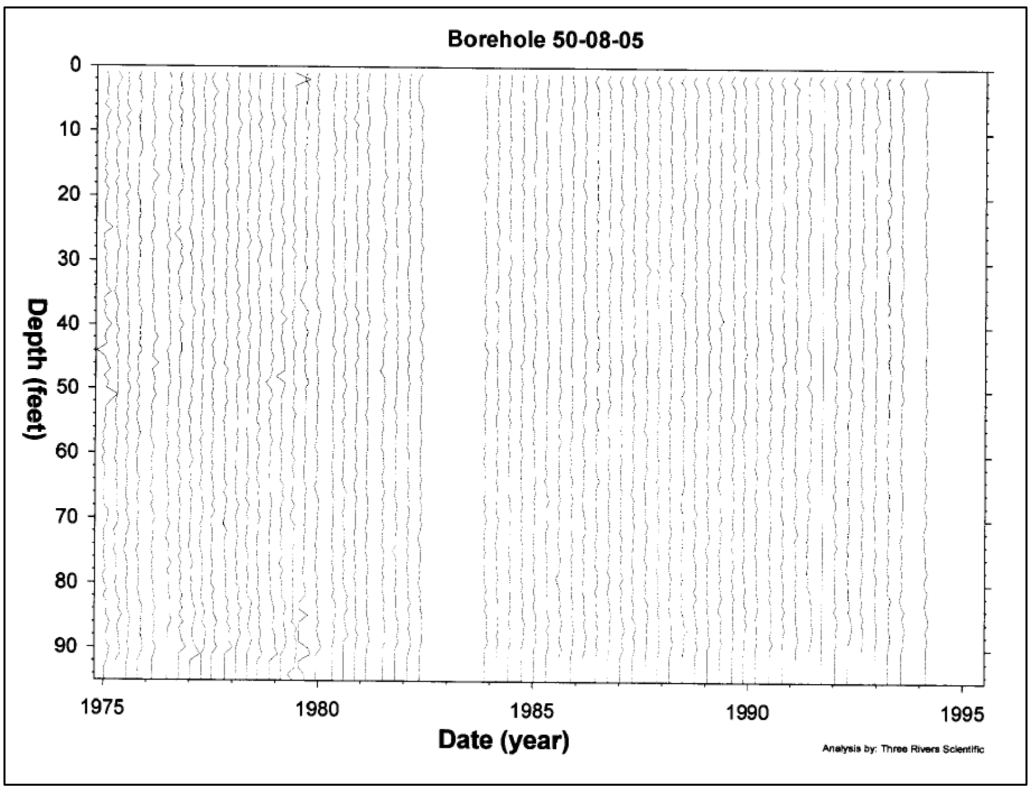
5.5.1.1 Drywell 50-08-05

Drywell 50-08-05 is located approximately 12-ft from the tank T-111 footing. Drywell 50-08-05 was drilled in March 1974 with the first recoverable reading on April 5, 1974 reported a peak of 16.2K cpm at an unspecified BGS depth (see Appendix A2). Readings gradually declined to 6K cpm by August 9, 1974 and then were reported as less than values beginning January 31, 1975 indicating this earlier radioactivity was likely due to short-lived radioisotopes.

In December 1998, Cs-137 was the only man-made gamma-emitting radionuclide detected in drywell 50-08-05 (GJ-HAN-123, *Vadose Zone Characterization Project at the Hanford Tank Farms Tank Summary Data Report for Tank T-111*). The maximum Cs-137 detected was at 0.5-ft BGS at a concentration of 1 pCi/g. Document GJ-HAN-123 reports, "*There is no indication of anomalous activity in the earlier historical gross gamma-ray logs.*"

Since historical radioactivity in this drywell is very low, the 0.3-in leak volume is very low, and the GJ-HAN-123 report indicated low levels of radioactivity, drywell 50-08-05 is not being included as part of the leak location for tank T-111. Figure 5-6 shows the depths of radioactivity from 1975 to 1995 (RPP-6088).

Figure 5-6. Tank T-111 Drywell 50-08-05 (RPP-6088)



Note: Bottom of the tank footing is ~38-ft 1-in BGS

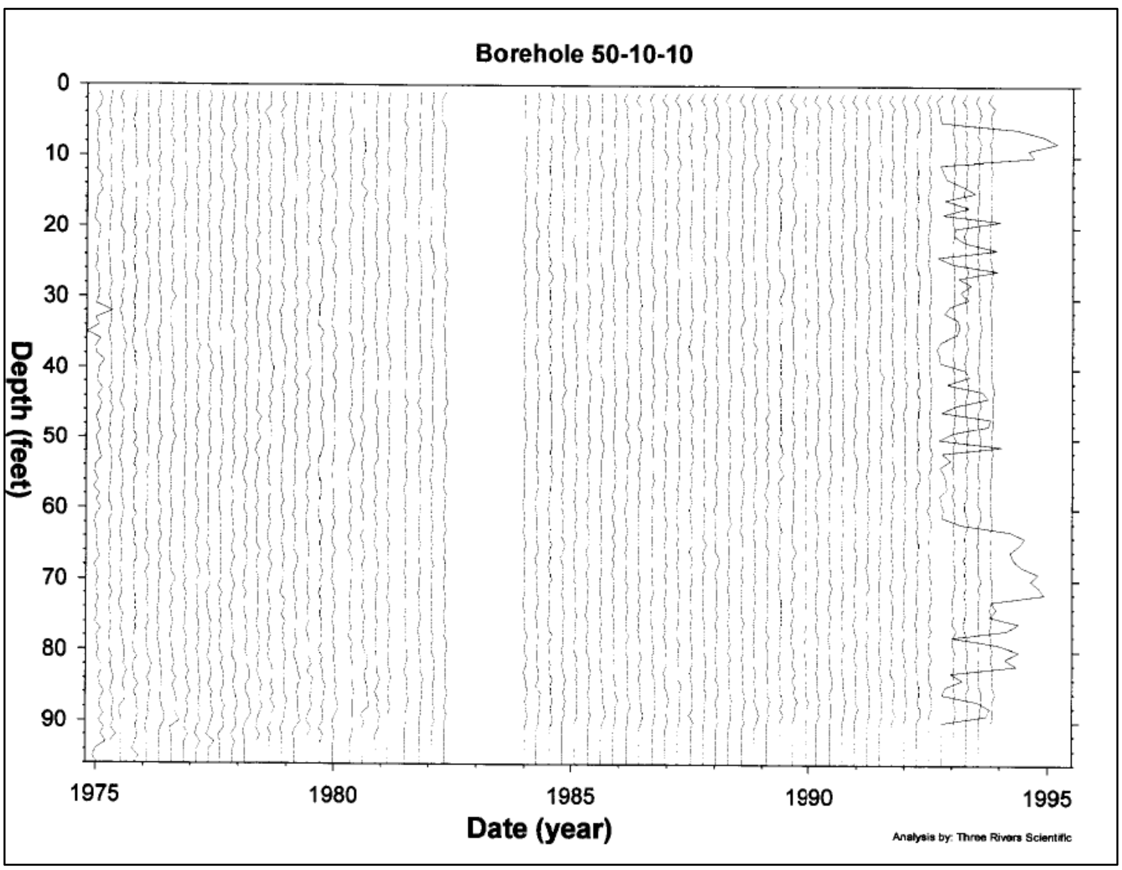
5.5.1.2 Drywell 50-10-10

Drywell 50-10-10 is located approximately 15-ft from the tank T-111 footing. Drywell 50-10-10 was drilled in February 1974 with the first recoverable reading on April 4, 1974 reported as a less than value (see Appendix A2). Readings continued to be reported as less than values through September 1987.

In December 1998, Cs-137 was the only man-made gamma-emitting radionuclide detected in drywell 50-10-10 (GJ-HAN-123). Concentrations of Cs-137 ranged between 0.2 to 0.4 pCi/g intermittently at depths ranging from 6.5 to 74.5-ft BGS. The maximum concentration of 2.5 pCi/g was detected at 1.5-ft BGS. Document GJ-HAN-123 reports, "*The Cs-137 contamination detected between the ground surface and 3 ft probably resulted from a surface spill that migrated down into the shallow backfill surrounding the borehole. The Cs-137 contamination detected discontinuously between 8 and 75 ft was probably carried downward from the near-surface contaminated zone during the borehole installation activity.*"

Since historical radioactivity in this drywell is very low, the 0.3-in leak volume is very low, and GJ-HAN-123 report indicated low levels of radioactivity, drywell 50-10-10 is not being included as part of the leak location for tank T-111. Figure 5-7 shows the depths of radioactivity from 1975 to 1995 (RPP-6088).

Figure 5-7. Tank T-111 Drywell 50-10-10 (RPP-6088)



Note: Bottom of the tank footing is ~38-ft 1-in BGS

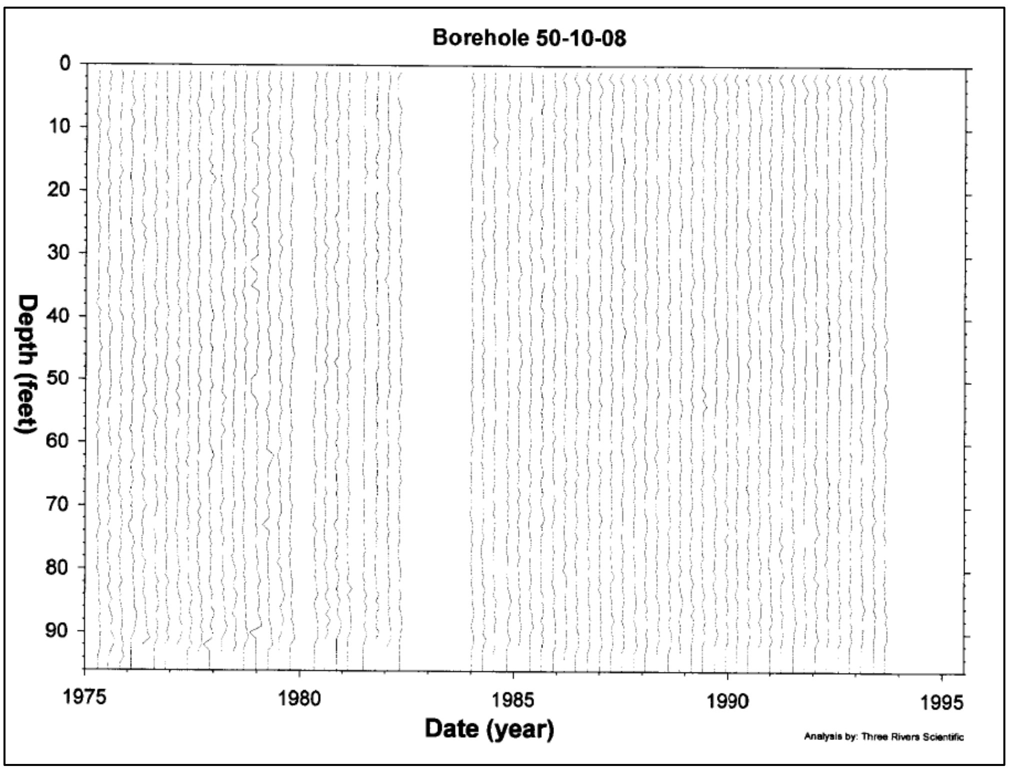
5.5.1.3 Drywell 50-10-08

Drywell 50-10-08 is located approximately 15-ft from the tank T-111 footing. Drywell 50-10-08 was drilled in March 1975 with the first recoverable reading on April 18, 1975 reported as a less than values (see Appendix A2). Readings continued to be reported as less than values through September 1987.

In December 1998, Cs-137 was the only man-made gamma-emitting radionuclide detected in drywell 50-10-08 (GJ-HAN-123). Concentrations of Cs-137 ranged from 0.2 to 0.25 pCi/g and were detected continuously from 1.5 to 2.5-ft BGS. Document GJ-HAN-123 reports, "*The Cs-137 contamination is probably from a surface spill that migrated down into the shallow backfill surrounding the borehole or may be the result of statistical noise.*"

Since historical radioactivity in this drywell is near the surface, drywell 50-10-08 is not being included as part of the leak location for tank T-111. Figure 5-8 shows the depths of radioactivity from 1975 to 1995 (RPP-6088).

Figure 5-8. Tank T-111 Drywell 50-10-08 (RPP-6088)



Note: Bottom of the tank footing is ~38-ft 1-in BGS

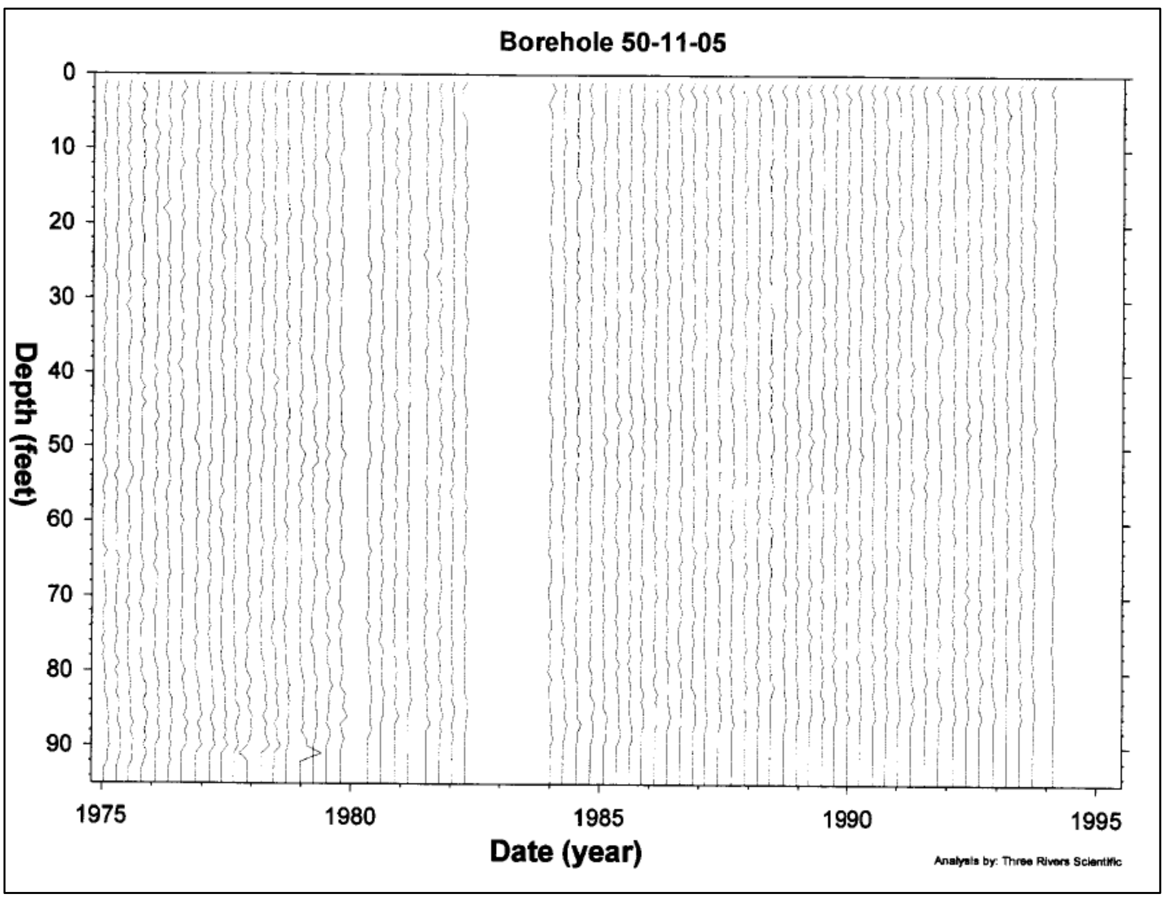
5.5.1.4 Drywell 50-11-05

Drywell 50-11-05 is located approximately 4.7-ft from the tank T-111 footing. Drywell 50-11-05 was drilled in February 1974 with the first recoverable reading on April 5, 1974 reported as a less than values (see Appendix A2). Readings continued to be reported as less than values through September 1987.

In December 1998, Cs-137 was the only man-made gamma-emitting radionuclide detected in drywell 50-11-05 (GJ-HAN-123). Cs-137 was only detected at the ground surface at a concentration of 0.35 pCi/g. Document GJ-HAN-123 states, "*The Cs-137 contamination is probably related to direct radiation (shine) from contamination on the ground surface or from nearby contaminated equipment.*"

Since historical radioactivity in this drywell was detected at the ground surface, drywell 50-11-05 is not being included as part of the leak location for tank T-111. Figure 5-9 shows the depths of radioactivity from 1975 to 1995 (RPP-6088).

Figure 5-9. Tank T-111 Drywell 50-11-05 (RPP-6088)



Note: Bottom of the tank footing is ~38-ft 1-in BGS

5.5.1.5 Drywell 50-00-06

Drywell 50-00-06 is located approximately 42-ft from the tank T-111 footing. Drywell 50-00-06 was drilled in September 1944 with the first recoverable reading on September 21, 1973 reported as a less than values (see Appendix A2). Readings continued to be reported as less than values through April 1975. No additional drywell data were recovered after April 1975.

In December 1998, Cs-137 was the only man-made gamma-emitting radionuclide detected in drywell 50-00-06 (GJ-HAN-123). Cs-137 contamination was detected continuously from 0.5 to 20-ft BGS at concentrations ranging from 0.2 to 2 pCi/g, intermittently from 110 to 147.5-ft BGS at concentrations ranging from 0.2 to 0.6 pCi/g. The maximum Cs-137 concentration detected was at 1-ft BGS at 2 pCi/g. Document GJ-HAN-123 states, "*The Cs-137 contamination detected between the ground surface and 3 ft probably resulted from a surface spill that migrated down into the shallow backfill surrounding the borehole. The low concentrations of Cs-137 detected intermittently below 110 ft were probably carried downward from the near-surface contaminated zone during construction of the borehole. The contamination at the bottom of the borehole is probably particulate matter that has fallen into the borehole from the ground surface.*"

Since historical radioactivity in this drywell is very low, the 0.3-in leak volume is very low, and GJ-HAN-123 report indicated low levels of radioactivity, drywell 50-00-06 is not being included as part of the leak location for tank T-111.

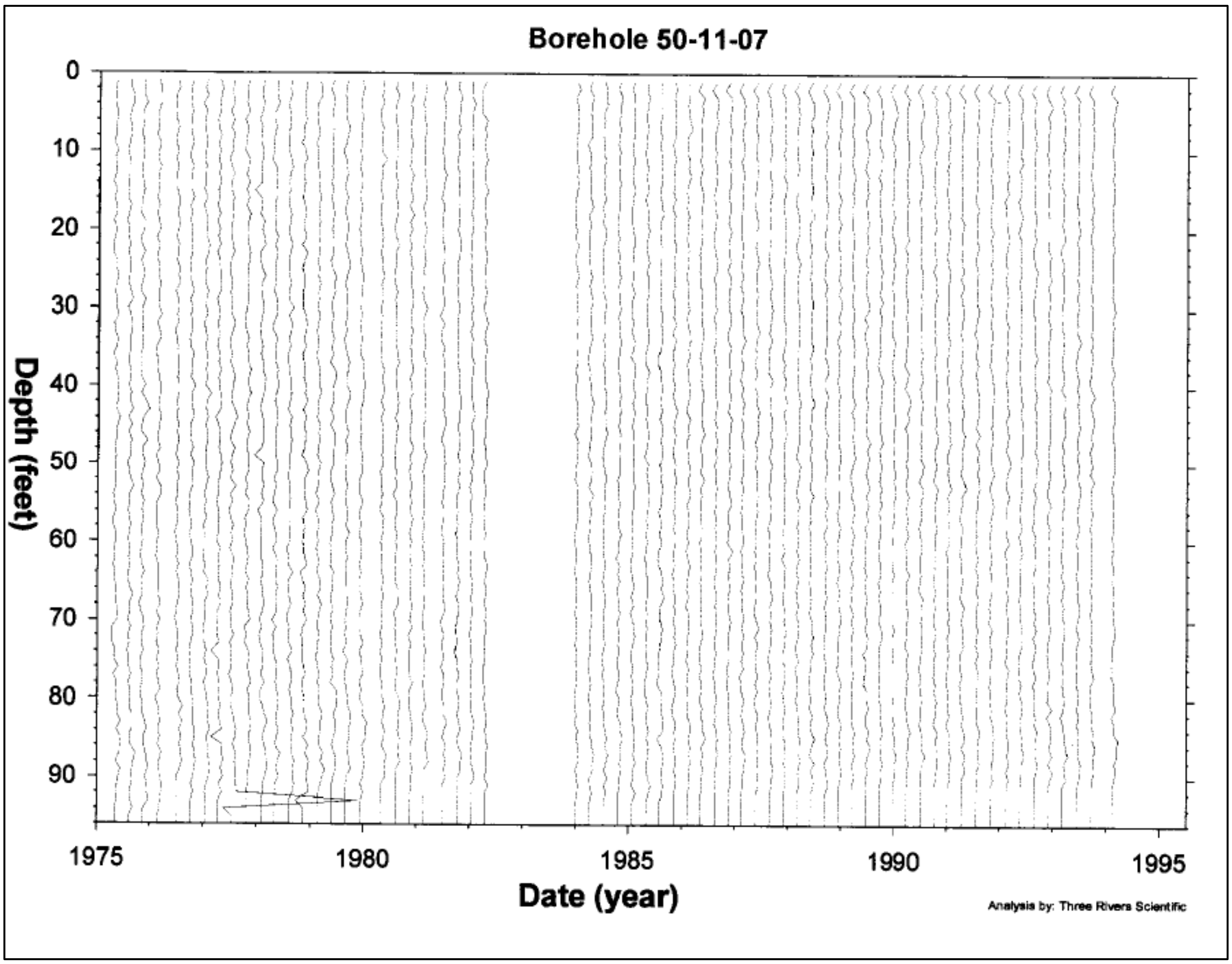
5.5.1.6 Drywell 50-11-07

Drywell 50-11-07 is located approximately 4.7-ft from the tank T-111 footing. Drywell 50-11-07 was drilled in February 1975 with the first recoverable reading on May 2, 1975 reported as a less than values (see Appendix A2). Readings continued to be reported as less than values through September 1987.

In December 1998, Cs-137 was the only man-made gamma-emitting radionuclide detected in drywell 50-11-07 (GJ-HAN-123). Cs-137 was detected at the ground surface at a concentration of 0.15 pCi/g, from 3 to 6-ft BGS at concentrations ranging between 0.25 and 0.4 pCi/g, and at 84-ft BGS at concentrations just above the minimum detection limit. The maximum Cs-137 concentration was 0.4 pCi/g at 5-ft BGS. Document GJ-HAN-123 reports, "*The locations and concentrations of the Cs-137 contamination are not indicative of a subsurface source.*"

Since historical radioactivity in this drywell is very low, the 0.3-in leak volume is very low, drywell 50-11-07 is not being included as part of the leak location for tank T-111. Figure 5-10 shows the depths of radioactivity from 1975 to 1995 (RPP-6088).

Figure 5-10. Tank T-111 Drywell 50-11-07 (RPP-6088)



Note: Bottom of the tank footing is ~38-ft 1-in BGS

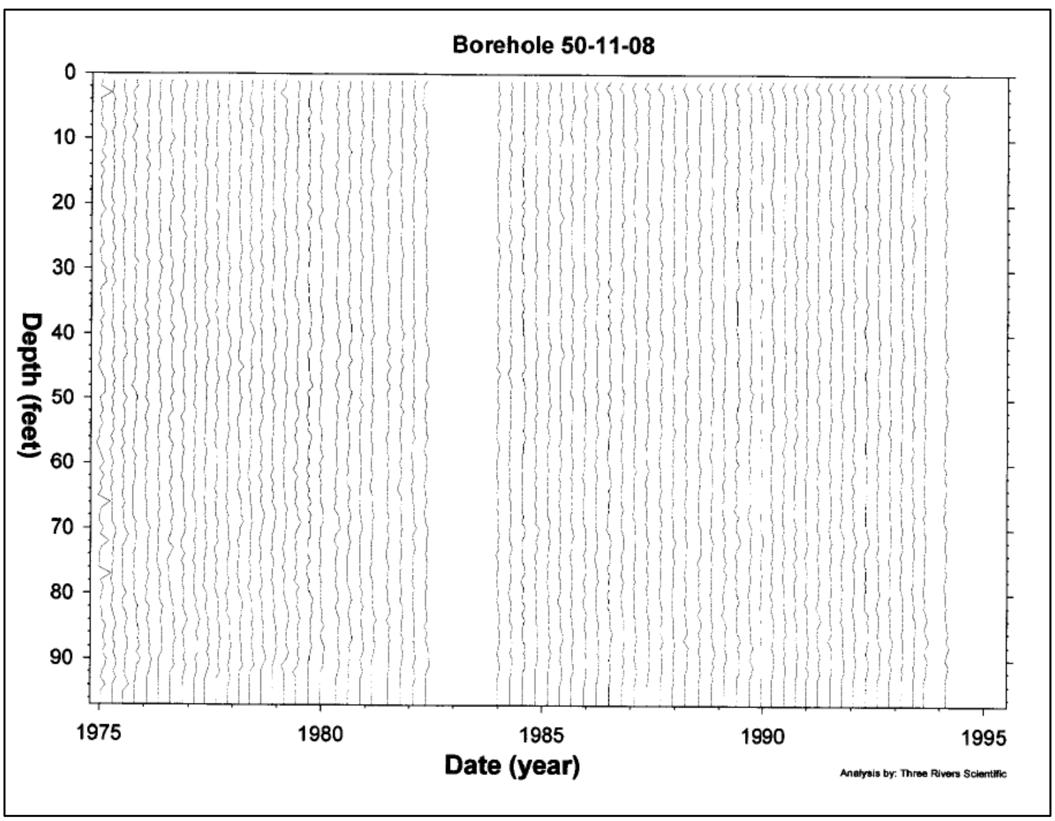
5.5.1.7 Drywell 50-11-08

Drywell 50-11-08 is located approximately 12-ft from the tank T-111 footing. Drywell 50-11-08 was drilled in February 1974 with the first recoverable reading on April 5, 1974 reported as a less than values (see Appendix A2). Readings continued to be reported as less than values through September 1987.

In December 1998, Cs-137 was the only man-made gamma-emitting radionuclide detected in drywell 50-11-08 (GJ-HAN-123). The maximum Cs-137 concentration of 0.5 pCi/g was detected at the ground surface. Cs-137 contamination was also detected at 0.5, 10.5, and 13-ft BGS at the minimum detection limit (0.2 pCi/g). Document GJ-HAN-123 reports, "*The Cs-137 contamination detected at the ground surface is probably attributable to direct radiation (shine) from contamination on the ground surface or nearby equipment. The contamination at 0.5 ft is probably related to surface spills that have migrated into the backfill material surrounding the borehole. The Cs-137 contamination detected below 10 ft could have been carried down from the ground surface during the borehole construction activities. Regardless of how the contamination reached its present location, a subsurface source is not indicated.*"

Since historical radioactivity in this drywell is very low and near the surface, drywell 50-11-08 is not being included as part of the leak location for tank T-111. Figure 5-11 shows the depths of radioactivity from 1975 to 1995 (RPP-6088).

Figure 5-11. Tank T-111 Drywell 50-11-08 (RPP-6088)



Note: Bottom of the tank footing is ~38-ft 1-in BGS

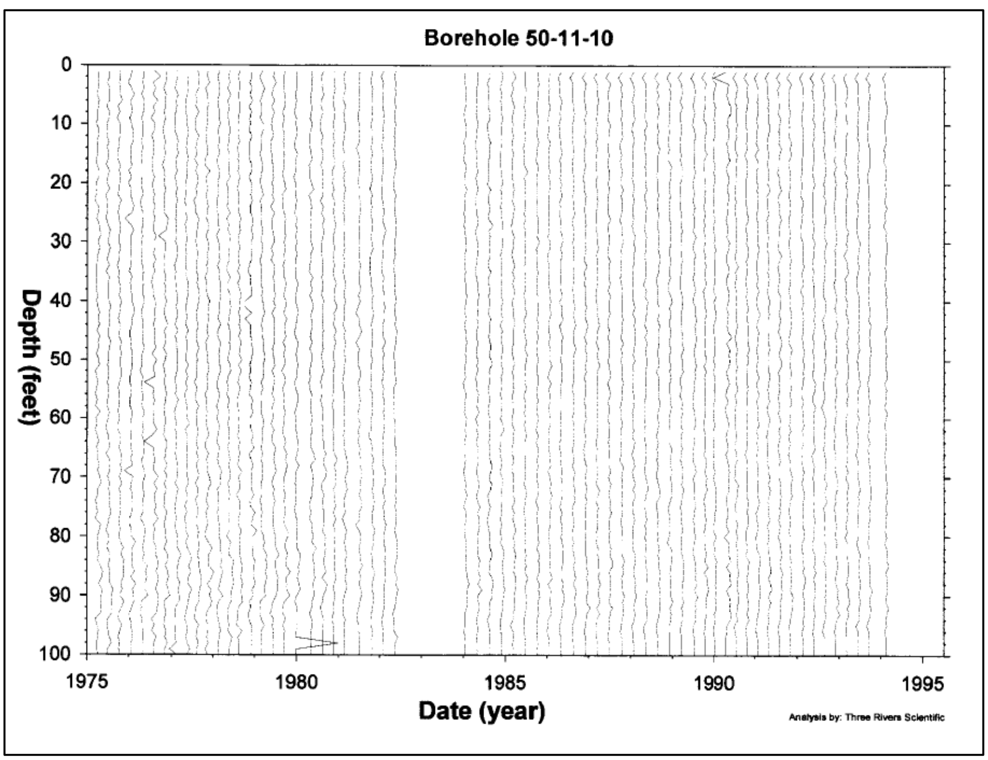
5.5.1.8 Drywell 50-11-10

Drywell 50-11-10 is located approximately 15-ft from the tank T-111 footing. Drywell 50-11-10 was drilled in January 1975 with the first recoverable reading on April 2, 1975 reported as a less than values (see Appendix A2). Readings continued to be reported as less than values through September 1987.

In December 1998, Cs-137 and Co-60 were the only man-made gamma-emitting radionuclides detected in drywell 50-11-10 (GJ-HAN-123). Cs-137 contamination was detected continuously from the ground surface to 2.5-ft BGS at concentrations of 0.2 pCi/g. Co-60 contamination was detected between 68 and 69-ft BGS at very low concentrations ranging from 0.06 to 0.08 pCi/g. Document GJ-HAN-123 states, "*Only low concentrations of Cs-137 contamination were detected near the ground surface in this borehole. This contamination was just above the MDL and may be the result of a surface spill that migrated down into the shallow backfill surrounding the borehole or the result of statistical noise.*" In regards to the Co-60 detected in this drywell, GJ-HAN-123 states "*The source of the plume is not from tank T-111, but is probably associated with a plume that has migrated from the north where thicker intervals and higher concentrations of Co-60 contamination are found*."

Since historical radioactivity in this drywell is very low, the 0.03-in leak volume is very low, and the GJ-HAN-123 report indicated low levels of radioactivity, drywell 50-11-10 is not being included as part of the leak location for tank T-111. Figure 5-12 shows the depths of radioactivity from 1975 to 1995 (RPP-6088).

Figure 5-12. Tank T-111 Drywell 50-11-10 (RPP-6088)



Note: Bottom of the tank footing is ~38-ft 1-in BGS

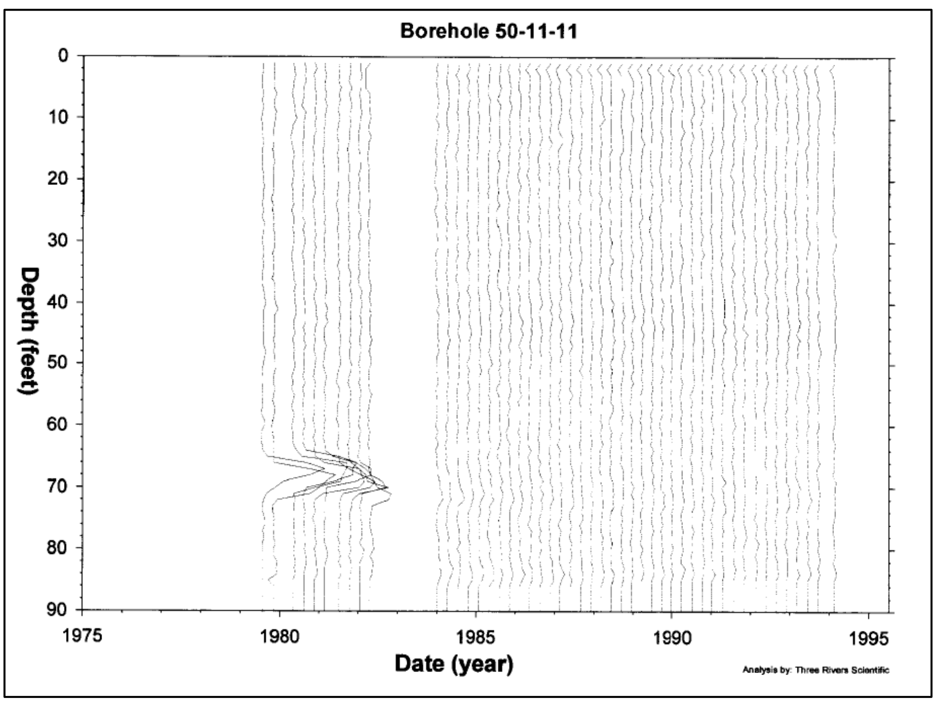
5.5.1.9 Drywell 50-11-11

Drywell 50-11-11 is located approximately 3.8-ft from the tank T-111 footing. Drywell 50-11-11 was drilled in July 1979 with the first recoverable reading on July 26, 1979 which reported a peak of 46.1K cpm at 67-ft BGS (see Appendix A2). Readings continued to be reported at roughly the same BGS level and activity level through February 5, 1980. Beginning on August 19, 1980, the peak declined to 22.3K cpm at 67-ft BGS and slowly decreased to 2.3K cpm by September 29, 1987 at 73-ft BGS.

In December 1998, Cs-137 and Co-60 were the only man-made gamma-emitting radionuclides detected in drywell 50-11-11 (GJ-HAN-123). Cs-137 contamination was detected almost continuously from the ground surface to 14-ft BGS at concentrations ranging from 0.15 to 0.9 pCi/g with the maximum concentration of 0.9 pCi/g detected at 12-ft BGS. Co-60 contamination was detected continuously from 68.5 to 71.5-ft BGS at concentrations ranging from 0.1 to 0.3 pCi/g with the maximum concentration of 0.3 pCi/g detected at 68.5-ft BGS. Document GJ-HAN-123 states, "*The Cs-137 contamination detected from the ground surface to 14 ft may be the result of surface spills that have migrated through the backfill material surrounding the borehole.*"…and, "*The Co-60 contamination detected at the 70-ft depth probably did not originate from tank T-111 because there are no other indications of contamination in the vicinity of the tank.*"

Since historical radioactivity in this drywell is low, at a low BGS level, and the drywell was drilled approximately five years after the tank was suspected of leaking, drywell 50-11-11 is not being included as part of the leak location for tank T-111. Figure 5-13 shows the depths of radioactivity from 1975 to 1995 (RPP-6088).

Figure 5-13. Tank T-111 Drywell 50-11-11 (RPP-6088)



Note: Bottom of the tank footing is ~38-ft 1-in BGS

5.5.1.10 Drywell 50-08-07

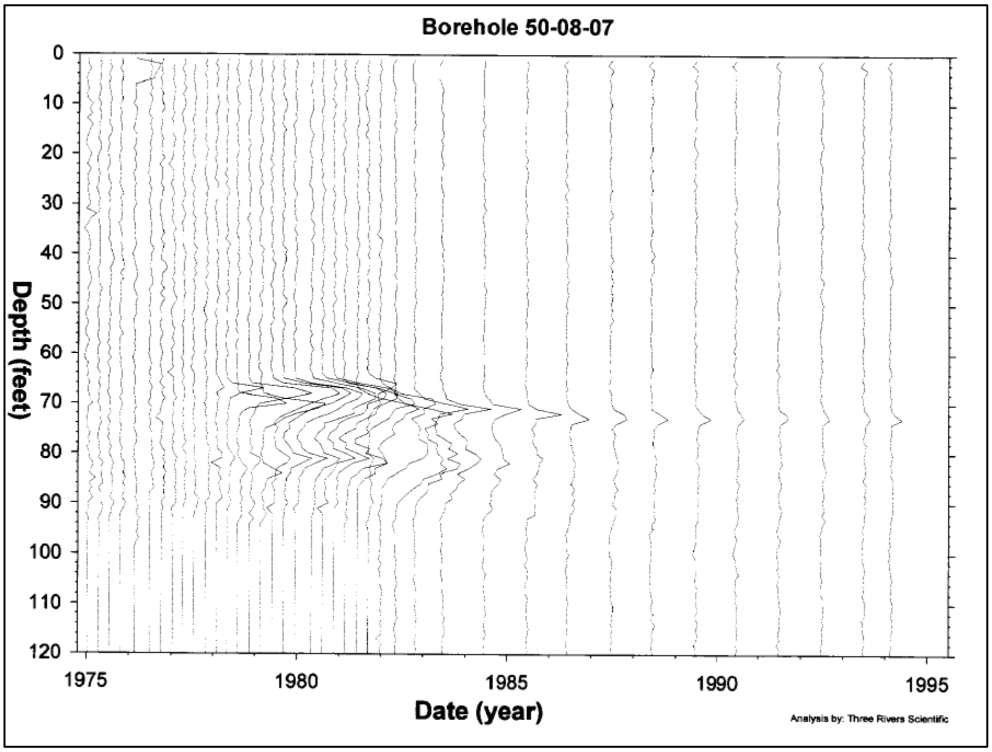
Drywell 50-08-07 is located approximately 15-ft from the tank T-111 footing. Drywell 50-08-07 was drilled in February 1974 with the first recoverable reading on April 5, 1974 reported as a less than values (see Appendix A2). Readings continued to be reported as less than values through October 14, 1977. Beginning on January 6, 1978, a peak of 3.2K cpm was reported at 67-ft BGS. The next recoverable reading on May 5, 1978 reported two peaks of 8.9K cpm at 67-ft BGS and 3.2K cpm at 80-ft BGS. Radioactivity continued to increase at both peaks through August 8, 1979, then remained relatively stable through 1981, and then slowly declined through June 1987.

In December 1998, Cs-137 and Co-60 were the only gamma-emitting man-made radionuclides detected in drywell 50-08-07 (GJ-HAN-123). Cs-137 was detected from the ground surface to 3-ft BGS, at 101-ft BGS, and from 117 to 119-ft BGS with concentrations ranging from 0.15 to 1.9 pCi/g. The maximum Cs-137 concentration of 1.9 pCi/g was detected at 1-ft BGS. Co-60 contamination was detected continuously from 68.5 to 95.5-ft BGS and intermittently from 103.5 to 110.5-ft BGS. The maximum Co-60 contamination of 3.9 pCi/g was detected at 72-ft BGS. Document GJ-HAN-123 states, "*The Cs-137 contamination detected from the ground surface to 3 ft could be the result of surface spills migrating through the backfill material surrounding the borehole or might have resulted from carrydown during borehole construction activities. The Cs-137 contamination detected at 101 ft was probably carried down from the near-surface contaminated zone during borehole construction activities. The Cs-137 contamination at the bottom of the borehole is most likely particulate matter that has fallen into the borehole from the ground surface*." In regards to Co-60, GJ-HAN-123 states, "*The Co-60 contamination detected below 69 ft probably did not originate from tank T-111, but migrated from tank T-108*."

In 2008, drywell 50-08-07 was re-logged with SGLS to update the 1998 baseline efforts which coincided with the installation of the T Farm surface barrier (RPP-RPT-44202, Rev. 1, *Hanford Geophysical Logging Project Spectral Gamma Re-Baseline Logging for the T-Farm Interim Surface Barrier*). Co-60 was the only man-made radionuclide detected in this drywell below 70-ft BGS with the maximum concentration detected at 71.5-ft BGS (approximately 1 pCi/g). Since 1998, increases in Co-60 concentrations were indicated at depths below 83-ft BGS; however, these increases were reported to not be statistically significant (RPP-RPT-44202, Rev. 1).

Since historical radioactivity in this drywell is very low in concentration and BGS depth, the 0.3-in leak volume is very low, and the SGLS results indicated low levels of radioactivity, drywell 50-08-07 is not being included as part of the leak location for tank T-111. Figure 5-14 shows the depths of radioactivity from 1975 to 1995 (RPP-6088).

Figure 5-14. Tank T-111 Drywell 50-08-07 (RPP-6088)



Note: Bottom of the tank footing is ~38-ft 1-in BGS

5.5.1.11 Drywell Summary

Tank T-111 was first suspected of leaking due to a 0.3-in liquid level decrease (~700 gallons) in April 1974. The liquid level decrease was reported to have occurred starting July 26, 1973 to April 13, 1974, a period of nine months. There were seven drywells located near tank T-111 when the tank was first suspected of leaking (drywells 50-08-05, 50-10-10, 50-10-08, 50-00-06, 50-11-05, 50-11-08, and 50-08-07). Drywells 50-11-07, 50-11-10, and 50-11-11 were installed later in January 1975 to 1979.

Data obtained from drywells 50-10-10, 50-10-08, 50-00-06, 50-11-05, 50-11-07, 50-11-08, and 50-11-10 do not report any radioactivity indicative of a tank leak and therefore are not included as part of the leak location for tank T-111.

Drywell 50-08-05 reported small levels of radioactivity at an unspecified BGS depth in the earliest recoverable data in April 1974; however, radioactivity declined to less than values by January 1975. Thus, earlier reported radioactivity could be from short-lived radioisotopes. Therefore, drywell 50-08-05 is not included as part of the leak location for tank T-111.

Radioactivity in drywell 50-08-07 reported less than values from the first recoverable reading in April 1974 through October 1977. Beginning in January 1978, a peak of low level radioactivity was reported at 67-ft BGS. The next recoverable reading in May 1978 reported two low level peaks at 67 and 80-ft BGS and remained relatively stable through 1981 and then slowly declined through June 1987. Since historical readings were very low at a much lower BGS depth from the tank footing, drywell 50-08-07 is therefore not included as part of the leak location for tank T-111.

Drywell 50-11-11 reported low level radioactivity in 1979, or about five years after tank T-111 was first suspected of leaking. Radioactivity was reported at a much lower BGS level (~67-ft BGS) compared to the tank footing (~38-ft 1-in BGS). Therefore, drywell 50-11-11 is not being included as part of the leak location for tank T-111.

The deeper contamination at ~67-ft BGS reported in drywells 50-08-07 and 50-11-11 may have resulted from lateral transport of a leak from another source. Document RPP-RPT-55084, Rev. 0, also states, "*The contamination plumes that were identified in the vicinity of tank T-111 in drywells 50-11-11 and 50-08-07 can be directly correlated to contamination detected in monitoring drywells surrounding tank T-108.*"

None of the surrounding tank T-111 drywells reported radioactivity associated with tank T-111. Therefore, these drywells are not being included as part of the leak location for tank T-111. No leak detection laterals or direct pushes were installed near tank T-111.

The following paragraph from RPP-RPT-54964, Rev. 1, indicates that the tank T-111 drywells did not detect the post 1994 leak volume estimated at a likely volume of 2,000 gal at the time.

> "Baseline spectral gamma scans of drywells around tank T-111 were obtained in 1998 along with other T-Farm drywells. Selected drywells were relogged with the spectral gamma system in 2008-2009 following installation of the T-Farm barrier (RPP-RPT-44202, *Hanford Geophysical Logging Project Spectral Gamma Re-Baseline Logging for the T-Farm Interim Surface Barrier,* Rev. 0). Only two of the relogged drywells, 50-08-07 and 50-08-19, are near tank T-111, and adjacent to each other. This relogging showed minor movement of 60Co 83 ft. Below Grade Surface (BGS) in 50-08-07 and possibly very minor movement of 60Co 80 ft. BGS in 50-08-19 when compared to the 1998 scans. No change was detected in 137Cs movement compared to the 1998 scans."

5.6 POSSIBLE TANK T-111 LINER LEAK LOCATION(S)

A liner leak may have penetrated the waterproof membrane at any location or pooled on the waterproof membrane and followed concrete cracks or construction joints to a different location for egress to the soil, including the top of the tank footing.

The ten drywells surrounding tank T-111 did not show radiation that indicated a possible tank liner leak from tank T-111. There is deeper contamination at ~67-ft BGS in a couple of the drywells, but this activity may have resulted from lateral transport of a leak from another source. The liquid level decrease of 0.3-in in 1974 (~700 gal) and the subsequent leak volume calculated from 1995 to 2014 was probably not large enough to be detected by any of the ten drywells depending on the exact location of any liner leak with the closest drywell at 3.8-ft from the tank outer foundation. A tank liner leak location is therefore not able to be predicted.

The tank T-111 data is insufficient to identify a leak location and no laterals or direct pushes were installed near tank T-111.

5.7 POSSIBLE TANK T-111 LINER LEAK CAUSE(S)

Tank T-111 was evaluated for five conditions known to contribute to a failed liner.

5.7.1 Tank Design

The T Farm tank design does not appear to be a factor contributing to a failed liner (see Section 3.1.1).

5.7.2 Thermal Conditions

No temperature data are available for tank T-111 prior to 1976, however, tank T-111 held only non-boiling waste. Thermal shock creates stress both from rapid temperature rise as well as waste-induced high temperatures. Since no records are available, it is uncertain what the maximum temperature was in tank T-111 during operation as well as the rate of temperature rise when waste was added. The thermal attributes of the waste and other information (see Section 5.4.2) would indicate that thermal stresses were likely minimal and should not have challenged the tank storage limits.

Temperature requirements in ARH-951 issued December 18, 1969 indicated that tank temperatures should be held below 230°F.

5.7.3 Chemistry-Corrosion

Tank T-111 initially received 2C waste cascaded from tank T-110 and stored only this waste type for approximately seven years. Tank T-111 started to receive 224 waste mixed with 2C waste at unknown ratios beginning in 1952 and stored this waste type until the tank was first suspected of leaking in 1974. Waste type 2C does not meet the current DST specifications for waste chemistry and would therefore create an environment conducive to pitting and/or SCC especially in the first seven years of service when in contact with only 2C waste. However, the 2C waste temperatures were below 100°F and therefore would have little effect on corrosion. With the addition of 224 waste, this would likely reduced the corrosiveness of the 2C waste.

5.7.4 Liner Observations

A review of the available photographs for tank T-111 does not contain any evidence pointing to a tank leak. There is no documentation available indicating a liner bulge was present in the tank.

5.7.5 Tank Construction

The T Farm tank liners were constructed between January 1944 and September 1944. Only isolated minimum temperatures were experienced during tank construction at or below 18°F with day time temperatures between 41°F and 56°F (see Section 4.3.2). Impact occurrences could have occurred during cold temperatures that may have triggered fissures in the steel liner; however, the possibility seems much less than that which might have occurred during construction in other tank farms.

The T Farm tanks experienced warping of the bottom liner during construction of the tanks and all of the T Farm tank bottom liners required replacement (see Section 5.3.2). The July monthly report (HW-7-384) reported that all tanks passed X-ray test; however, there may have been quality issues that were not identified by X-ray testing.

5.8 TANK T-111 CONCLUSIONS

A tank T-111 liner leak may have penetrated the waterproof membrane at any location and followed different paths to the soil. However, the size of the 1973/1974 leak and 1995 to 2014 were apparently not large enough to be detected in the drywells around the tank. Therefore there is insufficient data to identify a leak location.

There are several liner leak cause conditions that were examined; however, no one individual condition stands out as the likely cause of the tank T-111 leak. Storage of 2C wastes would be a possible cause except the likely storage temperature of less than 100°F should not have caused a corrosion problem. There may have been anomalies in the bottom liner after replacement, and storage of 2C wastes may have increased the propensity for corrosion in a stressed liner.

There appears to be very little contribution to a leak cause from storage of waste, thermal conditions, tank design, or construction temperatures. The evidence that T Farm tank bottom liners required replacement causes concern with the quality of the replacement especially on any one tank. The tank T-111 leak could have been influenced by the T Farm tank bottom liner replacement effort. Some or all of the factors can act serially or together to contribute to tank liner failure.

APPENDIX A2

TANK T-111 GROSS GAMMA DRYWELL DATA

Table A2-1. Tank T-111 Drywell Radioactivity (K counts per minute) (April 1974 through September 1987) (SD-WM-TI-356)

50-11-05		50-11-07		50-11-08		50-11-10		50-11-11		
Drilled 2/28/1974		**Drilled 2/28/1975**		**Drilled 2/28/1974**		**Drilled 1/31/1975**		**Drilled 7/31/1979**		
Date	**Peak (K cpm)**	**Date**	**Peak (K cpm)**	**Date**	**Peak (K cpm)**	**Date**	**Peak (K cpm)**	**Date**	**Peak (K cpm)**	**Depth (ft)**
4/5/1974	< 15	Drywell 50-11-07 drilled February 28, 1975		4/5/1974	< 15.6	Drywell 50-11-10 drilled January 31, 1975		Drywell 50-11-11 drilled on July 31, 1979		
4/19/1974	< 15			4/19/1974	< 15					
8/9/1974	< 3			8/16/1974	< 3					
2/20/1975	< 3	5/2/1975	< 3	2/20/1975	< 3	4/2/1975	< 3			
7/25/1975	< 3	7/25/1975	< 3	7/25/1975	< 3	7/25/1975	< 3			
4/9/1976	< 3	4/9/1976	< 3	4/9/1976	< 3	4/9/1976	< 3			
10/22/1976	< 3	10/22/1976	< 3	10/22/1976	< 3	10/15/1976	< 3			
4/22/1977	< 3	4/22/1977	< 3	4/22/1977	< 3	4/29/1977	< 3			
10/14/1977	< 3	10/17/1977	< 3	10/14/1977	< 3	10/17/1977	< 3			
8/11/1978	< 3	8/11/1978	< 3	8/11/1978	< 3	8/11/1978	< 3			
8/7/1979	< 3	8/7/1979	< 3	8/8/1979	< 3	8/8/1979	< 3	7/26/1979	46.1	67
N/A[1]		N/A[1]		N/A[1]		N/A[1]		8/8/1979	48.0	65
N/A[1]		N/A[1]		N/A[1]		N/A[1]		2/5/1980	41.5	66
8/19/1980	< 3	8/19/1980	< 3	8/19/1980	< 3	8/19/1980	< 3	8/19/1980	22.3	67
8/11/1981	< 3	8/11/1981	< 3	8/11/1981	< 3	8/11/1981	< 3	8/11/1981	11.5	69
8/10/1982	< 3	8/13/1982	< 3	8/10/1982	< 3	8/10/1982	< 3	8/10/1982	5.2	71
8/23/1983	< 3	8/23/1983	< 3	8/23/1983	< 3	8/23/1983	< 3	8/23/1983	2.9	70
8/14/1984	< 3	8/14/1984	< 3	8/14/1984	< 3	8/14/1984	< 3	8/14/1984	2.3	70
7/31/1985	< 3	7/31/1985	< 3	7/18/1985	< 3	7/18/1985	< 3	7/23/1985	2.5	71
7/15/1986	< 3	7/15/1986	< 3	7/7/1986	< 3	7/7/1986	< 3	7/15/1986	2.0	73
9/29/1987	< 3	9/29/1987	< 3	9/22/1987	< 3	9/22/1987	< 3	9/29/1987	2.3	73

Note: [1]N/A: Data not available

Table A2-2. Tank T-111 Drywell Radioactivity (K counts per minute) (April 1974 through September 1987) (SD-WM-TI-356) (1 of 2 Sheets)

50-08-05		50-10-10		50-10-08		50-00-06		50-08-07		
Drilled 3/31/1974		Drilled 2/28/1974		Drilled 3/31/1975		Drilled 9/30/1944		Drilled 2/28/1974		
Date	Peak (K cpm)	Date	Peak (K cpm)	Date	Peak (K cpm)	Date	Peak (K cpm)	Date	Peak (K cpm)	Depth (ft)
Drywell 50-08-05 drilled March 31, 1974		Drywell 50-10-10 drilled February 28, 1974		Drywell 50-10-08 drilled March 31, 1975		9/21/1973	< 10.8	N/A[1]		
						12/22/1973	< 12	N/A[1]		
4/5/1974	16.2	4/5/1974	< 3			4/19/1974	< 12	4/5/1974	< 15	N/A[1]
4/19/1974	12.0	4/19/1974	< 3			N/A[1]		N/A[1]		
N/A[1]		6/1/1974	< 3			N/A[1]		6/1/1974	< 12	N/A[1]
8/9/1974	6.0	8/16/1974	< 3			8/9/1974	< 3	8/9/1974	< 6	N/A[1]
1/31/1975	< 3	2/20/1975	< 3	4/18/1975	< 3	1/22/1975	< 3	1/31/1975	< 3	N/A[1]
7/25/1975	< 3	7/25/1975	< 3	7/25/1975	< 3	4/18/1975	< 3	7/25/1975	< 3	N/A[1]
4/9/1976	< 3	4/9/1976	< 3	4/16/1976	< 3	N/A[1]		4/9/1976	< 3	N/A[1]
10/29/1976	< 3	10/22/1976	< 3	10/22/1976	< 3	N/A[1]		10/22/1976	< 3	N/A[1]
4/29/1977	< 3	4/22/1977	< 3	4/22/1977	< 3	N/A[1]		4/22/1977	< 3	N/A[1]
10/14/1977	< 3	10/14/1977	< 3	10/14/1977	< 3	N/A[1]		10/14/1977	< 3	N/A[1]
8/11/1978	< 3	8/11/1978	< 3	8/11/1978	< 3	N/A[1]		1/6/1978	3.2	67.0
N/A[1]		N/A[1]		N/A[1]		N/A[1]		5/5/1978	8.9	67.0
									3.2	80.0
N/A[1]		N/A[1]		N/A[1]		N/A[1]		12/13/1978	35.8	67.0
									5.3	81.0
8/8/1979	< 3	8/8/1979	< 3	8/8/1979	< 3	N/A[1]		4/3/1979	47.6	68.0
									6.7	81.0
N/A[1]		N/A[1]		N/A[1]		N/A[1]		8/8/1979	48.5	66.0
									6.7	79.0
8/19/1980	< 3	8/19/1980	< 3	8/19/1980	< 3	N/A[1]		8/5/1980	40.2	68.0
									9.7	81
N/A[1]		N/A[1]		N/A[1]		N/A[1]		4/14/1981	54.5	70.0
									11.4	82.0

Table A2-2. Tank T-111 Drywell Radioactivity (K counts per minute) (September 1973 through September 1987) (SD-WM-TI-356) (2 of 2 Sheets)

50-08-05		50-10-10		50-10-08		50-00-06		50-08-07		
Date	Peak (K cpm)	Date	Peak (K cpm)	Date	Peak (K cpm)	Date	Peak (K cpm)	Date	Peak (K cpm)	Depth (ft)
8/11/1981	< 3	8/11/1981	< 3	8/11/1981	< 3	N/A[1]		8/11/1981	36.1	71.0
									12.0	80.0
8/10/1982	< 3	8/10/1982	< 3	8/10/1982	< 3	N/A[1]		N/A[1]		
8/23/1983	< 3	8/17/1983	< 3	8/17/1983	< 3	N/A[1]		6/15/1983	16.8	71.0
									11.1	81.0
8/14/1984	< 3	8/14/1984	< 3	8/14/1984	< 3	N/A[1]		6/13/1984	10.7	71.0
									7.8	82.0
7/18/1985	< 3	7/31/1985	< 3	7/31/1985	< 3	N/A[1]		6/18/1985	10.3	72.0
									5.4	81.0
7/7/1986	< 3	7/15/1986	< 3	7/15/1986	< 3	N/A[1]		6/10/1986	6.6	73.0
									3.3	82.0
9/22/1987	< 3	9/22/1987	< 3	9/22/1987	< 3	N/A[1]		6/24/1987	5.0	73.0
									2.8	82.0

Note: [1]N/A: Data not available

6.0 CONCLUSIONS

Liner leaks probably occurred at or near the base and possible sidewall of tank T-106. The location of the tank T-111 leak could not be determined from the data; however, the T Farm bottom liners were required to be replaced therefore the bottom liner may be a possible leak location.

There are several liner leak cause conditions that were examined for tanks T-106 and T-111. These include tank design, construction conditions and activities, thermal waste storage conditions, and chemistry-corrosion. No one single condition stood out as the likely cause of either of the T Farm tank leaks. The leaks may have been influenced by the T Farm tank bottom liner replacement with some or all of the other factors acting serially or together to contribute to tank failure.

Tanks T-106 and T-111 experienced liner failures that were detected by a liquid level decreases and in the case of tank T-106 subsequently confirmed by the detection of drywell radioactivity. The tank T-111 small liquid level decreases both in 1974 and after 1994 were apparently not large enough to be convincingly detected by drywell radioactivity.

Basic information on the leaking T Farm tanks and the T Farm sound tanks are listed separately in Table 6-1 and Table 6-2. The information was reviewed to identify any differences between leaking and sound tanks related to liner failure. Both the leaking and sound tanks contained 2C wastes under similar conditions; however, the waste temperature below 100°F would have little effect on corrosion. No single parameter seems to stand out as a possible difference between leaking and sound tanks.

Table 6-1. T Farm Leaking Tanks

Leaking Tank	Waste Details		Leak Status		1C or 2C Waste Storage		Thermal Conditions
	First Filled	Major Waste Type	Leak Detected	Indication of leak	Stored 1C/2C Waste	1C/2C Only Storage Length	Estimated Max Temp
T-106	June 1947	1C, 2C, REDOX CW, IX	April 20, 1973	LL decrease, drywell	1C, 2C	~ 8 years[1]	< 100°F
T-111	October 1945	2C, 224	April 1974	LL decrease	2C	~ 7 years	< 100°F

Notes: Waste Types: 1C: first cycle decontamination waste; 2C: second cycle decontamination waste; REDOX CW: REDOX coating waste; IX: ion exchange waste; 224: 224 building lanthanum fluoride waste

1. Stored 1C/REDOX CW for approximately 13 years in addition to the 8 years of 1C and 2C storage

Table 6-2. T Farm Sound Tanks

Sound Tank	Waste Details		Leak Status		1C or 2C Waste Storage[4]		Thermal Conditions
	First Filled[1]	Major Waste Type[4]	Leak Integrity Classification[2]	Basis for Formal Leak Assessment	Stored 1C/2C Waste	1C/2C Only Storage Length	Estimated Max Temp[3]
T-101	December 1944	MW, TBP, CW, BL, IX , EB, R, DW, BNW, Evap., 224, NCPLX	"Assumed leaker" but TFC-ENG-CHEM-D-42	Possible spare inlet overflow	-	-	103°F
T-102	September 1945	MW, CW, BL, IX, EB, R	"Sound" but TFC-ENG-CHEM-D-42	Additional characterization needed	-	-	94°F
T-103	November 1945	MW, CW, BL, IX, EB, R	"Assumed leaker" but TFC-ENG-CHEM-D-42	Inlet line leak or sidewall leak	-	-	96°F
T-104	March 1946	1C	Sound	-	1C	~ 24 years	90°F
T-105	July 1946	2C, 1C, CW, HLO, DW, BL, IX	Sound	-	1C, 2C	~ 9 years	93°F
T-107	February 1945	1C, TBP, CW, BL, IX, Evap., NCPLX	"Assumed leaker" but TFC-ENG-CHEM-D-42	Additional characterization near spare inlets needed	1C	~ 8 years	114°F
T-108	September 1945	1C, TBP, EB, HLO, BNW, BL, IX,	"Assumed leaker" but TFC-ENG-CHEM-D-42	Additional characterization needed	1C	~ 8 years	90°F
T-109	December 1945	1C, TBP, EB, BL, IX, BNW	"Assumed leaker" but TFC-ENG-CHEM-D-42	Possible migration from T-106 leak	1C	~ 7 years	91°F
T-110	December 1944	2C, 224	Sound	-	2C	~ 7 years	91°F
T-112	January 1946	2C, 224, DW, CW, BL, IX, Evap., NCPLX	Sound	-	2C	~ 5 years	87°F

Notes: Waste Types: TBP: Tri-butyl phosphate waste; 1C: First-cycle decontamination waste; CW: coating waste; MW: metal waste; EB: Evaporator bottoms; R: REDOX HLW; Evap: Evaporator feed (post 1976); NCPLX: Non-Complexed waste; DW: decontamination waste; BL: B Plant low-level waste; IX: ion exchange waste; 224: 224 building lanthanum fluoride waste; BNW: Laboratory waste from Pacific Northwest Laboratory; HLO: Laboratory waste from 300 Area

1. Reference: Tank Waste Information Network System
2. Reference: RPP-RPT-55084, Rev. 0, *Hanford 241-T Farm Leak Inventory Assessment Report*.
3. Reference: WHC-SD-WM-TI-591, Rev. 0, *Maximum Surface Level and Temperature Histories for Hanford Waste Tank*
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APPENDIX A

MEETING MINUTES

January 7, 2014

March 11, 2014

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MEETING SUMMARY

From:	C. L. Girardot *Crystal Girardot*
Phone:	376-0528
Location:	Ecology Office
Date:	January 7, 2014
Subject:	Tank Farm Leak Integrity Assessments
To:	Distribution

Jim Alzheimer, ECOLOGY*
Mike Barnes, ECOLOGY
Joe Caggiano, ECOLOGY*
Alan Carlson, WRPS*
Jim Field, WRPS*
Les Fort, WRPS*
*Attendees

Crystal Girardot, WRPS*
Don Harlow, WRPS
Jeremy Johnson, ORP*
Ted Venetz, WRPS*
Dennis Washenfelder, WRPS

PURPOSE:

The purpose of this meeting was to discuss elements that will become part of the Tank T-106 Leak Causes and Locations report. Handed out to the meeting attendees were draft copies of the tank T-106 report, the T-106 Summary sheet, and Tank Leak Cause matrix table.

Tank T-106 Leak Causes and Locations Status

The results from the tank T-106 analysis were discussed. Tank T-106 was first suspected of leaking in May/June 1973 based on a drop in liquid level coupled with radioactivity detected in drywell 50-08-11. It was later determined that the tank started leaking around April 20, 1973. The tank was declared a confirmed leaker on June 8, 1973 and it was estimated that approximately 115 kgal leaked from tank T-106 over a period of approximately two months (prior to having the liquid portion of the waste removed).

No temperature data is available for tank T-106 until 1975. Tank T-106 was put into service in June 1947. Earlier temperatures were estimated, based on the stored waste type, to be less than 100°F. Tank T-106 was the last tank in the three tank cascade series and stored mostly 1C and 2C wastes (relatively low in fission products). Waste types 1C and 2C do not meet current DST specifications for waste chemistry and therefore could have increased the propensity for corrosion in tank T-106; however, this was likely minimized because the waste storage temperatures were likely low.

There were only two drywells around tank T-106 when the tank was first suspected of leaking (drywells 50-08-11 and 50-00-10), and only drywell 50-08-11 indicated radioactivity. Seven drywells were drilled in July 1973, after the tank leaked, and all reported radioactivity from the northeast to the southwest portion of the tank centered on the southeast quadrant. One isolated drywell indicated radioactivity in the northwest portion of the tank. Most of the subsequent drywells drilled between 1975 and 1993 and two direct pushes (installed in 2003) confirmed the highest radioactivity measurements were located at the southeast quadrant near the bottom of the tank except for three drywells with some peaks reported between 29 and 35-ft BGS, which possibly indicated a sidewall leak. There is some indication from the liquid level data of a possible sidewall leak in the 94 to 139-in range (measured from the bottom sidewall), corresponding to ~28 to 32-ft BGS.

It was concluded that tank T-106 liner did fail and waste leaked at least at one location in the southeast portion of the tank at or near the tank base with the possibility of a sidewall leak. The cause of the liner failure was established as indeterminate, but may have been the result of the quality of the replaced T Farm bottom liners coupled with one or more of the conditions examined (construction temperatures, thermal conditions, and chemistry corrosion).

A tank leak cause matrix table was reviewed with thermal conditions, waste chemistry, and possible T Farm bottom liner replacement being probable contributors to the tank T-106 leak. However, there does not appear to be a dominant waste tank construction or waste storage condition that would be the cause of the tank T-106 leak. There was extensive discussion and speculation that the construction of the tank liner may have been the primary cause of the T-106 liner leak; however, no historical documentation regarding tank construction issues were recovered at the time except for the sentences in HW-7-103, *Hanford Engineering Works Monthly Report April 1944*, p. 14, stating,

"The extensive buckling of 75' liner bottoms at Bldg. 241-T received considerable attention, and it was decided that all twelve of the bottoms would require replacement. The subcontractor is proceeding with this work."

Subsequently the May, June, and July Hanford engineering Works Monthly Reports were located which continued to indicate the bottom liners were replaced and that all welding was complete and passed X-ray tests. The number of concurrent construction activities in T Farm during the bottom liner replacement continues to pose the possibility of quality issues that may not have been identified by X-ray testing.

It was suggested to distinguish in both the report and the tank leak cause matrix table the differences between liner bulging/ripples from construction and liner bottom bulging due to operational factors. It was also suggested that an appendix might be added to these reports to document any relevant oral history related to tank construction issues, such as replacement of T Farm liners, and material quality. The next meeting will discuss tank T-111 and the general T Farm commonalities of the Leak Causes and Locations report for T Farm.

ACTIONS:

1. All: Review the January 7, 2014 meeting summary from tank T-106 and provide comments by January 21, 2014.
   Status: Completed.
2. All: Provide comments for the draft report on Leak Causes and Locations for tank T-106 by January 21, 2014.
   Status: Completed.

NEXT MEETING:

Review Tank T-111 Leak Location and Cause report and general T Farm commonalities.

Date:	March 11, 2014
Time:	3:00pm
Location:	Ecology Room 3A

Attachment 1

Joe Caggiano REVIEW COMMENTS –RPP-RPT-54916, Rev. 0

T-106 Report

1. Pg. 4-8, Fig 4-3. Most of the lettering on this figure is illegible on the copy I have. Can this figure be improved? Please check.
   a. A clearer copy of this figure was found and inserted into the document.
2. If possible, it would be nice to know the amplitude and height of the “ripples” that were observed during tank construction that led to the call for replacement of the tank bottoms. If that information is available, then it would be useful to know how the quality of the rippled steel is degraded, if at all, and how that might affect the strength of the affected steel. Intuitively, this seems as if it could be a weak point that would foster corrosion or other mechanisms of failure.
   a. The amplitude and height of the ripples in T Farm prior to replacement cannot be found. There are photographs that show these ripples during T Farm construction that will be in the report. We have added in information about ripples and how they differ from liner bulging into the general T Farm background of the report.
3. Pg. 4-32, Sect. 4.6.4. The T-106 leak likely started in April, but a release wasn’t confirmed until gamma activity showed up in drywell 50-08-11 which is located ~40 ft. from the drywell. Spectral gamma logs indicate that the gamma activity was due primarily to Eu and Co isotopes. Notably absent is Cs-137 which would likely have sorbed closer to the point of egress. The actual date of first release to the soil likely occurred in late April or May. The June 4 date of a leak is the declaration of the leak. Maybe a timeline for this leak would be a good illustration.
   a. We will make sure this information is in the timeline figure (Figure 4-2 on page 4-6).
4. Pg. 4-35, top of page. Some clarification should be made about construction conditions compared with construction activities. “Construction conditions” has been used in the past to indicate climatic/weather conditions at the time of construction and that’s what is meant in the “blame button” tables. The rippling of the bottoms in T Farm tanks, which may or may not have been replaced, seems more a result of poor construction practices regarding the welding of the steel plates. Somehow, this distinction should be made.
   a. We will differentiate between construction conditions and construction activities for Sections 4.3.2. and 4.7.5. We will break Section 4.3.2. into two subsections (“Construction Conditions” and “Construction Activities”) and call the overall section Tank Construction. Then Section 4.7.5. will be titled section “Tank Construction” and summarize the information in 4.3.2.

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MEETING SUMMARY

From: C. L. Girardot *Crystal Girardot*
Phone: 376-0528
Location: Ecology Office
Date: March 11, 2014
Subject: Tank Farm Leak Integrity Assessments

To: Distribution

Jim Alzheimer, ECOLOGY*
Dan Baide, WRPS*
Mike Barnes, ECOLOGY
Joe Caggiano, ECOLOGY*
Alan Carlson, WRPS
Jim Field, WRPS
Les Fort, WRPS*
Crystal Girardot, WRPS*
Don Harlow, WRPS*
Jeremy Johnson, ORP*
Ted Venetz, WRPS*
Dennis Washenfelder, WRPS*

*Attended Meeting

PURPOSE:

The purpose of this meeting was to discuss portions of the Tank T-111 Leak Causes and Locations report. Handed out to those who attended the meeting were draft copies of the T Farm report which includes tanks T-106 and T-111, the T-111 Summary sheet, and Tank Leak Cause matrix table.

Tank T-111 Leak Causes and Locations Status

The results from the tank T-111 leak loss analysis were discussed. Tank T-111 was first suspected of leaking in April 1974 based on a 0.3-inch drop in liquid level over the preceding nine months which was in the level of uncertainty. Most of the supernatant was transferred out of the tank beginning April 14, 1974. Tank T-111 was declared an assumed leaker and was placed on the inactive list in 1976. Saltwell pumping began in 1976 and continued through 1978. Shortly after pumping, the waste level began to rise slowly from 1979 until 1993 likely as a result of water intrusion. Further leakage was observed between 1995 and January 2014 with a calculated leak volume of ~2,600 gal.

Tank T-111 was put into service in the 4th quarter of 1945. Tank T-111 temperature ranged between 93°F to 88°F between October 1945 and February 1946. No other temperature data is available for tank T-111 until 1976. Early temperatures were also estimated, based on the stored waste type, to be less than 100°F. Tank T-111 was the second tank in the three tank cascade series and stored mostly 2C and 224 wastes (relatively low in fission products). Waste type 2C does not meet current DST specifications for waste chemistry and therefore could have increased the propensity for corrosion in tank T-111; however, this was likely minimized because of the low waste storage temperatures. Waste type 224 should not be a concern for pitting and/or stress corrosion cracking (SCC).There are ten drywells located around tank T-111, and four were installed after the tank was first suspected of leaking in 1974. None of the ten tank T-111 drywells show any indication of a tank waste release through re-logging in 1998. Drywell 50-08-07 was re-logged in 2008 which did not show any indication of a change since the 1998 logging.

From the drywell information it was concluded that the size of the 1973/1974 and 1995 to 1998 waste level decreases representing a waste release were not significant enough to be detected in the drywells around the tank. Therefore, there is insufficient data to identify a leak location. The cause of the liner failure is also indeterminate, but surmised to be the result of the replaced T Farm bottom liner quality coupled with one or more of the conditions examined (construction temperatures, thermal conditions, and chemistry corrosion).

A tank leak cause matrix table was addressed containing thermal conditions, waste chemistry, and T Farm bottom liner replacement as possible contributors to the tank T-111 leak. With the information available there was not a dominant waste tank construction or waste storage condition identified as the cause of the tank T-111 leak.

Discussed was the recent tank T-111 in-tank visual inspection and the appearance of more sidewall corrosion compared to other single-shell tanks inspected. Also commented was the possibility that gas retention/release could account for the observed liquid level increases and decreases. These comments are addressed in RPP-RPT-54964, Rev. 2. Relevant information from RPP-RPT-54964, Rev. 2, will be added to the T Farm Leak Causes and Locations report.

The next meeting will discuss tank TX-107 Leak Causes and Locations report.

ACTIONS:

3. All: Review the March 11, 2014 tank T-111 meeting summary and provide comments by March 25, 2014.
   Status: Completed.
4. All: Provide comments on the draft report on Leak Causes and Locations for T Farm by March 25, 2014.
   Status: Completed, see Attachment 1.

<u>NEXT MEETING:</u>

Review Tank TX-107 Leak Location and Cause report.

Date:	Tuesday, April 15, 2014
Time:	3:00-4:30 pm
Location:	Ecology Room 3A

ATTACHMENT 1: REVIEW COMMENTS with RESPONSES
J. A. Caggiano March 18, 2014

T FARM DRAFT REPORT COMMENTS
RPP-RPT-54916, Rev. 0 (Leak Locations and Causes for the 241-T Tank Farm)

GENERAL COMMENTS

1. The B, C, T, and U Tank Farms were built during the Manhattan Project which was intended to last 5-10 years. At the time of construction, no one anticipated the Cold War which continued for decades. These tanks were built in war time and to different design and construction standards than are currently used for such structures. Materials were scarce during WW II, so the quality of carbon steel was likely different than current standards. Imposing today's design and construction standards on these tanks may be useful, but serves no meaningful purpose. Statements such as these are needed for the general public so they understand the nature of the times and haste for getting these tanks constructed and operating. The accelerated construction schedule may also account for the lack of documentation that is now available as record copy to document the events during construction. The high-level security surrounding the Hanford Site as well as more lax procedural requirements for operating records may also contribute to the scarcity of documentation. Historical perspective is advised.

   Response: Added a paragraph to the Construction Activities portion of Section 3.1.2. This information will also be addressed in the Summary Document.

2. In all these tank-leak cause reports, something should be said about the limitations of the data one has available. For example, quarterly LL readings as opposed to daily records, uncertainty of the LL measuring device which could differ at different times in different farms, inability to accurately measure LL in boiling tanks or tanks undergoing transfer, uncertainty in the mass balance calculations during waste transfer between tanks. All these, and perhaps more, limit what one can understand about various measurements during tank farm operational history and how they impact any leak cause analyses.

   Response: The above information is contained in Section 3.2.1, so far as it affects the T Farm leaking tanks in this document. Document RPP-RPT-54964, *Evaluation of Tank 241-T-111 Level Data and In-Tank Video Inspection* which deals with the actual leak quantity addresses liquid level determinations as well as RPP-RPT-55084, *Hanford 241-T Farm Leak Inventory Assessment Report.* The information will be addressed in the summary document.

3. It seems as if many of the procedures controlling parameters of waste and tank storage were developed from observation and experience years to decades after the onset of storage of waste in these tanks. The initial history of tank operations and storage were much less controlled than in later years. The entire storage history was a cumulative assortment of "lessons learned" that were made into procedures over a period of time. Might want to check with Michelle Gerber or other site historians who may have some knowledge of this.

Response: The observation appears to be valid and was probably caused in part as a response to the ever increasing separation plants process rates and process improvements resulting in increasing waste volumes and concentrations as well as the affect of major process changes in the separations plants and tank farm. These all combined to give the impression that tank farm was in a continual catch up mode and improving operating documents from observations and experience. The response will be developed further and be addressed in the Summary Document.

4. The limitations of drywells should be discussed somewhere; i.e., they had to be steel cased to keep the hole open, thus only gamma-emitting radionuclides could be detected as only the gamma energy would penetrate the steel casing to gamma detectors lowered within the hole. Thus, alpha- and beta-emitting radiation could not be detected, nor could any of the hazardous chemicals that would have accompanied a leak. Cs-137, the principal isotope detected in gamma logging, is not a good surrogate for other isotopes and mobile fractions of waste in soil, as it generally sorbs relatively close to the source—unlike other constituents. Furthermore, the gamma detectors employed in boreholes would interrogate only about a 12 inch radius from the borehole, so a leak would have to pass within this distance from a drywell to be detected. Most waste streams contained some level of Cs-137 which is easily detected. Initially, only gross gamma probes were utilized; i.e., detected only gamma energy from all gamma-emitting isotopes. Later, in the 1990s, spectral gamma logging tools were employed that enabled the detection of a gamma spectrum which could then be used to identify specific isotopes at different energy levels.

   Response: Comments on previous leak locations and causes documents have been received on the design, operation, interpretation, and changes to drywell monitoring as indicated above. A portion of the summary document will address this drywell subject matter.

5. When there is both intrusion and possible release from a single tank (e.g., T-111) how is one assured that these rates of addition and release from a tank are nearly in balance such that one really has an adequate measure of waste that may be being released to soil? This needs to be addressed. Please add.

   Response: The Leak Locations and Causes reports deal with the set of leaking tanks identified in the tank farm leak assessment documents per RPP-RPT-32681. RPP-RPT-32681 provides estimates of leak volume. The Tank T-111 intrusion which has been analyzed indicating further leakage in RPP-RPT-54964 would require a change in the T Farm leak assessment document and ultimately result in a change to HNF-EP-0182, *Waste Tank Summary*. Intrusions can mask leaks or portions of leaks and a general discussion will be added to the summary report on this subject.

6. With few exceptions (e.g., T-106, BX-102), the available data and its quality and the absence of detail in past reports do not allow one to make a convincing case for the condition of SSTs; i.e., whether they have released waste or not. DOE admits that they can't prove soundness of any of the tanks, but doesn't admit to leaks (a position I find to be contradictory, or at least illogical). I think that this uncertainty should at least be mentioned in introductory material so the reader understands that the designation "sound"

or “assumed leaker” has considerable uncertainty.

Response: The waste status summary report, HNF-EP-0182, contains the official definitions of waste tank status. The tank farm leak assessment reports address the status of individual tanks and provide recommendations for changes HNF-EP-0182 as information becomes available. Uncertainties will only be addressed in Leak Cause and Location reports on an individual tank basis which may prompt updates to the affected tank farm leak assessment report.

SPECIFIC COMMENTS

1. Executive Summary, para 2. A statement should be added to this paragraph to the effect that re-assessment using the TFC-ENG-CHEM-D-42 process has been requested because the data/information about possible releases from these 10 tanks is equivocal; they may have released waste to the soil. The “sound” designation is questionable because there isn’t clear, unequivocal evidence of either integrity or a release. Please add.

   Response: Tanks that may have released waste to the soil are not necessarily leaking because of a liner failure which is one of the main reasons to re-assess per TFC-ENG-CHEM-D-42. Document readers need to pursue references for further explanation as opposed to including more information at the risk of future changes causing disconnects between documents. The tanks designated as sound in the tank farm leak assessment reports fall under the definition in the waste status summary report all of which is reviewed with the ORP and State of Washington, Department of Ecology.

2. ES, para 4. To state that the T-111 “leaks” could not be detected in drywells is a stretch. The recent announcement of a release in the last 2 years indicated that this release hadn’t been detected in the drywells; but most of the drywells haven’t been logged since 1998. A few were logged in 2006 or 2007 as part of the baseline logging for the T-106 interim surface barrier. Please re-word this statement to more clearly reflect reality.

   Response: Added clarification on drywell re-logging and post 1994 liquid level decrease.

3. ES, para 5. I think it would be beneficial to distinguish the point of egress from the tank from the point of release to the soil. A slow leak on the tank wall may have “dribbled” down the side of the tank until it reached the footing which then directed outward to the soil. But it also may be that in some cases, the point of waste egress is very close to the point of release from the tank. Please clarify.

   Response: The details of how a leak may travel to the point of detection is covered in Section 3.3.

4. ES, para 6. It appears as if two time intervals are being described; the first, when the liner bottoms were replaced because of buckling during construction, and the second, buckling that was noted after liner replacement, perhaps during leak testing but before(?) waste was added to the tank. Please clarify.

Response: Added clarification of the subsequent repair of at least one of the replaced bottom liners that was identified.

5. ES, last para. It would probably be fair to state that many factors, acting synergistically, contributed to tank failure, including some factors during construction and operations that have not been identified from the available records. Please consider because this is likely the case for many tanks; no one knows how close to failure other tanks have come without failure or evidence of a release.

   Response: Added some additional information per the comment.

6. Pg. 1-1, para 1. The Hanlon reports indicate 67 assumed leaking tanks; this study looks at only 25 "leaking" tanks. This difference needs to be explained clearly, because DOE will get heat from various parties if there is an appearance of a deliberate effort to reduce the number of leaking tanks. Please clarify.

   Response: The tank farm leak assessment documents deal with the differences between what is documented per the RPP-RPT-32681 documents and HNF-EP-0182. The summary document will address origin of the 25 leaking tanks and the relationship to 67 assumed leakers in HNF-EP-0182.

7. Pg. 1-1, para 4. I would add two categories to this list; namely, construction activities—especially as it relates to the replacement of tank bottoms during construction. The second would be tank chemistry, particularly as it relates to corrosion potential. Please consider.

   Response: Added the categories.

8. Pg. 2-1. The 200 series are not mentioned here, despite the fact that they are shown on Fig.3-2, a construction photo of T Farm. Please make consistent.

   Response: Added a clarifying statement to the photo, page 3-4.

9. Pg. 3-5, Construction Activities. It would be useful to note that the reason(s) for replacing tank bottoms at T Farm (and other farms?) are not documented. This should be noted. Please add.

   Response: The April monthly report HW-7-103 indicated that buckling of the liner bottoms required replacement, Section 3.1.2 Construction Activities.

10. Pg. 3-11, Sect. 3.2.4 is entitled chemistry, but talks mostly about corrosion. Maybe it should be titled "Chemistry and Corrosion Conditions" or something like that. Chemistry to me implies properties of the waste; corrosion implies degradation of the steel of which the tanks are composed. Consider an alternate title for this section.

    Response: Section 3.2.4 added "Corrosion" which is consistent with the remainder of the document as well as the previously issued Leak Causes and Locations documents.

11. Pg. 4-13, Drywell 50-06-02, para 2. Sentence one needs clarification; Cs-137, Co-60, Eu-154, Eu-152, U-238 and U-235 were the only man-made gamma-emitting radionuclides detected in this drywell. Please correct here and elsewhere when discussing drywell logging results.

    Response: Added gamma and beta qualifier as appropriate.

12. Sect. 4.5.1. One of these drywells might be a good place to illustrate the difference between a gross gamma detector and the spectral gamma detectors. The drywells in the SE quadrant are actually a composite of several gamma-emitting radionuclides, something not detectable in the gross gamma historical logs. Some of the early gross gamma logs likely show Ru-106 which would have decayed to ground state before the spectral gamma logs were run. The suite of drywells also demonstrates the area of the likely source and spread from there around (and likely under) the tank.

    Response: Added a comment on Ru-106 and SGLS characterization in Section 3.3.2.

13. Pg. 4-29, Fig. 4-19. With only one drywell (50-08-11) shown on the map, what information was used to "map" this plume and how certain is it? If this is the only information, I suggest this be dotted or in somehow indicated that this is an estimated approximation of what the plume may have looked like. Once on paper, some people will take this as absolute, and I think you are only trying to show where the leak likely initiated. Please consider.

    Response: Added an explanation to Figure 4-19 footnote.

14. Pg. 4-30, Fig. 4-20. Similar to comment 13, if the radius of interrogation is ~1 ft. from a drywell and this is the only information you have, this seems like a "generous" plume map. Please adjust or indicate that this is just a schematic and not a true depiction of areal extent.

    Response: Adjusted the plume size.

15. Pg. 5-26,27 Sect. 5.6./5.7 Although T-111 is labeled as an assumed leaker, the evidence supporting a release is equivocal. There may have been some small releases, but there may be a cycle of gas buildup and release over a cycle of several years that could account for LL changes. Intrusion further masks the situation in this tank. The relatively rapid decline in LL over the past few years is now considered evidence for a release, but if it is a release, it is relatively small and, to date, not detected in the surrounding soil. Some qualification may be needed, because this tank is very different from its near neighbor, T-106. Please consider. Because the evidence of a release is equivocal, it becomes even more of a stretch to speculate on possible leak mechanisms/contributing factors when it is not certain that the tank has actually had any significant release.

    Response: RPP-RPT-54964 provides a review and analysis of the known factors impacting liquid level. The document is referenced in Section 5.4.1. Also as mentioned in Specific Comment #2. The tank T-111 drywells have not been logged for some time and may now be picking up radionuclide detection of the leak if they were logged.

APPENDIX B

T FARM PHOTOGRAPHS

P-1421 FEBRUARY 10, 1944
P-1697 MARCH 6, 1944
P-2130 APRIL 4, 1944
P-2373 APRIL 19, 1944
P-2569 MAY 3, 1944
P-2760 MAY 18, 1944
P-3036 JUNE 5, 1944
P-3495 JUNE 22, 1944

**Figure B-1. T Farm Initial Tank Liner Construction
February 10, 1944 (P-1421)**

Tank T-112 identified for reference

**Figure B-2. All T Farm 100 Series Tank Bottom Liner and Knuckles Fabricated
March 6, 1944 (P-1697)**

Tank T-112 identified for reference

Figure B-3. Start of Bottom Liner Replacement - Tank T-112
Tank Lowered and Bottom Liner Removed, Knuckle in Place
April 4, 1944 (P-2130)

Tank T-112 identified

Figure B-4. Tank T-112. Started Welding Replacement Bottom Liner, Two Knuckle Plates Positioned. Tank T-109 Lowered and Bottom Liner Removed, Knuckle to be Removed?
April 19, 1944 (P-2373)

Tank T-112 identified for reference

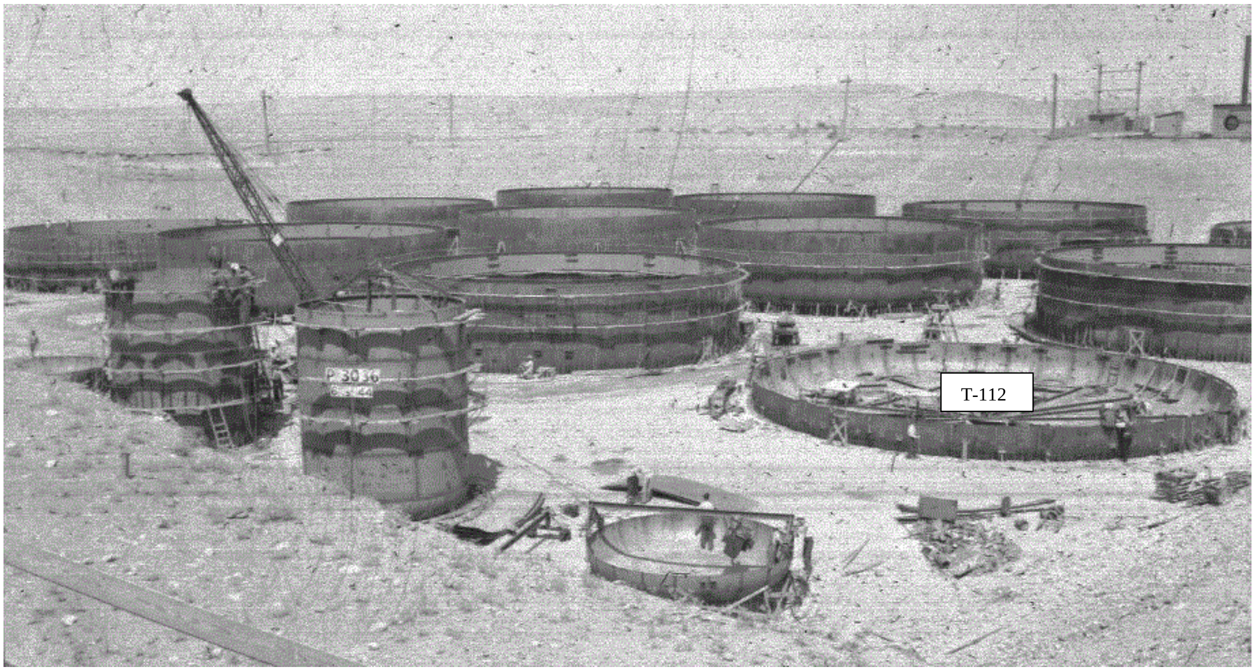
Figure B-5. Tank T-112 Bottom Liner and Knuckle Replaced Several Tanks Lowered with Bottom Liners Removed, Knuckles in Place May 3, 1944 (P-2569)

Tank T-112 identified for reference

Figure B-6. T Farm Bottom Liner Repairs in Place Eight Tanks with at Least One Tier of Sidewalls in Place May 18, 1944 (P-2760)

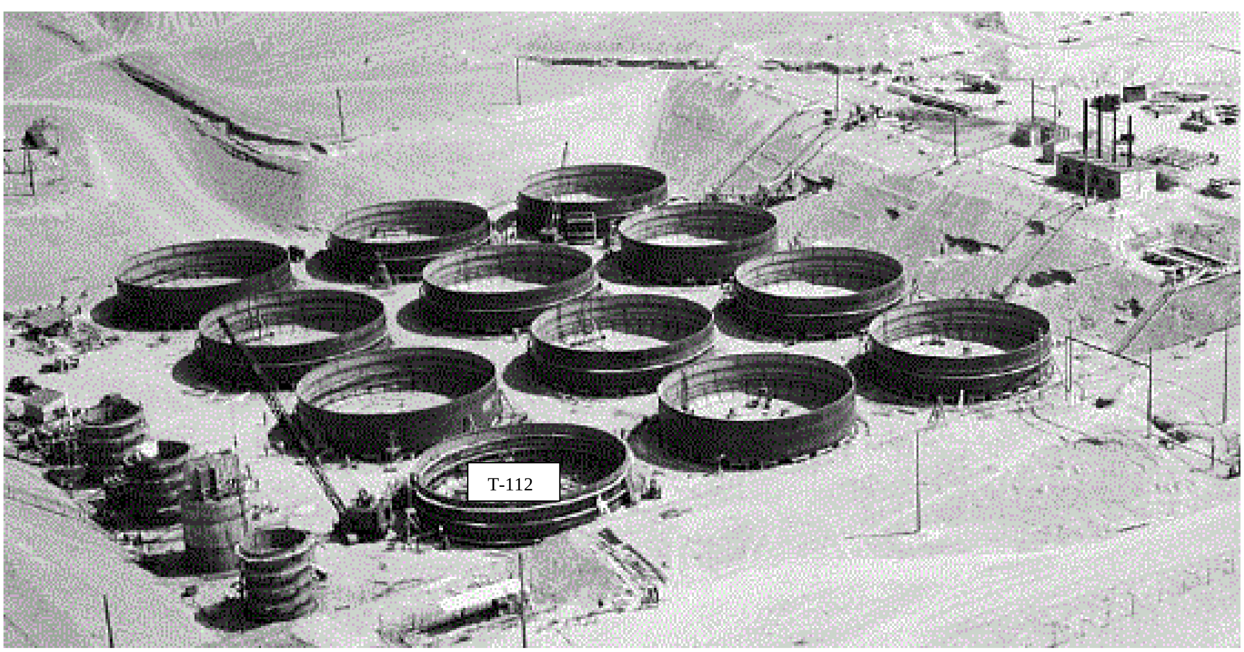
Tank T-112 identified for reference

Figure B-7. T Farm Bottom Liner Repairs Complete Eleven Tanks with Most Sidewalls in Place June 5, 1944 (P-3036)



Tank T-112 identified for reference

Figure B-8. T Farm Tank Bottom Liner Replacement/Repair Complete June 22, 1944 (P-3495)



Tank T-112 identified for reference. Tank T-112 sidewalls being installed but tank was lowered before June 5, 1944, indicating bottom liner replacement was complete before that date. Other tanks appear to be lowered onto concrete pads indicating no further work on replacement bottom liners.

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