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Data Quality Objectives for Single-Shell Tank Sidewall Coring Project

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Abstract: This DQO document describes the decision process to determine whether to core a SST and to choose a tank and contingency tanks for sidewall coring. The decision process included an evaluation of the expert panel recommendation to facilitate the tank selection. Concrete properties were examined, as well as methods to determine the concrete properties. A market survey of concrete testing laboratories was reviewed.

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DATA QUALITY OBJECTIVES FOR SINGLE-SHELL TANK SIDEWALL CORING PROJECT

May 2011

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EXECUTIVE SUMMARY

Tri-Party Agreement (TPA) Interim Milestone, M-045-91B, requires the Department of Energy Office of River Protection (DOE-ORP) to implement the data quality objectives (DQO) process, in consultation with the Washington State Department of Ecology (Ecology) to determine whether to core a single-shell tank (SST) sidewall for the purpose of determining concrete properties and to determine which tank, if any, would be cored.

Sidewall coring was a recommendation put forth by the expert panel assembled to provide Washington River Protection Solutions, LLC (WRPS) with recommendations to support the development of an enhanced Single-Shell Tank Integrity project (SSTIP). The expert panel recommended collecting a sidewall core from a tank that had been operated at high temperatures for comparison to the concrete properties used in the structural Analysis of Record (AOR) also recommended by the panel.

This DQO describes the decision process to determine whether to core a SST and to choose a tank and contingency tanks for sidewall coring. The decision process included an evaluation of the expert panel recommendation to facilitate the tank selection. Concrete properties were examined, as well as methods to determine the concrete properties. A market survey of concrete testing laboratories was reviewed.

While sampling design is normally the product of a DQO, two other key decisions were made as a result of the DQO process. The first was the decision to proceed with coring a single tank that has been exposed to high heat and has not previously leaked. The second decision was the choice of the tank to be cored, along with two contingency tanks. Tank 241-A-106 is the best choice for sidewall coring based on heat exposure and risk factors such as accessibility to the tank, interferences from retrieval, remaining waste volume, and expected soil contamination around the tank.

Two contingency tanks were chosen. Tank 241-A-101 is the second choice, and tank 241-SX-101 is the third. Both tanks have a similar thermal history. However, tank 241-SX-101 is more constrained from buried infrastructure and interferences. More extensive surface, near surface, and subsurface contamination is expected in 241-SX farm. These risks indicate, given the similar thermal history, tank 241-A-101 is a better second choice.

A non-random sampling design will be used. Due to the limited number of samples to be collected, the sampling plan is not statistically based. However, collecting the core from a high heat tank will increase the likelihood that data collected represent a worst case scenario for concrete degradation in the SSTs.

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Acronyms

EPA	Environmental Protection Agency
TPA	Tri-Party Agreement
DQO	Data quality objectives
SST	Single-shell tank
WRPS	Washington River Protection Solutions
SSTIP	Single-Shell Tank Integrity Program
SAP	Sampling and Analysis Plan
IQRPE	Independent Qualified Registered Professional Engineer
AOR	Analysis of record
DOE	Department of Energy
REDOX	Reduction Oxidation Plant
PUREX	Plutonium Uranium Extraction Plant
TBP	Tributyl phosphate
ITS	In-tank solidification
DST	Double-shell tank
WTP	Waste Treatment Plant and Immobilization
PSQ	Principal study question
AA	Alternative action
DS	Decision statement
DOE-ORP	Department of Energy Office of River Protection
NDE	Non-destructive evaluation
UPV	Ultrasonic pulse velocity
ASTM	American Society for Testing and Materials
CTL	Commercial Testing Laboratories
PSI	Professional Service Industries
PSQ	Principal Study Question
A2LA	American Association for Laboratory Accreditation
ISO	International Standard Organization
S&ME	Soil and Materials Engineers
Ecology	Washington State Department of Ecology
ALARA	As Low As Reasonably Achievable
AASHTO	American Association of State Highway and Transportation Officials

1.0 INTRODUCTION

The systematic planning, or data quality objective (DQO), process, defined by the U.S. Environmental Protection Agency (EPA) (EPA 2006), is used to identify type, quantity, and quality of data needed to support data collection activities. The DQO process used for this report was conducted according to procedures consistent with EPA guidance. The sections presented in this document follow the seven steps of the DQO process and describe information needed to support the single-shell tank (SST) sidewall coring program. The primary objectives of this project are to determine whether a concrete core sample should be collected from a SST, and if so, determine the tank to be cored, as required by Tri-Party Agreement (TPA) change notice M-45-10-01, approved on January 3, 2011.

TPA Interim Milestone M-045-91B, from change notice, M-45-10-01, approved on January 3, 2011, requires "DOE (the Department of Energy) shall implement the EPA Data Quality Objectives (DQO) process (EPA/240/B-06/001, February 2006) in consultation with Ecology to develop the Sampling and Analysis Plan. The DQO will consider whether the coring should be conducted and whether A-106 or an alternate tank should be cored."

1.1 EXPERT PANEL RECOMMENDATION

Sidewall coring of a SST was recommended as a result of an expert panel assembled to provide Washington River Protection Solutions, LLC (WRPS) with recommendations to support the development of an enhanced Single-Shell Tank Integrity project (SSTIP) (RPP-RPT-43116). The expert panel (the members of which are listed on the WRPS website) recommendation was to test "a vertical core from the entire depth of the sidewalls for two tanks that have leaked and had been operated at high temperatures for extended periods." Recommendations provided by the panel were categorized as in support of four key SSTIP elements. SST coring fell under the element, confirmation of tank structural integrity. Within each element, the recommendations were prioritized. Coring a sidewall was ranked number three in confirmation of tank structural integrity, and number three overall. The expert panel recommended the core undergo "careful visual inspection and concrete compression strength testing should be performed…" The panel also recommended that any rebar steel cut in the recovered core be carefully inspected, thickness measured, and tensile tested.

The expert panel report was very clear that the panel felt sidewall core testing is very important and it would be best to test two cores from high heat tanks known to have leaked. WRPS planned to collect a core from a tank that had not previously leaked because of as low as reasonably achievable (ALARA) and radiological concerns that arise from working with contaminated samples. The expert panel was asked to clarify their position on the need for a core from a leaking tank. A letter was received from the panel experts, dated January 12, 2011, stating coring a tank exposed to high heat was a higher priority than coring a tank having previously leaked. Therefore, it was decided that tanks exposed to high heat would be considered as candidates for coring.

The full expert panel clarified the reasons for coring a SST at a meeting during February 2011. The following excerpt from RPP-RPT-49272, *Fourth Single-Shell Tank Integrity Project Expert Panel Meeting Held February 23-25,2011,* summarizes their logic.

> The Panel continues to recommend SST sidewall coring as necessary to determine mechanical properties used in the structural Analysis of Record (AOR). Without such coring data the modeling results in the AOR for the assessment of SST tank integrity are uncertain.
>
> However, the Panel acknowledges concerns over handling contaminated samples and an increased potential for an environmental release during coring activities. As a result, the Panel recommends coring two tanks that have experienced elevated temperatures but are not assumed leakers. Evaluation of the cores should be focused on thermal degradation.

A total of eight questions were posed to the expert panel regarding reasons for SST sidewall coring. Answers to two of these questions are summarized in the following paragraphs. Answers to all of the questions are included as Appendix A.

When asked why two cores had been specified, the panel replied that two additional cores provide a total sample size of three, two additional cores and previously cored tank 241-SX-115. A sample size of three can provide substantially greater confidence in any conclusions reached if the results from all three cores are consistent. It also greatly increases the chances of finding serious defects if such defects exist in significant quantities. However, the expert panel stated there is no statistical significance to collecting the two additional cores mentioned above.

When asked for an opinion on what action should be taken if the data obtained from cores are very different from what is expected, the panel replied the AOR model will need to be revised to consider the worst concrete conditions observed in any of the cores.

The expert panel made 12 recommendations with respect to structural integrity. The AOR model (finite elemental analysis) is the first expert panel recommendation for structural integrity and is focused on using the presumed tank concrete properties to determine current structural integrity of the SSTs. The SST sidewall core data will be compared to the concrete properties being used in the modeling effort. For more information on how the concrete properties are being used in the AOR model, see Appendix A of RPP-46442.

1.2 GLOBAL ISSUE

The DQO Team, comprised of the DOE-ORP Project Manager and support personnel, Ecology Project Manager and support personnel, WRPS project technical lead, WRPS tank integrity lead, WRPS single-shell tank integrity lead, WRPS environmental personnel, Energy Solutions project manager for coring, and the Dade Moeller & Associates facilitator, agreed that the following is a Global Issue relevant to this DQO process: The expert panel recommendation is to core two tanks with histories of high operating temperatures. This systematic planning, or DQO effort, will choose the first tank to be cored, along with contingency tank(s) so any issues encountered in the field will not halt the coring effort altogether. After data from the first tank has been reported and lessons learned have been documented, a new effort will be initiated to evaluate whether to collect a core from a second tank and if so, identify the second tank to be cored.

1.3 TECHNICAL ISSUES

A Technical Issue that could impact the scope of data collected after coring is encountering rubblized concrete and/or radiologically contaminated concrete during core collection. In the case of rubblized concrete, mechanical testing is not possible due to the condition of the concrete, and only visual inspection would be conducted. In the case of a radiologically contaminated core there are currently no laboratories available that could accept the core for testing, and only a visual inspection would be conducted. The sample would then be archived while options for analyzing a radioactive core specimen are explored. The options for a radiologically contaminated core are explored in principal study questions (PSQ) P2Q12 a, b, and c.

1.4 PROCESS FOR SIDEWALL CORING

The flow diagram presented in Figure 1-1, Decision Logic for Sidewall Coring Project gives a baseline process flow with decisions made and captured within this document, or decisions that will be made once data are obtained. Note decision and process box numbers from Figure 1-1 are included in the discussion below. The timeline is discussed in Section 5.2, Temporal Boundaries.

The process begins with the DQO process to decide whether to core (D1). If the decision is made not to core, the process ends (P1). If the decision is made to core a tank, the tank and any contingency tanks are chosen as a continuation of the DQO process (P2).

This report lists the first tank chosen for coring along with contingency tanks as previously discussed.

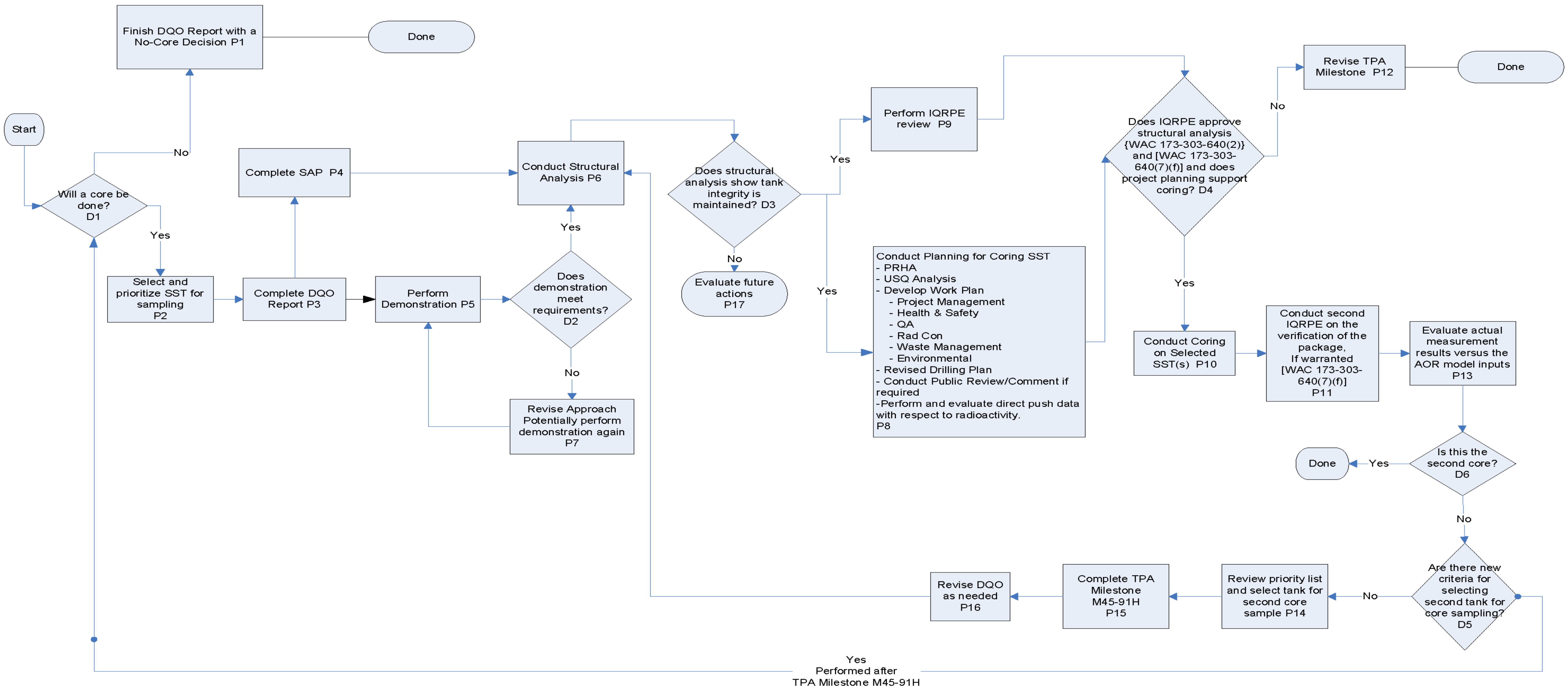
Once a tank(s) has been chosen, a Sampling and Analysis Plan (SAP) will be written (P4). Concurrently a demonstration will be performed showing, in particular, core hole deviation can be measured and controlled (P5, D2). If the demonstration fails to meet requirements, the coring approach may be revised and a demonstration may be performed again (P7). The demonstration's failure to meet requirements could also lead to abandoning the coring effort.

If the demonstration meets requirements, a structural integrity analysis will be conducted (P6). If structural integrity analysis fails to show that structural integrity would be maintained during and after coring, future actions will be evaluated, such as moving to a backup tank or redesign of the coring method (P17). If the structural integrity analysis shows that structural integrity will be maintained, an Independent Qualified Registered Professional Engineer (IQRPE) review of the structural integrity analysis will be performed (P9, D4) in parallel with the planning process for coring the chosen SST (P8, D4). The planning process includes hazards analysis and work plan development.

If the IQRPE review and/or the project planning determine coring should not be conducted, the TPA milestone would be revised and the process would be complete (P12). If the IQRPE review and the project planning determine that coring can be safely conducted, a core would be collected and tested (P10). A second IQRPE would verify the package (P11), if grouting the core hole is deemed a major repair by initial IQRPE review, and data from the core would be evaluated against the properties being used in the AOR model (P13).

After data from the first coring effort have been evaluated, it will be determined whether additional criteria for selecting a tank are needed (D5). If no additional criteria are needed, the next uncored tank from the original DQO process will be selected for future coring (P14).If discussions during TPA Milestone M-045-91H ("DOE shall submit a change package (if deemed necessary by DOE and Ecology) to establish additional milestones based on information obtained from the actions in the preceding M-045-91 series milestones to date." Deadline of July 31, 2015) determine the need for a second core, the tank selected at P14 will be chosen(P15), and this DQO will be revised, as needed, to support the second coring effort (P16). The process will then be repeated, including structural analysis through data evaluation. If additional criteria are needed to select a second tank after performing the first core, these criteria will be considered in discussions during M-045-091H and the the determination to proceed with the DQO process for a second core will be may be made.

Figure 1-1: Decision Logic for Sidewall Coring Project



2.0 DQO STEP 1 – STATE THE PROBLEM

The SSTs have been used at Hanford since the start of operations. Recent changes to the clean up mission call for the continued use of the SSTs to beyond 2040. With this new requirement, the Tri-Party Agreement members initiated a review of the SST integrity. A key question in that review is the current condition of the concrete used in the SSTs.

2.1 HISTORICAL BACKGROUND

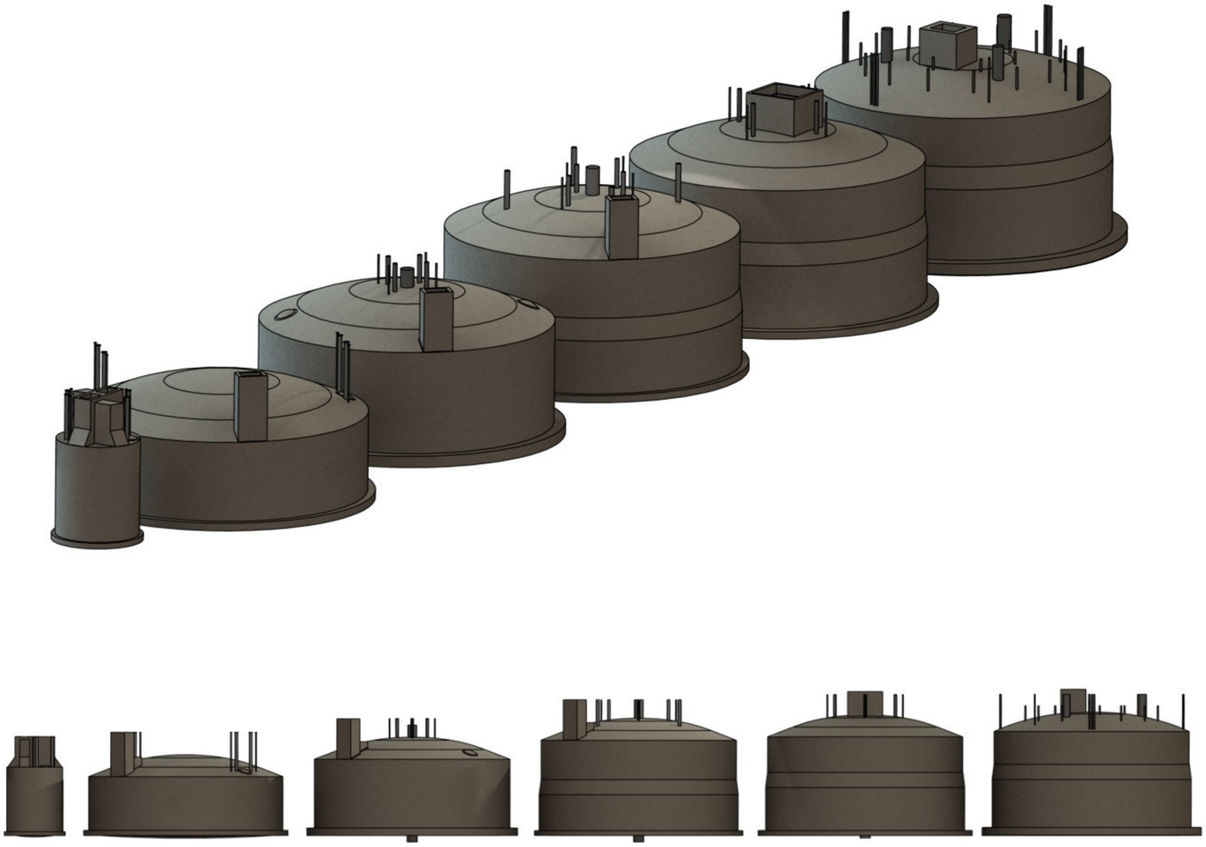
The discharge of waste from the nuclear fuel reprocessing plant at Hanford was controlled by the amount of radioactivity contained in the waste. Those wastes with the highest amount of activity were discharged to underground tank farms built to store the waste. As the concentration of radioactivity increased in the waste (and resultant heat generation), the stresses on the SSTs increased, which has led to a series of structural evaluations. As part of the Tri-Party Agreement, another such evaluation is being conducted. The sidewall coring of a SST will provide input to that analysis.

2.1.1 Single-Shell Tank Construction

The SST farms were constructed over a 20 year period as needed to support the reprocessing of fuel. Four farms were started in late 1943; two were completed in 1944, and two were completed in 1945. The rest of the SST farms were started and finished at various times between 1946 and 1964. The first four farms consisted of four 55,000 gallon tanks and twelve 530,000 gallon tanks. The other farms were built with three different capacities: 530,000, 750,000, and 1,000,000 gallons. In total, 149 SSTs, in 12 farms, were built for the storage of radioactive wastes at the Hanford Site.

As stated in the previous paragraph, four different tank types were constructed (see Figure 2-1). The first, Type I, have a 20 foot diameter, 38 foot height, and hold 55,000 gallons. The second, Type II, have a 75 foot diameter, 32 foot height, and hold 530,000 gallons. The third, Type III, also have a 75 foot diameter, but had a 39 foot height, and hold 750,000 gallons. The fourth, Type IV, was broken down into three sub-types. All three Type IV tanks – Types IVA, IVB, and IVC – had a 75 foot diameter and hold 1,000,000 gallons, with heights ranging from 46 feet to 48.75 feet.

Figure 2-1: Types of SSTs



I	II	III	IVA	IVB	IVC
241-B	241-B	241-BY	241-SX	241-A	241-AX
241-C	241-BX	241-S			
241-T	241-C	241-TX			
241-U	241-T	241-TY			
	241-U				
16 Tanks	60 Tanks	48Tanks	15 Tanks	6 Tanks	4 Tanks

In addition to the increasing volume of the tanks, other designed features changed over the years. The Type I and Type II tanks have 15-inch concrete domes, 12-inch walls, and dished bottoms. The walls for the Type II tanks were increased to 15 inches. The Type IV tanks went to flatter bottom designs: pan (or with a slight depression in the center) for the Type IVA tanks and flat for the other Type IV tanks. The bottom and the wall were welded with a fillet weld for the Type IVA and IVB tanks, but the Type IVC design has a 4-inch radius knuckle. For the increased heat loaded in the Type IV tanks, they were equipped with Air Lift Circulators up to four in the Type IVA tanks, four in the Type IVB tanks, and 22 in the Type IVC tanks.

Additionally Type IV tank walls transition from 15 inches at the top to two feet at the bottom. This transition occurs about half way down the tank wall.

2.1.2 Single Shell Tank Operational History

The SSTs received alkaline waste from multiple nuclear fuel reprocessing operations, starting in 1944. The initial radioactive wastes were principally derived from three different chemical processing operations, each of which produced several different types of waste; the bismuth phosphate process, Reduction Oxidation (Redox) process, and Plutonium Uranium Extraction (PUREX) process. The bismuth phosphate process only recovered plutonium from irradiated reactor fuels. The Redox and PUREX processes recovered both plutonium and uranium from the fuel.

The bismuth phosphate wastes discharged to the tanks were later processed to recover uranium from the wastes by using the tributyl phosphate (TBP) process. Potassium ferrocyanide was used to scavenge cesium ion from this waste. The oldest tanks (241-B, 241-BX, 241-BY, 241-C, 241-T, 241-TX, 241-TY, and 241-U farms) were constructed to receive waste from bismuth phosphate plants and received other wastes (e.g., low heat wastes from the Redox and PUREX plants). The Redox high heat wastes were stored in the 241-S and 241-SX farms. The PUREX high heat wastes were stored in 241-A, and 241-AX farms. The 241-SX, 241-A, and 241-AX designs allowed the storage of boiling wastes so water could be removed from the tanks to conserve space for the retention of radioactive materials. Other operations including the in-tank solidification (ITS) and tank farm evaporators were used to remove water and concentrate the wastes. Tanks in the 241-A, -AX, and –SX Farms experienced high temperatures ranging from 200° F to 594° F.

Waste additions to the SSTs ceased in 1980 and pumpable liquids have been transferred from the SSTs to the double-shell tanks (DSTs). SST wastes are slated for retrieval and treatment in a Waste Treatment Plant and Immobilization (WTP) that is currently under construction. Technical issues have delayed the schedule for initiating operations of the WTP. The delays to the WTP will necessitate extended storage in the SSTs, most of which are beyond their design life. The most recently built, 241-AX farm, tanks had a design life of 25 years which expired in 1990. Design life is based on steel liner corrosion rather than concrete degradation.

2.1.3 Tank 241-SX-115 Sidewall Core and Resulting Data

The coring data from 241-SX-115 are discussed because these were from the first coring of a sidewall of a SST. This data prove that coring can be done; however the data obtained were incomplete and were inconclusive with respect to the compressive strength in the footer sections of a SST sidewall, or the section of the tank that experienced the highest heat, approximately 260° F.

In 1981, tank 241-SX-115 sidewall was vertically core drilled from top to bottom (RHO-CD-1538). However, the last 8 feet of the sampled core (total sample of 38 feet 8 inches) could not be tested due to radiological contamination. Thus no data have been collected from a concrete sample of the haunch-to-footer, and footer sections of a SST sidewall.

There were some inconsistencies in the data from the core specimens that were tested. The first data point, closest to the surface, for each property measured was significantly different from subsequent measurements of concrete further down the sidewall. Also, in photographs of the collected core, the first section looks different from subsequent sections of collected core. These inconsistencies may indicate the specimens were collected from the concrete poured for the drilling pad at the bottom of the caisson and not from the tank haunch or wall.

Additional information on tank 241-SX-115 historical sidewall coring can be found in Appendix B.

2.2 CONCEPTUAL MODEL - EXPERT PANEL RECOMMENDATIONS

An expert panel was assembled to provide recommendations to support development of an enhanced SSTIP. Due to the delays in operation of the WTP that is currently under construction on the Hanford Site, determination of the integrity of the SSTs is an important consideration because the tanks are beyond their engineered life expectancy.

The panel developed recommendations based on the proceedings of two 2009 workshops and the research and deliberation of the panel and its members.

In developing its recommendations, the panel agreed on three overarching values that should guide the SSTIP (RPP-RPT-43116). First, the SSTIP activities should not adversely impact final disposition of tank waste. Such disposition of SST wastes requires retrieval from the tanks and treatment in the WTP. These two activities require certain physical and chemical waste characteristics that must be integrated into decision-making for the SSTIP.

Second, SSTIP activities should be strategically focused on programmatic needs. This acknowledges the pitfalls of developing SSTIP activities that may be of interest scientifically, but offer little prospect for directly supporting the programmatic needs of safe storage, retrieval, treatment, and disposal of SST wastes.

Third, SSTIP activities should protect the environment, public and worker health and safety.

The panel prioritized its recommendations (with one the highest) within four key elements: (1) confirmation of tank structural integrity, (2) assessment of the likelihood of future tank liner degradation, (3) leak identification and prevention, and (4) mitigation of contaminant migration. Of the four key element recommendations, the panel prioritized the top ten overall recommendations in the expert panel report that were to be a priority when beginning the SSTIP, and would form the foundation of the program (RPP-RPT-43116).

The third recommendation under key element "confirmation of tank structural integrity" is "Obtain and Test Sidewall Core." This recommendation is also the third overall recommendation.

The following excerpt is from the expert panel report:

> The panel recommends obtaining and testing a vertical core from the entire depth of the sidewalls for two tanks that have leaked and have been operated at high temperatures for extended periods…Careful visual inspection and concrete compression strength testing should be performed on the recovered core. If any rebar steel is cut in the recovered core, this rebar should be carefully inspected, thickness measured, and tensile tested. However, care should be taken not to cut any significant fraction of hoop reinforcement (rebar) at any level.

The subsequent clarifications mentioned in Section 1.1 led to the decision to select a tank exposed to high heat that had not leaked.

2.3 DQO STEP 1 - PROBLEM STATEMENTS

Based on the TPA Milestone the DQO must address whether the coring of a SST sidewall is needed. Following initial discussions regarding whether coring is needed, the next item that must be addressed per the TPA Milestone is which tank(s) will be cored. Based on the TPA requirements, the two problem statements listed below were agreed upon.

<u>Problem #1.</u> In order to better understand whether the coring of the SST concrete is needed, an evaluation of the information gained by coring the sidewall of a SST is warranted.

Problem #2. In order to better understand the current condition of SST concrete, testing of concrete core sample segments removed from a tank operated at a high temperature for extended periods is warranted. The core includes haunch, walls, and footing.

3.0 DQO STEP 2 – IDENTIFY THE DECISIONS

Each problem statement is associated with one or more decision statements. Decision statements are created using principle study questions (PSQ) and alternative actions (AA) which may address the question. After creating the PSQ and AA, a decision statement (DS) is written. Tables 3-1 and 3-2 present the PSQ, AA and DS associated respectively with each problem. P1 is associated with Problem #1 and P1DS1 is the decision statement associated with Problem #1 and Question #1.

Table 3-1: PSQs and Decision Statements Associated with Problem #1

No.	Principle Study Question	Alternate Actions
P1Q1	Should a tank sidewall be cored to provide concrete property data used for long term structural integrity evaluation?	Yes: Additional data related to the current condition of tank sidewall concrete is needed to provide actual visual and measurement data related to degradation of the SSTs due to exposure to heat. No: Data are either sufficient or for other reasons (e.g., no appropriate facility to perform analysis) coring is not performed.
P1DS1	Determine whether a sidewall should be cored and the new data are required for structural integrity evaluation or whether existing data are sufficient and no coring is required.	
P1Q2	Is there utility in performing side wall coring?	Yes: Data on current material properties will be used to evaluate input parameters used to generate the AOR model and other appropriate actions. Visual information on the condition of concrete in the SST will allow improved long term structural analysis decisions. No: Move forward based on current modeling assumptions; assume current modeling input parameters are acceptable.
P1DS2	Determine whether sidewall coring is needed to provide actual input parameters for comparison to the AOR or to use existing input parameters.	

Table 3-1: PSQs and Decision Statements Associated with Problem #1		
P1Q3	Does sidewall coring provide any useful information regarding structural integrity of SSTs not able to be obtained by other means?	Yes: The SSTs are aging reinforced concrete structures that are required to store waste for an unknown duration. Coring will provide both visual and measurement information on the actual condition of the concrete. No: Do not core
P1DS3	Determine whether the coring will provide useful information needed to evaluate structural integrity; if the information is not needed, do not core.	
P1Q4	If coring through the sidewall occurred, could the tank waste be retrieved?	Yes: Plug the hole, grout, and retrieve. No: Revert to P2Q14 (addressed in following table).
P1DS4	Determine whether coring through the side wall will allow waste retrieval or whether it will prevent retrieval.	
P1Q5	Is the risk of coring through the sidewall worth the effort?	Yes: Proceed with coring. No: Do not core.
P1DS5	Determine whether the effort of coring through the sidewall is worth any potential risk of structural failure. Otherwise, do not core.	

Table 3-2: PSQs and Decision Statements associated with Problem #2		
No.	Principle Study Question	Alternate Actions
P2Q1	Is core diameter important for testing?	Yes: Labs will only certify test results for cores meeting American Society for Testing and Materials (ASTM) standards. No: Do not use ASTM recommendations.
P2D1	Determine whether the core diameter specified in sampling design meets ASTM standards or use a diameter based on alternate requirements.	
P2Q2	Is temperature a contributing factor to concrete degradation?	Yes: Temperatures in excess of 200°F have been shown to reduce mechanical (elastic) properties. No: Select other properties to assess the tank structural integrity.
P2D2	Determine whether temperature is a contributing factor to concrete degradation, if not assess properties other than temperature.	
P2Q3	Is exposure to high heat the primary concern for structural integrity?	Yes: Published literature related to concrete degradation indicates that high heat exposure contributes to structural degradation of concrete. No: Given all the variables affecting structural integrity a direct cause to high heat exposure cannot be made, thus more than one core may be needed.
P2D3	Determine whether exposure to high heat is the primary concern related to structural degradation of concrete, otherwise identify other variables that affect structural integrity.	
P2Q4	Is the sidewall coring to be performed on a Type IV SST? (Refer to tank type descriptions in Section 2.1.1.)	Yes: The higher temperatures of 1 million gallon SSTs are important for sidewall coring. No: Select Type I – III tank.
P2D4	Determine whether the sidewall coring will be performed on a Type IV SST, otherwise select a Type I, II or III tank.	
P2Q5	Does the entire depth of the sidewall need to be cored?	Yes: The information regarding the higher stress regions (i.e the haunch to wall transition and wall to footing transition) is important. No: Single point samples provides enough information.
P2D5	Determine whether the entire depth of the sidewall needs to be cored or whether single point samples provide sufficient information.	

Table 3-2: PSQs and Decision Statements associated with Problem #2		
P2Q6	Should excavation site (to dome haunch) be characterized?	Yes: Soil characterization will allow for safer excavation. No: The unknown will be carried through the normal permitting process.
P2D6	Determine whether characterization of the soil to the dome haunch will be needed, otherwise carry these unknowns through the normal permitting processes for the excavation permit.	
P2Q7	Should coring site (adjacent to tank down to footing) be characterized?	Yes: Coring site characterization down to footing will provide increased confidence that core sample will not be contaminated. No: Possible source of contamination, aside from the SST, could be missed.
P2D7	Determine whether soil coring down to the footing will be needed, otherwise do not perform soil coring to the footing.	
P2Q8	Do other SST characteristics and parameters impact the choice of SST for this effort?	Yes: Characteristics other than temperature must be considered. No: Temperature is the most limiting parameter for structural integrity.
P2D8	Determine whether characteristics other than temperature exposure are limiting factors, otherwise consider only temperature as a factor.	
P2Q9	Is the tank near and long term structural integrity adversely affected by the sidewall coring activity?	Yes: Do not proceed if structural integrity evaluation shows adverse effects. No: Proceed with activity, ensuring sidewall coring will not introduce a loading scenario or tank configuration detrimental to the tank structural or leak integrity.
P2D9	Determine whether the near and long term structural integrity is adversely affected by the sidewall coring; if adversely affected then do not proceed with coring.	
P2Q10	Will coring affect tank leak integrity?	Yes: Do not core the SST No: Perform the SST core with specified vertical hole deviation to ensure leak integrity is maintained.
P2D10	Determine whether tank coring will affect leak integrity; if integrity is negatively affected do not core.	
P2Q11	Is concrete coring used in the nuclear industry to determine current condition of reinforced concrete structures?	Both lessons learned from past coring of 241-SX-115 and industry techniques will be considered in coring a SST.

Table 3-2: PSQs and Decision Statements associated with Problem #2		
P2D11	Determine whether concrete coring is used in the nuclear industry to assess current conditions of reinforced concrete; if not used in the industry develop plans to apply industry techniques to this coring.	
P2Q12a	Is the concrete core sample radioactively contaminated?	Yes: Determine unshielded dose rate, isotopes and specific activity for shipping requirements. No: Handle and ship as non-radioactive sample.
P2D12a	Determine whether the core sample is radioactively contaminated; if not ship the core as uncontaminated.	
P2Q12b	Is the unshielded dose rate and specific isotopic activity within limits for receipt and testing by designated radiological concrete testing laboratory?	Yes: Ship sample in accordance with DOT regulations for radiological sample. No: Archive radioactive contaminated samples for future testing. Note: core must be removed in order to determine contamination level.
P2D12b	Determine whether the dose rate and isotopic activity are within limits for receipt and testing by the laboratory; if not within limits do not ship and archive core.	
P2Q12c	Is there a radiologically licensed and accredited concrete testing laboratory capable of accepting and testing radioactively contaminated concrete core samples?	Yes: Determine acceptable dose and specific activity limits and ship acceptable core specimens. No: Determine requirements and feasibility to either a) procure and provide concrete testing equipment to an established licensed and certified commercial radioactive lab and train lab personnel, b) establish testing capabilities at an existing lab facility on the Hanford Site, c) fund establishment of capability to test radioactive cores at an existing certified concrete testing laboratory, or d) archive radioactive core samples for future testing.
P2D12c	Determine whether there is an accredited laboratory that can accept radioactive core samples for structural testing and if not, develop a contingency plan that includes options such as a) procure and provide concrete testing equipment to an established licensed and certified commercial rad lab and train lab personnel, b) establish testing capabilities at an existing lab facility on the Hanford Site, c) fund establishment of capability to test rad cores at an existing certified concrete testing laboratory. If no analyses can be performed, archive the samples.	

Table 3-2: PSQs and Decision Statements associated with Problem #2		
P2Q13	Did the cold coring demonstration pass criteria for vertical hole deviation? (Cold meaning coring of non-radioactive concrete, this is also referred to as 'the demonstration core'.)	Yes: Proceed to perform coring on SST. No: Reevaluate the process, improve technique, etc. and re-perform the demonstration, or do not proceed to coring SST.
P2D13	Determine whether the coring demonstration met criteria for vertical deviation control; if not reevaluate process and either demonstrate alternative vertical deviation process or if deviation cannot be achieved do not core.	
P2Q14	Will sidewall coring results be independently reviewed prior to performing the field activity to assure that structural integrity is maintained?	Yes: An independent reviewer (IQRPE) is required and important to the contractor, DOE, and Ecology. No is not an option for this work.
P2D14	Determine whether sidewall coring results will undergo IQRPE review; Per the Washington Administrative Code this is required after the initial structural integrity calculations/evaluation. Subsequent reviews may or may not be required.	
P2Q15	Can workers be properly protected from radiation during sidewall coring?	Yes: As part of ALARA program, workers should not be unnecessarily exposed to radiation. No: Do not perform the coring.
P2D15	Determine whether the workers can be properly protected from radiation during coring; otherwise do not core.	
P2Q16	Is there a risk of a failure of the liner (e.g. induce a leak path)?	Yes: USQ process establishes approach to minimize risk of liner failure. No: Outcome of USQ is that there is unacceptable risk, do not core.
P2D16	Determine whether the risk of failure of the liner is acceptable using the USQ process; if risk is unacceptable do not core.	

4.0 DQO STEP 3 – IDENTIFY INPUTS TO THE DECISION

4.1 EXPERT PANEL RECOMMENDATION

As stated previously in this document, the expert panel that was brought together to make recommendations on how to proceed in the SSTIP recommended that two sidewall concrete cores be obtained from tanks exposed to high heat. The two key characteristics used in the tank selection logic are

- maximum temperature, and
- duration of time at high temperatures.

4.2 AGREEMENT TO PROCEED WITH SST SIDEWALL CORE COLLECTION

Ecology and DOE Office of River Protection (ORP) agreed on performing one core in a SST initially. After data are obtained from the first core, evaluate the need for the second core with respect to the characteristics used to select the tank and information from the initial core. The expert panel recommended using heat exposure as the main criteria for tank selection. The panel was informed that analysis of a core from a leaking tank might result in a core that could not be analyzed due to high levels of radioactivity. Therefore, the consensus of the expert panel and DQO Team was to select a tank exposed to high heat and a tank that had not previously leaked.

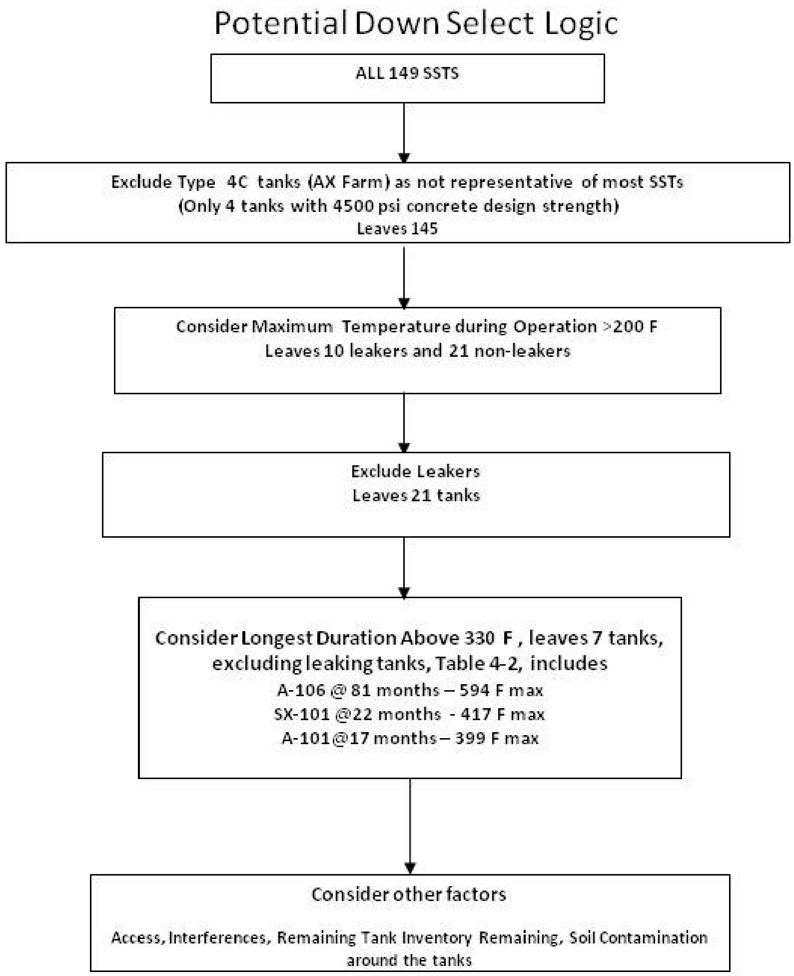
4.3 TANK SELECTION LOGIC

To obtain the data necessary, tanks that experienced high waste storage temperatures must be evaluated. In addition, given the previous agreements and discussion as the basis, one primary tank and two contingency tanks were selected.

4.3.1 Tank Selection Logic

This process considers all 149 tanks for core drilling, but through the agreed down selection process selects five tanks as candidates for core drilling. The selection logic is presented in Figure 4-1.

Figure 4-1: Tank Selection Logic



The tank selection logic begins with 149 SSTs. The Type IVC SSTs, of which only 4 were constructed, were excluded because the design strength of the concrete is 4,500 psi, which exceeds the typical design strength of 3,000 psi. Although some strength reduction could likely be seen if these tanks were operated at high temperatures, application of the results to the majority of tanks with the lower design strength would introduce additional uncertainty. Therefore, the four, higher design strength Type IVC tanks are not as useful for sampling and are excluded. This logical exclusion leaves 145 tanks for consideration. Additionally it will be seen later that these tanks were not subject to the highest temperatures

The next factor of concern for data quality is tanks need to have thermal operating history above 200° F. Review of the data showed that 31 SSTs have thermal operating histories that meet this criterion.

The next consideration for candidates is whether the tank is assumed to be sound or not. This factor is of importance because leaking tanks can lead to the loss of core sections due to contamination. Contamination is likely to occur lower in the tank wall and thus the area of greatest interest for thermal degradation would not be evaluated. Of the 31 SSTs listed above, 21 are known to not have leaked. A list of potential tanks, SSTs that have not leaked with waste storage temperatures above 200° F, is presented in Table 4-1.

The maximum temperature during operation and the duration at temperature are critical tank characteristics. Section 5.0 of RHO-C-54 concludes that the "Long-term tests at elevated temperatures produced properties losses that were more severe than those measured with short term tests of heated concrete." Thus tanks with long durations at elevated temperature are preferred.

For this study, tanks with waste storage temperatures greater than 330° F (the maximum temperature of the highest AX farm tank) and tanks that did not leak are listed in Table 4-2. Figure 4-2 presents a graph that shows the cumulative number of SSTs versus the maximum measured tank temperature. The graph shows the five tanks listed in Table 4-2 and the three 100 Series SSTs, which have been retrieved. The retrieved tanks have been included in the figure to show that, based on their temperature histories, they would not provide quality data for evaluating thermal degradation in SSTs.

Table 4-1: Non-Leaking SSTs with Temperature Maximums above 200°F

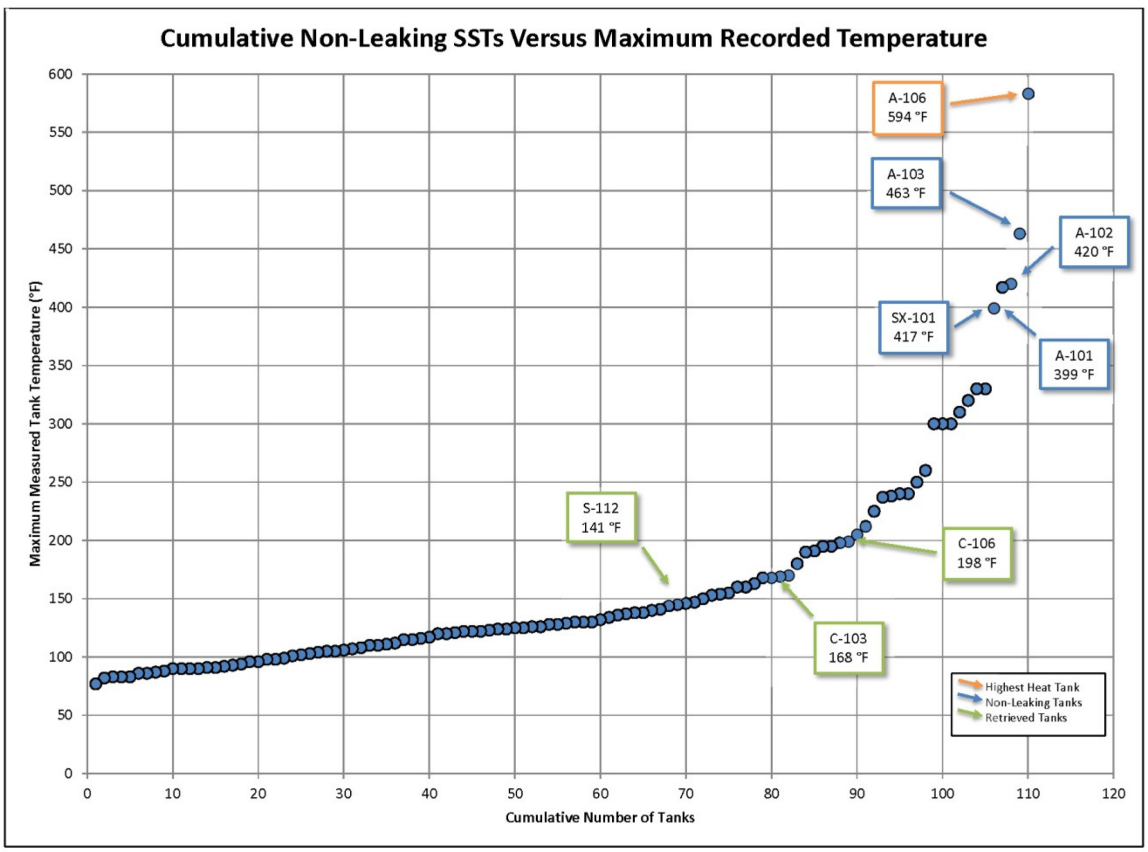
	Non-Leakers[1, 2]			
Number	Tank	Maximum Temperature (°F)	Months ≥ 200 °F	Months ≥ 300 °F
1.	A-106	594	87	81
2.	A-103	463[4]	91	3+
3.	A-102	420	93	3
4.	SX-101	417[4]	117	22
5.	A-101	399	130	17
6.	AX-103	330	69	25
7.	SX-105	330	2	0
8.	AX-104	320	40	4
9.	SX-110	310	80	5
10.	S-101	300	30	7
11.	S-104	300	61	13
12.	SX-104	300	109	13
13.	AX-101	260	28	0
14.	AX-102	250	27	0
15.	S-107	240	29	0
16.	S-110	240	25	0
17.	TX-105[3]	238	-	-
18.	BY-104[3]	237	-	-
19.	SX-103	225	3	0
20.	SX-102	212	1	0
21.	BY-110[3]	205	-	-

[1]Data compiled from *Survey of the Single-Shell Tank Thermal Histories* (RHO-CD-1172)
[2]Data compiled from Redox data sheets dating from 1952 - 1964
[3] Temperature data beyond the maximum temperature is not available.
[4] Temperature data from *Current Status of Redox Waste Self-Concentration* (HW-50216)

Table 4-2: Non-Leaking SSTs with Temperature Maximums above 330°F

Non-Leakers			
Tank	**Max. Temp. (°F)**	**Months ≥ 200 °F**	**Months ≥ 300 °F**
A-106	594	87	81
A-103	463[3]	91	3+
A-102	420	93	3
SX-101	417[3]	117	22
A-101	399	130	17

Figure 4-2: Cumulative Non-Leaking SSTs Versus Maximum Recorded Temperature



In addition to the maximum temperature, data has been collected on the duration at elevated temperature. A thermal history showing the typical month ending temperature for these five tanks is presented in Figure 4-3. Individual maximums are also shown (as dots), which probably represent transients not seen at the typical month-end reporting period.

From the data shown in Table 4-2 and Figure 4-3, if maximum temperature and the duration of the tank above 300° F are the primary criteria, tank 241-A-106 is the best choice for core drilling. Tanks 241-A-101 and 241-SX-101 are the best contingency choices, for coring based on their thermal history. The other tanks in Table 4-2 are still reasonable choices but lack an extended duration above 300° F.

To ensure the tanks selected were subject to maximum thermal and hydrostatic loading, the waste level at time of maximum temperature is considered. Table 4-3 shows the tank versus the maximum temperature, the date the maximum temperature was documented and waste volume/waste level when the maximum was reached. The concern was raised that though the tank had experience a high temperature service, the severe temperature could have been limited to just the lower portion of the tank. The table shows that all of the tanks were reasonably full of waste when waste temperature maximums were realized. At the time of their maximum temperatures, tanks 241-A-106 and 241-A-101 had the highest waste levels and tanks 241-SX-101 and 241-A-103 had the lowest waste levels.

Table 4-3: SST Data Associated with Maximum Temperature

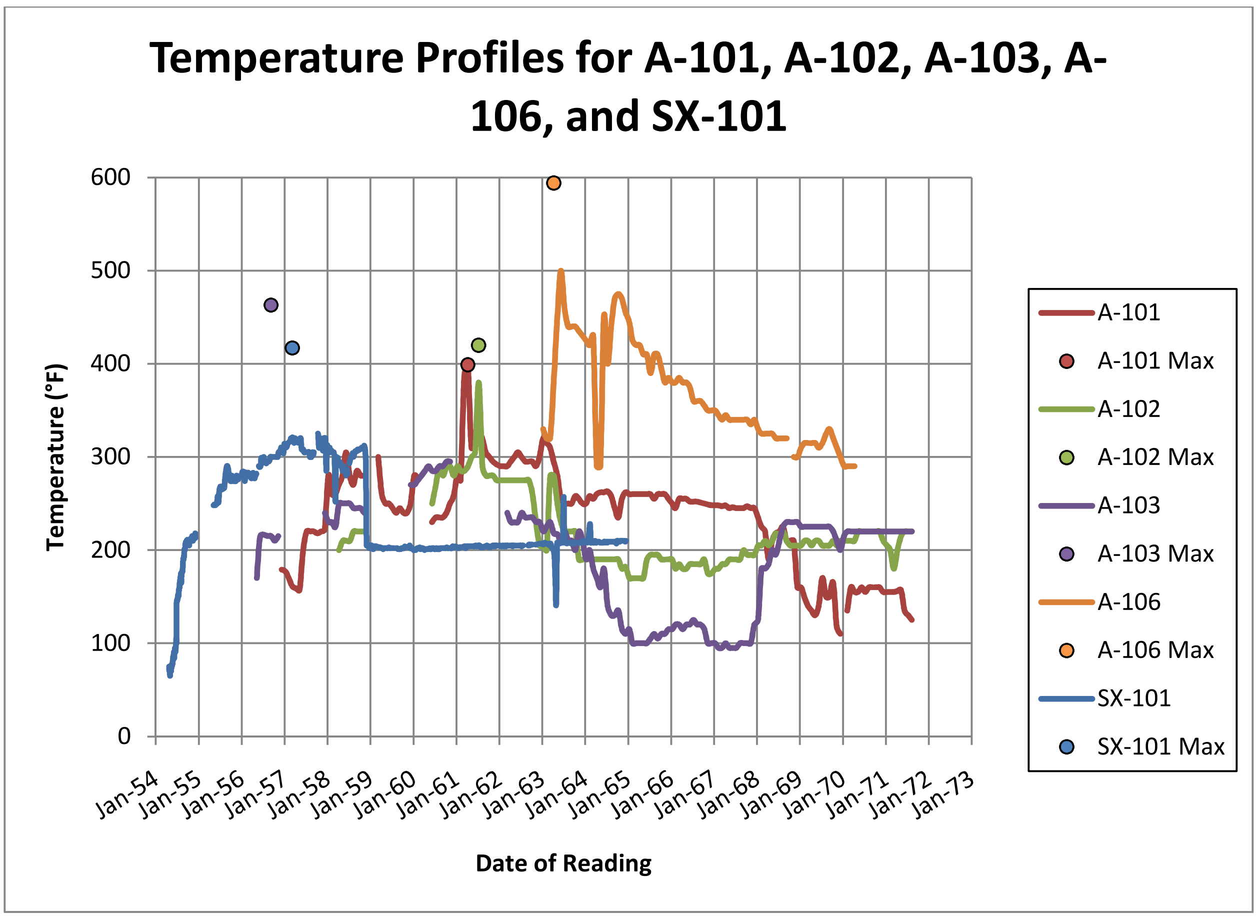
Tank	Maximum Temperature(°F)	Date Recorded	Waste Volume (kgal)	Waste Level (ft, in)	Volume Reference
241-A-106	594	May 1963	924	27' 11"	HW-78279
241-A-103	463[1]	October 1956[2]	522	15' 9 ½"	HW-46382
241-A-102	420	August 1961	888	26' 10"	HW-72625
241-SX-101	417[3]	April 1957	540	17' 0"	HW-50127
241-A-101	399	May 1961	930	28' 2"	HW-71610

1 Temperature reportedly was reduced rapidly to 240° F according to HW-50216

2 Estimated date based on the highest waste volume prior to the 463° F maximum reported in April 1957

3 Other thermocouples in the tank were reading 335° F and 380° F according to HW-50216

Figure 4-3: Temperature History Profiles for Candidate Tanks



4.3.2 Project Risks

Several factors influence the ease of core drilling an individual tank. During the course of discussion for the contingency tank these factors were discussed. Evaluation of these project risk factors reinforced that 241-A-106 should be the primary selection and helped prioritize the contingency selections. These factors include the following considerations.

- accessibility to the tank,
- logistics such as planned retrieval dates
- waste volume remaining in the tank,
- radioactive soil contamination surrounding the tanks.

Figure 4-4 shows the underground structures in the 241-A Tank Farm. Tank 241-A-106 is clearly accessible on the northeast corner with no identified buried infrastructure interferences. Tanks 241-A-103, 241-A-101 and 241-A-102 are listed in order of accessibility. In the 241-SX Tank Farm, the underground structures are shown in Figure 4-5, which shows 241-SX-101 located on the outer, northeast corner. The figure shows that 241-SX-101 has poor accessibility because it is surrounded by major underground process pipe encasements and direct buried lines.

Figure 4-6 provides aerial photos of both the 241-SX and 241-A Tank Farms from 2008. 241-A Tank Farm is next to the 242-A Evaporator. The evaporator is scheduled to be in operation in June of 2012. The operations manager stated as long as coring operations stay within the 241-A Farm fence, he sees no conflict with operations. The project must ensure that no space in the non-radioactive zone is needed. Again, the three best access tanks are 241-A-106, 241-A-101and 241-A-103.

Logistics of other planned events in tank farms were considered. The retrieval schedules of the 241-A and 241-SX Tank Farms are listed in Table 4-4. The retrieval schedule will not interfere with the coring for any of the tanks selected.

Figure 4-4: Infrastructure Map 241-A-AX Tank Farms

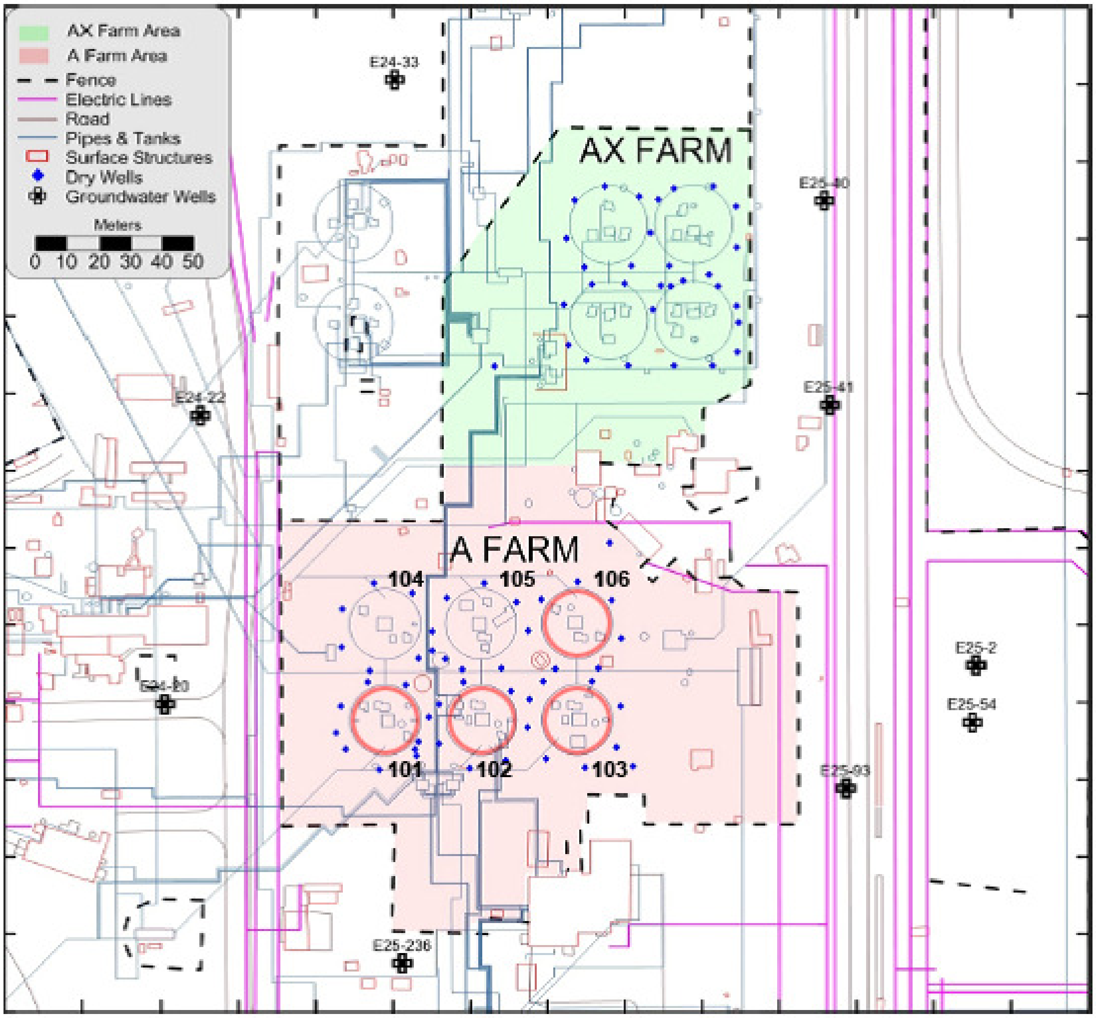


Figure 4-5: Infrastructure Map of Study Area that Includes 241-SX Tank Farm and Part of the S Tank Farm

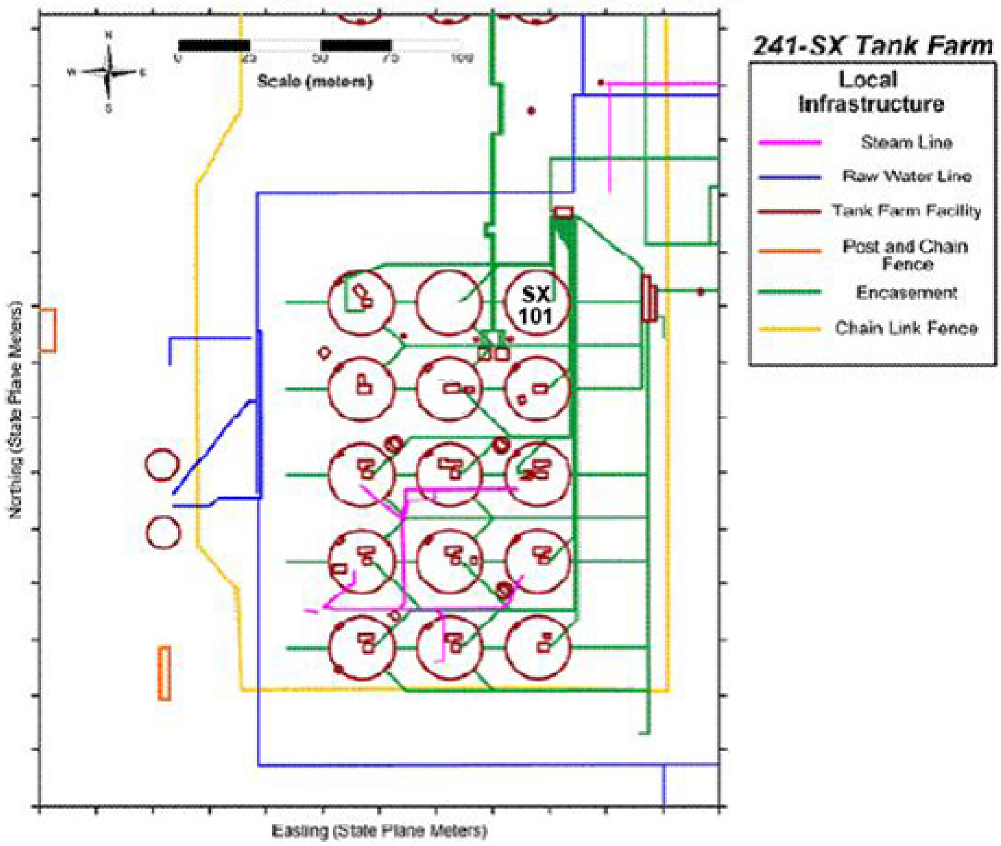
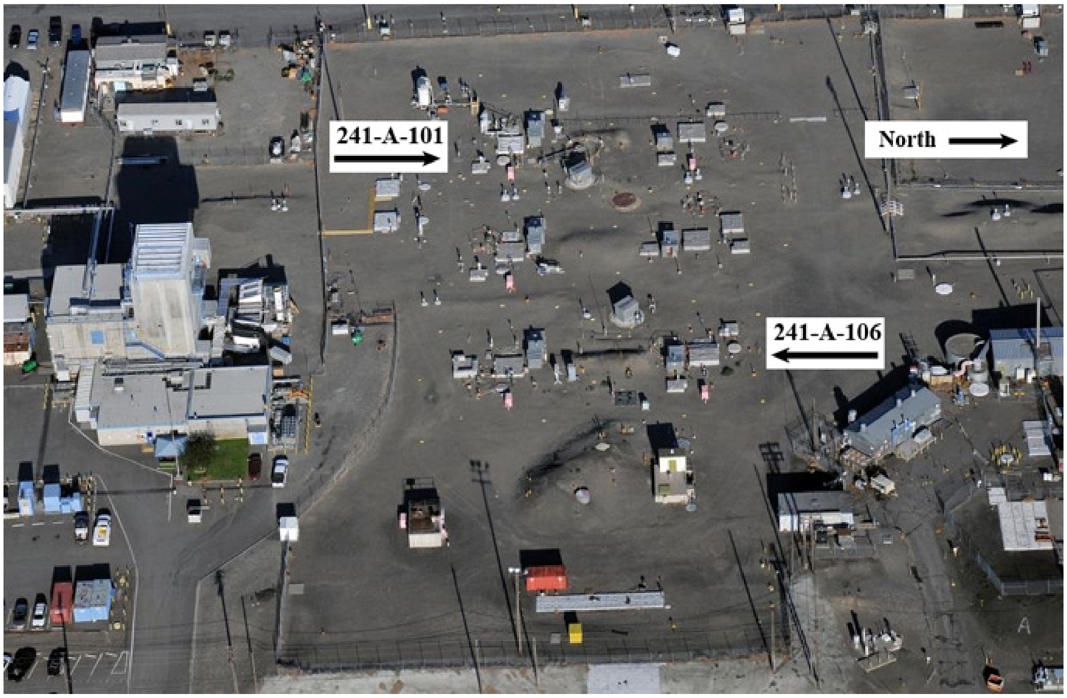


Figure 4-6: Aerial Photos of both the SX and A Tank Farms from 2008



A Farm Aerial Photo (2008)

SX Farm Aerial Photo (2008)

Table 4-4: SST Waste Retrieval Schedules

Tank	Planned Retrieval Dates for Revised Baseline
A-101	1/7/2018
A-102	1/9/2017
A-103	10/27/2018
A-106	9/16/2017
SX-101	10/11/2023

In the 241-SX Tank Farm, the barriers (two parts) will be installed this year and next year. It will not cover 241-SX-101, but there will be activity in the farm.

Remaining waste volumes in the tanks are listed in the following table.

Table 4-5: SSTs and Current Waste Volumes

Tank	Approximate Current Waste Volume, kgal
A-101	320
A-102	37
A-103	378
A-106	79
SX-101	430

While the coring is not expected to damage the steel liner that contains the waste, Tanks 241-A-102 and 241-A-106 clearly have less volume of waste that could result in an environmental release, should the liner be breached. Given the prerequisite of successful demonstration and the frequent down hole survey, as well as the presence of the inner rebar mat, which must be cut prior to being able to reach the liner, breach is considered extremely unlikely and therefore remaining waste volume is not a down select criterion.

The next consideration is potential soil contamination surrounding the tanks. The project will use existing data and/or collect additional data required to examine and evaluate the soil surrounding the selected tank and soil at depth to support safe excavation for the coring caisson and evaluate potential for contamination. The existing knowledge of soil contamination information can be considered to assess risk in tank selection. This information can be obtained from three sources: surface contamination surveys, estimated ^{137}Cs concentration plots, and soil resistivity measurements.

Figures 4-7 and 4-8 show the surface contamination surveys for 241-A and 241-SX farm, respectively. The surface contamination plots are generated by routine surveys and subject to change. Surface contamination is not indicative of buried contamination. The 241-A farm surface contamination maps show minimal contamination around 241-A-106 and a few localized contamination spots around other tanks, typically around pump pits. Surface contamination is widespread in 241-SX farm and extensive around 241-SX-101.

Figures 4-9 and 4-10 show the ^{137}Cs plots that are generated based on models and measurements from existing borehole surveys. The ^{137}Cs plots indicate minimal sub-surface contamination around 241-A-106 and 241-A-101. Extensive soil contamination exists in the 241-SX farm, with higher levels of near surface contamination around 241-SX-101.

Figures 4-11 and 4-12 show soil resistivity measurements performed that may correlate to changes in soil moisture or indicate residual chemical contamination. These can be used to gauge relative differences in apparent buried soil contamination. Soil resistivity measurements suggest lowest moisture in the east end of 241-A tank farm and north end of 241-SX tank farm. This data suggest minimal risk with 241-A-106, 241-SX-101, and some risk in 241-A-101.

Figure 4-7: Current 241-A Farm Surface Contamination Map

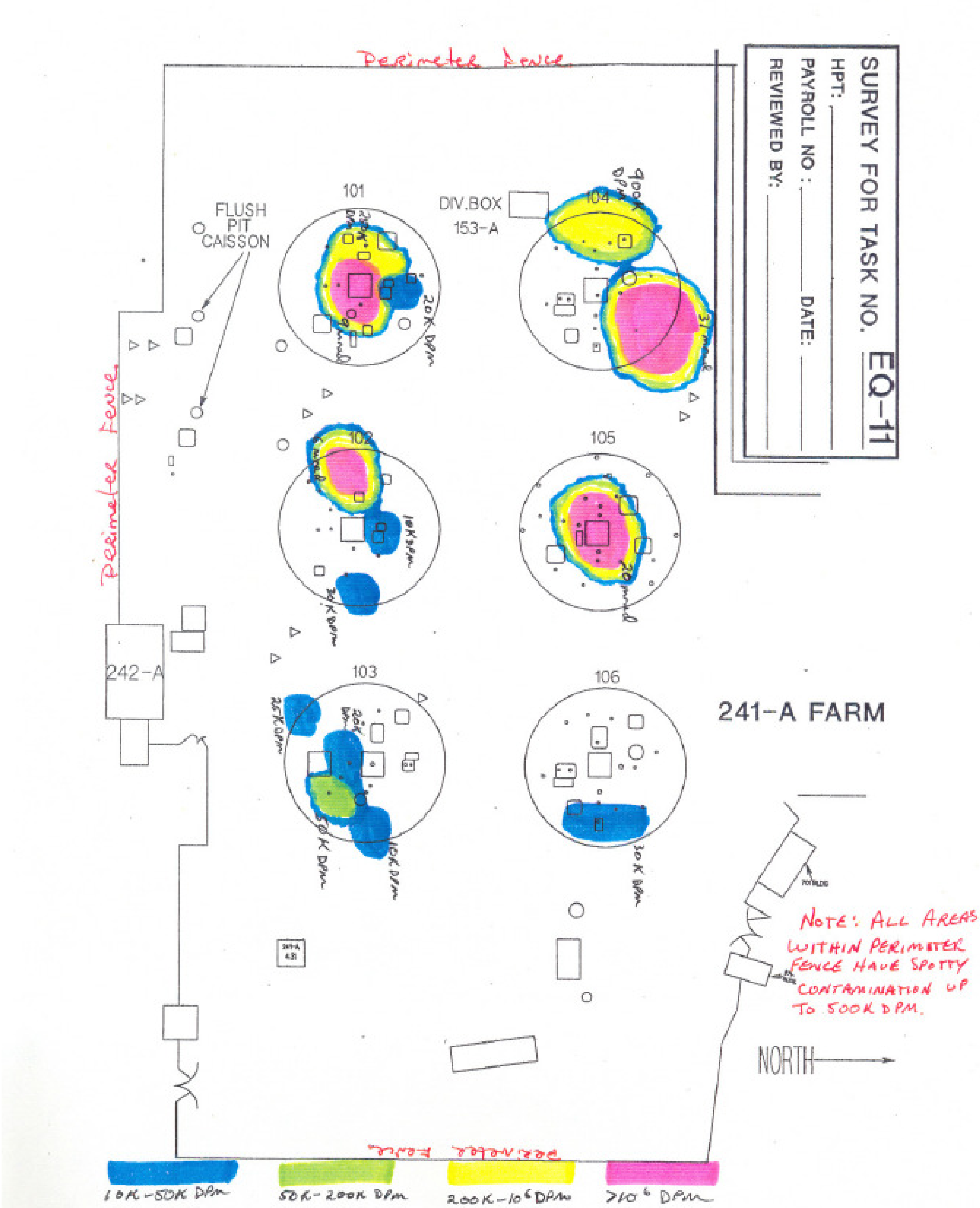


Figure 4-8: Current 241-SX Farm Surface Contamination Map

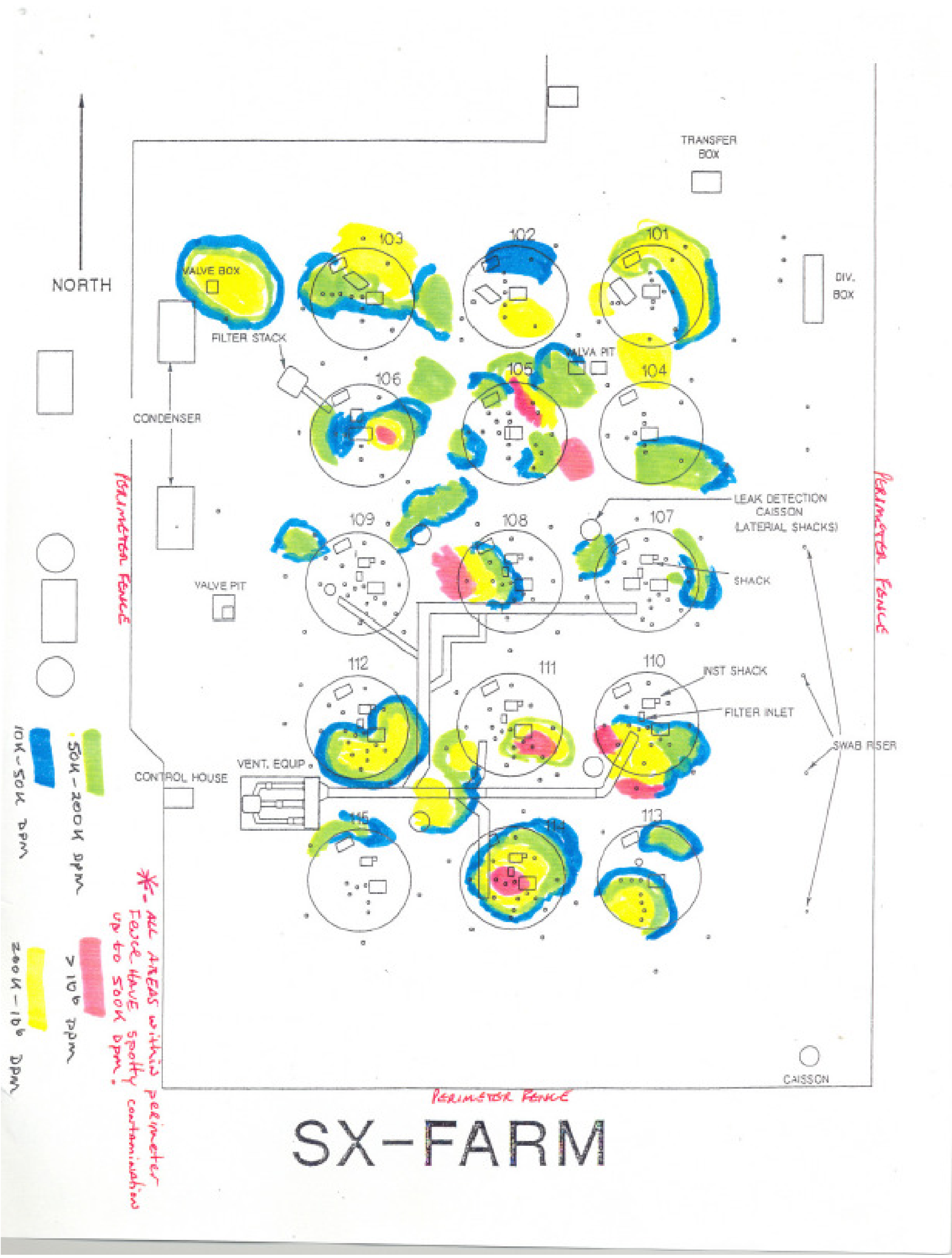


Figure 4-9: Estimated ^{137}Cs Concentration at 241-A Farm

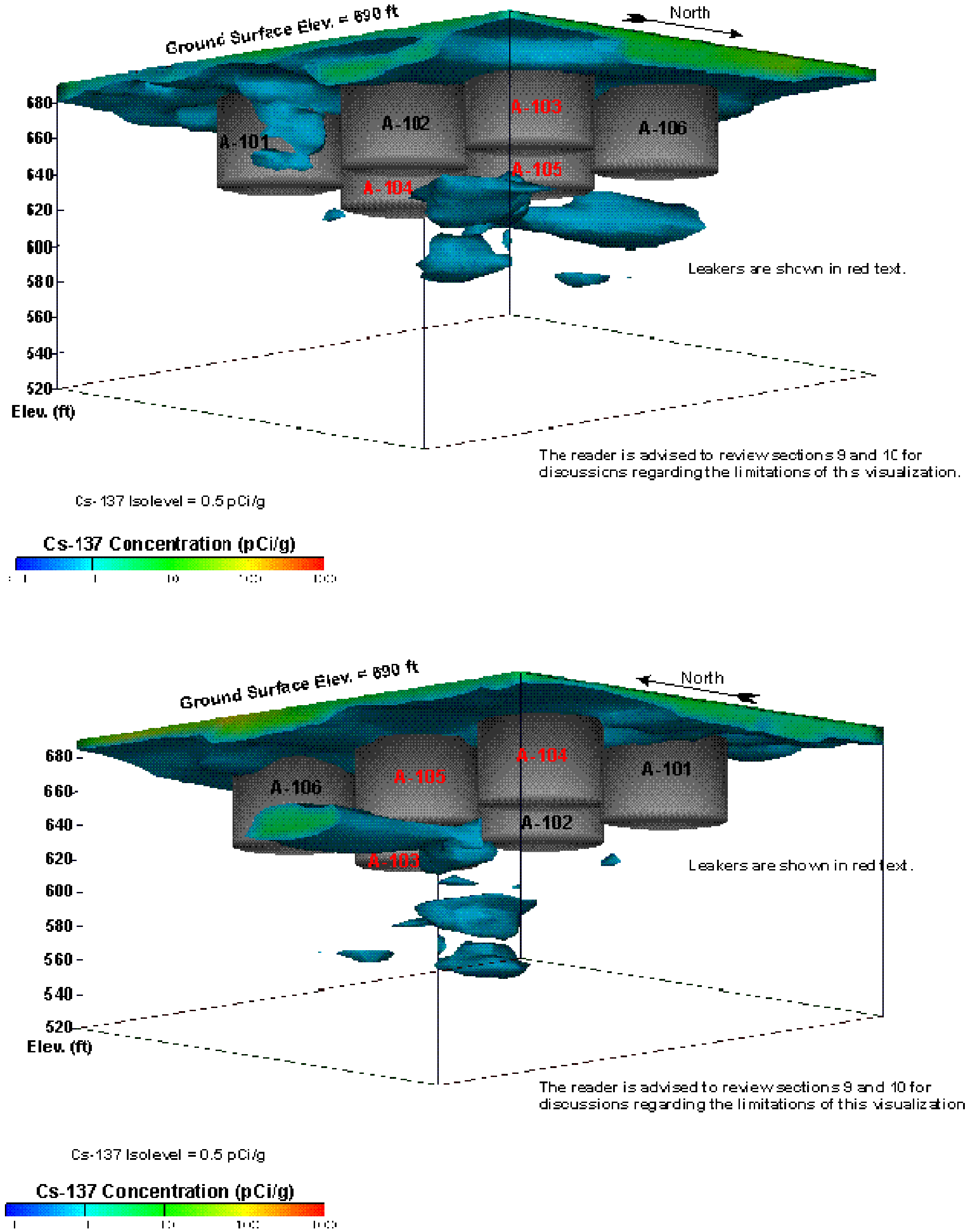


Figure 4-10: Estimated ^{137}Cs Concentration at 241-SX Farm

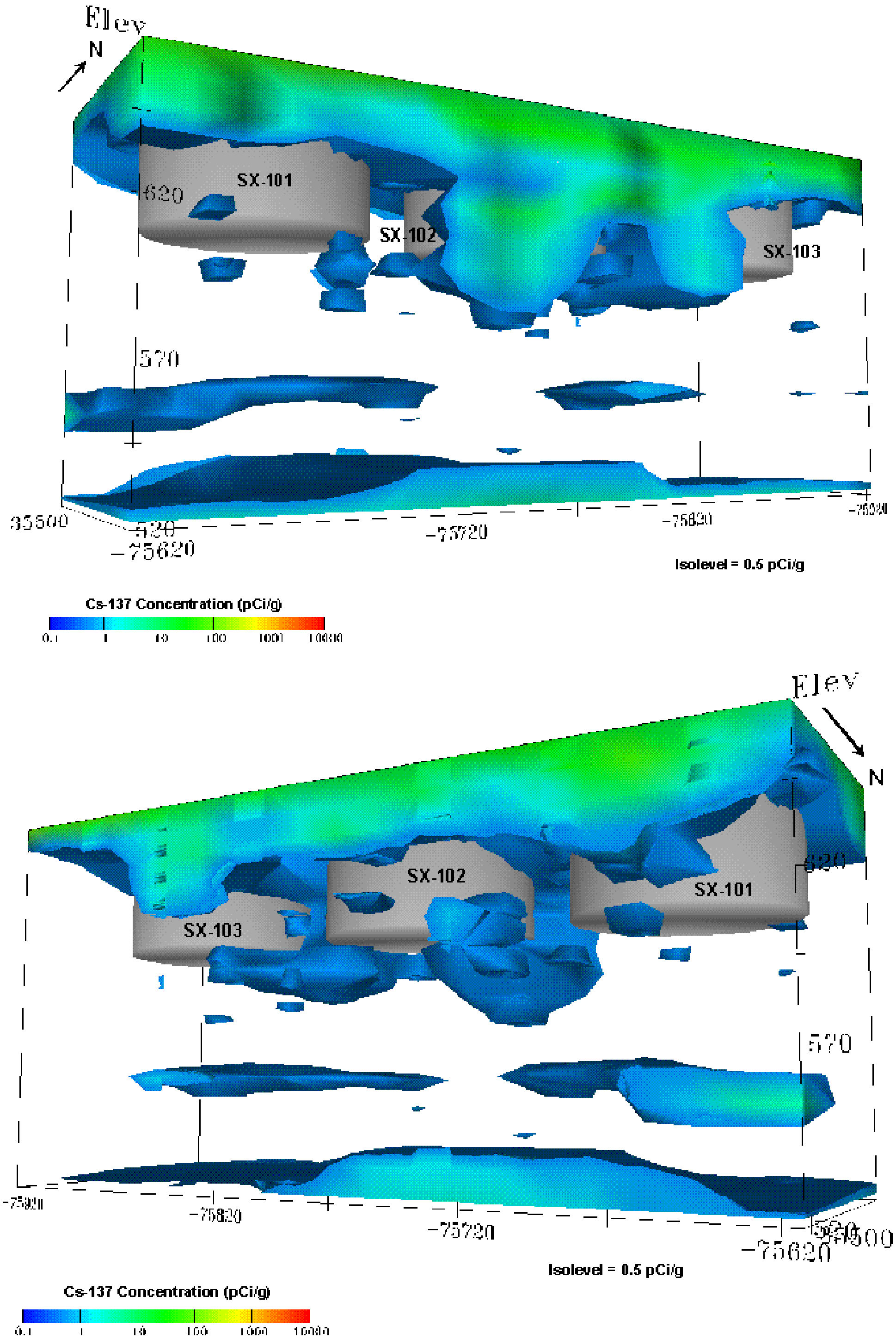


Figure 4-11: Soil Resistivity at 241-A Farm

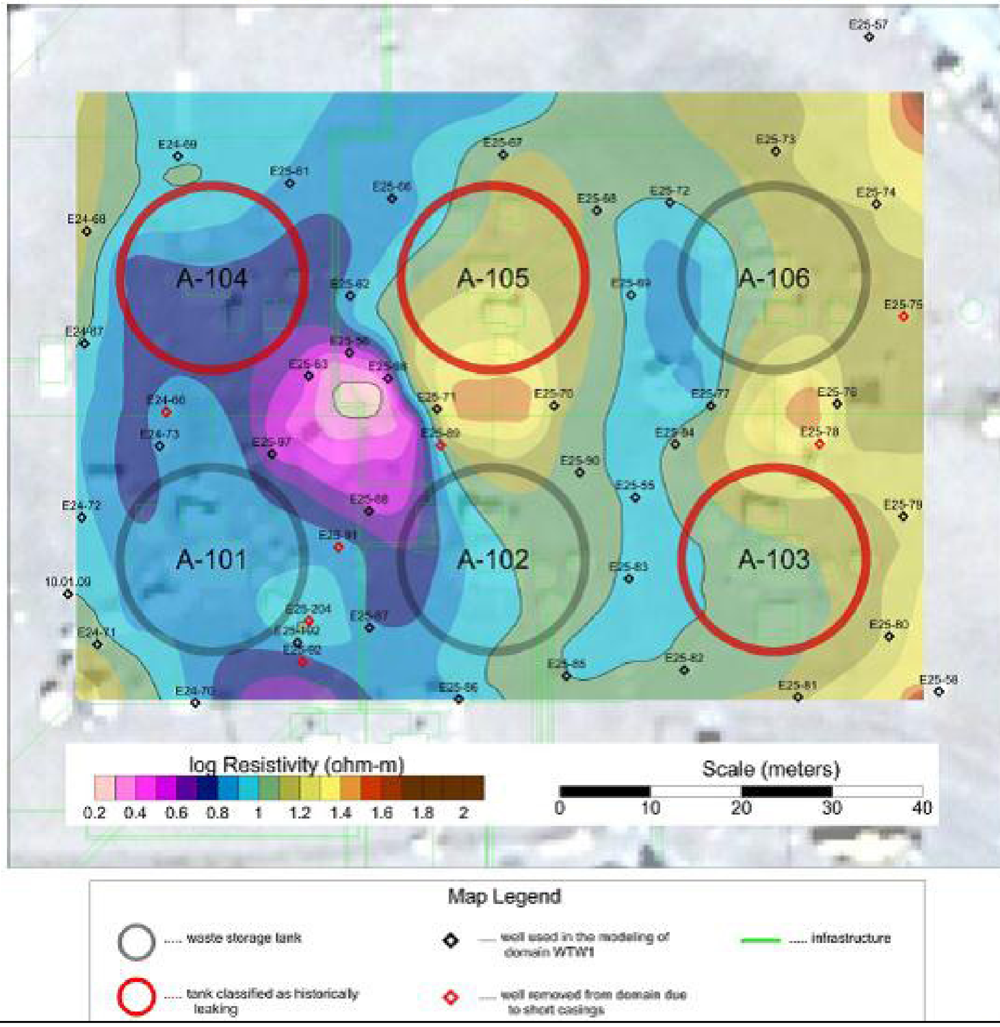
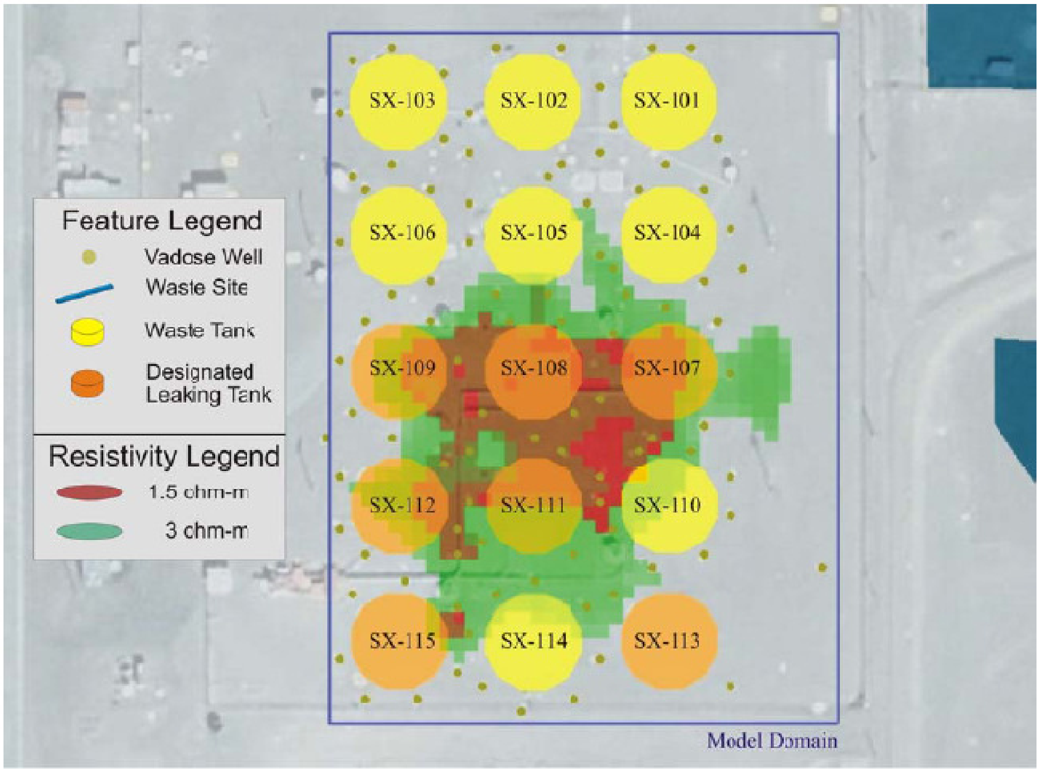


Figure 4-12: Soil Resistivity at 241-SX Farm



4.3.3 Summary of Tank Selection

In summary, based primarily on its bounding thermal history, tank 241-A-106 is the best choice for sidewall coring. A review of the risk factors validates the choice of this tank as having minimal impact from the risk factors of accessibility to the tank, including infrastructure interferences, interferences from retrieval, remaining waste volume and expected soil contamination surrounding the tanks.

Of the two contingency tanks, tank 241-A-101 represents a better second choice than tank 241-SX-101. Both tanks have a similar thermal history. Tank 241-SX-101 is more constrained from buried infrastructure and interferences. More extensive surface, near surface, and subsurface contamination is expected in 241-SX farm. These risks indicate, given the similar thermal history, tank 241-A-101 represents a better second choice.

4.4 SST CONCRETE CORES

The goal is to obtain a core of the SST sidewall. The testing and observations made are listed in the order of the steps of implementation.

- Non-Destructive Evaluation (NDE) performed in field
- Core Size
- Core Handling and Preparation
- Concrete Inspection

4.4.1 Nondestructive Evaluation (NDE)

The NDE was proposed by the Expert Panel in the February 25, 2011 out-brief. The approach recommended by the panel is acoustic wave technology. A hammer applies force to the tank sidewall and a receiver measures response. The response may indicate cracks or voids in the wall. The NDE performed on the tank will be performed prior to coring. The NDE would need to be correlated with an actual core and the visual inspection/testing of the core. If this technique is viable for the SST investigation, it could be used in the future to evaluate tanks without coring. The technical team stated that more investigation of this technique is needed before committing to perform the test.

4.4.2 Core Size

The core size is based on ASTM C42, *Standard Test Method for Obtaining and Testing Drilled Cores and Sawed Beams of Concrete*. The ASTM C42 states a minimum core diameter of 2.0 times the maximum aggregate size with a preferred core diameter of 3.0 times the aggregate size. Based on a maximum aggregate size of 1.5 inch, the minimum proposed core diameter is approximately 3.0 inches.

The following information is excerpted from ASTM C42/C42M-04:

> <u>Cores for Compressive Strength:</u>
>
> 7.1 Diameter—The diameter of core specimens for the determination of compressive strength in load bearing structural members shall be at least 3.70 in. [94 mm]… For non-load bearing structural members or when it is impossible to obtain cores with length-diameter radio (L/D) greater than or equal to 1, core diameters less than 3.70 in. [94 mm] are not prohibited (see Note 3). For concrete with nominal maximum aggregate size greater than or equal to 1 1⁄2 in. [37.5 mm], the core diameters shall be as directed by the specifier of the tests (see Note 4).
>
> NOTE 3—The compressive strength of nominal 2-in. [50-mm] diameter cores are known to be somewhat lower and more variable than those of nominal 4-in. [10-mm] diameter cores. In addition, smaller diameter cores appear to be more sensitive to the effect of the length-diameter ratio.
>
> NOTE 4—The preferred minimum core diameter is three times the nominal maximum size of the coarse aggregate, but it should be at least two times the nominal maximum size of the coarse aggregate.
>
> And, 7.2 Length—The preferred length of the capped or ground specimen is between 1.9 and 2.1 times the diameter. If the ratio of the length to the diameter (L/D) of the core exceeds 2.1, reduce the length of the core so that the ratio of the capped or ground specimen is between 1.9 and 2.1. Core specimens with length-diameter ratios equal to or less than 1.75 require corrections to the measured compressive strength [as identified in Section 7.9.1 of this standard]. A strength correction factor is not required for L/D greater than 1.75. A core having a maximum length of less than 95% of its diameter before capping or a length less than its diameter after capping or end grinding shall not be tested.

The maximum aggregate size for 241-A-106 is 1.5 inches. The spacing between the horizontal hoop rebar is 7.785 inches center-to-center (see Drawing H-2-55913), resulting in approximately 8.0 inches of space that is available for coring without cutting the rebar. Standard core tooling has been selected to meet both the core specimen size requirements as well as the requirement to minimize cutting the horizontal hoop rebar. The selected core tooling will retrieve a core diameter of 3.1 inches, which meets the minimum requirement identified in ASTM C42/C42M-04. The maximum length of intact core that could be retrieved in one core run will be 5 feet. There is flexibility in the lengths of core that can be retrieved, which enables maximum retrieval of usable core specimens at select tank wall locations.

In accordance with ASTM C42/C42M-04, the minimum length of a concrete specimen with a diameter of 3.1 inches shall be approximately 5.89 inches to 6.51 inches Using a length of 6.5 inches as a conservative approach, a maximum of nine core test specimens will be produced from each 5-foot core run. The objective of the coring of the tank sidewall is to obtain approximately 38 feet of concrete core from the tank haunch, sidewall, and tank footing. Assuming all core runs produce 5 feet of intact core, a total of 69 core specimens could potentially be provided for testing: 9 from the tank haunch, 58 from the tank sidewall, and 2 from the tank footing.

The number and size of specimens is subject to change based on demonstration results, retrieved core qualities, and the desired specimen locations.

4.4.3 Core Handling and Preparation

Handling of the core is important so that the core is not altered from its in-situ state. In order to preserve moisture conditions of the core, ASTM C42 recommends:

- Wiping off surface water from drilling
- Allowing remaining surface moisture to evaporate
- Placing cores in any sealed non-absorbent container (such as poly vinyl chloride pipe or a sealed plastic bag, and cap ends within 1 hour after removal
- Transporting to a qualified laboratory

At the laboratory and before testing, the ends of the core should be cut and capped in accordance with ASTM C42 and ASTM C39/C 39M-05, *Standard Test Method for Compressive Strength of Cylindrical Concrete Specimens*.

4.4.4 Core Inspection

A major part of the coring is inspection. The following will be performed in the field.

- Field notes will be taken during coring and will include descriptions of observations during drilling, including stoppage of the drilling due to problems and weather.
- The cores will be uniquely identified and connected to the section of the tank from which the core is removed. For example cores will be identified so that the order from the haunch to the footer can be reconstructed. Numbers and logs will connect which sections of core are sent for testing. At the laboratory, the laboratory will track each core by its identity so that the measured properties can be connected to a vertical profile of the core.
- The geometry will be measured for each core and documented.
- Any cracks or voids will be measured and documented.
- The condition of the core will be documented by depth.
- The core hole will be surveyed using a borehole camera. The survey video will be recorded.

4.4.5 Opportunistic Rebar Inspection and Testing

In the event that rebar is encountered and removed during the SST Sidewall Coring, the rebar will be inspected and, if it is a suitable size, tensile tested. If removed, the diameter of the rebar will be measured and photographs taken. The rebar would be inspected for rust and scaling. Any crack or elongated sections will be measured. If the rebar is suitable for testing, the testing of the rebar would be limited to tensile testing. As the function of rebar in reinforced concrete is to provide tensile strength, only tensile strength would be desired. The specimen would be prepared and tested in accordance with Appendix A9 of ASTM A370, *Standard Test Methods and Definitions for Mechanical Testing of Steel Products.*

4.5 LABORATORY TESTING OF SST CONCRETE CORES

Both nondestructive and destructive testing will be performed on the recovered concrete core. For purposes of this sidewall coring activity, nondestructive testing is defined as comprising those test methods that will not result in any permanent deformation or alteration of the concrete core. Destructive testing is defined as those test methods that render the core specimen as unusable for further testing. The nondestructive testing will be completed first, followed by destructive testing. [Ref RPP-PLAN-47370, Rev. 0]

Tests will encompass structural design parameters used in the AOR model and give a good indication of the overall strength and quality of the concrete.

- Ultrasonic Pulse Velocity (UPV) – ASTM C597
- Modulus of Elasticity – ASTM C469
- Poisson's Ratio – ASTM C469
- Compressive Strength – ASTM C39
- Petrographic Analysis – ASTM C856

The results of the completed testing will be provided to WRPS for further analyses. The results of these tests will be compared to predicted strengths, derived from design strengths, used to assess the structural integrity of the tank sidewall through the analysis of record (AOR) model. In addition, this testing will assess any thermal degradation. [Ref RPP-PLAN-47370, Rev. 0] The testing will also provide visual assessment of the concrete and identification of cracks or voids that are important to assess the current condition of the concrete.

All nondestructive and destructive testing will be performed at an International Standard Organization (ISO-17025) accredited structural testing laboratory or an equivalent quality assessment will be performed to verify that the laboratory has appropriate equipment, staff experience, and facilities.

4.5.1 Non-destructive Testing Performed in the Laboratory

The following nondestructive tests will be performed on the concrete core.

- Ultrasonic Pulse Velocity (UPV) per ASTM C597-09, *Standard Test Method for Pulse Velocity Through Concrete*. This test method is used to assess the uniformity and relative quality of concrete, and is also applied to indicate changes in the properties of the concrete. It can also be used to estimate the severity of deterioration or cracking in structures.

  Pulses of longitudinal stress waves are generated by an electro-acoustical transducer that is held in contact with one surface of the concrete under test. After traversing through the concrete, the pulses are received and converted into electrical energy by a second transducer located at a specified distance from the transmitting transducer. The transit time is measured electronically and the pulse velocity is calculated.

  The UPV test serves to measure elastic wave velocities in the material and provide correlation data between the static elastic properties of the sidewall concrete (i.e., compressive strength and modulus) and the elastic wave velocities. This data may be significant to other tank assessments and nondestructive activities. Since the relationship between (static) elastic properties of the concrete and the UPV is empirical in nature, this data will be necessary to effectively implement acoustic–based nondestructive examination for the concrete in the future, if it is determined to be necessary. Additionally, abnormal test results from UPV and static testing may indicate localized damage within a specific core, and this may assist in the interpretation of the test results.

The UPV tests will be performed on all available core specimens.

- Modulus of elasticity and Poisson's ratio per ASTM C 469-02, *Standard Test Method for Static Modulus of Elasticity and Poisson's Ratio of Concrete in Compression*. This test method covers determination of (1) chord modulus of elasticity (Young's), and (2) Poisson's ratio of molded concrete cylinders and diamond-drilled concrete cores when under longitudinal compressive stress. This test method provides a stress-to-strain ratio value and a ratio of transverse-to-longitudinal strain for hardened concrete. The modulus of elasticity and Poisson's ratio values are used in sizing reinforced and non-reinforced structural members, establishing the quantity of reinforcement, and computing stress for observed strains.

$$\text{Modulus of Elasticity} = \text{stress (psi)}/\ \text{strain (in/in)}. \qquad (1\text{-}1)$$

Modulus of Elasticity determines stiffness of structural members, and computing stress for observed strains. Load is applied and strain (ΔL/L) is measured by a wire strain gage or linear variable differential transformer

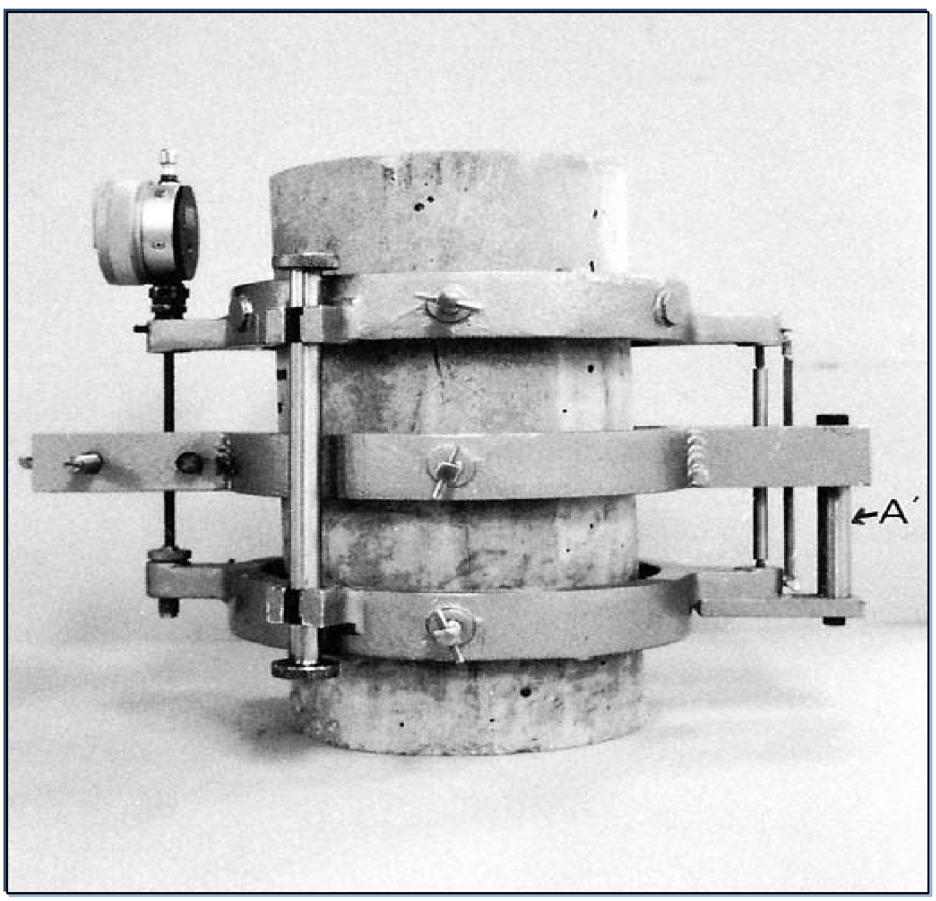
$$Poisson'sRatio = v = \frac{\text{trans}}{\text{longitudinal}} where\ = \Delta\text{L/L}\ ) \qquad (1\text{-}2)$$

Poisson's Ratio determines static elastic properties of concrete core and is compared to empirical results gained from UPV tests

The combined compressometer-extensometer pictured below in Figure 4-13 determines transverse strain by measuring change in diameter at the mid-height of the specimen.

The modulus of elasticity and Poisson's ratio tests will be performed on all available core specimens.

Figure 4-13: Combined Compressometer-Extensometer



4.5.2 Nondestructive Testing Not Performed

Common nondestructive testing that will not be performed includes the Schmidt hammer, Windsor probe, and Impact-Echo tests. The Schmidt hammer and Windsor probe test methods are used to estimate in-place strength of concrete. These two test methods would require testing be performed on the tank haunch within the caisson; therefore, to be in accordance with as low as reasonably achievable (ALARA) principles, these tests will not be performed. It should be noted that these tests were also abandoned for the SST 241-SX-115 core drilling task that was completed in 1981.

Since compressive strength testing in the laboratory will be conducted on all available core specimens, it is unnecessary to perform these additional strength tests. These tests, among many of the other possible field tests on the intact structure, would only provide information for the tank haunch. The Impact-Echo test is used for the location and characterization of internal discontinuities. This test is unnecessary as it is similar to the UPV test that will be performed in the laboratory, thus providing similar information.

4.5.3 Destructive Testing

The following destructive tests will be performed on the concrete core specimens.

- Compressive strength per ASTM C39/C39M-05, *Standard Test Method for Compressive Strength of Cylindrical Concrete Specimens*. This test method provides standardized procedures for the determination of compressive strength of cylindrical concrete specimens such as molded cylinders and drilled cores. This consists of applying a compressive axial load to molded cylinders or cores at a rate which is within a prescribed range until failure occurs. The compressive strength of the specimen is calculated by dividing the maximum load attained during the test by the cross-sectional area of the specimen.

- Petrographic analysis per ASTM C856-04, *Standard Practice for Petrographic Examination of Hardened Concrete*. The petrography examination will assess the quality and condition of the concrete and extent of any deterioration or deleterious reactions occurring within the concrete. Petrographic analysis will evaluate microcracking and discoloration of the cement associated with exposure to elevated temperatures.

  Petrographic analysis of the concrete core materials at different depths will be useful for characterizing the susceptibility of materials to corrosion-induced damage, chemical attack and extent, if any, of thermal damage in the cement matrix and cement paste/aggregate bonding characteristics. Such analysis typically includes the evaluation of sulphate attack, acid attack, chloride content, alkaline-silica reactivity, porosity, and evaluation of micro-cracking and discoloration of the cement associated with exposure to elevated temperatures.

Compressive strength will be performed on all available core specimens. A minimum of three core specimens will be reserved for conducting the petrographic analysis on intact core. The remainder of the petrography examinations will be conducted on core pieces remaining from cutting the core specimens to size or on fragments of fractured core not otherwise used for testing.

4.5.4 Destructive Testing Not Performed

Tensile strength testing of the core specimens will not be conducted. As discussed in RPP-46442, *Single-Shell Tank Structural Evaluation Criteria*, concrete tensile strength should be taken as zero (or as near zero as practical for convergence of the finite-element solution) in structural analyses of the SSTs. The concrete tensile strength will not be used in calculating the structural capacity of any tank.

Other mechanical tests not being performed, such as flexural strength and shear strength, are calculated using the compressive strength, and therefore not required to be directly tested.

The petrography examination will assess any chemical degradation of the concrete, rendering additional chemical tests unnecessary at this time. Due to the limited amount of core, additional chemical tests are not warranted, nor feasible.

4.5.5 Summary of Core Handling and Testing

In summary, the core samples will be properly handled to maintain their integrity. The core samples will undergo both non-destructive and destructive testing. The results of the laboratory testing will provide properties that will be evaluated and compared to the properties used as input to the finite element modeling performed in the AOR. The elastic modulus and compressive strength are properties used in the AOR, see Appendix A of the RPP-46442. All cores will be documented and any cores not tested will be archived in a manner to allow for possible additional future evaluation.

4.6 SELECTION OF CONCRETE TESTING LABORATORIES

A market search was performed to find qualified laboratories currently testing concrete for the parameters previously discussed. The primary goal was to find qualified laboratories that can perform both non-destructive and destructive testing. Secondary evaluation goals included accreditation, location, and ability to accept radiologically contaminated test specimens.

The laboratories surveyed included commercial, national, and other government organizations. Seven commercial laboratories were contacted and only two of those contacted can perform all required strength testing. At the date of this document, neither of the laboratories that can perform all of the required testing had confirmed that it is capable of accepting radioactive specimens.

The two commercial laboratories are Commercial Testing Laboratories (CTL) with locations all over the United States, and Professional Service Industries, Inc. (PSI) located in Portland, OR. CTL is American Association of State Highway and Transportation Officials (AASHTO) certified. PSI is accredited to ISO 17025 by the American Association for Laboratory Accreditation (A2LA). Certification and accreditation differ in that certification does not evaluate technical competence and implementation of a quality system, while accreditation requires technical competence and implementation of quality systems.

Eight national laboratories were contacted. Two of the laboratories, Los Alamos and Lawrence Livermore, could perform some strength tests and could accept radioactive specimens but require much more detail and communication about the test requirements and the radiation levels. Neither national laboratory routinely performs these tests. Brookhaven expressed interest and is looking into their capabilities.

The other facilities contacted included the Navy, Bureau of Reclamation, and Tennessee Valley Authority. The Navy has provided information and neither of the other two have the capability.

Of five private facilities contacted, Babcock and Wilcox can accept radioactive specimens but dose and nuclides must be discussed in advance. Babcock and Wilcox can only perform one test, compressive strength testing on a 50,000 pound load frame which is lower than the optimum testing requirement. Two of the five, Energy Northwest and MSE Technologies, Inc., have no capability and information is pending from the remaining two laboratories, Soil and Materials Engineers (S&ME) and Lucius Pitkin, Inc.

In summary, as of the date of this document, two commercial laboratories can perform required testing, provided the cores are not radioactive. Selecting tanks based on high heat, non-leaking, and using existing data to assist in evaluation of radioactivity around the tank coring vicinity increase the likelihood of obtaining non-radioactive cores. The sampling and analysis plan will provide some contingencies should cores be radioactive. See PSQs P2Q12 a, b, and c and Section 1.3, Technical Issues for more information. During the DQO process the DQO Team agreed that if a core is radiologically contaminated, Ecology would be contacted by DOE. Another search for a laboratory that could accept the core would be performed, and Ecology notified if a suitable laboratory is not found.

4.7 CORING OBJECTIVES AND APPROACH

The objectives of coring are:

- Avoid cutting the horizontal hoop rebar
- Core from the tank haunch down through sidewall and into but not through the footer
- Maintain vertical deviations to prevent damage of the tank steel liner or external concrete sides of the tank.

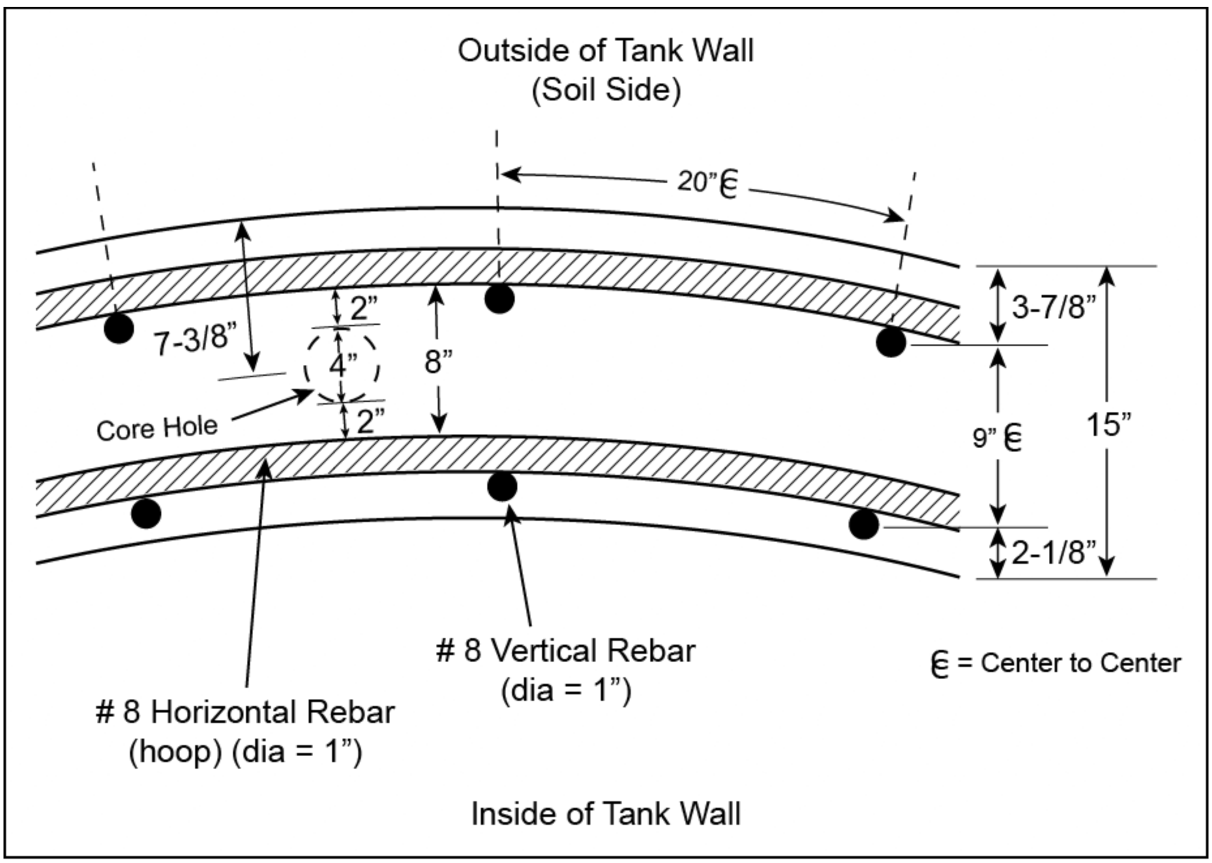
In order to achieve these objectives it is critical to clearly understand the diameter of the hole with respect to the tank wall thickness and vertical alignment that must be maintained.

Figure 4-14, Top View of Tank Wall, shows the distance between horizontal hoop rebar is 8 inches. Outside diameter for the current proposed core bit is 4 inches. A 3-inch diameter core is needed for compression testing. The 4-inch outside diameter will result in a 3-inch diameter core. The maximum deviation tolerance is 2 inches from the center of the core hole.

Initial calculations for coring tolerances are based on coring a Type IVA SST. Current as-built drawings for 241-A tank farm depicting "typical" tank construction were used for dimensions. The total length of the core hole, including a guide tube located above the drilling platform to 12 inches into the tank footing, is estimated to be approximately 55 feet as shown in Figure 4-15, Core Hole Configuration with Guide Tube. Assuming a proposed 4 inch outside diameter core hole with a completion depth of 55 feet from the top of the diverter to approximately 12 inches into the tank base, the maximum angle of deviation is 0.1736230° (0 degrees, 10 minutes, 25 seconds (0° 10' 25")). This equals a maximum deviation of 0.364 inch for every 10 feet of core hole advancement. Figure 4-16 Maximum Angle of Deviation The maximum angle of deviation will be recalculated based upon actual set-up configuration before initiation of SST sidewall coring. The actual tank design lengths, wall widths, heights, and rebar distances will be used based on tank(s) selected. The sampling design section of this document will address how deviation control will be maintained, and provide additional coring equipment details.

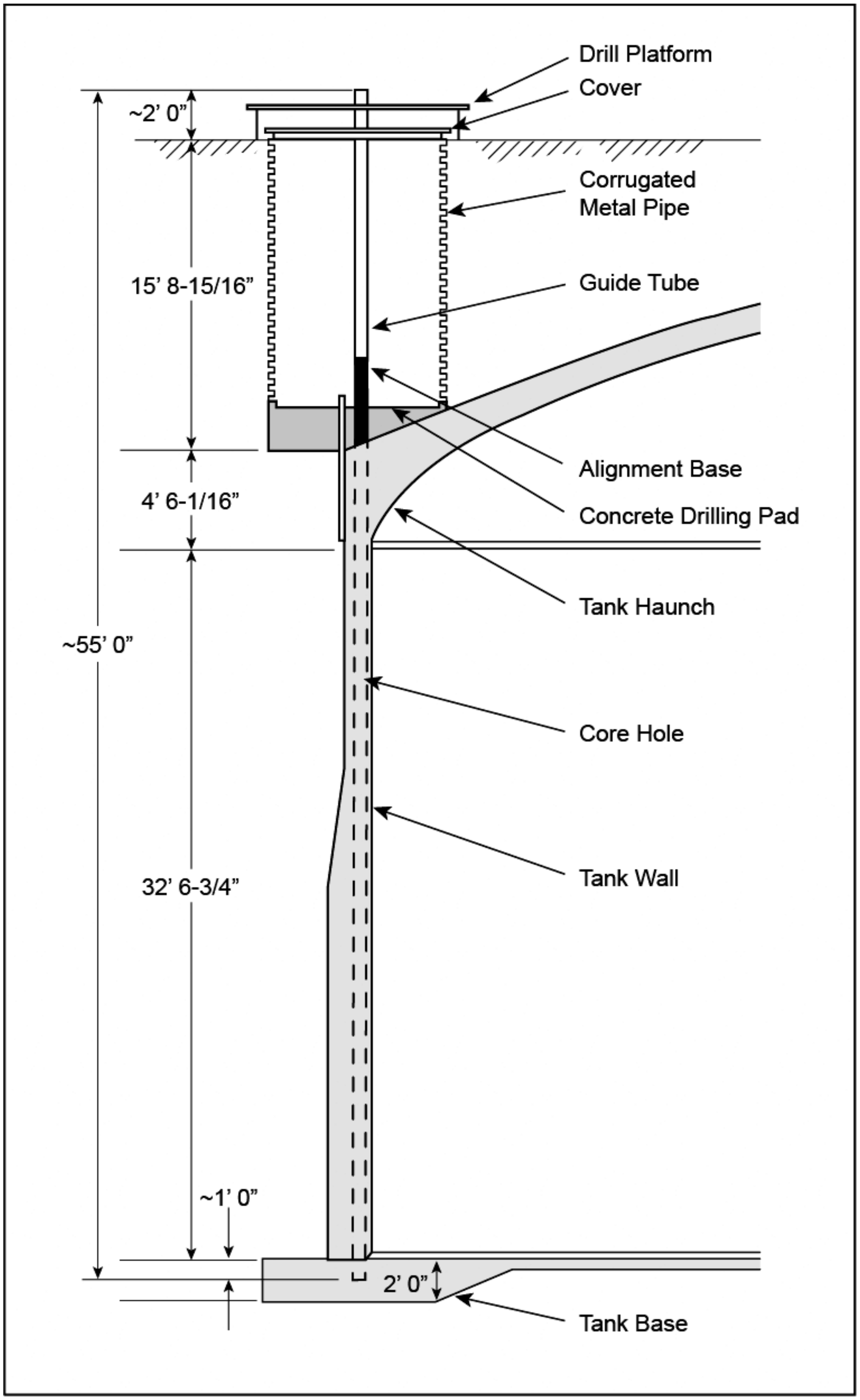
Core drilling will not advance through the footer. From the previous coring of 241-SX-115 it is thought that the core hole extended through the footer and the contamination encountered came from under the footer, resulting in a radioactive core. This contaminated core specimen was disposed and not made available for analysis. Depending on the tank selected, Figures 4-7, 4-8, 4-9, and 4-10 show potential radiological contamination below some tanks. The goal is to obtain a non-radiologically contaminated core, so test results can be focused on concrete degradation resulting from high heat exposure only and to provide more options for selection of testing laboratories. Due to the limited availability of qualified laboratories to conduct some or all of the required testing on radiologically contaminated specimens, drilling into, but not through, the footer increases the probability of obtaining an uncontaminated, testable core.

Figure 4-14: Top View of Tank Wall



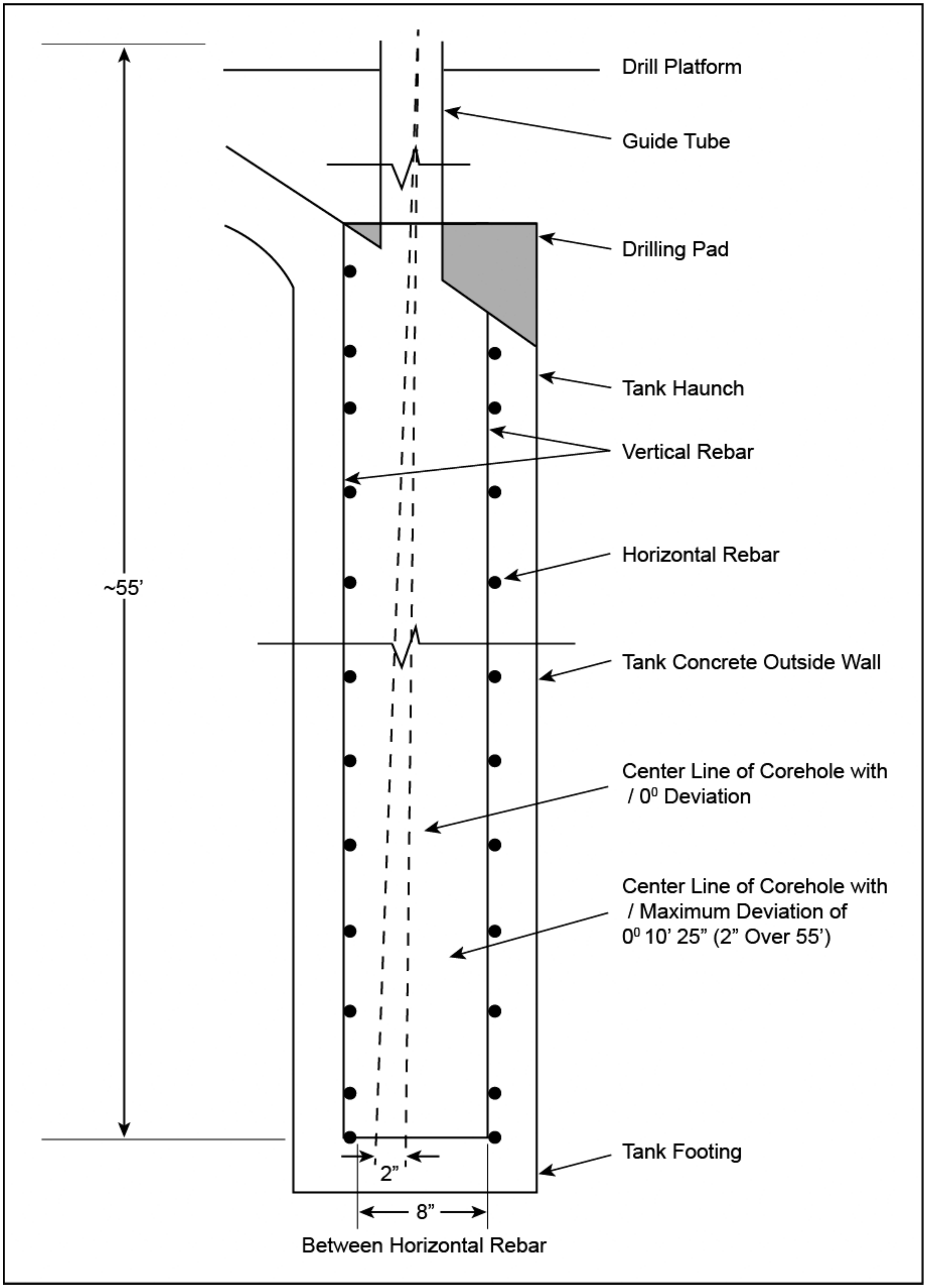
Not to scale.

Figure 4-15: Core Hole Configuration with Guide Tube



Not to scale.

Figure 4-16: Maximum Angle of Deviation



Not to scale.

4.8 CONFIRMING THE PROPERTIES USED IN THE MODELING EFFORT

The first expert panel recommendation was to perform modern structural analyses. The panel recommended that modern structural analyses should be performed on representative samples of SSTs exposed to high heat. The recommendation states "reasonable bounding estimates of material properties should be used in theses analyses." Sidewall coring can provide an indication as to how reasonable estimates of material properties are, and whether assumptions should be revisited and changed.

4.9 POST CORING

After coring is completed, if a repair is warranted, the IQRPE will certify the repair. The structural analysis performed initially may show that grouting is not needed to maintain structural integrity, and the hole may be kept open for possible future investigations.

5.0 DQO STEP 4 – DEFINE THE STUDY BOUNDARIES

The boundary section of the DQO establishes the populations for sampling and decision making. Time is also considered because properties may change with time.

5.1 SPATIAL BOUNDARY

The spatial boundary for sidewall coring is defined as the haunch, sidewall, and into but not through, the footer of the tank chosen for coring. Care must be taken to avoid both vertical and horizontal rebar in the tank sidewall (Figures 4-13 and 4-15), so the boundary is further narrowed to areas between rebar. It is also important to avoid any portion of the tank near contaminated soil in order to decrease the likelihood of coring contaminated concrete. Therefore, the tank section chosen for coring should be away from a tank that has leaked, if possible. The final consideration is whether the location to be cored is accessible for drilling equipment. Figures 4-13 and 4-14 provide pictures of the boundaries associated with drilling down the sidewall of an SST.

5.2 TEMPORAL BOUNDARY

All dates that follow are based upon dates for TPA Interim Milestones M-045-91B, M-045-91B-T01, and M-045-91H. If an update to the milestones and their dates occurs, the following dates may change.

The DQO report and the SAP will be written in fiscal year 2011 (FY11) (M-045-91B). The coring demonstration will take place during FY11. The structural analysis, engineering analysis, project hazards analysis, development of work plan, and other planning activities will take place in FY12. The core will be removed and tested in FY13 with the report due to Ecology in September 2014 (M-045-91B-T01). Testing results will be compared to mechanics properties used in the AOR once available. (FY13) Discussions on whether a second core will be obtained will take place by the end of July 2015 (M-045-91H).

There are no sample hold time limits affecting viability of concrete core samples, analyses, and subsequent data validation. The ASTM gives recommendations on core handling, such as test within five days of coring. This is primarily to prevent moisture exchange after coring so the sample will remain representative of the structure tested. It is of less concern in aged structures, but the cores should be wiped dry and bagged and wrapped to prevent moisture exchange and mechanical damage prior to testing.

6.0 DQO STEP 5 – DEVELOP DECISION RULES

The decision rules in the DQO process are normally based on quantitative criteria. A typical rule is 'if the soil is contaminated above 5 pCi/g with Cs-137, dispose in mixed waste landfill; otherwise leave the soil in place.' In this project quantitative decision criteria are not available and the number of samples is not based on statistical sampling. Therefore, decisions are based on logic presented in Figure 1-1.

Key points in the decision logic are whether to obtain a sidewall core from a SST and selection of applicable SST(s) to core. As stated in Figure 1-1, a key decision point will be the results from the coring demonstration and structural evaluation reviewed by the IQRPE.

7.0 DQO STEP 6 – SPECIFY TOLERABLE LIMITS ON DECISION ERRORS

As stated in Section 1.1, no statistics will be applicable to this sampling effort. The sample size of one core does not allow statistics, and treating multiple samples from a single core as statistically similar is inherently fallible.

8.0 DQO STEP 7 – OPTIMIZE THE DESIGN FOR OBTAINING DATA

Based on previous steps, and objectives for worst-case assessment within ALARA principles, a non-random sampling design will be used. The plan is to core a tank having withstood amongst the highest heat seen in a non-leaking SST. Thus, the data will be considered a worst-case scenario. The following sections outline the sampling design. This represents the best understanding of planning coring activities at the time, but is subject to change and improvement as design, detailed planning and demonstration activities progress.

8.1 PREPARATION FOR CORE DRILLING

Preparation for drilling includes initial soil characterization, installing the caisson, and pouring the concrete drilling pad. The steps to prepare for core drilling are in the following sections.

8.1.1 Selection of Drilling Location

Three sites in a quadrant along the tank wall will be selected as potential locations for tank sidewall coring. Ground-penetrating radar survey data will be used to select these sites to avoid subsurface interferences.

Radiation surveys will be conducted on the soil surface within the selected sites prior to initiating excavation. Surface soil samples may be collected from each of the three selected sites and transported to an onsite analytical laboratory for radiological and chemical contaminants analysis, if warranted.

8.1.2 Structural Analysis

Prior to excavation to expose the tank haunch, a structural analysis will be completed to determine possible structural effects resulting from the removal of soils from the dome and haunch areas of the tank (RPP-PLAN-47370). This study may reveal the need for additional measures or engineering for the installation of the caisson. This will also ensure the core hole does not weaken the tank wall.

The completed structural analysis will be reviewed by an IQRPE to assure the tank will remain structurally sound during and after core drilling.

8.1.3 Caisson Installation

To facilitate coring of the tank sidewall, surface soil will be excavated at the selected target location to expose the tank haunch, and an 8-foot diameter caisson will be installed to an estimated depth of 15 feet below grade to allow access to the haunch and sidewall (RPP-PLAN-47370). Prior to conducting any work, a statement of work, detailed procedure, engineering drawings, and work plan will be prepared. The soil excavation will be conducted by a construction subcontractor and accomplished using a government-owned mini-excavator and/or guzzler. As excavation advances, the engineered caisson will be installed in sections and secured until final depth is achieved.

The top of the caisson should extend approximately 1 foot above ground surface to prevent surface water from entering, and the bottom of the caisson should extend approximately 1 foot below the top of the haunch, approximately 17 feet below ground surface. The caisson should be centered over the tank wall. The open area behind the caisson will be backfilled and compacted with clean material. The surface area surrounding the top of the caisson will be leveled and prepared for staging coring equipment. A lid with access hatches will be fabricated for placement over the caisson. A permanent metal access ladder will be mounted on the side of the caisson. Figure 4-15 portrays the installed caisson. Appropriate lighting and ventilation will be installed as needed.

8.1.4 Locating Core Hole Entry Point on Wall

Once the caisson is in place, radiation levels at the exposed tank haunch will be measured and appropriate precautions taken to minimize dose rates. The surface of the tank haunch will be thoroughly cleaned down to bare concrete to allow for visual examination. The acoustic method of concrete determination may be carried out if research supports its use. Other than visual examination and, possibly, the acoustic method, no other nondestructive examination will be performed on the haunch concrete. The concrete surface will be prepared in a manner that provides a good surface for bonding of cement (i.e., scarring) allowing a drilling pad to be poured in the bottom of the caisson. A good cement bond is required to prevent water leakage at point of entry during the coring activities. Vertical angle iron stakes may be driven and secured against the tank wall and will extend through the drilling pad surface approximately 12 inches to aid in locating the centerline of the wall (RPP-PLAN-47370).

Prior to pouring the drilling pad, up to three locations along the exposed tank haunch will be selected for coring points of entry, one being the primary target and others as alternate targets. Each location will be surveyed to pinpoint the centerline of the wall between the horizontal hoop rebar. A prefabricated alignment base section will be secured to the tank haunch at each selected coring point target location to serve as starter for installing the guide tube. The alignment base, prefabricated to the angle of the haunch, will be bolted or otherwise secured to the tank haunch, and will extend approximately 3 feet above the top of the drilling pad.

It is critical that the alignment base be perfectly aligned and vertical. Levels and surveying techniques will be used to ensure verticality. Once the alignment base is secured in place, a final survey will be performed for location and elevation. This alignment base will provide the starter for the guide tube to be installed above the drill work platform following installation of the drilling pad. Refer to Section 8.2.2, “Deviation Control Strategy,” for alignment of the guide tube. The length of the guide tube, coupled with the centralization of the core tool string and use of stiff core rods, provides a high level of confidence that a vertical start will be achieved, and verticality of the core hole will be maintained throughout the coring process.

Multiple target locations are chosen so coring can continue if drilling problems such as contamination, vertical deviation, or a large void are encountered. Criteria for determining when it is appropriate to change locations will be set forth in the work plan.

8.1.5 Concrete Drilling Pad

Once the alignment base is installed, a concrete drilling pad will be poured to cover the exposed tank haunch, using the caisson as the concrete form. The pad should be as level as possible; however, it should gradually slope upward at the outside edges of the caisson to create a lip for water containment. The drilling pad shall be allowed to cure for a minimum of seven days before initiating drilling activities.

8.2 CORE HOLE DEVIATION CONTROL

Maintaining verticality of the core hole is essential to reduce the potential for cutting horizontal hoop rebar or penetrating the sides of the concrete sidewall. It is accepted that cutting of rebar in the tank haunch may occur due to the density of the reinforcing rebar. It is not the intent of this project to drill through or cut any rebar in the SST sidewall, particularly the horizontal hoop rebar. Extreme care will be taken to avoid drilling through or cutting rebar while performing the SST sidewall coring.

8.2.1 Criteria

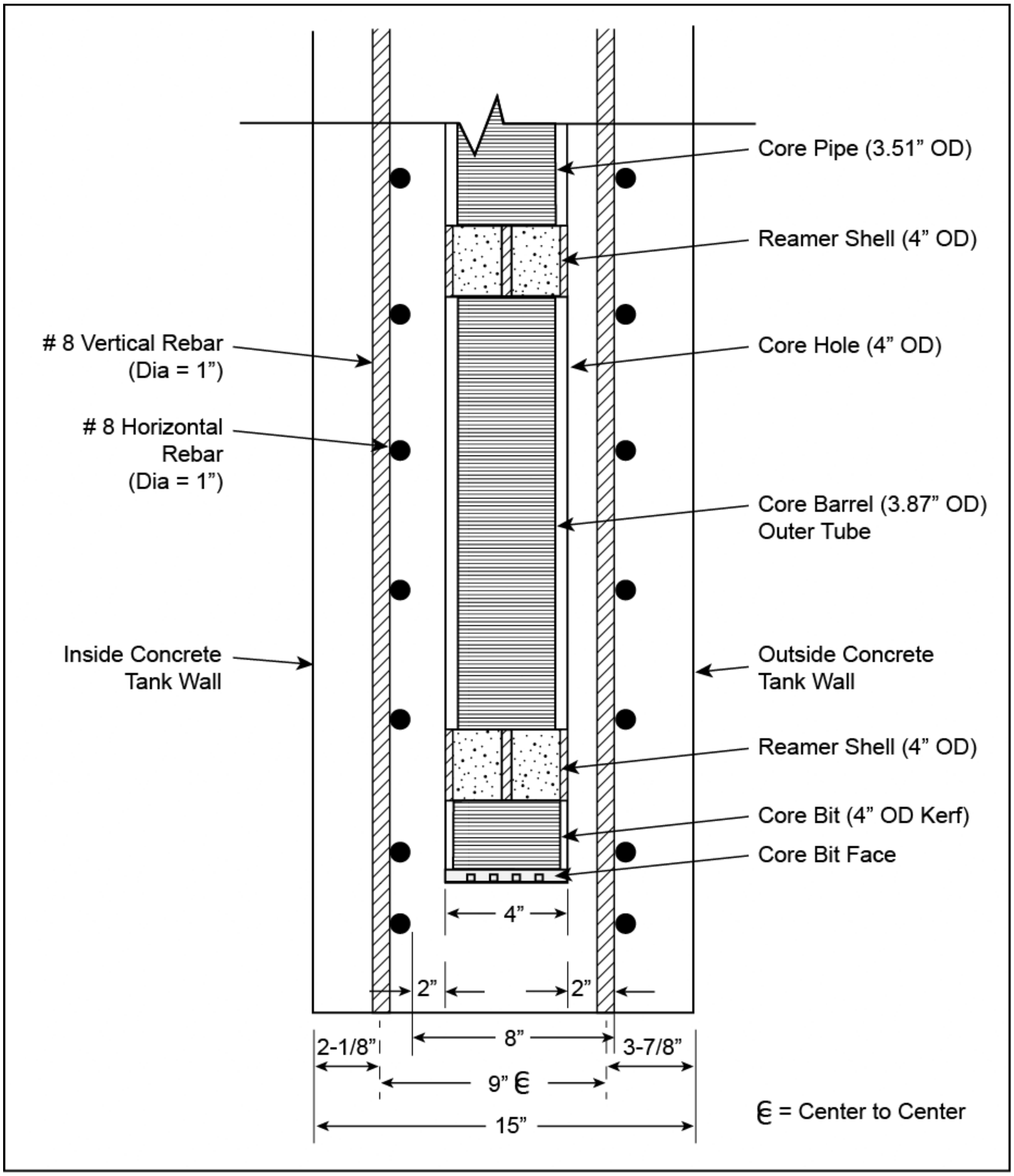
The location of the core hole entry point on top of the tank haunch will be centered on the wall between the horizontal hoop rebar. The center of the entry point will be approximately 7.875 inches from the outside surface of the haunch and upper sidewall. In a Type IVA tank, such as 241-A-106, the distance between the horizontal hoop rebar is approximately 9.0 inches center-to-center from the top of the sidewall down to approximately 9.5 feet into the sidewall where the wall thickness begins to increase. At an approximate depth of 12.5 feet into the sidewall, a center run of #5 rebar begins and extends to the tank footing, opening the distance between the horizontal hoop rebar to approximately 12 inches center-to-center. The total length of the core hole, including the guide tube that is located above the drilling platform to 12 inches into the tank footing, is estimated to be approximately 55 feet as shown in Figure 4-15.

The outside diameter of the core bit kerf will be 4 in., resulting in a nominal core hole diameter of approximately 4.0 in. The distance between the horizontal hoop rebar is 8.0 inches when measured from the outside face of the inner hoop to the inside face of the outer hoop. This results in a maximum tolerance of approximately 2.0 inches from the outside of the core bit kerf to the face of the horizontal hoop rebar. Figure 4-14 provides a top view of the tank wall showing inner rebar placement and various dimensions of consideration as described within this section.

As previously discussed in Section 4.7, the allowable vertical angle of deviation limit is 0° 10’ 25” for the 4.0-inch core hole from the surface to a depth of 55 feet. The inclination of the core hole must be maintained within this maximum vertical deviation throughout the coring process to ensure no horizontal hoop rebar is cut. Figure 4-16 depicts the maximum angle of deviation at the core hole. Figure 8-1 shows the core bit and core barrel located between the rebar in the tank wall.

Prior to initiation of actual tank sidewall coring, the angle of deviation limit will be recalculated based on actual set-up configuration and final core hole dimensions. Alternate sizes of core tooling to increase core size may be tested in the demonstration phase, which may result in a larger size core hole being drilled and lower allowable vertical angle of deviation.

Figure 8-1: Core Barrel and Reamer Shells Between Rebar



8.2.2 Deviation Control Strategy

The most critical aspect in maintaining verticality in the core hole will be ensuring the vertical alignment of the core drill at the start of the drilling. This will be achieved by use of leveling jacks on the drill rig, and use of hand levels and survey instruments to align the drill chuck and quill over the guide tube. As described in Section 8.1.3, "Caisson Installation," a guide tube will be installed to the alignment base, located near the top of the tank haunch, and up through and above the drill platform. This guide tube will be surveyed for verticality and alignment to the entry point on the tank sidewall and secured to the concrete pad. Standard survey methods as well as an optical plummet will be used for alignment. The coring tool string will be centralized within the guide tube to ensure as near vertical entry into the sidewall as possible. The approximate length of the guide tube will be 17 to 19 feet depending on the height of the drill platform above the top of the caisson. The length of the guide tube, coupled with the centralization of the core tool string and use of stiff core rods, provides a high level of confidence that a vertical start will be achieved, and core hole verticality will be maintained throughout the coring process.

8.2.2.1 Control Methods In addition to the strategy for achieving a vertical entry at the start of the coring, operational practices by the driller will help ensure significant deviation of the core hole does not occur as it is advanced. Rotation speed of the core bit and weight on bit (pull down force) will be key to controlling deviation and maintaining verticality. The driller will make adjustments to these drilling parameters as deemed necessary, based on results from verticality checks (discussed below). Should the verticality checks indicate a deviation in excess of the allowable limit, the core hole advancement will be discontinued and the core hole decommissioned.

8.2.2.2 Deviation Verification Survey Method and Frequency Verticality of the core hole will be monitored throughout the coring process. Standard surveying methods will be utilized to align the drill rig and guide tube prior to the start of coring. While coring, verticality will be verified using an optical plummet and/or a borehole gyroscope. The optical plummet will require a lighted target placed at the bottom of the core hole. After removing the core string from the core hole and removing the core at the end of a run, the core bit will be removed and replaced with a lighted target sub having the same dimensions as the bit. The core string will be run back into the core hole and placed just above bottom. The optical plummet will be set up and a vertical alignment measurement will be made. It may be necessary to pump the drill fluid from the core hole should the core string leak at rod connections. A portable, submersible pump will be utilized to remove core fluid. Due to potential limitations of the optical plummet at depth, a borehole gyroscope may be run to verify core hole deviation. The effectiveness of both methods for measuring verticality will be tested in the demonstration phase.

The first measurement will be made prior to the initiation of coring, at the top of the concrete. A second measurement will be made after advancing the core hole through the haunch (approximately 5 feet). Thereafter, a verticality measurement will be made following each core run (approximately every 5 feet of core hole advancement).

8.3 CORING TECHNIQUE

Drilling technique selection for recovering concrete core samples considers the required specimen size (diameter), ability to retrieve intact core, control of drilling angle, and control of circulating fluid. Prior to deployment into the tank farm and coring of the tank sidewall, the coring method and equipment will be tested in a demonstration phase (see Section 8.7, "Demonstration Phase").

8.3.1 Coring Approach

During the tank wall coring effort conducted in 1981 on SST 241-SX-115, a Concrete Coring Model CDC-500 portable drill unit was used to perform the coring. The drill unit was bolted to the drilling pad poured at the bottom of the caisson. This drilling method required the drill operator to work within the confines of the caisson to operate the drill unit and extract the core. All support equipment, including the fluid circulating system, was required to be staged within the caisson. For the coring of the tank sidewall of SST 241-A-106 or backup, all drilling equipment will be located and operated from ground surface. This approach will enhance safety, reduce potential personnel exposure to radiation, and maintain ALARA principles.

The 1981 coring effort utilized a standard concrete coring bit and barrel and undersized drill rods. For long core runs, as experienced during the 1981 coring, this design may cause core breakage as well as present difficulties in providing adequate cleaning of drill cuttings, resulting in stuck tools and reduced drilling rates. For the coring of SST 241-A-106 or backup, a conventional core barrel and properly sized drill tubing will be used. The core barrel is designed with an inner liner that does not spin with the barrel as it rotates, reducing core breakage. The design of the core system will maximize the ability for core hole cleaning, thereby reducing potential for sticking tools.

To facilitate surface operations, a guide tube will be installed. This guide tube will attach to the prefabricated starter alignment base installed as part of the caisson installation (refer to

Section 8.1.4, "Locating Core Hole Entry Point on Wall"). The guide tube will be sized to optimize stability of the core string and coring fluid circulation rate. Once the guide tube is in place and secured, a cover will be placed over the caisson with an access hatch and opening for the guide tube. The drill rig work platform will extend out over the caisson. All drilling and support equipment will be staged on the surface, minimizing need to access the caisson during coring operations.

8.3.2 Coring Method

A standard double tube conventional coring method will be used for coring the SST concrete sidewall. The drill unit will be a government-owned Longyear[1] Model 44 truck-mounted core drill. During the tank sidewall coring effort conducted in 1981, difficulties were experienced in retrieving core and cleaning the core hole. For this effort, the coring rig, tools, and drilling fluid circulating system have been selected/designed to overcome these potential issues. The selected core rig has been used to support a variety of coring tasks on the Hanford Site, including coring of various concrete structures and vitrified material. The driller who operated this core rig in support of these previous projects will be assigned to operate the rig for core drilling the tank concrete sidewall. This driller, has over 30 years of drilling background, and is experienced operating this equipment in radiological environments.

8.3.2.1 Core Dimensional Requirements For discussion on core dimensional requirements refer to Section 4.4.2. The requirement to obtain concrete core from the tank sidewall without cutting the horizontal hoop rebar limits the diameter of core that can be retrieved. Assuming uniform placement of the rebar hoops, a maximum distance of approximately 8.0 inches between the hoops exists; however, this uniform spacing is an unreasonable expectation. Although strict deviation control measures will be applied, some deviation from verticality is anticipated. Therefore, the minimum core size acceptable for testing, 3-inch diameter, will be selected to increase deviation tolerance and maximize the number of potential test specimens. Additional sizes of coring tool strings may be tested in the demonstration phase. Final determination of core size will be based on the ability to meet project goals.

8.3.2.2 Coring System Tooling To maximize annular clearances and meet minimum core diameter requirements, a thin wall double tube conventional core barrel will be utilized. The core string components are manufactured by Atlas Copco.[2] Figure 8-2 provides a diagram of a typical core barrel assembly. The core string is designed to retrieve a 3.11-inch. diameter core

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[1]Longyear is a registered trademark of Longyear TM, Inc., South Jordan, Utah.
[2]Copco is a registered trademark of Copco Corporation, Stockholm, Sweden.

with an approximate length of 5 feet, and will produce a core hole with a nominal diameter of 4 inches. The core string configuration will be comprised of a core bit with a 0.43-inch kerf, reaming shell 4-inch outside diameter), core barrel, core rods, and in-line stabilizers. A reaming shell will be placed between the core bit and core barrel. In-line stabilizers will be placed at the top of each core rod to provide additional stability and verticality control. The guide tube will be 4.67-inch inside diameter.

Figure 8-2: Configuration with Guide Tube

Three core bit designs will be available to accommodate potential varying drilling conditions; diamond impregnated, multi-step surface set, and tungsten carbide bit designs will be available. These bits will be tested in the demonstration phase to assess performance. Figure 8-3 provides examples of the various core bit designs from which a selection will be made.

Figure 8-3: Various Core Bit Designs

During the actual coring of the sidewall, the driller will make bit selections as needed to optimize coring rates and maintain verticality. An adequate supply of each bit will be available as spare parts during the coring to allow for necessary bit change out due to wear or performance concerns.

As previously stated, additional tooling sizes may be tested during the demonstration phase, possibly resulting in an alternate tool selection.

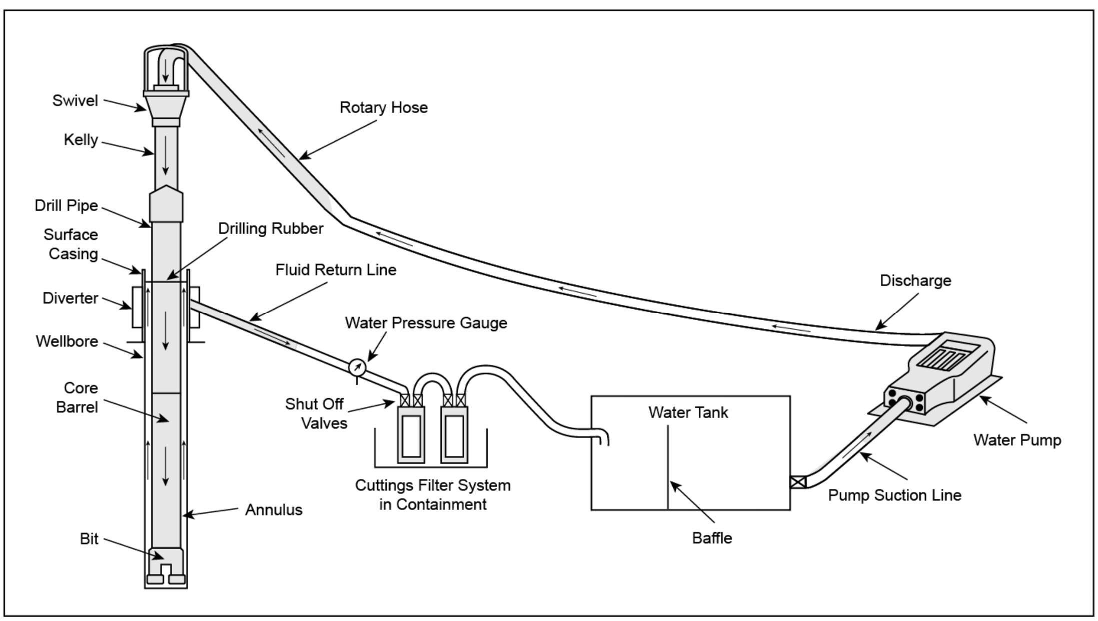
8.3.3 Coring Fluid Circulation System

These details represent a planning basis and could change depending on design review and results of the demonstration.

Coring fluid will be required during the coring process to cool the core bit and remove concrete cuttings from the cored hole. Clean water will be used as the coring fluid. Due to the potential for radiological contamination, the fluid will be maintained in a closed system. Use of air as the circulating medium will not be considered for this effort.

To reduce waste, the coring fluid will be recirculated. It is essential that the fluid returned to the bit face be clean and free of cuttings. To accomplish this, the circulating system will be designed to circulate the return fluid through two CUNO 100 micron CTG-Klean canister filters and then into a holding/settling tank. The replaceable filters will be easily removed for exchange with a new filter to optimize cleaning of the drilling fluid. The system is designed to allow for monitoring of fluid volume and circulating pressures. The driller will continuously monitor the circulating pressures and change out the filter as necessary to ensure adequate circulation rates are maintained for proper core hole cleaning. The circulating fluid will be changed out on a daily basis or more frequently as needed. The core fluid circulation system will have a capacity of approximately 150 to 170 gallons. Figure 8-4 provides a concept of the coring fluid circulating system. The entire circulating system will be located above grade on ground surface, with only the guide tube being located in the caisson. Tape will be used at the guide tube connections to prevent coring fluids from leaking into the caisson.

Figure 8-4: Circulation System



A Bean 22 or Bean 35 positive displacement pump will be used to pump and circulate the coring fluid. Pumping rates are 22 gallons per minute and 35 gallons per minute respectively. Based on the current configuration of the coring system, it is estimated that a minimum pump rate of 22 gallons per minute will be required to provide for proper cleaning of the core hole.

A diverter head will be installed on the top of the guide tube to direct the coring fluid to a return line and into the filters. The top of the diverter will have a drilling rubber through which the core rods run. This drilling rubber will contain the core fluid and direct it out the discharge of the diverter.

This is a proven coring fluid circulation system used successfully in support of various Hanford Site projects to contain and clean coring fluids during the coring of nonradioactive and radioactively contaminated vitrified materials.

A portable submersible pump with flexible hose on a reel will be provided and used to facilitate removal of drilling fluid from the core hole for verticality checks or as otherwise necessary during the coring process.

8.3.4 Coring Objectives and Approach

The overall objective of coring activities is to retrieve approximately 38 feet of concrete core from the tank haunch, sidewall, and footing, but not drill through the footing. After initiation of coring, the core bit will be advanced through the haunch and into the wall, approximately 5 feet and the initial 5 feet of core retrieved. The core hole will be surveyed for verticality, and a decision on how to proceed will be made based on survey results. The core hole will be advanced to total depth, retrieving core in 5 foot increments following the same sequence of core retrieval and verticality surveying. Throughout the coring process, accurate depth measurements will be maintained by measuring the coring string as well as taking depth tag measurements in the core hole.

Core retrieval is accomplished by removal of the entire core string from the core hole. A core lifter is integral to the core barrel and allows retrieval of the core when the core barrel is brought to surface. This eliminates the need to make a separate run to retrieve the core. The core barrel will be removed and placed onto the breakdown table, enabling the core sample to be removed and packaged (refer to Section 8.4, "Core Collection"). A verticality check using an optical plummet will be performed by changing out the core bit with a target sub and running the core string back to the bottom of the core hole. This action may require coring fluid to be pumped from the core hole. The verticality check may be conducted using a borehole gyroscope instead of the optical plummet. Following completion of the verticality check, the target sub, if installed, will be removed and the core bit installed. The core bit will be inspected and replaced, if required, prior to conducting the next core run.

During the coring process, circulating fluid volume will be monitored. Some amount of coring fluid will be lost during the drilling process due to evaporation, absorption from the core hole into the concrete wall, potential spills when retrieving core samples, and change-out of filters. The core fluid circulation system will have a capacity of approximately 150 to170 gallons, and would be the maximum potential fluid loss to the soil should a crack or void be encountered while coring. If substantial fluid loss occurs, coring will be discontinued, and cause of fluid loss identified, evaluated, and if possible, resolved. A borehole camera survey may be performed to verify fluid loss, and identify its cause from within the core hole. It is possible that a large crack or void may be encountered, causing significant fluid loss. If this is determined to be the cause, the core hole will be grouted to seal the crack or fill the void, and then coring can resume following a 24-hour set time. In the event that fluid loss is unable to be controlled, coring will be discontinued, and a decision made as to whether to relocate the core hole to one of the alternate target locations or terminate coring operations.

The drilling parameters will be continuously monitored and adjusted to obtain optimum coring rates and core retrieval. Core fluid circulation rate and pressure will be monitored and fluid circulating system filters replaced as needed. Reduced flow rates or increased pump pressure may be an indication the bit or filters have become plugged. Should this occur, coring will cease, and the core will be retrieved. The bit or filters will be cleared and coring resumed.

Drilling progress will also be monitored and evaluated. The coring rate will be controlled to maintain verticality and ensure proper core hole cleaning. An approximate coring rate of 2 inches per minute is anticipated. At this rate, coring 5 feet will take approximately 30 minutes. A complete core run including trip time and verticality checks is estimated to take approximately 1.5 hours.

After coring operations are completed, the core hole will be filled with nonshrink grout. The coring equipment will be surveyed in accordance with an approved radiological release plan. Released equipment and materials will be demobilized from the tank farm and taken to a predetermined location for storage. All items not released as clean will be disposed of in accordance with the approved Waste Control Plan and radiological control documentation.

Final disposition of the caisson at project completion will be identified and discussed in the sampling and analysis plan.

The information in this section serves as a guideline and identifies general processes used. Detailed procedures and work plans will be prepared prior to actual coring of a tank sidewall. Environmental and safety compliance will be upheld and maintained.

8.4 CORE COLLECTION

The core barrel selected will provide for collection of core in 5-foot lengths. Due to bit wear and possibility of blockage, a shorter length of core may be retrieved. The driller will determine when it is necessary to retrieve the core based on depth cored or drilling parameters (e.g., penetration rate, fluid circulation, revolutions per minute, etc.). Once the core has been retrieved to the surface, the driller will remove the core barrel from the core string and place it on the breakout table.

8.4.1 Core Removal and Handling

The core will be removed from the core barrel once placed on the breakout table. Utmost care will be exercised during core removal to avoid breakage. Fractures in the concrete core may be present. The concrete testing laboratory will cut the core to the required lengths for testing; therefore, maximum core lengths are desired to optimize number of intact core specimens for testing.

The core will be handled in accordance with Section 4.4.3. In addition, the core will be surveyed for radiological contamination. After the core has dried, it will be marked, using an indelible marker, with an orientation arrow, tank number, and footage. Properly packaged cores will be placed in a core box. Core boxes that have been determined to be free of radiological contamination will be transferred to an identified staging station. Any core boxes not released for transfer will be covered with plastic and stored in an approved area within the tank farm for further disposition.

8.4.2 Core Transport

The concrete core will be transported to the selected testing laboratory. To reduce breakage of the core, additional packaging may be utilized during transport. The gross estimated weight of a loaded core box is expected to be approximately 50 to 60 pounds.

8.5 DATA COLLECTION DURING CORING

Complete and detailed records will be maintained during the coring process. Following are the data to be recorded.

- Core Log recording details of core retrieved including length of core runs, depths, date, and time. Core lengths will be recorded to the nearest tenth of a foot.
- Driller's Log providing information on coring process. Personnel, depths cored, core retrieval, advancement rates, coring parameters (revolutions per minute, weight on bit, etc.), information on fluid circulation, coring problems, issues, radiological survey results, verticality checks, and other pertinent information should be recorded.
- Photographs of the retrieved core.
- Written observations of the core retrieval, removal and packaging activities, as well as a description of the retrieved core identifying color, observed fractures/cracks and voids, estimated aggregate size, presence of rebar, etc.
- Radiation monitoring data and survey logs.

A daily log will be maintained of all other operations related to this project, including survey logs done to locate the caisson and set up the core drill.

8.6 WASTE CONTROL AND DISPOSAL

Wastes expected to be generated as a result of coring activities include excavated soils, miscellaneous solid waste, contaminated personal protective equipment, core cuttings, and water (circulating fluid). Handling and disposition of generated waste will be controlled in accordance with a project-specific Waste Control Plan.

8.7 DEMONSTRATION PHASE

Prior to initiating coring of an actual SST concrete sidewall, testing will be required to demonstrate the capabilities of the proposed coring method, feasibility of the operation, and ability to conduct activities safely.

A demonstration test plan will be prepared to outline the general requirements for the testing activities and provide specifics on demonstration site location, site preparation and setup, coring equipment to be used, and the coring methods and processes to be tested. At the completion of the testing a decision will be made on whether to proceed with the selected coring method or to modify the approach and retest.

8.7.1 Demonstration Objectives

The objectives of the concrete coring demonstration phase are as follows:

- The coring method and tooling can successfully core and retrieve the required core size;
- Core hole verticality can be accurately measured;
- Verticality of the cored hole can be measured and maintained within calculated tolerances to prevent the bit from deviating (preventing breakout through the concrete wall or cutting of horizontal hoop rebar);
- The coring fluid circulation system provides for adequate hole cleaning; and
- The coring fluid can be controlled and contained.

8.7.2 Site Selection

The demonstration activities will not be conducted in any radiological zone. The demonstration for the 1981 tank sidewall coring effort used the 181-F Pump House foundation for testing the coring equipment and process. This facility has been decommissioned and is no longer available for use. An alternate site located within the 200 West Area of the Hanford Site has been identified as a potential test site. Building UR-201 (also known as the rock slinger pit) offers a 2-foot wide wall having a depth of approximately 15 feet (including footing). There is good access to the wall for equipment setup and coring. This facility also offers the ability to test the installation of a guide tube.

Other facilities potentially offering acceptable test structures are the 181-KE Pump House (200 East Area), 181-KW Pump House (200 West Area), Maintenance and Storage Facility, Fuels and Materials Examination Facility (both located in the 400 Area), and one of the abandoned reactor facilities (WNP-1 or WNP-4) located at Energy Northwest Industrial Complex. The Energy Northwest sites provide 2-foot to 4-foot thick reinforced walls with depths of 50 to 60 feet.

To ensure that all objectives have been met, one or a combination of two or more sites will be selected to conduct the demonstration testing. The selected sites must be able to demonstrate guide tube installation and use, and provide the ability to test coring to the maximum required depth.

8.7.3 Test Report

Upon completion of demonstration testing activities, a lessons-learned critique will be conducted. A completion report will be prepared providing testing results and identified lessons learned. Final selection of core tooling will be based on the results of the testing.

8.8 NONDESTRUCTIVE AND DESTRUCTIVE TESTING

As stated previously in Section 4.5, both nondestructive and destructive testing will be performed on the recovered concrete core.

Section 4.5 discussed the following tests to be performed on the cores.

- Ultrasonic Pulse Velocity (NDE)
- Modulus of elasticity (NDE)
- Poisson's ratio (NDE)
- Compressive strength
- Petrographic analysis

8.8.1 Concrete Test Specimen Requirements

The requirements for concrete test specimens and proposed dimensions for cores collected during sidewall coring are outlined in Section 4.4. As stated in Section 4.4, the cores collected will be approximately 3.1 inches in diameter and will be required to be approximately 5.89 inches to 6.51 inches long for testing. A potential of 69 core specimens could be provided for testing.

8.8.2 Concrete Testing Laboratory

A concrete testing laboratory will be selected using the criteria set forth in Section 4.6. Two commercial laboratories can perform the testing required so long as the cores are not radioactive. Though every effort will be made to collect a core that is not radiologically contaminated, it is recognized that a contaminated core is a possibility. If a core is contaminated, efforts will be made to find a laboratory that can test them at the time of collection.

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APPENDIX A

RESPONSE TO QUESTIONS FOR THE EXPERT PANEL, ATTACHMENT 1 FROM RPP-RPT-49272

Response to Questions for the Expert Panel, Attachment 1 from RPP-RPT-49272

1. **Why does the expert panel recommend coring the sidewall of the tank?**

   Response: The expert panel recommends coring the sidewall of the tank to determine the condition and strength of the concrete in the lower portion of the sidewall and at the junction of the sidewall and foundations.

2. **Why did the expert panel think coring was important to do?**

   Response: It is very important for an assessment of the structural integrity of the tank under seismic loads to determine whether the sidewall concrete remains intact or whether it has rubblized. It is also desirable to determine the compressive strength of the concrete in the lower portion of the sidewall.

3. **What specific data will be gained from the cores?**

   Response: The condition of the concrete and its compressive strength will be determined.

4. **What specific benefits will be gained by collecting additional SST Core data?**

   Response: Collecting additional SST Core data will provide greater confidence that the condition of the concrete in the lower portion of the sidewall is understood. Based on the single existing core, it is the premise of all structural analyses that the concrete is in good condition and has a compressive strength in excess of the design strength. These analyses will be deficient if this premise is incorrect and the concrete has rubblized.

5. **Why were two cores specified?**

   Response: Two additional cores provide a total sample size of three. A sample size of three can provide substantially greater confidence in any conclusions reached if the results from all three cores are consistent. It also greatly increases the chances of finding serious defects if such defects exist in significant quantities.

6. **Is there any statistical significance to two cores?**

   Response: No.

7. What is the consequence of not coring the SSTs? Will not having the core data affect the outcome?

Response: If no additional core data is collected, structural evaluation of the tanks will continue to accept the premise that the sidewall concrete is intact and has a compressive strength in excess of the design strength. Having additional core data will either provide greater confidence in this premise or possibly result in its rejection. This premise has considerable influence on any conclusions reached concerning the structural integrity of the concrete sidewalls during any strong seismic event.

8. Opinion of the panel on what happens if data do not support the model.

Response: The structural model will have to be revised to consider the worst concrete conditions observed in any of the three cores.

APPENDIX B

TANK 241-SX-115 SIDEWALL CORE AND RESULTING DATA WITH ADDITIONAL DETAIL

Tank 241-SX-115 Sidewall Core and Resulting Data with Additional Detail

In 1981, tank 241-SX-115 sidewall was vertically core drilled from top to bottom (RHO-CD-1538). The concrete core obtained was 38 feet 8 inches long and approximately 3-inch diameter. Some reinforcing steel was cut in the first 17 feet. However, less reinforcing steel was encountered than expected. The drilling accuracy was maintained. The aggregate sizing was not uniform which led to an uneven drilling rate. Drilling was halted when the recirculating drilling fluid was determined to be radiologically contaminated. The bottom 8 feet of core was not tested. See Figure B-1 for a depiction of tank sidewall.

The drilling was performed by installing an 8-foot caisson and pouring a concrete support pad. The excavation to allow placement of the caisson was performed by hand digging down to the haunch. The drill stand for the concrete core drill was mounted to the concrete support pad with a single ¾-inch diameter expansion bolt. The drill stand was 6 feet high. Downward force was applied by crank handle. Water circulation was from a 55 gallon drum with returns collected with a wet/dry vacuum. Removal of the rod sections and core was manual, or by hand.

The deviation criteria set for drilling were 0.266 inch per five feet of depth if the drill was initially placed at centerline. These criteria changed to 0.198 inch per five feet of depth if the drill was initially offset by a half inch from the centerline. Deviation control was measured snd maintained during the drilling of the 241-SX-115 core, and the deviation criteria were met.

241-SX-115 is a Type IVA SST which can hold 1,000,000 gallons. 241-SX-115 was pumped in 1965 after it was determined to be leaking. The tank lost approximately 50,000 gallons in 10 days, leading to the leak determination.

This tank received REDOX high level waste from 1958 to 1964. It reached self boiling about one month after the first high level waste addition. The maximum waste temperature measured in the tank was 260 °F and the tank spent 57 months above 200 °F, but no time above 300 °F (see Figures B-2 through B-5).

From the 38 feet 8 inches of core obtained, 18 core specimens were tested, about three specimens per 5-foot section of core. The tested core samples were approximately 2.7-inch diameter and 5.4 inches long. Testing performed included compression tests and splitting tensile tests. The results indicated the strength of the concrete is higher than design (specified 28-day was 3000 psi).

There were some inconsistencies in the data. The first data point, closest to the surface, for each property measured was significantly different from subsequent measurements of concrete further down the sidewall. Also, in photographs of the collected core, the first section looks different from subsequent sections of collected core (see core at the bottom of Figure B-6).

Figure B-1: Type IVA Sidewall Diagram

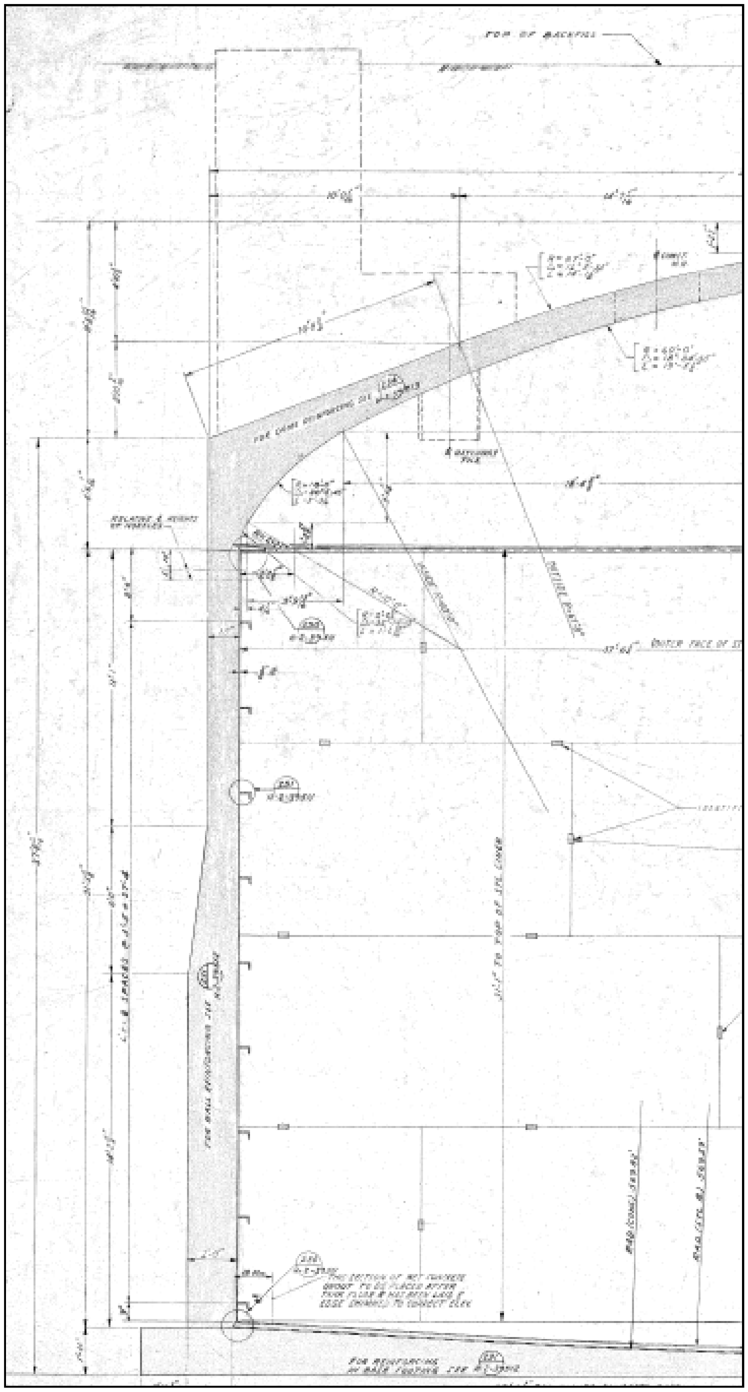
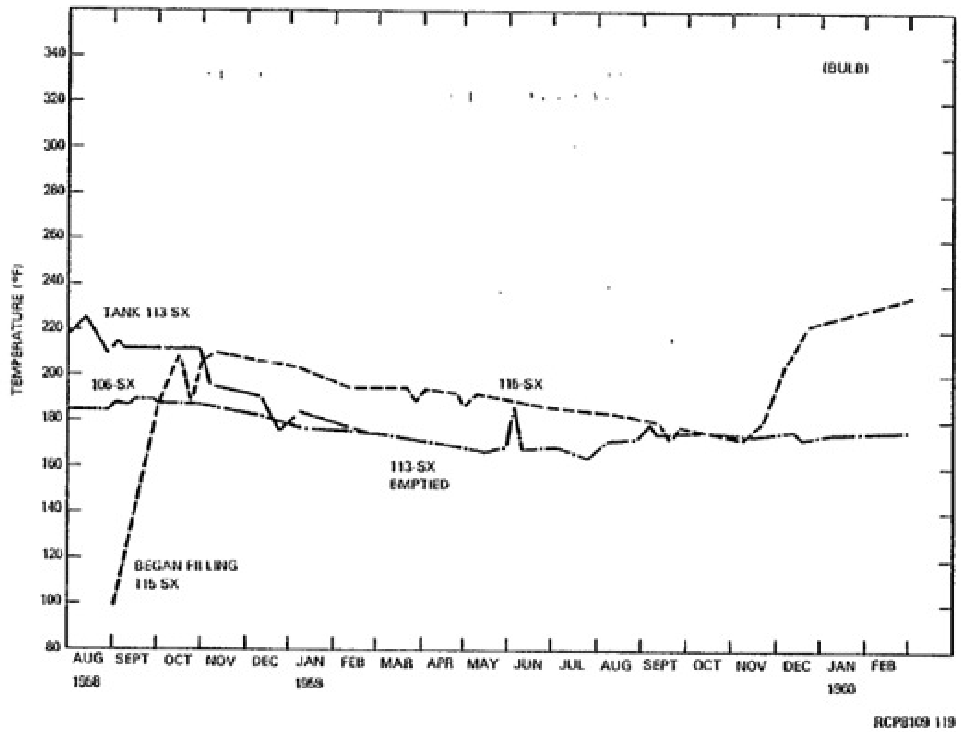
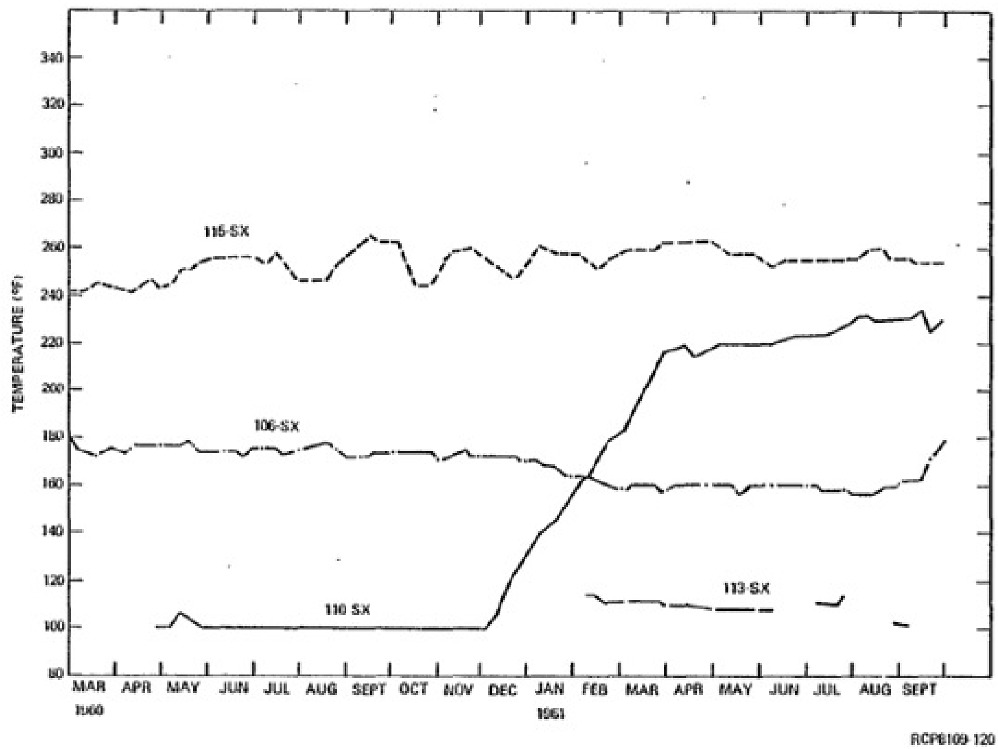


Figure B-2: Thermal History 1 of 4



241-SX-106, -113, and -115 (Bulb Temp.)
August 1958 thru February 1960

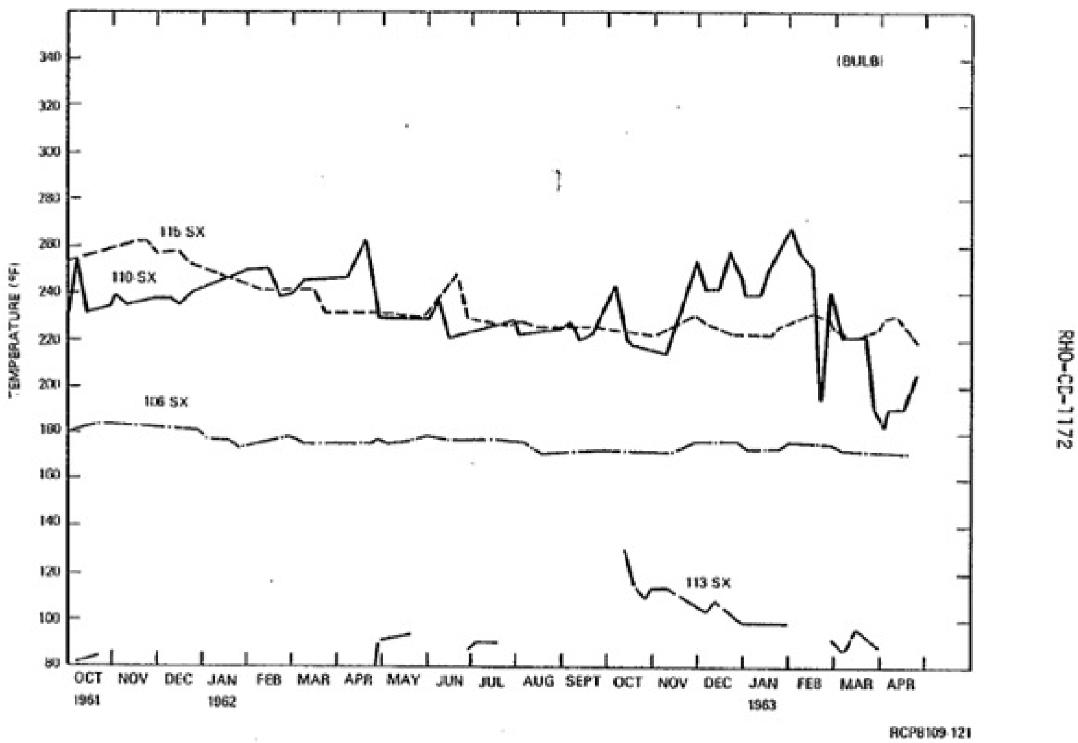
Figure B-3: Thermal History 2 of 4



RHO-CD-1172

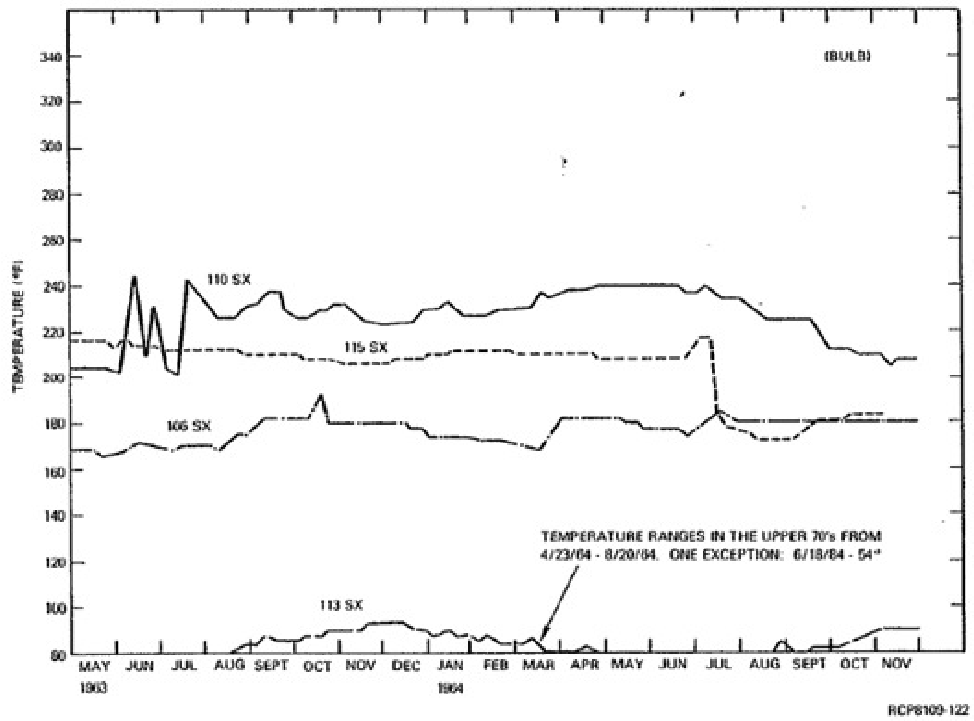
241-SX-106, -110, -113, and -115 (Bulb Temp.)
March 1960 thru September 1961

Figure B-4: Thermal History 3 of 4



241-SX-106, -110, -113, and -115 (Bulb Temp.)
October 1961 thru April 1963

Figure B-5: Thermal History 4 of 4



241-SX-106, -110, -113, and -115 (Bulb Temp.)
May 1963 thru November 1964

RHO-CD-1172

Figure B-6: Photo of Cores Pulled From 241-SX-115