Briefing for PWSRCAC Board of Directors – May 2025

ACTION ITEM

Sponsor: Sadie Blancaflor and the TOEM Committee

Project number and name or topic: 6512 – Maintaining the Secondary Containment Liner

1. **Description of agenda item:** This item provides the Board with 1) an update on the results from the Electrical Leak Location and Electrical Resistivity Tomography Pilot Study of the Secondary Containment System at the Valdez Marine Terminal West Tank Farm Conducted July 2024, 2) an overview of Alyeska's February 28, 2025 testing plan, titled "VMT- East Tank Farm Secondary Containment System Final Evaluation Method Selection," and 3) Dr. Benson (PWSRCAC's contractor) recommendations for Alyeska's testing plan.

Furthermore, the Board is being asked to accept the report titled "Review of Electrical Leak Location and Electrical Resistivity Tomography Pilot Study of the Secondary Containment System at the Valdez Marine Terminal West Tank Farm Conducted July 2024," by Dr. Joseph Scalia and Dr. Craig H. Benson.

2. **Why is this item important to PWSRCAC:** Secondary containment systems are required by state and federal regulation to hold oil in the event of a spill from a tank or pipe until the spill can be detected and cleaned up. The Alyeska Pipeline Service Company (APSC) Valdez Marine Terminal (VMT) utilizes 13 crude oil storage tanks located in their East Tank Farm to facilitate terminal operations.[1] The VMT also has a West Tank Farm that is not currently in use and has four out-of-service crude oil storage tanks. All the in-service and out-of-service crude oil tanks, as well as other storage tanks at the VMT are within secondary containment systems.

One of the major components of the secondary containment systems at the VMT's East Tank Farm is a special subsurface liner, called a catalytically blown asphalt (CBA) liner. The CBA liner was installed around 1976, when the terminal was constructed. The CBA liner is located under about five feet of earthen fill throughout each of the seven secondary containment areas (also referred to as "dike cells") in the East Tank Farm. There are two crude oil storage tanks per dike cell. Holes or cracks through the East Tank Farm's CBA liner have consistently been found when it is exposed (about 19% of the time it is uncovered) indicating that the liner and thereby, the secondary containment system may not hold spilled oil before it could be detected and cleaned up.

The area underlain by CBA liner is very large. The average containment area in each dike cell is about eight acres, and the total containment area in the East Tank Farm is about 57

[1] As of October 22, 2024, Tank 8 has been cleaned and isolated from the system, reducing the number of active tanks in the East Tank Farm from 14 to 13.

acres, the majority of which is underlain by CBA liner. CBA liner is installed underneath all the tanks as well as around the tank perimeters. Only a small percentage of the liner area has ever been uncovered and evaluated for damage.

For two decades the PWSRCAC has voiced concern to Alyeska, and state and federal regulators, regarding the ability of the CBA liner to meet regulatory standards and the risks that a compromised liner poses in the event of a spill from the crude oil storage tanks at the VMT. In the most recent development, a May 11, 2022 decision by the Alaska Department of Environmental Conservation (ADEC) – which was henceforth incorporated into the most recent 2024 VMT C-Plan Renewal -- required that Alyeska:

- Identify “preliminary” methods to evaluate the integrity of the CBA liner in the East Tank Farm by October 1, 2023
- Identify “final” evaluation methods by March 1, 2025

Alyeska has since completed a pilot test of the West Tank Farm using electrical leak Location (ELL), and that methodology was indicated to have some degree of effectiveness in detecting large liner defects. Alyeska selected ELL as their methodology in their February 28, 2025 plan for testing the East Tank Farm.

3. **Previous actions taken by the Board on this item:**

Meeting	Date	Action
XCOM	4/28/2022	Accepted the report titled “Utilizing Numerical Simulation to Estimate the Volume of Oil Leaked Through a Damaged Secondary Containment Liner” dated February 7, 2022 as final and for public distribution.
Board	1/26/2023	Accepted the report titled “Methodologies for Evaluating Defects in the Catalytically Blown Asphalt Liner in the Secondary Containment System at the Valdez Marine Terminal” by Dr. Craig H. Benson dated November 29, 2022, as meeting the terms and conditions of Contract 6512.22.02, with direction to staff to forward the report to Alyeska, and state and federal regulators accompanied by a cover letter summarizing findings and recommendations with requests for appropriate action and a complete response; and authorized staff to negotiate a contract change order, for contract #6512.22.02, with Dr. Craig H. Benson, adding $7,900 for compensation to attend meetings with the Council, Alyeska, and state and federal regulators promoting the findings and recommendations of his November 29, 2022 report and extending the term of the contract to June 30, 2023.
XCOM	7/18/2024	Authorized the Executive Director to increase the contract with Dr. Craig Benson for deliverables associated with project 6512 Maintaining the Secondary Containment Liner, in an amount not to exceed $38,000.
Board	11/24/2024	Directed staff to request an informal review to ADEC pertaining to Condition of Approval #1 related inspection of the secondary containment liners as outlined in the recently approved Valdez Marine Terminal Oil Discharge Prevention and Contingency Plan.
Board	3/19/2025	Directed staff to request an adjudicatory hearing pertaining to Condition of Approval #1 related to the inspection of the secondary containment liners as outlined in the recently approved Valdez Marine Terminal Oil Discharge Prevention and Contingency Plan; and to authorize a FY2025 budget modification of $15,000 from the contingency fund to project 6510: State Contingency Plan Reviews, and to

authorize a corresponding contract increase for selected contingency plan review contractors for an aggregate amount not to exceed $95,000; and, to authorize a FY2025 budget modification of $25,000 from the contingency fund to project 6512: Secondary Containment Systems at the VMT, and authorize a contract increase of $16,800 for Dr. Benson and Dr. Scalia for new not to exceed amount of $61,800.

4. **Summary of policy, issues, support, or opposition:** For at least the past three VMT contingency plan (C-Plan) renewals (going back to the 2008 renewal), the Council has submitted comments to Alyeska and ADEC with recommendations pertaining to the CBA liner and secondary containment systems. For the 2019 C-Plan renewal, the Council and Alyeska both filed "informal reviews" with ADEC regarding the secondary containment systems. Those two "informal reviews", which is a formal way of working out disagreements about the C-Plan without going to court, were resolved when ADEC issued the aforementioned May 11, 2022 decision requiring Alyeska to identify final CBA liner evaluation methods for the East Tank Farm by March 1, 2025. This March 1, 2025 submission date was in turn incorporated into the most recent 2024 VMT C-Plan renewal, under Condition of Approval #1.

5. **Committee Recommendation:** At the March 7, 2025 TOEM Committee meeting, the TOEM Committee recommended Board acceptance of the report titled "Review of Electrical Leak Location and Electrical Resistivity Tomography Pilot Study of the Secondary Containment System at the VMT West Tank Farm Conducted July 2024" as meeting the terms and conditions of contract number 6512, and for distribution to the public.

6. **Relationship to LRP and Budget:** Work associated with this project was included in the FY2025 budget under contract 6512.24.01 in the amount of $38,000.

7. **Action Requested of the Board of Directors:** Accept the report titled "Review of Electrical Leak Location and Electrical Resistivity Tomography Pilot Study of the Secondary Containment System at the Valdez Marine Terminal West Tank Farm Conducted July 2024," by Dr. Joseph Scalia and Dr. Craig H. Benson. in fulfillment of contract 6512.24.01.

8. **Attachments:**
   - A) Draft report titled "Review of Electrical Leak Location and Electrical Resistivity Tomography Pilot Study of the Secondary Containment System at the Valdez Marine Terminal West Tank Farm Conducted July 2024."
   - B) Alyeska's February 28, 2025 testing plan, titled "VMT- East Tank Farm Secondary Containment System Final Evaluation Method Selection."

DRAFT

Review of Electrical Leak Location and Electrical Resistivity Tomography Pilot Study of the Secondary Containment System at the Valdez Marine Terminal West Tank Farm Conducted July 2024

By

Joseph Scalia IV, PhD

Craig H. Benson, PhD, PE, NAE

22 January 2025

"The opinions expressed in this PWSRCAC commissioned report are not necessarily those of PWSRCAC."

EXECUTIVE SUMMARY

This review provides an assessment of the report from a pilot study undertaken by Alyeska Pipeline Service Company in July 2024, to evaluate if electrical leak location (ELL) and/or electrical resistivity tomography (ERT) are feasible methods to evaluate the integrity of catalytically blown asphalt (CBA) liner of the secondary containment system (SCS) at the Valdez Marine Terminal (VMT) tank farm. The pilot study was conducted at the West Tank Farm.

Standard methods and equipment were used for the ELL and ERT testing. Results of the pilot study demonstrate that ELL was successful in detecting manufactured leaks (holes) in the CBA liner, whereas the ERT method was unsuccessful at detecting manufactured leaks during the pilot study. Both methods required excavation of a perimeter trench around the test area down to the CBA, and installation of a geomembrane rain flap to the CBA to achieve necessary electrical isolation.

Our recommended path forward is implementation of ELL over at least 20% of the <u>buried</u> CBA-lined area of the East Tank Farm, prioritizing areas that may have suffered damage from past oil spills. This recommendation differs from WSP's (Alyeska's contractor, formerly known as Golder Associates) recommendation to test 5% of the buried CBA-lined area combined with a visual inspection of 15% of the unburied area. Testing 20% of the buried CBA-lined area is necessary to (i) establish the frequency and size-range of defects in the CBA liner, (ii) establish a quantitative definition (minimum performance threshold) for the required condition that the secondary containment be "sufficiently impermeable," (iii) establish a methodology for calculating leakage (or equivalent permeability) of oil through the SCS, and (iv) ultimately determine if the current SCS meets the "sufficiently impermeable" requirement.

Additional laboratory testing is also needed to demonstrate that the liner will maintain effectiveness in containing oil over the necessary duration of performance for a liner thickness of 3/16 inches (0.1875 in).

ACRONYMS

APSC	Alyeska Pipeline Service Company
CBA	Catalytically Blown Asphalt
ELL	Electrical Leak Location
ERT	Electrical Resistivity Tomography
SCS	Secondary Containment System
VMT	Valdez Marine Terminal
WTF	West Tank Farm
WSP	Alyeska's contractor, formerly known as Golder Associates

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1. INTRODUCTION

Secondary containment systems (SCS) are used at the Valdez Marine Terminal (VMT) to prevent the release of oil to the environment should a leak or other spill occur from oil storage tanks at the terminal. Each SCS consists of an area surrounding a pair of tanks with a containment berm and/or wall around the perimeter and a catalytically blown asphalt (CBA) liner placed across the surface. As shown in Figure 1 the liner is underlain by a layer of gravel prepared from crushed rock and is overlain by a thin gravel bedding layer and a thick layer of cover soil comprised of gravel fill. The SCSs also contain XR-5 Geomembrane patch areas and have exposed XR-5 on sidewall slopes. The CBA layer was specified to be at least 5/16 inches according to the construction documentation for the VMT (Golder 2018). The SCSs at VMT were constructed in the 1970s, when lining technology was in its infancy.

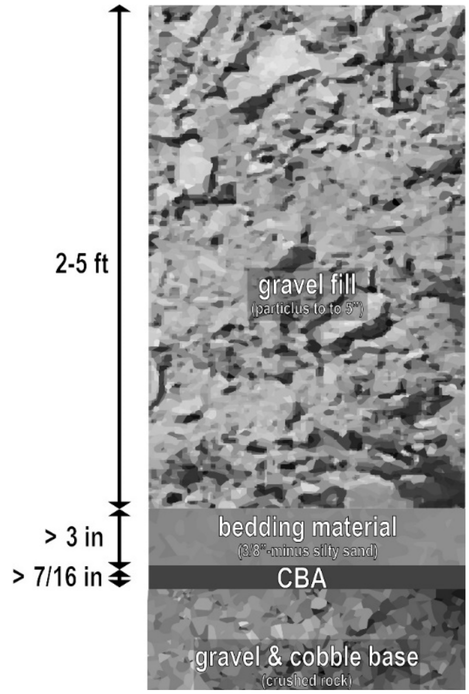


Figure 1. Schematic of the catalytically blown asphalt (CBA) portion of the secondary containment system (SCS) at the Valdez Marine Terminal (VMT).

The VMT SCS must be "sufficiently impermeable[1]" to protect groundwater from contamination and to contain a discharge or release until it can be detected and cleaned up. The impermeability of the SCS depends on the integrity of the CBA liner. As noted in Golder (2018) "*Based on laboratory permeability test results, the CBA lined SCS will meet the 'sufficiently impermeable' criteria as defined in the State of Alaska Administrative Code 18 AAC 75.990 (124)* ***as long as there are no open perforations in the SCS [emphasis added]***." The effectiveness of any lining system is influenced by the number of leaks present in the liner. The term leak used in this report follows the definition adopted by the standardization body ASTM International, which defines "leak" as "*any unintended opening, perforation, breach, slit, tear, puncture, crack, or seam breach*" (ASTM 2021). Leak assessments are often made to determine the number, size, and location of defects. Data collected from the leak assessment are then compared to specifications for an acceptable liner, and repairs are made as needed. Most leak assessments are conducted immediately after construction of the lining system, although they can be conducted at any time.

Liners can be assessed by direct or indirect assessment methods. A direct assessment is made through visual inspection of a liner. For the SCS at the VMT, direct assessments of the CBA liner can only be conducted when the overlying material is removed (e.g., as reported in Golder 2015, 2016, 2017, 2018). Removal of existing material imposes risk, as equipment used to remove overlying soils

[1] 18 AAC 75.990 (124) "sufficiently impermeable" means, for a secondary containment system, that its design and construction has the impermeability necessary to protect groundwater from contamination and to contain a discharge or release until it can be detected and cleaned up; for design purposes for tanks constructed after May 1992, "sufficiently impermeable" means using a layer of natural or manufactured material of sufficient thickness, density, and composition to produce a maximum permeability for the substance being contained of 1 x 10^{-6} cm per second at a maximum anticipated hydrostatic pressure, unless the department determines that an alternate design standard protects groundwater from contamination and contains a discharge or release until detection and cleanup.

can damage the liner, necessitating repairs and potentially creating ambiguity regarding whether a defect existed before or was caused by excavation. Direct assessment is also labor intensive. The East Tank Farm (ETF) is ~ 2,373,000 ft^2, but only ~ 23,000 ft^2 have been directly inspected visually (~ 1%). To provide a statistically significant assessment of CBA liner integrity, more than 20% of the CBA liner should be inspected (Benson 2022). Direct assessment of the exposed SCS liner is significantly easier because removal of overlying material is not required but does not reflect the condition of the buried CBA liner.

Indirect assessment consists of imposing a known condition above the liner and measuring response that is influenced by the presence of leaks in the liner. A key difference between indirect and direct methods is that the presence and characteristics of defects are inferred from an indirect method, rather than being observed directly. Thus, outcomes of indirect assessments inherently have ambiguity that is absent from direct assessments. This ambiguity is often addressed by coupling indirect and direct methods, using the indirect method to identify or locate defects followed by excavation, visual inspection, and repair.

Geophysical methods are the preferred method for assessing the integrity of the CBA liner in the SCS at the VMT (Benson 2022). These methods consist of applying an electrical or mechanical signal to the surface of the material overlying the liner and measuring the response to the signal. Benson (2022) identified Electrical Leak Location (ELL) surveys and Electrical Resistivity Tomography (ERT) as potential methods for use in assessing the integrity of the CBA liner in the East Tank Farm SCS at the VMT.

ELL surveys are the most common geophysical method used to evaluate the integrity of liners constructed with thin non-polar materials (e.g., geomembranes and CBA liners). A high voltage and low current DC power source is used to apply an electric field across the surface of the liner (Peggs 2007, Koerner et al. 2013, Calendine et al. 2018, Gilson-Beck 2019). When intact, the non-polar liner (such as a geomembrane or the CBA liner) acts as an insulator that prevents current flow. When a leak in the liner exists, current flows through the leak and into the adjacent soils. This current flow is recorded as a change in voltage between pairs of points measured across the ground surface. Surveys are conducted by walking in parallel lines across the surface of the liner, and mapping voltage looking for anomalies that indicate potential leaks. The surveyed area must be electrically isolated from the outside of the liner for ELL to work. The specific location and size of the leak is identified by removing the soils overlying the liner in the vicinity of the location where the survey identified the presence of a leak and performing a direct assessment. The leak is then repaired, and the area re-surveyed to ensure the leak was not obscuring the signature of nearby smaller leaks.

ERT is a more elaborate application of the principles used in ELL. An array of electrodes is deployed at the ground surface and a current is applied across every combination of electrode couples in the array. The voltage drop across each electrode couple is then measured. The array of voltage drops is then used to constrain a 2D inversion of Gauss' Law to obtain a cross-section of electrical resistivity over the area of assessment (Schmia et al. 1996, Zhou 2019).

A pilot study was undertaken by Alyeska Pipeline Service Company (APSC) on July 22-29, 2024, to evaluate if ELL and/or ERT surveys are feasible methods to evaluate the integrity of CBA component of the East Tank Farm SCS at the VMT (i.e., can one or both indirect assessment methods reliably identify leaks.) If the pilot study is successful, ELL and/or ERT can be used to evaluate the presence and prevalence of leaks in the SCS over larger portions of the VMT East Tank Farm. The pilot study was completed on an approximate 15,000 ft^2 area of the cell containing Tanks 15 and 16 in the West Tank Farm (WTF). Figure 2 provides a photograph of the pilot study area, which is outlined by the electrical isolation trench. The WTF tanks have been drained and decommissioned, although cathodic/corrosion protection remains normally energized (APSC temporarily deenergized these systems during the pilot study) (ELL and ERT Survey at VMT SCS – July 2024, Pilot Study, West Tank Farm; WSP 2024a). The pilot study consisted of establishment and verification of electrical isolation, ELL testing, ERT testing, installation of three defects (a large gash, small gash, and knife slit), additional ELL testing of the defect area, and SCS repair. The results of the pilot study are reported in WSP (2024a). This report provides a review of the pilot study results, and recommendations for the path forward.

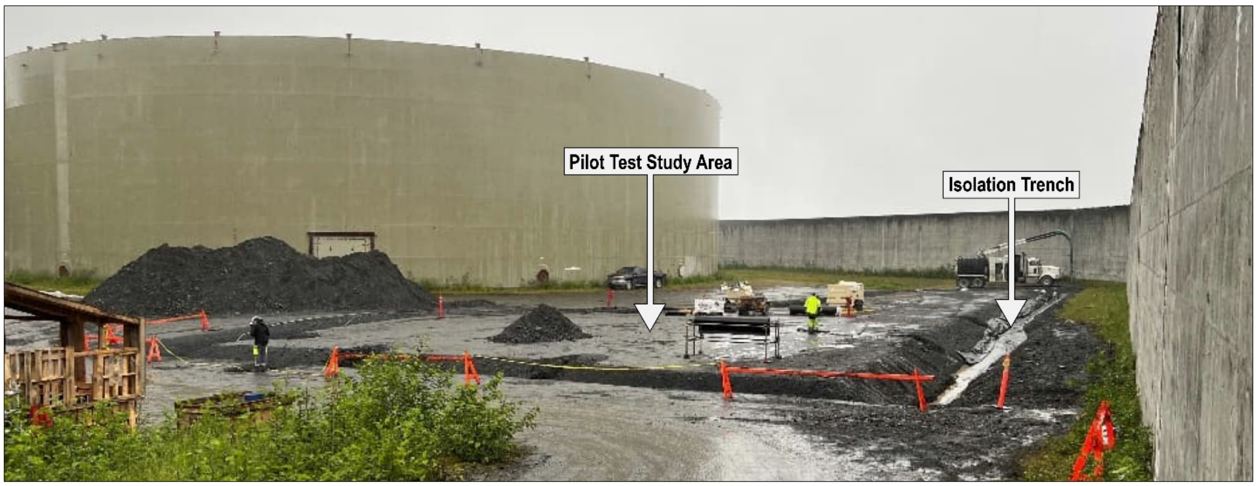


Figure 2. Photograph of pilot study test area (trimmed from WSP 2024a).

2. REVIEW OF PILOT TEST METHODS

The effectiveness of ELL and ERT depends on electrical isolation of the test area (open air and the CBA barrier layer serve as electrical insulators). Achieving electrical isolation was the most difficult aspect of the pilot study fieldwork. Prior to testing and isolation, a trench (moat) was excavated around the perimeter of the test area to the CBA (refer to Figure 2). Appreciable rainfall, which is common in the temperate rainforest climate in which Valdez is situated, necessitated the further installation of a rain flap consisting of a strip of non-conductive geomembrane (XR-5) bonded to the CBA surface (see Figure 3) using hot asphalt "*in accordance with Alyeska's CIVE-50 Catalytically Blown Asphalt (CBA), Hypalon, or XR-5 Liner Repair Procedure*" (WSP 2024a). The shape was chosen to achieve a 15,000 ft^2 test intended to "*optimize drainage and minimize other conflicts*" (WSP 2024a). The shape that was selected added complexity to trenching and the installation of the rain flap.

Figure 3. Photographs of installed rain flap (from WSP 2024a).

ELL surveying (shown in Figure 4a) was performed in general accordance with ASTM D7007-24, *Standard Practices for Electrical Locating Leaks in Geomembranes Covered with Water or Earthen Materials* (ASTM 2024) and ASTM D8265-23, *Standard Practices for Electrical Methods for Mapping Leaks in Installed Geomembranes* (ASTM 2023). These methods are appropriate for ELL testing and are widely used in practice. Equipment used for ELL surveys is described in WSP (2024a) and is typical and appropriate for the work conducted. Initial testing demonstrated the gravel cover over the CBA was electrically isolated via the isolation trench. The ELL survey was initially conducted using east-west transects, but both north-south and east-west transects were used to evaluate manufactured leaks.

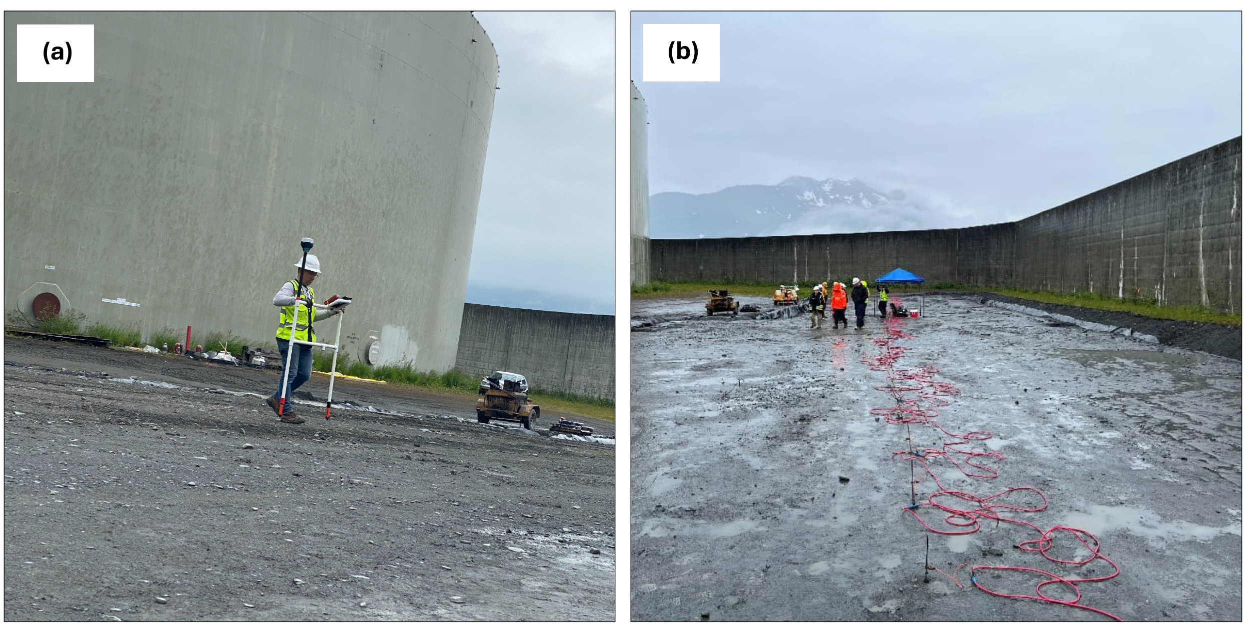


Figure 4. Photographs (a) electrical leak location survey and (b) electrical resistivity tomography (from WSP 2024a)

ERT (shown in Figure 4b) was performed along three approximately parallel transects running north-south in general accordance with ASTM D6431-18, *Standard Guide for Using Direct Current Resistivity Method for Subsurface Investigation* (ASTM 2018). Equipment used for ERT surveys is described in WSP (2024a) and is appropriate for the work conducted. Data were processed and the interpretation was conducted using industry standard commercial software.

After initial ELL and ERT surveys, four fully penetrating rips/cuts or holes were intentionally made (manufactured) in the CBA liner and re-buried. These defects are shown in Figure 5 and consisted of (1) a rip/cut 12-inch long with a ½-inch gap, (2) a rip/cut 6-in long without a gap, (3) a 1-in-diameter hole, and (4) a ½-inch-diameter hole.

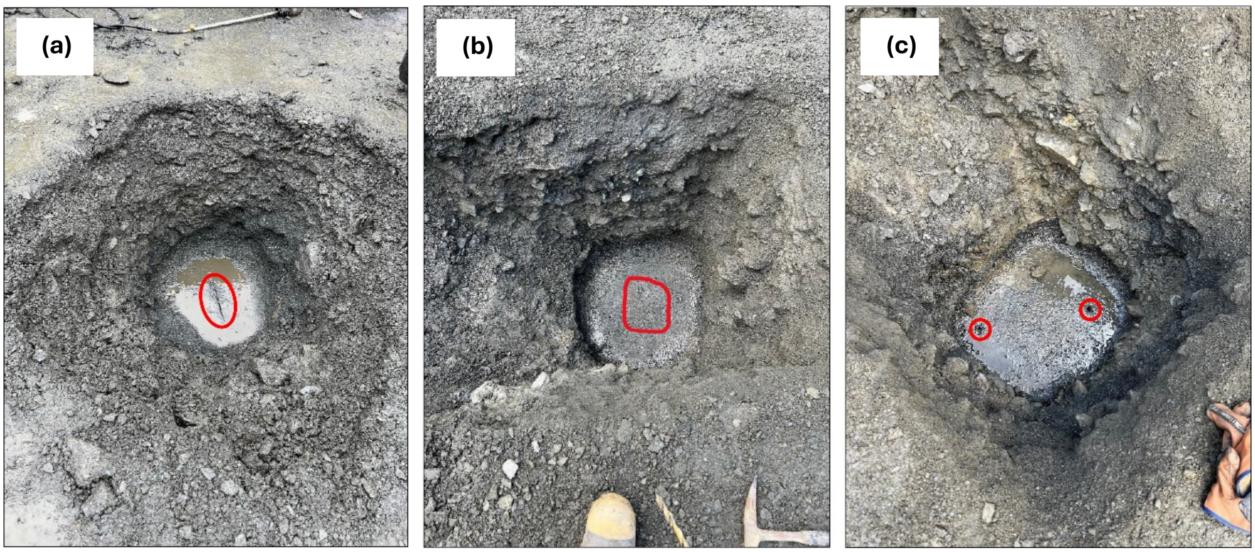


Figure 5. Photographs of manufactured defects: (a) a rip/cut 12-inch long with a ½-inch gap, (b) a rip/cut 6-in long without a gap, (c) a 1-in-diameter hole and a ½-inch-diameter hole (photos from WSP 2024a). Red oval in (a) outlines the rip/cut. Red outline in (b) outlines the rip/cut. Red circles in (c) outline the holes.

3. REVIEW OF PILOT STUDY FINDINGS

Key findings from the ELL and ERT pilot study reported in WSP (2024a) are summarized below in *italics*, followed by point-by-point comments.

1. ***ELL can effectively locate larger leaks in the CBA.*** *East-west ELL survey transects did not detect any potential leaks but also did not detect any of the manufactured leaks. North-south ELL survey transects were effective at locating the larger manufactured leaks. Therefore, future ELL survey transects should be run both parallel and perpendicular to one another (e.g., both north-south and east-west).*

   We agree that based on the findings of this study, ELL has been demonstrated to provide a method for indirect assessment of leaks in the SCS for the VMT East Tank Farm.

WSP notes that north-south survey transects were effective at locating the larger manufactured leaks, whereas none of the manufactured leaks were identified along the east-west survey transects. This dependence of transect orientation (north-south vs. east-west) is not common and is likely due to subsurface features that exist in the West Tank Farm, such as metal pipes, storm drains, and structural elements associated with the tank farm. These features may act as preferential flow paths for current below the liner, affecting orientation of the applied electrical field and masking electrical anomalies from defects in the CBA. Similar subsurface features are likely to exist in the East Tank Farm.

Furthermore, even though identified manufactured leaks were only detected using ELL surveys along north-south transects, the pilot study should not be interpreted to indicate that pre-existing leaks (non-manufactured) leaks do not exist along the east-west transects (or elsewhere). North-south ELL survey transects were only conducted over a limited area around the manufactured defects (less than 1/3 of the total area). Consequently, pre-existing leaks may exist but were not found detected along the north-south transects.

2. *Based on the results of the pilot study, ERT does not appear to be effective in delineating leaks in the CBA.*

   ERT surveys were only conducted in a north-south orientation and not in perpendicular orientations like the ELL surveys around the manufactured leaks. However, given the data were collected in the same orientation as ELL surveys that were successful in identifying the larger manufactured leaks, the likelihood of detecting leaks with additional perpendicular ERT transects is small. Therefore, we agree that ERT does not appear to be effective for delineating leaks in the CBA at the VMT.

3. *Effort was required to create an electrically isolating trench given the wet climate in Valdez.*

   We agree with this conclusion but also note that the isolation trench was constructed successfully for the pilot test. Additionally, Alyeska and their contractor (WSP) now have a much better sense of the level of effort and timing needed to successfully construct an isolation trench for future testing.

4. REVIEW OF PILOT STUDY RECOMMENDATIONS

Recommendations from the ELL and ERT pilot study reported in WSP (2024a) are summarized in *italics* below, followed by point-by-point comments.

1. *Based on the results of the pilot study, future efforts to evaluate the integrity of the East Tank Farm CBA liner at the VMT should include ELL surveys, temporarily de-energizing cathodic protection systems, and isolating any known potentially conductive perforations (e.g., metal pipes, storm drain catch basins) where practical.*

   We agree with this recommendation.

2. *ELL survey areas should be sized for each cell to include sufficient area to statistically calculate the estimated permeability of the SCS. WSP recommends a test area of 5% of the SCS (based on Pump*

Station 1, 3, 4, and 5 Liner Evaluation Method Recommendations; WSP 2024b; [this report was not made available for the authors' review]

We agree that the size of the ELL survey area should be selected for each cell so the evaluated area is sufficient to provide statistical confidence in the assessment. We disagree with the recommendation that 5% of the area should be tested. As described in Benson (2022), at least 20% of the CBA liner must be tested to adequately reduce uncertainty in the total number of defects determined from the survey. Additionally, assessments conducted on exposed CBA liner should not be extrapolated to represent conditions for buried CBA liner.

We disagree that the findings from the ELL surveys should be used to calculate an effective permeability of the SCS. Instead, we recommend that the findings be used to estimate a leakage rate (e.g., gallons per acre per day). Permeabilities are appropriate for porous media (e.g., soils), but are not appropriate for flow through defects in membrane-type liners such as the CBA liner.

We also agree with WSP (2024b) that the surveyed area should not include the isolation trench or a 5-ft-wide strip extending inward from the strip due to edge effects.

3. *Where future ELL indicates potential defects/leaks, the locations should be marked and excavated for visual inspection. If leaks are discovered, they should be patched, backfilled, and the ELL survey rerun over the location to verify there are no additional leaks.*

We agree with this recommendation.

5. RECOMMENDED PATH FORWARD

The pilot study demonstrated that ELL is effective at identifying larger leaks in the CBA liner in the SCS of the VMT. The following path forward is recommended to continue the evaluation of the SCS and to determine whether the SCS is "*sufficiently impermeable.*"

1. ELL surveys should be implemented over at least 20% of the CBA-lined area of the East Tank Farm. This does not include SCS area with exposed geomembrane that can be directly inspected, as this is a different liner material. Testing should consider the lessons learned from the pilot study, including:
    a. Use of similar methods and equipment as the pilot study (see WSP 2024a for specific testing details).
    b. Implementation of a series of orthogonal ELL survey transects by a skilled implementation team.
    c. The need for effective isolation of the test area.

    The ELL surveys can then be used to establish the frequency and size range of defects in the total East Tank Farm CBA liner.

2. Establish a quantitative definition of "*sufficiently impermeable*" as it applies to the SCS of the VMT. If the SCS had been built after May 1992, the definition would be "*sufficiently*

impermeable" would be "*using a layer of natural or manufactured material of sufficient thickness, density, and composition to produce a maximum permeability for the substance being contained of 1 x 10^{-6} cm per second at a maximum anticipated hydrostatic pressure, unless the department determines that an alternate design standard protects groundwater from contamination and contains a discharge or release until detection and cleanup.*"

[18 AAC 75.990 (124)] states that *"for a secondary containment system, that its design and construction has the impermeability necessary to protect groundwater from contamination and to contain a discharge or release until it can be detected and cleaned up.*"

A definition in terms of a maximum allowable leakage rate per unit area (i.e., maximum allowable oil leakage per acre of SCS per day) is preferred over a maximum permeability because the release of oil would occur predominantly through discrete defects in the liner and not by flow (permeation) of oil through the CBA liner.

3. Establish a methodology for computing the leakage rate (or equivalent permeability) of oil through the SCS. There are numerous methodologies used in practice for calculating leakage of liquids through defects in geomembranes. Modification of current state-of-practice methods to compute the leakage of oil will likely be required because the existing methods were developed for computing leakage rates for water. Additional physical characterization of the materials above and below the CBA liner will likely be required as inputs for these calculations.

4. Use the extrapolated survey results in (1) and the methodology in (3) to compute a leakage rate (or effective permeability) of the SCS and compare to this leakage rate to quantitative definition of "sufficiently impermeable" identified in (2).

Finally, WSP (2024a) indicates that the CBA liner has a "*thickness ranging from 0.1875 to 1.625 inches*." This is a change from earlier reports, which state that "*According to the construction documentation for the VMT, the specified minimum CBA liner thickness was 5/16 inch (0.31 inches)"* (Golder 2018). A portion of the CBA liner was observed to be thin (i.e., approximately 0.1875 inches) during pilot testing. Previous laboratory testing reported and summarized in Golder (2018) was conducted on liner as thin as 0.31 inches. Consequently, additional laboratory testing is needed to demonstrate that the liner will be effective in containing oil over the anticipated necessary duration of performance at a thickness of 3/16 inches (0.1875 inches).

REFERENCES

ASTM International (2018), "Standard Guide for Using the Direct Current Resistivity Method for Subsurface Site Investigation," D6431-18, West Conshohocken, Pennsylvania.

ASTM International, (2021), "Standard Guide for Selection of Techniques for Electrical Leak Location of Leaks in Geomembranes," D6747-21, West Conshohocken, Pennsylvania.

ASTM International. (2023), "Standard Practices for Electrical Methods for Mapping Leaks in Installed Geomembranes," D8265-23, West Conshohocken, Pennsylvania.

ASTM International, (2024), “Standard Practices for Electrical Locating Leaks in Geomembranes Covered with Water or Earthen Material,” ASTM D7007-24, West Conshohocken, Pennsylvania.

Benson, C. (2022), Methodologies for Evaluating Defects in Catalytically Blow Asphalt Liner in the Secondary Containment System at the Valdez Marine Terminal, report to the Prince William Sound Regional Citizen’s Advisory Council, prepared by Craig Benson, Madison, Wisconsin.

Calendine, S., Crook, N., and Baldyga, C. (2018), Electric leak detection and leak location on geosynthetic liners in the mining industry, https://www.semanticscholar.org/paper/Electric-leak-detection-and-leak-location-on-liners-CalendineCrook/af5c7e73e5dfc7ccbae8c867d93540b7d800f6f6 (accessed 15 June 2022).

Gilson-Beck, A. (2019), Controlling leakage through installed geomembranes using electrical leak Location, *Geotextiles and Geomembranes*, 47(5), 697-710.

Golder (2015), Field Inspection and Liner Evaluation for Catalytically Blown Asphalt CBA Liner at the Valdez Marine Terminal, report to Alyeska Pipeline Service Company by Golder Associates Inc., Anchorage, Alaska.

Golder (2016), Additional Liner Testing and Evaluation for Catalytically Blown Asphalt (CBA) Liner at the Valdez Marine Terminal, report to Alyeska Pipeline Service Company by Golder Associates Inc., Anchorage, Alaska.

Golder (2017), 2016 Liner Testing and Evaluation for Catalytically Blown Asphalt (CBA) Liner at the Valdez Marine Terminal, report to Alyeska Pipeline Service Company, prepared by Golder Associates, Anchorage, Alaska.

Golder (2018), 2017 Liner Testing and Evaluation for Catalytically Blown Asphalt (CBA) Liner at the Valdez Marine Terminal, report to Alyeska Pipeline Service Company, prepared by Golder Associates, Anchorage, Alaska.

Koerner, J., Koerner, R., and Koerner, G. (2016), Status of the Electrical Leak Location Survey (ELLS) Method Among State Environmental Protection Agencies in the USA, GSI White Paper No. 34, Geosynthetic Institute, Folsom, PA.

Peggs, I. (2007), Liner integrity/leak-location survey: The significance of boundary conditions. *Geosynthetics*, Industrial Fabrics Association International, February-March 2007, 34-38.

Schmia, S., LaBrecque, D., and Lundegard, P. (1996), Monitoring air sparging using resistivity tomography, *Groundwater Monitoring and Remediation*, 132-138.

WSP (2024a), ELL and ERT Survey at VMT SCS - July 2024, report to Alyeska Pipeline Service Company, prepared by Golder Associates, Anchorage, Alaska.

WSP (2024b), Pump Station 1, 3, 4, and 5 Liner Evaluation Method Recommendations.

Zhou, B. (2019), Electrical resistivity tomography: a subsurface-imaging technique, *Applied Geophysics with Case Studies on Environmental, Exploration and Engineering Geophysics*, Intech Open, London.

Alyeska pipeline SERVICE COMPANY

P.O. Box 109 VALDEZ, ALASKA 99686 TELEPHONE (907) 834-6480

Government Letter No. 60158
APSC File No. 8.02

February 28, 2025

State of Alaska
Department of Environmental Conservation
Division of Spill Prevention, Preparedness, & Response
213 Meals Ave., Ste. #17
P.O. Box 1709
Valdez, AK 99686

Attention: Anna Carey, Environmental Program Manager

Subject: **Valdez Marine Terminal (VMT) Oil Discharge Prevention and Contingency Plan; ADEC Plan No. 23-4057**

Re: **VMT East Tank Farm (ETF) Secondary Containment System: Final Evaluation Method Selection**

Dear Ms. Carey:

With this letter Alyeska Pipeline Service Co. (APSC) is providing the report on the Final Evaluation Method Selection as required by the informal review decision letter dated May 11, 2022, and the November 8, 2024, approval package. The enclosed report details the Scope, Pilot Testing, Method Selection, Schedule, and Communication Plan as proposed.

If there are any changes to this arrangement due to anticipated events you will be notified, and timely updates will be provided. If you have any questions or comments regarding this matter, please contact me at 907-834-6988 or direct all written correspondence to:

Allison Iversen
HSEC Director
Alyeska Pipeline Service Company
P O Box 196660, MS 502
Anchorage, Alaska 99519-6660

Sincerely,

for Andres Morales

Andres Morales
EP&R Director

AM/jm

cc: Electronically

Mike Day, APSC
Martin Parsons, APSC
Melany Brewi, APSC
Jess Elder, APSC
Lindsey Vorachek, APSC
Klint VanWingerden, APSC
Dustin Smith, APSC
Wendy Duran, APSC

SPCO Records (ADNR/SPCO)
Melissa Woodgate, ADEC
Mo Radotich, ADEC
Mollie Dunkin, ADEC
Sonja Mishmash, ADEC
Bob Whittier, EPA
BLM/BPM Records (BLM/BPM)
MSU Valdez CDO

Alyeska pipeline SERVICE COMPANY

Memorandum

To:	Subject:	
Lindsey Vorachek, System Integrity Director 184557 Klint VanWingerden, Valdez Marine Terminal Director 184024	VMT – East Tank Farm Secondary Containment System Final Evaluation Method Selection	
From:	Date:	File Number:
Dustin Smith, Systems Integrity 184804	02/27/2025	SYIN-0225-006 Rev0

General

The ETF hosts fourteen (14) 510,000 bbl nominal capacity, in-service crude oil aboveground storage tanks, arranged in pairs, making seven independent containment cells. The secondary containment cells are generally comprised of surface lined dikes (XR-5 installed in 1992), concrete walls and a buried catalytically blown asphalt (CBA) liner on the floor of the cell. Each cell includes concrete pipe supports, fire suppression piping, catch basins and manholes that penetrate the liner. The XR-5 was sealed to the CBA and concrete structures upon installation. IWWS system modifications and repairs have replaced existing manholes and catch basins within the tank farm and were resealed to the existing CBA liner.

Scope

As required by the informal review decision letter dated May 11, 2022; Alyeska is required to propose a method to evaluate the condition of the buried VMT East Tank Farm (ETF) Secondary Containment System (SCS). Specifically, the evaluation shall determine the condition as it relates to 18 AAC 75.075(a)(2)(C), which states that the secondary containment liner shall consist of a material that is ‘sufficiently impermeable’, as defined by 18 AAC.75.990(124).

18 AAC 75.075: Secondary containment requirements for aboveground oil storage tanks.

(a) Onshore aboveground oil storage tanks must be located within a secondary containment area that has the capacity to hold the volume of the largest tank within the containment area, plus enough additional capacity to allow for local precipitation. Minimum secondary containment system requirements include

> (2) with the exception of the area under a tank, components constructed of, or lined with, materials that are
>
> > (C) sufficiently impermeable

18 AAC 75.990: Definitions

> (124) “sufficiently impermeable” means, for a secondary containment system, that its design and construction has the impermeability necessary to protect groundwater from contamination and to contain a discharge or release until it can be detected and cleaned up; for design purposes for tanks constructed after May 1992, “sufficiently impermeable” means using a layer of natural or manufactured material of sufficient thickness, density, and composition to produce a maximum permeability for the substance being contained of 1×10^{-6} cm per second at a maximum anticipated hydrostatic pressure, unless the department determines that an alternate design standard protects groundwater from contamination and contains a discharge or release until detection and cleanup;

Historical Evaluation and Testing

Historical examinations have exposed approximately 23,000 sq ft out of a total of approximately 1,532,697 sq ft (excluding area under tanks) of buried CBA liner. Examinations occurred in every one of the seven cells (roughly 1% has been exposed in these efforts). Most recently, 2014-2017 program upgrades to the IWWS manholes, catch basins, and piping inside containment cells provided opportunistic evaluations of approximately 14,200 sq ft of CBA liner.

Durability experiments have been conducted on samples removed from the existing CBA liner. Laboratory tests indicated the CBA to be adequately resistant to crude oil and capable of containing a crude oil spill until it can be cleaned up. Testing revealed that after CBA has degraded or softened enough to leak after extended contact with crude, the material will seal itself and re-harden, minimizing the leakage volume. The CBA liner has also demonstrated self-healing and sealing characteristics. Testing indicates that with a rock or cobble embedded through the CBA (two instances noted) the liner remains sufficiently impermeable.

Historical examinations of the line have occurred over a small percentage of the liner area. Most damage found within the CBA liner appears to be mechanical in nature, potentially resulting from prior exposure during excavation. Physical excavation of the CBA tends to cause damage to the lining system. In 2014-2017 program upgrades to the IWWS manholes, catch basins, and piping inside containment cells provided opportunistic evaluations examinations of the CBA liner. Testing at that time found the liner has remained flexible, pliable, well bonded to penetrating structures and collected water on surface during rain events.

Existing damage to the CBA liner was found to include; a 4,400 sq ft area of cracking (surface cracks with some fully penetrating cracks), two instances of a rock or cobble embedded through the full thickness of the liner, two isolated areas of small perforations, what appeared to be an unrepaired historical sample location, and seven areas of perforated liner.

Testing conducted in 2014-2017 found the average CBA liner permeability to be 6.48 x 10^{-9} cm/s. The overall permeability of the lining system will be largely determined by any defects or perforations that may be present.

Based on the configuration of the SCS, the area most susceptible to damage is where liner is exposed above grade. Alyeska conducts annual visual inspections to address the above grade containment. Damage to CBA is not expected unless in proximity of historical excavations. The most significant excavation to have occurred in ETF is attributed to the installation of XR-5 on the SCS side slopes.

Spills of significant size and/or duration to infiltrate down to the CBA liner have not occurred within the ETF SCS. Liner examinations conducted during the IWWS upgrades did not identify deleterious CBA conditions attributed to contamination from below the SCS.

Pilot Testing

In July of 2024, a pilot test was conducted in the West Tank Farm (WTF) to determine feasibility of using geoelectric/electrical leak location (GELL/ELL) and electrical resistivity tomography (ERT) to locate damage within the buried sections of the secondary containment system. The WTF SCS construction is similar to the ETF with a CBA floor and sidewalls consisting of geomembrane and concrete.

A test area of 17,141 ft^2 was constructed within the Tank 16/17 dike cell. To facilitate the ELL testing method, an isolation trench was excavated around the test area, and a 'rain flap' of XR-5 was bonded to the exposed CBA liner. The trench, in conjunction with the rain flap, provided electrical isolation across the trench throughout significant rainfall typical at the VMT.

Electrical Leakage Location (ELL)

ELL methods are an effective and proven quality assurance measure to locate leaks (where "leak" is defined by ASTM as any unintended opening, perforation, breach, slit, tear, puncture, crack, or seam breach). Such methods have been used successfully to locate leaks in electrically insulating geomembranes (includes bituminous membranes) installed in basins, ponds, tanks, ore and waste pads, and landfill cells. The principle behind this technique is to place a voltage across a sufficiently electrically insulating geomembrane and then locate areas where electrical current flows through leaks in the geomembrane. Other electrical leak paths such as piping penetrations, metal conduit, steel drains, concrete and other extraneous electrical paths should be electrically isolated to prevent masking of leak signals caused by electrical short-circuiting through those preferential electrical paths.

The ELL surveys were conducted along multiple parallel lines to create a roughly orthogonal grid of data which was used to contour data and identify potential leaks. The spacing of the dipole electrodes is based on the thickness of the soils or depth of fluid above the geomembrane (generally dipole spacing is approximately equal to cover thickness). The line spacing was nominally 3 feet with measurements recorded every 18 to 36 inches along survey lines.

Initial ELL surveys found the liner to be in sound condition and did not identify any leaks. To advance the pilot study, three locations were excavated, through-thickness defects manufactured in the CBA, backfilled, and resurveyed with ELL. One additional location of interest was excavated based on resurvey with the ELL however, no leaks or damage to the CBA was encountered.

Electrical Resistivity Tomography (ERT)

Electrical Resistivity Tomography (ERT) is an electrical method used to determine the lateral and vertical changes in electrical resistivity of subsurface materials. These changes may result from variations in lithology and mineralogy, water content, and pore-water chemistry. In the case of liner leak detection, fluid seeping through a defect/leak would be detected as an area of decreased resistivity/increased conductivity. The method involves transmitting an electric current into the ground between two current electrodes and measuring the voltage between two separate potential electrodes.

The ERT was conducted in various configurations using the same electrodes as the ELL survey. Both pre-defect and post-defect ERT tests were conducted to evaluate the method.

Pilot Test Results

- ERT was not effective in delineating or mapping vertical plumes or other leakage from defects in the CBA liner.
- Results suggest ELL can effectively locate significant defects/leaks in the CBA liner.
- Both source electrode geometry and receiver/jig survey electrode orientation must be carefully considered for the ELL method to successfully detect and locate potential defects/leaks in the CBA liner. ELL survey lines should be run both parallel and perpendicular to one another (e.g., both north-south and east-west orientations).
- For ELL to be successful in locating defects in the SCS, the soil above the liner must be electrically isolated from conductive penetrations and buried piping by trenching around a test area. VMT rainfall necessitated the use of pumps and XR-5 rain flaps to maintain isolation across the trench.
- Due to edge effects, the ELL survey will be less effective at the edge, adjacent to the isolation trench.
- If a defect/leak in the SCS is discovered, the defect should be repaired, the excavation backfilled, and the ELL survey rerun over the location to verify there are no additional defects/leaks.

Method Selection

To examine the SCS of the ETF, Alyeska has selected Electrical Leakage Location (ELL) coupled with Visual Inspection (VT) as the methods of evaluation. ELL was selected as the least invasive, non-destructive method that successfully located manufactured damage within the CBA liner during the WTF Pilot Test. The CBA subjected to VT will be limited to areas exposed to conduct the ELL survey or opportunistically, during other field work.

Other methods considered were Electrical Resistance Tomography (ERT), Hydraulic Assessment, and Ground Penetrating Radar (GPR). ERT was not found to be effective during the WTF pilot testing, and GPR data was described as “ambiguous and undefined” during evaluations of Pump Station liners in 2000. Hydraulic assessment was not considered due to its inability to define the location of defects, operation interference of flooding dike cells and magnitude of effort required to adequately complete the test.

Limitations:

The buried portion of the ETF SCS consists of several configurations including the CBA floor, XR-5 side slopes, various sealed penetrations through the liner, and historical liner repairs. ELL relies on electrical current passing through discrete points within the survey area to identify defects. Therefore, the designated survey areas must be isolated from any potential interferences or other conductive appurtenances within the containment cell. These may include concrete pipe supports, piping penetrating the liner, tank foundations, concrete cell walls, etc. Any conductive liner penetrations, such as historical bentonite repairs, will be falsely identified as leaks by the ELL testing. Conductive penetrations within a test area must be excavated around to maintain electrical isolation.

As ELL evaluation cannot be conducted at conductive liner penetrations, and therefore cannot evaluate the bond between the existing liner and a conductive structure. These junctures will be examined visually when exposed. Historical reports consistently indicate the CBA has been found to be well-bonded to penetrating structures and thus is not a point of interest for this examination.

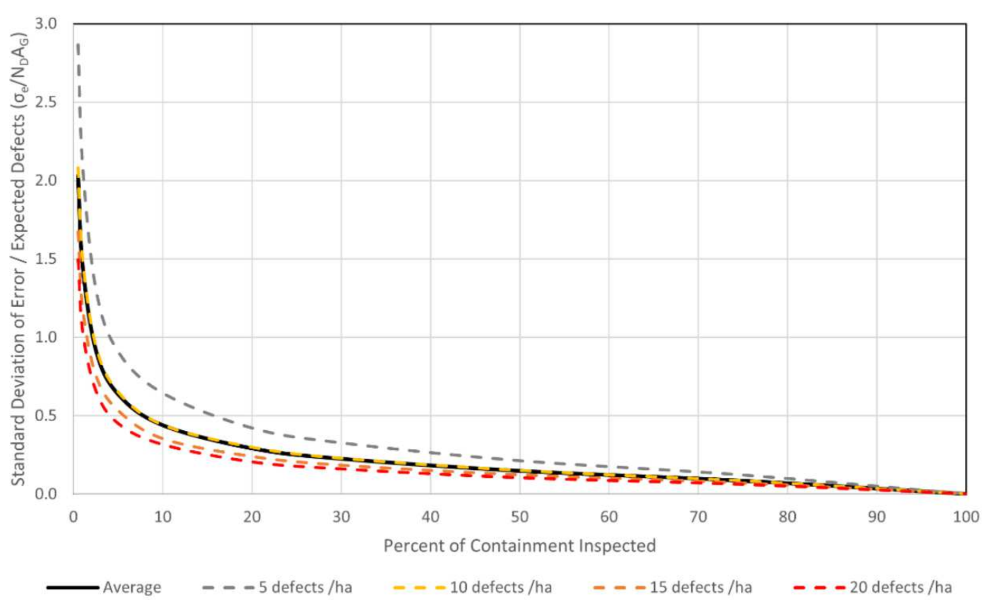
Scale of Evaluation:

To identify and locate defects, the evaluation will be performed on an area large enough to provide an accurate characterization of the condition of the liner. A probabilistic simulation was used to demonstrate the fraction of buried CBA liner to be evaluated to accurately characterize the liner system.

WSP conducted a statistical analysis for a generic secondary containment model, similar to the Monte Carlo analysis done on behalf the PWSRCAC by Dr. Benson in 2022 but differs as it is for a contiguous area. This is warranted for feasibility reasons as the cover soil must be isolated for an ELL survey. Comparing Dr. Benson's Model (2022) and the WSP Model (2024) at a defect density of 10 defects/ha, both reach a similar "Standard Deviation of Error/Expected Defects" ratio of approximately 0.6, corresponding to 10% (Benson) and 5% (WSP) inspection of liner area.

- Based on the statistical simulation, Alyeska will test at least 5% of the buried SCS within each dike cell with a combination of ELL and VT to provide a realistic estimate of permeability.

Figure 1 – Statistical Analysis (WSP, 2024)



Historical information suggests the CBA liner typically incurs substantially more damage by the excavation activity itself compared to existing damage found. As the replacement of the perimeter geomembrane with XR-5 represents the most extensive excavation to have occurred, some evaluation areas will be primarily focused on the XR-5 to CBA transition.

One evaluation area will be selected for each dike cell. Precise location and dimensions will be dependent on Process Hazards Analysis, avoiding operational upsets, and maintaining access for response to emergencies or abnormal conditions.

Table 1 – SCS Area

Cell No.	Total SCS Area[A] (ft^2)	Slope SCS Area (ft^2)	Buried Floor SCS Area[B] (ft^2)	Applicable SCS Area[C] (ft^2)	Evaluation Area[D] (ft^2)
1	406,250	100,460	305,790	206,038	10,302
2	363,710	38,140	325,570	225,818	11,291
3	361,910	41,460	320,450	220,698	11,035
4	374,440	38,910	335,530	235,778	11,789
5	378,200	40,660	337,540	237,788	11,889
6	389,210	82,240	306,970	207,218	10,361
7	392,040	92,930	299,110	199,358	9,968
Total	2,665,760	434,800	2,230,960	1,532,697	76,635

Notes:

A) Area of tank farm cell
B) Area of SCS excluding SCS slopes
C) Area of SCS floor excluding tank and ring wall (252' diameter -> 99752 sq ft)
D) 5% of Applicable SCS Area

Quality Assurance and Accuracy

The WTF Pilot Testing provides assurance that liner perforations can be located by ELL. The following measures will be implemented for quality assurance and accuracy.

- The ELL surveys will be conducted in both East-West and North-South orientations, which is normally not required per ASTM D7007 but noted to be critical in finding manufactured liner damage during the pilot testing.
- Leak indications noted by ELL will be excavated. Where buried liner damage is encountered, a post-repair ELL survey will be completed to verify no leaks exist in the proximity that could potentially be masked by a larger defect's electrical signature.
- To reduce interference from edge effects, ELL survey area trench perimeter will be expanded to include a 5-foot buffer between the isolation trench and area selected for evaluation.
- A visual inspection (VT) checklist will provide consistency across various inspectors and personnel performing VT of exposed CBA.

Data Analysis

Laboratory analysis indicates that intact CBA impermeability exceeds ADEC criteria for newly installed liner systems, and therefore overall dike cell permeability would be defined by the defects or perforations existing within the liner system if present.

In 18 AAC 75.990 Definitions (124), ADEC defines sufficiently impermeable for a secondary containment system as *"a layer of natural or manufactured material of sufficient thickness, density, and composition to produce a* *maximum permeability for the substance being contained of 1 x 10^{-6} cm per second at a maximum anticipated hydrostatic pressure"*.

Following evaluation of each dike cell containment, the overall flow and "pseudo permeability" of each dike cell will be calculated and compared to the theoretical flow which would occur through a newly installed, soil lined SCS with a permeability 1×10^{-6} cm/s.

- A pseudo permeability of less than 1×10^{-6} cm/s would indicate a dike cell exceeds the ADEC criteria for both new and existing facilities. This is consistent with SCS liner evaluations conducted at various TAPS Pump Stations in 2000.
- Pseudo permeability greater than 1×10^{-6} cm/s may still satisfy ADEC requirements for tanks installed prior to 1992 in *"that its design and construction has the impermeability necessary to protect groundwater from contamination and to contain a discharge or release until it can be detected and cleaned up".* These instances, if any, will be evaluated on a case-by-case basis and may require additional site evaluation, expanded ELL surveys, and laboratory testing.

Schedule

Alyeska will submit to SPAR a timeline outlining target dates for key deliverables and project milestones by April 1, 2025.

Communication Plan

An annual report would be provided to ADEC containing:

- Summary of evaluation areas covered that season.
- Summary of findings from ELL and VT inspections.
- Permeability analysis and calculations for the tested secondary containment cell.

References:

- Golder Associates, 1999. "Evaluation of Liner Seam and Perforation Leakage Rates in Secondary Containment Systems at TAPS Pump Stations, dated January 5, 1999.
- Golder Associates, 2000. "Field Investigation and Evaluation for Pump Station Tank Farm Liners", October 2000.
- Golder Associates, 2013. "Evaluation of Methods for Establishing the Integrity of the Secondary Containment Liners at the Valdez Marine Terminal", dated August 21, 2013.
- Golder Associates, 2014. "Field Inspection and Liner Evaluation for Catalytically Blown Asphalt (CBA) Liner at the Valdez Marine Terminal", dated April 1, 2015.
- Golder Associates, 2015. "Additional Liner Testing and Evaluation for Catalytically Blown Asphalt (CBA) Liner at the Valdez Marine Terminal", dated June 27, 2016.
- Golder Associates, 2016. "Liner Testing and Evaluation for Catalytically Blown Asphalt (CBA) Liner at the Valdez Marine Terminal", dated July 18, 2017.
- Golder Associates, 2017. "Liner Testing and Evaluation for Catalytically Blown Asphalt (CBA) Liner at the Valdez Marine Terminal", dated June 2018.
- WSP Golder, 2023. "Secondary Containment Liner Evaluation Method Recommendations", dated May 2, 2023.
- WSP, 2024, "Pump Station 1, 3, 4, and 5 Liner Evaluation Method Recommendations", dated March 27, 2024
- WSP, 2024. "ELL and ERT Survey at VMT SCS – July 2024", dated October 2, 2024.
- APSC, 2020. CP-35-2 Vol.1, Ed. 2, Revision 7 "Oil Discharge Prevention and Contingency Plan Regulatory Manual", dated January 2022.
- APSC, 2022. OMS-3.16 Revision 22 "Tank Farm Operator Duties – Required Checks", dated December 8, 2022.
- APSC, 2022. CIV-50 Rev 16 "Catalytically Blown Asphalt (CBA), Hypalon, or XR-5 Liner Repair Procedure", dated May 24, 2022.

- *ASTM D6747*, “Standard Guide for Selection of Techniques for Electrical Detection of Potential Leak Paths in Geomembrane”
- *ASTM D7007*, “Electrical Methods for Locating Leaks in Geomembranes Covered with Water or Earthen Materials”
- *ASTM D8265*, “Standard Practice for Electrical Methods for Mapping Leaks in Installed Geomembranes”

--END--

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