Consent Agenda Briefing for PWSRCAC Board of Directors – September 2025

ACTION ITEM

Sponsor: Joe Lally & TOEM Committee
Project number and name or topic: 5081 – Storage Tank Maintenance Review

1. **Description of agenda item:** The Board is being asked to accept the report titled "Review of Ballast Water Tank 93 Out-of-Service Inspection Report and Tank Repairs," by Taku Engineering, LLC, dated July 2025, as meeting the terms and conditions of contract number 5081.25.01 and for distribution to the public.

2. **Why is this item important to PWSRCAC:** This report offers a technical review of the maintenance of Ballast Water Storage Tank 93 at the Valdez Marine Terminal. The goal of this project is to review maintenance practices and provide recommendations for improvement to help minimize the risk of an oil spill from the crude oil and ballast water storage tanks at the Valdez Marine Terminal.

3. **Previous actions taken by the Board on this item:** No previous action has been taken by the Board on this item.

4. **Summary of policy, issues, support, or opposition:** None known.

5. **Committee Recommendation:** The Terminal Operations and Environmental Monitoring Committee provided consensus via poll to recommend the report "Review of Ballast Water Tank 93 Out-of-Service Inspection Report and Tank Repairs," by Taku Engineering, LLC, dated July 2025, be accepted by the Board as meeting the terms and conditions of contract number 5081.25.01, 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 5081.25.01in the amount of $28,097.

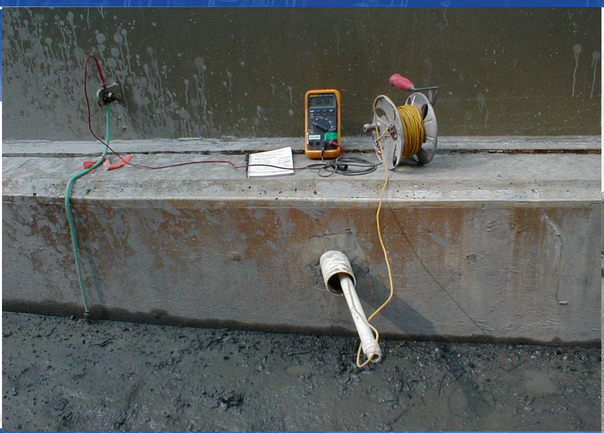
7. **Action Requested of the Board of Directors:** Accept "Review of Ballast Water Tank 93 Out-of-Service Inspection Report and Tank Repairs," by Taku Engineering, LLC, dated July 2025 as meeting the terms and conditions of contract number 5081.25.01, and for distribution to the public.

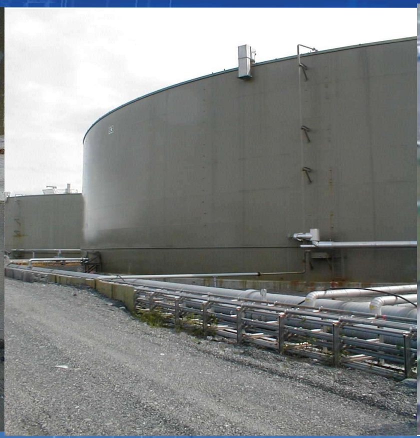
8. **Alternatives:** None recommended.

9. **Attachments:** Draft report titled "Review of Ballast Water Tank 93 Out-of-Service Inspection Report and Tank Repairs," by Taku Engineering, LLC, dated July 2025.

FINAL REPORT

Review of Ballast Water Tank 93 Out-of-Service Inspection Report and Tank Repairs





Report Prepared for:

PRINCE WILLIAM SOUND RCAC REGIONAL CITIZENS' ADVISORY COUNCIL

PWSRCAC Contract # 5081.25.01

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July 2025

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ACRONYMS & ABBREVIATIONS

API – American Petroleum Institute

APSC – Alyeska Pipeline Service Company

AUT – Automated Ultrasonic Testing

BWTF – Ballast Water Treatment Facility

CP – Cathodic Protection

CR_{EST} – Effective Structural Thickness Corrosion Rate

EST- Effective Structural Thickness (tank column)

MFE – Magnetic-Flux Exclusion

MIL –1/1000th of an Inch

MMO – Mixed Metal Oxide

MP – Monitoring Procedure

MPY – Mils-Per-Year

MRT – Minimum Remaining Thickness

MRWT – Minimum Remaining Wall Thickness

MV – Millivolt

NACE – National Association of Corrosion Engineers

PE – Professional Engineer

PWSRCAC – Prince William Sound Regional Citizens' Advisory Council

RFT – Remaining Floor Thickness

SP – Standard Practice

STD – Standard

T_{EST} – Minimum Effective Structural Thickness (tank column)

$T_{EST,MIN}$ – Minimum Remaining Effective Structural Thickness (tank column)

TK – Tank

T_{NOM} – Nominal Thickness

UT – Ultrasonic Testing

VMT – Valdez Marine Terminal

1.0 EXECUTIVE SUMMARY

1.1 GENERAL

In October of 2024, the Prince William Sound Regional Citizens' Advisory Council (PWSRCAC or Council) tasked Taku Engineering (Taku) with reviewing documents associated with the American Petroleum Institute (API) Standard (STD) 653 Out-of-Service inspection of Valdez Marine Terminal (VMT) Ballast Water Storage Tank 93 (Tag number 51-TK-93), as well as documents associated with the tank annular plate replacement. The intent of this project was to review maintenance practices associated with the tank internal inspection and provide recommendations for improvement to help minimize the risk of an oil spill from the ballast water storage tanks at the VMT.

This report addresses a review of the inspection procedures and reports for the 2023 inspections and modifications on Tank 93 located in Alyeska Pipeline Service Company's (APSC or Alyeska) VMT Ballast Water Treatment Facility (BWTF).

Background on Tank 93

Constructed in 1976, Tank 93 is a 250-foot diameter, 430,000-barrel, welded steel, ballast water storage tank located in the VMT's BWTF. This tank was designed and constructed to API STD 650, and has been inspected and maintained in accordance with API STD 650 and STD 653.

In 2002, Tank 93 was removed from service, lifted 18 inches, and a new ring wall foundation, floor, and sub-floor mixed metal oxide (MMO) grid-type cathodic protection (CP) system were installed. Follow-up out-of-service inspections on Tank 93 were completed in 2012, after which it was returned to service. In 2023, Tank 93 was removed from service, inspected, the annular ring was replaced, repairs were completed, and the tank was returned to service.

Background on Study Documents

PWSRCAC initially requested documents related to this project in September 2023, which Alyeska provided in December 2023. These included:

- Tank 93 floorplate layout and subfloor drawings.
- Tank 93 CP system as-built documents.
- Tank 93 CP Reports/Data.
- Design package for current Tank 93 modifications.
- Data from the current Tank 93 API 653 Out-of-Service inspection (2023).

Based on a review of those initial documents, PWSRCAC submitted additional clarifying document requests in October 2024, which were partially provided by Alyeska in January 2025. The documents received included:

- 2002-2017 Tank 93 CP Data.
- 2023 Tank 93 Engineering Summary Report.

- Explanation of the purpose of the new vapor nozzle installed on Tank 93 and the design of vapor system modifications.
- As-built drawings of Tank CP System (Missing Drawings D-51-E802 Sheets 2 through 8).
- 2012 Tank 93 API 653 Out-of-Service Inspection Report.
- 2017 Tank 93 API 653 5-Year In-Service Inspection Report.
- 2012 Tank 93 Engineering Summary Report.

As of July 14, 2025, PWSRCAC has not received from Alyeska the 2024 Tank 93 Cathodic Protection Data, new vapor nozzle designs and purpose, Repair Procedures WOCR 001- through 028, or the 2023 Tank 93 Annular Plate Design Drawings. Given this, the scope of the project and recommendations for Alyeska were limited to a review of the information provided.

This study reviewed designs for the modifications completed on the tank as well as the API 653 Out-of-Service Inspection reports for the tank. This review has resulted in the development of several findings and recommendations. Detailed discussions are provided in Sections 3 of this document. General findings and recommendations are discussed below.

1.2 FINDINGS

Based on our review of the Tank 93 documents received, we have drawn the following conclusions:

- The techniques and equipment used to inspect the tank components align with industry standards.
- The inspectors that completed the tank inspection appear to have the proper training and credentials.
- Alyeska's decision to install a drip ring on the annular plate extension is a positive improvement and may help to reduce the corrosion rate of the annular and perimeter plates. However, it is not expected to fully ameliorate the high corrosion rates noted in these areas. Modifications to the CP system beneath the tank perimeter would be required to fully alleviate the high corrosion rates noted in the annular and perimeter floor plates (see below).
- The existing perimeter anodes are 9 feet from the tank perimeter and buried 18-inches from the floor bottom. In this configuration, the CP system is not positioned to provide sufficient CP current to the perimeter floorplates and annular plates, leaving the perimeter soil-side surfaces of those areas unprotected. This is evidenced by the high corrosion rate identified in the annular plates and perimeter floorplates.
- The tank CP system design drawings indicate that the CP monitoring tubes are not slotted for the outermost 10 feet, which prevents monitoring of CP levels on the tank perimeter. No CP data has been reported for the outermost 10 feet of the soil-side surfaces of the tank bottom.
- The CP data for Tank 93 indicates that the tank does not meet the --850 millivolt (mV) criteria for cathodic protection. Therefore, Alyeska has been relying on the 100 mV of polarization to

confirm that the structure is protected. When utilizing the 100 mV shift criteria, Alyeska has not been monitoring the formation or decay of polarization as required in National Association of Corrosion Engineers (NACE) SP-0193 and their own internal monitoring procedure (MP-166.23).

- The corrosion rate calculations for the roof plates appear to be correct.
- The 2023 Tank 93 API 653 Inspection Report indicates that the tank could be returned to service for more than 20 years based on floorplate corrosion rates and 10+ years based on replacement of the annular plate.
- The floorplate calculations in the Alyeska Engineering Summary Report for Tank 93 align closely with Taku's findings but diverge significantly from the Tank 93 API 653 Report.
- The Engineering Summary Report noted a critical limit on the roof support column thickness of a 40% wall loss of the effective structural thickness (EST) for the outer (0.375" wall) columns and 55% EST wall loss for the inner (0.500-inch wall) columns. No basis for that definition of the critical limits and no supporting calculations and data for that assumption were included.
- While the Engineering Summary Report defined the minimum remaining EST ($T_{EST,MIN}$) identified in the tank as 0.245 inches, the supporting calculations and data for this number were not provided in the API 653 Report or in the Engineering Summary Report.
- Data for the roof support column inspections was limited to the lower 20 feet of the columns. High levels of corrosion were noted in lower column areas prompting the addition of column repair sleeves for the bottom 15 feet of the columns. No data was provided that indicated if inspections were completed beyond 20 feet up or if the corrosion extended above 20 feet, to the upper areas of the columns. The upper sections of the tank columns are subjected to intermittent wetting with oxygenated seawater and exposed to extremely corrosive gases. The upper areas of the columns are likely to be a more corrosive environment than the lower sections of the columns.
- It appears that full through-wall corrosion pitting in two roof support columns was not identified during the API 653 inspection and enhanced inspection, and was only discovered during abrasive blasting.
- The Engineering Summary Report indicates that internal column anode strings are expected to reduce the rate of corrosion within the columns. However, these anode strings will only protect the internal surfaces when they are submerged, as the liquid plays a critical component as an electrolyte in the electrochemical cell created by the submerged metal and electric current. Anode strings will offer limited protection to the intermittently wetted surfaces of the columns and will offer no protection to the areas of the column that are in the vapor space.
- PWSRCAC was not provided with a full engineering design package for the annular plate replacement. A copy of one of the design drawings was included in the API 653 Inspection Report. That drawing was completed by a third party. However, it lacks an engineer's seal as

required by State of Alaska code. Further verification is necessary to ensure that the full engineering design package was completed by a Professional Engineer (PE).

1.3 RECOMMENDATIONS

Based on the study findings, we offer the following recommendations pertaining to Ballast Water Storage Tank 93:

- Taku compliments Alyeska for utilizing the highest overall floorplate corrosion rate (as opposed to the unrepaired corrosion rate) to estimate future corrosion rates in their Engineering Summary Report. From a review of empirical data collected on VMT tanks, this methodology is the best predictor for actual future corrosion rates.
- The 2023 Tank 93 API 653 Out-of-Service Inspection Report should be revised to reflect calculations that align with the Engineering Summary Report (and closely with Taku's calculations). They should consider empirical Alyeska tank floorplate corrosion data that shows that the deepest overall pit provides a more accurate predictor of the corrosion rate in the next service interval.
- Taku recommends the CP systems for Ballast Water Storage Tank 93 be upgraded in the perimeter areas to protect those areas from corrosion.
- Taku recommends the CP system monitoring tubes be slotted in the perimeter area to allow CP monitoring of that area, to ensure effective corrosion mitigation.
- Taku recommends that Alyeska monitor CP levels on their tanks in accordance with code requirements, industry standards, and their own internal monitoring procedures.
- Taku recommends Alyeska provide justification and data for their definition of the tank column critical EST (T_{EST}) to provide stakeholders with confidence that the tank column structural thickness is sound. Alyeska defined a critical limit of 40% EST wall loss for the outer columns and 55% EST wall loss for the inner columns.
- Taku recommends Alyeska define what corrective action will be undertaken to correct the initial oversight for column through-wall corrosion penetrations during tank column inspections in the future. This is necessary to provide stakeholders with confidence that significant corrosion of the columns will not be missed in future inspections.
- Taku recommends that Alyeska provide data supporting their definition of the tank column minimum remaining effective structural thickness ($T_{EST,MIN}$) identified in the Tank 93 Engineering Summary Report as 0.245 inches, to provide stakeholders with confidence that the tank column structural thickness is sound.
- Alyeska should provide evidence that corrosion degradation of the Tank 93 roof support columns did not extend above 20 feet. If no data was collected to confirm the limits of the corrosion that was discovered, Alyeska should assess the likelihood that the upper areas of the roof support columns are deteriorated and ascertain the risk of allowing the tank to remain in service without inspecting those areas. If the likelihood or risk cannot be ascertained, Alyeska should consider taking Tank 93 out of service and completing a detailed

inspection of the upper areas (above 20 feet) of the roof support columns, to ensure that the column's remaining wall thickness does not pose any concerns for the structural integrity of the tank.

2.0 INTRODUCTION

2.1 Tank 93

Ballast Water Storage Tank 93 at the VMT is one of the two active, primary ballast water storage tanks in the BWTF (see Figure 1). The other active, primary ballast water storage tank is Ballast Water Storage Tank 94. One additional ballast water tank (Tank 92) is located in the BWTF tank farm; however, that tank was removed from service in the early 2000s.

Both active ballast water storage tanks are 250 feet in diameter, 53.5 feet in height, welded steel, storage tanks built to API Standard 650. The tanks have been inspected and maintained to API Standard 653. They were designed and erected by Chicago Bridge and Iron in 1976. The BWTF tanks were constructed using seven shell courses on fixed concrete ring walls. Their tanks have subsurface secondary containment liners of unknown condition. The sketch in Figure 2 shows the general layout and typical components of a VMT ballast water storage tank.

Figure 1 - VMT Aerial Photo (photo courtesy of NOAA)

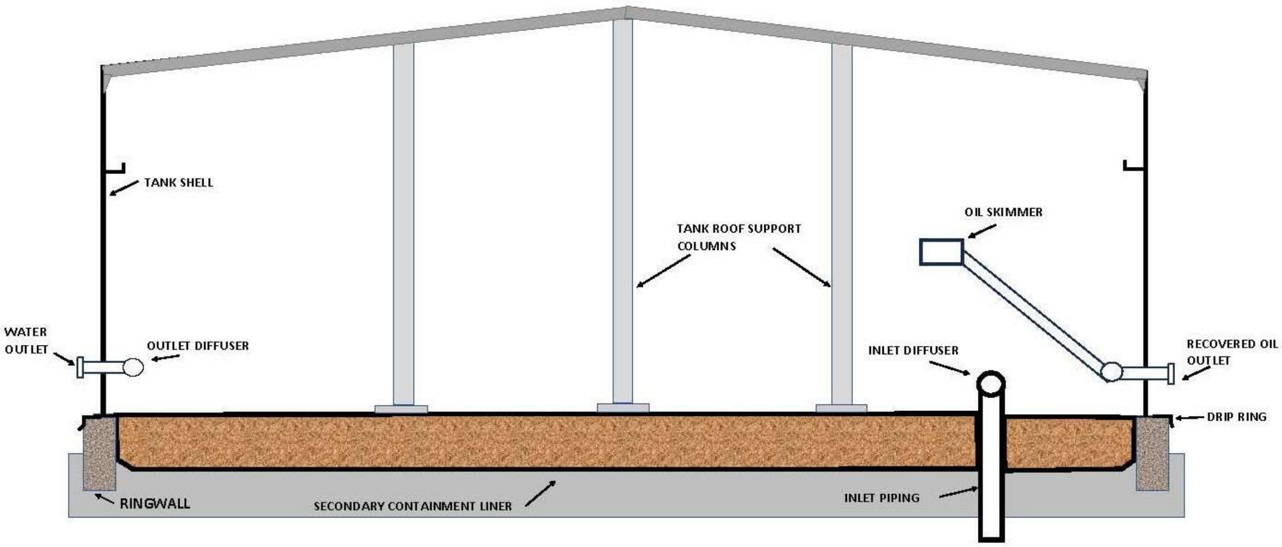

Figure 2- Typical VMT Ballast Tank Configuration

In the late 1990s, it was determined that the bases of ballast water storage tanks were too low. That allowed water to pool at the base and migrate beneath the tank floors, causing high rates of floorplate corrosion. In 2002, Tank 93 was removed from service to address this issue. The tank was lifted and the ring wall foundation height was raised by 18 inches. A new floor and sub-floor grid CP system were added at that time. The existing annular (perimeter) plates remained in place.

Tank 93 was again removed from service for internal inspection in 2012 and 2023. During the 2023 inspection the tank annular plates were replaced and a drip ring was added to the annular plate extension. Despite the high rates of corrosion on the annular plate and perimeter floorplates, no upgrades were executed on the existing bottom side CP system. The drip ring is intended to prevent rainwater from seeping between the floorplate and secondary containment liner. After the 2023 out-of-service inspection and repairs were completed, the tank floor coatings were replaced and the tank was returned to service.

3.0 FINDINGS AND DISCUSSION

3.1 GENERAL

This assessment was based upon a review of the current (2023) and past API STD 653 Out-of-Service Inspection reports for Tank 93, the Tank 93 Engineering Summary Report, CP system drawings for the tank, and historical knowledge of the VMT. The author worked as a contract corrosion and project engineer with Alyeska from 1990 to 2015. This included oversight of the tank and repair program at the VMT.

3.2 Detailed Discussion

PERIMETER CATHODIC PROTECTION

The CP ground bed for the Tank 93 CP system consists of an MMO grid distributed throughout the area beneath the tank floorplate. The CP design includes a separate MMO loop intended to protect the tank's annular plates. According to the design drawings, the outermost anode loop for the existing CP system is more than 9 feet from the tank shell. In this position, the perimeter anode is located beneath the floorplate and not beneath the annular plate (Figure 3).[1]

The location of the perimeter anode is such that it is not physically possible to provide sufficient CP current to the annular plate and first few feet of the perimeter plates.

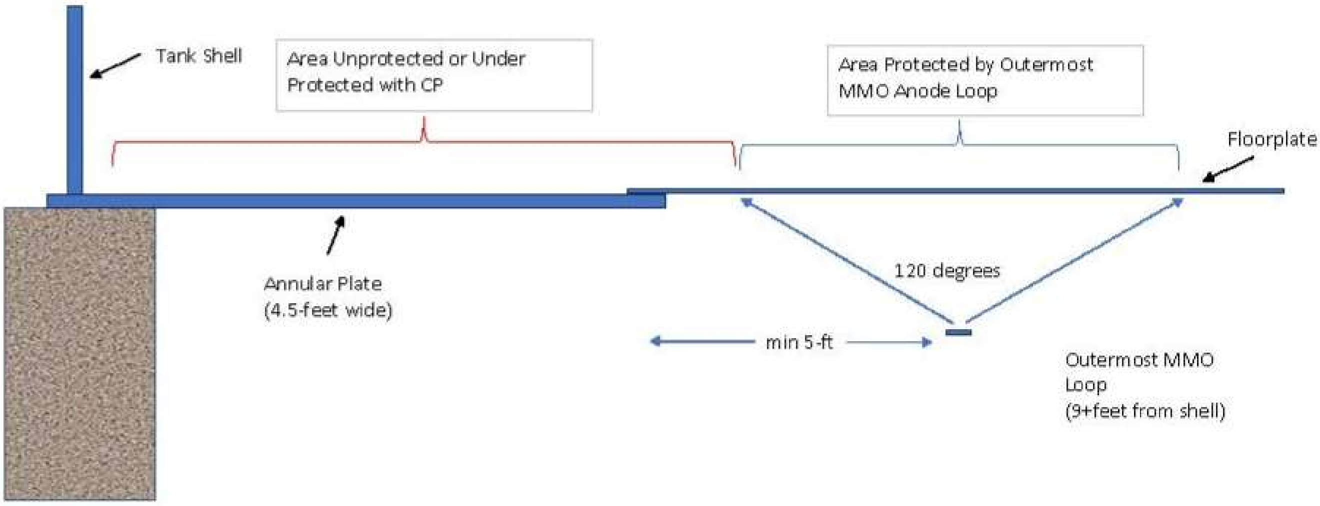

Figure 3 – Schematic of Tank 93 Perimeter Section

The corrosion rate of the annular plate was significant enough to merit full replacement of the annular ring in 2023. Additionally, there were numerous perimeter plates that required patching or overlay (by new perimeter plates installed during annular plate replacement). This supports our finding that the CP current density provided to the annular plate and perimeter floor plates is insufficient to protect the floor from soil-side corrosion.

This anode configuration does not protect the annular plates and perimeter floor plates for the following reasons:

- First, the annular plate and floorplate are welded together and therefore electrically continuous. The MMO loop intended to protect the annular plates and perimeter plates will distribute current primarily via the lowest resistance pathways. In this case, assuming similar backfill resistivity, the current will go to the closest steel, which is the regular floorplate immediately above the anode loop, not the perimeter or annular plate.
- The ratio of floorplate surface area to anode length is significantly larger at the tank perimeter than it is closer to the center. Without the ability to drive the current from the

[1] Alyeska Drawing D-51-E802 Sht. 2, "VMT 51-TK-93 Cathodic Protection System Ref Cell & Anode Ribbon Sec & Details."

perimeter anode separately from the remainder to the floorplate, the CP current density to the perimeter floorplate and annular plate will be significantly lower than the rest of the floor.

- Distribution of CP currents is directed by the resistance of the pathway between the structure being protected (the tank floor) and the anode. The longer the distance between the tank floor and the anode, the greater the electrical resistance. The CP current moves along the lowest resistance path and will protect the areas of the floor that are closest to the anode because the electrical resistance is lowest along that path. The general rule of thumb is that the anode can drive current to a pattern within a 120-degree arc from the anode. Beyond that area, the pathway resistance becomes too high for CP current to distribute.
- The MMO loop that is intended to protect the annular plate and perimeter floorplates is tied to a single circuit that cannot be adjusted independently of the floorplate system. Even if the system had the ability to independently power the MMO loop nearest to the annular plate, the resulting CP current would still go predominantly to the floorplate immediately above the perimeter anode loop and will not measurably impact the annular plate or outer perimeter plate surfaces.

CATHODIC PROTECTION MONITORING

CP monitoring data collected on Tank 93 between 2014 and 2022 was not collected in accordance with industry standards and Alyeska's own monitoring procedures. Industry standards and Alyeska's CP monitoring procedures require that the readings either meet the -850 mV criteria for CP or 100 mV polarization criteria. It appears that only one of the hundreds of "Instant Off" or "IR-Free" readings for Tank 93 met the -850 mV criteria for CP. Therefore, Alyeska has been relying exclusively on the 100 mV of polarization criteria to show that the tank is protected.

The NACE standard requires that the formation or decay of polarization be monitored when utilizing the 100 mV criteria for CP, as the depolarized voltage of a structure fluctuates over time due to soil chemistry, temperature, moisture content, and even the application of CP.[2] Because of the long-term fluctuations in a structure's depolarized value, a measurement of the formation or decay of polarization must be done during the same relative timeframe as collection of the IR-Free or Instant Off data. The use of old depolarized data to determine the polarization of a structure does not meet the requirements of NACE SP-0193 and does not provide accurate measurement of the true level of polarization. This means that Alyeska does not have accurate CP data to determine if the tank floor is protected from bottom-side corrosion.

Similarly, Alyeska's own Monitoring Procedure, MP-166-3.23 "Facilities Cathodic Protection Systems," Revision 9, requires that areas not meeting -850 mV criteria be assessed for 100 mV of polarization. MP-166-3.23 dictates that areas failing the -850 mV criteria must be depolarized and that the operator, "Periodically check the structure to soil potentials at these locations until they have stopped shifting (depolarizing) or have shifted at least 100 mV more positive than the Instant

[2] Dr. T. J. Barlo, "Cathodic Protection Parameters Measured on Corrosion Coupons and Pipes Buried in the Field." CORROSION 1988.

Off potentials that were recorded…"[3] Alyeska's procedure aligns with the requirements of NACE SP-0193. However, Alyeska has not been following that procedure when collecting their CP data.

The 2013-2022 Tank 93 CP raw and calculated data provided by Alyeska utilized depolarized data that was up to nine years old to determine if the structure met the 100 mV criteria for CP. That does not align with industry standards or Alyeska's internal procedures.

The 2018-2022 CP data provided by Alyeska indicates that all areas of the soil-side tank bottom had 100 mV of polarization or greater and were fully protected. This should have resulted in significantly reduced corrosion rates. To the contrary, the tank annular plate and floor plates have consistently shown elevated corrosion rates indicating that the CP on the tank floor is insufficient. The CP monitoring as it is currently being conducted does not provide accurate representation of the efficacy of the CP system.

The practice of using outdated depolarized data conflicts with recognized industry practices, Alaska Department of Environmental Conservation requirements, and Alyeska's own internal CP data collection procedures. As such, the effectiveness of Alyeska's CP system to mitigate tank corrosion is indeterminant and must be re-assessed using current and accurate IR-Free readings and determining the amount of polarization by measuring or monitoring the formation or decay of polarization.

In addition to recommendations regarding CP testing protocol adherence, Taku also notes concerns regarding the CP system monitoring tubes in the perimeter area. Based on a review of the Tank 93 drawings, the CP system monitoring tubes are not slotted for the first 10 feet into the tank.[4] Consequentially, the CP monitoring data provided by Alyeska does not include any data for the first 10 feet of the tank floor (starting at the tank shell). That prevents Alyeska from being able to monitor CP levels in the areas that consistently display the highest levels of corrosion.

ANNULAR PLATE EXTENSION TO RINGWALL SEAL

Taku commends Alyeska for the positive effort to attach drip rings to the annular plate of Tank 93 in 2023, which should limit future intrusion of rainwater or snowmelt water from seeping between the annular plate and ring wall. The annular plate extension to ring wall seal on Tank 93 was replaced in 2012. As with installation of a drip ring, the 2012, replacement of the seal reduced water intrusion beneath the tank floor. However, despite the replacement of the perimeter seal, corrosion rates of the annular plate and perimeter plates remained extremely high between 2012 and 2023, suggesting that just reducing the water migration beneath the tank may not alleviate the elevated floorplate corrosion rates. Alyeska should anticipate that the addition of a drip ring will not fully alleviate the perimeter corrosion on the tank floor.

The historical use of salt water to deice the ballast water tanks in the winter may have left the existing soils saturated with chlorides, sulfides, and other corrosive constituents that remain in contact with the perimeter plates. Without an upgrade of the perimeter CP system, Alyeska should expect the annular plate and perimeter floorplate corrosion rates to remain elevated.

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3 MP-166-3.23, "Facilities Cathodic Protection Systems," Revision 13. Paragraph 4.8 Depolarized Potential Measurements.

4 Alyeska Drawing D-51- E802 Sht. 2, "VMT 51-TK-93 Cathodic Protection System Ref Cell & Anode Ribbon Sec & Details."

FLOORPLATE SOIL-SIDE CORROSION RATES

During the 2023 Tank 93 inspection, magnetic-flux exclusion (MFE) examination of the tank floor was conducted with an inspection threshold of 215 mils remaining floor thickness (RFT). The MFE inspection identified 870 indications which were then proved up by ultrasonic testing (UT). That is an extraordinarily high number of MFE indications. The API 653 report lists less than 700 prove-up locations. However, many of the MFE callouts may have resided in the perimeter area slated for replacement with the annular ring and may not have been further inspected. Follow-up ultrasonic testing inspections identified the deepest corrosion defect with a RFT of 139 mils.

Using UT follow up inspections, Alyeska identified 60 areas with 179 mils or less of remaining floorplate thickness. Fourteen of those areas were reported to be located in areas to be removed or overlaid during the annular plate replacement. Alyeska completed 46 floor repairs on the remaining indications with 179 mils RFT or less.

The 2023 Tank 93 API 653 Out-of-Service Inspection Report indicated that based on the bottom plate corrosion rates, the tank could be returned to service for an interval of greater than 20 years and based on the annular plate replacement, the tank could be returned to service for greater than 10 years.[5]

The 3.5 mils-per-year (MPY) corrosion rate that was reported in the API 653 Report appears to be in error. The deepest pit identified was 139 mils RFT. Considering the 2023 139 mils RFT, the repair threshold of 215 mils during the 2012 inspection, and the 11-year service interval, results in a short-term corrosion rate of 6.9 MPY.

(215 mils – 139 mils)/11 years = 6.9 MPY

API 653 allows the operator to use the minimum remaining thickness (MRT) <u>after</u> repairs to establish the overall floorplate corrosion rate for unrepaired areas. The author of the API 653 Report appears to be using that approach. However, empirical data from Alyeska tanks indicates that this approach significantly under-predicts the corrosion rates that are experienced in subsequent service intervals. *That approach increases the risk that tanks will leak before they are removed from service for inspection again.* API 653 reports for Alyeska's tanks should utilize the deepest overall pitting in their floorplate corrosion calculations and service interval recommendations.

Empirical data from Alyeska's tanks have shown that the use of the deepest pit for establishing corrosion rates more accurately predicts the deepest corrosion pit expected in subsequent service intervals. API 653 requirements present the minimum effort that an operator must make to protect their above-ground storage tanks.

However, it is the operator's responsibility to ensure the integrity of their tanks regardless of Code allowances. As a prudent operator and given the empirical data that they have for their tanks, Alyeska should continue to use calculations that meet or exceed API 653 requirements but also align with known empirical data on Alyeska infrastructure. Taku commends Alyeska's Engineering

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[5] Greater than 10 years and an open-ended recommendation. The API 653 report should define the maximum service interval not an open-ended interval.

Team for their more conservative approach, which uses the deepest overall pit to define the next service interval in the Engineering Summary Reports. Data on Alyeska's tanks show that this provides more accurate predictions of corrosion rates in ensuing service intervals. However, Alyeska should require the API 653 Inspection Reports to also use the deepest pit for establishing corrosion rates, to reflect the same empirical trends in corrosion.

While Alyeska added a drip ring to Tank 93, which will reduce the future intrusion of water beneath the tank floor, additional measures would are necessary to ameliorate the active perimeter soil-side tank floor corrosion. The CP system is insufficient in providing effective CP protection to the perimeter, and the existing soils are likely saturated with chlorides and other corrosive constituents, which are in contact with the tank floor. In corrosive environments, new steel can act as an anode to old steel, thereby accelerating the corrosion rates on the new steel. By installing new steel plate adjacent to aged steel without adequate CP, Alyeska could actually experience an increase in the corrosion rate of the new steel. Alyeska should expect that the corrosion rates on the perimeter and annular plates will remain elevated despite installation of a drip ring unless efforts are taken to actively address the CP monitoring and protection of the perimeter.

FLOORPLATE SERVICE INTERVAL CALCULATIONS

Alyeska's 2023 Tank 93 API 653 Out-of-Service Inspection Report suggests that the tank can be returned to service for more than 20 years based on a maximum bottom-side corrosion rate reported as 3.5 MPY.

Alyeska's 2023 Tank 93 Engineering Summary Report calculated the long-term (2002-2023) floorplate corrosion rate using the original plate thickness and the deepest pit found in 2023, divided by the full 21 years of service resulting in a long-term corrosion rate of 5.3 MPY.

Taku used the inspection threshold from 2012, and the deepest pitting discovered in 2023, to calculate a bottom-side short-term corrosion rate of 6.9 MPY for the period between 2012 and 2023.

The deepest pit discovered during a VMT tank inspection should be utilized to set the next service interval, regardless of repair thresholds. Revisiting the 2012 inspection and repair results provides another data point supporting this approach. Figure 4 graphically illustrates the predicted and actual corrosion rates for Tank 93 for the 2012-2023 period based on the 2012 inspection and current inspection findings.

The red line in the graph represents the predicted corrosion rate using the deepest unrepaired pit from 2012 (as allowed by API 653). Based on the deepest unrepaired pit after the 2012 inspection (215 mils RFT), the predicted corrosion rate for the Tank 94 floorplate was 3.5 MPY and the predicted deepest pit in 2021 was 180 mils RFT.

The use of the deepest pit from the 2012 inspection (171 mils RFT) to calculate corrosion rate and predict the deepest pit in 2023, resulted in a 2012-2023 predicted corrosion rate of 7.9 MPY and a predicted deepest pit (in 2023) of 128 mils RFT. This is represented by the blue line in Figure 4.

The actual deepest floorplate pit identified in 2023 was 139 mils RFT, representing a corrosion rate of 6.9 MPY. This is represented by the green line in Figure 4.

Using the 2012 deepest pit to define the 2012-2023 corrosion rate, the actual rate of corrosion was over-estimated by 14%. Using the deepest unrepaired pit (from the 2012 inspection) to predict the Tank 93 floorplate corrosion rate between 2012 and 2023, the actual corrosion rate was underestimated by 49%.

This finding is not unique to Tank 93. For nearly every Alyeska tank, the use of the corrosion rate in the unrepaired area as the basis for predicting future corrosion on the tank floors significantly underestimates the corrosion that occurs during ensuing service intervals.

We commend that Alyeska is using the deepest overall pit to calculate corrosion rates and service intervals in their tank Engineering Summary Reports. However, they continue to use the deepest unrepaired pit to calculate corrosion rates and service intervals in their API 653 Reports. *This creates unnecessary confusion and risk.* Inspection reporting should be consistent. The API 653 Reports should utilize the more accurate methodology that aligns with the Engineering Summary Reports. This is a simple, inexpensive step that can alleviate risk and confusion.

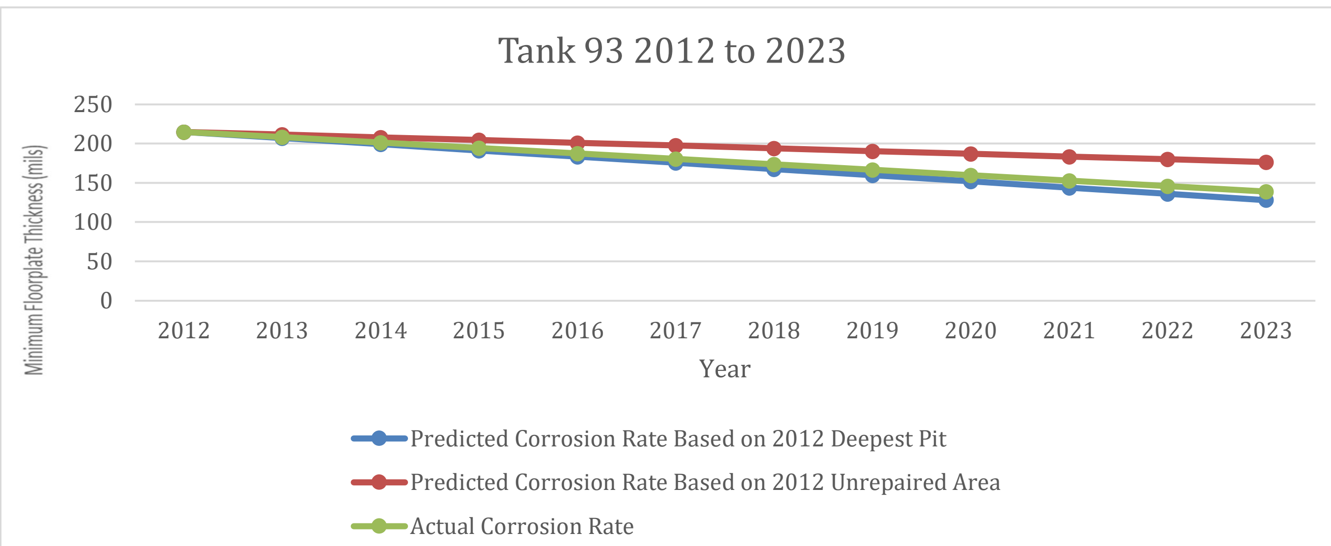

Figure 4 – Predicted Versus Actual Corrosion Depths for Tank 93

Given that the tank is experiencing aggressive corrosion despite an active CP system, the operator should take immediate action to enable monitoring of CP on the outermost 10 feet and ensure the CP system is being accurately monitored in accordance with industry standards and Alyeska's procedures.

DISCREPANCIES BETWEEN REPORTS

Alyeska's 2023 Tank 93 API 653 Out-of-Service Inspection Report suggests that the tank can be returned to service for more than a 20-year service interval based on floorplate corrosion for greater than a 10-year service interval based on the annular plate replacement.

Alyeska's Engineering Summary Report aligns relatively well with Taku's findings and recommends that the tank be removed from service for inspection again in 10 years or 2033.

The following table summarizes the differences in the findings between the Tank 93 2023 API 653 Out-of-Service Inspection Report, Alyeska's 2023 Engineering Summary Report for Tank 93, and Taku's findings in this study.

	2012-2023 Floorplate Corrosion Rate	Recommended Service Interval	
BASIS		Based on Floorplate	Based on Annular Plate
2023 Tank 93 API 653 Out-of-Service Inspection Report	3.5 MPY	> 20 years	> 10 years
2023 APSC Tank 93 Engineering Summary Report	5.3 MPY	15 years	10 years
Taku Report on Tank 93 2023 Out-of-Service Inspection	6.9 MPY	11 years	10 years

Alyeska's Tank 93 Engineering Summary Report largely corrects the errors in the API 653 Report. Assuming Alyeska continues to conservatively calculate the floorplate corrosion rate in their Engineering Summary Reports, regulators should utilize these Summary Reports in determining tank inspection intervals. However, Alyeska should ensure consistency in their reporting to avoid unnecessary confusion.

ROOF SUPPORT COLUMN INSPECTION AND REPAIR

Alyeska's 2023 Tank 93 API 653 Out-of-Service Inspection Report indicates that the bottom 20 feet of the outermost 24 columns were inspected using automated ultrasonic testing (AUT). The API 653 Report indicates that the column wall thickness readings ranged from 0.225 to 0.496 inches. However, data provided in the API 653 Report indicates up to 67% corrosion wall loss (122 mils remaining of 375 mils nominal) was discovered during the AUT inspected area of the outermost 24 columns. Further, the Engineering Summary Report indicates that full wall thickness corrosion through holes were discovered in the columns during abrasive blasting.

Five of the remaining 37 inner columns were randomly selected for AUT inspection from approximately 6 feet to 20 feet from the bottom. That inspection data, provided in the API 653 Report, indicated up to 53% wall loss on those columns (233 mils remaining of 500 mils nominal).

Based on the limits of the column inspection area, the top 30 to 40 feet of each of the columns was not inspected. The integrity of that area of each of the columns is indeterminant.

The 2023 Engineering Summary Report for Tank 93 includes calculations that were intended to define the Effective Structural Thickness Corrosion Rate (CR_{EST}). CR_{EST} is essentially the average general corrosion rate of the columns.[6] Alyeska's calculation is as follows:

[6] 2023 Engineering Summary Report 51-TK-93. Page 6 of 8.

$$CR_{EST} = \frac{T_{NOM,C} - T_{EST,MIN}}{L_C} = \frac{0.375\text{inch} - 0.245\,inch}{48\text{ years}} = 2.71\ mpy$$

Where:

CR_{EST} = Effective Structural Thickness Corrosion Rate

$T_{NOM,C}$ = Column Nominal Thickness

$T_{EST,MIN}$ = Minimum EST Identified

L_C = Column Service Life

Alyeska defined the existing Minimum Remaining Effective Structural Thickness (T_{EST}) as 0.245-inches. T_{EST} is defined as the minimum average column thickness in a horizontal section. There is no data in the API 653 Inspection Report regarding that value for T_{EST} and no calculations in the Engineering Summary Report to support a T_{EST} of 0.245 inches. Most of the column minimum remaining wall thickness (MRWT) data provided in the API 653 Report is below 0.245-inches. Additionally, through-hole corrosion was identified on the columns during abrasive blasting but not noted in the special testing report. This suggests that T_{EST} may be lower than 0.245 inches.

Alyeska should provide clarification of how T_{EST} was calculated. The value used for T_{EST} is critical to determining the safe remaining life of the tank columns and should be based on verifiable data.

In that calculation, Alyeska used 48 years as the column service life. The tanks were placed in service in 1977. The inspection was conducted in 2023. The service life used for these calculations should have been 46 years, not 48 years. Assuming the T_{EST} that Alyeska utilized in their calculation was correct, that would result in a general corrosion rate for the columns of 2.8 mils per year.

Alyeska defined a critical limit of 40% wall loss for the 0.375-inch nominal thickness columns and 55% wall loss for the 0.500 nominal thickness columns. If Alyeska's definition of the critical wall loss is correct, then the calculated minimum average thickness of 0.225 inches is required for any horizontal section of each column.

Assuming that the Minimum (Critical) Effective Structural Thickness of 225 mils that Alyeska defined in the Engineering Summary Report (40% loss of 375 mils and 55% loss of 500 mils) is correct, and the existing Effective Structural Thickness (T_{EST}) they defined as 245 mils are correct, then the columns only have 20 mils of remaining general corrosion allowance in the columns (245 mils – 225 mils). Using a corrosion rate of 2.8 MPY, the column life before the Minimum Effective Structural Thickness is exceeded is:

20-mils/2.8 MPY = 7.14 years

Based on these calculations, one can expect that the minimum critical EST within the inspected column area would be exceeded roughly seven years after the tank is returned to service.

Alyeska indicated that "using a 2.8 MPY corrosion rate, an outer column EST is expected to deteriorate by 7.5% in 10 years." However, Alyeska defined the current minimum EST as 245 mils. At a corrosion rate of 2.8 MPY, the EST will be reduced by 28 mils to 217 mils which is below the critical EST that Alyeska defined as 60% of T_{NOM} or 225 mils. Using percentages:

28 mils/245 mils = 11.4%

Based on our calculations the EST is expected to decrease by 11.4% in 10 years.

According to the Tank 93 Engineering Summary Report and the supplemental API 653 Report for tank repairs, structural sleeves were added to the bottom 15 feet of each of the outermost columns (Columns 1-24).

AUT inspection of the outer columns was completed from approximately 10 feet up to 20 feet above the floor. Although significant column corrosion was identified at locations higher than 15 feet, the height of the column sleeves was limited to 15 feet. Corrosion identified above the height of 15 feet was not covered by the column sleeves installed in 2023.

The Engineering Summary Report indicated that through-wall corrosion defects were discovered in the columns during the abrasive blasting. No indication was given as to the location of those through holes. Alyeska should provide some explanation as to how the through-wall corrosion was missed during the inspection process and what corrective measures are being put in place to ensure that ensuing inspections will identify all injurious corrosion present.

The highest rates of column corrosion are likely to be above the limits of the inspections executed in 2023. The column inspections were limited to the bottom 20 feet of the columns. The columns are greater than 55 feet in length. A majority of the column area was not inspected. Generally, the highest rates of corrosion in marine steel structures would occur in areas that are exposed to a wet/dry cycle. Once column corrosion was discovered in the lower areas of the columns, the inspections should have been modified to define the extent of corrosion including full inspection of one or more columns. This should have included the upper areas of the columns to incorporate the areas that are most likely to have the highest corrosion rates.

The Engineering Summary Report included a statement that "the internal column anode strings are expected to significantly reduce the rate of corrosion within the columns." The column anode strings will only significantly reduce corrosion in the column areas that are constantly immersed. The internal column anode string will do little to mitigate corrosion in the intermittently immersed areas and have little to no impact in mitigating column corrosion in the areas in the vapor space.

In the wet/dry cyclic areas of the columns, the anodes will only provide protective currents when the anodes are immersed. When the tank level drops below that, the steel surface will corrode freely. Likewise, the areas in the vapor space have been shown to be highly corrosive. These areas are above the liquid level. The CP system will not function in these areas because there is no electrolyte present.

Alyeska should provide data showing the limits of the column corrosion and confirming the integrity of the upper areas of the columns. If no data for the upper areas of the columns was collected, Alyeska should assess the likelihood that the upper areas of the columns are deteriorated and the risk of failure associated with significant deterioration. Based on that assessment, Alyeska should address whether the tank should be removed from service to more thoroughly investigate the roof support column integrity.

Annular Plate Replacement

During the Tank 93 outage, Alyeska replaced the tank annular plates due to extensive corrosion. The annular plates would not have required replacement if the CP system was effectively protecting those areas. The fact that the annular plate was extensively corroded indicates that the existing CP is not sufficient in the perimeter areas of the tank.

The annular plate design package was not transmitted to PWSRCAC. However, one page of the engineering design drawings (Tanco Drawing # 554-4) was provided on page 9 of the Tank 93 API 653 Out-of-Service Inspection Report. The drawing is not stamped or sealed as required by Alaska regulations. PWSRCAC should request a full copy of the design package to confirm that the design package was completed by an engineer licensed by the State of Alaska.