FINAL REPORT

Review of Ballast Water Tank 94 and Crude Oil Storage Tank 7 Out-of-Service Inspection Reports



Report Prepared for:

PRINCE WILLIAM SOUND RCAC REGIONAL CITIZENS' ADVISORY COUNCIL

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ACRONYMS & ABBREVIATIONS

ADEC – Alaska Department of Environmental Conservation

API – American Petroleum Institute

APSC – Alyeska Pipeline Service Company

BWTF – Ballast Water Treatment Facility

CP – Cathodic Protection

ETF – East Tank Farm

MFE – Mag-Flux Exclusion

MIL –1/1000th of an Inch

MMO - Mixed Metal Oxide

MP – Monitoring Procedure

MPY – Mils-Per-Year

MRT – Minimum Remaining Thickness

MRFT – Minimum Remaining Floor Thickness

MRWT – Minimum Remaining Wall Thickness

NACE – National Association of Corrosion Engineers

MV - Millivolt

PWSRCAC - Prince William Sound Regional Citizens' Advisory Council

RFT – Remaining Floor Thickness

RWT – Remaining Wall Thickness

STD- Standard

UT – Ultrasonic Testing

VMT – Valdez Marine Terminal

WTF – West Tank Farm

1.0 EXECUTIVE SUMMARY

1.1 GENERAL

In September of 2021, the Prince William Sound Regional Citizen's Advisory Council (PWSRCAC) tasked Taku Engineering (Taku) with reviewing documents associated with American Petroleum Institute (API) 653 Out-of-Service inspections of Ballast Water Storage Tank 94 and Crude Oil Storage Tank 7 at the Alyeska Pipeline Service Company (APSC) Valdez Marine Terminal (VMT). The intent was to identify opportunities for reducing the risks of a future leak associated with the VMT tanks.

This report addresses a review of the inspection procedures and reports for the 2021 inspections on both Tanks 7 and 94.

Background on Tank 7

Constructed in 1976, Tank 7 is a 250-foot diameter, 510,000-barrel, welded steel, crude oil storage tank located in the VMT's East Tank Farm (ETF).

In 1996, Tank 7 was removed from service for the installation of a new floor with a sub-floor cathodic protection (CP) system for corrosion mitigation. Follow-up out-of-service inspections on Tank 7 were completed in 2008 and 2021, with Tank 7 being returned to service after each inspection.

Background on Tank 94

Also constructed in 1976, Tank 94 is a 250-foot diameter, 430,000-barrel, welded steel, ballast water storage tank located in the VMT's Ballast Water Treatment Facility (BWTF).

In 2000 and 2001, Tank 94 was removed from service, lifted 18 inches, and a new ring wall foundation, floor, and sub-floor CP system were installed for corrosion mitigation. Follow-up out-of-service inspections on Tank 94 were completed in 2011 and 2021, with Tank 94 being returned to service after each inspection.

Background on Study Documents

PWSRCAC did not receive the specific documents requested from APSC pertaining to this study until late in 2023. However, in the Summer of 2023 APSC provided some of the relevant documents to the Alaska Department of Environmental Conservation (ADEC), who in turn provided them to PWSRCAC, thus allowing for the completion of this report in a timely fashion.

This study reviewed the modifications completed on the tanks as well as the API 653 Out-of-Service inspection reports for each tank. It 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.

Subsequent to the issuance of a draft of this report, Alyeska provided comments in tabular form. We have recreated that table and added a column to respond to those comments. That information is provided in this report as Attachment B.

1.2 FINDINGS

Findings for Tank 7

Based on our review of the Crude Oil Storage Tank 7 API 653 Out-of-Service Report provided by the ADEC, we have derived 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.
- The existing CP system will not provide sufficient CP current to the perimeter floorplates and annular plates. Those surfaces will remain largely unprotected.
- As-built drawings suggest that the existing CP monitoring tubes are not slotted for the first 10 feet. This would prevent the ability to monitor CP levels on the first 10 feet of the tank floor (annular plates and perimeter plates). In recent correspondence, APSC has indicated that the monitoring tubes are actually slotted for the first 10 feet. However, no CP data has been provided for this area.
- APSC is not collecting CP data for Tank 7 in accordance with NACE SP-0193 or their own internal monitoring procedure (MP-166.23).
- The corrosion rate calculations for the annular plate and roof plates appear to be correct.
- The tank floor coatings were <u>not</u> fully replaced prior to returning the tank to service. Only minor coating repairs were completed. This is a deviation from APSC historical practices of fully replacing the tank floor coatings after tank internal inspection and repair. To our knowledge, this is the first time APSC has returned a tank to long-term service without fully recoating the tank floor. Given that the coating was last replaced in 2008, by the next inspection recommended in the API 653 report, the floor coatings will be more than 33 years old. It is not reasonable to expect that an immersion coating will perform without failure for more than 20 years.
- The API 653 inspection report includes errors in calculations for the 2008-2021 floorplate soil-side corrosion rates. The reports suggest that between 2008 and 2021, the Tank 7 floor recorded a maximum floorplate corrosion rate of 3.3 mils-per-year (MPY). The actual maximum floorplate corrosion rate between 2008 and 2021 was 5.9 MPY (based on the repair threshold in 2008 and the deepest pit discovered in 2021).
- The API 653 inspection report appears to have assumed no topside corrosion rate in the future. However, because the floorplate coating was not removed and replaced and considering the age of the existing coatings, a topside corrosion rate should have been included in the corrosion rate calculations. During a 10/12/22 meeting between APSC and PWSRCAC, APSC indicated that they included a topside corrosion component in the service interval calculations to accommodate the age of the floorplate coatings. However, the final inspection report did not include a topside corrosion rate for the service interval calculations.

- The API 653 inspection report includes errors in calculations pertaining to the allowable duration of the next tank service interval. When accurate bottom-side corrosion rates are utilized, and a topside corrosion rate is included, the API 653 service life calculations for the floorplate indicate that the tank will exceed 100 mils minimum remaining thickness (MRT) in 2031, which is the minimum required thickness by API 653 standards without an effective CP system and a competent leak prevention liner. The corrosion would likely penetrate the floor before the next out-of-service inspection recommended in the API 653 report (2041).
- The lack of an annular plate to ring wall seal will exacerbate the inadequacy of corrosion protection afforded the annular plate and perimeter floorplates, due to the migration of rainwater and lack of an effective water drainage systems under the tank floor.
- Subsequent to Taku's September 2023 draft report submitted to APSC for review, APSC provided an Engineering Summary Report for Tank 7. The calculations in the Engineering Summary report conflict with the current Tank 7 API 653 report but align closely with Taku's findings.
- APSC has indicated that they did not intend to have the Tank 7 API 653 report corrected to align with the Engineering Summary Report.
- The as-built drawings for Tank 7 are not accurate with regard to the monitoring tubes and the perimeter drain.
- In the late 1980s APSC changed the color of the crude tank roofs from earth green to white to reduce the solar gain in the tanks and reduce the gas evolution from the crude oil.

Findings for Tank 94

Based on our review of the Tank 94 API 653 Out-of-Service Report provided by the ADEC, we have derived 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.
- The existing CP system has not afforded sufficient corrosion protection to the annular plates and perimeter plates. This is evident in the fact that the annular plate required replacement in 2021 and 2022, due to aggressive corrosion. No modifications were made to the existing CP system during this outage. Therefore, going forward, the existing CP system will still not provide sufficient CP current to the perimeter floorplates and annular plates. Those soil-side surfaces will remain unprotected.
- The installation of a drip ring on the annular plate extension will somewhat reduce the corrosivity of the soil beneath the annular plates. However, it will not fully alleviate the high corrosion rates in the annular plate because the CP system beneath the tank is inadequate to protect the annular plates.

- The existing CP monitoring tubes do not allow monitoring of CP levels on the tank perimeter. No perimeter CP data is being collected.
- APSC is not collecting CP data for Tank 94 in accordance with NACE SP-0193 or their own internal monitoring procedure (MP-166.23).
- The installation of a drip ring on the annular plate extension will not entirely alleviate the high corrosion rates on the tank perimeter floorplates. The CP system beneath the tank is inadequate to protect the perimeter floorplates and the soil beneath the floorplates is already contaminated with chlorides from the practice of clearing snow off the tank with seawater.
- The corrosion rate calculations for the roof plates appear to be correct.
- The annular plates were replaced in 2021/2022, but this change does not impact the duration of the next tank service interval.
- The 2021 Tank 94 API 653 inspection report includes significant errors in calculations for the 2012-2021 floorplate corrosion rates. The report indicates that the long-term bottom corrosion rate is 1.1 MPY. The actual long-term bottom-side corrosion rate based on Taku's calculations was 6.9 MPY and the short-term bottom-side corrosion rate was 11.0 MPY.
- The 2021 Tank 94 API 653 inspection report includes significant errors in calculations pertaining to the allowable duration of the next tank service interval. The report suggests that the tank can be returned to service for a 20-year service interval. Based on Taku's calculations and the short-term bottom-side corrosion rate, the next out-of-service tank should take place in 9 years or in 2030. **If the tank is placed in service for the 20-year service interval that the API 653 report has suggested, there is a high probability that the tank bottom will leak prior to the next out-of-service inspection.**
- Subsequent to Taku's September 2023 draft report, Alyeska provided an Engineering Summary Report for Tank 94. The calculations in the Engineering Summary Report conflict with the Tank 94 API 653 report but align closely with Taku's findings.
- Alyeska has indicated that they did not intend to have the Tank 94 API 653 report amended to align with APSC's Engineering Summary Report.

1.3 RECOMMENDATIONS

Recommendations for Tank 7

Based on the study findings, we offer the following recommendations pertaining to Crude Oil Storage Tank 7:

- APSC should use empirical data from their own tanks in conjunction with the minimum requirements of API 653, when calculating corrosion rates, and the next appropriate service interval for Tank 7.
- The Tank 7 2021 Out-of-Service inspection report should be revised and re-issued to reflect calculations that align with API STD 653 and empirical APSC tank data.

- The Tank 7 annular plate to ring wall seal should be replaced and maintained, or drip rings should be installed on the annular plate extension, to prevent the ingress of water between the tank floor and secondary containment liner in order to reduce active bottom-side corrosion and reduce future floorplate corrosion rates.
- APSC should follow recognized industry practices (NACE SP-0193), ADEC requirements, and APSC's own internal CP data collection procedures when collecting CP data.
- Based on the actual bottom-side and predicted topside corrosion rates, Tank 7 tank should be removed from service in 10 years (or 2031) for the next out-of-service inspection.
- The Tank 7 API 653 inspection report should be corrected and updated to align with APSC's Engineering Summary Report.
- CP data should be collected in the outermost 10 feet beneath the tank floor.
- APSC should ensure that their systems are accurately as-built.
- APSC should consider coating the crude tank roofs with a darker colored paint to increase solar gain and decrease snow build-up on the tanks during the winter. This could reduce the risk of vent damage and reduce the level of effort to clear the tanks of snow. This would have to be weighed with the risk of overwhelming the vapor system during the summer.

Recommendations for Tank 94

Based on the study findings, we offer the following recommendations pertaining to Ballast Water Storage Tank 94:

- APSC should follow the general requirements of API 653 but utilize the highest overall corrosion rate to estimate future corrosion rates, to establish the next Tank 94 service interval.
- The 2021, Tank 94 Out-of-Service inspection report should be revised and re-issued to reflect calculations that include a topside corrosion rate, align with API STD 653, and consider empirical APSC tank corrosion data.
- The perimeter CP systems on other ballast water tanks with similar CP systems, should be upgraded when the tank is removed from service for inspection and repairs.
- Most critically, Tank 94 should be removed from service for the next out-of-service inspection in 9 years, not 20 years as noted in the 2021 API 653 Out-of-Service inspection report.
- The Tank 94 API 653 report should be amended and updated to align with APSC's Engineering Summary Report.

2.0 INTRODUCTION

2.1 Tank 7

Crude Oil Tank 7 at the VMT is one of the 14 crude oil storage tanks that make up the VMT's ETF. Four additional tanks are located in the West Tank Farm (WTF). However, the WTF was removed from service in the early 2010s. The general VMT layout is shown below in Figure 1 highlighting the location of Tank 7.

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

All 14 ETF tanks are 250 feet in diameter, 62 feet high, welded steel, crude storage tanks built to API Standard 650. They were designed and erected by Chicago Bridge and Iron in 1976. The ETF tanks were constructed on concrete ring walls with subsurface secondary containment liners and oiled sand bedding. The sketch in Figure 2 shows the general layout and typical components of a VMT crude storage tank.

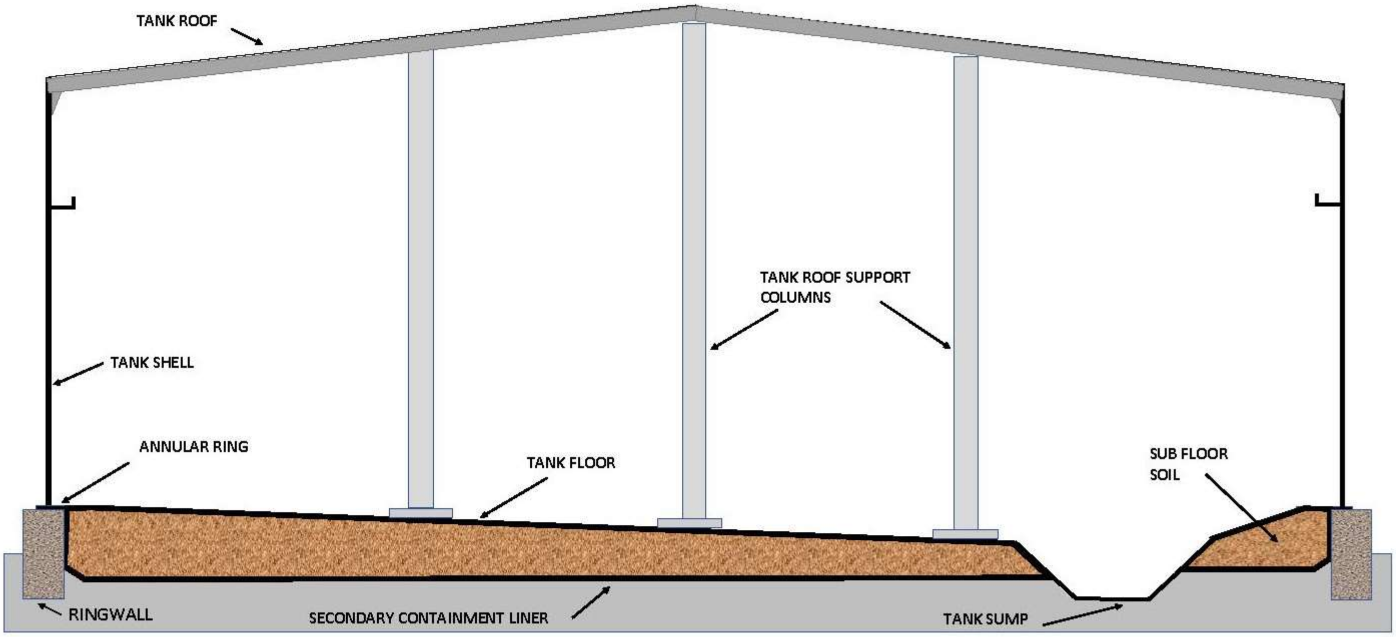

Figure 2 - Typical VMT Crude Tank Configuration

The 1991 discovery of soil-side corrosion in the tank floors prompted APSC to systematically replace the tank floors and install sub-floor CP systems on all ETF tanks between the years 1991 and 1998. The initial CP system installed on Tank 5 in 1991 consisted of mixed metal oxide rod anodes. After the Tank 5 floor replacement, all other tanks were fitted with mixed metal oxide (MMO) grid CP systems which included monitoring tubes and/or permanent reference cells for collection of tank-to-soil potential measurements. The Tank 5 CP system was later replaced with a grid CP system in 2002.

The floorplates on Tank 7 were removed and replaced in 1996. The original oiled sand bedding was excavated and clean bedding, an MMO grid CP system, and new floorplates were installed in the tank. The existing annular plates remained in place around the tank perimeter and beneath the shell.

Tank 7 was removed from service for internal inspection in 2008 and 2021. After the 2008 inspection, the tank floor was recoated prior to returning the tank to service. After the 2021 out-of-service inspection, minor repairs were completed on the tank floor. Historically, APSC has fully recoated the tank floors after repairs. However, in 2021 the tank floor coating only received minor repairs prior to returning the tank to service.

2.2 Tank 94

Ballast Water Storage Tank 94 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 93. 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, welded steel, storage tanks built to API Standard 650. 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. They tanks have subsurface secondary containment liners of unknown condition. The sketch in Figure 3 shows the general layout and typical components of a VMT ballast water storage tank.

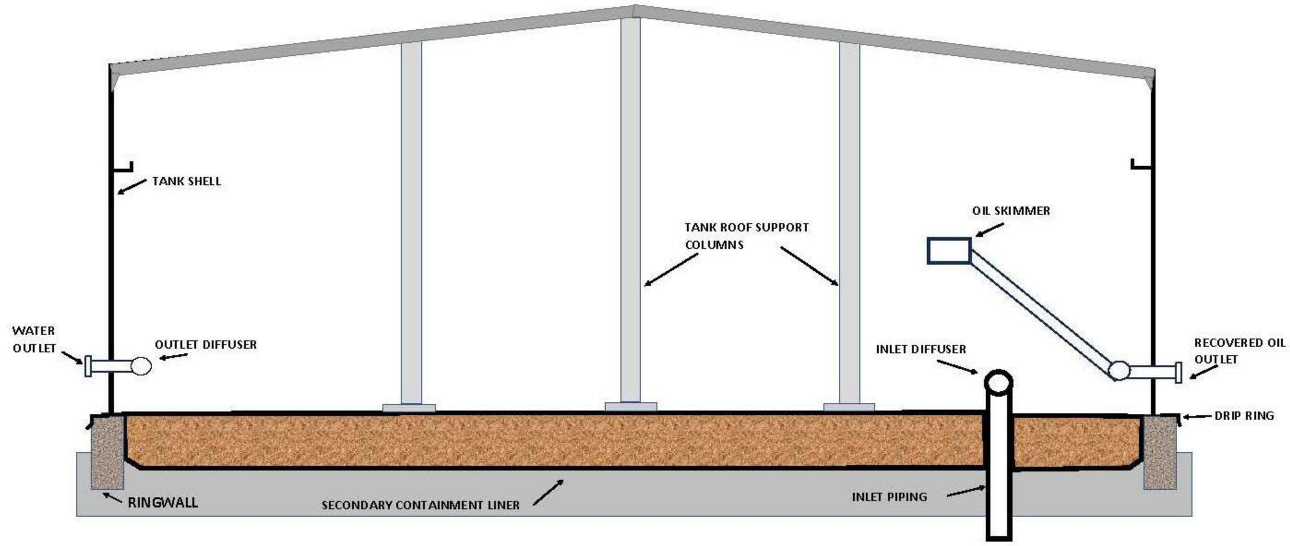

Figure 3- Typical VMT Ballast Tank Configuration

In the late 1990s, it was determined that the bases of ballast water storage tanks were too low, allowing water to pool at the base and migrate beneath the tank floors, causing high rates of floorplate corrosion. In 2000 and 2001, Tank 94 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 94 was again removed from service for internal inspection in 2011 and 2021. During the 2021 inspection the tank annular plates were replaced and a drip ring was added to the annular plate extension. Despite the aggressive corrosion on the annular plate, no upgrades were executed on the existing CP system. The drip ring was intended to prevent rainwater from seeping between the floorplate and secondary containment liner. After the 2021 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 2021 and past API STD 653 out-of-service inspection reports for Tanks 7 and 94, CP system drawings for the tanks, and historical knowledge of the VMT. The author worked as a contract corrosion and project engineer with Alyeska from 1990 to 2015. This included oversite of the tank and repair program at the VMT.

3.2 Tank 7

PERIMETER CATHODIC PROTECTION

The ground bed for the Tank 7 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. However, in the system design, the annular ring MMO loop is located beneath the floorplate and does not extend to the annular plate. It is located more than 10 feet from the tank shell and more than 3 feet from the innermost edge of the annular plate (see Figure 4, excerpted from drawing D-54-E806). Figure 4, excerpted from APSC's as-built drawings of the tank, indicates that the CP monitoring tubes beneath the annular plates are not slotted for the first 10 feet, negating the ability to monitor CP below the annular plate and outermost 3 feet of floorplate.

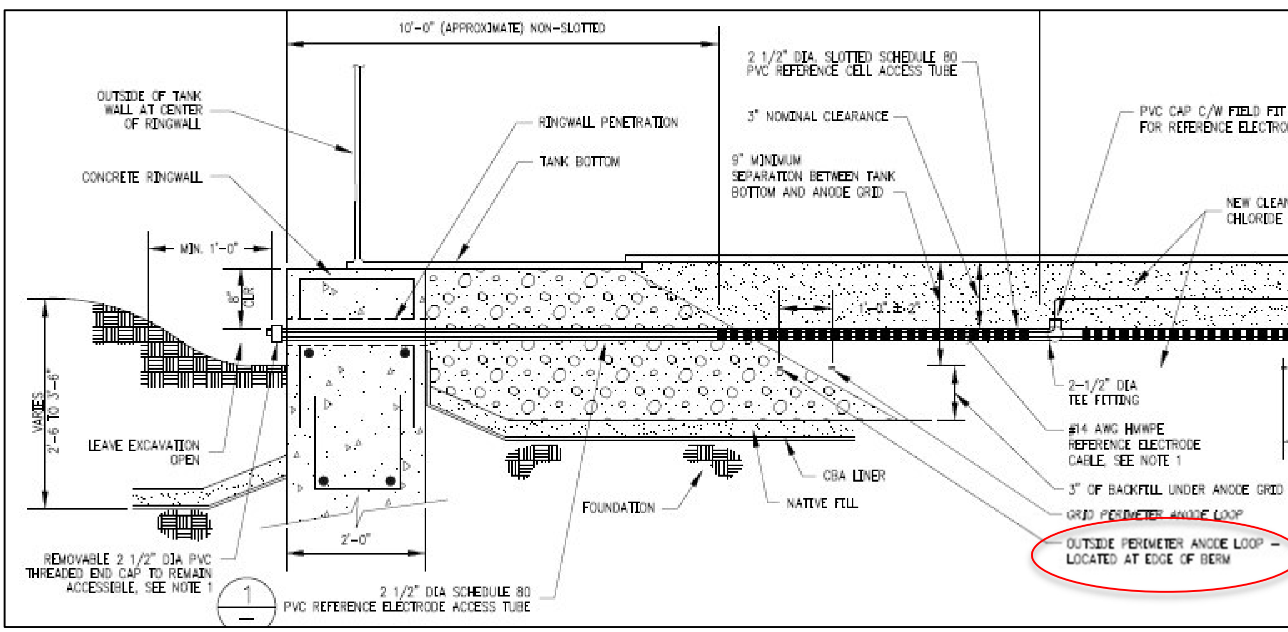

Figure 4 – Tank 7 Annular Ring CP Ground bed Design

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 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 steel, not the annular plate.

The ratio of floorplate surface area to anode length is significantly larger at the tank perimeter. Without the ability to drive the perimeter anode separately from the remainder of the groundbed, the CP current density to the perimeter floorplate and annular plate will be significantly lower than the rest of the floor.

A general rule of thumb used for designing for the uniform distribution of CP current for close coupled anodes, is to assume that the anode will distribute current to the steel surface in a (roughly) 120-degree arc of influence.[1] This rule of thumb is based on the resistance of the path length between the anode and structure. This is depicted below in Figure 5. As shown in the figure, the MMO loop intended to protect the tank perimeter plates will not provide protective current to the annular plate (also depicted in Figure 5).

The MMO loop that is dedicated for the annular plate and perimeter floorplates is tied to a single circuit that cannot be adjusted independently of the rest of the anode groundbed. Even if the system had the ability to independently power the MMO loop nearest to the annular plate, the resulting CP current will go predominantly to the perimeter floorplate and will not measurably impact the annular plate.

In response to the draft of this report, APSC indicated that contrary to the as-built drawings, the first 10 feet of the CP monitoring tube is slotted. This should have enabled APSC to collect CP data for the perimeter area. However, no area CP data was reported for the outermost 10 feet of the tank despite the reported presence of slotted tube. Given that the empirical data indicates elevated corrosion rates in this area, the collection of area CP data should be prioritized. Further, the conflict between the system drawings and their reported condition raises the concern that APSC has not maintained accurate as-built drawings of their systems.

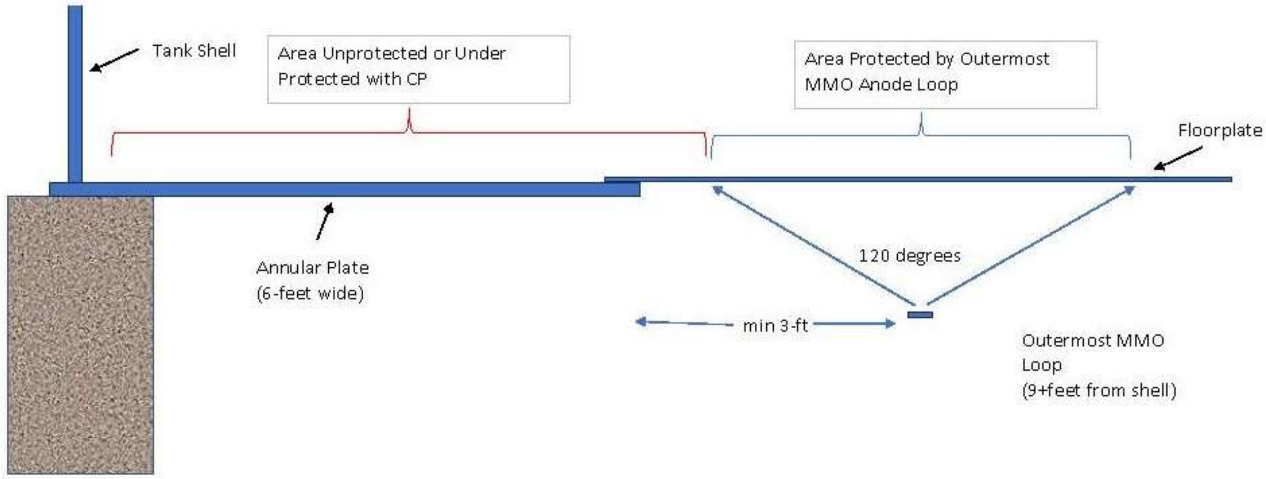

Figure 5 – Tank 7 CP System Perimeter Current Distribution

[1] NACE CP-3 Cathodic Protection Technologist Manual, Section 4.1.1.4, "Effects of Anode-to-Structure Spacing on Current Distribution," January 2010.

During the 2021 tank outage, 15 patch plates were installed due to bottom-side corrosion. Nearly all repairs were on perimeter floorplates, validating that the CP current being provided to the perimeter areas is insufficient and that water intrusion through the failed annular plate extension to ringwall seal is causing corrosion.

CATHODIC PROTECTION MONITORING

The CP monitoring data collected on Tank 7 between 2015 and 2018 is not valid. Instant off (referred to as IR-free) data cannot be more negative than -1.1 – 1.2 V.[2] Data more negative than that suggests that all voltage drops (IR) in the soil have not been accounted for and that there are outside current sources still acting on the structure. CP monitoring readings reported by APSC for Tank 7 between 2016 and 2018, include “IR-Free” data as negative as -2.684 volts.

The depolarized voltage of a structure changes over time due to soil chemistry, temperature, moisture content, and even the application of CP.[3] For this reason, the National Association of Corrosion Engineers (NACE) standard requires that the formation or decay of polarization be measured when utilizing the 100 millivolt (mV) criteria for CP. 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 1-, 2- or 3-year-old depolarized data, to determine the polarization of a structure, does not meet the requirements of NACE SP-0193 (or RP-0193), and does not provide accurate measurement of the true level of polarization. This means that APSC does not have accurate CP data to determine if the tank floor is protected from bottom-side corrosion.

Similarly, APSC’s 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 OFF potentials that were recorded…”[4] While this aligns with the requirements of NACE SP-0193, APSC has not been following that procedure when collecting CP data.

2016-2018 CP data reported by APSC utilized depolarized data from 2015 to determine if the structure met the 100 mV criteria for CP. The practice of using outdated depolarized data conflicts with recognized industry practices, ADEC requirements, and APSC’s own internal CP data collection procedures.

2021 CP data for Tank 7 provided by the ADEC included only depolarized data. Without current relevant Instant off data to compare against to measure polarization, this data is not meaningful. Further, APSC has provided conflicting information regarding whether the CP monitoring tubes are slotted or not for the first 10 feet beneath the tank. The lack of slots prevents the operator from monitoring the most highly corrosive area of the tank floor. No CP data was collected for the first

[2] Barlo & Fessler, “Interpretation of True Pipe-to-Soil Potentials on Coated Pipelines with Holidays.” CORROSION 1983.
[3] Dr. T. J. Barlo, “Cathodic Protection Parameters Measured on Corrosion Coupons and Pipes Buried in the Field.” CORROSION 1988.
[4] MP-166-3.23, “Facilities Cathodic Protection Systems,” Revision 13. Paragraph 4.8 Depolarized Potential Measurements.

10 feet beneath the tank floor despite this being the location of most of the corrosion identified on the tank floor.

ANNULAR PLATE EXTENSION TO RINGWALL SEAL

The annular plate extension to ring wall seal on Tank 7 has not been maintained or replaced for more than 30 years. The lack of a ring wall to annular plate seal or drip ring on the tank will exacerbate corrosion of the annular plate and perimeter plates by allowing rainwater flowing off the tank to seep beneath the annular plate. The constant influx of oxygenated water will increase the CP current required to protect the annular plate, further exacerbating the shortfall in CP to that region of the tank bottom.

FLOORPLATE SOIL-SIDE CORROSION RATES

The report for the 2021 Tank 7 API 653 Out-of-Service inspection indicated that the deepest corrosion pitting on the bottom plates was 138 mils remaining floor thickness (RFT) and that the tank floor had been subjected to a maximum long-term corrosion rate of 3.3 MPY. The report also indicated that the tank could be returned to service for an interval of greater than 20 years.

The 3.3 MPY corrosion rate that was reported is in error may be a carryover error from the annular plate corrosion rate calculations results. Between 2008 and 2021, the annular plate soil-side corrosion rate reported by APSC and calculated by Taku was 3.3 MPY. Alyeska's report indicates that the pit correlating to that corrosion rate was from Annular Plate # 15. However, the reported floorplate corrosion rate was also attributed to "@AP15" or annual plate 15, not a floorplate.

Based on the deepest floorplate corrosion pit identified in the 2021 Tank 7 inspection (138 mils remaining floor thickness - RFT), and a 2008 MFE and repair threshold of 215 mils, the floorplate corroded 77 mils over 13 years resulting in a short-term corrosion rate of 5.92 MPY.

(215 mils – 138 mils)/13 years = 5.92 MPY

Based on the deepest floorplate corrosion pit identified in the 2021 Tank 7 inspection, 138 mils RFT, and the original 1996 floorplate thickness of 250 mils, the floorplate corroded 112 mils over 25 years resulting in a long-term corrosion rate of 4.48 MPY.

(250 mils – 138 mils)/25 years = 4.48 MPY

API 653 allows the operator to use the minimum remaining thickness after repairs to establish the overall floorplate corrosion rate for unrepaired areas. However, empirical data from Tank 7 and other APSC tanks indicate that this approach significantly underpredicts the corrosion rates that are experienced in subsequent service intervals. Data from APSC's tanks have shown that the use of the deepest pit for establishing corrosion rates, usually more accurately predicts the deepest corrosion pit expected in subsequent service intervals.

Figure 6 graphically presents the predicted 2008-2021 corrosion rates on the Tank 7 floorplate compared to the actual rates as discovered during inspection. The blue line represents the predicted floorplate corrosion rates based on the deepest unrepaired pit from 2008 (as allowed by API 653). That predicts that the 2008-2021 corrosion rate would have been 2.92 MPY with a minimum remaining floor thickness (MRFT) of 177 mils.

The green line in Figure 6 represents the predicted 2008-2021 corrosion rate based on the overall deepest pit discovered during the 2008 inspection.[5] That predicted a soil-side corrosion rate of 4.58 MPY and a MRFT of 155 mils.

The red line in Figure 6 represents the actual 2008-2021 Tank 7 soil-side floorplate corrosion rate of 5.92 MPY and a MRFT of 138 mils.

The 2008-2021 Tank 7 floorplate corrosion rate predicted using the deepest unrepaired pit discovered in 2008, underestimated the actual corrosion pitting depth by 51%.

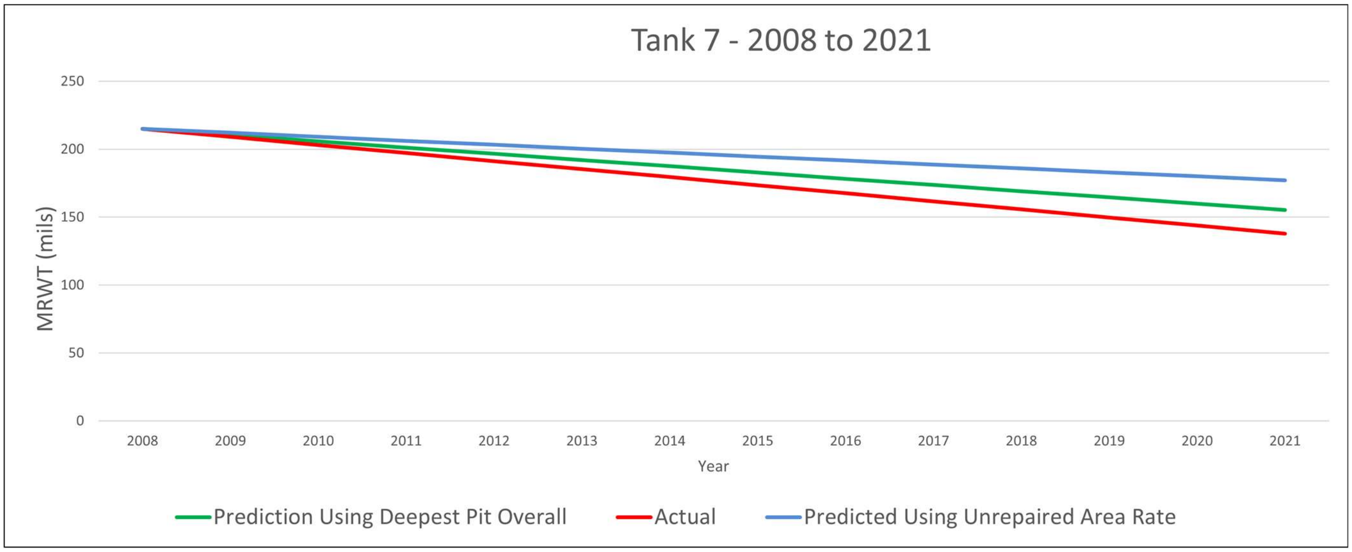

Figure 6 – Corrosion Rates for the Tank 7 Floorplates 2008-2021

API 653 requirements present the minimum effort that an operator must take to protect their aboveground storage tanks. However, it is the operator's responsibility to ensure the integrity of their tanks regardless of code allowances.

The empirical data available on numerous APSC's tanks shows that using the corrosion rate in the unrepaired area to predict future corrosion generally underestimates the rate of corrosion during the ensuing service interval. APSC should continue to use calculations that meet or exceed API 653 requirements, but also align with empirical data on their own infrastructure. Empirical data from APSC tanks suggests that that practice of utilizing calculations based on corrosion rates in unrepaired areas, although allowed by API 653, significantly underestimates the actual corrosion rates experienced in subsequent service intervals and in some cases predicts a spill before the next out-of-service inspection.

APSC has historically utilized the more conservative approach which used the deepest overall pit as the basis for future corrosion rates to define the next service interval. APSC's report on the 2021 Tank 7 Out-of-Service inspection suggests that they are deviating from that approach.

[5] The 2008 API 653 report identified a 120 mils RWT location that they attributed to an inclusion. Therefore, the next deepest pit of 195 mils RWT was used for this assessment.

Furthermore, during the 2021 out-of-service inspection, APSC made no changes to the tank that would correct the cause of the active soil-side tank floor corrosion.

FLOORPLATE TOPSIDE CORROSION RATES

APSC has historically fully recoated the tank floors after each out-of-service inspection. This has resulted in fully protecting the tanks floors from topside corrosion. However, in 2021, only minor, "touch-up" coating repairs were completed on Tank 7 prior to returning it to service. If the tank is returned to service for a full 20-year service interval (2041) as suggested by APSC's API 653 report, the coatings will be 33-years old when the tank is removed from service.

Coatings in aggressive immersion service are not expected to perform more than 15 or 20 years without some level of failure. The water that settles out in the VMT crude tanks is high in chlorides, sulfides, and other corrosive constituents. Once floor coating failures occur, very high rates of topside corrosion can be expected on the floor.

This concern regarding an aged coating and topside corrosion was raised by Taku during an October 12, 2021, meeting between Taku, PWSRCAC, and APSC. During that meeting, Chism Henry (Integrity Engineer with APSC) indicated that they were including a topside corrosion rate in the service interval calculations to accommodate the age of the tank floor coatings. Taku suggests that the assumed corrosion rate should be at least 5 MPY[6] based on immersion in seawater.[7] 5 MPY is likely not conservative since the water also contains sulfides that will make it more corrosive to the steel tanks.

However, the 2021 Tank 7 API 653 out-of-service inspection report included no topside corrosion rate when determining the next tank service interval. APSC and the regulators should view the deviation from the practice of fully recoating the tank floor, as a change in maintenance practices, prompting an earlier re-inspection, or the inclusion of a realistic topside corrosion rate in the service interval calculations.

Figure 7 provides a graphical representation of the predicted floorplate corrosion rates for Tank 7 for the 20-year service interval that the APSC API 653 report recommends.

The blue line in Figure 7 represents the predicted Tank 7 2021-2041 floorplate corrosion rate based on the unrepaired areas from the 2021 inspection. Although allowed by API 653, empirical data for Tank 7 suggests that this significantly underestimates the actual corrosion rate.

The purple line in Figure 7 represents the predicted Tank 7 2021-2041 floorplate corrosion rate as reported in the APSC 2021 API 653 report. That rate does not appear to align with API 653 procedures.

The green line represents the predicted Tank 7 2021-2041 floorplate soil-side corrosion rate based on the deepest floorplate soil-side pit identified in the 2021 inspection. However, this does not include a topside corrosion rate, which is prudent given the age of the existing coatings.

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[6] "Corrosion Engineering," Mars Fontana. 3rd Edition 1986. P 375.

[7] The water fallout from North Slope crude oil is residual seawater resulting from oilfield seawater injection used to enhance production.

The red line represents the predicted Tank 7 2021-2041 floorplate soil-side corrosion rate based on the deepest floorplate soil-side pit identified in the 2021 inspection, along with a 5 MPY topside corrosion component.

This approach, based on empirical data for Tank 7, predicts that if the tank is returned to service for 20 years, as the APSC API 653 report suggests, the floorplate thickness will fall below 100 mils between 2031 and 2032. Most critically, it also predicts that the floor will leak between 2040 and 2041, if action is not taken to correct current corrosion rates.

The Tank 7 Engineering Summary Report includes calculations based on a long-term bottom-side floorplate corrosion rate of 4.48 MPY and a topside floorplate corrosion rate of 4.42 MPY. The Engineering Summary Report recommended that the tank be removed from service for inspection again in 12 years or 2034. Taku's calculations predict that the tank minimum floorplate thickness will fall below 100 mils between 2031 and 2032.

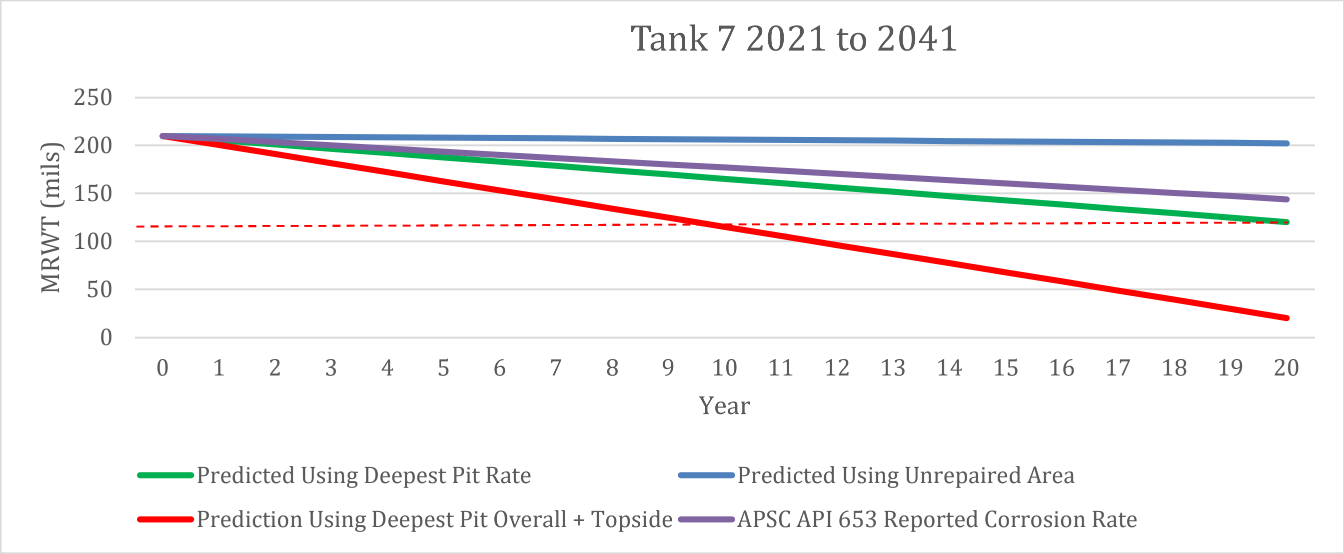


Figure 7 – Predicted Corrosion Rates for Tank 7 (2021-2041)

FLOORPLATE SERVICE INTERVAL CALCULATIONS

APSC's Tank 7 API 653 report suggests that the tank can be returned to service for more than 20 years.

Calculations for the next tank service interval should use a bottom-side corrosion rate of 5.92 as this meets or exceeds API 653 requirements and aligns with empirical data on APSC's tanks.

The service interval calculations should include a topside corrosion rate of at least 5 MPY.

Given that the tank is experiencing active corrosion, the operator cannot assume that the CP system is fully effective. Likewise, the condition of the secondary containment liner is unknown. APSC should plan to remove the tank from service for the next inspection before the minimum remaining floorplate thickness drops below 100 mils.

Based on a 2021 MFE inspection and repair threshold of 210 mils, a short-term soil-side corrosion rate of 5.92 MPY and a topside corrosion rate of 5 MPY, the tank should be removed from service again for inspection 10 years after the last inspection (or 2031).

3.3 Tank 94

PERIMETER CATHODIC PROTECTION

The CP ground bed for the Tank 94 CP system consists of an MMO grid distributed throughout the area beneath the tank floorplate. The CP design includes a separate MMO loop with a radius of 123 feet, intended to protect the tank's annular plates. The perimeter anode is located beneath the floorplate and not the annular plate. Additionally, it is electrically common with the rest of the CP grid. It cannot be adjusted separately from the rest of the ground bed.

The corrosion rate of the annular plate was significant enough to merit full replacement of the annular ring in 2021 and 2022. This indicates that the CP current density provided to the annular plate and perimeter floor plates is not sufficient to achieve full CP.

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 steel 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. Without the ability to drive the 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.
- The MMO loop that is dedicated for 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 will go predominantly to the perimeter floorplate and will not measurably impact the annular plate.
- The fact that the annular plate for Tank 94 required replacement due to corrosion damage provides evidence that the CP current levels at the tank perimeter are insufficient.

CATHODIC PROTECTION MONITORING

The CP monitoring data collected on Tank 94 between 2010 and 2020 appears to not have been collected in accordance with industry standards and Alyeska's own monitoring procedures, which requires that the readings either meet the -850 mV criteria for CP or 100 mV polarization criteria. It appears that none of the "Instant Off" or "IR-Free" readings for Tank 94 meet the - 850 mV criteria for CP. Therefore, Alyeska has been relying on the 100 mV of polarization criteria to show that the tanks are protected.

The depolarized voltage of a structure fluctuates over time due to soil chemistry, temperature, moisture content, and even the application of CP.[8] For this reason, the NACE standard requires that the formation or decay of polarization be measured when utilizing the 100 mV criteria for CP, in order to account for the impact of these outside influences. 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 1-, 2- or 3-year-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 APSC does not have accurate CP data to determine if the tank floor is protected from bottom-side corrosion.

Similarly, APSC'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 OFF potentials that were recorded…"[9] While this aligns with the requirements of NACE SP-0193, APSC has not been following that procedure when collecting their CP data.

The 2010-2020 Tank 94 CP data reported by APSC utilized depolarized data that was up to 6 years old to determine if the structure met the 100 mV criteria for CP. **The practice of using outdated depolarized data conflicts with recognized industry practices, ADEC requirements, and APSC's own internal CP data collection procedures. As such, the effectiveness of Alyeska's CP system to mitigate tank corrosion cannot be effectively assessed until accurate IR-free readings are collected and the formation or decay of polarization is measured.**

ANNULAR PLATE EXTENSION TO RINGWALL SEAL

The annular plate extension to ring wall seal on Tank 94 had not been maintained or replaced since the mid 1980s. The lack of a ring wall to annular plate seal or drip ring on the tank exacerbates corrosion of the annular plate and perimeter plates by allowing rainwater flowing off the tank to seep beneath the annular plate. The constant influx of oxygenated water will also increase the CP current necessary to protect the annular plate, further exacerbating the shortfall in CP to that region of the tank bottom. However, in 2021, APSC attached drip rings to the annular plate. While this does not remediate all the causes of the perimeter area corrosion that is occurring on the tank, the addition of a drip ring does limit future intrusion of rainwater or snowmelt water from seeping between the annular plate and ring wall. However, the existing soils are likely saturated with chlorides, sulfides, and other corrosive constituents that are in contact with the annular plate and ring wall.

[8] Dr. T. J. Barlo, "Cathodic Protection Parameters Measured on Corrosion Coupons and Pipes Buried in the Field." CORROSION 1988.
[9] MP-166-3.23, "Facilities Cathodic Protection Systems," Revision 13. Paragraph 4.8 Depolarized Potential Measurements.

FLOORPLATE SOIL-SIDE CORROSION RATES

During the 2021 Tank 94 inspection, mag-flux exclusion (MFL) examination of the tank floor was conducted with a threshold of 215 mils RFT. The MFL inspection identified 77 locations. Follow-up ultrasonic testing (UT) inspections of the MFL callouts identified a corrosion defect with a RFT of 105 mils. APSC completed 29 floor repairs on all indications with less than 200 mils RFT.

The 2021 report for the Tank 94 API 653 out-of-service inspection indicated that the bottom plates had been subjected to a maximum long-term corrosion rate of 1.1 MPY and that the tank could be returned to service for an interval of greater than 20 years.

The 1.1 MPY corrosion rate that was reported appears to be significantly in error. The deepest pit identified was 105 mils RFT. Considering the 2021 105 mils RFT, the repair threshold of 215 mils during the 2012 inspection, and the 10-year service interval, results in a maximum short term corrosion rate of 11 MPY.

(215 mils – 105 mils)/10 years = 11 MPY

API 653 allows the operator to use the MRT <u>after</u> repairs to establish the overall floorplate corrosion rate for unrepaired areas. Empirical data from APSC tanks indicates that this approach significantly under-predicts the corrosion rates that are experienced in subsequent service intervals (supporting data is provided as Attachment A). Empirical data from APSC'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 take to protect their aboveground 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, APSC should continue to use calculations that meet or exceed API 653 requirements, but also align with known empirical data on APSC infrastructure.

APSC has historically utilized a more conservative approach, which uses the deepest overall pit to define the next service interval. Data on APSC's tanks show that this still typically underpredicts the ensuing corrosion rates for their tanks, but it is more accurate than the use of data from unrepaired areas, which in most cases significantly underpredicts the ensuing corrosion rates.

During the 2021 out-of-service inspection, APSC made no changes to the tank that would fully correct the cause of the active perimeter soil-side tank floor corrosion. The addition of a drip ring will reduce the future intrusion of water beneath the tank floor. However, the perimeter CP system is insufficient and the existing soils are likely saturated with chlorides, and other corrosive constituents, that are in contact with the tank floor.

FLOORPLATE SERVICE INTERVAL CALCULATIONS

APSC's 2021 Tank 94 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 1.1 MPY. However, the actual maximum bottom-side short-term corrosion rate between 2011 and 2021 was 11 MPY. The 1.1 MPY corrosion rate reported does not align with API 653 requirements or any other acceptable practice.

It appears that Alyeska may have used the full 45-year life of the tank to calculate the corrosion rate on the floorplate. However, the floorplate was replaced in 2000, so the life of the floorplate was only 21 years in 2021.

Figure 8 graphically illustrates the predicted and actual corrosion rates for Tank 94 for the 2011-2021 period. The blue line represents the predicted corrosion rate using the deepest unrepaired pit from 2011 (as allowed by API 653). Based on the deepest unrepaired pit after the 2011 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 2011 inspection (155 mils RFT) to calculate corrosion rate and predict the deepest pit in 2021, resulted in a 2011-2021 predicted corrosion rate of 9.5 MPY and a predicted deepest pit (in 2021) of 120 mils RFT. This is represented by the green line in Figure 8.

The actual deepest floorplate pit identified in 2021 was 105 mils remaining wall thickness (RWT), representing a corrosion rate of 11 MPY. This is represented by the red line in Figure 8.

Using the 2011 deepest pit to define the 2011-2021 corrosion rate, the actual rate of corrosion was underestimated by 14%. Using the deepest unrepaired pit (from the 2011 inspection) to predict the Tank 94 floorplate corrosion rate between 2011 and 2021, the actual corrosion rate was underestimated by 68%.

This finding is not unique to Tank 94. Across nearly every APSC tank that we have data on, 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 (see data for additional tanks in Attachment A). **With that data in hand, it would be remiss for APSC to continue the practice of using corrosion rates from unrepaired areas, to predict corrosion rates in ensuing service intervals.**

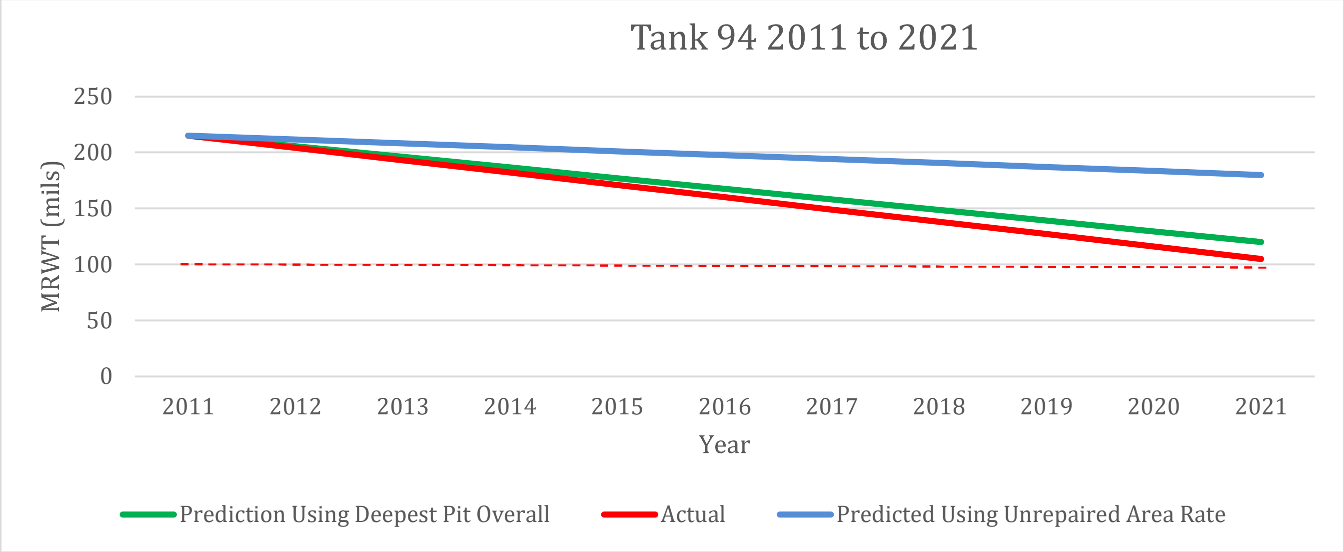


Figure 8 – Predicted Versus Actual Corrosion Depths for Tank 94

Given that the tank is experiencing active corrosion, the operator should not assume that the CP system is effective. As such, APSC should plan to remove the tank from service for the next inspection before the MRFT drops below 100 mils.

Using a corrosion rate of 11 MPY and a 2021 repair threshold of 200 mils, the tank floor will thin to below 100 mils RFT in 9 years. Therefore, the tank should be removed from service for the next out of service inspection in 2030, as opposed to the currently proposed 2041 inspection.

The APSC API 653 report recommends a 20-year service interval for Tank 94. Figure 9 graphically represents the predicted corrosion rates for the Tank 94 floorplate during a 20-year service interval. The blue line represents a corrosion rate based on the deepest unrepaired pit discovered in 2021 (as allowed by API 653). That predicts that the MRFT in 2041 will be 199 mils.

The purple line in Figure 9 represents the predicted corrosion using the 1.1 MPY corrosion rate reported by APSC in their 2021 API 653 report. That predicts that the deepest pitting on the floorplate will be 188 mils RFT in 2041.

The green line in Figure 9 represents the predicted corrosion rate using the deepest pit discovered in 2021, and the associated 11 MPY corrosion rate. Based on the 2011-2021 maximum corrosion rate, these calculations predict that the tank floor will thin beyond 100-mil RFT between 2030 and 2031. These calculations also predict that the tank will leak between 2038 and 2039.

Studies on APSC's tanks have shown that the use of the deepest pit to predict future corrosion rates, while more accurate than the use of pitting rates in unrepaired areas, usually underestimates the actual corrosion rate experienced in subsequent service intervals. Based on that, the green line in Figure 9 should not be viewed as a conservative assessment, but more likely an underestimation of the actual corrosion rates that should be expected on the Tank 94 floorplate going forward.

APSC may suggest that the addition of drip rings onto the annular plate removes the cause of corrosion and therefore negates the viability of using the deepest pit found in 2021 to predict corrosion rates in the current service interval. However, the soil beneath the floorplates was not replaced. That soil is still likely to be damp and saturated with chlorides, due to a past historical practice of washing the ballast water tanks with saltwater to remove snow.

Further, the floorplate corrosion rates reported between 2011 and 2021 indicate that the CP system is inadequate to protect the perimeter floorplate (and annular plate) from corrosion. No upgrades to the CP system were executed during the 2021 repairs.

The addition of a drip ring on Tank 94 is a great step in helping alleviate corrosion. However, many of the causes of corrosion are still in place and have not been remediated. The CP current density in the perimeter is insufficient and the soils beneath the floorplates are likely contaminated with chlorides. The sub-floorplate soils were not replaced and the CP system was not upgraded. **Based on empirical data for Tank 94, the next out-of-service inspection on Tank 94 should be executed in 2030, not 2041 as proposed in the API 653 report or 2031 as proposed in the Engineering Summary Report.**

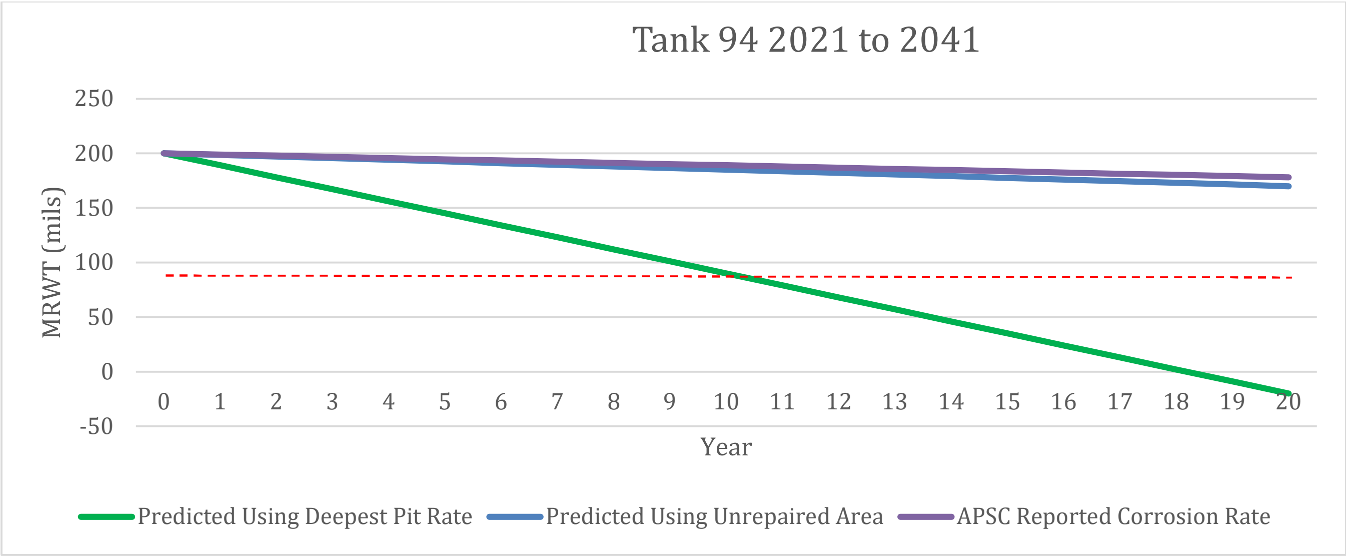
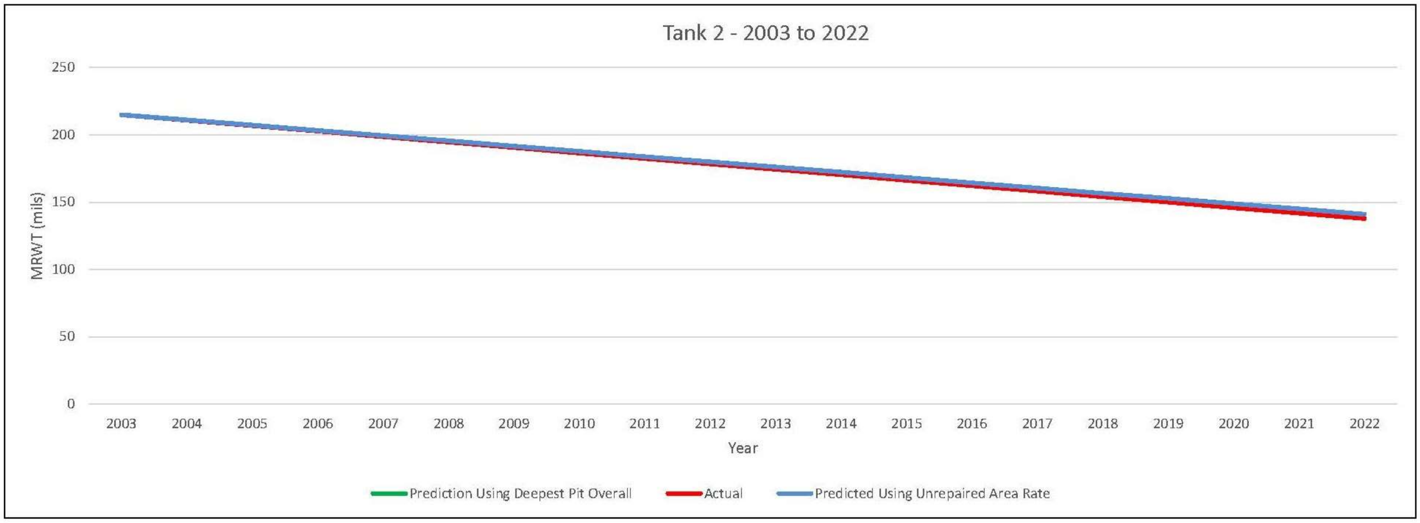
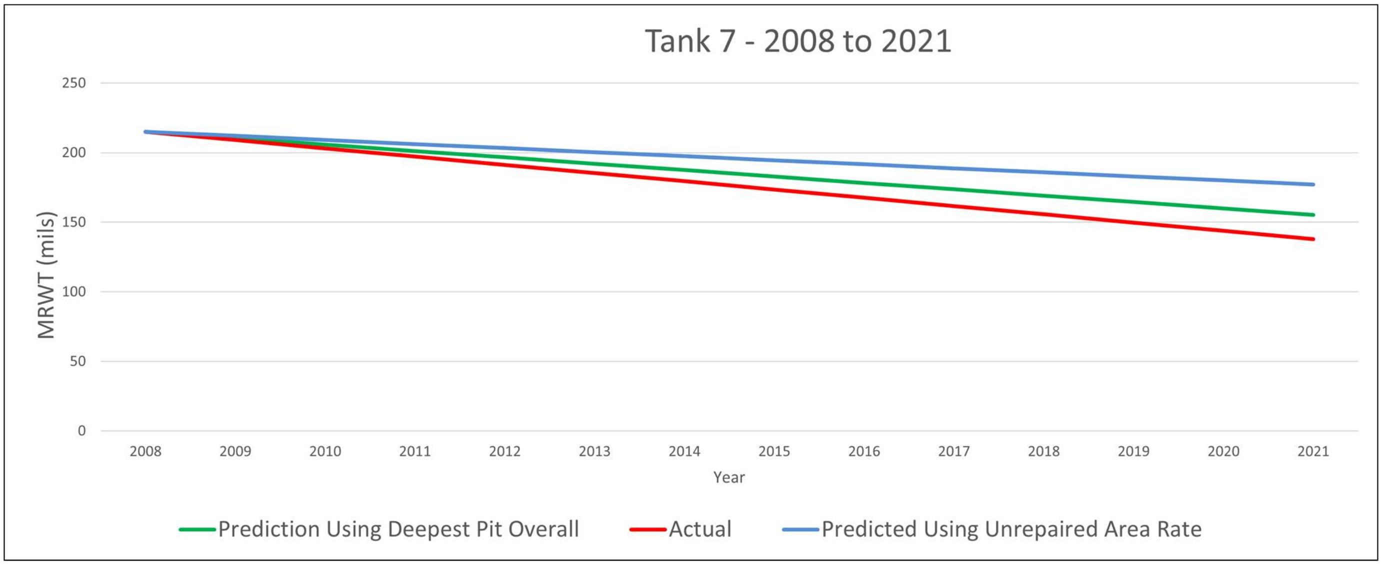


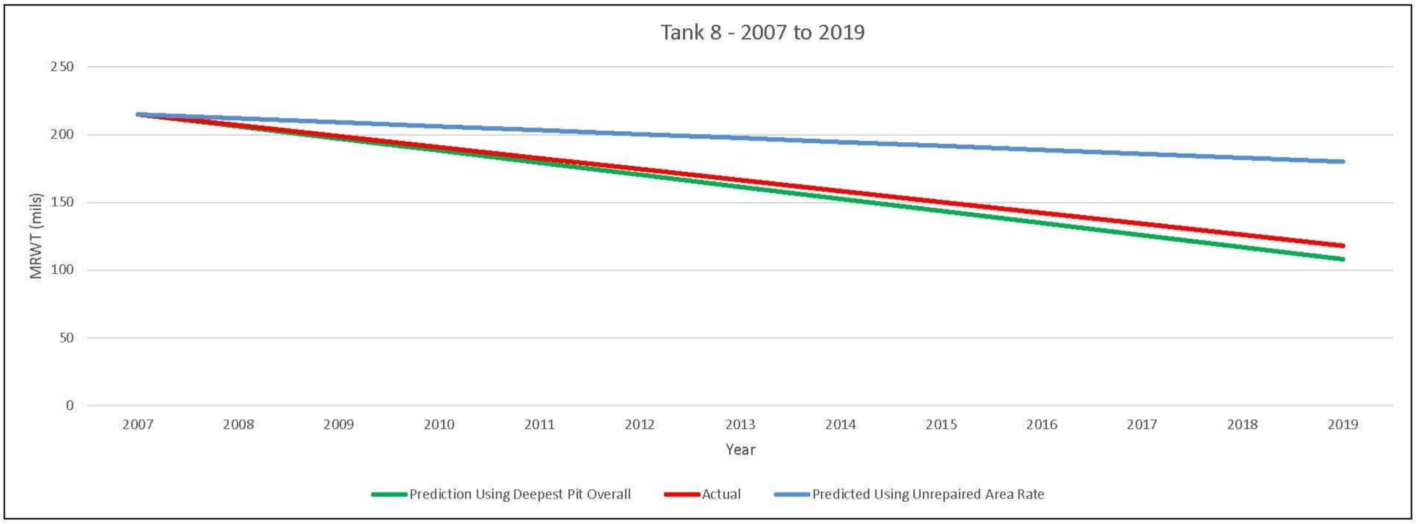
Figure 9 – Predicted Corrosion Rates for the Tank 94 Floorplate Between 2021 and 2041

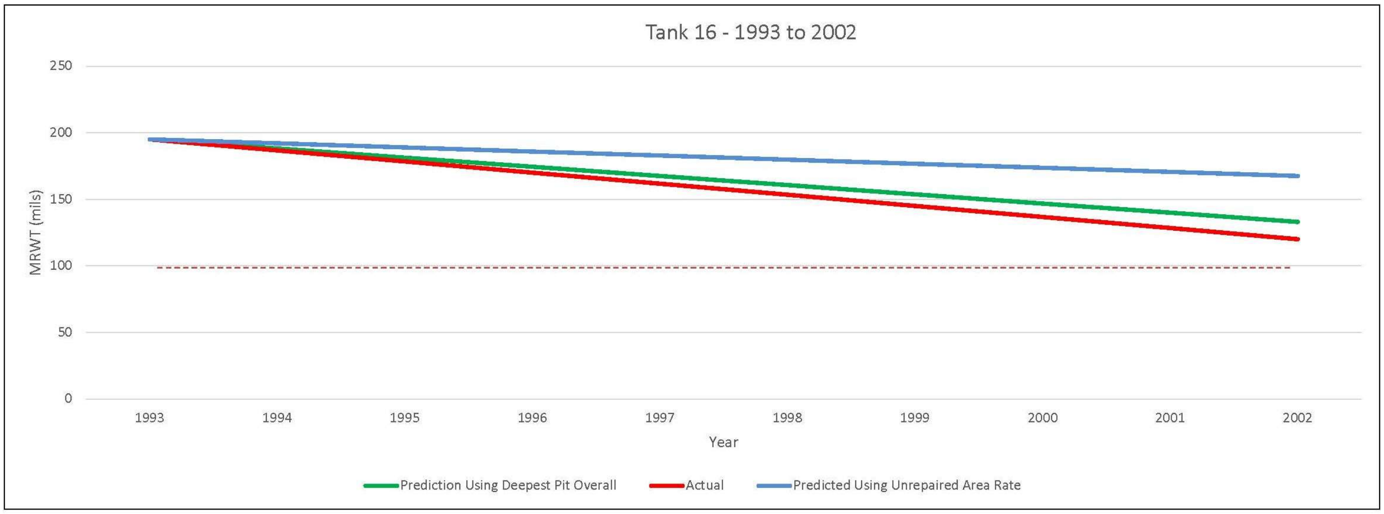
ATTACHMENT A

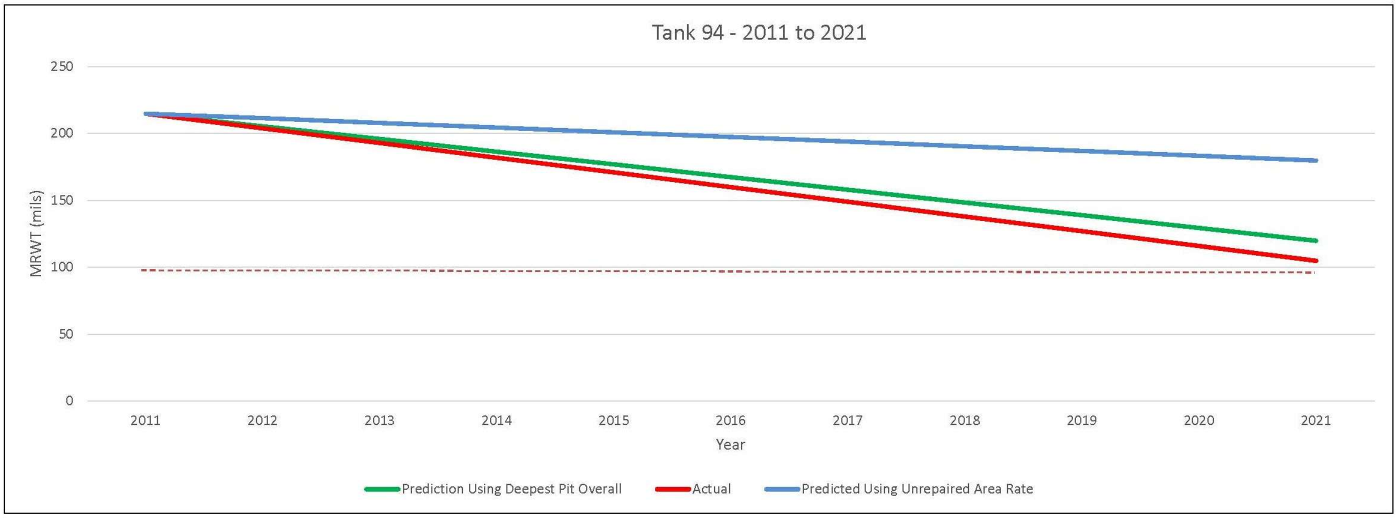
Tank Floor Corrosion Rate Graphs


Tank 2 - 2003 to 2022
MRWT (mils)
250
200
150
100
50
0
2003
2004
2005
2006
2007
2008
2009
2010
2011
2012
2013
2014
2015
2016
2017
2018
2019
2020
2021
2022
Year
Prediction Using Deepest Pit Overall
Actual
Predicted Using Unrepaired Area Rate

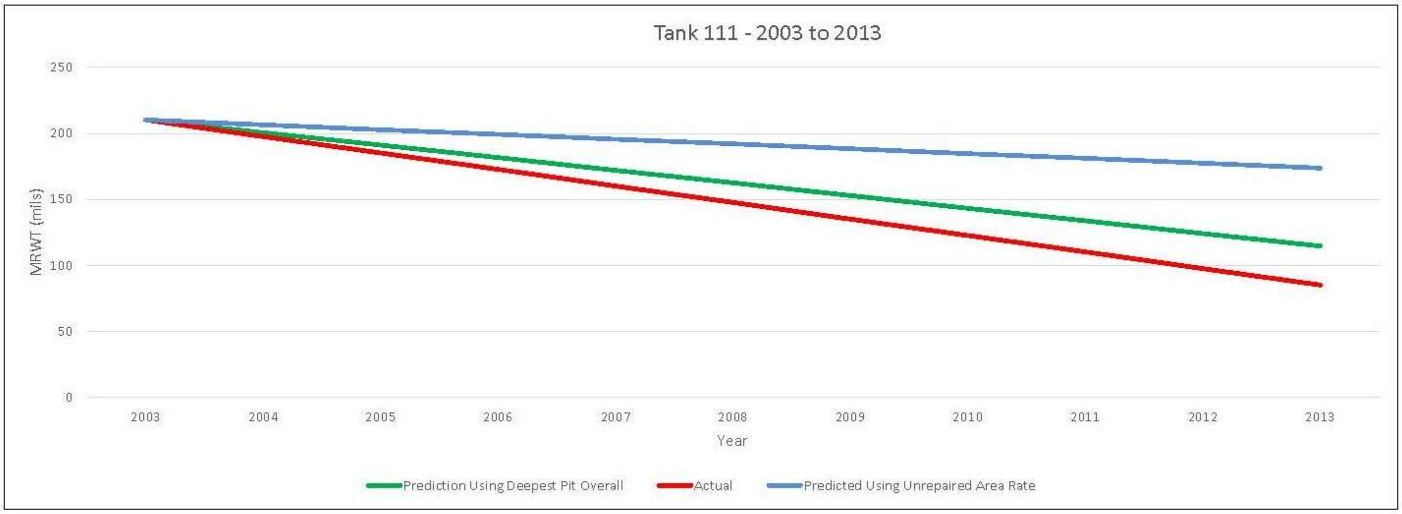

Tank 7 - 2008 to 2021
MRWT (mils)
250
200
150
100
50
0
2008
2009
2010
2011
2012
2013
2014
2015
2016
2017
2018
2019
2020
2021
Year
Prediction Using Deepest Pit Overall
Actual
Predicted Using Unrepaired Area Rate


Tank 8 - 2007 to 2019
250
200
150
100
50
0
MRWT (mils)
2007
2008
2009
2010
2011
2012
2013
2014
2015
2016
2017
2018
2019
Year
Prediction Using Deepest Pit Overall
Actual
Predicted Using Unrepaired Area Rate

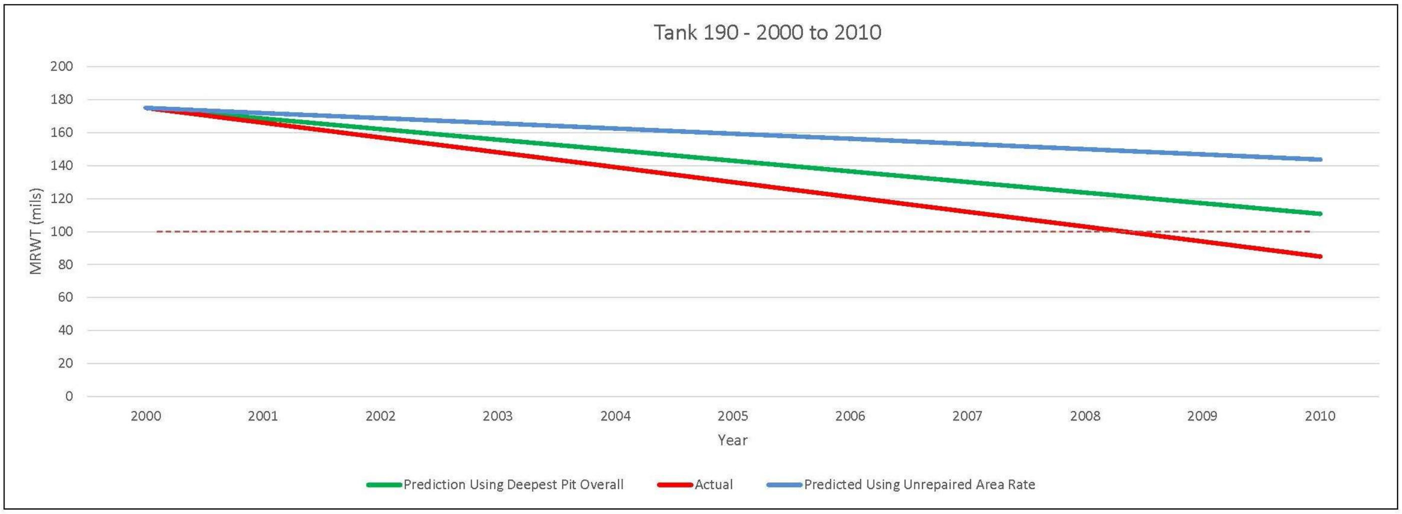

Tank 16 - 1993 to 2002
250
200
150
100
50
0
MRWT (mils)
1993
1994
1995
1996
1997
1998
1999
2000
2001
2002
Year
Prediction Using Deepest Pit Overall
Actual
Predicted Using Unrepaired Area Rate



Tank 94 - 2011 to 2021
250
200
150
100
50
0
MRWT (mils)
2011
2012
2013
2014
2015
2016
2017
2018
2019
2020
2021
Year
Prediction Using Deepest Pit Overall
Actual
Predicted Using Unrepaired Area Rate



Tank 111 - 2003 to 2013
250
200
150
100
50
0
MRWT (mils)
2003
2004
2005
2006
2007
2008
2009
2010
2011
2012
2013
Year
Prediction Using Deepest Pit Overall
Actual
Predicted Using Unrepaired Area Rate



Tank 190 - 2000 to 2010
MRWT (mils)
200
180
160
140
120
100
80
60
40
20
0
2000
2001
2002
2003
2004
2005
2006
2007
2008
2009
2010
Year
Prediction Using Deepest Pit Overall
Actual
Predicted Using Unrepaired Area Rate

ATTACHMENT B

Response to Alyeska's Comments

PWSRCAC transmitted Taku's draft report titled "Review of Ballast Water Tank 94 and Crude Oil Storage Tank 7 Out-of-Service Inspection Reports" to APSC in December of 2023. On February 8, 2024, Alyeska responded to that report via Letter No. 53566.

APSC's response consisted of line-item responses to Taku recommendations, in tabular form. In that response, they provided several internal documents including Engineering Summary Reports for Tanks 7 and 94. These reports had not been previously provided to the Council.

There are numerous, significant discrepancies between the findings in the Engineering Summary Reports and the API 653 Inspection Reports. In their response, APSC indicated that the findings and recommendations provided in their internal Engineering Summary Reports supersede the findings and recommendations laid out in the regulatorily required API 653 inspection reports for Tanks 7 and 94.

APSC's responses to Taku's report, as well as the discrepancies between the Engineering Summary Reports and the API 653 Inspection reports, raise additional issues that should be addressed by APSC, and as appropriate, ADEC:

- The discrepancies between the Engineering Summary Reports and the 2021 API 653 Reports (provided to the ADEC and to PWSRCAC) include numerous errors in the API 653 reports. It is concerning that there are two conflicting technical reports for each of those tanks. It is also concerning that inaccurate reports were provided to the regulators for the determination of the next tank inspection interval as stipulated in the VMT Contingency Plan. Despite this, **APSC noted that they did not intend to have the API 653 reports corrected. We recommend that ADEC request that APSC update the regulatorily-required API 653 reports to reflect the correct corrosion rates and inspection intervals as defined in APSC's own internal Engineering Summary reports.**
- Second, APSC's response included noting that errors exist on the as-built drawings regarding the construction of the CP monitoring tubes. It is a concern that APSC has failed to maintain accurate as-built drawings for their systems.
    - As APSC noted, the tank subfloor drain system drawings are inaccurate regarding the presence of slotted tubes through the tank perimeter.
    - APSC's drawings also have discrepancies with the location of the sub-floor drain in relation to the tank secondary containment liner.
    - Further, APSC does not appear to have as-built drawings indicating which tanks have subfloor drains and which do not.
    - Inaccurate maintenance of system as-built drawings makes the effective maintenance of structures at the VMT extremely difficult. Accurate as-built drawings of the systems should be developed and maintained.

In the following pages, Taku has taken the tabular response that APSC provided and expanded it to include a column with Taku's responses to APSC's comments.

Taku Reporting Findings and Recommendations for Tank 7 – September 2023	Alyeska Response – February 2024	Taku Follow-up Comments – March 2024
1. Cathodic Protection: The existing CP system will not provide sufficient CP current to the perimeter floorplates and annular plates. Those surfaces will remain largely unprotected.	With the existing cathodic protection system design installed beneath the tank bottom, the tanks' annular plates have a reduction in corrosion rates. Empirical inspection data does not support the statement that there is insufficient CP at the perimeter or justify an upgrade to the system	APSC's response is incorrect. Their empirical data clearly supports that there is insufficient CP on the annular and perimeter plates. * The annular plates are displaying a corrosion rate of 3.3 MPY. This empirical evidence indicates that the CP afforded the annular plates is insufficient in preventing high corrosion rates as designed. * The annular plates are a higher strength material than the floorplates (ASTM A-537 versus A-36), with different metallurgy and an inherently different corrosion susceptibility. The annular plate is also normalized, creating further differences in metallurgy. The difference in metallurgy is likely the reason that the long-term corrosion rate of the annular plate is slightly lower than the long-term corrosion rate of the floorplate (3.3 MPY versus 4.5 MPY). * Nearly all of the floorplate repairs for Tank 7 were on the perimeter floorplates. This is clear empirical evidence that the existing crude tank CP systems are not providing sufficient CP current to the perimeter areas of the crude tank floor.
The existing CP monitoring tubes are not slotted for the first 10 feet and do not allow monitoring of CP levels on the first 10 feet of the tank floor (annular plates and perimeter plates).	The existing CP monitoring tubes for TK-7 are slotted to the outside edge of the tank shell. This was confirmed based on visual borescope investigations completed in 2022. Alyeska will update the existing drawings to accurately depict the slot locations. This additional slotting does allow Alyeska to monitor CP levels on the annular plates and perimeter plates as well as the tank floor.	It is concerning that APSC does not have accurate as-builts of their systems, as tanks are considered critical facility. If the tubes are slotted, that is great news. Once Alyeska discovered that the tubes were slotted for the first 10 feet, did they complete CP monitoring in this section? If so, please provide the results of the tube inspection and the CP survey data. If not, why was this section precluded from monitoring given that a majority of the tank floor repairs were in this area? APSC's 2018-2021 CP data for Tank 7, indicates that no CP readings

Taku Reporting Findings and Recommendations for Tank 7 – September 2023	Alyeska Response – February 2024	Taku Follow-up Comments – March 2024
		were collected in the first 10 feet of the monitoring tubes (the area where the CP design results in insufficient CP current). If APSC knows that they have the capability to collect CP data in the perimeter areas, and their tank inspections are showing that the highest rates of corrosion are on the perimeter plates, why aren't they monitoring the levels of CP in those areas? Given the empirical data showing the perimeter floorplates have accelerated corrosion, APSC should collect CP data beneath the annular plates and perimeter plates and should upgrade the perimeter CP.
APSC is not collecting CP data for Tank 7 in accordance with NACE SP-0193 or their own internal monitoring procedures. APSC should be following recognized industry practices (NACE SP-0193), ADEC requirements, and APSC's own internal CP data collection procedures when collecting cathodic protection data.	APSC meets the intent of both NACE SP-0193 and internal procedure MP-166-3.23. Alyeska believes the statement that APSC is not collecting CP data in accordance with NACE is about timing of depolarization data collection. Timelines for measurement of depolarized potentials are not prescribed in NACE SP-0193 nor MP-166-3.23. Through historical experience and recent special testing that has included system balancing, APSC confirms that TK-7 has ample and relatively consistent levels of polarization. APSC exercises sound engineering judgement to balance the frequency of depolarized surveys with the importance of CP system uptime.	APSC is clearly not collecting CP data in accordance with NACE SP-0193 or their internal procedure, MP-166-3.23. NACE SP-0193 4.3.1.3 states: "A minimum of 100 mV of cathodic polarization between the carbon steel surface of the tank bottom and a stable reference electrode contacting the electrolyte. The formation or decay of polarization may be measured to satisfy this criterion." This requires that you measure the formation or decay of polarization. Using multi-year-old depolarized readings is not measuring the formation or decay of polarization. Using old data ignores all of the other parameters that impact the depolarized reading of a structure such as temperature, soil chemistry, soil moisture content, etc. APSC is not measuring the formation or decay of polarization. Additionally, NACE SP-0193 4.2.3 states, "consideration must be given to voltage drops other than those across the structure-to-electrolyte boundary" when measuring polarized potentials. The other voltage drop referred to in that statement is called IR-drop. APSC reported IR-free (IRF) readings as negative as -2700 mV. These readings are too

Taku Reporting Findings and Recommendations for Tank 7 – September 2023	Alyeska Response – February 2024	Taku Follow-up Comments – March 2024
	Please provide the specific code references that Taku Engineering identifies Alyeska to be deficient.	negative to be valid and indicate that APSC has not accounted for all "voltage drops other than those across the structure-to-electrolyte boundary" as required in SP-0193. The "IR-free" data that APSC is reporting is clearly not IR-free. A qualified Operator should recognize that the data is not IR-free as reported. Section 4.1.7 Depolarized Potential Measurements (PS & VMT) of MP-166.23 states: "These measurements are required at any monitored location that exhibited INSTANT OFF potentials more positive than -850-mV. On the appropriate form, record these measurements and their associated INSTANT OFF potentials. 1. Turn off all cathodic protection current sources that may affect the structures at the locations to be tested. Energy Isolation Training is not required for the purposes of this test. 2. Place the portable reference electrode in the same locations used to collect the INSTANT OFF readings. 3. 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 OFF potentials that were recorded on the cathodic protection potentials data sheet. (This activity may take as long as a week for some structures, such as tank bottoms). 4. Measure and record the depolarized potentials for each identified location. Indicate the amount of time the cathodic protection sources were turned off before the readings were collected." MP-166-23 clearly calls for monitoring the decay of polarization (in areas not meeting the -850 mV criteria) AFTER collecting instant off

Taku Reporting Findings and Recommendations for Tank 7 – September 2023	Alyeska Response – February 2024	Taku Follow-up Comments – March 2024
		readings. APSC's current practice of using old depolarized data is not monitoring the decay of polarization and is clearly in conflict with those requirements. APSC has been aware of the inaccuracy of using old depolarized data to confirm CP criteria for nearly 20 years. Between 2002 and 2005 APSC collected depolarized data on select crude tanks. That study showed that the depolarized readings for the same location could change by more than 300 mV from one year to the next. This APSC study showed that the use of old depolarized data is invalid. APSC continues to use old depolarized data for CP monitoring purposes. They have suggested that this represents the use of sound engineering judgement, despite having internal data suggesting otherwise.
2. Tank Coating: The tank floor coatings were not fully replaced prior to returning the tank to service. Only minor coating repairs were completed. This is a deviation from APSC historical practices of fully replacing the tank floor coatings after tank internal inspection and repair. To our knowledge, this is the first time APSC has returned a tank to long-term service without fully recoating the tank floor. Given that the coating was last replaced in 2008 following the previous inspection, by the next scheduled inspection, the floor coatings will be more than 33 years old. It is not reasonable to expect that an immersion	The Tank 7 internal lining system (coating) was 13 years old at the time of the inspection and will be a total of 25 years old at the next scheduled internal inspection. Alyeska has extensive experience with the performance of these internal tank linings and finds them to be in exceptional condition. For Tank 7, the existing 13-year-old liner was found to be in very good condition, with excellent adhesion as demonstrated by pull-testing. The lining was subjected to 100% holiday testing and repaired. Given Alyeska's experience with this internal lining system and	Taku's initial comments were based on the March 2022 data and reports provided to the regulators, which indicated that the tank was being returned to service without recoating, for a 20-year interval. The engineering summary report that APSC has since provided PWSRCAC indicates that the tank is being returned to service for a 12-year service interval, not 20 as the API 653 report indicated. The shorter service interval reduces the risk of a failure during the next service interval. The act of taking the tank out of service causes flexing of the floorplates when it emptied. The activities associated with cleaning, inspection, and repair of the tank as well as the stresses on the coating during tank refilling can damage the coating. The floor coatings are epoxy materials which are relatively brittle. They do not stand up to any significant bending and movement that can be associated with the out-of-service maintenance activities. It is not evident that any detailed research was done to determine the long-term impact that the out-of-service activities will have on the coating performance.

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coating will perform without failure for more than 20 years.	the repairs performed on the Tank 7 liner, Alyeska does not anticipate significant liner degradation to occur within the next 12 year service interval. An internal corrosion rate was applied to the service interval calculation as a conservative measure. See 2021 Engineering Summary Report: 54-TK-7.	However, if research was conducted, please provide. The discrepancies between the API 653 report and APSC's Internal Engineering Summary are a serious concern. The data, calculations, and findings of the two documents should match. APSC has been seeing an unprecedented level of turnover in their technical staff. Having a regulated document (like an API 653 report) in direct conflict with an internal document such as the Engineering Summary, coupled with employee departures, increases the risk that a tank service interval could be incorrectly adjusted in the future resulting in a leak or spill.
3. Corrosion Rate Calculations: The inspection report includes errors in calculations for the 2008-2021 floorplate soil-side corrosion rates. The report suggests that between 2008 and 2021, the Tank 7 floor recorded a maximum floorplate corrosion rate of 3.3 MPY. The actual maximum floorplate corrosion rate between 2008 and 2021 was 5.9 MPY (based on the repair threshold in 2008 and the deepest pit discovered in 2021).	See 2021 Engineering Summary Report: 54-TK-7. Alyeska has set the reinspection interval for Tank 7 at 12-years.	The Engineering Summary Report for Tank 7 aligns very closely with the Taku report. APSC settled on a service interval of 12 years. We don't believe that this will result in a leak, but it is our belief that it will encroach into the minimum 100-mils remaining floorplate thickness required by code. However, it is a serious concern that there is conflicting information being reported between APSC's Engineering Summary Report and the API 653 Report. These discrepancies increase the potential for miscommunications that could push out the service interval to the point that it results in a tank leak.
The inspection report appears to have assumed no topside corrosion rate in the future. However, because the floorplate coating was not removed and replaced, and considering the age of the existing coatings, a topside corrosion rate should have been included in the corrosion rate calculations. During a	This reinspection interval includes a topside corrosion rate. Alyeska meets the requirements of API 653 and determines the service interval calculation method with a conservative approach based on empirical data. Based on testing and repairs implemented on the Tank 7	The Engineering Summary report aligns much more closely with Taku's findings. However, APSC's topside corrosion rate of 4.4 MPY is not conservative as suggested. The water fallout in the tanks is seawater carryover from oil-recovery enhancement techniques. The seawater has entrained sulfates and other contaminants that could cause corrosion at a rate significantly higher then 4.4 MPY. Again, the discrepancies between the Engineering Summary Report

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10/12/22 meeting between APSC and PWSRCAC, APSC indicated that they included a topside corrosion component in the service interval calculations in order to accommodate the age of the floorplate coatings. However, the final inspection report did not include a topside corrosion rate for the service interval calculations.	liner, Alyeska anticipates the top-side corrosion rate used to be conservative. Additionally, there is internal galvanic cathodic protection within Tank 7 that was not credited in the reinspection interval determination. Tank 7 retains twenty-eight anodes distributed throughout the tank and another four located within the tank sump itself. These anodes provide protection against internal corrosion if coating failure occurs. Alyeska disagrees with the corrosion rate calculation in the Taku Engineering Report, dated December 2023.	and the API 653 report (that was submitted to the ADEC) is a very significant concern that should be rectified. The internal anodes that APSC is referencing are mounted with a slight offset from the floor. Due to this offset, the anodes will not function until the water buildup in the tank has risen to the level that the anodes are exposed to water. Any water buildup below that level will allow the floorplate to corrode freely at all coating holidays. Additionally, the anode's close proximity to the floor will prevent them from distributing CP current broadly across the tank floor. Each anode will only protect the floor immediately adjacent to the column where it is installed.
The inspection report includes errors in calculations pertaining to the allowable duration of the next tank service interval. When accurate bottom-side corrosion rates are utilized and a topside corrosion rate is included, the API 653 service life calculations for the floorplate indicate that the tank will exceed 100-mils minimum remaining thickness (MRT) (in 2031), (which is the	An inspection contractor provides an independent API 653 inspection report referenced in the Taku Engineering report. Revisions to the independent report are not necessary. Alyeska uses this information and empirical data and engineering analysis to make decisions documented in the Engineering Summary. Alyeska's position is	The existence of conflicting technical reports is not an acceptable practice. Inspection reports found to be inaccurate should be revised and reissued. The independent Tank 7 API 653 report was provided to the ADEC or PWSRCAC. The Tank 7 Engineering Summary Report was internal and was not initially shared with the ADEC or PWSRCAC. Accurate reports should be provided to the regulators who oversee TAPS. APSC's position may be well represented in their Engineering Summary Reports, but if conflicting reports are provided to the regulators, they aren't accurately communicating their position to the regulators or the public.

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minimum required thickness by API 653 standards without an effective CP system and a competent leak prevention liner) and could penetrate the floor before the next scheduled out-of-service inspection in 2041.	documented in the 2021 Engineering Summary Report: 54-TK-7.	
4. Seal Maintenance: The lack of annular plate to ring wall seal will exacerbate the inadequacy of CP afforded the annular plate and perimeter floorplates, due to the migration of rainwater and lack of an effective water drainage system under the tank floor.	The annular plate to ring wall seal is not necessary for effective tank integrity management. Tank 7 has adequate drainage provided by a sub-floor perimeter French drain type system.	The empirical data from the Tank 7 inspection does not support APSC's response. New sub-floor drains (between the secondary containment liner and the tank floor) were not installed on all ETF tanks. APSC has failed to provide as-built documentation to clarify specifically which ETF tanks have the new drains and which ones do not. The as-built drawings for the drain system appear to be inaccurate. The drawing that was provided for the subfloor drains (D-54-C825 Sht 20) pictorially shows that the drain is located on several inches of padding above the CBA liner. However, in the same drawing, the bottom of pipe elevation given for the drain would place it below the CBA liner. Placement of the drain several inches above the liner will allow water to migrate beneath the drain to the lowest sections of the cone-down tank floor. If the bottom of the drain pipe is 2.5 feet below the top of the ring wall (as noted in drawing D-4-C825 sht 20), then the drain is below the liner and will not be managing water between the liner and tank floor. ASPC should confirm that a drain exists for Tank 7 and verify the location (relative to the liner and tank floor), then provide that information accordingly.

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		Most of the floorplate patches installed on Tank 7 were in the perimeter plates. That is empirical evidence that the existing drain is not effective at managing the sub-floor water and that replacing the annular plate to ring wall seal, or installing a drip ring, is necessary. If the drain were fully removing water from the space between the liner and the tank floor, and adequate CP current density was being provided to these areas, then the annular plate would not have a 3.3 MPY corrosion rate and APSC wouldn't have had to patch numerous perimeter plates in the tank. Industry standards recognize the risk associated with failure to maintain the seal between the ring wall and annular plate extension. API 575, " Inspection of Atmospheric and Low Pressure Storage Tanks," states, "for tanks that are supported above grade, an improperly sealed ringwall, as shown in Figure 27, can allow moisture to accumulate between the tank and the support, thereby accelerating corrosion."

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5. Cathodic Protection: The existing CP system has not afforded sufficient corrosion protection to the annular plates and perimeter plates. This is evident in the fact that the annular plate required replacement in 2021 and 2022 due to aggressive corrosion. No modifications were made to the existing CP system during this outage. Therefore, going forward, the existing CP system will still not provide sufficient CP current to the perimeter floorplates and annular plates. Those soil-side surfaces will remain unprotected. The installation of a drip ring on the annular plate extension will somewhat reduce the corrosivity of the soils beneath the annular plates. However, it will not fully alleviate the high corrosion rates in the annular plate because the CP system beneath the tank is inadequate to protect the annular plates.	The annular plate replacements for the Ballast Water Tanks in 2021 and 2022 were after ~45 years of service which is within industry expectations. The addition of the drip ring is expected to reduce corrosion rates on the annular plates critical zone and extend the life of the new infrastructure.	Replacement of the Ballast Water Annular Plate after 45 years of service is <u>not</u> within industry expectations. It is the result of failing to properly manage water beneath the tank floor coupled with a CP system that does not adequately protect the perimeter tank floor plates. If the CP system was providing adequate CP current to all areas of the annular plate, and they maintained a seal or drip ring between the annular plate extension and ring wall, APSC would never have had to replace the annular plate.

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The existing CP monitoring tubes do not allow monitoring of CP levels on the tank perimeter. No perimeter CP data is being collected.	Due to project work, Alyeska has not measured the distance between the existing monitoring tube slots and the tank shell at Tank 94. Alyeska is including this measurement in 2024's CP Monitoring Program scope. Adequate levels of cathodic protection were measured for both the annular plates and perimeter plates in 2023.	APSC's response is inaccurate. APSC indicates that they "did not measure the distance between the existing monitoring tube slots and the tank shell at Tank 94." We request APSC provide evidence that the monitoring tubes are slotted beneath the annual plates. It is not possible to measure levels of CP on the annular plate and perimeter plates, without knowing that the monitoring tubes are slotted through that area. Yet, in APSC's next sentence, they indicate that "adequate levels of cathodic protection were measured for both the annular plates and the perimeter plates in 2023." If they haven't confirmed that the monitoring tubes are slotted through the perimeter area, then they cannot definitively state that CP data they collected is representative of the perimeter and that the perimeter plates and annular plates are protected.
The perimeter CP systems on other ballast water tanks with similar CP systems should be upgraded when the tank is removed from service for inspection and repairs.		It is evident that APSC's replacement of the annular plate shows that the perimeter CP is inadequate in preventing high corrosion rates as designed and should be upgraded.
APSC is not collecting CP data for Tank 94 in accordance with NACE SP-0193 or their own internal monitoring procedures.	APSC meets both **NACE SP-0193** and internal procedure MP-166-3.23. Alyeska believes the statement that APSC is not collecting CP data in accordance with NACE is about timing of depolarization data collection. Timelines for measurement of depolarized potentials are not prescribed in NACE SP-0193 nor MP-166-3.23.	NACE SP-0193 4.3.1.3 states: "A minimum of 100 mV of cathodic polarization between the carbon steel surface of the tank bottom and a stable reference electrode contacting the electrolyte. The formation or decay of polarization may be measured to satisfy this criterion." Timelines and sequencing for the measurement of depolarized potentials are very much prescribed in NACE SP-0193 and MP-166-3.23. NACE SP-0193 requires that testers measure the formation or decay of polarization to utilize the 100 mV criteria for protection. Measuring the formation or decay of polarization is a time based, dynamic requirement. Using multi-year-old depolarized readings is not measuring the formation or decay of polarization. As APSC's

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		internal studies have shown, depolarized potentials change over time due to soil chemistry, temperature, and soil moisture content. The use of old depolarized potential data is inaccurate because it ignores the changes that are caused by these other variables APSC's current practice of using old, depolarized data is also invalidated by their own internal data showing that depolarized values change significantly from year-to-year. APSC has been aware of the inaccuracy of using old, depolarized data to confirm CP criteria for nearly 20 years. Between 2002 and 2005, APSC collected depolarized data on select crude tanks. That study showed that the depolarized readings for the same location could change by more than 300 mV from one year to the next. This APSC study proved that the use of old depolarized data is invalid. APSC was made aware of the year-to-year changes in depolarized data nearly 20 years ago, yet APSC continues to use old, depolarized data for CP monitoring purposes and argue that it is valid, despite having internal data proving that it is not.
APSC is not collecting CP data for Tank 94 in accordance with NACE SP-0193 or their own internal monitoring procedures.	APSC meets both NACE SP-0193 and internal procedure MP-166-3.23. Alyeska believes the statement that APSC is not collecting CP data in accordance with NACE is about timing of depolarization data collection. Timelines for measurement of depolarized potentials are not prescribed in NACE SP-0193 nor MP-166-3.23.	The following is an excerpt from MP-166.23 regarding the collection of depolarized data for areas not meeting the -850 mV criteria. MP-166.23 instructs the operator to: 1. Turn off all cathodic protection current sources that may affect the structures at the locations to be tested. Energy Isolation Training is not required for the purposes of this test. 2. Place the portable reference electrode in the same locations used to collect the INSTANT OFF readings. 3. Periodically check the structure to soil potentials at these locations until they have stopped shifting (depolarizing) or have

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		shifted at least 100-mV more positive than the INSTANT OFF potentials that were recorded on the cathodic protection potentials data sheet. (This activity may take as long as a week for some structures, such as tank bottoms.) 4. Measure and record the depolarized potentials for each identified location. Indicate the amount of time the cathodic protection sources were turned off before the readings were collected. MP-166-23 clearly calls for monitoring and measuring the decay of polarization (in areas not meeting the -850 mV criteria).
6. Corrosion Rate Calcs: The annular plates were replaced, but this change does not impact the duration of the next tank service interval. The inspection report includes significant errors in calculations for the 2012-2021 floorplate corrosion rates. The report indicates that the long-term bottom corrosion rate is 1.1 MPY. The actual long-term bottom-side corrosion rate was 6.9 MPY and the short-term bottom-side corrosion rate was 11.0 MPY. The inspection report suggests that the tank can be returned to service for a 20-year service interval. However, the	See 2021 Engineering Summary Report: 51-TK-94. Alyeska has set the reinspection interval for Tank 94 at 10-years. Alyeska meets the requirements of API 653 and determines the service interval calculation method with a conservative approach based on empirical data. Alyeska disagrees with the corrosion rate calculation in the Taku Engineering Report dated December 2023. The statement that there is a high probability that the tank bottom will leak prior to the next inspection is not accurate.	The Engineering Summary Report for Tank 94 aligns very closely with the Taku report. APSC settled on a service interval of 10 years. We don't believe that this will result in a leak, but it is our belief that it will encroach into the minimum 100-mils remaining floorplate thickness required by code. However, it is a significant concern that there is conflicting information being reported between the internal Engineering Summary Report for Tank 94 and the Tank 94 API 653 Report. These discrepancies increase the potential for miscommunication both internally within APSC, and with regulator decision-making. These discrepancies could easily establish a service interval that results in a tank leak. Given the turnover in experienced technical employees and personnel that APSC continues to experience, it is even more imperative that discrepancies between the Engineering Summaries and API 653 reports be corrected. The existence and distribution of inaccurate and conflicting technical reports is not an acceptable practice. Inspection reports

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report includes significant errors in the calculation's pertaining to the allowable duration of the next tank service interval. Based on the short-term bottom-side corrosion rate, the next out-of-service tank inspection should take place in 9 years or in 2030. If the tank is placed in service for the 20-year service interval APSC has suggested, there is a high probability that the tank bottom will leak prior to the next out-of-service inspection. Most critically, Tank 94 should be removed from service for the next out-of-service inspection in 9 years, not 20 years as noted in the 2021 API 653 Out-of-Service inspection report.		found to have errors should be corrected. The independent Tank 94 API 653 report was provided to the ADEC. The Tank 94 Engineering Summary Report was not. Accurate reports should be provided to the regulators who oversee TAPS. APSC's position may be well represented in their Engineering Summary Reports, but if conflicting reports are provided to the regulators, they aren't accurately communicating their position to the regulators or the public.